

***PJM Generator Interconnection Request  
Queue #O66/V1-034  
Bergen 230kV  
Facilities Study Report***

**August 2009  
Docs#556390  
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## **Appendices**

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CONDUCTOR

## **1.0 Description of the Project**

Hudson Transmission Partners, LLC proposes to interconnect between Public Service Electric and Gas Company's (PSE&G) Bergen 230 kV Switching Station and Consolidated Edison's (ConEd) W. 49<sup>th</sup> Street 345 kV Substation in New York City. The request is identified as PJM Generator Interconnection Request Queue #O66.

Hudson Transmission Partners, LLC proposes a back-to-back HVDC facility located in Ridgefield, Bergen County, New Jersey. The connection will be a submarine AC cable system to interconnect to ConEd. Firm transmission withdrawal rights of 670 MW were originally requested by Hudson Transmission Partners. This request was later modified to be for 320 MW Firm Withdrawal Rights and 350 Non-Firm Withdrawal Rights

The purpose of this Facilities Study is to examine the PSE&G facilities identified in the Impact Study and define the project requirements for each of these facilities. This Facilities Study shall identify the purpose and necessity; provide a general description of the work; define the design requirements; identify the major materials; provide preliminary cost estimates; and develop a preliminary schedule for each of the facilities.

## **2.0 Amendments to the System Impact Study**

Since the in-service date for the project has been extended by Hudson Transmission Partners to January 31, 2012, none of the advancement of 2011 base line projects to 2010 described in the "O66 Bergen Revised Network Upgrades" document dated 10/09/08 are required.

Hudson Transmission Partners has revised the interconnection request to be for 320 MW Firm Withdrawal Rights and 350 Non-Firm Withdrawal Rights. This change eliminates the need for upgrades #8, #9 and #11 described in the "O66 Bergen Revised Network Upgrades" document dated 10/09/08.

## **3.0 Hudson Transmission Partners Milestone Schedule**

- Start Construction                      March 1, 2011
- Delivery of major electrical equipment. July 15, 2011,
- Commercial Operation. January 31, 2012,

## **4.0 List of Work**

The PJM Generator Interconnection Request Queue #O66 requires the following system upgrades to PSE&G facilities:

- Sewaren–Woodbridge 138 kV O-1315 Circuit Re-Conductor and Terminal Upgrade. (Network Upgrade #n0629)
- Roseland 230 kV Terminal Upgrade. (Network Upgrade #n0645.2)
- Bergen 230 kV Install breakers to terminate the transmission line from the HVDC Facility. (Direct Connection)
- Bergen-Athenia 230kV Install a new underground line and Terminations. (Network Upgrade #n1035)
- Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade. (Upgrades n0666.1, n0666.2, n0666.3, n0666.4, n0666.5, n0666.6, n0666.7, n0666.8, n0666.9, n0666.10, n0666.11, n0666.12, and n0666.13)
- Bergen 12H Breaker Replacement. (Network Upgrade #n0984)
- Athenia 21H, 11H, 51H, 2BH Breaker Replacement. (Upgrades n0985, n0986, n0987, and n0988)

The PJM Generator Interconnection Request Queue #O66 requires the following system upgrades to FirstEnergy facilities:

- Whippany-Roseland 230kV line reconductor and replace terminal equipment at Whippany. (Network Upgrade #n0645.1)
- Atlantic-Larrabee 230kV line reconductor and replace terminal equipment at Atlantic and Larrabee. (Network Upgrade #n0657)
- Portland 230kV – Replace terminal equipment on the Portland-Martins Creek 230kV circuit. (Network Upgrade #n0636.2)
- Whippany 230kV Station – Replace circuit breaker JB. (Network Upgrade #0670)
- Whippany 230kV Station – Replace circuit breaker QJ. (Network Upgrade #0671)

## **1.2 Milestone Schedule**

The following major milestone dates have been established for the PSE&G work required for the project. Preliminary Project Schedules have been provided in Appendix A.

| <b><u>Milestone</u></b>           | <b><u>Date</u></b>         |
|-----------------------------------|----------------------------|
| Issue Final Facility Study Report | May 2009                   |
| Project Start (Notice to Proceed) | June 2009                  |
| Engineering                       | June 2009 – June 2011      |
| Material Procurement              | September 2009 – June 2012 |
| Construction                      | May 2010 – June 2012       |
| Final Completion Date             | June 2012                  |

These major milestone dates are contingent upon the timely completion of project development activities including licensing and permitting.

The following major milestone dates have been established for the FirstEnergy work required for the project.

| <b>Activity</b>                    | <b>Start Month</b> | <b>End Month</b> |
|------------------------------------|--------------------|------------------|
|                                    |                    |                  |
| • Preliminary Engineering          | <b>1</b>           | <b>1</b>         |
| • Permits & Real Estate            | <b>1</b>           | <b>8</b>         |
| • Detailed Engineering             | <b>2</b>           | <b>7</b>         |
| • Equipment Procurement – Delivery | <b>9</b>           | <b>10</b>        |
| • Below Grade Construction         | <b>9</b>           | <b>9</b>         |
| • Above Grade Construction         | <b>9</b>           | <b>13</b>        |
| • Testing & Commissioning          | <b>12</b>          | <b>13</b>        |

## **1.3 General Design Criteria**

### **PSE&G**

#### **1.3.1 Codes and Standards**

Engineering design will be in accordance with the applicable laws and regulations of the federal government, the state of New Jersey, and the local codes and ordinances. Following is a summary of the current codes and industry standards to be used:

- American Concrete Institute (ACI) Code.
- American Institute of Steel Construction (AISC) Code.
- American Iron and Steel Institute (AISI).
- American National Standards Institute (ANSI) standards.
- American Society for Testing and Materials (ASTM) standards.
- American Society of Civil Engineers (ASCE).
- American Welding Society (AWS).
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
- Concrete Reinforcing Steel Institute (CRSI).
- Institute for Electrical and Electronics Engineers (IEEE) Standards.
- National Electrical Code (NEC).
- National Electrical Manufacturer's Association (NEMA).
- National Electrical Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Occupational Safety and Health Administration (OSHA).
- Steel Structures Painting Council (SSPC).
- Building Officials and Code Administrators International, Inc. (BOCA).
- International Building Code (IBC).

Other recognized standards and ordinances will be used where required to serve as guidelines for the design, when not in conflict with the above listed standards.

#### **1.3.2 Civil/Structural Substation Design Criteria**

##### **1.3.2.1 Transformer Oil Containment**

Per PSE&G Standards, Oil Containment Criteria shall be as follows:

- The volume of the basin will be calculated to contain 100 percent of the total oil volume of one transformer with no rainfall.

- A 6 inch freeboard and 50% void ratio will be used.
- Transformer containment pit shall be filled with 3/4 inch clean crushed stone meeting the following gradation:
- 100 percent passing 1-1/4 inch screen.
- 45 to 75 percent passing 3/4 inch screen.
- 25 to 45 percent passing 1/2 inch screen.
- 0 to 10 percent passing 1/4 inch screen.
- Geosynthetic Clay Liner (GCL) shall be “Bentomat CL” liners, as manufactured by Cetco, Arlington Heights, IL, or approved equal. “Bentomat CL” liner seaming shall consist of bentonite-enhanced seams, where panels are overlapped a minimum of 6 inches and seamed together with a continuous bead of granular sodium bentonite. Seaming shall be performed in accordance with the manufacturer’s recommendations.

#### **1.3.2.2 Structure Design**

Deadend structures will be designed using the Ultimate Strength Design (USD) method. Design and fabrication will be in accordance with the latest edition of ASCE 7, the NESC and the ASCE Publication 72.

Equipment support structures will be designed using the Allowable Strength Design (ASD) method. Design and fabrication will be in accordance with the Ninth Edition of the AISC “Manual of Steel Construction, ASCE 7, and the NESC.

#### **1.3.2.3 Material**

Steel structures will be designed using hot-rolled structural steel shapes such as wide flange, tubing, channels and angles or as folded plate tapered tubular structures. All structures will be ASTM A36 or ASTM A572 steel hot-dip galvanized for corrosion protection.

#### **1.3.2.4 Loading Conditions for Analysis**

##### **Dead End Structures**

The deadend structures will be designed to withstand the following loads:

- Loading Case 1 – NESC Heavy
- Loading Case 2 - Extreme Ice (1.5” radial ice)
- Loading Case 3 - Concurrent Wind and Ice (6.4 psf wind, 0.75” radial ice)
- Loading Case 4 – Extreme Wind (31 psf wind)

### **Equipment Support Structures**

The bus, insulator, switch and equipment supports will be designed to withstand the following loads:

- Loading Case 1 – NESC Heavy
- Loading Case 2 – Extreme Wind (110 mph, deflections will be less than those specified in NEMA SG-6-36)
- Loading Case 3 - Short Circuit (100% of insulator cantilever, wind from Loading Case 2 elsewhere)

#### **1.3.2.5 Foundation Design**

The foundation design will conform to the latest edition of the current issue of the “Building Code Requirements for Reinforced Concrete,” AC1 318, County and State Codes and will be in accordance with the following general criteria:

|                    |                              |
|--------------------|------------------------------|
| Concrete Strength: | $F_c = 4,000$ psi at 28 days |
|--------------------|------------------------------|

|                    |                    |
|--------------------|--------------------|
| Reinforcing Steel: |                    |
| ASTM A615 Gr60     | $F_y = 60,000$ psi |

|                                     |     |
|-------------------------------------|-----|
| Safety factor against soil failure: |     |
| Spread footing                      | 3.0 |
| Minimum overturning ratio:          | 1.5 |

### **Equipment and Structure Foundations**

Ground support pieces of equipment such as the circuit breakers will be supported by cast-in-place reinforced concrete slabs.

Foundations for the equipment support structures, such as bus supports, disconnect switches, etc., and dead end structures, will be spread footings.

#### **1.3.3 Electrical General Design Requirements**

The general design requirements are as follows:

|                                |               |
|--------------------------------|---------------|
| System frequency:              | 60 hertz      |
| Elevation, AMSL:               | < 1000 feet   |
| Keraunic level:                | 40            |
| Maximum ambient temperature:   | +40 degrees C |
| Minimum ambient temperature:   | -40 degrees C |
| Maximum wind velocity:         | 110 mph       |
| Maximum ice loading (no wind): | 1.5 inches    |

|                                           |            |
|-------------------------------------------|------------|
| Maximum ice loading (with wind – 40 mph): | 0.5 inches |
| Seismic zone:                             | (Per IBC)  |

### **1.3.3.1 Voltage and Current Ratings**

The voltage and current ratings are as follows:

#### 230 kV

|                                                        |           |
|--------------------------------------------------------|-----------|
| Nominal phase-to-phase voltage:                        | 230 kV    |
| Maximum phase-to-phase voltage:                        | 242 kV    |
| Nominal phase-to-ground voltage:                       | 133 kV    |
| Maximum phase-to-ground voltage:                       | 140 kV    |
| Basic impulse level (BIL):                             | 900 kV    |
| Maximum continuous current carrying capacity           | 3000 A    |
| Maximum three phase available fault current:           | 40 kA     |
| Maximum single phase to ground available fault current | 40 kA     |
| Maximum fault clearing time:                           | 30 cycles |

#### 138 kV

|                                                        |           |
|--------------------------------------------------------|-----------|
| Nominal phase-to-phase voltage:                        | 138 kV    |
| Maximum phase-to-phase voltage:                        | 145 kV    |
| Nominal phase-to-ground voltage:                       | 80 kV     |
| Maximum phase-to-ground voltage:                       | 84 kV     |
| Basic impulse level (BIL):                             | 650 kV    |
| Maximum continuous current carrying capacity           | 3000 A    |
| Maximum three phase available fault current:           | 40 kA     |
| Maximum single phase to ground available fault current | 40 kA     |
| Maximum fault clearing time:                           | 30 cycles |

### **1.3.3.2 Clearances and Spacings**

The clearances and spacings are as follows:

#### 230 kV

|                                                       |            |
|-------------------------------------------------------|------------|
| Rigid bus center-to-center phase spacing              | 144 inches |
| Minimum phase-to-phase, metal-to-metal distance       | 80 inches  |
| Minimum phase-to-ground                               | 71 inches  |
| Minimum vertical clearance from live parts to grade   | 180 inches |
| Minimum conductor clearance above roads in switchyard | 324 inches |

### 138 kV

|                                                       |            |
|-------------------------------------------------------|------------|
| Rigid bus center-to-center phase spacing              | 96 inches  |
| Minimum phase-to-phase, metal-to-metal distance       | 62 inches  |
| Minimum phase-to-ground                               | 50 inches  |
| Minimum vertical clearance from live parts to grade   | 156 inches |
| Minimum conductor clearance above roads in switchyard | 276 inches |

### **Bus Conductor Selection and Design**

New bus will be designed to meet bus ratings at 40°C ambient and 40°C temperature rise with two feet per second crosswind and will be designed to withstand the appropriate mechanical forces.

### **Bus Fitting Selection**

Fittings for the aluminum tubular bus will be bolted.

Fittings for conductor jumpers will be bolted for all aluminum conductors to a bolted pad. Equipment terminal connections will be NEMA 4-hole bolted type so they may be easily removed for equipment maintenance, repair, or replacement.

### **Insulator Selection**

Porcelain station post insulators will be used on all bus supports, under hung cable supports and disconnect switches.

### **1.3.3.3 Lightning Shielding Design**

The shielding design will be verified using the application of that model called the “Rolling Sphere Technique” developed by R. H. Lee.

After the detailed bus and equipment layout is completed, the shielding design will be analyzed to verify that all equipment within the Switchyard perimeter fence is adequately protected. Structure lightning finials and shield masts will be included in the shielding analysis.

### **1.3.3.4 Grounding**

The grounding system will be designed in a manner that provides a means to safely discharge lightning strokes to earth, reduce step and touch potentials to safe levels, and confine dangerous soil currents to inaccessible areas. The grounding system will also be designed to allow the detection of ground fault currents by protective relaying systems, limit electromagnetic interference (EMI) in low voltage circuits, and provide a common

ground reference. The grounding procedures stated herein are based on ANSI/IEEE Standard 80.

The grounding system for the Switchyard will consist of the following components:

- Ground grid conductors, which will form a network of bare, 4/0 AWG BTN (minimum) interconnected copper conductors buried 18 inches below finished earth grade and extended three feet beyond the Switchyard fence and three feet beyond the Switchyard fence gate swing, where applicable.
- Ground rods connected to the ground grid, and driven or buried vertically to a depth to reach soil of stable moisture content and resistivity.
- Lightning finials, and shield masts for direct stroke lightning protection.
- Crushed stone layer of high resistivity surfacing covering the yard to a depth of approximately 4 inches.
- The main ground grid including equipment stinger connections will be exothermically welded.
- Connections to steel structures and equipment will be bolted, with a minimum of two connections between the ground grid and structure, or as follows:
  - Single-leg bus supports – 1 connections
  - Two-leg bus supports – 2 connections
  - Switches – 1 connection per leg
  - Dead end tower – 1 connection per leg
- Connections of two points at opposite ends of control enclosure to ground grid.
- Connections to the Ring Bus fence at 50 foot intervals (maximum) and continuing up through the fence fabric.
- All horizontal or vertical bolted-connection structural members shall be bonded to a grounded structural member with a jumper of 350 MCM BTN copper.

#### **1.3.3.5 Raceway Systems**

The main raceway systems will consist of pre-cast High Density Polymer Concrete (HDPC) cable trench. Underground conduit will be schedule 40 PVC with PVC fittings and buried not less than 18 inches below grade.

#### **1.3.3.6 Yard Lighting**

Switchyard lighting will provide illumination for security and some operational functions. The outdoor lights will be installed on the deadend structures and switch legs.

#### **1.3.3.7 Control and Power Cable**

All single and multi-conductor power and control cables will be 600 volt, Class B, stranded copper. Cables will be marked at each end with circuit and wire numbers.

The minimum cable size for control and potential circuits will be 9 AWG copper. The minimum cable size for current circuits will be 9 AWG copper. All 9 AWG conductors will be multi-conductor, jacketed cable.

For potential circuits within the enclosure, 9 AWG cable will be used. For current circuits within the enclosure, 9 AWG cable will be used. For alarm circuits within the enclosure, 14 AWG cable will be used.

Single conductor cables 10 AWG and smaller will not be routed in the cable trench raceway system.

All cable terminations will be made using ring type non-insulated terminals manufactured by Burndy or Amp per PSE&G control & relaying standards.

#### **1.3.3.8 Control, Protection, and Metering**

Any new control and relay racks will be designed in accordance with PSE&G standard rack mechanical drawings and will utilize PSE&G standard relays and devices where possible. PSE&G shall provide specific manufacturer and model numbers where specific equipment is required.

### **1.3.4 General Transmission Line Design Criteria**

#### **1.3.4.1 Mechanical Loading Criteria**

The following mechanical loading conditions will be used for the design of transmission line structures.

Loading Case 1 – NESC Heavy (4 psf wind, 0.5” radial ice, 0°F, Initial)

Loading Case 2 – Extreme Wind (31 psf wind, no ice, 60°F, Initial)

Loading Case 3 – Concurrent Wind and Ice (6.4 psf wind, 0.75” radial ice, 0°F, Initial)

Loading Case 4 – Extreme Ice (no wind, 1.5” radial ice, 32°F, Initial)

Loading Case 5 – Deflection Loading (no wind, no ice, 60°F, Final). Deflection of the structure top shall be limited to the greater of 1% of total structure height or 40% of the base diameter.

#### 1.3.4.2 Electrical Clearances

The clearances used in the design of the transmission lines will meet or exceed the requirements of the National Electrical Safety Code (NESC), 2007 Edition and PJM design criteria, whichever is greater. The clearances pertain to vertical clearances, horizontal clearances, lateral clearances, and air gap clearances. Lateral clearances are included in the horizontal clearance subsection.

##### Vertical Clearances

230 kV vertical clearances will be designed to accommodate the design ACSS conductor at a maximum operating temperature of 200°C (392°F), and the design ACSR conductor at a maximum operating temperature of 100°C (212°F), unless otherwise specified. The vertical clearances indicated below meet the requirements of the NESC for 230 kV line voltage.

| <u>Description of Crossing</u>                                                                                                             | <u>230 kV<br/>Clearance</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads, except electrified trolleys (except as specified by the affected Railroad)                                            | 34ft                        |
| Roads, streets, driveways parking lots, alleys, and all other areas subject to truck traffic                                               | 26 ft                       |
| Spaces and ways subject to pedestrians or restricted traffic less than 8 feet in height                                                    | 22 ft                       |
| Pedestrian Traffic                                                                                                                         | 22 ft                       |
| Water areas not suitable for sailboating or where sailboating is prohibited                                                                | 24 ft                       |
| Water areas suitable for sailboating including lakes, ponds, reservoirs, rivers, streams, and canals with an unobstructed surface area of: |                             |
| Less than 20 acres                                                                                                                         | 28 ft                       |
| Over 20 to 200 acres                                                                                                                       | 36 ft                       |
| Over 200 to 2000 acres                                                                                                                     | 42 ft                       |
| Over 2000 acres                                                                                                                            | 48 ft                       |

| <u>Description of Crossing</u>                                                    | <u>230 kV<br/>Clearance</u> |
|-----------------------------------------------------------------------------------|-----------------------------|
| Public or private land and water areas posted for rigging or launching sailboats: |                             |
| Less than 20 acres                                                                | 33 ft                       |
| Over 20 to 200 acres                                                              | 41 ft                       |
| Over 200 to 2000 acres                                                            | 47 ft                       |
| Over 2000 acres                                                                   | 53 ft                       |
| Communication lines                                                               | 12 ft                       |
| Overhead ground wires and guy wires                                               | 9 ft                        |
| Open supply conductors over or under subject line:                                |                             |
| 22 kV and below                                                                   | 9 ft                        |
| 46 kV                                                                             | 10 ft                       |
| 69 kV                                                                             | 10 ft                       |
| 115 kV                                                                            | 11 ft                       |
| 138 kV                                                                            | 11 ft                       |
| 161 kV                                                                            | 12 ft                       |
| 230 kV                                                                            | 13 ft                       |
| 345 kV                                                                            | 16 ft                       |
| 500 kV                                                                            | 19 ft                       |
| Buildings:                                                                        |                             |
| Over roofs or projections not readily accessible to pedestrians                   | 20 ft                       |
| Over roofs or projections readily accessible to pedestrians                       | 21 ft                       |
| Over roofs accessible to vehicles but not trucks 8 ft high                        | 21 ft                       |
| Over roofs accessible to truck traffic                                            | 26 ft                       |
| Bridges: Over (not attached)                                                      | 20 ft                       |
| Installations not classified as buildings or bridges attached)                    |                             |
| Upon which personnel walk                                                         | 21 ft                       |
| Other portions of such installations                                              | 15 ft                       |

| <u>Description of Crossing</u> | <u>230 kV<br/>Clearance</u> |
|--------------------------------|-----------------------------|
| Another supporting structure   | 12 ft                       |
| Top of rail cars               | 14 ft                       |

138 kV vertical clearances will be designed to accommodate the design ACSS conductor at a maximum operating temperature of 200°C (392°F), unless otherwise specified. The vertical clearances indicated below meet the requirements of the NESC for 138kV line voltage.

| <u>Description of Crossing</u>                                                                                                             | <u>138 kV<br/>Clearance</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads, except electrified trolleys (except as specified by the affected Railroad)                                            | 32ft                        |
| Roads, streets, driveways parking lots, alleys, and all other areas subject to truck traffic                                               | 24 ft                       |
| Spaces and ways subject to pedestrians or restricted traffic less than 8 feet in height                                                    | 20 ft                       |
| Pedestrian Traffic                                                                                                                         | 20 ft                       |
| Water areas not suitable for sailboating or where sailboating is prohibited                                                                | 22 ft                       |
| Water areas suitable for sailboating including lakes, ponds, reservoirs, rivers, streams, and canals with an unobstructed surface area of: |                             |
| Less than 20 acres                                                                                                                         | 26 ft                       |
| Over 20 to 200 acres                                                                                                                       | 34 ft                       |
| Over 200 to 2000 acres                                                                                                                     | 40 ft                       |
| Over 2000 acres                                                                                                                            | 46 ft                       |

| <u>Description of Crossing</u>                                                    | <u>138 kV<br/>Clearance</u> |
|-----------------------------------------------------------------------------------|-----------------------------|
| Public or private land and water areas posted for rigging or launching sailboats: |                             |
| Less than 20 acres                                                                | 31 ft                       |
| Over 20 to 200 acres                                                              | 39 ft                       |
| Over 200 to 2000 acres                                                            | 45 ft                       |
| Over 2000 acres                                                                   | 51 ft                       |
| Communication lines                                                               | 10 ft                       |
| Overhead ground wires and guy wires                                               | 7 ft                        |
| Open supply conductors over or under subject line:                                |                             |
| 22 kV and below                                                                   | 7 ft                        |
| 46 kV                                                                             | 8 ft                        |
| 69 kV                                                                             | 8 ft                        |
| 115 kV                                                                            | 9 ft                        |
| 138 kV                                                                            | 9 ft                        |
| 161 kV                                                                            | 10 ft                       |
| 230 kV                                                                            | 11 ft                       |
| 345 kV                                                                            | 14 ft                       |
| 500 kV                                                                            | 17 ft                       |
| Buildings:                                                                        |                             |
| Over roofs or projections not readily accessible to pedestrians                   | 18 ft                       |
| Over roofs or projections readily accessible to pedestrians                       | 19 ft                       |
| Over roofs accessible to vehicles but not trucks 8 ft high                        | 18 ft                       |
| Over roofs accessible to truck traffic                                            | 24 ft                       |
| Bridges: Over (not attached)                                                      | 19 ft                       |
| Installations not classified as buildings or bridges attached)                    |                             |
| Upon which personnel walk                                                         | 19 ft                       |
| Other portions of such installations                                              | 13 ft                       |
| Another supporting structure                                                      | 10 ft                       |
| Top of rail cars                                                                  | 12 ft                       |

### Horizontal Clearances

230 kV horizontal clearances are based on a maximum operating temperature of 200°C (392°F) for the design of ACSS conductor, or a maximum operating temperature of 100°C (212°F) for the design of ACSR conductor; with the conductor in the final maximum sag condition with no wind, unless otherwise specified. The horizontal clearances indicated below meet the requirements of the NESC for 230 kV line voltage and include a minimum of 3 feet additional clearance to allow for construction and survey tolerances.

| <u>Description of Obstacle</u>                                                                                                                              | <u>230 kV<br/>Clearance</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads                                                                                                                                         | 19 ft                       |
| Buildings, signs, chimneys, billboards, radio & TV antennas, tanks<br>& other installations not classified as buildings or bridges (wires not<br>attached): |                             |
| With no wind displacement                                                                                                                                   | 15 ft                       |
| With 6 psf wind displacement                                                                                                                                | 12 ft                       |
| Lighting supports, traffic signals, or supporting structures of another line:                                                                               |                             |
| With no wind displacement                                                                                                                                   | 11 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10.5 ft                     |
| Bridges (unattached):                                                                                                                                       |                             |
| With no wind displacement                                                                                                                                   | 14 ft                       |
| With 6 psf wind displacement                                                                                                                                | 12 ft                       |

138 kV horizontal clearances are based on a maximum operating temperature of 200°C (392°F) for the design of ACSS conductor; with the conductor in the final maximum sag condition with no wind, unless otherwise specified. The horizontal clearances indicated below meet the requirements of the NESC for 138 kV line voltage.

| <u>Description of Obstacle</u>                                                                                                                              | <u>138 kV<br/>Clearance</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads                                                                                                                                         | 17 ft                       |
| Buildings, signs, chimneys, billboards, radio & TV antennas, tanks<br>& other installations not classified as buildings or bridges (wires not<br>attached): |                             |
| With no wind displacement                                                                                                                                   | 13 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10 ft                       |
| Lighting supports, traffic signals, or supporting structures of another line:                                                                               |                             |
| With no wind displacement                                                                                                                                   | 9 ft                        |
| With 6 psf wind displacement                                                                                                                                | 8.5 ft                      |
| Bridges (unattached):                                                                                                                                       |                             |
| With no wind displacement                                                                                                                                   | 12 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10 ft                       |

### **Air Gap Clearances**

Air gap clearances are indicated below.

| <u>Voltage</u> | <u>Air Gap</u> | <u>Clearance Description</u>              |
|----------------|----------------|-------------------------------------------|
| 230 kV         | 80 in          | Full Impulse                              |
|                | 56 in          | 6 psf Wind Displacement                   |
|                | 20 in          | 60 Hertz Extreme Wind Operating Clearance |
| <u>Voltage</u> | <u>Air Gap</u> | <u>Clearance Description</u>              |
| 138 kV         | 52 in          | Full Impulse                              |
|                | 30 in          | 6 psf Wind Displacement                   |
|                | 12 in          | 60 Hertz Extreme Wind Operating Clearance |

### **1.3.4.3 Galloping**

An elliptical analysis will be performed to investigate the potential for galloping throughout the relocated transmission line. The analysis will consider the conductor operating at either of two conditions; either a 2 psf wind, 1/2" radial ice, at 32°F loading condition; or a no wind, 1/2" radial ice, 32°F loading condition. A single loop calculation will be performed for spans of 600 feet or less, and a double loop calculation will be performed for spans in excess of 600 feet. The line design will incorporate a clearance of 12 inches between conductor ellipses to minimize conductor and/or structure damage.

#### 1.3.4.4 Conductors and Static Wires

The following sub-sections will describe the physical properties of the conductor and static wire to be used for this project.

##### Conductor

The 230 kV transmission conductors to be used for this project is as follows:

| Code Word | Class<br>Type | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|-----------|---------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| Falcon    | ACSR          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 54,500            |
| Falcon    | ACSS          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 42,600            |

The 138 kV transmission conductor to be used for this project is as follows:

| Code Word | Class<br>Type | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|-----------|---------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| Falcon    | ACSS          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 42,600            |

##### Fiber Optic Cables

The 138 kV and 230 kV shield wire to be used for this project is an optical ground wire (OPGW) as follows:

| Description   | Class<br>Type           | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|---------------|-------------------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| AFL AC 73/551 | 24 Fibers<br>(DNO-6967) | -    | 12        | 0.1671          | 0.551            | 0.4028             | 24,014            |

##### Conductor Tension Limits

The following maximum tension limits will be used in the determination of conductor sag and tension values. The first set of limits below meet NESC code requirements, and the second set of limits are PSE&G tension controls that will normally be the controlling limitation in non-slack span tensions.

| <b><u>Load Case</u></b> | <b><u>NESC Limits</u></b> |
|-------------------------|---------------------------|
| NESC Heavy              | 60% Initial               |
| Extreme Wind            | 75% Initial               |
| Heavy Ice               | 75% Initial               |
| 60°F                    | 35% Initial               |
| 60°F                    | 25% Final                 |

| <b><u>Load Case</u></b> | <b><u>PSE&amp;G Limits</u></b>                           |
|-------------------------|----------------------------------------------------------|
| -20°F                   | 20% Initial                                              |
| NESC Heavy              | 10,000 lbs (1590 ACSS – Sewaren to Woodbridge 138 kV)    |
| NESC Heavy              | 17,400 lbs (1590 ACSS – Branchburg to Readington 230 kV) |
| NESC Heavy              | 22,500 lbs (1590 ACSR – Readington to Roseland 230 kV)   |
| NESC Heavy              | 15,600 lbs (1590 ACSS – Roseland to Hudson 230 kV)       |

The static wire tension is based on 80% of the conductor sag at 60°F, no ice, no wind, final sag condition, and must also meet the same criteria as a conductor. This 80% sag criteria will apply to both full tension and slack tension spans.

