PJM Generator Interconnection
V4-048 Braidwood 1— 20MW
System Impact Study

April 30, 2013

Revised June 2016

Preface

The intent of this System Impact Study is to determine a plan, with cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the Interconnection Customer. The Interconnection Customer may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

The PJM Reliability Planning Process utilizes PJM planning criteria, NERC Planning Standards, NERC Regional Council planning criteria, and the individual Transmission Owner FERC filed planning criteria. In all cases, PJM applies the most conservative of all applicable planning criteria when identifying reliability problems and determining the need for system upgrades on the PJM system. The application of the NERC Planning Standards is adapted to the specific needs of the PJM system.

In some instances an interconnection customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. All facilities required for interconnection of a generation interconnection project must be designed in compliance with the technical specifications (on PJM web site) for the appropriate Transmission Owner.

After the System Impact Study Agreement is executed and prior to execution of the Interconnection Service Agreement, an Interconnection Customer may modify its project to reduce the electrical output (MW) (in the case of a Generation Interconnection Request) of the proposed project by up to the larger of 20 percent of the capability considered in the System Impact Study or 50 MW.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Queue V4-048 is an Exelon Generation Company, LLC (Interconnection Customer) 20 MW uprate to the Braidwood Nuclear Station Unit 1, 35100 S. Route 63, Suite 84, Braceville, IL 60407. As a result of the V4-048 request, the Capacity Interconnection Rights for Unit 1 will increase from 1183 MW to 1203 MW (Maximum Facility Output of Unit 1 — 1240 MW) which is a 20 MW increase over the current values specified in Original Service Agreement Number 3070, filed with the FERC in Docket No. ER11-4697-000. The Interconnection Customer has indicated that the facility is installing more accurate feedwater flow instruments. This will allow the reactor to be operated at higher power level and increase the electrical generation. There will be no other changes to the reactor, generator, or station transformers. The modifications associated with Queue V4-048 are in service.

Direct Connection Requirements

Braidwood Unit 1 is an existing generating unit and no changes to the attachment facilities are expected.

Interconnection Customer Scope of Direct Connection Work

Queue V4-048 Interconnection Customer is responsible for all work on the V4-048 side of the POI (Point of Interconnection).

ComEd Scope of Direct Connection work

No ComEd Direct Connection work is anticipated.

Network Impacts

Queue V4-048 was studied as an injection of 20 MW into the Station 20 Braidwood 345kV substation. Project V4-048 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

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

No violations identified.

Light Load Analysis

No violations identified.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies only with full energy output. Stuck Breaker and Bus Fault contingencies will be applied during the Impact Study)

No violations identified.

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.)

No violations identified.

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

None required.

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.)

None required.

Short Circuit
(Report over-dutied breakers.)

Not required since there are no changes to the Queue V4-048 generator or generator step-up transformer impedance.

Stability Analysis

No violations identified.

Power Factor and Reactive Requirements

The existing Interconnection Service Agreement states that at 1,262 MW gross output, the Customer Facility shall retain its existing ability to maintain a power factor of at least 1.0 (unity) to supplying 509.6 MVAr to the transmission system as measured at the generator's terminals.

To operate at the designated output of 1282 MW winter gross, and meet the power factor requirement, queue project V4-048 must provide an additional 9.7 MVAr to the transmission system (total 519.3 MVAr)

Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of the surrounding generation. Any potential problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Transmission Interconnection request.
Note: *Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which analyzes all overload conditions associated with the overloaded element(s) identified. As a result of the aggregate energy resources in the area, the following violations were identified.*

Not applicable.

ATTACHMENT A

The following information was entered into the Impact Study Data Sheet form by the Interconnection Customer:

Refer to TODI DIT-BRW-2015-0021

ATTACHMENT B

Reactive power assessment

Description

The V4-048 queue project was evaluated for compliance with the reactive power requirements of the Open Access Transmission Tariff (OATT). The OATT establishes that:

- All increases in the capacity or energy output of any generation facility interconnected with the Transmission System, other than wind powered and non-synchronous generating facilities, shall be designed with the ability to maintain a composite power delivery at continuous rated power output at a power factor for all incremental MW of capacity or energy output of at least 1.0 (unity) to 0.90 lagging.

