PJM Generator Interconnection Request Queue #W4-036 Buckskin (Ohio Solar I) 12.47kV Feasibility/Impact Study

Request

The AEP GUIDE TO THE INTERCONNECTION OF DISTRIBUTED RESOURCES TO THE AEP DISTRIBUTION SYSTEM is referred to throughout this document as the interconnection guide. Ohio Solar I has received a copy to guide them through the application process.

Ohio Solar I LLC (Generator) has requested an impact study for a solar powered distributed generation (DG) facility capable of 12.63 MW maximum output power. The DG consists of multiple solar arrays connected to 12 dc/ac inverters each rated for 1000 kW giving the installation an effective rating of 12 MW. The output of the inverters will be connected to twelve 1000 kVA 480/277 V – 12.47/7.2 kV transformers connected ungrounded wye – grounded wye with no grounding impedance. The output of the transformers will be daisy chained in two underground runs with six transformer/inverter power stations on each run. Each of these underground runs will terminate at a riser pole and then continue 50 feet via a primary overhead line consisting of 3 – 556 kcmil ACSR phase conductors and 1 - #6 ACSR neutral to a pole mounted recloser installation. After leaving each recloser each overhead line will go through a group operated switch and continue another 100 feet to a common pole. A single overhead line will continue from the common pole to the AEP primary metering installation where the Generator will terminate their lines. The primary metering pole will be the Point of Common Coupling (PCC). AEP will install distribution facilities to interconnect the solar facility to the Buckskin Station Greenfield 12.47kV circuit. See Figure 1.

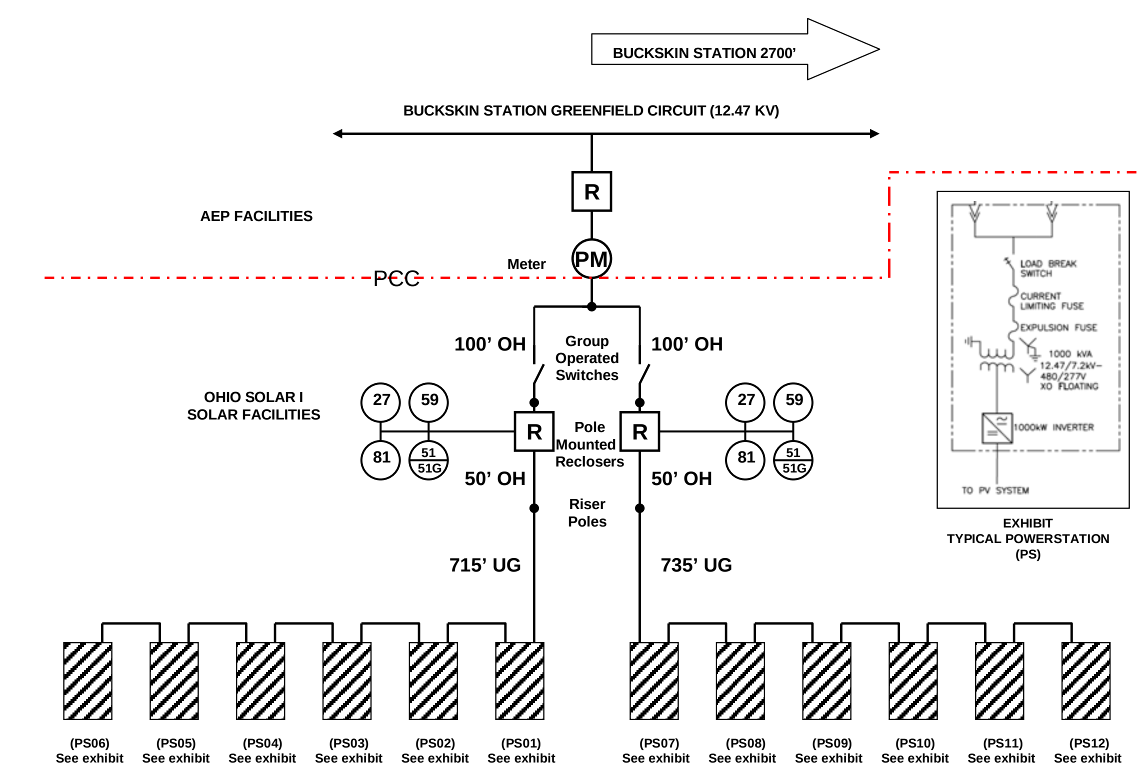

Figure 1

Disclaimer

The contents of this impact study apply only to the system described in the attached Distributed Generation Interconnection Request application. All modeling is based on the DG location on the South Side of Lower Twin Rd, 2700' W. of the Intersection of Lower Twin Rd & S.R. 41 and interconnected as stated above.