#### **1.3.4.5 Structures**

Any new 230 kV and 138 kV structures for this project will be single or double circuit tubular steel poles with anchor bolts. All new steel structures will have a painted finish (valley green).

#### **1.3.4.6 Insulation**

Several design considerations have been utilized to determine the standard number of insulators required for 230 kV and 138 kV construction, including arcing distance, basic impulse insulation level (BIL), contamination, dry flashover, impulse flashover, switching surge, and insulator coordination. A shielding angle of 25 degrees or less will be used on all structures to help avoid lightning flashovers.

#### **Insulators**

The 230 kV insulator strings used for all structure types will consist of toughened glass ball & socket insulator bells, with 16 bells (30 kips) in each suspension string and 18 bells (50 kips) in each deadend string. The 138 kV insulator strings used for all structure types will consist of toughened glass ball & socket insulator bells, with 14 bells in each string. For all insulator applications, the insulator mechanical loading will not exceed 50% of the insulator M&E

rating for NESC working loads and 75% of the insulator M&E rating for all other loads with overload capacity factors.

Insulator swing clearances for suspension insulators are as follows:

| <u>Voltage</u> | <u>Condition</u>             | <u>Clear to Arm or Structure</u> |
|----------------|------------------------------|----------------------------------|
| 230 kV         | 60°F, no wind, final (1)     | 80"                              |
|                | 60°F, 6 psf wind, final      | 56"                              |
|                | 60°F, 31 psf wind, final (2) | 20"                              |

No wind clearance for suspension insulators (impulse air gap or insulator length)

Extreme wind 60 Hz minimum flashover distance

| <u>Voltage</u> | <u>Condition</u>             | <u>Clear to Arm or Structure</u> |
|----------------|------------------------------|----------------------------------|
| 138 kV         | 60°F, no wind, final (1)     | 52"                              |
|                | 60°F, 6 psf wind, final      | 30"                              |
|                | 60°F, 31 psf wind, final (2) | 12"                              |

(1) No wind clearance for suspension insulators (impulse air gap or insulator length)

(2) Extreme wind 60 Hz minimum flashover distance

#### **1.3.4.7 Hardware and Accessories**

The strength of hardware will equal or exceed the M&E rating of the insulators. Typical conductor and static wire accessories include compression sleeves and splices, which will develop the strength of the wire being spliced. The quantity, location and type of dampers to be installed on conductors and static wires will be according to manufacturers' recommendations, and based on sag/tension and applicable weather condition information provided for analysis.

All 230 kV and 138 kV conductor and static wire deadends will use compression fittings suitable for the conductors or cables used. All hardware and accessories will be made from steel, malleable iron or aluminum. Steel and malleable iron fittings will be galvanized after fabrication.

#### **1.3.4.8 Structure Foundations**

The majority of the foundations for the new tubular steel poles will consist of drilled piers with anchor bolts. The diameter and length of each drilled pier foundation will be determined from soil data taken along the transmission line route. The foundations will be limited to approximately 3 inches of groundline movement under the worst case foundation reactions, including overload capacity factors.

The drilled pier foundations will be designed using the L-Pile 5.0 Plus software program.

In some cases, soil conditions will most likely dictate that driven pile foundations will be required.

#### **1.3.4.9 Structure Grounding**

All transmission structures will be individually grounded through a dedicated earth driven grounding system composed of ground rods. The maximum allowable ground resistance on a transmission structure is 25 ohms with the overhead static wire disconnected. Measurements are to be made on each structure using an approved megger and recorded during construction before connection to static wire is made.

### **FirstEnergy**

Facilities owned and operated by FirstEnergy (FE) and Jersey Central Power and Light, its operating company, shall comply with the applicable FE technical requirements and standards posted on the PJM website per the PJM Tariff, the “PJM transmission and Substation Design Subcommittee Technical Requirements,” the “PJM Relay Philosophy Design Standards” and the following criteria. Where there are different requirements for the same criterion, the more restrictive shall apply.

#### **General Design Requirements**

- |                                            |                                                                                 |
|--------------------------------------------|---------------------------------------------------------------------------------|
| • System phasing (counter clockwise)       | 1-2-3 (FE)/X-Y-Z (Penelec)                                                      |
| • System frequency:                        | 60 hertz                                                                        |
| • Elevation, AMSL:                         | 2254 feet                                                                       |
| • Isokeraunic level:                       | 40                                                                              |
| • Maximum ambient temperature:             | 40 degrees C                                                                    |
| • Minimum ambient temperature:             | -40 degrees C                                                                   |
| • Maximum conductor operating temperature: | Per PJM Document “Outdoor Substation Conductor Ratings” dated 10/19/04          |
| • Wind Loading (no ice):                   | Per ASCE 7-98, Fig. 6-1                                                         |
| • Wind coincident with 13 mm radial ice    | 64 km/h (40 mph)                                                                |
| • Ice loading – Substations (no wind):     | 25 mm                                                                           |
| • Seismic zone:                            | Per ASCE 7-98, Fig. 9.4.1.1(a) and (b). Equipment qualification per IEEE 693-97 |

## **Voltage and Current Ratings**

### **230 kV System**

- Nominal phase-to-phase: 230 kV
- Maximum phase-to-phase: 242 kV
- Basic impulse level (BIL): 900 kV
- Minimum continuous current carrying capacity: 2000 A
- Design fault current (equipment & bus): 40 kA
- Single Contingency (breaker or relay failure) clearing time: 45 cycles

## **Clearances and Spacing**

### **230 kV System**

- Recommended rigid bus center-to-center phase spacing: 132"
- Minimum phase-to-phase, metal-to-metal distance: 89"
- Recommended phase-to-ground: 80"
- Minimum phase-to-ground: 71"
- Minimum vertical clearance from live parts to grade: 12'-9"
- Minimum horizontal clearance from live parts: 8'-3"
- Minimum conductor clearance above roads, streets, and other areas subject to truck traffic: 23'-0"
- Minimum conductor clearance above spaces and ways subject to pedestrian or restricted traffic: 20'-2"
- Minimum bottom of insulator to top of foundation: 8'-6"

## **2.0 SUMMARY OF RESULTS**

### **2.1 Total Cost Breakdown**

The following table identifies the estimated costs by project for the PSE&G work.

(The remainder of this page is intentionally left blank.)

| <u>Facility</u>                                                                                                                                             | <u>Engineering</u> | <u>Materials</u>  | <u>Construction<br/>Mgmt</u> | <u>Construction</u> | <u>PSE&amp;G<br/>Program<br/>Mgmt</u> | <u>PSE&amp;G<br/>Engineering</u> | <u>PSE&amp;G<br/>Construction<br/>Support</u> | <u>PSE&amp;G<br/>Relaying,<br/>Mechanics,<br/>Lab. &amp; System<br/>Prot.</u> | <u>Environmental<br/>&amp; Resource<br/>Recovery</u> | <u>Licensing &amp;<br/>Permitting</u> | <u>Corporate<br/>Properties</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|------------------------------|---------------------|---------------------------------------|----------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------|---------------------------------------|---------------------------------|
| 3.1 Sewaren – Woodbridge<br>138 kV O-1315 Circuit Re-<br>Conductor                                                                                          | 708,000            | 4,528,000         | 208,000                      | 4,103,000           | 668,000                               | 212,000                          | 229,000                                       | 0                                                                             | 10,000                                               | 900,000                               | 200,000                         |
| 3.1 Sewaren Terminal<br>Upgrade                                                                                                                             | 20,000             | 52,000            | 10,000                       | 60,000              | 10,000                                | 6,000                            | 11,000                                        | 15,000                                                                        | 10,000                                               | 0                                     | 0                               |
| 3.2 Roseland 230 kV<br>Terminal Upgrade                                                                                                                     | 10,000             | 2,000             | 13,000                       | 15,000              | 3,000                                 | 3,000                            | 14,000                                        | 10,000                                                                        | 0                                                    | 50,000                                | 0                               |
| 3.3 Bergen 230 kV<br>Underground Line (See<br>Note 1)                                                                                                       | 1,750,000          | 33,610,000        | 2,340,000                    | 37,725,000          | 3,771,000                             | 525,000                          | 566,000                                       | 0                                                                             | 3,950,000                                            | 3,500,000                             | 5,000,000                       |
| 3.3 Athenia Terminal<br>Upgrade                                                                                                                             | 130,000            | 540,000           | 33,000                       | 514,000             | 85,000                                | 39,000                           | 36,000                                        | 60,000                                                                        | 250,000                                              | 200,000                               | 0                               |
| 3.3 Bergen Terminal<br>Upgrade - HTP Circuit                                                                                                                | 345,500            | 1,725,000         | 202,000                      | 2,392,500           | 326,500                               | 103,500                          | 222,000                                       | 30,000                                                                        | 0                                                    | 750,000                               | 50,000                          |
| 3.3 Bergen Terminal<br>Upgrade - Athenia Circuit                                                                                                            | 345,500            | 1,725,000         | 202,000                      | 2,392,500           | 326,500                               | 103,500                          | 222,000                                       | 30,000                                                                        | 0                                                    | 750,000                               | 50,000                          |
| 3.4 Hudson 2HC, 2HA,<br>3HA, 1HB, 4HA, 4HC,<br>3HB, 3HC, 2HB, 4HB,<br>1HA, 1HC, Breaker and<br>Disconnect Switch<br>Replacements and Ground<br>Grid Upgrade | 2,005,000          | 12,658,000        | 583,000                      | 11,822,000          | 1,894,000                             | 602,000                          | 641,000                                       | 370,000                                                                       | 100,000                                              | 2,000,000                             | 500,000                         |
| 3.5 Bergen 12H Breaker<br>Replacement                                                                                                                       | 80,000             | 430,000           | 27,000                       | 116,000             | 46,000                                | 24,000                           | 30,000                                        | 25,000                                                                        | 10,000                                               | 0                                     | 0                               |
| 3.6 Athenia 21H, 11H, 51H,<br>2BH Breaker Replacement                                                                                                       | 350,000            | 890,000           | 80,000                       | 433,000             | 123,000                               | 90,000                           | 88,000                                        | 100,000                                                                       | 25,000                                               | 0                                     | 0                               |
| <b>Subtotal</b>                                                                                                                                             | <b>5,744,000</b>   | <b>56,160,000</b> | <b>3,698,000</b>             | <b>59,573,000</b>   | <b>7,253,000</b>                      | <b>1,708,000</b>                 | <b>2,059,000</b>                              | <b>640,000</b>                                                                | <b>4,355,000</b>                                     | <b>8,150,000</b>                      | <b>5,800,000</b>                |

*Note 1: Includes the Proposed Route for Athenia – Bergen Transmission Line*

The following general assumptions were used in estimating PSE&G costs at each Facility. Facility unique assumptions are listed in the respective Facility Study Results sections.

- Costs are in 2009 dollars.
- A budgetary quotation from suppliers, or historical data was utilized for the major equipment pricing.
- Equipment and material costs assume normal (non-expedited) procurements.
- Existing substation facility resources are available and will be utilized as required for station expansion projects including control building space, AC and DC power sources, raceway and control cable systems, communications systems, and SCADA remote terminal unit (RTU) I/O.
- Construction labor assumes the use of union labor.
- In Substation facilities, it is assumed that a spread footing type foundations can be utilized and adequate soils are present. An allowance has been included for soil borings.
- All existing shield wires on the transmission lines will be replaced with OPGW conductor and hardware assemblies.
- When transmission line conductors are to be replaced, it is assumed that the existing transmission line insulator and hardware assemblies will be replaced as part of this project.
- Costs associated with a transmission line EMF and audible noise study have been included in the estimated engineering costs for the project. The studies will be performed during the detailed design phase of the project in support of the permitting process.
- When transmission line structure replacements are required, the existing lattice steel towers will be replaced with new tubular steel poles directly adjacent to the existing structure location.
- All new tubular steel poles will be painted. Galvanizing has not been included in the estimate.
- It has been assumed that extended construction outages will be available to support the structure modifications and replacements throughout the project limits.
- Existing telecommunication cellular antennas will need to be temporarily relocated while structure modification and/or replacement work occurs at required locations at the cost of the developer. These costs are not included in the estimates.
- Lattice tower structural analysis was not performed for the purposes of this report. Tower replacements or modifications are based on one of the following: 1) Evaluation of ground clearances with the proposed conductor modeled at its maximum operating temperature and proposed line tensions not exceeding existing line tensions. 2) Empirical evaluation of existing towers based on tower type, height, line angle, span length and with proposed line tensions higher than existing line tensions.
- Costs for modifications to existing lattice towers have been estimated with respect to a percentage of the replacement cost for a new tubular steel structure as follows:

Minor modifications (20%), Average modifications (40%), Major modifications (70%).

- Final costs are contingent upon structural analysis of the lattice towers that is required for determining tower replacements and modifications. Minor allowances have been included in the estimate to provide structural analysis of the lattice towers.
- Evaluation of existing foundations was not performed for the purposes of this report. No allowances have been included in the estimate for the repair or modification of existing foundations.
- Final costs are contingent upon detailed analysis of existing foundations. Allowances have been included in the estimate to provide detailed engineering analysis of existing foundations.
- Costs associated with ROW access and site restoration have been included within the construction portion of the cost estimates. These costs are approximately 4% of the construction costs.
- Sales, use, or other taxes are not included.
- Demolition costs have been included, where required, but do not include allowances for unknown underground obstructions, such as abandoned pipe, tanks, foundations, wells, rock, etc.
- No allowance is included for contaminated soil disposal or environmental mitigation, if required.
- No material escalation costs have been included in the estimate.
- Program Management costs have been estimated to be approximately 7% of the sum of the Engineering, Materials, Construction, and Construction Management costs.
- The Licensing & Permitting estimates assume that there will be no Federal Environmental Impact Statement required. If an FEIS is required the schedule will require an additional 24 to 36 months for the process.
- If a National Environmental Policy Act process is required, those costs are not included in the estimates.
- Costs are based upon using existing rights-of-way with the exception of the pipe type cable route. The pipe type cable installation will require local, county, and state approvals.
- Estimates do not include wetland mitigation and/or approvals of the mitigation.
- The estimate does not include additional costs incurred as a result of condemnation proceedings, if required. As of this date, it has not been determined that PSE&G can utilize condemnation to acquire land rights for this project.
- Any land right acquisitions required from PSEG Power LLC have not been included in this estimate.

An estimated cost summary in 2009 dollars, excluding taxes or effects from Contribution In Aid of Construction, for the FirstEnergy required network upgrades is shown below:

[PJM Network Upgrade n0645.1]

|                                               |             |
|-----------------------------------------------|-------------|
| Whippany-Roseland 230 kV DCT Line Reconductor |             |
|                                               |             |
| Engineering                                   | \$314,900   |
| Material & Equipment                          | \$2,591,400 |
| Construction & Testing                        | \$2,956,500 |
|                                               |             |
| Total                                         | \$5,862,800 |

. [PJM Network Upgrade n0657]

|                                           |             |
|-------------------------------------------|-------------|
| Larrabee-Atlantic 230 kV Line Reconductor |             |
|                                           |             |
| Engineering                               | \$158,300   |
| Material & Equipment                      | \$1,411,600 |
| Construction & Testing                    | \$4,362,900 |
|                                           |             |
| Total                                     | \$5,932,800 |

[PJM Network Upgrade n0636.2]

|                                                  |             |
|--------------------------------------------------|-------------|
| Portland – Martins Creek 230 kV Terminal Upgrade |             |
|                                                  |             |
| Engineering                                      | \$259,400   |
| Material & Equipment                             | \$428,800   |
| Construction & Testing                           | \$360,700   |
|                                                  |             |
| Total                                            | \$1,048,900 |

[PJM Network Upgrade n0657]

|                                      |          |
|--------------------------------------|----------|
| Atlantic Substation Drop Replacement |          |
|                                      |          |
| Engineering                          | \$23,800 |
| Material & Equipment                 | \$6,100  |
| Construction & Testing               | \$10,000 |
|                                      |          |
| Total                                | \$39,900 |

[PJM Network Upgrade n0657]

|                                      |          |
|--------------------------------------|----------|
| Larrabee Substation Drop Replacement |          |
|                                      |          |
| Engineering                          | \$23,800 |
| Material & Equipment                 | \$6,100  |
| Construction & Testing               | \$10,000 |
|                                      |          |
| Total                                | \$39,900 |

[PJM Network Upgrade n0670]

|                                        |           |
|----------------------------------------|-----------|
| Whippany Substation Replace Breaker JB |           |
|                                        |           |
| Engineering                            | \$123,800 |
| Material & Equipment                   | \$209,900 |
| Construction & Testing                 | \$87,500  |
|                                        |           |
| Total                                  | \$421,200 |

[PJM Network Upgrade n0671]

|                                        |           |
|----------------------------------------|-----------|
| Whippany Substation Replace Breaker QJ |           |
|                                        |           |
| Engineering                            | \$123,800 |
| Material & Equipment                   | \$209,900 |
| Construction & Testing                 | \$87,500  |
|                                        |           |
| Total                                  | \$421,200 |

**Assumptions/Qualifiers**

The accomplishment of the work on the FirstEnergy system to support the costs and schedule is dependent upon the following:

- Obtaining the necessary transmission line outages.
- No equipment delivery, environmental or regulatory delays.
- No permitting or real estate delays.
- No extreme weather.
- No force majeure.
- Schedule assumes contractor availability for helicopter installation of the transmission line conductors.
- Schedule assumes concurrent outage availability for the reconductor of the Atlantic-Larrabee and Whippany-Roseland line work.

## **2.2 Summary Schedule**

Following is the proposed summary schedule based upon the Preliminary Project Schedule provided in Appendix A for the PSE&G projects. The start date indicates when engineering will commence. The finish date indicates when the Facility will be placed back in service after the proposed upgrades are completed.

| <b><u>Facility</u></b>                                                                                                                | <b><u>Start</u></b> | <b><u>Finish</u></b> |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|
| Sewaren – Woodbridge 138 kV O-1315” Circuit Re-Conductor and Terminal Upgrade                                                         | June 2009           | February 2011        |
| Roseland 230 kV Terminal Upgrade                                                                                                      | January 2010        | May 2010             |
| Bergen 230 kV Underground line and Terminal Upgrades                                                                                  | April 2009          | May 2012             |
| Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade | June 2009           | April 2012           |
| Bergen 12H Breaker Replacement                                                                                                        | January 2011        | October 2011         |
| Athenia 21H, 11H, 51H, 2BH Breaker Replacement                                                                                        | October 2010        | December 2011        |

The following assumptions were used in developing the facility schedules.

- Start and finish dates are for duration identification only. Actual start dates will commence 60 to 90 days after execution of ISA/CSA.
- Equipment and material lead times are typical for normal (non-expedited) procurements.
- Typical system outage windows are from mid-September to mid-May.
- Facility start dates reflect an estimate for when engineering must commence in order for a desired outage window to be utilized.
- Major schedule impacts and considerations which could delay the upgrade of this facility include the following:
  - Permitting and licensing activities.
  - Construction outage requirements.

### **3.0 FACILITY STUDY RESULTS**

The Facility Study Results are divided into sections for each of the defined major projects to be constructed by PSE&G. Each section is organized into the following general outline.

1. Purpose and Necessity
2. General Description
3. Design Requirements
4. Major Materials
5. Cost Estimate
6. Preliminary Schedule

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### **3.1 Sewaren – Woodbridge 138 kV O-1315 Circuit Re-Conductor and Terminal Upgrade (Upgrade n0629)**

#### **3.1.1 Purpose and Necessity**

The solution to alleviate the overload on the Sewaren-Woodbridge O-1315 138 kV circuit is to re-conductor the circuit. A summer normal continuous rating of 400 MVA is required with a four hour summer emergency rating of 488 MVA.

The existing 138 kV O-1315 transmission circuit consists of a single 795 KCMIL ACSR conductor per phase.

The upgrades will include replacing the existing conductor with a single 1590 KCMIL ACSS conductor per phase.

The terminal equipment at Woodbridge includes single 1590 ACSR conductor per phase and one 138 kV 2000 A continuous circuit switcher. PSE&G has a four hour summer emergency rating of 2063 A for the 1590 ACSR and 2189 A for the circuit switcher. The four hour summer emergency rating required is 2042 A; therefore, no terminal upgrade is required at the Woodbridge Substation.

The terminal equipment at Sewaren includes a wave trap and a line disconnect switch rated 1200 A. The wave trap and disconnect switch will be replaced with equipment rated 3000 A continuous. The new jumper conductors to the wave trap will be two 1590 MCM ACSR per phase; the existing 3 1/2 inch aluminum bus is acceptable.

No other taps of the O-1315 line exist between Sewaren Station and Woodbridge Station.

#### **3.1.2 General Description**

Install new line conductor, OPGW, structures, and hardware for single 1590 KCMIL 54/19 ACSS “Falcon” conductor per phase along the O-1315 circuit from Sewaren Station to Woodbridge Station.

Install a new 3000 A wave trap and double end break disconnect switch in the O-1315 line terminal at the Sewaren station

#### **General Description of Proposed Route**

The portion of the O-1315 circuit proposed for upgrade traverses along the existing Sewaren-Brunswick transmission line corridor from Sewaren Station to the Woodbridge Station. Both of the stations and the route are located in Middlesex County, Township of Woodbridge, New Jersey.

Along the existing route multiple road, railroad and state highway crossings are encountered. The areas surrounding the line would be classified as heavy urban and commercial development.

The terminal points for the upgraded circuit are at the existing Sewaren Station and the existing Woodbridge Station.

The upgraded circuit length is approximately 3.3 miles.

The existing circuit is located on a double circuit 138 kV line supported by lattice steel towers. Several spans along the route also support low voltage underbuild.

### **3.1.3 Design Requirements**

The following are specific facility design requirements for the Sewaren-Woodbridge line; other general design requirements are included in section 1.3 General Design Criteria.

- Phase conductor: Single 1590 KCMIL 54/19 ACSS Falcon  
Emergency operating temperature – 200°C (392°F)
- All electrical clearances are based on a 138 kV voltage level.

### **3.1.4 Major Materials**

#### **O-1315 Line**

| <u>Item</u>                                     | <u>Description</u>                                                                                                          | <u>Quantity</u> |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------|
| New Steel Structures and Associated Foundations | Self supported, painted steel poles. Double circuit deadends and tangent type poles ranging from 125 to 175 feet in height. | 8               |
| Minor Steel Modifications                       | Modifications to existing lattice steel towers.                                                                             | 5               |
| Average Steel Modifications                     | Modifications to existing lattice steel towers.                                                                             | 4               |
| Major Steel Modifications                       | Modifications to existing lattice steel towers.                                                                             | 3               |
| 138 kV Line Conductor                           | Single 1590 ACSS Falcon per phase (circuit feet).                                                                           | 18,500          |

| <u>Item</u>                          | <u>Description</u>                                                                         | <u>Quantity</u> |
|--------------------------------------|--------------------------------------------------------------------------------------------|-----------------|
| 138 kV Suspension Insulator Assembly | Suspension insulator assembly, toughened glass, including hardware and fittings.           | 93              |
| 138 kV Deadend Insulator Assembly    | Deadend insulator assembly, toughened glass, including hardware and fittings.              | 90              |
| OPGW                                 | 24 Fiber DNO-6967 (feet).                                                                  | 38,800          |
| OPGW Suspension Assembly             | AFL Hardware, per PSE&G standards                                                          | 11              |
| OPGW Deadend Assembly                | AFL Hardware, per PSE&G standards                                                          | 22              |
| 26 kV Line Conductor                 | Single 795 ACSR Condor per phase (feet)                                                    | 4,500           |
| 26 kV Deadend Insulator              | Deadend insulator, porcelain, transmission line assembly, including hardware and fittings. | 48              |

#### **Sewaren Station**

| <u>Item</u>       | <u>Description</u>                                                                | <u>Quantity</u> |
|-------------------|-----------------------------------------------------------------------------------|-----------------|
| Disconnect Switch | Manually operated 138 kV disconnect switch, 3000 A, three phase, double end break | 1               |
| Ground Switch     | Manually operated 138 kV ground switch, three phase                               | 1               |
| Wave Trap         | Wave trap, 3000 A, horizontal mount                                               | 1               |

### **3.1.5 Cost Estimate**

The Sewaren – Woodbridge 138 kV O-1315 Circuit Re-Conductor costs are estimated as follows:

|                               |                     |
|-------------------------------|---------------------|
| Engineering                   | \$ 708,000          |
| Equipment and Materials       |                     |
| Steel Structures & Assemblies | \$ 4,016,000        |
| Conductor                     | \$ 299,000          |
| OPGW                          | \$ 213,000          |
| Construction Management       | \$ 208,000          |
| <u>Construction</u>           | <u>\$ 4,103,000</u> |
| Subtotal                      | \$ 9,547,000        |

The Sewaren – Woodbridge 138 kV O-1315 PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 668,000        |
| Engineering                                      | \$ 212,000        |
| Construction Support                             | \$ 229,000        |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 0              |
| Environmental & Resource Recovery                | \$ 10,000         |
| Licensing & Permitting                           | \$ 900,000        |
| <u>Corporate Properties</u>                      | <u>\$ 200,000</u> |
| Subtotal                                         | \$ 2,219,000      |

**Total cost for the Sewaren – Woodbridge O-1315 Re-Conductor      \$ 11,766,000**

The Sewaren line terminal upgrade costs are estimated as follows:

|                         |                  |
|-------------------------|------------------|
| Engineering             | \$ 20,000        |
| Equipment and Materials |                  |
| Steel Structure         | \$ 1,000         |
| Switchyard Buswork      | \$ 1,000         |
| Disconnect Switches     | \$ 20,000        |
| Wave Trap               | \$ 30,000        |
| Construction Management | \$ 10,000        |
| <u>Construction</u>     | <u>\$ 60,000</u> |
| Subtotal                | \$ 142,000       |

The Sewaren line terminal PSE&G costs are estimated as follows:

|                                                  |             |
|--------------------------------------------------|-------------|
| Program Management                               | \$ 10,000   |
| Engineering                                      | \$ 6,000    |
| Construction Support                             | \$ 11,000   |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 15,000   |
| Environmental & Resource Recovery                | \$ 10,000   |
| Licensing & Permitting                           | \$ 0        |
| <u>Corporate Properties</u>                      | <u>\$ 0</u> |
| Subtotal                                         | \$ 52,000   |

**Total cost for the Sewaren Line Terminal Upgrade      \$ 194,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

#### Sewaren – Woodbridge Line

- Existing tower 3/6 requires replacement. Telecommunication cellular antennas are located on this tower. No allowances are included in the estimate for the removal, modification, relocation or replacement of the equipment.

#### Sewaren Switching Station

- Minor steel modifications will be required, but the existing steel structure is adequate for the new switch.
- No control and relaying upgrades have been included.

### **3.1.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.

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## **3.2 Roseland 230 kV Terminal Upgrade (Upgrade n0645.2)**

### **3.2.1 Purpose and Necessity**

Recommended solution to alleviate the overload of the Roseland terminal of the Whippany-Roseland 230 kV line is to upgrade the terminal. The terminal upgrade requires that the summer normal continuous rating of 995 MVA and a summer four-hour emergency rating of 1233 MVA.

### **3.2.2 General Description**

The existing terminal includes the following equipment: a 3000 A metering transformer, a 3000 A wave trap, and a 2500 A rated disconnect switch; buswork includes two 1590 ACSR conductors per phase, two 1000 MCM copper per phase, and 3 inch copper tubing.

The metering transformer is rated by PSE&G for 1367 for summer normal continuous and 1730 MVA for a four-hour summer emergency; therefore no upgrade is required.

The wave trap is rated by PSE&G for 1221 for summer normal continuous and 1387 MVA for a four-hour summer emergency; therefore no upgrade is required.