- The power factor requirement associated with increases in capacity or energy output of 20 MW or less to synchronous generation facilities and all increases to wind powered and non-synchronous generation facilities interconnected to the Transmission System shall be measured at the Point of Interconnection.

Data

For purposes of this study, the corresponding winter values will be used as the **grandfathered MVAR levels**.

In addition, the following parameters were provided by the developer:

1. Generator capability: **1361** MVA (from Attachment A)
2. New winter max gross output of request: **1282** MW
3. Generator interconnection request: **20** MW

Results

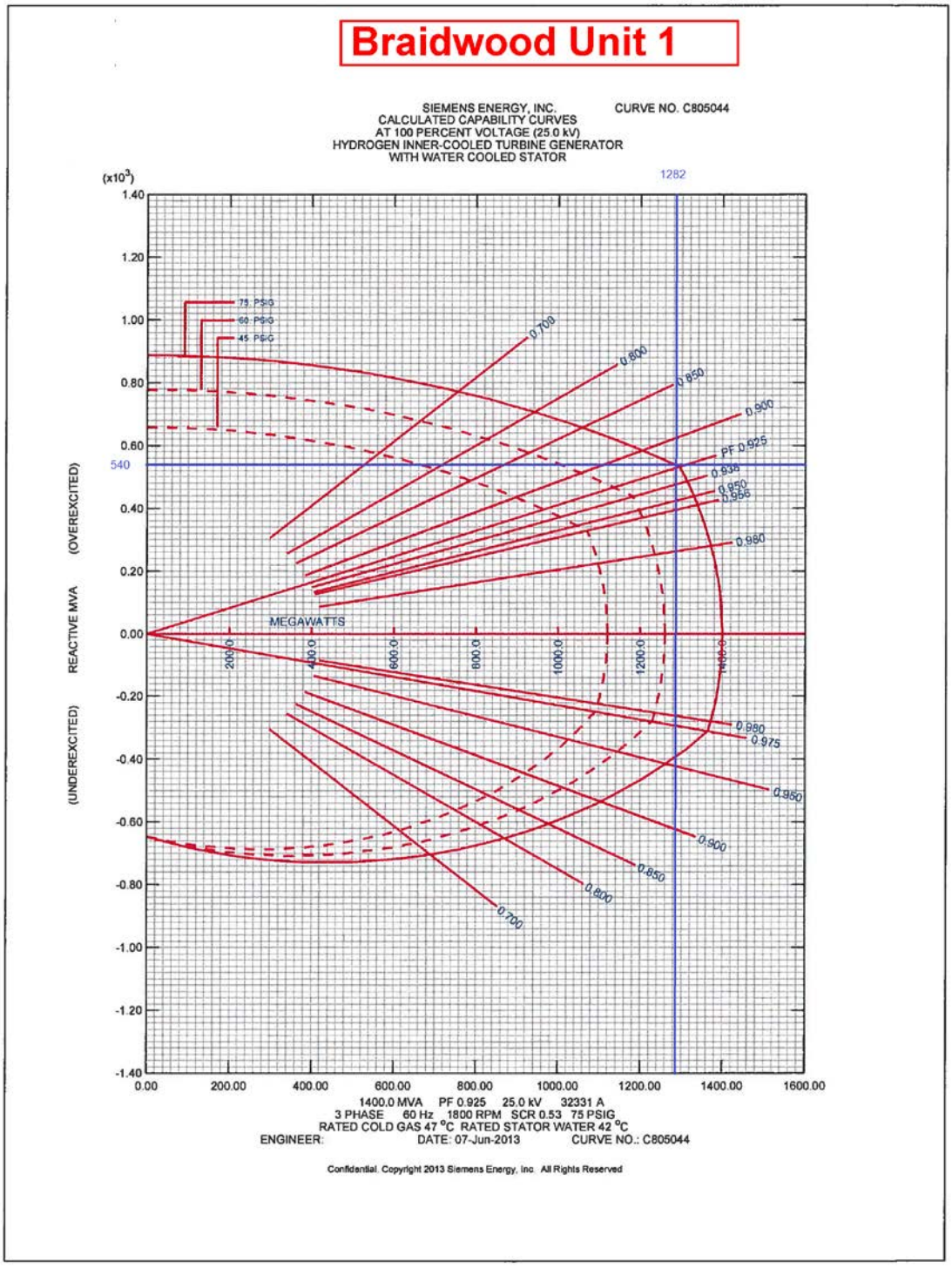
The V4-048 queue project was found to be **in compliance** for the reactive power requirement based on the suggested operating point and the project design capability. Results for the reactive power requirement assessment are shown in Table I.