Modeling and Assumptions

The Buckskin Station Greenfield circuit (feeder F-12601) is a radial configuration, three-phase multi-grounded four-wire wye system. The primary voltage is 12.47 kV line-to-line and 7.2 kV line-to-ground. The Greenfield circuit is served from the 12 kV station bus via a 69/12 kV, 20 MVA transformer. See Figure 2.

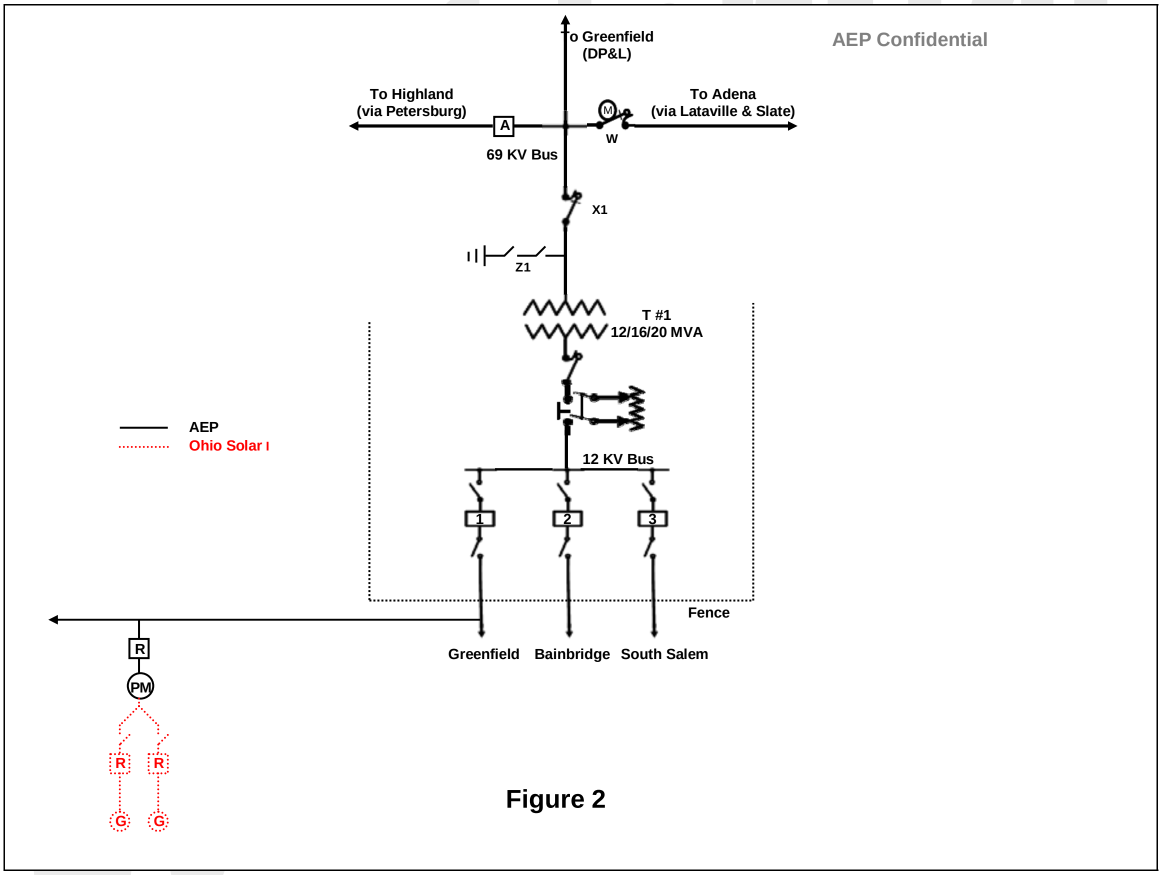

Figure 2

Generator Provided Information

The Generator has submitted the following information in addition to the information contained in their application for interconnection:

Inverter

- Generation = 1000kW
- Output AC voltage = 480V
- Nominal AC current = 1204A; Maximum AC current = 1267A
- Maximum AC short circuit current (sustained) = 1338A

Transformer

- 1000 kVA
- 480/277 V – 12.47/7.2 kV
- Z=5.39 %; X/R=5.24

Underground Cable

- 15 kV Shielded Power Cable
  - 3 – 250 kcmil aluminum with #6 AWG neutral; Direct buried
  - EPR 220 mil insulation 105 degrees C
  - 7.5 inch spacing

Overhead Conductor

- Phase conductor 556.5 kcmil ACSR “Parakeet”
- Neutral conductor #6 ACSR “Turkey”
- Armless configuration
  - Outside phase spacing 7.33’
  - Outside phase to pole top spacing 4.49’
  - Pole top to neutral spacing 4.0’

Distances

Underground Feeders

- PS1 – Project Substation = 715’
- PS1 – PS2 = 630’
- PS2 – PS3 = 630’
- PS3 – PS4 = 42’
- PS4 – PS5 = 320’
- PS5 – PS6 = 50’
- PS7 – Project Substation = 735’
- PS7 – PS8 = 42’
- PS8 – PS9 = 625’
- PS9 – PS10 = 42’
- PS10 – PS11 = 625’
- PS11 – PS12 = 42’

Overhead Lines

- Riser to Recloser = 50’
- Recloser to AEP Lines = 100’

AEP Fault Values and Thevenin Impedances

The following are AEP symmetrical fault values and Thevenin impedances calculated at the PCC without the solar facility connected:

Fault Values and Impedances for 12.47/7.2 kV system.
System voltage can vary +/- 5%.

- LLL = 4294 A LG = 3963 A
- Z1 = Z2 = 0.2034 + j 1.7197 ohms
- Z0 = 0.3531 + j 2.1384 ohms

Analysis

Cymdist Version 4.7 revision 17 was utilized to model the DG effects on the following:

1. System Load Flows
2. System Voltage Levels
3. System Fault Levels and Overcurrent Protection

System Load Flows

Circuit models indicate that the Generator's DG facilities will require approximately 0.6 MVAR to support the 12 MW output of the solar facility. These VARS may be supplied by either AEP or Ohio Solar I or both as the power factor is adjusted at the inverter output. A power factor of 100% would require AEP to supply all the necessary VARS and at an approximate power factor of -99.9% Ohio Solar I would provide all of the VARS.

The circuit models have indicated that voltage levels at the solar facility would be as high as 127.8 volts (on a 120 volt base) at the inverter output and 125.7 volts at the PCC if the Generator supplies all the VARS. The voltage would be as high as 127.4 volts at the inverter output and 125.6 volts at the PCC if AEP supplies all the VARS.

The power factor at the Transformer at Buckskin Station will vary significantly since it is anticipated that the solar facility will not generate any VAR support for the AEP distribution circuits at Buckskin Station. There will be times when quite a few MW's will be flowing into the 69 kV system while all the MVAR's associated with the Buckskin distribution circuits will be flowing out of the 69 kV system. No adverse impact of this phenomenon and low power factor was seen in the circuit models. No AEP equipment will be overloaded.

System Voltage Levels

It is anticipated that the output of the solar facility will vary significantly during periods of clouds and sun and this will affect the Buckskin Station bus voltage. Some IEEE research indicates that the output ramp rate for a cloud transient over a large area may be on the order of 3% per second. It is assumed that under this type of ramp rate, the solar facility could go from full output to zero output in approximately 33 seconds. The number of expected cloud transients per hour or per day is unknown.