The 2500 A disconnect switch is rated by PSE&G for 1076 MVA for summer normal continuous and 1298 for a four-hour summer emergency; therefore no upgrade is required.

The 1000 MCM copper conductor is rated by PSE&G for 1055 A summer normal, and 1375 A four-hour summer emergency per conductor. The summer normal required rating is 2498 A. The upgrade requires that the 1000 MCM copper be replaced with two 1590 ACSR per phase.

No other equipment is required to be upgraded.

### **3.2.3 Design Requirements**

The following are specific facility design requirements for the Whippany-Roseland 230 kV line terminal upgrades; other general design requirements are included in section 1.3 General Design Criteria.

- None

### **3.2.4 Major Materials**

#### **Roseland Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 80              |

### **3.2.5 Cost Estimate**

The Whippany-Roseland 230 kV line terminal costs are estimated as follows:

|                                               |                  |
|-----------------------------------------------|------------------|
| Engineering                                   | \$ 10,000        |
| Equipment and Materials<br>Switchyard Buswork | \$ 2,000         |
| Construction Management                       | \$ 13,000        |
| <u>Construction</u>                           | <u>\$ 15,000</u> |
| Subtotal                                      | \$ 40,000        |

The Whippany-Roseland 230 kV PSE&G costs are estimated as follows:

|                                                  |             |
|--------------------------------------------------|-------------|
| Program Management                               | \$ 3,000    |
| Engineering                                      | \$ 3,000    |
| Construction Support                             | \$ 14,000   |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 10,000   |
| Environmental & Resource Recovery                | \$ 0        |
| Licensing & Permitting                           | \$ 50,000   |
| <u>Corporate Properties</u>                      | <u>\$ 0</u> |
| Subtotal                                         | \$ 80,000   |

**Total cost for the Whippany-Roseland 230 kV line terminal     \$ 120,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Transmission Line and Whippany terminal upgrades are to be done by others and are not within the scope of this Facilities Study.
- No control and relaying upgrades have been included.

### **3.2.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Construction outage required on the Roseland – Whippany line.

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### **3.3 Athenia - Bergen 230 kV Underground line and Terminal Upgrades**

#### **3.3.1 Purpose and Necessity**

The recommended solution to alleviate the overloads of the Athenia-Saddle Brook, Saddle Brook-Maywood, Maywood-New Milford and New Milford-Leonia 230 kV lines is to build a new 230 kV underground cable circuit from Athenia to Bergen. The Athenia and Bergen stations will also need to be upgraded to accommodate the new circuit.

#### **3.3.2 General Description**

The Athenia to Bergen underground circuit will consist of a new pipe-type high pressure fluid filled (HPFF) cable system. The new line will have a summer normal continuous rating of 305 MVA and a summer four-hour emergency rating of 524 MVA.

The pipe-type cable system will consist of three single core laminated paper-polypropylene (LPP) insulated cables installed in a coated steel pipe. The pipe is pressurized with dielectric fluid (alkyl benzene/polybutene mixture) to a nominal pressure of 200 pounds per square inch (psi). The pressurized dielectric fluid prevents ionization in the insulation and prevents moisture ingress if the pipe is breached.

The pipe is typically installed in a single open trench, approximately 4 to 5 feet deep, and backfilled with either soil or a specially designed thermal backfill. Certain obstructions, such as water or railroad crossings will require the pipe to be installed by trenchless installation methods, such as auger boring (jack and bore) or horizontal directional drilling (HDD). These methods allow the pipes to be installed without disturbing the surface.

230 kV HPFF cable can be transported in reels up to approximately 3,300 feet. These reels would be 12 feet high, 8 feet wide and weigh approximately 40,000 lbs. Larger reels can be obtained, but will require special transportation arrangements. Due to the reel length limitations and allowable cable tension and sidewall pressure, individual cable lengths will need to be spliced together. Cable splicing requires a clean, dry area. This is usually accomplished by installing an underground splicing vault. These vaults are large (18'x8'x8') concrete structures buried completely underground with manhole covers for access.

At Athenia a new 230 kV line terminal will be required. The upgrade will include new equipment and bus support structures, one (1) circuit breaker, two (2) disconnect switches, three (3) CCVTs, three (3) surge arrestors, bus, jumpers, and all foundations, grounding, raceway, control cable, and control and relaying equipment necessary for a complete installation.

At Bergen, two new 230 kV line terminals will be required; one for the new O-66 underground circuit, and one for the AC connection to the Hudson Transmission Partners HVDC facility. The upgrade will include new equipment and bus support structures, three (3) circuit breakers, eight (8) disconnect switches, twelve (12) CCVTs, six (6) surge arrestors, bus, jumpers, equipment support structures, and all foundations, grounding,

raceway, control cable, and control and relaying equipment necessary for a complete installation.

### **3.3.3 Design Requirements**

The following are specific facility design requirements for the O-66 line and terminal upgrades; other general design requirements are included in section 1.4 General Design Criteria.

### **Underground Circuit Requirements**

The following electrical requirements apply to the entire cable system.

- o Number of Circuits: 1
- o Rated Voltage: 230 kV
- o BIL: 1050 kV
- o Daily Load Factor: 100%
- o Peak Normal Load at DLF: 305 MVA
- o Emergency Maximum Duration: 4 Hours
- o Emergency Maximum Load: 524 MVA

### **Routing**

The routing for the transmission line has not yet been set. Based on maps, overhead images and existing transmission line routing, three preliminary routes have been selected for estimating purposes only.

### **Communications Requirements**

The following communications installation will be installed in parallel with the cable circuit.

- o Two (2) 48-fiber single-mode loose buffer tube cables
- o Two (2) 5-inch Sch. 40 PVC conduits
- o Three (3) 1-1/4-inch HPDE innerducts per 5-inch conduit

### **Temperature Monitoring Requirements**

No temperature monitoring equipment has been included for the circuit.

### **Trenched Installation**

The pipelines will be installed by trenching where possible. The trenching installation will meet the following requirements.

- o Pipeline Minimum Cover: 36 inches
- o Number of pipes: 1
- o Pipeline: 8 inch steel, 0.250 inch wall thickness
- o Pipe Coating: 60/10 Pritec
- o Typical Trench Width: 3.0 feet

- o Corrective Backfill Height: Entire trench, up to 18” below grade

### **Auger Bored Installation**

Where the route encounters obstacles that can not be crossed by normal trenching, such as railroads or major roads, the pipeline will be installed by auger boring. Auger boring is carried out by digging an entry pit on one side of the obstacle, then advancing a steel casing to a receiving pit on the other side. An auger removes the spoils from inside the casing. After the casing is in place, the pipeline and communications ducts are slid through the casing on spacers. The pipeline and ducts used are the same as for the trenched installation. The annular space between the pipeline and the casing is filled with a thermal grout.

The auger bored installation will meet the following requirements:

- o Number of Casings: 1
- o Size of Casings: 36”
- o Pipes per casing: one 8-inch steel and two 5-inch PVC

### **HDD Installation**

When the obstacle to be crossed is wider than an auger boring can accomplish, approximately 300 feet, horizontal directional drilling (HDD) will be used to drill under the obstacle. HDD is accomplished by using a steerable hydraulic drill rig on the surface to drill a pilot hole from one side of the obstacle to the other. The pipelines will be pulled, along with communications conduits, directly into the borehole.

The HDD installation will meet the following requirements:

- o Number of Boreholes: 1
- o Cable pipes per borehole: one 8-inch, 0.375 inch wall steel
- o Communications ducts per borehole: one 5 inch I.D. HDPE

### **Splicing Vaults**

Underground splicing vaults will be installed to allow for cable splicing. The splicing vaults will be a double circuit design and meet the following requirements.

- o Minimum Length: 18’
- o Minimum Height: 8’
- o Minimum Width: 8’
- o Access: Two (2) 36” manholes with 30” lids
- o Traffic Loading: HS-25

### **Cathodic Protection Requirements**

The steel pipes will require a cathodic protection system to prevent corrosion of the pipes. The cathodic protection system will be designed taking into account the length of the pipe lines, soil conditions, and nearby utilities that may have their own cathodic protection systems. At a minimum the cathodic protections system will include impressed current

rectifiers, AC/DC blocking devices, anode beds (deep well or shallow subsurface), and test stations.

### **Dielectric Fluid Pressurization Plants**

Due to the length of the line, a dielectric fluid pressurization plant will be required at each substation. The pressurization plants regulate the pressure on the pipelines, absorbing fluid as the cable system heats and releasing fluid when it cools. The pressurization plants will be designed to oscillate or circulate the fluid in the pipelines, reducing the impact due to hot spots. The pressurization plants will include alarmed system operation, and chart recorders or data logging.

### **3.3.4 Major Materials**

#### **HPFF Underground O-66 Line**

| <u>Item</u>               | <u>Description</u>                                                                 | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|---------------------------|------------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Route Length              | Substation to Substation (miles)                                                   | 9.7                                 | 10.7                                   | 11.1                                   | 9.7                                                        |
| 230 kV Cable              | 230 kV, 3500 kcmil copper, 500 mil LPP insulated HPFF cable (feet)                 | 157,054                             | 171,768                                | 177,438                                | 157,054                                                    |
| Spare Cable               | 230 kV, 3000 kcmil copper, 500 mil LPP insulated HPFF cable (feet)                 | 3,200                               | 3,200                                  | 3,200                                  | 3,200                                                      |
| 230 kV Cable Splices      | 230 kV, 3-phase joint kit (each)                                                   | 21                                  | 23                                     | 24                                     | 21                                                         |
| 230 kV Semi-Stop Splice   | 230 kV, 3-phase, semi-stop joint (each)                                            | 6                                   | 6                                      | 6                                      | 6                                                          |
| 230 kV Cable Terminations | 230 kV, single phase porcelain insulator terminations (each)                       | 6                                   | 6                                      | 6                                      | 6                                                          |
| Fiber-Optic Cable         | 48 single-mode fiber optic cable, loose tube (feet)                                | 106,682                             | 116,612                                | 120,452                                | 106,682                                                    |
| Pipe for Cable            | 8-inch ASTM 523 ERW steel pipe, 0.250" wall thickness, 60/10 Pritec Coating (feet) | 42,691                              | 47,556                                 | 49,426                                 | 42,691                                                     |

| <u>Item</u>               | <u>Description</u>                                                                             | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|---------------------------|------------------------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Pipe for fluid return     | 5-inch ASTM 523 ERW steel pipe, 0.250" wall thickness, 60/10 Pritec Coating (feet)             | 0                                   | 0                                      | 0                                      | 42,691                                                     |
| Ducts for F-O cable       | 5-inch Sch. 40 PVC conduit (feet)                                                              | 83,902                              | 95,112                                 | 98,852                                 | 83,902                                                     |
| Innerduct for F-O cable   | 1 1/4" HDPE Innerducts (feet)                                                                  | 305,707                             | 339,336                                | 350,556                                | 305,707                                                    |
| Flowable Thermal Backfill | Low strength, high slump concrete slurry with a low thermal resistivity (cubic yards)          | 39,621                              | 44,215                                 | 45,981                                 | 46,224                                                     |
| Splicing Vaults           | 18'x8'x8' pre-cast concrete vaults (each)                                                      | 29                                  | 31                                     | 32                                     | 29                                                         |
| Casing for Auger Boring   | 36-inch O.D. steel casing (feet)                                                               | 740                                 | 740                                    | 740                                    | 740                                                        |
| Flowable Fill for Boring  | Low strength, low thermal resistivity grout (cubic yards)                                      | 178                                 | 178                                    | 178                                    | 178                                                        |
| HDD Cable Pipe            | 8-inch ASTM 523 ERW steel pipe, 0.375" wall thickness, abrasion resistant epoxy coating (feet) | 9,000                               | 9,000                                  | 9,000                                  | 9,000                                                      |
| HDD F-O cable Ducts       | 6-inch SDR 11 HDPE pipe (feet)                                                                 | 18,000                              | 18,000                                 | 18,000                                 | 18,000                                                     |
| Splicing Trifurcator      | Cable pipe to riser pipe transition, pull-through (each)                                       | 2                                   | 2                                      | 2                                      | 2                                                          |
| Riser Pipe for Cable      | 4-inch stainless steel pipe (feet)                                                             | 900                                 | 900                                    | 900                                    | 900                                                        |
| Dielectric Fluid          | Alkyl Benzene/Polybutene Mixture (DCL 100) (gallons)                                           | 110,089                             | 117,627                                | 120,524                                | 168,087                                                    |

| <u>Item</u>                | <u>Description</u>                                                            | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|----------------------------|-------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Pressurization Plant       | Dielectric fluid pressurization and pumping plant, 20,000 gal capacity (each) | 2                                   | 2                                      | 2                                      | 2                                                          |
| Fluid Piping               | 2" coated steel piping (feet)                                                 | 800                                 | 800                                    | 800                                    | 800                                                        |
| Cathodic Protection System | Impressed current cathodic protection system (lot)                            | 1                                   | 1                                      | 1                                      | 1                                                          |

### **Athenia Switching Station**

| <u>Item</u>             | <u>Description</u>                                                                                             | <u>Quantity</u> |
|-------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus               | Aluminum bus, 6063-T6 alloy, 4" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 150             |
| Jumper Conductor        | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 350             |
| High Strength Insulator | Station post insulator, porcelain for disconnect switch and bus supports.                                      | 24              |
| Circuit Breaker         | 230 kV SF6 gas insulated circuit breaker, 63 kA, 3000 A                                                        | 1               |
| Disconnect Switch       | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 2               |
| Ground Switch           | Manually operated 230 kV ground switch, three phase                                                            | 1               |
| Disconnect Switch Stand | High bus height, three phase, four vertical support columns.                                                   | 1               |
| Disconnect Switch Stand | Low bus height, three phase, four vertical support columns.                                                    | 1               |
| Bus Support Low-3P      | Bus insulator support stand, low bus, three-phase, one insulator per phase                                     | 1               |

| <u>Item</u>                    | <u>Description</u>                                                                                                                                                                                                                                       | <u>Quantity</u> |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Bus Support High-3P            | Bus insulator support stand, high bus, three-phase, one insulator per phase                                                                                                                                                                              | 1               |
| UG Line Termination Support-3P | UG Line termination support stand, low bus, three-phase                                                                                                                                                                                                  | 1               |
| CCVT                           | Coupling capacitor voltage transformers, three windings                                                                                                                                                                                                  | 3               |
| CCVT Stand                     | Single-phase, 8'-6" safety clearance                                                                                                                                                                                                                     | 3               |
| Surge Arrester                 | Surge Arrester                                                                                                                                                                                                                                           | 3               |
| Surge Arrester Stand           | Single-phase, 8'-6" safety clearance                                                                                                                                                                                                                     | 3               |
| Foundations                    | Spread footing type foundations                                                                                                                                                                                                                          | Lot             |
| Grounding Grid                 | 350 MCM BTN Copper                                                                                                                                                                                                                                       | Lot             |
| Control and Relaying           | PSE&G Standard control and relaying racks to include the following racks: <ul style="list-style-type: none"> <li>• Primary line relaying</li> <li>• Backup line relaying</li> <li>• Line instrumentation</li> <li>• Line fiber communications</li> </ul> | Lot             |
| Key Interlocks                 | Key interlock system for isolation switches and grounding switches.                                                                                                                                                                                      | Lot             |
| Station Lighting               | Up-down lighting fixtures with ballasts and photocell for operations and maintenance. Lighting junction boxes to include AC outlet and switch.                                                                                                           | 2               |

**Bergen Switching Station**

| <u>Item</u>                    | <u>Description</u>                                                                                             | <u>Quantity</u> |
|--------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus                      | Aluminum bus, 6063-T6 alloy, 4" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 1000            |
| Jumper Conductor               | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 700             |
| High Strength Insulator        | Station post insulator, porcelain for disconnect switch and bus supports.                                      | 102             |
| Circuit Breaker                | 230 kV SF6 gas insulated circuit breaker, 63 kA, 3000 A                                                        | 3               |
| Disconnect Switch              | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 8               |
| Ground Switch                  | Manually operated 230 kV ground switch, three phase                                                            | 2               |
| Disconnect Switch Stand        | High bus height, three phase, four vertical support columns.                                                   | 2               |
| Disconnect Switch Stand        | Low bus height, three phase, four vertical support columns.                                                    | 6               |
| Bus Support Low-1P             | Bus insulator support stand, low bus, single-phase, one insulator per phase                                    | 12              |
| Bus Support High-3P            | Bus insulator support stand, high bus, single-phase, one insulator per phase                                   | 2               |
| UG Line Termination Support-3P | UG Line termination support stand, low bus, three-phase                                                        | 2               |
| CCVT                           | Coupling capacitor voltage transformers, three windings                                                        | 12              |
| CCVT Stand                     | Single-phase, 8'-6" safety clearance.                                                                          | 12              |
| Surge Arrester                 | Surge Arrester                                                                                                 | 6               |
| Surge Arrester Stand           | Single-phase, 8'-6" safety clearance.                                                                          | 6               |

| <u>Item</u>          | <u>Description</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <u>Quantity</u> |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Foundations          | Spread footing type foundations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lot             |
| Grounding Grid       | 350 MCM BTN Copper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lot             |
| Control and Relaying | PSE&G Standard control and relaying racks to include the following racks: <ul style="list-style-type: none"> <li>• Line 1 Primary line relaying</li> <li>• Line 1 Backup line relaying</li> <li>• Line 1 instrumentation</li> <li>• Line 1 fiber communications</li> <li>• Line 2 Primary line relaying</li> <li>• Line 2 Backup line relaying</li> <li>• Line 2 instrumentation</li> <li>• Line 2 fiber communications</li> <li>• Breaker 1 primary relaying</li> <li>• Breaker 1 backup relaying</li> <li>• Breaker 1 instrumentation</li> <li>• Breaker 2 primary relaying</li> <li>• Breaker 2 backup relaying</li> <li>• Breaker 2 instrumentation</li> </ul> | Lot             |
| Station Lighting     | Up-down lighting fixtures with ballasts and photocell for operations and maintenance.<br>Lighting junction boxes to include AC outlet and switch.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 12              |
| Pole #2/1            | Transmission pole to be relocated                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1               |

(The remainder of this page is intentionally left blank.)

### **3.3.5 Cost Estimate**

The O-66 Line costs are estimated as follows:

| <u>Item</u>             | <u>Proposed</u><br><u>Route Cost</u> | <u>Route</u><br><u>Option 1 Cost</u> | <u>Route</u><br><u>Option 2 Cost</u> | <u>Prop. w/ Fluid</u><br><u>Return Cost</u> |
|-------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------------------------------------------|
| Engineering             | \$1,750,000                          | \$1,750,000                          | \$1,750,000                          | \$1,750,000                                 |
| Equipment and Materials |                                      |                                      |                                      |                                             |
| Cable & Accessories     | \$16,325,000                         | \$17,736,000                         | \$18,286,000                         | \$16,325,000                                |
| Pipeline                | \$5,379,000                          | \$5,669,000                          | \$5,781,000                          | \$6,995,000                                 |
| Cathodic Prot. System   | \$88,000                             | \$90,000                             | \$92,000                             | \$88,000                                    |
| Parallel F-O Cable      | \$405,000                            | \$441,000                            | \$455,000                            | \$405,000                                   |
| Splicing Vaults         | \$1,094,000                          | \$1,165,000                          | \$1,201,000                          | \$1,094,000                                 |
| Trenching & Backfill    | \$9,004,000                          | \$10,048,000                         | \$10,449,000                         | \$9,862,000                                 |
| HDD Materials           | \$1,114,000                          | \$1,114,000                          | \$1,114,000                          | \$1,481,000                                 |
| Jack & Bore Materials   | \$201,000                            | \$201,000                            | \$201,000                            | \$201,000                                   |
| Construction Management | \$2,340,000                          | \$2,340,000                          | \$2,340,000                          | \$2,580,000                                 |
| Construction            |                                      |                                      |                                      |                                             |
| Cable & Accessories     | \$6,044,000                          | \$6,505,000                          | \$6,706,000                          | \$6,044,000                                 |
| Pipeline                | \$5,632,000                          | \$6,061,000                          | \$6,228,000                          | \$7,840,000                                 |
| Cathodic Prot. System   | \$109,000                            | \$112,000                            | \$114,000                            | \$109,000                                   |
| Parallel F-O Cable      | \$529,000                            | \$575,000                            | \$593,000                            | \$529,000                                   |
| Splicing Vaults         | \$984,000                            | \$1,016,000                          | \$1,048,000                          | \$984,000                                   |
| Trenching & Backfill    | \$17,744,000                         | \$20,021,000                         | \$20,796,000                         | \$19,244,000                                |
| HDD Installation        | \$6,089,000                          | \$6,089,000                          | \$6,089,000                          | \$6,555,000                                 |
| Jack & Bore Install     | \$594,000                            | \$594,000                            | \$594,000                            | \$594,000                                   |
| Subtotal                | \$75,425,000                         | \$81,527,000                         | \$83,837,000                         | \$82,680,000                                |

The O-66 Line PSE&G costs are estimated as follows:

|                                                          |                          |
|----------------------------------------------------------|--------------------------|
| Program Management                                       | \$ 3,771,000             |
| Engineering                                              | \$ 525,000               |
| Construction Support                                     | \$ 566,000               |
| Relaying, Mechanics, Lab, &<br>System Protection         | \$ 0                     |
| Environmental & Resource Recovery                        | \$ 3,950,000             |
| Licensing & Permitting                                   | \$ 3,500,000             |
| <u>Corporate Properties</u>                              | <u>\$ 5,000,000</u>      |
| Subtotal                                                 | \$ 17,312,000            |
| <br><b>Total cost for the O-66 Line (Proposed Route)</b> | <br><b>\$ 92,737,000</b> |

The Athenia Facility costs are estimated as follows:

|                         |                   |
|-------------------------|-------------------|
| Engineering             | \$ 130,000        |
| Equipment and Materials |                   |
| Site Work               | \$ 5,000          |
| Concrete                | \$ 65,000         |
| Lighting                | \$ 10,000         |
| Steel Structure         | \$ 59,000         |
| Raceway                 | \$ 3,000          |
| Grounding               | \$ 10,000         |
| Conductor               | \$ 34,000         |
| Switchyard Buswork      | \$ 21,000         |
| Circuit Breakers        | \$ 151,000        |
| CCVTs                   | \$ 30,000         |
| Disconnect Switches     | \$ 40,000         |
| Surge Arresters         | \$ 15,000         |
| Control and Relaying    | \$ 97,000         |
| Construction Management | \$ 33,000         |
| <u>Construction</u>     | <u>\$ 514,000</u> |
| Subtotal                | \$ 1,217,000      |

The Athenia Facility PSE&G costs are estimated as follows:

|                                                  |                     |
|--------------------------------------------------|---------------------|
| Program Management                               | \$ 85,000           |
| Engineering                                      | \$ 39,000           |
| Construction Support                             | \$ 36,000           |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 60,000           |
| Environmental & Resource Recovery                | \$ 250,000          |
| Licensing & Permitting                           | \$ 200,000          |
| <u>Corporate Properties</u>                      | <u>\$ 0</u>         |
| Subtotal                                         | \$ 670,000          |
| <b>Total cost for the Athenia Facility</b>       | <b>\$ 1,887,000</b> |

The Bergen Facility costs are estimated as follows:

|                         |                     |
|-------------------------|---------------------|
| Engineering             | \$ 691,000          |
| Equipment and Materials |                     |
| Site Work               | \$ 69,000           |
| Concrete                | \$ 364,000          |
| Lighting                | \$ 60,000           |
| Steel Structure         | \$ 966,000          |
| Raceway                 | \$ 83,000           |
| Grounding               | \$ 111,000          |
| Conductor               | \$ 323,000          |
| Switchyard Buswork      | \$ 269,000          |
| Circuit Breakers        | \$ 455,000          |
| CCVTs                   | \$ 120,000          |
| Disconnect Switches     | \$ 160,000          |
| Surge Arresters         | \$ 30,000           |
| Control and Relaying    | \$ 440,000          |
| Construction Management | \$ 404,000          |
| <u>Construction</u>     | <u>\$ 4,785,000</u> |
| Subtotal                | \$ 9,330,000        |

The Bergen Facility PSE&G costs are estimated as follows:

|                                                  |                      |
|--------------------------------------------------|----------------------|
| Program Management                               | \$ 653,000           |
| Engineering                                      | \$ 207,000           |
| Construction Support                             | \$ 444,000           |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 60,000            |
| Environmental & Resource Recovery                | \$ 0                 |
| Licensing & Permitting                           | \$ 1,500,000         |
| <u>Corporate Properties</u>                      | <u>\$ 100,000</u>    |
| Subtotal                                         | \$ 2,964,000         |
| <b>Total cost for Bergen Facility</b>            | <b>\$ 12,294,000</b> |

Facility unique assumptions for the cost estimates include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimates.

#### O-66 Underground Line

- The estimate is based upon a single circuit 230 kV HPFF installation with (2) 3000 kcmil cables per phase.
- The conductor sizing calculations are based on conservative installation conditions and soils data from PSE&G records.
- The estimate includes 3,200 feet of spare cable.
- The number of splices is based on a 2000' average spacing between splices.
- The splicing trifurcators are located in splicing vaults near the terminations. Trifurcators are installed as pull-through, with provisions for future splicing.
- The estimate includes 4" stainless steel riser pipe for 150' feet from trifurcator to termination.
- Two 20,000 gal fluid pressurization plants have been assumed.
- A separate impressed current cathodic protection system for each pipeline has been assumed.
- Two separate fiber-optic communications installations have been assumed.
- Fiber-optic cables are assumed to be 48 fiber, single mode outdoor cable.
- Separate pull/splicing boxes are included for the fiber-optic cable.
- Temperature monitoring has not been included in the estimate.
- Four 3-phase substation termination structures are included.
- It is assumed that all trenching will be in city streets.
- Traffic control for city streets has been included in the estimated costs.
- Soil erosion and sediment control measures for city streets has been included in the estimated costs.
- It is assumed that the minimum trench dimensions are 4.5' wide and 10' deep, based on a 2' pipeline separation.
- It is assumed that trenches will be backfilled with thermal slurry or flowable thermal backfill to 1'-6" below grade.
- It is assumed that the top 1'-6" of the trench will be pavement over compacted gravel.
- Paving removal and replacement has been included at an estimated width of 11' for 100% of the route.
- Seeding, sodding, and landscaping are not included in the estimate.
- It is assumed that dewatering will be required for approximately 50% of the route.
- It is assumed that sheeting and shoring will be required for approximately 50% of the route.
- It is assumed that the HDD crossings will consist of two separate bundles, in separate boreholes. Each borehole contains one cable pipe and one communications duct.
- It is assumed that the HDD installation does not include a casing or carrier pipe.
- It is assumed that the HDD installation does not include grouting of the bore hole.

- The estimate includes Jack & Bore crossings consisting of two separate 36" steel casing with flowable fill. Each casing contains one cable pipe and one communications duct.
- It is assumed that the annular space between pipeline, duct, and casing will be filled with flowable thermal fill or grout.
- The estimate includes approximate costs for surveying and soils exploration, based on the route length.
- Two circuits are required to accommodate the required loading; it is assumed that the two circuits are within 12 feet of each other in the same street or right-of-way.
- Final circuit routing is required to finalize the detailed estimate.
- The acquisition of land rights for the 230 kV pipe type cables between Bergen Switching Station and Athenia Switching Station requires the acquisition of land rights from a variety of land owners. The timeframe to acquire the rights depends on whether the landowners are willing to accept directional drilling as the installation method.

#### Bergen

- Steel pipe pile supported spread footing foundations shall be utilized at Bergen switching station due to the existing soil conditions.
- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.
- Foundations for future bus tie breaker locations at Bergen will be installed as part of this project because pile type foundations will be required and access will be limited to those areas once the new bus and equipment is erected.
- Modifications to the existing Bergen ground grid were not included as part of the scope of this Facilities Study. New ground grid and stingers will be added in the expansion area and connected to the existing grounding system.
- At Bergen, a pole relocation is required prior to construction of the new terminals, these costs are included in the Bergen estimate.
- At Bergen, 14,900 cubic yards of fill is required to facilitate the station expansion. Costs associated with adding fill in a flood plain, such as mitigation at another location, have not been included.

#### Athenia

- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.
- Modifications to the existing Athenia ground grid was not included as part of the scope of this Facilities Study. New ground stingers will be connected to the existing grounding system and the new equipment.

### **3.3.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Right-of-way acquisition.
- Major equipment lead times including HPFF cable and pipe and oil facilities.
- The feasibility of construction in wetlands, along busy corridors, and road and river crossings.
- Construction outage requirements at the Bergen and Athenia Switching Station.