Table I. Reactive power requirement with V4-048 request

Generator Old Gross MW	1262
Grandfathered MVAr Capability	509.6
Reactive Power Requirement for 20MW increase	9.7
Total Reactive Requirement	519.3

Notes: Transformer losses were ignored during this study.

Braidwood Unit 1



PJM Generator Interconnection
V4-048 Braidwood 1— 20MW
System Impact Study

April 30, 2013

DMS #750234v1

Preface

The intent of this System Impact Study is to determine a plan, with cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the Interconnection Customer. The Interconnection Customer may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

The PJM Reliability Planning Process utilizes PJM planning criteria, NERC Planning Standards, NERC Regional Council planning criteria, and the individual Transmission Owner FERC filed planning criteria. In all cases, PJM applies the most conservative of all applicable planning criteria when identifying reliability problems and determining the need for system upgrades on the PJM system. The application of the NERC Planning Standards is adapted to the specific needs of the PJM system.

In some instances an interconnection customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. All facilities required for interconnection of a generation interconnection project must be designed in compliance with the technical specifications (on PJM web site) for the appropriate Transmission Owner.

After the System Impact Study Agreement is executed and prior to execution of the Interconnection Service Agreement, an Interconnection Customer may modify its project to reduce the electrical output (MW) (in the case of a Generation Interconnection Request) of the proposed project by up to the larger of 20 percent of the capability considered in the System Impact Study or 50 MW.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Queue V4-048 is an Exelon Generation Company, LLC (Interconnection Customer) 20 MW uprate to the Braidwood Nuclear Station Unit 1, 35100 S. Route 63, Suite 84, Braceville, IL 60407. As a result of the V4-048 request, the Capacity Interconnection Rights for Unit 1 will increase from 1183 MW to 1203 MW (Maximum Facility Output of Unit 1 — 1240 MW) which is a 20 MW increase over the current values specified in Original Service Agreement Number 3070, filed with the FERC in Docket No. ER11-4697-000. The Interconnection Customer has indicated that the facility is installing more accurate feedwater flow instruments. This will allow the reactor to be operated at higher power level and increase the electrical generation. There will be no other changes to the reactor, generator, or station transformers. Queue V4-048 proposed an in-service date of January 1, 2012, however, the application for this uprate is pending NRC approval.

Direct Connection Requirements

Braidwood Unit 1 is an existing generating unit and no changes to the attachment facilities are expected.

Interconnection Customer Scope of Direct Connection Work

Queue V4-048 Interconnection Customer is responsible for all work on the V4-048 side of the POI (Point of Interconnection).

ComEd Scope of Direct Connection work

No ComEd Direct Connection work is anticipated.

Network Impacts

Queue V4-048 was studied as an injection of 20 MW into the Station 20 Braidwood 345kV substation. Project V4-048 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

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

No violations identified.

Light Load Analysis

Light Load Studies to be conducted during Facilities Study phase (applicable to wind, coal, nuclear, and pumped storage projects).

Multiple Facility Contingency

(Double Circuit Tower Line contingencies only with full energy output. Stuck Breaker and Bus Fault contingencies will be applied during the Impact Study)

No violations identified.

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.)

No violations identified.

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

None required.

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.)

None required.