To analyze the effect of a drop in output from the solar facility, circuit studies were run at full 12 MW output during both peak and light circuit loading conditions (light loading was 20% of peak loading). The station bus regulators were then locked to the calculated position and another study was run for both peak and light circuit loading conditions with the solar facility output at zero. These studies reflect an instantaneous loss of full solar output. Similar studies were conducted for instantaneous zero output to full output. The worst case swing in station bus voltage for the above cases was 0.75%. A 0.75% bus voltage change over 33 sec is not expected to be perceptible to AEP customers. Because the worst case cloud transient ramp rate is unknown, it is impossible to determine if cloud transients will cause a perception of voltage fluctuations by AEP customers.

The above studies also indicated the AEP primary distribution steady state circuit voltages were always within the acceptable 117V – 126V range if the station bus regulators were set to 125V +/- 1V.

System Fault Levels and Overcurrent Protection

The Generator has indicated that the maximum available fault current at the solar facility is limited by the inverter to 111% of full load current. It will not be necessary to upgrade or re-coordinate the AEP distribution system overcurrent protective devices for the additional fault contribution.

The reclose time on the breaker for the Buckskin Station, Greenfield Circuit will be changed from one second reclose after the first trip to three seconds to allow time for the solar facility to disconnect following a line fault. The other two feeder breakers already have three second reclose times in case circuits need to be tied together.

System Protection

The Generator responsibilities include providing adequate protection to AEP facilities due to events arising from the operation of the DG under all AEP distribution system operating conditions. The Generator is responsible for protecting their own facility under all AEP distribution system operating conditions whether the DG is connected to AEP facilities or not including but not limited to:

1. Abnormal voltage or frequency
2. Loss of a single phase of supply
3. Equipment failure
4. Distribution system faults
5. Lightning
6. Excessive harmonic voltages
7. Excessive negative sequence voltages
8. Separation from supply
9. Loss of synchronization

IEEE Standard 1547-2003 "Standard for Interconnecting Distributed Resources with Electric Power Systems" is the basis for interconnection technical requirements for system protection.

The interconnection system hardware and software used by a Distributed Resource to meet the technical requirements do not have to be located at the Point of Common Coupling. However, the technical requirements shall be met at the Point of Common Coupling.

For additional information on interconnection technical requirements please refer to the AEP interconnection guide.

Summary

The cost of any damage resulting from a system condition caused by the installation and/or operation of the DG will be borne by the owner of the DG facility.

Abnormal distribution system events will be addressed on an individual basis through the AEP system operator. Corrective action shall be based on the judgment of the AEP system operator. Possible corrective action can include, but is not limited to, DG isolation from the distribution system.

This review has been limited to items which may affect the AEP system or to suggestions which may improve operations. The Generator must take all necessary steps to assure compliance with all laws, ordinances, building codes and other applicable regulations. Approval of this connection by AEP, when granted, is not an endorsement of a particular design nor does it assure fitness to accomplish an intended function.

Any additional AEP work to mitigate power quality issues not foreseen by this study but associated with the interconnection of the Ohio Solar I facility will be at the sole cost and expense of the Generator.

Metering

The DG delivery into and out of the American Electric Power (AEP) system will be metered at 12.47 kV.

Communication

No dedicated Generator communication is required for the installation described in the attached Distributed Generation Interconnection Request application. A connection to AEP SCADA will be installed at the primary metering point and connected to the existing SCADA at Buckskin Station.

Additional Generator Requirements for Interconnection

The Generator must meet all the requirements in the AEP GUIDE TO THE INTERCONNECTION OF DISTRIBUTED RESOURCES TO THE AEP DISTRIBUTION SYSTEM. Additionally, the Generator must meet the following requirements.

- The documentation submitted by the Generator does not explicitly state that the installation meets IEEE 1547. Ohio Administrative Code requires installations up to 20 MW in size meet IEEE 1547. Therefore:
    - The Generator must conduct testing according to the procedures of IEEE Standard 1547.1-2005 to verify compliance with the requirements of IEEE Standard 1547-2003.
    - Prior to any IEEE 1547.1 specified testing the Generator must supply to AEP proposed testing procedures.
    - Prior to any IEEE 1547.1 specified testing the Generator must supply to AEP a 3rd party to conduct the testing.
    - AEP must approve the test procedures and the 3rd party before testing may begin.
    - The 3rd party shall provide certification that this installation meets IEEE 1547. Documentation and results of the testing must be provided to AEP before final approval is granted for interconnection.
    - Upon AEP verification that all testing shows the Generator complies with IEEE 1547 the Generator may connect and begin parallel operation with AEP distribution facilities.
- The Generator shall terminate their overhead line on the AEP primary metering structure utilizing the dead-ends provided by AEP. If the wire size or type is changed from that described elsewhere in this document, AEP must be notified well in advance to ensure that proper material is on hand. The metering structure will be designed for the maximum AEP line tension along with an adequate margin of safety. AEP maximum design tension is 3,000 lbs per phase conductor and 3,000 lbs for the neutral conductor (NESC medium loading conditions). The Generator shall contact AEP Ohio Project Design to insure the installation location for the primary metering structure meets the needs of both parties.