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**3.4 Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade (Upgrades n0666.1, n0666.2, n0666.3, n0666.4, n0666.5, n0666.6, n0666.7, n0666.8, n0666.9, n0666.10, n0666.11, n0666.12, and n0666.13)**

**3.4.1 Purpose and Necessity**

The Hudson 230 kV Switching Station will be upgraded with equipment rated for a fault current of 80kA.

The existing station consists of breakers, equipment, and bus that do not meet the 80 kV fault current criteria; therefore, a major rebuild of the station is required. All foundations, circuit breakers, disconnect switches, bus, jumpers, bus and equipment supports, raceway, and control cable will be replaced. In addition, a new ground grid rated for the increased fault duty is required.

**3.4.2 General Description**

The new circuit breakers will be ABB breakers, Type PM, rated for 80 kA fault duty and 3000 A continuous operation. The breakers will include capacitors on both the line and bus side to meet the fault duty requirements.

The new disconnect switches will be double end break design rated for 80 kA momentary duty and 3000 A continuous operation.

The new bus will be 5 inch aluminum schedule 80 bus supported by extra high strength insulators rated 900 kV BIL. Bus support spacing, phase spacing, bus fitting arrangements, and additional insulators will be utilized to meet the 80 kA criteria. Equipment jumpers will be two 1590 MCM ACSR conductors per phase for current carrying equipment and one 795 ACSR conductor per phase for non current carrying equipment. All bus and jumpers will be replaced as part of this rebuild.

Existing equipment, jumpers, bus, insulators, and structures will be removed as part of the work. Of the existing structures, only two existing four bay lattice A-frames will remain in service.

New foundations will be required to support the new and relocated structures and equipment. Foundations will be steel pile supported spread footing type foundations.

New grounding, raceway, and control cable will be installed as part of the rebuild.

### **3.4.3 Design Requirements**

The following are specific facility design requirements for the Hudson station; other general design requirements are included in section 1.4 General Design Criteria.

- Steel pipe pile supported spread footing foundations shall be utilized due to the existing soil conditions.
- The ground grid shall be 500 MCM copper BTN because of the 80 kV fault current requirement.

### **3.4.4 Major Materials**

The following major material list was developed for the Hudson Switching Station:

| <u>Item</u>                   | <u>Description</u>                                                                                             | <u>Quantity</u> |
|-------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus                     | Aluminum bus, 6063-T6 alloy, 5" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 5200            |
| Jumper Conductor              | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 5600            |
| High Strength Insulator       | Station post insulator, porcelain for disconnect switches.                                                     | 252             |
| Extra High Strength Insulator | Station post insulator, porcelain for rigid bus support.                                                       | 298             |
| Circuit Breaker               | 230 kV SF6 gas insulated circuit breaker, 80 kA, 3000 A, with TRV capacitors on bus and line side bushings     | 14              |
| Disconnect Switch             | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 28              |
| Ground Switch                 | Manually operated 230 kV ground switch, three phase                                                            | 12              |
| Circuit Switchers             | 230 kV circuit switchers, with high strength insulators and stands                                             | 4               |
| Disconnect Switch Stand       | Low bus height, three phase, four vertical support columns.                                                    | 24              |
| Disconnect Switch Stand       | High bus height, three phase, four vertical support columns.                                                   | 4               |

| <u>Item</u>                                         | <u>Description</u>                                                                    | <u>Quantity</u> |
|-----------------------------------------------------|---------------------------------------------------------------------------------------|-----------------|
| Bus Support High-1P (with one insulator per phase)  | Bus insulator support stand, high bus, single-phase, one insulator per phase          | 29              |
| Bus Support High-1P (with two insulators per phase) | Bus insulator support stand, high bus, single-phase, two insulators per phase         | 7               |
| Bus Support Low-1P (with one insulator per phase)   | Bus insulator support stand, low bus, single-phase, one insulator per phase           | 43              |
| Bus Support Low-1P (with two insulators per phase)  | Bus insulator support stand, high bus, single-phase, two insulators per structure     | 13              |
| Bus Support High-3P (with one insulator per phase)  | Bus insulator support stand, high bus, three-phase, one insulator per phase           | 4               |
| Bus Support High-3P (with two insulators per phase) | Bus insulator support stand, high bus, three-phase, two insulators per phase          | 13              |
| Bus Support Low-3P (with one insulator per phase)   | Bus insulator support stand, low bus, three-phase, one insulator per phase            | 28              |
| Bus Support High-2P (with one insulator per phase)  | Bus insulator support stand, high bus, three-phase, one insulator per phase           | 6               |
| CCVT                                                | Coupling capacitor voltage transformers, three windings                               | 36              |
| CCVT Stand                                          | Single-phase, 8'-6" safety clearance.                                                 | 36              |
| Surge Arrester                                      | Surge Arrester                                                                        | 24              |
| Surge Arrester Stand                                | Single-phase, 8'-6" safety clearance.                                                 | 24              |
| Steel Pipe Pile Supported Foundations               | Spread footing type foundations                                                       | Lot             |
| Grounding Grid                                      | 500 MCM BTN Copper                                                                    | Lot             |
| Control and Relaying                                | Modifications to existing control and relaying racks to accommodate the new equipment | Lot             |
| Safety Fence                                        | Aluminum chain link perimeter fence                                                   | 540             |

| <u>Item</u>      | <u>Description</u>                                                                                                                                | <u>Quantity</u> |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Station Lighting | Up-down lighting fixtures with ballasts and photocell for operations and maintenance.<br>Lighting junction boxes to include AC outlet and switch. | 38              |

(The remainder of this page is intentionally left blank.)

### **3.4.5 Cost Estimate**

The Hudson Facility costs are estimated as follows:

|                         |               |
|-------------------------|---------------|
| Engineering             | \$ 2,005,000  |
| Equipment and Materials |               |
| Site Work               | \$ 72,000     |
| Concrete                | \$ 1,134,000  |
| Lighting                | \$ 190,000    |
| Steel Structure         | \$ 3,173,000  |
| Raceway                 | \$ 183,000    |
| Grounding               | \$ 125,000    |
| Conductor               | \$ 497,000    |
| Switchyard Buswork      | \$ 759,000    |
| Circuit Breakers        | \$ 4,795,000  |
| Circuit Switchers       | \$ 318,000    |
| CCVTs                   | \$ 359,000    |
| Disconnect Switches     | \$ 559,000    |
| Surge Arresters         | \$ 120,000    |
| Control and Relaying    | \$ 374,000    |
| Construction Management | \$ 583,000    |
| Construction            | \$ 11,822,000 |
| Subtotal                | \$27,068,000  |

The Hudson Facility PSE&G costs are estimated as follows:

|                                                  |              |
|--------------------------------------------------|--------------|
| Program Management                               | \$ 1,894,000 |
| Engineering                                      | \$ 602,000   |
| Construction Support                             | \$ 641,000   |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 370,000   |
| Environmental & Resource Recovery                | \$ 100,000   |
| Licensing & Permitting                           | \$ 2,000,000 |
| Corporate Properties                             | \$ 500,000   |
| Subtotal                                         | \$ 6,107,000 |

**Total cost for the Hudson Substation Facility      \$ 33,175,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Steel pipe pile supported spread footing foundations shall be utilized due to the existing soil conditions.
- The ground grid shall be 500 MCM copper BTN because of the 80 kV fault current requirement.
- Existing breaker foundations are to be reused for the new circuit breakers.
- No line terminal switches have been included in the layout because line switches did not exist at the existing station.
- The existing SF6 gas insulated bus and terminator located on bus section 7 will remain in place.
- New control cable and raceway systems will be installed as part of the rebuild to accommodate the new foundations and equipment layout.
- Existing relaying schemes will be modified to accommodate the new equipment.
- No major upgrades to the existing control building have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the replaced equipment.
- Conversion of the bus tie breakers to normally closed is included in this design.
- It is assumed that the existing Transformer No. 1 and 2, reactor, and Generator No. 3 circuit switchers will be replaced.
- Lengthy and substantial outages will be required at the Hudson station for the rebuild.
- The project scope as identified in the impact study did not identify the modification or replacement of some of the existing Hudson equipment. The following list provides an overview of equipment which may need additional study and investigation to determine if the equipment will be adequate for the increased fault current. These items have not been included in the scope of this Facilities Study, if it is determined that this equipment will need to be modified or replaced during detailed design, additional costs will need to be added to the estimate.
  - The two 230 to 345 kV autotransformers are supplied by 230 kV underground SF6 gas insulated buses. The capability of these buses to withstand the additional fault current needs to be investigated during detailed design.
  - Hudson 1 and 2 generation: The additional fault current at Hudson switching station will impact the generator step-up transformers, the generator isolated phase bus, the auxiliary power transformers, the auxiliary 4kV buses and switchgear, and settings for the excitation system. The transformers will have to be considered in terms of their capability to withstand the short circuit forces from through fault currents relative to their design. The mechanical withstand strength of the isolated phase bus and 4 kV buses have to be reviewed and validated to be adequate for the increased fault currents. The interrupting capability of the 4 kV breakers must be studied to confirm adequacy for the increased fault currents. Transient stability, damping, and minimum excitation limits should be reviewed to see if setting adjustments are required.

- There are four autotransformers connected to the buses at Hudson switching station, two 345/230 kV units, and two 230/138 kV units. A review of all of these units will have to be made to determine if their designed mechanical strength to withstand through fault short circuit forces is adequate.
- In addition to equipment, there are three oil filled pipe type cables connected at Hudson switching station. The grounding and cathodic protection isolation devices require review to determine their adequacy. In addition, the pipe type cable designs will need to be reviewed relative to the increased fault current to determine their adequacy.

#### **3.4.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Installation of pipe piles in an operating generating station.
- Lengthy and substantial outages will be required at the Hudson station for the rebuild.

### **3.5 Bergen 12H Breaker Replacement (Upgrade n0984)**

#### **3.5.1 Purpose and Necessity**

The over-duty condition of the Bergen 12H breaker can be alleviated by replacing the existing circuit breaker with a breaker rated for an 80 kA fault current.

The existing breaker is a live tank, 3000 A breaker with free standing CT's also rated 3000 A. The existing jumper conductors are 1590 MCM, two per phase.

#### **3.5.2 General Description**

The new circuit breaker will be ABB type PM rated for 80 kA fault duty and 3000 A continuous operation. The breaker will include capacitors on both the line and bus side to meet the fault duty requirements.

The upgrade will include two (2) new breaker isolation disconnect switches rated 3000 A, and a new circuit breaker platform to bridge across the existing breaker pad and CT support foundations. New bus jumpers, raceway, and control cable will also be installed.

Equipment jumpers will be two 1590 MCM ACSR conductors per phase.

The existing ground grid will not be modified, new ground stingers will be extended to connect to the new equipment.

#### **3.5.3 Design Requirements**

The following are specific facility design requirements for the Bergen station; other general design requirements are included in section 1.4 General Design Criteria.

- Ground stingers will be 500 MCM copper BTN to meet 80 kA fault current criteria.
- A structural steel platform is required to support the new circuit breaker.

#### **3.5.4 Major Materials**

##### **Bergen Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 200             |

| <u>Item</u>       | <u>Description</u>                                                                                         | <u>Quantity</u> |
|-------------------|------------------------------------------------------------------------------------------------------------|-----------------|
| Circuit Breaker   | 230 kV SF6 gas insulated circuit breaker, 80 kA, 3000 A, with TRV capacitors on bus and line side bushings | 1               |
| Disconnect Switch | Manually operated 230 kV disconnect switch, 3000 A, three phase                                            | 2               |

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### **3.5.5 Cost Estimate**

The Bergen Facility costs are estimated as follows:

|                         |                   |
|-------------------------|-------------------|
| Engineering             | \$ 80,000         |
| Equipment and Materials |                   |
| Site Work               | \$ 1,000          |
| Steel Structure         | \$ 12,000         |
| Raceway                 | \$ 1,000          |
| Grounding               | \$ 2,000          |
| Conductor               | \$ 16,000         |
| Switchyard Buswork      | \$ 3,000          |
| Circuit Breakers        | \$ 343,000        |
| Disconnect Switches     | \$ 40,000         |
| Control and Relaying    | \$ 12,000         |
| Construction Management | \$ 27,000         |
| <u>Construction</u>     | <u>\$ 116,000</u> |
| Subtotal                | \$ 653,000        |

The Bergen Facility PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 46,000         |
| Engineering                                      | \$ 24,000         |
| Construction Support                             | \$ 30,000         |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 25,000         |
| Environmental & Resource Recovery                | \$ 10,000         |
| Licensing & Permitting                           | \$ 0              |
| <u>Corporate Properties</u>                      | <u>\$ 0</u>       |
| Subtotal                                         | \$ 135,000        |
| <b>Total cost for the Bergen Facility</b>        | <b>\$ 788,000</b> |

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Modifications to the existing ground grid was not included as part of the scope of this Facilities Study. New 500 MCM copper BTN ground stingers will be connected to the existing grounding system and the new equipment.
- No new control and relaying schemes are required; the existing control and relaying will be modified to accommodate the new circuit breaker.
- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.

### **3.5.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage at the Bergen Switching Station.

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### **3.6 Athenia 21H, 11H, 51H, 2BH Breaker Replacement (Upgrades n0985, n0986, n0987, and n0988)**

#### **3.6.1 Purpose and Necessity**

The over-duty condition of the Athenia 230 kV breakers 11H, 21H, and 51H, and 138 KV breaker 2BH can be alleviated by replacing the existing circuit breakers with breakers rated for a 63 kA fault current.

#### **3.6.2 General Description**

The new circuit breakers will be ABB rated for 63 kA fault duty and 3000 A continuous operation. The breakers will include capacitors on both the line and bus side to meet the fault duty requirements.

The upgrade will include two (2) new breaker isolation disconnect switches rated 3000 A, for each breaker and a new circuit breaker platform to bridge across the existing breaker foundations. New bus jumpers, raceway, and control cable will also be installed.

Equipment jumpers will be two 1590 MCM ACSR conductors per phase.

The existing ground grid will not be modified, new ground stingers will be extended to connect to the new equipment.

#### **3.6.3 Design Requirements**

The following are specific facility design requirements for the Athenia station; other general design requirements are included in section 1.4 General Design Criteria.

- Structural steel platforms are required to support the new circuit breakers.

#### **3.6.4 Major Materials**

##### **Athenia Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 800             |

| <u>Item</u>       | <u>Description</u>                                                 | <u>Quantity</u> |
|-------------------|--------------------------------------------------------------------|-----------------|
| Circuit Breaker   | 230 kV SF6 gas insulated circuit breaker,<br>63 kA, 3000 A         | 3               |
| Circuit Breaker   | 138 kV SF6 gas insulated circuit breaker,<br>63 kA, 3000 A         | 1               |
| Disconnect Switch | Manually operated 230 kV disconnect<br>switch, 3000 A, three phase | 6               |
| Disconnect Switch | Manually operated 138 kV disconnect<br>switch, 3000 A, three phase | 2               |

(The remainder of this page is intentionally left blank.)

### **3.6.5 Cost Estimate**

The Athenia Substation Facility costs are estimated as follows:

|                         |                   |
|-------------------------|-------------------|
| Engineering             | \$ 350,000        |
| Equipment and Materials |                   |
| Site Work               | \$ 2,000          |
| Steel Structure         | \$ 50,000         |
| Raceway                 | \$ 6,000          |
| Grounding               | \$ 5,000          |
| Conductor               | \$ 52,000         |
| Switchyard Buswork      | \$ 11,000         |
| Circuit Breakers        | \$ 569,000        |
| Disconnect Switches     | \$ 145,000        |
| Control and Relaying    | \$ 50,000         |
| Construction Management | \$ 80,000         |
| <u>Construction</u>     | <u>\$ 433,000</u> |
| Subtotal                | \$ 1,753,000      |

The Athenia PSE&G costs are estimated as follows:

|                                                  |                     |
|--------------------------------------------------|---------------------|
| Program Management                               | \$ 123,000          |
| Engineering                                      | \$ 90,000           |
| Construction Support                             | \$ 88,000           |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 100,000          |
| Environmental & Resource Recovery                | \$ 25,000           |
| Licensing & Permitting                           | \$ 0                |
| <u>Corporate Properties</u>                      | <u>\$ 0</u>         |
| Subtotal                                         | \$ 426,000          |
| <b>Total cost for the Athenia Facility</b>       | <b>\$ 2,179,000</b> |

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Modifications to the existing ground grid was not included as part of the scope of this Facilities Study. New 500 MCM copper BTN ground stingers will be connected to the existing grounding system and the new equipment.
- No new control and relaying schemes are required; the existing control and relaying will be modified to accommodate the new circuit breaker.
- No major upgrades to the existing switching station control building have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.

### **3.6.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.

(The remainder of this page is intentionally left blank.)

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- The estimate assumes open access to the cable splices and does not include any costs related to work restrictions due to private property or state right-of-ways.
- A single circuit 230 kV HPFF installation with (1) 3000 kcmil cables per phase has been included.
- Conductor sizing calculations have not been performed to verify the line capacity before or after reconductoring.
- It is assumed that no modifications to the existing pipeline or hydraulic system will be required.
- It is assumed that no modifications or repairs are included for the cathodic protection system.
- It is assumed that no additional communications will be required.
- It is assumed that no additional temperature monitoring is required.
- It is assumed that no traffic control is required.
- The estimate includes soil erosion and sediment control measures for excavations only.
- It is assumed that no paving removal or replacement is required.
- It is assumed that seeding, sodding and landscaping are not required.
- Dewatering has been included in the estimate for all excavations.
- It is assumed that sheeting and shoring is required for all excavations.
- The estimate does not include costs for surveying or soil testing.

## **FirstEnergy Work**

### **Transmission Lines – New/Upgraded**

#### 1. Whippany-Roseland 230 kV DCT Line Reconductor

Whippany-Roseland 230kV - Reconductor the Whippany-Roseland (A941) 230 kV line (2.7 miles, double circuit) with 1590 54/19 ACSS/AW wire. [PJM Network Upgrade n0645.1]

The estimated cost for this work is \$5,862,800 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### 2. Larrabee-Atlantic 230 kV Line Reconductor

Reconductor the Larrabee - Atlantic (R1032) 230 kV line (11.8 miles) with 1590 54/19 ACSS/AW wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$5,932,800 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

### **Substations – New/Upgraded**

#### **1. Portland – Martins Creek 230 kV Terminal Upgrade**

Design, furnish and install the following equipment at the Portland terminal of the Portland – Martins Creek 230 kV Line.

- Replace one 3000 amp circuit breaker at the Portland terminal of the Portland - Martins Creek 230 kV line with one rated for a 4000 amp capability.
- Replace one 3000 amp line trap at the Portland terminal of the Portland - Martins Creek 230 kV line with one rated for a 4000 amp capability.
- Replace 1590 ACSR bus conductor with 2493 ACAR 54/37 bundled conductor.
- Replace the GCX17A relay at Portland with an SEL321 relay [PJM Network Upgrade n0636.2]

The estimated cost for this work is \$1,048,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **2. Atlantic Substation Drop Replacement**

Replace drop loop conductors on the Atlantic-Larrabee (R1032) Line with bundled 1590 54/19 ACSS/AW Wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$39,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **3. Larrabee Substation Drop Replacement**

Replace drop loop conductors on the Atlantic-Larrabee (R1032) Line with bundled 1590 54/19 ACSS/AW Wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$39,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **4. Whippany Substation Replace Breaker JB**

Replace breaker JB at Whippany Substation with 63kA, 4000 A breaker. Replace the 3000A wave trap with 4000 A rated equipment and conductors associated with the Roseland Line. The drop loop conductors shall be bundled. [PJM Network Upgrade n0670]

The estimated cost for this work is \$421,200 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### 5. Whippany Substation Replace Breaker QJ

Replace breaker QJ at Whippany Substation with 63kA, 4000 A breaker. Replace the 3000A wave trap with 4000 A rated equipment and conductors associated with the Roseland Line. The drop loop conductors shall be bundled. [PJM Network Upgrade n0671]

The estimated cost for this work is \$421,200 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

### **Environmental, Real Estate and Permitting**

The following are possible environmental, real estate and permitting issues:

#### Larrabee-Atlantic 230 kV Line Reconductor

- The existing line has extensive wetlands in the project ROW, requiring coordination with FE Environmental Group in New Jersey
- All permitting will be at the local level. Rejection of any local permits will require an appeal to the Bureau of Public Utilities, which is not included in the estimated costs .

#### Whippany-Roseland 230 kV DCT Line Reconductor

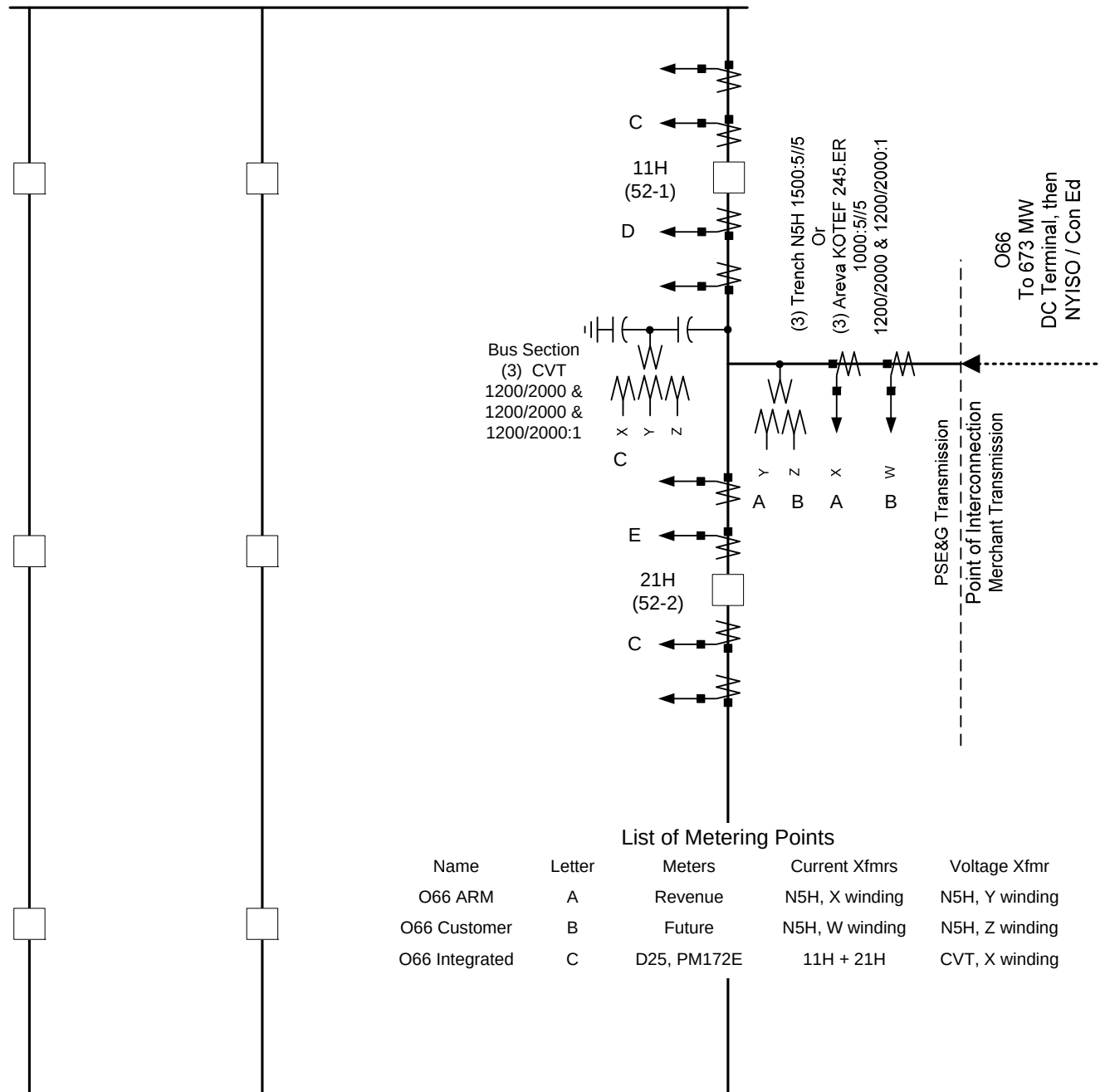
- The existing line is located in the Upper Passaic, Whippany & Rockaway Watershed Management Areas, requiring coordination with FE Environmental Group in New Jersey
- All permitting will be at the local level. Rejection of any local permits will require

### **Metering**

A 673 MW Interconnection Customer will be metered with an ANSI C12.20 revenue meter (0.2 accuracy class). The meter will be connected to (3) instrument transformers that combine CT and VT in one assembly. The combined instrument transformers will be 0.15 accuracy class.

Back-up metering will be provided via an integrated Watt signal from a D-25 RTU. The back-up metering will have instrument transformers that are separate from the primary metering. The one line shows a metering CT on each 230 kV circuit breaker which are totaled before connection to the D25. Each breaker would have (4) CTs for relaying and (2) CTs for metering & instrumentation. The voltage signal for the back-up meter will come from a Capacitive Voltage Transformer that is rated for metering accuracy.

PSE&G will purchase all instrument transformers. The metering will be installed in the Bergen Switch Yard.



### Information Required for the Facilities Study

The following table summarizes the total estimated costs according to FERC criteria. The estimated costs are in 2009 dollars and do not include taxes or effects from Contribution In Aid of Construction.

PSE&G Work

|                                                   |               |
|---------------------------------------------------|---------------|
| <b>Direct Connection &amp; Network Facilities</b> |               |
|                                                   |               |
| Direct Charges Labor                              | \$98,980,000  |
| Direct Charges Material                           | \$56,160,000  |
| Indirect Charges Labor                            | \$10,823,620  |
| Indirect Charges Material                         | \$0           |
|                                                   |               |
| Total                                             | \$165,963,620 |

FirstEnergy Work

|                           |              |
|---------------------------|--------------|
| <b>Network Facilities</b> |              |
|                           |              |
| Direct Charges Labor      | \$5,417,400  |
| Direct Charges Material   | \$3,728,800  |
| Indirect Charges Labor    | \$3,485,500  |
| Indirect Charges Material | \$1,135,000  |
|                           |              |
| Total                     | \$13,666,700 |

Total

|                                                   |               |
|---------------------------------------------------|---------------|
| <b>Direct Connection &amp; Network Facilities</b> |               |
|                                                   |               |
| Direct Charges Labor                              | \$104,397,400 |
| Direct Charges Material                           | \$59,888,800  |
| Indirect Charges Labor                            | \$14,309,120  |
| Indirect Charges Material                         | \$1,135,000   |
|                                                   |               |
| Total                                             | \$179,730,320 |

## **Schedules**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.
- HPFF cable lead time and availability.

## APPENDIX A - SCHEDULES

***PJM Generator Interconnection Request  
Queue #O66/V1-034  
Bergen 230kV  
Facilities Study Report***

**August 2009  
Docs#556390  
Version 4 October 2009**

## **Appendices**

### APPENDIX A - SCHEDULES

- B.3.1 SEWAREN – WOODBRIDGE O-1315 RE-  
CONDUCTOR AND TERMINAL UPGRADE
- B.3.2 ROSELAND A-941 TERMINAL UPGRADE
- B.3.3 ATHENIA – BERGEN UNDERGROUND  
TRANSMISSION LINE
- B.3.4 HUDSON SWITCHING STATION REBUILD
- B.3.5 BERGEN BREAKER REPLACEMENT
- B.3.6 ATHENIA BREAKER REPLACEMENTS
- B.3.7 ATHENIA – SADDLE BROOK RE-  
CONDUCTOR

## **1.0 Description of the Project**

Hudson Transmission Partners, LLC proposes to interconnect between Public Service Electric and Gas Company's (PSE&G) Bergen 230 kV Switching Station and Consolidated Edison's (ConEd) W. 49<sup>th</sup> Street 345 kV Substation in New York City. The request is identified as PJM Generator Interconnection Request Queue #O66.

Hudson Transmission Partners, LLC proposes a back-to-back HVDC facility located in Ridgefield, Bergen County, New Jersey. The connection will be a submarine AC cable system to interconnect to ConEd. Firm transmission withdrawal rights of 670 MW were originally requested by Hudson Transmission Partners. This request was later modified to be for 320 MW Firm Withdrawal Rights and 350 Non-Firm Withdrawal Rights

The purpose of this Facilities Study is to examine the PSE&G facilities identified in the Impact Study and define the project requirements for each of these facilities. This Facilities Study shall identify the purpose and necessity; provide a general description of the work; define the design requirements; identify the major materials; provide preliminary cost estimates; and develop a preliminary schedule for each of the facilities.