Short Circuit
(Report over-dutied breakers.)

Not required since there are no changes to the Queue V4-048 generator or generator step-up transformer impedance.

Stability Analysis

No stability issues were identified in an interim stability study for this uprate. A final stability study will be performed as part of the Facilities Study.

Power Factor and Reactive Requirements

The existing Interconnection Service Agreement states that at 1,262 MW gross output, the Customer Facility shall retain its existing ability to maintain a power factor of at least 1.0 (unity) to supplying 509.6 MVAr to the transmission system as measured at the generator's terminals.

To operate at the designated output of 1282 MW winter gross, and meet the power factor requirement, queue project V4-048 must install 62.3 MVAr power factor correction equipment at the plant or provide an additional 62.3 MVAr dynamic reactive capability to

meet the reactive power requirement as shown in Table I in Attachment B. See PJM Manual 14A, Attachment H for additional details and the mitigation process.

Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of the surrounding generation. Any potential problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Transmission Interconnection request.

Note: *Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which analyzes all overload conditions associated with the overloaded element(s) identified. As a result of the aggregate energy resources in the area, the following violations were identified*.

Not applicable.

ATTACHMENT A

The following information was entered into the Impact Study Data Sheet form by the Interconnection Customer:

Study Type:	Non-Wind
Unit Capability Data Request Form	
Queue letter and position / Unit ID:	V4-048
Primary fuel type:	Nuclear
Maximum Summer (92º F ambient air temp.) Net MW Output:	1213.4
Maximum Summer (92º F ambient air temp.) Gross MW Output:	1256
Minimum Summer (92º F ambient air temp.) Gross MW Output:	700
Maximum Winter (30º F ambient air temp.) Gross MW Output:	1282.5
Minimum Winter (30º F ambient air temp.) Gross MW Output:	700
Gross Reactive Power Capability at Maximum Gross MW Output	
Please include Reactive Capability Curve:	
Leading(MVAR):	
Lagging(MVAR):	
Individual Unit Auxiliary Load at Maximum Summer MW Output:	
MW:	
MVAR:	
Individual Unit Auxiliary Load at Minimum Summer MW Output:	
MW:	
MVAR:	
Individual Unit Auxiliary Load at Maximum Winter MW Output (MW/MVAR)	
MW:	
MVAR:	
Individual Unit Auxiliary Load at Minimum Winter MW Output (MW/MVAR):	
MW:	
MVAR:	
Station service load (MW/MVAR):	
MW:	
MVAR:	
Station load connected to::	High side of GSU
Unit Generator Dynamics Data Request Form	
Total Number of Machines:	1

MVA Base (upon which all reactances, resistance and inertia are calculated):	1361
Nominal Power Factor:	0.90
Terminal Voltage (kV):	25

Unsaturated Reactances (on MVA Base)	
Direct Axis Synchronous Reactance, Xd(i):	
Direct Axis Transient Reactance, X'd(i):	
Direct Axis Sub-transient Reactance, X"d(i):	
Quadrature Axis Synchronous Reactance, Xq(i):	
Quadrature Axis Transient Reactance, X'q(i):	
Quadrature Axis Sub-transient Reactance, X"q(i):	
Stator Leakage Reactance, Xl:	
Negative Sequence Reactance, X2(i):	
Zero Sequence Reactance, X0:	

Saturated Reactances (on MVA Base)	
Saturated Sub-transient Reactance, X"d(v) (on MVA Base):	
Negative Sequence Reactance, X2(v):	
Zero Sequence Reactance, X0(v):	

Resistance Values	
DC Armature Resistance, Ra (ohms):	
Positive Sequence Resistance, R1 (on MVA Base):	
Negative Sequence Resistance, R2 (on MVA Base):	
Zero Sequence Resistance, R0 (on MVA Base):	

Time Constants (seconds)	
Direct Axis Transient Open Circuit, T'do:	
Direct Axis Sub-transient Open Circuit, T"do:	
Quadrature Axis Transient Open Circuit, T'qo:	
Quadrature Axis Sub-transient Open Circuit, T"qo:	
Inertia, H (kW-sec/kVA, on KVA Base:	
Speed Damping, D:	
Saturation Values at Per-Unit Voltage S(1.0):	
Saturation Values at Per-Unit Voltage S(1.2):	