- AEP requires that the Generator shall install a group-operated load break disconnecting device located on their last structure. In this case the Generator has indicated the desire to use two switches, one at each of the two recloser locations. AEP has determined that this is acceptable as long as both switches are clearly visible from the primary metering location and within 100'. The disconnecting devices must be accessible to AEP personnel, must be suitable for use by AEP personnel at all times and must be suitable for use by AEP as a protective tagging location. Each disconnecting device shall have a visible open gap when in the open position and be capable of being locked in the open position. Each disconnecting device must have a ground grid designed in accordance with specifications to be provided by AEP. Operation of each device must be restricted to AEP personnel and properly trained operators designated by the interconnection customer. Each disconnecting device must comply with the applicable current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.
- The Generator has indicated plans to install two Viper reclosers or the equivalent with SEL 351-R relaying packages. These will meet our requirement that the Generator install a three-phase protective device such as a line recloser, within one span of the terminating structure. This protective device must operate as a single trip to lockout device to separate the Generator's facilities from AEP for any fault on the Generator's facilities. The Generator shall contact AEP Ohio Project Design to coordinate the protective devices with AEP protective relay settings.
- The Generator's protective relays must be utilized to detect line-to-ground faults. The Generator shall provide adequate protection to comply with IEEE Standard 1547 to clear their generation source for all types of faults on the AEP system including any breaker failure event. Adequate protection requires that all fault types are cleared before equipment damage occurs to AEP facilities. If the Generator fails to provide adequate protection for faults on the AEP system, then the Generator will pay all costs associated with AEP facility damages.
- Automatic high speed reclosing could be applied to the transmission circuits supplying Buckskin Station. When the AEP source breakers trip and isolate the Generator's facilities, the Generator shall ensure that their generation equipment is disconnected from AEP facilities in accordance with requirements established in IEEE Standard 1547 prior to automatic reclosure by AEP. Automatic reclosing out-of-phase with the Generator's generation equipment may cause damage to the Generator's equipment. The Generator is solely responsible for the protection of their equipment from automatic reclosing by AEP.
- All synchronization of the Generator's unit with AEP must be done by the Generator's unit.
- The Generator must inform AEP if they desire remote access to real time primary metering information at the time they indicate their desire to proceed with this project.

AEP System Improvements for Interconnection

- Station Improvements -
  - Relocate the 3 - 69 kV line CCVTs and add 3 new CTs to the transformer to allow proper fault sensing with the addition of a distribution generation source.
  - The 69 kV carrier relay and RTU will be upgraded due to the new generation source. This will require remote end relay replacements at Greenfield Station (DP&L) and Adena Station (AEP).
  - Replace two of the station bus regulator controls (one control is already of the proper type) and set controls for co-generation mode.
  - Replace two feeder breaker relays with SEL-351S to maintain the existing Under Frequency Load Shedding functionality.
  - Change the settings on the Buckskin Greenfield feeder breaker relay to a three second reclose time (over current settings may also need to be changed to accommodate the Generator's reclosers as well as the new one to be installed by AEP).
- Line Improvements -
  - Install a communication line with converters at each end between Buckskin Station and the primary metering point.
  - Install one primary metering installation with SCADA (see Figure 3).
  - Install three wood distribution poles (see Figure 3).
  - Install 85 feet of three phase 12.47 kV primary (see Figure 3).
  - Install one 12.47 kV three phase recloser with SCADA (see Figure 3).