## **2.0 Amendments to the System Impact Study**

Since the in-service date for the project has been extended by Hudson Transmission Partners to January 31, 2012, none of the advancement of 2011 base line projects to 2010 described in the "O66 Bergen Revised Network Upgrades" document dated 10/09/08 are required.

Hudson Transmission Partners has revised the interconnection request to be for 320 MW Firm Withdrawal Rights and 350 Non-Firm Withdrawal Rights. This change eliminates the need for upgrades #8, #9 and #11 described in the "O66 Bergen Revised Network Upgrades" document dated 10/09/08.

## **3.0 Hudson Transmission Partners Milestone Schedule**

- Start Construction                      March 1, 2011
- Delivery of major electrical equipment. July 15, 2011,
- Commercial Operation. January 31, 2012,

## **4.0 List of Work**

The PJM Generator Interconnection Request Queue #O66 requires the following system upgrades to PSE&G facilities:

- Sewaren–Woodbridge 138 kV O-1315 Circuit Re-Conductor and Terminal Upgrade. (Network Upgrade #n0629)
- Roseland 230 kV Terminal Upgrade. (Network Upgrade #n0645.2)
- Bergen 230 kV Install breakers to terminate the transmission line from the HVDC Facility. (Direct Connection)
- Bergen-Athenia 230kV Install a new underground line and Terminations. (Network Upgrade #n1035)
- Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade. (Upgrades n0666.1, n0666.2, n0666.3, n0666.4, n0666.5, n0666.6, n0666.7, n0666.8, n0666.9, n0666.10, n0666.11, n0666.12, and n0666.13)
- Bergen 12H Breaker Replacement. (Network Upgrade #n0984)
- Athenia 21H, 11H, 51H, 2BH Breaker Replacement. (Upgrades n0985, n0986, n0987, and n0988)

The PJM Generator Interconnection Request Queue #O66 requires the following system upgrades to FirstEnergy facilities:

- Whippany-Roseland 230kV line reconductor and replace terminal equipment at Whippany. (Network Upgrade #n0645.1)
- Atlantic-Larrabee 230kV line reconductor and replace terminal equipment at Atlantic and Larrabee. (Network Upgrade #n0657)
- Portland 230kV – Replace terminal equipment on the Portland-Martins Creek 230kV circuit. (Network Upgrade #n0636.2)
- Whippany 230kV Station – Replace circuit breaker JB. (Network Upgrade #0670)
- Whippany 230kV Station – Replace circuit breaker QJ. (Network Upgrade #0671)

## **1.2 Milestone Schedule**

The following major milestone dates have been established for the PSE&G work required for the project. Preliminary Project Schedules have been provided in Appendix A.

| <b><u>Milestone</u></b>           | <b><u>Date</u></b>         |
|-----------------------------------|----------------------------|
| Issue Final Facility Study Report | May 2009                   |
| Project Start (Notice to Proceed) | June 2009                  |
| Engineering                       | June 2009 – June 2011      |
| Material Procurement              | September 2009 – June 2012 |
| Construction                      | May 2010 – June 2012       |
| Final Completion Date             | June 2012                  |

These major milestone dates are contingent upon the timely completion of project development activities including licensing and permitting.

The following major milestone dates have been established for the FirstEnergy work required for the project.

| <b>Activity</b>                    | <b>Start Month</b> | <b>End Month</b> |
|------------------------------------|--------------------|------------------|
|                                    |                    |                  |
| • Preliminary Engineering          | <b>1</b>           | <b>1</b>         |
| • Permits & Real Estate            | <b>1</b>           | <b>8</b>         |
| • Detailed Engineering             | <b>2</b>           | <b>7</b>         |
| • Equipment Procurement – Delivery | <b>9</b>           | <b>10</b>        |
| • Below Grade Construction         | <b>9</b>           | <b>9</b>         |
| • Above Grade Construction         | <b>9</b>           | <b>13</b>        |
| • Testing & Commissioning          | <b>12</b>          | <b>13</b>        |

## **1.3 General Design Criteria**

### **PSE&G**

#### **1.3.1 Codes and Standards**

Engineering design will be in accordance with the applicable laws and regulations of the federal government, the state of New Jersey, and the local codes and ordinances. Following is a summary of the current codes and industry standards to be used:

- American Concrete Institute (ACI) Code.
- American Institute of Steel Construction (AISC) Code.
- American Iron and Steel Institute (AISI).
- American National Standards Institute (ANSI) standards.
- American Society for Testing and Materials (ASTM) standards.
- American Society of Civil Engineers (ASCE).
- American Welding Society (AWS).
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
- Concrete Reinforcing Steel Institute (CRSI).
- Institute for Electrical and Electronics Engineers (IEEE) Standards.
- National Electrical Code (NEC).
- National Electrical Manufacturer's Association (NEMA).
- National Electrical Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Occupational Safety and Health Administration (OSHA).
- Steel Structures Painting Council (SSPC).
- Building Officials and Code Administrators International, Inc. (BOCA).
- International Building Code (IBC).

Other recognized standards and ordinances will be used where required to serve as guidelines for the design, when not in conflict with the above listed standards.

#### **1.3.2 Civil/Structural Substation Design Criteria**

##### **1.3.2.1 Transformer Oil Containment**

Per PSE&G Standards, Oil Containment Criteria shall be as follows:

- The volume of the basin will be calculated to contain 100 percent of the total oil volume of one transformer with no rainfall.

- A 6 inch freeboard and 50% void ratio will be used.
- Transformer containment pit shall be filled with 3/4 inch clean crushed stone meeting the following gradation:
- 100 percent passing 1-1/4 inch screen.
- 45 to 75 percent passing 3/4 inch screen.
- 25 to 45 percent passing 1/2 inch screen.
- 0 to 10 percent passing 1/4 inch screen.
- Geosynthetic Clay Liner (GCL) shall be “Bentomat CL” liners, as manufactured by Cetco, Arlington Heights, IL, or approved equal. “Bentomat CL” liner seaming shall consist of bentonite-enhanced seams, where panels are overlapped a minimum of 6 inches and seamed together with a continuous bead of granular sodium bentonite. Seaming shall be performed in accordance with the manufacturer’s recommendations.

#### **1.3.2.2 Structure Design**

Deadend structures will be designed using the Ultimate Strength Design (USD) method. Design and fabrication will be in accordance with the latest edition of ASCE 7, the NESC and the ASCE Publication 72.

Equipment support structures will be designed using the Allowable Strength Design (ASD) method. Design and fabrication will be in accordance with the Ninth Edition of the AISC “Manual of Steel Construction, ASCE 7, and the NESC.

#### **1.3.2.3 Material**

Steel structures will be designed using hot-rolled structural steel shapes such as wide flange, tubing, channels and angles or as folded plate tapered tubular structures. All structures will be ASTM A36 or ASTM A572 steel hot-dip galvanized for corrosion protection.

#### **1.3.2.4 Loading Conditions for Analysis**

##### **Dead End Structures**

The deadend structures will be designed to withstand the following loads:

- Loading Case 1 – NESC Heavy
- Loading Case 2 - Extreme Ice (1.5” radial ice)
- Loading Case 3 - Concurrent Wind and Ice (6.4 psf wind, 0.75” radial ice)
- Loading Case 4 – Extreme Wind (31 psf wind)

### Equipment Support Structures

The bus, insulator, switch and equipment supports will be designed to withstand the following loads:

- Loading Case 1 – NESC Heavy
- Loading Case 2 – Extreme Wind (110 mph, deflections will be less than those specified in NEMA SG-6-36)
- Loading Case 3 - Short Circuit (100% of insulator cantilever, wind from Loading Case 2 elsewhere)

#### 1.3.2.5 Foundation Design

The foundation design will conform to the latest edition of the current issue of the “Building Code Requirements for Reinforced Concrete,” AC1 318, County and State Codes and will be in accordance with the following general criteria:

|                    |                              |
|--------------------|------------------------------|
| Concrete Strength: | $F_c = 4,000$ psi at 28 days |
|--------------------|------------------------------|

|                    |                    |
|--------------------|--------------------|
| Reinforcing Steel: |                    |
| ASTM A615 Gr60     | $F_y = 60,000$ psi |

|                                     |     |
|-------------------------------------|-----|
| Safety factor against soil failure: |     |
| Spread footing                      | 3.0 |
| Minimum overturning ratio:          | 1.5 |

### Equipment and Structure Foundations

Ground support pieces of equipment such as the circuit breakers will be supported by cast-in-place reinforced concrete slabs.

Foundations for the equipment support structures, such as bus supports, disconnect switches, etc., and dead end structures, will be spread footings.

#### 1.3.3 Electrical General Design Requirements

The general design requirements are as follows:

|                                |               |
|--------------------------------|---------------|
| System frequency:              | 60 hertz      |
| Elevation, AMSL:               | < 1000 feet   |
| Keraunic level:                | 40            |
| Maximum ambient temperature:   | +40 degrees C |
| Minimum ambient temperature:   | -40 degrees C |
| Maximum wind velocity:         | 110 mph       |
| Maximum ice loading (no wind): | 1.5 inches    |

|                                           |            |
|-------------------------------------------|------------|
| Maximum ice loading (with wind – 40 mph): | 0.5 inches |
| Seismic zone:                             | (Per IBC)  |

### **1.3.3.1 Voltage and Current Ratings**

The voltage and current ratings are as follows:

#### 230 kV

|                                                        |           |
|--------------------------------------------------------|-----------|
| Nominal phase-to-phase voltage:                        | 230 kV    |
| Maximum phase-to-phase voltage:                        | 242 kV    |
| Nominal phase-to-ground voltage:                       | 133 kV    |
| Maximum phase-to-ground voltage:                       | 140 kV    |
| Basic impulse level (BIL):                             | 900 kV    |
| Maximum continuous current carrying capacity           | 3000 A    |
| Maximum three phase available fault current:           | 40 kA     |
| Maximum single phase to ground available fault current | 40 kA     |
| Maximum fault clearing time:                           | 30 cycles |

#### 138 kV

|                                                        |           |
|--------------------------------------------------------|-----------|
| Nominal phase-to-phase voltage:                        | 138 kV    |
| Maximum phase-to-phase voltage:                        | 145 kV    |
| Nominal phase-to-ground voltage:                       | 80 kV     |
| Maximum phase-to-ground voltage:                       | 84 kV     |
| Basic impulse level (BIL):                             | 650 kV    |
| Maximum continuous current carrying capacity           | 3000 A    |
| Maximum three phase available fault current:           | 40 kA     |
| Maximum single phase to ground available fault current | 40 kA     |
| Maximum fault clearing time:                           | 30 cycles |

### **1.3.3.2 Clearances and Spacings**

The clearances and spacings are as follows:

#### 230 kV

|                                                       |            |
|-------------------------------------------------------|------------|
| Rigid bus center-to-center phase spacing              | 144 inches |
| Minimum phase-to-phase, metal-to-metal distance       | 80 inches  |
| Minimum phase-to-ground                               | 71 inches  |
| Minimum vertical clearance from live parts to grade   | 180 inches |
| Minimum conductor clearance above roads in switchyard | 324 inches |

### 138 kV

|                                                       |            |
|-------------------------------------------------------|------------|
| Rigid bus center-to-center phase spacing              | 96 inches  |
| Minimum phase-to-phase, metal-to-metal distance       | 62 inches  |
| Minimum phase-to-ground                               | 50 inches  |
| Minimum vertical clearance from live parts to grade   | 156 inches |
| Minimum conductor clearance above roads in switchyard | 276 inches |

### **Bus Conductor Selection and Design**

New bus will be designed to meet bus ratings at 40°C ambient and 40°C temperature rise with two feet per second crosswind and will be designed to withstand the appropriate mechanical forces.

### **Bus Fitting Selection**

Fittings for the aluminum tubular bus will be bolted.

Fittings for conductor jumpers will be bolted for all aluminum conductors to a bolted pad. Equipment terminal connections will be NEMA 4-hole bolted type so they may be easily removed for equipment maintenance, repair, or replacement.

### **Insulator Selection**

Porcelain station post insulators will be used on all bus supports, under hung cable supports and disconnect switches.

### **1.3.3.3 Lightning Shielding Design**

The shielding design will be verified using the application of that model called the “Rolling Sphere Technique” developed by R. H. Lee.

After the detailed bus and equipment layout is completed, the shielding design will be analyzed to verify that all equipment within the Switchyard perimeter fence is adequately protected. Structure lightning finials and shield masts will be included in the shielding analysis.

### **1.3.3.4 Grounding**

The grounding system will be designed in a manner that provides a means to safely discharge lightning strokes to earth, reduce step and touch potentials to safe levels, and confine dangerous soil currents to inaccessible areas. The grounding system will also be designed to allow the detection of ground fault currents by protective relaying systems, limit electromagnetic interference (EMI) in low voltage circuits, and provide a common

ground reference. The grounding procedures stated herein are based on ANSI/IEEE Standard 80.

The grounding system for the Switchyard will consist of the following components:

- Ground grid conductors, which will form a network of bare, 4/0 AWG BTN (minimum) interconnected copper conductors buried 18 inches below finished earth grade and extended three feet beyond the Switchyard fence and three feet beyond the Switchyard fence gate swing, where applicable.
- Ground rods connected to the ground grid, and driven or buried vertically to a depth to reach soil of stable moisture content and resistivity.
- Lightning finials, and shield masts for direct stroke lightning protection.
- Crushed stone layer of high resistivity surfacing covering the yard to a depth of approximately 4 inches.
- The main ground grid including equipment stinger connections will be exothermically welded.
- Connections to steel structures and equipment will be bolted, with a minimum of two connections between the ground grid and structure, or as follows:
  - Single-leg bus supports – 1 connections
  - Two-leg bus supports – 2 connections
  - Switches – 1 connection per leg
  - Dead end tower – 1 connection per leg
- Connections of two points at opposite ends of control enclosure to ground grid.
- Connections to the Ring Bus fence at 50 foot intervals (maximum) and continuing up through the fence fabric.
- All horizontal or vertical bolted-connection structural members shall be bonded to a grounded structural member with a jumper of 350 MCM BTN copper.

#### **1.3.3.5 Raceway Systems**

The main raceway systems will consist of pre-cast High Density Polymer Concrete (HDPC) cable trench. Underground conduit will be schedule 40 PVC with PVC fittings and buried not less than 18 inches below grade.

#### **1.3.3.6 Yard Lighting**

Switchyard lighting will provide illumination for security and some operational functions. The outdoor lights will be installed on the deadend structures and switch legs.

#### **1.3.3.7 Control and Power Cable**

All single and multi-conductor power and control cables will be 600 volt, Class B, stranded copper. Cables will be marked at each end with circuit and wire numbers.

The minimum cable size for control and potential circuits will be 9 AWG copper. The minimum cable size for current circuits will be 9 AWG copper. All 9 AWG conductors will be multi-conductor, jacketed cable.

For potential circuits within the enclosure, 9 AWG cable will be used. For current circuits within the enclosure, 9 AWG cable will be used. For alarm circuits within the enclosure, 14 AWG cable will be used.

Single conductor cables 10 AWG and smaller will not be routed in the cable trench raceway system.

All cable terminations will be made using ring type non-insulated terminals manufactured by Burndy or Amp per PSE&G control & relaying standards.

#### **1.3.3.8 Control, Protection, and Metering**

Any new control and relay racks will be designed in accordance with PSE&G standard rack mechanical drawings and will utilize PSE&G standard relays and devices where possible. PSE&G shall provide specific manufacturer and model numbers where specific equipment is required.

### **1.3.4 General Transmission Line Design Criteria**

#### **1.3.4.1 Mechanical Loading Criteria**

The following mechanical loading conditions will be used for the design of transmission line structures.

Loading Case 1 – NESC Heavy (4 psf wind, 0.5” radial ice, 0°F, Initial)

Loading Case 2 – Extreme Wind (31 psf wind, no ice, 60°F, Initial)

Loading Case 3 – Concurrent Wind and Ice (6.4 psf wind, 0.75” radial ice, 0°F, Initial)

Loading Case 4 – Extreme Ice (no wind, 1.5” radial ice, 32°F, Initial)

Loading Case 5 – Deflection Loading (no wind, no ice, 60°F, Final). Deflection of the structure top shall be limited to the greater of 1% of total structure height or 40% of the base diameter.

### 1.3.4.2 Electrical Clearances

The clearances used in the design of the transmission lines will meet or exceed the requirements of the National Electrical Safety Code (NESC), 2007 Edition and PJM design criteria, whichever is greater. The clearances pertain to vertical clearances, horizontal clearances, lateral clearances, and air gap clearances. Lateral clearances are included in the horizontal clearance subsection.

#### Vertical Clearances

230 kV vertical clearances will be designed to accommodate the design ACSS conductor at a maximum operating temperature of 200°C (392°F), and the design ACSR conductor at a maximum operating temperature of 100°C (212°F), unless otherwise specified. The vertical clearances indicated below meet the requirements of the NESC for 230 kV line voltage.

| <u>Description of Crossing</u>                                                                                                             | <u>230 kV<br/>Clearance</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads, except electrified trolleys (except as specified by the affected Railroad)                                            | 34ft                        |
| Roads, streets, driveways parking lots, alleys, and all other areas subject to truck traffic                                               | 26 ft                       |
| Spaces and ways subject to pedestrians or restricted traffic less than 8 feet in height                                                    | 22 ft                       |
| Pedestrian Traffic                                                                                                                         | 22 ft                       |
| Water areas not suitable for sailboating or where sailboating is prohibited                                                                | 24 ft                       |
| Water areas suitable for sailboating including lakes, ponds, reservoirs, rivers, streams, and canals with an unobstructed surface area of: |                             |
| Less than 20 acres                                                                                                                         | 28 ft                       |
| Over 20 to 200 acres                                                                                                                       | 36 ft                       |
| Over 200 to 2000 acres                                                                                                                     | 42 ft                       |
| Over 2000 acres                                                                                                                            | 48 ft                       |

| <u>Description of Crossing</u>                                                    | <u>230 kV<br/>Clearance</u> |
|-----------------------------------------------------------------------------------|-----------------------------|
| Public or private land and water areas posted for rigging or launching sailboats: |                             |
| Less than 20 acres                                                                | 33 ft                       |
| Over 20 to 200 acres                                                              | 41 ft                       |
| Over 200 to 2000 acres                                                            | 47 ft                       |
| Over 2000 acres                                                                   | 53 ft                       |
| Communication lines                                                               | 12 ft                       |
| Overhead ground wires and guy wires                                               | 9 ft                        |
| Open supply conductors over or under subject line:                                |                             |
| 22 kV and below                                                                   | 9 ft                        |
| 46 kV                                                                             | 10 ft                       |
| 69 kV                                                                             | 10 ft                       |
| 115 kV                                                                            | 11 ft                       |
| 138 kV                                                                            | 11 ft                       |
| 161 kV                                                                            | 12 ft                       |
| 230 kV                                                                            | 13 ft                       |
| 345 kV                                                                            | 16 ft                       |
| 500 kV                                                                            | 19 ft                       |
| Buildings:                                                                        |                             |
| Over roofs or projections not readily accessible to pedestrians                   | 20 ft                       |
| Over roofs or projections readily accessible to pedestrians                       | 21 ft                       |
| Over roofs accessible to vehicles but not trucks 8 ft high                        | 21 ft                       |
| Over roofs accessible to truck traffic                                            | 26 ft                       |
| Bridges: Over (not attached)                                                      | 20 ft                       |
| Installations not classified as buildings or bridges attached)                    |                             |
| Upon which personnel walk                                                         | 21 ft                       |
| Other portions of such installations                                              | 15 ft                       |

| <u>Description of Crossing</u> | <u>230 kV<br/>Clearance</u> |
|--------------------------------|-----------------------------|
| Another supporting structure   | 12 ft                       |
| Top of rail cars               | 14 ft                       |

138 kV vertical clearances will be designed to accommodate the design ACSS conductor at a maximum operating temperature of 200°C (392°F), unless otherwise specified. The vertical clearances indicated below meet the requirements of the NESC for 138kV line voltage.

| <u>Description of Crossing</u>                                                                                                             | <u>138 kV<br/>Clearance</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads, except electrified trolleys (except as specified by the affected Railroad)                                            | 32ft                        |
| Roads, streets, driveways parking lots, alleys, and all other areas subject to truck traffic                                               | 24 ft                       |
| Spaces and ways subject to pedestrians or restricted traffic less than 8 feet in height                                                    | 20 ft                       |
| Pedestrian Traffic                                                                                                                         | 20 ft                       |
| Water areas not suitable for sailboating or where sailboating is prohibited                                                                | 22 ft                       |
| Water areas suitable for sailboating including lakes, ponds, reservoirs, rivers, streams, and canals with an unobstructed surface area of: |                             |
| Less than 20 acres                                                                                                                         | 26 ft                       |
| Over 20 to 200 acres                                                                                                                       | 34 ft                       |
| Over 200 to 2000 acres                                                                                                                     | 40 ft                       |
| Over 2000 acres                                                                                                                            | 46 ft                       |

| <u>Description of Crossing</u>                                                    | <u>138 kV<br/>Clearance</u> |
|-----------------------------------------------------------------------------------|-----------------------------|
| Public or private land and water areas posted for rigging or launching sailboats: |                             |
| Less than 20 acres                                                                | 31 ft                       |
| Over 20 to 200 acres                                                              | 39 ft                       |
| Over 200 to 2000 acres                                                            | 45 ft                       |
| Over 2000 acres                                                                   | 51 ft                       |
| Communication lines                                                               | 10 ft                       |
| Overhead ground wires and guy wires                                               | 7 ft                        |
| Open supply conductors over or under subject line:                                |                             |
| 22 kV and below                                                                   | 7 ft                        |
| 46 kV                                                                             | 8 ft                        |
| 69 kV                                                                             | 8 ft                        |
| 115 kV                                                                            | 9 ft                        |
| 138 kV                                                                            | 9 ft                        |
| 161 kV                                                                            | 10 ft                       |
| 230 kV                                                                            | 11 ft                       |
| 345 kV                                                                            | 14 ft                       |
| 500 kV                                                                            | 17 ft                       |
| Buildings:                                                                        |                             |
| Over roofs or projections not readily accessible to pedestrians                   | 18 ft                       |
| Over roofs or projections readily accessible to pedestrians                       | 19 ft                       |
| Over roofs accessible to vehicles but not trucks 8 ft high                        | 18 ft                       |
| Over roofs accessible to truck traffic                                            | 24 ft                       |
| Bridges: Over (not attached)                                                      | 19 ft                       |
| Installations not classified as buildings or bridges attached)                    |                             |
| Upon which personnel walk                                                         | 19 ft                       |
| Other portions of such installations                                              | 13 ft                       |
| Another supporting structure                                                      | 10 ft                       |
| Top of rail cars                                                                  | 12 ft                       |

### Horizontal Clearances

230 kV horizontal clearances are based on a maximum operating temperature of 200°C (392°F) for the design of ACSS conductor, or a maximum operating temperature of 100°C (212°F) for the design of ACSR conductor; with the conductor in the final maximum sag condition with no wind, unless otherwise specified. The horizontal clearances indicated below meet the requirements of the NESC for 230 kV line voltage and include a minimum of 3 feet additional clearance to allow for construction and survey tolerances.

| <u>Description of Obstacle</u>                                                                                                                              | <u>230 kV<br/>Clearance</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads                                                                                                                                         | 19 ft                       |
| Buildings, signs, chimneys, billboards, radio & TV antennas, tanks<br>& other installations not classified as buildings or bridges (wires not<br>attached): |                             |
| With no wind displacement                                                                                                                                   | 15 ft                       |
| With 6 psf wind displacement                                                                                                                                | 12 ft                       |
| Lighting supports, traffic signals, or supporting structures of another line:                                                                               |                             |
| With no wind displacement                                                                                                                                   | 11 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10.5 ft                     |
| Bridges (unattached):                                                                                                                                       |                             |
| With no wind displacement                                                                                                                                   | 14 ft                       |
| With 6 psf wind displacement                                                                                                                                | 12 ft                       |

138 kV horizontal clearances are based on a maximum operating temperature of 200°C (392°F) for the design of ACSS conductor; with the conductor in the final maximum sag condition with no wind, unless otherwise specified. The horizontal clearances indicated below meet the requirements of the NESC for 138 kV line voltage.

| <u>Description of Obstacle</u>                                                                                                                              | <u>138 kV<br/>Clearance</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Tracks of railroads                                                                                                                                         | 17 ft                       |
| Buildings, signs, chimneys, billboards, radio & TV antennas, tanks<br>& other installations not classified as buildings or bridges (wires not<br>attached): |                             |
| With no wind displacement                                                                                                                                   | 13 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10 ft                       |
| Lighting supports, traffic signals, or supporting structures of another line:                                                                               |                             |
| With no wind displacement                                                                                                                                   | 9 ft                        |
| With 6 psf wind displacement                                                                                                                                | 8.5 ft                      |
| Bridges (unattached):                                                                                                                                       |                             |
| With no wind displacement                                                                                                                                   | 12 ft                       |
| With 6 psf wind displacement                                                                                                                                | 10 ft                       |

### **Air Gap Clearances**

Air gap clearances are indicated below.

| <u>Voltage</u> | <u>Air Gap</u> | <u>Clearance Description</u>              |
|----------------|----------------|-------------------------------------------|
| 230 kV         | 80 in          | Full Impulse                              |
|                | 56 in          | 6 psf Wind Displacement                   |
|                | 20 in          | 60 Hertz Extreme Wind Operating Clearance |
|                |                |                                           |
| <u>Voltage</u> | <u>Air Gap</u> | <u>Clearance Description</u>              |
| 138 kV         | 52 in          | Full Impulse                              |
|                | 30 in          | 6 psf Wind Displacement                   |
|                | 12 in          | 60 Hertz Extreme Wind Operating Clearance |

### **1.3.4.3 Galloping**

An elliptical analysis will be performed to investigate the potential for galloping throughout the relocated transmission line. The analysis will consider the conductor operating at either of two conditions; either a 2 psf wind, 1/2" radial ice, at 32°F loading condition; or a no wind, 1/2" radial ice, 32°F loading condition. A single loop calculation will be performed for spans of 600 feet or less, and a double loop calculation will be performed for spans in excess of 600 feet. The line design will incorporate a clearance of 12 inches between conductor ellipses to minimize conductor and/or structure damage.

#### 1.3.4.4 Conductors and Static Wires

The following sub-sections will describe the physical properties of the conductor and static wire to be used for this project.

##### Conductor

The 230 kV transmission conductors to be used for this project is as follows:

| Code Word | Class<br>Type | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|-----------|---------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| Falcon    | ACSR          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 54,500            |
| Falcon    | ACSS          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 42,600            |

The 138 kV transmission conductor to be used for this project is as follows:

| Code Word | Class<br>Type | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|-----------|---------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| Falcon    | ACSS          | 1590 | 54/19     | 1.407           | 1.545            | 2.044              | 42,600            |

##### Fiber Optic Cables

The 138 kV and 230 kV shield wire to be used for this project is an optical ground wire (OPGW) as follows:

| Description   | Class<br>Type           | Size | Stranding | Area<br>(sq in) | Diameter<br>(in) | Weight<br>(lbs/ft) | Strength<br>(lbs) |
|---------------|-------------------------|------|-----------|-----------------|------------------|--------------------|-------------------|
| AFL AC 73/551 | 24 Fibers<br>(DNO-6967) | -    | 12        | 0.1671          | 0.551            | 0.4028             | 24,014            |

##### Conductor Tension Limits

The following maximum tension limits will be used in the determination of conductor sag and tension values. The first set of limits below meet NESC code requirements, and the second set of limits are PSE&G tension controls that will normally be the controlling limitation in non-slack span tensions.

| <b><u>Load Case</u></b> | <b><u>NESC Limits</u></b> |
|-------------------------|---------------------------|
| NESC Heavy              | 60% Initial               |
| Extreme Wind            | 75% Initial               |
| Heavy Ice               | 75% Initial               |
| 60°F                    | 35% Initial               |
| 60°F                    | 25% Final                 |

| <b><u>Load Case</u></b> | <b><u>PSE&amp;G Limits</u></b>                           |
|-------------------------|----------------------------------------------------------|
| -20°F                   | 20% Initial                                              |
| NESC Heavy              | 10,000 lbs (1590 ACSS – Sewaren to Woodbridge 138 kV)    |
| NESC Heavy              | 17,400 lbs (1590 ACSS – Branchburg to Readington 230 kV) |
| NESC Heavy              | 22,500 lbs (1590 ACSR – Readington to Roseland 230 kV)   |
| NESC Heavy              | 15,600 lbs (1590 ACSS – Roseland to Hudson 230 kV)       |

The static wire tension is based on 80% of the conductor sag at 60°F, no ice, no wind, final sag condition, and must also meet the same criteria as a conductor. This 80% sag criteria will apply to both full tension and slack tension spans.

#### **1.3.4.5 Structures**

Any new 230 kV and 138 kV structures for this project will be single or double circuit tubular steel poles with anchor bolts. All new steel structures will have a painted finish (valley green).

#### **1.3.4.6 Insulation**

Several design considerations have been utilized to determine the standard number of insulators required for 230 kV and 138 kV construction, including arcing distance, basic impulse insulation level (BIL), contamination, dry flashover, impulse flashover, switching surge, and insulator coordination. A shielding angle of 25 degrees or less will be used on all structures to help avoid lightning flashovers.

#### **Insulators**

The 230 kV insulator strings used for all structure types will consist of toughened glass ball & socket insulator bells, with 16 bells (30 kips) in each suspension string and 18 bells (50 kips) in each deadend string. The 138 kV insulator strings used for all structure types will consist of toughened glass ball & socket insulator bells, with 14 bells in each string. For all insulator applications, the insulator mechanical loading will not exceed 50% of the insulator M&E

rating for NESC working loads and 75% of the insulator M&E rating for all other loads with overload capacity factors.

Insulator swing clearances for suspension insulators are as follows:

| <u>Voltage</u> | <u>Condition</u>             | <u>Clear to Arm or Structure</u> |
|----------------|------------------------------|----------------------------------|
| 230 kV         | 60°F, no wind, final (1)     | 80"                              |
|                | 60°F, 6 psf wind, final      | 56"                              |
|                | 60°F, 31 psf wind, final (2) | 20"                              |

No wind clearance for suspension insulators (impulse air gap or insulator length)

Extreme wind 60 Hz minimum flashover distance

| <u>Voltage</u> | <u>Condition</u>             | <u>Clear to Arm or Structure</u> |
|----------------|------------------------------|----------------------------------|
| 138 kV         | 60°F, no wind, final (1)     | 52"                              |
|                | 60°F, 6 psf wind, final      | 30"                              |
|                | 60°F, 31 psf wind, final (2) | 12"                              |

(1) No wind clearance for suspension insulators (impulse air gap or insulator length)

(2) Extreme wind 60 Hz minimum flashover distance

#### **1.3.4.7 Hardware and Accessories**

The strength of hardware will equal or exceed the M&E rating of the insulators. Typical conductor and static wire accessories include compression sleeves and splices, which will develop the strength of the wire being spliced. The quantity, location and type of dampers to be installed on conductors and static wires will be according to manufacturers' recommendations, and based on sag/tension and applicable weather condition information provided for analysis.

All 230 kV and 138 kV conductor and static wire deadends will use compression fittings suitable for the conductors or cables used. All hardware and accessories will be made from steel, malleable iron or aluminum. Steel and malleable iron fittings will be galvanized after fabrication.

#### **1.3.4.8 Structure Foundations**

The majority of the foundations for the new tubular steel poles will consist of drilled piers with anchor bolts. The diameter and length of each drilled pier foundation will be determined from soil data taken along the transmission line route. The foundations will be limited to approximately 3 inches of groundline movement under the worst case foundation reactions, including overload capacity factors.

The drilled pier foundations will be designed using the L-Pile 5.0 Plus software program.

In some cases, soil conditions will most likely dictate that driven pile foundations will be required.

#### **1.3.4.9 Structure Grounding**

All transmission structures will be individually grounded through a dedicated earth driven grounding system composed of ground rods. The maximum allowable ground resistance on a transmission structure is 25 ohms with the overhead static wire disconnected. Measurements are to be made on each structure using an approved megger and recorded during construction before connection to static wire is made.

### **FirstEnergy**

Facilities owned and operated by FirstEnergy (FE) and Jersey Central Power and Light, its operating company, shall comply with the applicable FE technical requirements and standards posted on the PJM website per the PJM Tariff, the “PJM transmission and Substation Design Subcommittee Technical Requirements,” the “PJM Relay Philosophy Design Standards” and the following criteria. Where there are different requirements for the same criterion, the more restrictive shall apply.

#### **General Design Requirements**

- |                                            |                                                                                 |
|--------------------------------------------|---------------------------------------------------------------------------------|
| • System phasing (counter clockwise)       | 1-2-3 (FE)/X-Y-Z (Penelec)                                                      |
| • System frequency:                        | 60 hertz                                                                        |
| • Elevation, AMSL:                         | 2254 feet                                                                       |
| • Isokeraunic level:                       | 40                                                                              |
| • Maximum ambient temperature:             | 40 degrees C                                                                    |
| • Minimum ambient temperature:             | -40 degrees C                                                                   |
| • Maximum conductor operating temperature: | Per PJM Document “Outdoor Substation Conductor Ratings” dated 10/19/04          |
| • Wind Loading (no ice):                   | Per ASCE 7-98, Fig. 6-1                                                         |
| • Wind coincident with 13 mm radial ice    | 64 km/h (40 mph)                                                                |
| • Ice loading – Substations (no wind):     | 25 mm                                                                           |
| • Seismic zone:                            | Per ASCE 7-98, Fig. 9.4.1.1(a) and (b). Equipment qualification per IEEE 693-97 |

## **Voltage and Current Ratings**

### **230 kV System**

- Nominal phase-to-phase: 230 kV
- Maximum phase-to-phase: 242 kV
- Basic impulse level (BIL): 900 kV
- Minimum continuous current carrying capacity: 2000 A
- Design fault current (equipment & bus): 40 kA
- Single Contingency (breaker or relay failure) clearing time: 45 cycles

## **Clearances and Spacing**

### **230 kV System**

- Recommended rigid bus center-to-center phase spacing: 132"
- Minimum phase-to-phase, metal-to-metal distance: 89"
- Recommended phase-to-ground: 80"
- Minimum phase-to-ground: 71"
- Minimum vertical clearance from live parts to grade: 12'-9"
- Minimum horizontal clearance from live parts: 8'-3"
- Minimum conductor clearance above roads, streets, and other areas subject to truck traffic: 23'-0"
- Minimum conductor clearance above spaces and ways subject to pedestrian or restricted traffic: 20'-2"
- Minimum bottom of insulator to top of foundation: 8'-6"

## **2.0 SUMMARY OF RESULTS**

### **2.1 Total Cost Breakdown**

The following table identifies the estimated costs by project for the PSE&G work.

(The remainder of this page is intentionally left blank.)

| <u>Facility</u>                                                                                                                           | <u>Engineering</u> | <u>Materials</u>  | <u>Construction<br/>Mgmt</u> | <u>Construction</u> | <u>PSE&amp;G<br/>Program<br/>Mgmt</u> | <u>PSE&amp;G<br/>Engineering</u> | <u>PSE&amp;G<br/>Construction<br/>Support</u> | <u>PSE&amp;G<br/>Relaying,<br/>Mechanics,<br/>Lab, &amp;<br/>System Prot.</u> | <u>Environmental<br/>&amp; Resource<br/>Recovery</u> | <u>Licensing &amp;<br/>Permitting</u> | <u>Corporate<br/>Properties</u> | <u>Subtotal</u>    | <u>Surcharge</u>  | <u>Total with<br/>Surcharge</u> | <u>Contingency<br/>(50%)</u> | <u>Total with<br/>Contingency</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|------------------------------|---------------------|---------------------------------------|----------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------|---------------------------------------|---------------------------------|--------------------|-------------------|---------------------------------|------------------------------|-----------------------------------|
| 3.1 Sewaren – Woodbridge 138 kV O-1315 Circuit Re-Conductor                                                                               | 708,000            | 4,528,000         | 208,000                      | 4,103,000           | 668,000                               | 212,000                          | 229,000                                       | 0                                                                             | 10,000                                               | 900,000                               | 200,000                         | 11,766,000         | 705,380           | 12,471,380                      | 6,235,690                    | <b>18,707,070</b>                 |
| 3.1 Sewaren Terminal Upgrade                                                                                                              | 20,000             | 52,000            | 10,000                       | 60,000              | 10,000                                | 6,000                            | 11,000                                        | 15,000                                                                        | 10,000                                               | 0                                     | 0                               | 194,000            | 51,930            | 245,930                         | 122,965                      | <b>368,895</b>                    |
| 3.2 Roseland 230 kV Terminal Upgrade                                                                                                      | 10,000             | 2,000             | 13,000                       | 15,000              | 3,000                                 | 3,000                            | 14,000                                        | 10,000                                                                        | 0                                                    | 50,000                                | 0                               | 120,000            | 33,580            | 153,580                         | 76,790                       | <b>230,370</b>                    |
| 3.3 Bergen 230 kV Underground Line (See Note 1)                                                                                           | 1,750,000          | 33,610,000        | 2,340,000                    | 37,725,000          | 3,771,000                             | 525,000                          | 566,000                                       | 0                                                                             | 3,950,000                                            | 3,500,000                             | 5,000,000                       | 92,737,000         | 5,329,740         | 98,066,740                      | 49,033,370                   | <b>147,100,110</b>                |
| 3.3 Athenia Terminal Upgrade                                                                                                              | 130,000            | 540,000           | 33,000                       | 514,000             | 85,000                                | 39,000                           | 36,000                                        | 60,000                                                                        | 250,000                                              | 200,000                               | 0                               | 1,887,000          | 246,070           | 2,133,070                       | 1,066,535                    | <b>3,199,605</b>                  |
| 3.3 Bergen Terminal Upgrade - HTP Circuit                                                                                                 | 345,500            | 1,725,000         | 202,000                      | 2,392,500           | 326,500                               | 103,500                          | 222,000                                       | 30,000                                                                        | 0                                                    | 750,000                               | 50,000                          | 6,147,000          | 512,970           | 6,659,970                       | 3,329,985                    | <b>9,989,955</b>                  |
| 3.3 Bergen Terminal Upgrade - Athenia Circuit                                                                                             | 345,500            | 1,725,000         | 202,000                      | 2,392,500           | 326,500                               | 103,500                          | 222,000                                       | 30,000                                                                        | 0                                                    | 750,000                               | 50,000                          | 6,147,000          | 512,970           | 6,659,970                       | 3,329,985                    | <b>9,989,955</b>                  |
| 3.4 Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade | 2,005,000          | 12,658,000        | 583,000                      | 11,822,000          | 1,894,000                             | 602,000                          | 641,000                                       | 370,000                                                                       | 100,000                                              | 2,000,000                             | 500,000                         | 33,175,000         | 2,946,630         | 36,121,630                      | 18,060,815                   | <b>54,182,445</b>                 |
| 3.5 Bergen 12H Breaker Replacement                                                                                                        | 80,000             | 430,000           | 27,000                       | 116,000             | 46,000                                | 24,000                           | 30,000                                        | 25,000                                                                        | 10,000                                               | 0                                     | 0                               | 788,000            | 98,640            | 886,640                         | 443,320                      | <b>1,329,960</b>                  |
| 3.6 Athenia 21H, 11H, 51H, 2BH Breaker Replacement                                                                                        | 350,000            | 890,000           | 80,000                       | 433,000             | 123,000                               | 90,000                           | 88,000                                        | 100,000                                                                       | 25,000                                               | 0                                     | 0                               | 2,179,000          | 375,710           | 2,554,710                       | 1,277,355                    | <b>3,832,065</b>                  |
| <b>Subtotal</b>                                                                                                                           | <b>5,744,000</b>   | <b>56,160,000</b> | <b>3,698,000</b>             | <b>59,573,000</b>   | <b>7,253,000</b>                      | <b>1,708,000</b>                 | <b>2,059,000</b>                              | <b>640,000</b>                                                                | <b>4,355,000</b>                                     | <b>8,150,000</b>                      | <b>5,800,000</b>                | <b>155,140,000</b> | <b>10,813,620</b> | <b>165,953,620</b>              | <b>82,976,810</b>            | <b>248,930,430</b>                |

*Note 1: Includes the Proposed Route for Athenia – Bergen Transmission Line*

The following general assumptions were used in estimating PSE&G costs at each Facility. Facility unique assumptions are listed in the respective Facility Study Results sections.

- Costs are in 2009 dollars.
- A budgetary quotation from suppliers, or historical data was utilized for the major equipment pricing.
- Equipment and material costs assume normal (non-expedited) procurements.
- Existing substation facility resources are available and will be utilized as required for station expansion projects including control building space, AC and DC power sources, raceway and control cable systems, communications systems, and SCADA remote terminal unit (RTU) I/O.
- Construction labor assumes the use of union labor.
- In Substation facilities, it is assumed that a spread footing type foundations can be utilized and adequate soils are present. An allowance has been included for soil borings.
- All existing shield wires on the transmission lines will be replaced with OPGW conductor and hardware assemblies.
- When transmission line conductors are to be replaced, it is assumed that the existing transmission line insulator and hardware assemblies will be replaced as part of this project.
- Costs associated with a transmission line EMF and audible noise study have been included in the estimated engineering costs for the project. The studies will be performed during the detailed design phase of the project in support of the permitting process.
- When transmission line structure replacements are required, the existing lattice steel towers will be replaced with new tubular steel poles directly adjacent to the existing structure location.
- All new tubular steel poles will be painted. Galvanizing has not been included in the estimate.
- It has been assumed that extended construction outages will be available to support the structure modifications and replacements throughout the project limits.
- Existing telecommunication cellular antennas will need to be temporarily relocated while structure modification and/or replacement work occurs at required locations at the cost of the developer. These costs are not included in the estimates.
- Lattice tower structural analysis was not performed for the purposes of this report. Tower replacements or modifications are based on one of the following: 1) Evaluation of ground clearances with the proposed conductor modeled at its maximum operating temperature and proposed line tensions not exceeding existing line tensions. 2) Empirical evaluation of existing towers based on tower type, height, line angle, span length and with proposed line tensions higher than existing line tensions.
- Costs for modifications to existing lattice towers have been estimated with respect to a percentage of the replacement cost for a new tubular steel structure as follows:

Minor modifications (20%), Average modifications (40%), Major modifications (70%).

- Final costs are contingent upon structural analysis of the lattice towers that is required for determining tower replacements and modifications. Minor allowances have been included in the estimate to provide structural analysis of the lattice towers.
- Evaluation of existing foundations was not performed for the purposes of this report. No allowances have been included in the estimate for the repair or modification of existing foundations.
- Final costs are contingent upon detailed analysis of existing foundations. Allowances have been included in the estimate to provide detailed engineering analysis of existing foundations.
- Costs associated with ROW access and site restoration have been included within the construction portion of the cost estimates. These costs are approximately 4% of the construction costs.
- Sales, use, or other taxes are not included.
- Demolition costs have been included, where required, but do not include allowances for unknown underground obstructions, such as abandoned pipe, tanks, foundations, wells, rock, etc.
- No allowance is included for contaminated soil disposal or environmental mitigation, if required.
- No material escalation costs have been included in the estimate.
- Program Management costs have been estimated to be approximately 7% of the sum of the Engineering, Materials, Construction, and Construction Management costs.
- The Licensing & Permitting estimates assume that there will be no Federal Environmental Impact Statement required. If an FEIS is required the schedule will require an additional 24 to 36 months for the process.
- If a National Environmental Policy Act process is required, those costs are not included in the estimates.
- Costs are based upon using existing rights-of-way with the exception of the pipe type cable route. The pipe type cable installation will require local, county, and state approvals.
- Estimates do not include wetland mitigation and/or approvals of the mitigation.
- The estimate does not include additional costs incurred as a result of condemnation proceedings, if required. As of this date, it has not been determined that PSE&G can utilize condemnation to acquire land rights for this project.
- Any land right acquisitions required from PSEG Power LLC have not been included in this estimate.

An estimated cost summary in 2009 dollars, excluding taxes or effects from Contribution In Aid of Construction, for the FirstEnergy required network upgrades is shown below:

[PJM Network Upgrade n0645.1]

|                                               |             |
|-----------------------------------------------|-------------|
| Whippany-Roseland 230 kV DCT Line Reconductor |             |
|                                               |             |
| Engineering                                   | \$314,900   |
| Material & Equipment                          | \$2,591,400 |
| Construction & Testing                        | \$2,956,500 |
|                                               |             |
| Total                                         | \$5,862,800 |

. [PJM Network Upgrade n0657]

|                                           |             |
|-------------------------------------------|-------------|
| Larrabee-Atlantic 230 kV Line Reconductor |             |
|                                           |             |
| Engineering                               | \$158,300   |
| Material & Equipment                      | \$1,411,600 |
| Construction & Testing                    | \$4,362,900 |
|                                           |             |
| Total                                     | \$5,932,800 |

[PJM Network Upgrade n0636.2]

|                                                  |             |
|--------------------------------------------------|-------------|
| Portland – Martins Creek 230 kV Terminal Upgrade |             |
|                                                  |             |
| Engineering                                      | \$259,400   |
| Material & Equipment                             | \$428,800   |
| Construction & Testing                           | \$360,700   |
|                                                  |             |
| Total                                            | \$1,048,900 |

[PJM Network Upgrade n0657]

|                                      |          |
|--------------------------------------|----------|
| Atlantic Substation Drop Replacement |          |
|                                      |          |
| Engineering                          | \$23,800 |
| Material & Equipment                 | \$6,100  |
| Construction & Testing               | \$10,000 |
|                                      |          |
| Total                                | \$39,900 |

[PJM Network Upgrade n0657]

|                                      |          |
|--------------------------------------|----------|
| Larrabee Substation Drop Replacement |          |
|                                      |          |
| Engineering                          | \$23,800 |
| Material & Equipment                 | \$6,100  |
| Construction & Testing               | \$10,000 |
|                                      |          |
| Total                                | \$39,900 |

[PJM Network Upgrade n0670]

|                                        |           |
|----------------------------------------|-----------|
| Whippany Substation Replace Breaker JB |           |
|                                        |           |
| Engineering                            | \$123,800 |
| Material & Equipment                   | \$209,900 |
| Construction & Testing                 | \$87,500  |
|                                        |           |
| Total                                  | \$421,200 |

[PJM Network Upgrade n0671]

|                                        |           |
|----------------------------------------|-----------|
| Whippany Substation Replace Breaker QJ |           |
|                                        |           |
| Engineering                            | \$123,800 |
| Material & Equipment                   | \$209,900 |
| Construction & Testing                 | \$87,500  |
|                                        |           |
| Total                                  | \$421,200 |

**Assumptions/Qualifiers**

The accomplishment of the work on the FirstEnergy system to support the costs and schedule is dependent upon the following:

- Obtaining the necessary transmission line outages.
- No equipment delivery, environmental or regulatory delays.
- No permitting or real estate delays.
- No extreme weather.
- No force majeure.
- Schedule assumes contractor availability for helicopter installation of the transmission line conductors.
- Schedule assumes concurrent outage availability for the reconductor of the Atlantic-Larrabee and Whippany-Roseland line work.

## **2.2 Summary Schedule**

Following is the proposed summary schedule based upon the Preliminary Project Schedule provided in Appendix A for the PSE&G projects. The start date indicates when engineering will commence. The finish date indicates when the Facility will be placed back in service after the proposed upgrades are completed.

| <b><u>Facility</u></b>                                                                                                                | <b><u>Start</u></b> | <b><u>Finish</u></b> |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|
| Sewaren – Woodbridge 138 kV O-1315” Circuit Re-Conductor and Terminal Upgrade                                                         | June 2009           | February 2011        |
| Roseland 230 kV Terminal Upgrade                                                                                                      | January 2010        | May 2010             |
| Bergen 230 kV Underground line and Terminal Upgrades                                                                                  | April 2009          | May 2012             |
| Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade | June 2009           | April 2012           |
| Bergen 12H Breaker Replacement                                                                                                        | January 2011        | October 2011         |
| Athenia 21H, 11H, 51H, 2BH Breaker Replacement                                                                                        | October 2010        | December 2011        |

The following assumptions were used in developing the facility schedules.

- Start and finish dates are for duration identification only. Actual start dates will commence 60 to 90 days after execution of ISA/CSA.
- Equipment and material lead times are typical for normal (non-expedited) procurements.
- Typical system outage windows are from mid-September to mid-May.
- Facility start dates reflect an estimate for when engineering must commence in order for a desired outage window to be utilized.
- Major schedule impacts and considerations which could delay the upgrade of this facility include the following:
  - Permitting and licensing activities.
  - Construction outage requirements.

### **3.0 FACILITY STUDY RESULTS**

The Facility Study Results are divided into sections for each of the defined major projects to be constructed by PSE&G. Each section is organized into the following general outline.

1. Purpose and Necessity
2. General Description
3. Design Requirements
4. Major Materials
5. Cost Estimate
6. Preliminary Schedule

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### **3.1 Sewaren – Woodbridge 138 kV O-1315 Circuit Re-Conductor and Terminal Upgrade (Upgrade n0629)**

#### **3.1.1 Purpose and Necessity**

The solution to alleviate the overload on the Sewaren-Woodbridge O-1315 138 kV circuit is to re-conductor the circuit. A summer normal continuous rating of 400 MVA is required with a four hour summer emergency rating of 488 MVA.

The existing 138 kV O-1315 transmission circuit consists of a single 795 KCMIL ACSR conductor per phase.

The upgrades will include replacing the existing conductor with a single 1590 KCMIL ACSS conductor per phase.

The terminal equipment at Woodbridge includes single 1590 ACSR conductor per phase and one 138 kV 2000 A continuous circuit switcher. PSE&G has a four hour summer emergency rating of 2063 A for the 1590 ACSR and 2189 A for the circuit switcher. The four hour summer emergency rating required is 2042 A; therefore, no terminal upgrade is required at the Woodbridge Substation.

The terminal equipment at Sewaren includes a wave trap and a line disconnect switch rated 1200 A. The wave trap and disconnect switch will be replaced with equipment rated 3000 A continuous. The new jumper conductors to the wave trap will be two 1590 MCM ACSR per phase; the existing 3 1/2 inch aluminum bus is acceptable.

No other taps of the O-1315 line exist between Sewaren Station and Woodbridge Station.

#### **3.1.2 General Description**

Install new line conductor, OPGW, structures, and hardware for single 1590 KCMIL 54/19 ACSS “Falcon” conductor per phase along the O-1315 circuit from Sewaren Station to Woodbridge Station.

Install a new 3000 A wave trap and double end break disconnect switch in the O-1315 line terminal at the Sewaren station

#### **General Description of Proposed Route**

The portion of the O-1315 circuit proposed for upgrade traverses along the existing Sewaren-Brunswick transmission line corridor from Sewaren Station to the Woodbridge Station. Both of the stations and the route are located in Middlesex County, Township of Woodbridge, New Jersey.

Along the existing route multiple road, railroad and state highway crossings are encountered. The areas surrounding the line would be classified as heavy urban and commercial development.

The terminal points for the upgraded circuit are at the existing Sewaren Station and the existing Woodbridge Station.

The upgraded circuit length is approximately 3.3 miles.

The existing circuit is located on a double circuit 138 kV line supported by lattice steel towers. Several spans along the route also support low voltage underbuild.

### **3.1.3 Design Requirements**

The following are specific facility design requirements for the Sewaren-Woodbridge line; other general design requirements are included in section 1.3 General Design Criteria.

- Phase conductor: Single 1590 KCMIL 54/19 ACSS Falcon  
Emergency operating temperature – 200°C (392°F)
- All electrical clearances are based on a 138 kV voltage level.

### **3.1.4 Major Materials**

#### **O-1315 Line**

| <u>Item</u>                                     | <u>Description</u>                                                                                                          | <u>Quantity</u> |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------|
| New Steel Structures and Associated Foundations | Self supported, painted steel poles. Double circuit deadends and tangent type poles ranging from 125 to 175 feet in height. | 8               |
| Minor Steel Modifications                       | Modifications to existing lattice steel towers.                                                                             | 5               |
| Average Steel Modifications                     | Modifications to existing lattice steel towers.                                                                             | 4               |
| Major Steel Modifications                       | Modifications to existing lattice steel towers.                                                                             | 3               |
| 138 kV Line Conductor                           | Single 1590 ACSS Falcon per phase (circuit feet).                                                                           | 18,500          |

| <u>Item</u>                          | <u>Description</u>                                                                         | <u>Quantity</u> |
|--------------------------------------|--------------------------------------------------------------------------------------------|-----------------|
| 138 kV Suspension Insulator Assembly | Suspension insulator assembly, toughened glass, including hardware and fittings.           | 93              |
| 138 kV Deadend Insulator Assembly    | Deadend insulator assembly, toughened glass, including hardware and fittings.              | 90              |
| OPGW                                 | 24 Fiber DNO-6967 (feet).                                                                  | 38,800          |
| OPGW Suspension Assembly             | AFL Hardware, per PSE&G standards                                                          | 11              |
| OPGW Deadend Assembly                | AFL Hardware, per PSE&G standards                                                          | 22              |
| 26 kV Line Conductor                 | Single 795 ACSR Condor per phase (feet)                                                    | 4,500           |
| 26 kV Deadend Insulator              | Deadend insulator, porcelain, transmission line assembly, including hardware and fittings. | 48              |

#### **Sewaren Station**

| <u>Item</u>       | <u>Description</u>                                                                | <u>Quantity</u> |
|-------------------|-----------------------------------------------------------------------------------|-----------------|
| Disconnect Switch | Manually operated 138 kV disconnect switch, 3000 A, three phase, double end break | 1               |
| Ground Switch     | Manually operated 138 kV ground switch, three phase                               | 1               |
| Wave Trap         | Wave trap, 3000 A, horizontal mount                                               | 1               |

### **3.1.5 Cost Estimate**

The Sewaren – Woodbridge 138 kV O-1315 Circuit Re-Conductor costs are estimated as follows:

|                               |                     |
|-------------------------------|---------------------|
| Engineering                   | \$ 708,000          |
| Equipment and Materials       |                     |
| Steel Structures & Assemblies | \$ 4,016,000        |
| Conductor                     | \$ 299,000          |
| OPGW                          | \$ 213,000          |
| Construction Management       | \$ 208,000          |
| <u>Construction</u>           | <u>\$ 4,103,000</u> |
| Subtotal                      | \$ 9,547,000        |

The Sewaren – Woodbridge 138 kV O-1315 PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 668,000        |
| Engineering                                      | \$ 212,000        |
| Construction Support                             | \$ 229,000        |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 0              |
| Environmental & Resource Recovery                | \$ 10,000         |
| Licensing & Permitting                           | \$ 900,000        |
| <u>Corporate Properties</u>                      | <u>\$ 200,000</u> |
| Subtotal                                         | \$ 2,219,000      |

**Total cost for the Sewaren – Woodbridge O-1315 Re-Conductor      \$ 11,766,000**

The Sewaren line terminal upgrade costs are estimated as follows:

|                         |                  |
|-------------------------|------------------|
| Engineering             | \$ 20,000        |
| Equipment and Materials |                  |
| Steel Structure         | \$ 1,000         |
| Switchyard Buswork      | \$ 1,000         |
| Disconnect Switches     | \$ 20,000        |
| Wave Trap               | \$ 30,000        |
| Construction Management | \$ 10,000        |
| <u>Construction</u>     | <u>\$ 60,000</u> |
| Subtotal                | \$ 142,000       |

The Sewaren line terminal PSE&G costs are estimated as follows:

|                                                  |             |
|--------------------------------------------------|-------------|
| Program Management                               | \$ 10,000   |
| Engineering                                      | \$ 6,000    |
| Construction Support                             | \$ 11,000   |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 15,000   |
| Environmental & Resource Recovery                | \$ 10,000   |
| Licensing & Permitting                           | \$ 0        |
| <u>Corporate Properties</u>                      | <u>\$ 0</u> |
| Subtotal                                         | \$ 52,000   |

**Total cost for the Sewaren Line Terminal Upgrade      \$ 194,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

Sewaren – Woodbridge Line

- Existing tower 3/6 requires replacement. Telecommunication cellular antennas are located on this tower. No allowances are included in the estimate for the removal, modification, relocation or replacement of the equipment.

Sewaren Switching Station

- Minor steel modifications will be required, but the existing steel structure is adequate for the new switch.
- No control and relaying upgrades have been included.

**3.1.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.

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## **3.2 Roseland 230 kV Terminal Upgrade (Upgrade n0645.2)**

### **3.2.1 Purpose and Necessity**

Recommended solution to alleviate the overload of the Roseland terminal of the Whippany-Roseland 230 kV line is to upgrade the terminal. The terminal upgrade requires that the summer normal continuous rating of 995 MVA and a summer four-hour emergency rating of 1233 MVA.

### **3.2.2 General Description**

The existing terminal includes the following equipment: a 3000 A metering transformer, a 3000 A wave trap, and a 2500 A rated disconnect switch; buswork includes two 1590 ACSR conductors per phase, two 1000 MCM copper per phase, and 3 inch copper tubing.

The metering transformer is rated by PSE&G for 1367 for summer normal continuous and 1730 MVA for a four-hour summer emergency; therefore no upgrade is required.