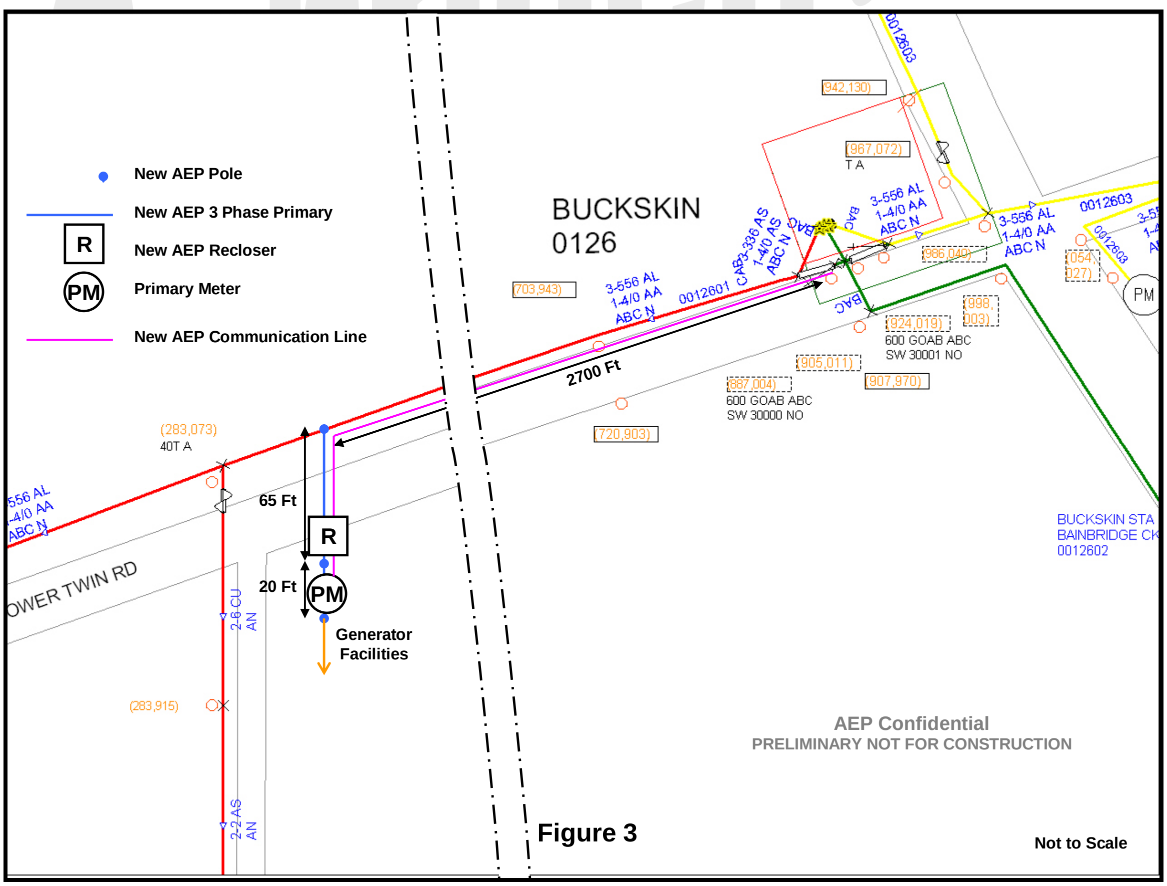

Figure 3

Cost to the Generator

The high level cost estimate for the described work is approximately $550,000. It is estimated that the process to design and build will take approximately nine months from the time an agreement is reached between AEP and Ohio Solar I to proceed.

Appendix

The following documents are in the appendix in order of list:

1. Attachment N (PJM).
2. Generator facility one line.
3. Generator facility site plan.
4. Generator facility technical information.

Network Impacts

Queue project W4-036 was studied as a(n) 12.0 MW (0.0 MW of which was Capacity) injection into AEP's system at the 05BCKSKI 69.0 kV substation. Project W4-036 was evaluated for compliance with reliability criteria for summer peak conditions in 2014.

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

No problems identified

Multiple Facility Contingency

(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)

No problems identified

Short Circuit

(Summary form of Cost allocation for breakers will be inserted here if any)

No problems identified.

Stability Analysis

Not required

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

None

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None