The wave trap is rated by PSE&G for 1221 for summer normal continuous and 1387 MVA for a four-hour summer emergency; therefore no upgrade is required.

The 2500 A disconnect switch is rated by PSE&G for 1076 MVA for summer normal continuous and 1298 for a four-hour summer emergency; therefore no upgrade is required.

The 1000 MCM copper conductor is rated by PSE&G for 1055 A summer normal, and 1375 A four-hour summer emergency per conductor. The summer normal required rating is 2498 A. The upgrade requires that the 1000 MCM copper be replaced with two 1590 ACSR per phase.

No other equipment is required to be upgraded.

### **3.2.3 Design Requirements**

The following are specific facility design requirements for the Whippany-Roseland 230 kV line terminal upgrades; other general design requirements are included in section 1.3 General Design Criteria.

- None

### **3.2.4 Major Materials**

#### **Roseland Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 80              |

### **3.2.5 Cost Estimate**

The Whippany-Roseland 230 kV line terminal costs are estimated as follows:

|                                               |                  |
|-----------------------------------------------|------------------|
| Engineering                                   | \$ 10,000        |
| Equipment and Materials<br>Switchyard Buswork | \$ 2,000         |
| Construction Management                       | \$ 13,000        |
| <u>Construction</u>                           | <u>\$ 15,000</u> |
| Subtotal                                      | \$ 40,000        |

The Whippany-Roseland 230 kV PSE&G costs are estimated as follows:

|                                                  |             |
|--------------------------------------------------|-------------|
| Program Management                               | \$ 3,000    |
| Engineering                                      | \$ 3,000    |
| Construction Support                             | \$ 14,000   |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 10,000   |
| Environmental & Resource Recovery                | \$ 0        |
| Licensing & Permitting                           | \$ 50,000   |
| <u>Corporate Properties</u>                      | <u>\$ 0</u> |
| Subtotal                                         | \$ 80,000   |

**Total cost for the Whippany-Roseland 230 kV line terminal     \$ 120,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Transmission Line and Whippany terminal upgrades are to be done by others and are not within the scope of this Facilities Study.
- No control and relaying upgrades have been included.

### **3.2.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Construction outage required on the Roseland – Whippany line.

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### **3.3 Athenia - Bergen 230 kV Underground line and Terminal Upgrades**

#### **3.3.1 Purpose and Necessity**

The recommended solution to alleviate the overloads of the Athenia-Saddle Brook, Saddle Brook-Maywood, Maywood-New Milford and New Milford-Leonia 230 kV lines is to build a new 230 kV underground cable circuit from Athenia to Bergen. The Athenia and Bergen stations will also need to be upgraded to accommodate the new circuit.

#### **3.3.2 General Description**

The Athenia to Bergen underground circuit will consist of a new pipe-type high pressure fluid filled (HPFF) cable system. The new line will have a summer normal continuous rating of 305 MVA and a summer four-hour emergency rating of 524 MVA.

The pipe-type cable system will consist of three single core laminated paper-polypropylene (LPP) insulated cables installed in a coated steel pipe. The pipe is pressurized with dielectric fluid (alkyl benzene/polybutene mixture) to a nominal pressure of 200 pounds per square inch (psi). The pressurized dielectric fluid prevents ionization in the insulation and prevents moisture ingress if the pipe is breached.

The pipe is typically installed in a single open trench, approximately 4 to 5 feet deep, and backfilled with either soil or a specially designed thermal backfill. Certain obstructions, such as water or railroad crossings will require the pipe to be installed by trenchless installation methods, such as auger boring (jack and bore) or horizontal directional drilling (HDD). These methods allow the pipes to be installed without disturbing the surface.

230 kV HPFF cable can be transported in reels up to approximately 3,300 feet. These reels would be 12 feet high, 8 feet wide and weigh approximately 40,000 lbs. Larger reels can be obtained, but will require special transportation arrangements. Due to the reel length limitations and allowable cable tension and sidewall pressure, individual cable lengths will need to be spliced together. Cable splicing requires a clean, dry area. This is usually accomplished by installing an underground splicing vault. These vaults are large (18'x8'x8') concrete structures buried completely underground with manhole covers for access.

At Athenia a new 230 kV line terminal will be required. The upgrade will include new equipment and bus support structures, one (1) circuit breaker, two (2) disconnect switches, three (3) CCVTs, three (3) surge arrestors, bus, jumpers, and all foundations, grounding, raceway, control cable, and control and relaying equipment necessary for a complete installation.

At Bergen, two new 230 kV line terminals will be required; one for the new O-66 underground circuit, and one for the AC connection to the Hudson Transmission Partners HVDC facility. The upgrade will include new equipment and bus support structures, three (3) circuit breakers, eight (8) disconnect switches, twelve (12) CCVTs, six (6) surge arrestors, bus, jumpers, equipment support structures, and all foundations, grounding,

raceway, control cable, and control and relaying equipment necessary for a complete installation.

### **3.3.3 Design Requirements**

The following are specific facility design requirements for the O-66 line and terminal upgrades; other general design requirements are included in section 1.4 General Design Criteria.

### **Underground Circuit Requirements**

The following electrical requirements apply to the entire cable system.

- o Number of Circuits: 1
- o Rated Voltage: 230 kV
- o BIL: 1050 kV
- o Daily Load Factor: 100%
- o Peak Normal Load at DLF: 305 MVA
- o Emergency Maximum Duration: 4 Hours
- o Emergency Maximum Load: 524 MVA

### **Routing**

The routing for the transmission line has not yet been set. Based on maps, overhead images and existing transmission line routing, three preliminary routes have been selected for estimating purposes only.

### **Communications Requirements**

The following communications installation will be installed in parallel with the cable circuit.

- o Two (2) 48-fiber single-mode loose buffer tube cables
- o Two (2) 5-inch Sch. 40 PVC conduits
- o Three (3) 1-1/4-inch HPDE innerducts per 5-inch conduit

### **Temperature Monitoring Requirements**

No temperature monitoring equipment has been included for the circuit.

### **Trenched Installation**

The pipelines will be installed by trenching where possible. The trenching installation will meet the following requirements.

- o Pipeline Minimum Cover: 36 inches
- o Number of pipes: 1
- o Pipeline: 8 inch steel, 0.250 inch wall thickness
- o Pipe Coating: 60/10 Pritec
- o Typical Trench Width: 3.0 feet

- o Corrective Backfill Height: Entire trench, up to 18” below grade

### **Auger Bored Installation**

Where the route encounters obstacles that can not be crossed by normal trenching, such as railroads or major roads, the pipeline will be installed by auger boring. Auger boring is carried out by digging an entry pit on one side of the obstacle, then advancing a steel casing to a receiving pit on the other side. An auger removes the spoils from inside the casing. After the casing is in place, the pipeline and communications ducts are slid through the casing on spacers. The pipeline and ducts used are the same as for the trenched installation. The annular space between the pipeline and the casing is filled with a thermal grout.

The auger bored installation will meet the following requirements:

- o Number of Casings: 1
- o Size of Casings: 36”
- o Pipes per casing: one 8-inch steel and two 5-inch PVC

### **HDD Installation**

When the obstacle to be crossed is wider than an auger boring can accomplish, approximately 300 feet, horizontal directional drilling (HDD) will be used to drill under the obstacle. HDD is accomplished by using a steerable hydraulic drill rig on the surface to drill a pilot hole from one side of the obstacle to the other. The pipelines will be pulled, along with communications conduits, directly into the borehole.

The HDD installation will meet the following requirements:

- o Number of Boreholes: 1
- o Cable pipes per borehole: one 8-inch, 0.375 inch wall steel
- o Communications ducts per borehole: one 5 inch I.D. HDPE

### **Splicing Vaults**

Underground splicing vaults will be installed to allow for cable splicing. The splicing vaults will be a double circuit design and meet the following requirements.

- o Minimum Length: 18’
- o Minimum Height: 8’
- o Minimum Width: 8’
- o Access: Two (2) 36” manholes with 30” lids
- o Traffic Loading: HS-25

### **Cathodic Protection Requirements**

The steel pipes will require a cathodic protection system to prevent corrosion of the pipes. The cathodic protection system will be designed taking into account the length of the pipe lines, soil conditions, and nearby utilities that may have their own cathodic protection systems. At a minimum the cathodic protections system will include impressed current

rectifiers, AC/DC blocking devices, anode beds (deep well or shallow subsurface), and test stations.

### **Dielectric Fluid Pressurization Plants**

Due to the length of the line, a dielectric fluid pressurization plant will be required at each substation. The pressurization plants regulate the pressure on the pipelines, absorbing fluid as the cable system heats and releasing fluid when it cools. The pressurization plants will be designed to oscillate or circulate the fluid in the pipelines, reducing the impact due to hot spots. The pressurization plants will include alarmed system operation, and chart recorders or data logging.

### **3.3.4 Major Materials**

#### **HPFF Underground O-66 Line**

| <u>Item</u>               | <u>Description</u>                                                                 | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|---------------------------|------------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Route Length              | Substation to Substation (miles)                                                   | 9.7                                 | 10.7                                   | 11.1                                   | 9.7                                                        |
| 230 kV Cable              | 230 kV, 3500 kcmil copper, 500 mil LPP insulated HPFF cable (feet)                 | 157,054                             | 171,768                                | 177,438                                | 157,054                                                    |
| Spare Cable               | 230 kV, 3000 kcmil copper, 500 mil LPP insulated HPFF cable (feet)                 | 3,200                               | 3,200                                  | 3,200                                  | 3,200                                                      |
| 230 kV Cable Splices      | 230 kV, 3-phase joint kit (each)                                                   | 21                                  | 23                                     | 24                                     | 21                                                         |
| 230 kV Semi-Stop Splice   | 230 kV, 3-phase, semi-stop joint (each)                                            | 6                                   | 6                                      | 6                                      | 6                                                          |
| 230 kV Cable Terminations | 230 kV, single phase porcelain insulator terminations (each)                       | 6                                   | 6                                      | 6                                      | 6                                                          |
| Fiber-Optic Cable         | 48 single-mode fiber optic cable, loose tube (feet)                                | 106,682                             | 116,612                                | 120,452                                | 106,682                                                    |
| Pipe for Cable            | 8-inch ASTM 523 ERW steel pipe, 0.250" wall thickness, 60/10 Pritec Coating (feet) | 42,691                              | 47,556                                 | 49,426                                 | 42,691                                                     |

| <u>Item</u>               | <u>Description</u>                                                                             | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|---------------------------|------------------------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Pipe for fluid return     | 5-inch ASTM 523 ERW steel pipe, 0.250" wall thickness, 60/10 Pritec Coating (feet)             | 0                                   | 0                                      | 0                                      | 42,691                                                     |
| Ducts for F-O cable       | 5-inch Sch. 40 PVC conduit (feet)                                                              | 83,902                              | 95,112                                 | 98,852                                 | 83,902                                                     |
| Innerduct for F-O cable   | 1 1/4" HDPE Innerducts (feet)                                                                  | 305,707                             | 339,336                                | 350,556                                | 305,707                                                    |
| Flowable Thermal Backfill | Low strength, high slump concrete slurry with a low thermal resistivity (cubic yards)          | 39,621                              | 44,215                                 | 45,981                                 | 46,224                                                     |
| Splicing Vaults           | 18'x8'x8' pre-cast concrete vaults (each)                                                      | 29                                  | 31                                     | 32                                     | 29                                                         |
| Casing for Auger Boring   | 36-inch O.D. steel casing (feet)                                                               | 740                                 | 740                                    | 740                                    | 740                                                        |
| Flowable Fill for Boring  | Low strength, low thermal resistivity grout (cubic yards)                                      | 178                                 | 178                                    | 178                                    | 178                                                        |
| HDD Cable Pipe            | 8-inch ASTM 523 ERW steel pipe, 0.375" wall thickness, abrasion resistant epoxy coating (feet) | 9,000                               | 9,000                                  | 9,000                                  | 9,000                                                      |
| HDD F-O cable Ducts       | 6-inch SDR 11 HDPE pipe (feet)                                                                 | 18,000                              | 18,000                                 | 18,000                                 | 18,000                                                     |
| Splicing Trifurcator      | Cable pipe to riser pipe transition, pull-through (each)                                       | 2                                   | 2                                      | 2                                      | 2                                                          |
| Riser Pipe for Cable      | 4-inch stainless steel pipe (feet)                                                             | 900                                 | 900                                    | 900                                    | 900                                                        |
| Dielectric Fluid          | Alkyl Benzene/Polybutene Mixture (DCL 100) (gallons)                                           | 110,089                             | 117,627                                | 120,524                                | 168,087                                                    |

| <u>Item</u>                | <u>Description</u>                                                            | <u>Prop.<br/>Route<br/>Quantity</u> | <u>Route<br/>Option 1<br/>Quantity</u> | <u>Route<br/>Option 2<br/>Quantity</u> | <u>Prop.<br/>Route<br/>w/Fluid<br/>Return<br/>Quantity</u> |
|----------------------------|-------------------------------------------------------------------------------|-------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------|
| Pressurization Plant       | Dielectric fluid pressurization and pumping plant, 20,000 gal capacity (each) | 2                                   | 2                                      | 2                                      | 2                                                          |
| Fluid Piping               | 2" coated steel piping (feet)                                                 | 800                                 | 800                                    | 800                                    | 800                                                        |
| Cathodic Protection System | Impressed current cathodic protection system (lot)                            | 1                                   | 1                                      | 1                                      | 1                                                          |

### **Athenia Switching Station**

| <u>Item</u>             | <u>Description</u>                                                                                             | <u>Quantity</u> |
|-------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus               | Aluminum bus, 6063-T6 alloy, 4" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 150             |
| Jumper Conductor        | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 350             |
| High Strength Insulator | Station post insulator, porcelain for disconnect switch and bus supports.                                      | 24              |
| Circuit Breaker         | 230 kV SF6 gas insulated circuit breaker, 63 kA, 3000 A                                                        | 1               |
| Disconnect Switch       | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 2               |
| Ground Switch           | Manually operated 230 kV ground switch, three phase                                                            | 1               |
| Disconnect Switch Stand | High bus height, three phase, four vertical support columns.                                                   | 1               |
| Disconnect Switch Stand | Low bus height, three phase, four vertical support columns.                                                    | 1               |
| Bus Support Low-3P      | Bus insulator support stand, low bus, three-phase, one insulator per phase                                     | 1               |

| <u>Item</u>                    | <u>Description</u>                                                                                                                                                                                                                                       | <u>Quantity</u> |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Bus Support High-3P            | Bus insulator support stand, high bus, three-phase, one insulator per phase                                                                                                                                                                              | 1               |
| UG Line Termination Support-3P | UG Line termination support stand, low bus, three-phase                                                                                                                                                                                                  | 1               |
| CCVT                           | Coupling capacitor voltage transformers, three windings                                                                                                                                                                                                  | 3               |
| CCVT Stand                     | Single-phase, 8'-6" safety clearance                                                                                                                                                                                                                     | 3               |
| Surge Arrester                 | Surge Arrester                                                                                                                                                                                                                                           | 3               |
| Surge Arrester Stand           | Single-phase, 8'-6" safety clearance                                                                                                                                                                                                                     | 3               |
| Foundations                    | Spread footing type foundations                                                                                                                                                                                                                          | Lot             |
| Grounding Grid                 | 350 MCM BTN Copper                                                                                                                                                                                                                                       | Lot             |
| Control and Relaying           | PSE&G Standard control and relaying racks to include the following racks: <ul style="list-style-type: none"> <li>• Primary line relaying</li> <li>• Backup line relaying</li> <li>• Line instrumentation</li> <li>• Line fiber communications</li> </ul> | Lot             |
| Key Interlocks                 | Key interlock system for isolation switches and grounding switches.                                                                                                                                                                                      | Lot             |
| Station Lighting               | Up-down lighting fixtures with ballasts and photocell for operations and maintenance. Lighting junction boxes to include AC outlet and switch.                                                                                                           | 2               |

**Bergen Switching Station**

| <u>Item</u>                    | <u>Description</u>                                                                                             | <u>Quantity</u> |
|--------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus                      | Aluminum bus, 6063-T6 alloy, 4" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 1000            |
| Jumper Conductor               | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 700             |
| High Strength Insulator        | Station post insulator, porcelain for disconnect switch and bus supports.                                      | 102             |
| Circuit Breaker                | 230 kV SF6 gas insulated circuit breaker, 63 kA, 3000 A                                                        | 3               |
| Disconnect Switch              | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 8               |
| Ground Switch                  | Manually operated 230 kV ground switch, three phase                                                            | 2               |
| Disconnect Switch Stand        | High bus height, three phase, four vertical support columns.                                                   | 2               |
| Disconnect Switch Stand        | Low bus height, three phase, four vertical support columns.                                                    | 6               |
| Bus Support Low-1P             | Bus insulator support stand, low bus, single-phase, one insulator per phase                                    | 12              |
| Bus Support High-3P            | Bus insulator support stand, high bus, single-phase, one insulator per phase                                   | 2               |
| UG Line Termination Support-3P | UG Line termination support stand, low bus, three-phase                                                        | 2               |
| CCVT                           | Coupling capacitor voltage transformers, three windings                                                        | 12              |
| CCVT Stand                     | Single-phase, 8'-6" safety clearance.                                                                          | 12              |
| Surge Arrester                 | Surge Arrester                                                                                                 | 6               |
| Surge Arrester Stand           | Single-phase, 8'-6" safety clearance.                                                                          | 6               |

| <u>Item</u>          | <u>Description</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <u>Quantity</u> |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Foundations          | Spread footing type foundations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lot             |
| Grounding Grid       | 350 MCM BTN Copper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lot             |
| Control and Relaying | PSE&G Standard control and relaying racks to include the following racks: <ul style="list-style-type: none"> <li>• Line 1 Primary line relaying</li> <li>• Line 1 Backup line relaying</li> <li>• Line 1 instrumentation</li> <li>• Line 1 fiber communications</li> <li>• Line 2 Primary line relaying</li> <li>• Line 2 Backup line relaying</li> <li>• Line 2 instrumentation</li> <li>• Line 2 fiber communications</li> <li>• Breaker 1 primary relaying</li> <li>• Breaker 1 backup relaying</li> <li>• Breaker 1 instrumentation</li> <li>• Breaker 2 primary relaying</li> <li>• Breaker 2 backup relaying</li> <li>• Breaker 2 instrumentation</li> </ul> | Lot             |
| Station Lighting     | Up-down lighting fixtures with ballasts and photocell for operations and maintenance. Lighting junction boxes to include AC outlet and switch.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 12              |
| Pole #2/1            | Transmission pole to be relocated                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1               |

(The remainder of this page is intentionally left blank.)

### **3.3.5 Cost Estimate**

The O-66 Line costs are estimated as follows:

| <u>Item</u>             | <u>Proposed</u><br><u>Route Cost</u> | <u>Route</u><br><u>Option 1 Cost</u> | <u>Route</u><br><u>Option 2 Cost</u> | <u>Prop. w/ Fluid</u><br><u>Return Cost</u> |
|-------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------------------------------------------|
| Engineering             | \$1,750,000                          | \$1,750,000                          | \$1,750,000                          | \$1,750,000                                 |
| Equipment and Materials |                                      |                                      |                                      |                                             |
| Cable & Accessories     | \$16,325,000                         | \$17,736,000                         | \$18,286,000                         | \$16,325,000                                |
| Pipeline                | \$5,379,000                          | \$5,669,000                          | \$5,781,000                          | \$6,995,000                                 |
| Cathodic Prot. System   | \$88,000                             | \$90,000                             | \$92,000                             | \$88,000                                    |
| Parallel F-O Cable      | \$405,000                            | \$441,000                            | \$455,000                            | \$405,000                                   |
| Splicing Vaults         | \$1,094,000                          | \$1,165,000                          | \$1,201,000                          | \$1,094,000                                 |
| Trenching & Backfill    | \$9,004,000                          | \$10,048,000                         | \$10,449,000                         | \$9,862,000                                 |
| HDD Materials           | \$1,114,000                          | \$1,114,000                          | \$1,114,000                          | \$1,481,000                                 |
| Jack & Bore Materials   | \$201,000                            | \$201,000                            | \$201,000                            | \$201,000                                   |
| Construction Management | \$2,340,000                          | \$2,340,000                          | \$2,340,000                          | \$2,580,000                                 |
| Construction            |                                      |                                      |                                      |                                             |
| Cable & Accessories     | \$6,044,000                          | \$6,505,000                          | \$6,706,000                          | \$6,044,000                                 |
| Pipeline                | \$5,632,000                          | \$6,061,000                          | \$6,228,000                          | \$7,840,000                                 |
| Cathodic Prot. System   | \$109,000                            | \$112,000                            | \$114,000                            | \$109,000                                   |
| Parallel F-O Cable      | \$529,000                            | \$575,000                            | \$593,000                            | \$529,000                                   |
| Splicing Vaults         | \$984,000                            | \$1,016,000                          | \$1,048,000                          | \$984,000                                   |
| Trenching & Backfill    | \$17,744,000                         | \$20,021,000                         | \$20,796,000                         | \$19,244,000                                |
| HDD Installation        | \$6,089,000                          | \$6,089,000                          | \$6,089,000                          | \$6,555,000                                 |
| Jack & Bore Install     | \$594,000                            | \$594,000                            | \$594,000                            | \$594,000                                   |
| Subtotal                | \$75,425,000                         | \$81,527,000                         | \$83,837,000                         | \$82,680,000                                |

The O-66 Line PSE&G costs are estimated as follows:

|                                                          |                          |
|----------------------------------------------------------|--------------------------|
| Program Management                                       | \$ 3,771,000             |
| Engineering                                              | \$ 525,000               |
| Construction Support                                     | \$ 566,000               |
| Relaying, Mechanics, Lab, &<br>System Protection         | \$ 0                     |
| Environmental & Resource Recovery                        | \$ 3,950,000             |
| Licensing & Permitting                                   | \$ 3,500,000             |
| <u>Corporate Properties</u>                              | <u>\$ 5,000,000</u>      |
| Subtotal                                                 | \$ 17,312,000            |
| <br><b>Total cost for the O-66 Line (Proposed Route)</b> | <br><b>\$ 92,737,000</b> |

The Athenia Facility costs are estimated as follows:

|                                                            |                     |
|------------------------------------------------------------|---------------------|
| Engineering                                                | \$ 130,000          |
| Equipment and Materials                                    |                     |
| Site Work                                                  | \$ 5,000            |
| Concrete                                                   | \$ 65,000           |
| Lighting                                                   | \$ 10,000           |
| Steel Structure                                            | \$ 59,000           |
| Raceway                                                    | \$ 3,000            |
| Grounding                                                  | \$ 10,000           |
| Conductor                                                  | \$ 34,000           |
| Switchyard Buswork                                         | \$ 21,000           |
| Circuit Breakers                                           | \$ 151,000          |
| CCVTs                                                      | \$ 30,000           |
| Disconnect Switches                                        | \$ 40,000           |
| Surge Arresters                                            | \$ 15,000           |
| Control and Relaying                                       | \$ 97,000           |
| Construction Management                                    | \$ 33,000           |
| <u>Construction</u>                                        | <u>\$ 514,000</u>   |
| Subtotal                                                   | \$ 1,217,000        |
| The Athenia Facility PSE&G costs are estimated as follows: |                     |
| Program Management                                         | \$ 85,000           |
| Engineering                                                | \$ 39,000           |
| Construction Support                                       | \$ 36,000           |
| Relaying, Mechanics, Lab, &<br>System Protection           | \$ 60,000           |
| Environmental & Resource Recovery                          | \$ 250,000          |
| Licensing & Permitting                                     | \$ 200,000          |
| <u>Corporate Properties</u>                                | <u>\$ 0</u>         |
| Subtotal                                                   | \$ 670,000          |
| <b>Total cost for the Athenia Facility</b>                 | <b>\$ 1,887,000</b> |

The Bergen Facility costs are estimated as follows:

|                         |                     |
|-------------------------|---------------------|
| Engineering             | \$ 691,000          |
| Equipment and Materials |                     |
| Site Work               | \$ 69,000           |
| Concrete                | \$ 364,000          |
| Lighting                | \$ 60,000           |
| Steel Structure         | \$ 966,000          |
| Raceway                 | \$ 83,000           |
| Grounding               | \$ 111,000          |
| Conductor               | \$ 323,000          |
| Switchyard Buswork      | \$ 269,000          |
| Circuit Breakers        | \$ 455,000          |
| CCVTs                   | \$ 120,000          |
| Disconnect Switches     | \$ 160,000          |
| Surge Arresters         | \$ 30,000           |
| Control and Relaying    | \$ 440,000          |
| Construction Management | \$ 404,000          |
| <u>Construction</u>     | <u>\$ 4,785,000</u> |
| Subtotal                | \$ 9,330,000        |

The Bergen Facility PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 653,000        |
| Engineering                                      | \$ 207,000        |
| Construction Support                             | \$ 444,000        |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 60,000         |
| Environmental & Resource Recovery                | \$ 0              |
| Licensing & Permitting                           | \$ 1,500,000      |
| <u>Corporate Properties</u>                      | <u>\$ 100,000</u> |
| Subtotal                                         | \$ 2,964,000      |

**Total cost for Bergen Facility \$ 12,294,000**

Facility unique assumptions for the cost estimates include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimates.

#### O-66 Underground Line

- The estimate is based upon a single circuit 230 kV HPFF installation with (2) 3000 kcmil cables per phase.
- The conductor sizing calculations are based on conservative installation conditions and soils data from PSE&G records.
- The estimate includes 3,200 feet of spare cable.
- The number of splices is based on a 2000' average spacing between splices.
- The splicing trifurcators are located in splicing vaults near the terminations. Trifurcators are installed as pull-through, with provisions for future splicing.
- The estimate includes 4" stainless steel riser pipe for 150' feet from trifurcator to termination.
- Two 20,000 gal fluid pressurization plants have been assumed.
- A separate impressed current cathodic protection system for each pipeline has been assumed.
- Two separate fiber-optic communications installations have been assumed.
- Fiber-optic cables are assumed to be 48 fiber, single mode outdoor cable.
- Separate pull/splicing boxes are included for the fiber-optic cable.
- Temperature monitoring has not been included in the estimate.
- Four 3-phase substation termination structures are included.
- It is assumed that all trenching will be in city streets.
- Traffic control for city streets has been included in the estimated costs.
- Soil erosion and sediment control measures for city streets has been included in the estimated costs.
- It is assumed that the minimum trench dimensions are 4.5' wide and 10' deep, based on a 2' pipeline separation.
- It is assumed that trenches will be backfilled with thermal slurry or flowable thermal backfill to 1'-6" below grade.
- It is assumed that the top 1'-6" of the trench will be pavement over compacted gravel.
- Paving removal and replacement has been included at an estimated width of 11' for 100% of the route.
- Seeding, sodding, and landscaping are not included in the estimate.
- It is assumed that dewatering will be required for approximately 50% of the route.
- It is assumed that sheeting and shoring will be required for approximately 50% of the route.
- It is assumed that the HDD crossings will consist of two separate bundles, in separate boreholes. Each borehole contains one cable pipe and one communications duct.
- It is assumed that the HDD installation does not include a casing or carrier pipe.
- It is assumed that the HDD installation does not include grouting of the bore hole.

- The estimate includes Jack & Bore crossings consisting of two separate 36" steel casing with flowable fill. Each casing contains one cable pipe and one communications duct.
- It is assumed that the annular space between pipeline, duct, and casing will be filled with flowable thermal fill or grout.
- The estimate includes approximate costs for surveying and soils exploration, based on the route length.
- Two circuits are required to accommodate the required loading; it is assumed that the two circuits are within 12 feet of each other in the same street or right-of-way.
- Final circuit routing is required to finalize the detailed estimate.
- The acquisition of land rights for the 230 kV pipe type cables between Bergen Switching Station and Athenia Switching Station requires the acquisition of land rights from a variety of land owners. The timeframe to acquire the rights depends on whether the landowners are willing to accept directional drilling as the installation method.

#### Bergen

- Steel pipe pile supported spread footing foundations shall be utilized at Bergen switching station due to the existing soil conditions.
- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.
- Foundations for future bus tie breaker locations at Bergen will be installed as part of this project because pile type foundations will be required and access will be limited to those areas once the new bus and equipment is erected.
- Modifications to the existing Bergen ground grid were not included as part of the scope of this Facilities Study. New ground grid and stingers will be added in the expansion area and connected to the existing grounding system.
- At Bergen, a pole relocation is required prior to construction of the new terminals, these costs are included in the Bergen estimate.
- At Bergen, 14,900 cubic yards of fill is required to facilitate the station expansion. Costs associated with adding fill in a flood plain, such as mitigation at another location, have not been included.

#### Athenia

- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.
- Modifications to the existing Athenia ground grid was not included as part of the scope of this Facilities Study. New ground stingers will be connected to the existing grounding system and the new equipment.

### **3.3.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Right-of-way acquisition.
- Major equipment lead times including HPFF cable and pipe and oil facilities.
- The feasibility of construction in wetlands, along busy corridors, and road and river crossings.
- Construction outage requirements at the Bergen and Athenia Switching Station.

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**3.4 Hudson 2HC, 2HA, 3HA, 1HB, 4HA, 4HC, 3HB, 3HC, 2HB, 4HB, 1HA, 1HC, Breaker and Disconnect Switch Replacements and Ground Grid Upgrade (Upgrades n0666.1, n0666.2, n0666.3, n0666.4, n0666.5, n0666.6, n0666.7, n0666.8, n0666.9, n0666.10, n0666.11, n0666.12, and n0666.13)**

**3.4.1 Purpose and Necessity**

The Hudson 230 kV Switching Station will be upgraded with equipment rated for a fault current of 80kA.

The existing station consists of breakers, equipment, and bus that do not meet the 80 kV fault current criteria; therefore, a major rebuild of the station is required. All foundations, circuit breakers, disconnect switches, bus, jumpers, bus and equipment supports, raceway, and control cable will be replaced. In addition, a new ground grid rated for the increased fault duty is required.

**3.4.2 General Description**

The new circuit breakers will be ABB breakers, Type PM, rated for 80 kA fault duty and 3000 A continuous operation. The breakers will include capacitors on both the line and bus side to meet the fault duty requirements.

The new disconnect switches will be double end break design rated for 80 kA momentary duty and 3000 A continuous operation.

The new bus will be 5 inch aluminum schedule 80 bus supported by extra high strength insulators rated 900 kV BIL. Bus support spacing, phase spacing, bus fitting arrangements, and additional insulators will be utilized to meet the 80 kA criteria. Equipment jumpers will be two 1590 MCM ACSR conductors per phase for current carrying equipment and one 795 ACSR conductor per phase for non current carrying equipment. All bus and jumpers will be replaced as part of this rebuild.

Existing equipment, jumpers, bus, insulators, and structures will be removed as part of the work. Of the existing structures, only two existing four bay lattice A-frames will remain in service.

New foundations will be required to support the new and relocated structures and equipment. Foundations will be steel pile supported spread footing type foundations.

New grounding, raceway, and control cable will be installed as part of the rebuild.

### **3.4.3 Design Requirements**

The following are specific facility design requirements for the Hudson station; other general design requirements are included in section 1.4 General Design Criteria.

- Steel pipe pile supported spread footing foundations shall be utilized due to the existing soil conditions.
- The ground grid shall be 500 MCM copper BTN because of the 80 kV fault current requirement.

### **3.4.4 Major Materials**

The following major material list was developed for the Hudson Switching Station:

| <u>Item</u>                   | <u>Description</u>                                                                                             | <u>Quantity</u> |
|-------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------|
| Rigid Bus                     | Aluminum bus, 6063-T6 alloy, 5" inch, schedule 80, with 795 kcmil ACSR conductor installed for damping. (feet) | 5200            |
| Jumper Conductor              | 2-1590 kcmil AAC per phase, Falcon (feet).                                                                     | 5600            |
| High Strength Insulator       | Station post insulator, porcelain for disconnect switches.                                                     | 252             |
| Extra High Strength Insulator | Station post insulator, porcelain for rigid bus support.                                                       | 298             |
| Circuit Breaker               | 230 kV SF6 gas insulated circuit breaker, 80 kA, 3000 A, with TRV capacitors on bus and line side bushings     | 14              |
| Disconnect Switch             | Manually operated 230 kV disconnect switch, 3000 A, three phase                                                | 28              |
| Ground Switch                 | Manually operated 230 kV ground switch, three phase                                                            | 12              |
| Circuit Switchers             | 230 kV circuit switchers, with high strength insulators and stands                                             | 4               |
| Disconnect Switch Stand       | Low bus height, three phase, four vertical support columns.                                                    | 24              |
| Disconnect Switch Stand       | High bus height, three phase, four vertical support columns.                                                   | 4               |

| <u>Item</u>                                         | <u>Description</u>                                                                    | <u>Quantity</u> |
|-----------------------------------------------------|---------------------------------------------------------------------------------------|-----------------|
| Bus Support High-1P (with one insulator per phase)  | Bus insulator support stand, high bus, single-phase, one insulator per phase          | 29              |
| Bus Support High-1P (with two insulators per phase) | Bus insulator support stand, high bus, single-phase, two insulators per phase         | 7               |
| Bus Support Low-1P (with one insulator per phase)   | Bus insulator support stand, low bus, single-phase, one insulator per phase           | 43              |
| Bus Support Low-1P (with two insulators per phase)  | Bus insulator support stand, high bus, single-phase, two insulators per structure     | 13              |
| Bus Support High-3P (with one insulator per phase)  | Bus insulator support stand, high bus, three-phase, one insulator per phase           | 4               |
| Bus Support High-3P (with two insulators per phase) | Bus insulator support stand, high bus, three-phase, two insulators per phase          | 13              |
| Bus Support Low-3P (with one insulator per phase)   | Bus insulator support stand, low bus, three-phase, one insulator per phase            | 28              |
| Bus Support High-2P (with one insulator per phase)  | Bus insulator support stand, high bus, three-phase, one insulator per phase           | 6               |
| CCVT                                                | Coupling capacitor voltage transformers, three windings                               | 36              |
| CCVT Stand                                          | Single-phase, 8'-6" safety clearance.                                                 | 36              |
| Surge Arrester                                      | Surge Arrester                                                                        | 24              |
| Surge Arrester Stand                                | Single-phase, 8'-6" safety clearance.                                                 | 24              |
| Steel Pipe Pile Supported Foundations               | Spread footing type foundations                                                       | Lot             |
| Grounding Grid                                      | 500 MCM BTN Copper                                                                    | Lot             |
| Control and Relaying                                | Modifications to existing control and relaying racks to accommodate the new equipment | Lot             |
| Safety Fence                                        | Aluminum chain link perimeter fence                                                   | 540             |

| <u>Item</u>      | <u>Description</u>                                                                                                                                | <u>Quantity</u> |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Station Lighting | Up-down lighting fixtures with ballasts and photocell for operations and maintenance.<br>Lighting junction boxes to include AC outlet and switch. | 38              |

(The remainder of this page is intentionally left blank.)

### **3.4.5 Cost Estimate**

The Hudson Facility costs are estimated as follows:

|                         |                      |
|-------------------------|----------------------|
| Engineering             | \$ 2,005,000         |
| Equipment and Materials |                      |
| Site Work               | \$ 72,000            |
| Concrete                | \$ 1,134,000         |
| Lighting                | \$ 190,000           |
| Steel Structure         | \$ 3,173,000         |
| Raceway                 | \$ 183,000           |
| Grounding               | \$ 125,000           |
| Conductor               | \$ 497,000           |
| Switchyard Buswork      | \$ 759,000           |
| Circuit Breakers        | \$ 4,795,000         |
| Circuit Switchers       | \$ 318,000           |
| CCVTs                   | \$ 359,000           |
| Disconnect Switches     | \$ 559,000           |
| Surge Arresters         | \$ 120,000           |
| Control and Relaying    | \$ 374,000           |
| Construction Management | \$ 583,000           |
| <u>Construction</u>     | <u>\$ 11,822,000</u> |
| Subtotal                | \$27,068,000         |

The Hudson Facility PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 1,894,000      |
| Engineering                                      | \$ 602,000        |
| Construction Support                             | \$ 641,000        |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 370,000        |
| Environmental & Resource Recovery                | \$ 100,000        |
| Licensing & Permitting                           | \$ 2,000,000      |
| <u>Corporate Properties</u>                      | <u>\$ 500,000</u> |
| Subtotal                                         | \$ 6,107,000      |

**Total cost for the Hudson Substation Facility      \$ 33,175,000**

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Steel pipe pile supported spread footing foundations shall be utilized due to the existing soil conditions.
- The ground grid shall be 500 MCM copper BTN because of the 80 kV fault current requirement.
- Existing breaker foundations are to be reused for the new circuit breakers.
- No line terminal switches have been included in the layout because line switches did not exist at the existing station.
- The existing SF6 gas insulated bus and terminator located on bus section 7 will remain in place.
- New control cable and raceway systems will be installed as part of the rebuild to accommodate the new foundations and equipment layout.
- Existing relaying schemes will be modified to accommodate the new equipment.
- No major upgrades to the existing control building have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the replaced equipment.
- Conversion of the bus tie breakers to normally closed is included in this design.
- It is assumed that the existing Transformer No. 1 and 2, reactor, and Generator No. 3 circuit switchers will be replaced.
- Lengthy and substantial outages will be required at the Hudson station for the rebuild.
- The project scope as identified in the impact study did not identify the modification or replacement of some of the existing Hudson equipment. The following list provides an overview of equipment which may need additional study and investigation to determine if the equipment will be adequate for the increased fault current. These items have not been included in the scope of this Facilities Study, if it is determined that this equipment will need to be modified or replaced during detailed design, additional costs will need to be added to the estimate.
  - The two 230 to 345 kV autotransformers are supplied by 230 kV underground SF6 gas insulated buses. The capability of these buses to withstand the additional fault current needs to be investigated during detailed design.
  - Hudson 1 and 2 generation: The additional fault current at Hudson switching station will impact the generator step-up transformers, the generator isolated phase bus, the auxiliary power transformers, the auxiliary 4kV buses and switchgear, and settings for the excitation system. The transformers will have to be considered in terms of their capability to withstand the short circuit forces from through fault currents relative to their design. The mechanical withstand strength of the isolated phase bus and 4 kV buses have to be reviewed and validated to be adequate for the increased fault currents. The interrupting capability of the 4 kV breakers must be studied to confirm adequacy for the increased fault currents. Transient stability, damping, and minimum excitation limits should be reviewed to see if setting adjustments are required.

- There are four autotransformers connected to the buses at Hudson switching station, two 345/230 kV units, and two 230/138 kV units. A review of all of these units will have to be made to determine if their designed mechanical strength to withstand through fault short circuit forces is adequate.
- In addition to equipment, there are three oil filled pipe type cables connected at Hudson switching station. The grounding and cathodic protection isolation devices require review to determine their adequacy. In addition, the pipe type cable designs will need to be reviewed relative to the increased fault current to determine their adequacy.

#### **3.4.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Installation of pipe piles in an operating generating station.
- Lengthy and substantial outages will be required at the Hudson station for the rebuild.

### **3.5 Bergen 12H Breaker Replacement (Upgrade n0984)**

#### **3.5.1 Purpose and Necessity**

The over-duty condition of the Bergen 12H breaker can be alleviated by replacing the existing circuit breaker with a breaker rated for an 80 kA fault current.

The existing breaker is a live tank, 3000 A breaker with free standing CT's also rated 3000 A. The existing jumper conductors are 1590 MCM, two per phase.

#### **3.5.2 General Description**

The new circuit breaker will be ABB type PM rated for 80 kA fault duty and 3000 A continuous operation. The breaker will include capacitors on both the line and bus side to meet the fault duty requirements.

The upgrade will include two (2) new breaker isolation disconnect switches rated 3000 A, and a new circuit breaker platform to bridge across the existing breaker pad and CT support foundations. New bus jumpers, raceway, and control cable will also be installed.

Equipment jumpers will be two 1590 MCM ACSR conductors per phase.

The existing ground grid will not be modified, new ground stingers will be extended to connect to the new equipment.

#### **3.5.3 Design Requirements**

The following are specific facility design requirements for the Bergen station; other general design requirements are included in section 1.4 General Design Criteria.

- Ground stingers will be 500 MCM copper BTN to meet 80 kA fault current criteria.
- A structural steel platform is required to support the new circuit breaker.

#### **3.5.4 Major Materials**

##### **Bergen Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 200             |

| <u>Item</u>       | <u>Description</u>                                                                                         | <u>Quantity</u> |
|-------------------|------------------------------------------------------------------------------------------------------------|-----------------|
| Circuit Breaker   | 230 kV SF6 gas insulated circuit breaker, 80 kA, 3000 A, with TRV capacitors on bus and line side bushings | 1               |
| Disconnect Switch | Manually operated 230 kV disconnect switch, 3000 A, three phase                                            | 2               |

(The remainder of this page is intentionally left blank.)

### **3.5.5 Cost Estimate**

The Bergen Facility costs are estimated as follows:

|                         |                   |
|-------------------------|-------------------|
| Engineering             | \$ 80,000         |
| Equipment and Materials |                   |
| Site Work               | \$ 1,000          |
| Steel Structure         | \$ 12,000         |
| Raceway                 | \$ 1,000          |
| Grounding               | \$ 2,000          |
| Conductor               | \$ 16,000         |
| Switchyard Buswork      | \$ 3,000          |
| Circuit Breakers        | \$ 343,000        |
| Disconnect Switches     | \$ 40,000         |
| Control and Relaying    | \$ 12,000         |
| Construction Management | \$ 27,000         |
| <u>Construction</u>     | <u>\$ 116,000</u> |
| Subtotal                | \$ 653,000        |

The Bergen Facility PSE&G costs are estimated as follows:

|                                                  |                   |
|--------------------------------------------------|-------------------|
| Program Management                               | \$ 46,000         |
| Engineering                                      | \$ 24,000         |
| Construction Support                             | \$ 30,000         |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 25,000         |
| Environmental & Resource Recovery                | \$ 10,000         |
| Licensing & Permitting                           | \$ 0              |
| <u>Corporate Properties</u>                      | <u>\$ 0</u>       |
| Subtotal                                         | \$ 135,000        |
| <b>Total cost for the Bergen Facility</b>        | <b>\$ 788,000</b> |

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Modifications to the existing ground grid was not included as part of the scope of this Facilities Study. New 500 MCM copper BTN ground stingers will be connected to the existing grounding system and the new equipment.
- No new control and relaying schemes are required; the existing control and relaying will be modified to accommodate the new circuit breaker.
- No major upgrades to the existing switching station control buildings have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.

### **3.5.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage at the Bergen Switching Station.

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### **3.6 Athenia 21H, 11H, 51H, 2BH Breaker Replacement (Upgrades n0985, n0986, n0987, and n0988)**

#### **3.6.1 Purpose and Necessity**

The over-duty condition of the Athenia 230 kV breakers 11H, 21H, and 51H, and 138 KV breaker 2BH can be alleviated by replacing the existing circuit breakers with breakers rated for a 63 kA fault current.

#### **3.6.2 General Description**

The new circuit breakers will be ABB rated for 63 kA fault duty and 3000 A continuous operation. The breakers will include capacitors on both the line and bus side to meet the fault duty requirements.

The upgrade will include two (2) new breaker isolation disconnect switches rated 3000 A, for each breaker and a new circuit breaker platform to bridge across the existing breaker foundations. New bus jumpers, raceway, and control cable will also be installed.

Equipment jumpers will be two 1590 MCM ACSR conductors per phase.

The existing ground grid will not be modified, new ground stingers will be extended to connect to the new equipment.

#### **3.6.3 Design Requirements**

The following are specific facility design requirements for the Athenia station; other general design requirements are included in section 1.4 General Design Criteria.

- Structural steel platforms are required to support the new circuit breakers.

#### **3.6.4 Major Materials**

##### **Athenia Switching Station**

| <u>Item</u>      | <u>Description</u>                         | <u>Quantity</u> |
|------------------|--------------------------------------------|-----------------|
| Jumper Conductor | 2-1590 kcmil AAC per phase, Falcon (feet). | 800             |

| <u>Item</u>       | <u>Description</u>                                                 | <u>Quantity</u> |
|-------------------|--------------------------------------------------------------------|-----------------|
| Circuit Breaker   | 230 kV SF6 gas insulated circuit breaker,<br>63 kA, 3000 A         | 3               |
| Circuit Breaker   | 138 kV SF6 gas insulated circuit breaker,<br>63 kA, 3000 A         | 1               |
| Disconnect Switch | Manually operated 230 kV disconnect<br>switch, 3000 A, three phase | 6               |
| Disconnect Switch | Manually operated 138 kV disconnect<br>switch, 3000 A, three phase | 2               |

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### **3.6.5 Cost Estimate**

The Athenia Substation Facility costs are estimated as follows:

|                         |                   |
|-------------------------|-------------------|
| Engineering             | \$ 350,000        |
| Equipment and Materials |                   |
| Site Work               | \$ 2,000          |
| Steel Structure         | \$ 50,000         |
| Raceway                 | \$ 6,000          |
| Grounding               | \$ 5,000          |
| Conductor               | \$ 52,000         |
| Switchyard Buswork      | \$ 11,000         |
| Circuit Breakers        | \$ 569,000        |
| Disconnect Switches     | \$ 145,000        |
| Control and Relaying    | \$ 50,000         |
| Construction Management | \$ 80,000         |
| <u>Construction</u>     | <u>\$ 433,000</u> |
| Subtotal                | \$ 1,753,000      |

The Athenia PSE&G costs are estimated as follows:

|                                                  |                     |
|--------------------------------------------------|---------------------|
| Program Management                               | \$ 123,000          |
| Engineering                                      | \$ 90,000           |
| Construction Support                             | \$ 88,000           |
| Relaying, Mechanics, Lab, &<br>System Protection | \$ 100,000          |
| Environmental & Resource Recovery                | \$ 25,000           |
| Licensing & Permitting                           | \$ 0                |
| <u>Corporate Properties</u>                      | <u>\$ 0</u>         |
| Subtotal                                         | \$ 426,000          |
| <b>Total cost for the Athenia Facility</b>       | <b>\$ 2,179,000</b> |

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- Modifications to the existing ground grid was not included as part of the scope of this Facilities Study. New 500 MCM copper BTN ground stingers will be connected to the existing grounding system and the new equipment.
- No new control and relaying schemes are required; the existing control and relaying will be modified to accommodate the new circuit breaker.
- No major upgrades to the existing switching station control building have been included in the scope. It is assumed that the existing AC and DC and communications systems are sufficient for the new equipment.

### **3.6.6 Schedule**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.

(The remainder of this page is intentionally left blank.)

Facility unique assumptions for the cost estimate include the following. Refer to the Summary of Results section for all general assumptions related to the cost estimate.

- The estimate assumes open access to the cable splices and does not include any costs related to work restrictions due to private property or state right-of-ways.
- A single circuit 230 kV HPFF installation with (1) 3000 kcmil cables per phase has been included.
- Conductor sizing calculations have not been performed to verify the line capacity before or after reconductoring.
- It is assumed that no modifications to the existing pipeline or hydraulic system will be required.
- It is assumed that no modifications or repairs are included for the cathodic protection system.
- It is assumed that no additional communications will be required.
- It is assumed that no additional temperature monitoring is required.
- It is assumed that no traffic control is required.
- The estimate includes soil erosion and sediment control measures for excavations only.
- It is assumed that no paving removal or replacement is required.
- It is assumed that seeding, sodding and landscaping are not required.
- Dewatering has been included in the estimate for all excavations.
- It is assumed that sheeting and shoring is required for all excavations.
- The estimate does not include costs for surveying or soil testing.

## **FirstEnergy Work**

### **Transmission Lines – New/Upgraded**

#### 1. Whippany-Roseland 230 kV DCT Line Reconductor

Whippany-Roseland 230kV - Reconductor the Whippany-Roseland (A941) 230 kV line (2.7 miles, double circuit) with 1590 54/19 ACSS/AW wire. [PJM Network Upgrade n0645.1]

The estimated cost for this work is \$5,862,800 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### 2. Larrabee-Atlantic 230 kV Line Reconductor

Reconductor the Larrabee - Atlantic (R1032) 230 kV line (11.8 miles) with 1590 54/19 ACSS/AW wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$5,932,800 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

### **Substations – New/Upgraded**

#### **1. Portland – Martins Creek 230 kV Terminal Upgrade**

Design, furnish and install the following equipment at the Portland terminal of the Portland – Martins Creek 230 kV Line.

- Replace one 3000 amp circuit breaker at the Portland terminal of the Portland - Martins Creek 230 kV line with one rated for a 4000 amp capability.
- Replace one 3000 amp line trap at the Portland terminal of the Portland - Martins Creek 230 kV line with one rated for a 4000 amp capability.
- Replace 1590 ACSR bus conductor with 2493 ACAR 54/37 bundled conductor.
- Replace the GCX17A relay at Portland with an SEL321 relay [PJM Network Upgrade n0636.2]

The estimated cost for this work is \$1,048,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **2. Atlantic Substation Drop Replacement**

Replace drop loop conductors on the Atlantic-Larrabee (R1032) Line with bundled 1590 54/19 ACSS/AW Wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$39,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **3. Larrabee Substation Drop Replacement**

Replace drop loop conductors on the Atlantic-Larrabee (R1032) Line with bundled 1590 54/19 ACSS/AW Wire. [PJM Network Upgrade n0657]

The estimated cost for this work is \$39,900 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### **4. Whippany Substation Replace Breaker JB**

Replace breaker JB at Whippany Substation with 63kA, 4000 A breaker. Replace the 3000A wave trap with 4000 A rated equipment and conductors associated with the Roseland Line. The drop loop conductors shall be bundled. [PJM Network Upgrade n0670]

The estimated cost for this work is \$421,200 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

#### 5. Whippany Substation Replace Breaker QJ

Replace breaker QJ at Whippany Substation with 63kA, 4000 A breaker. Replace the 3000A wave trap with 4000 A rated equipment and conductors associated with the Roseland Line. The drop loop conductors shall be bundled. [PJM Network Upgrade n0671]

The estimated cost for this work is \$421,200 and could be completed as noted in the “Summary of Proposed Schedule for Completion of Work” on page 3 of this Facility Study Report.

### **Environmental, Real Estate and Permitting**

The following are possible environmental, real estate and permitting issues:

#### Larrabee-Atlantic 230 kV Line Reconductor

- The existing line has extensive wetlands in the project ROW, requiring coordination with FE Environmental Group in New Jersey
- All permitting will be at the local level. Rejection of any local permits will require an appeal to the Bureau of Public Utilities, which is not included in the estimated costs .

#### Whippany-Roseland 230 kV DCT Line Reconductor

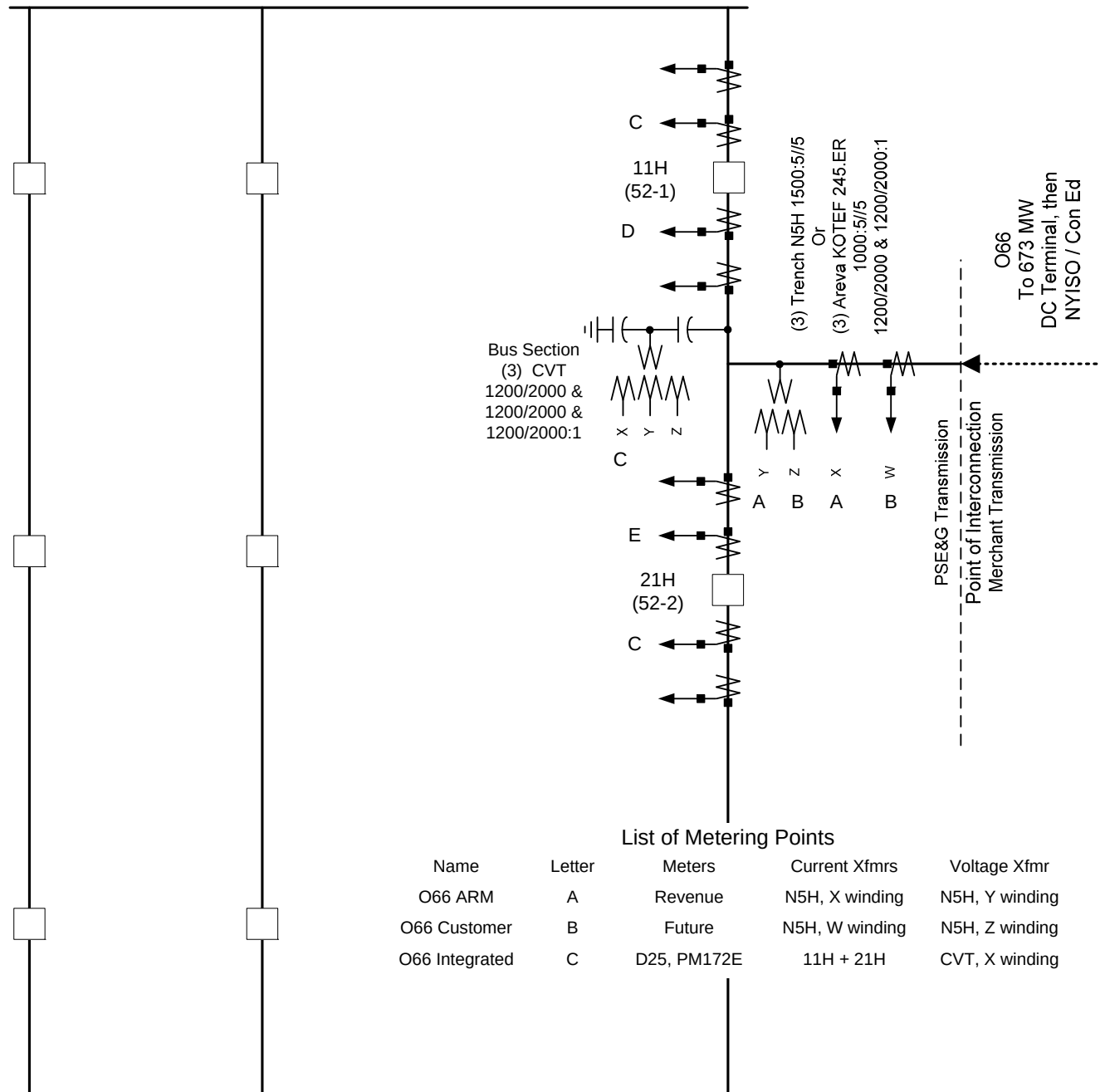
- The existing line is located in the Upper Passaic, Whippany & Rockaway Watershed Management Areas, requiring coordination with FE Environmental Group in New Jersey
- All permitting will be at the local level. Rejection of any local permits will require

### **Metering**

A 673 MW Interconnection Customer will be metered with an ANSI C12.20 revenue meter (0.2 accuracy class). The meter will be connected to (3) instrument transformers that combine CT and VT in one assembly. The combined instrument transformers will be 0.15 accuracy class.

Back-up metering will be provided via an integrated Watt signal from a D-25 RTU. The back-up metering will have instrument transformers that are separate from the primary metering. The one line shows a metering CT on each 230 kV circuit breaker which are totaled before connection to the D25. Each breaker would have (4) CTs for relaying and (2) CTs for metering & instrumentation. The voltage signal for the back-up meter will come from a Capacitive Voltage Transformer that is rated for metering accuracy.

PSE&G will purchase all instrument transformers. The metering will be installed in the Bergen Switch Yard.



### Information Required for the Facilities Study

The following table summarizes the total estimated costs according to FERC criteria. The estimated costs are in 2009 dollars and do not include taxes or effects from Contribution In Aid of Construction.

PSE&G Work

|                                                   |               |
|---------------------------------------------------|---------------|
| <b>Direct Connection &amp; Network Facilities</b> |               |
|                                                   |               |
| Direct Charges Labor                              | \$98,980,000  |
| Direct Charges Material                           | \$56,160,000  |
| Indirect Charges Labor                            | \$10,823,620  |
| Indirect Charges Material                         | \$0           |
|                                                   |               |
| Total                                             | \$165,963,620 |

FirstEnergy Work

|                           |              |
|---------------------------|--------------|
| <b>Network Facilities</b> |              |
|                           |              |
| Direct Charges Labor      | \$5,417,400  |
| Direct Charges Material   | \$3,728,800  |
| Indirect Charges Labor    | \$3,485,500  |
| Indirect Charges Material | \$1,135,000  |
|                           |              |
| Total                     | \$13,666,700 |

Total

|                                                   |               |
|---------------------------------------------------|---------------|
| <b>Direct Connection &amp; Network Facilities</b> |               |
|                                                   |               |
| Direct Charges Labor                              | \$104,397,400 |
| Direct Charges Material                           | \$59,888,800  |
| Indirect Charges Labor                            | \$14,309,120  |
| Indirect Charges Material                         | \$1,135,000   |
|                                                   |               |
| Total                                             | \$179,730,320 |

## **Schedules**

The O-66 Facilities Study Project Schedules included in Appendix A provide a summary of the major engineering, procurement, and construction activities for the facilities.

Major schedule impacts and considerations which could delay the upgrade of this facility include the following:

- Permitting and licensing activities.
- Construction outage requirements.
- HPFF cable lead time and availability.

## APPENDIX A - SCHEDULES