Main GSU Data Request Form	
Number of Machine's per GSU:	1
Generator Step-up Transformer MVA Base:	625
Generator Step-up Transformer Impedance (R+jX, or % on transformer MVA Base):	
High-side to Low-side R:	See Comment 1 below
High-side to Low-side jX:	See Comment 1 below
High-side to Tertiary R:	
High-side to Tertiary jX:	
Low-side to Tertiary R:	
Low-side to Tertiary jX:	

Generator Step-up Transformer Reactance-to-Resistance Ratio (X/R):
See Comment 2 below

Generator Step-up Transformer OA/FA/FA Rating (MVA):
- OA: See Comment 3 below
- F1: See Comment 3 below
- F2: See Comment 3 below

Generator Step-up Transformer Low-side Voltage (kV): 23.7
Generator Step-up Transformer High-side Voltage (kV): 345
Generator Step-up Transformer Tertiary Voltage (kV):
Generator Step-up Transformer Off-nominal Turns Ratio:
Generator Step-up Transformer Number of Taps and Step Size:
- Number of Taps:
- Step Size:

High Voltage Winding Connection (i.e. wye grounded, delta): Wye Gnd
Low Voltage Winding Connection (i.e. wye grounded, delta): Delta
Tertiary Voltage Winding Connection (i.e. wye grounded, delta):

Transmission Line Data
Line length from main transformer high-side to Point of Interconnection:
See Comment 4 below

Voltage level (kV):
Conductor type (ACSR, AAC, AAAC, ACAR, etc):
Transmission line MVA base:
Positive sequence impedance (R+jX per mile on line MVA base):
- R:
- jX:

Zero sequence impedance (R+jX per mile on line MVA base):
- R:
- jX:

Positive sequence charging admittance: See Comment 5 below

Comments: Values for Item 49,50,51,61 and 67:
(1)Item 49: Two xfmrs in parallel;
Impedances in %= A:8.33%,B:8.37%
(2)Item 50: A=41.635, B=39.843
(3)Item 51: 625 MVA@55C, 700MVA@65C
(4)Item 61: Unchanged
(5)Item 67: TBD
The above parameters cannot be submitted in their form fields due to limitations. The form fields are populated as 1,2,3,4,5 for above items.

ATTACHMENT B

Reactive power assessment

Description

The V4-048 queue project was evaluated for compliance with the reactive power requirements of the Open Access Transmission Tariff (OATT). The OATT establishes that:

- All increases in the capacity or energy output of any generation facility interconnected with the Transmission System, other than wind powered and non-synchronous generating facilities, shall be designed with the ability to maintain a composite power delivery at continuous rated power output at a power factor for all incremental MW of capacity or energy output of at least 1.0 (unity) to 0.90 lagging.

- The power factor requirement associated with increases in capacity or energy output of 20 MW or less to synchronous generation facilities and all increases to wind powered and non-synchronous generation facilities interconnected to the Transmission System shall be measured at the Point of Interconnection.

Because of an inconsistency between the PJM OATT and the PJM Manuals this queue project was allowed to maintain the units' Grandfathered MVAR levels, plus provide additional MVARs for the incremental MWs requested in the new Generator Interconnection Request.

Data

For purposes of this study, the corresponding winter values will be used as the **grandfathered MVAR levels**.

In addition, the following parameters were provided by the developer:

1. Generator capability: **1361** MVA (from Attachment A)
2. New winter max gross output of request: **1282** MW (from Attachment A)
3. Generator interconnection request: **20** MW

Results

The V4-048 queue project was found to be **deficient** for the reactive power requirement based on the suggested operating point and the project design capability. Results for the reactive power requirement assessment are shown in Table I.

Table I. Reactive power requirement with V4-048 request

Generator Old Gross MW	1262
Grandfathered MVAr Capability	509.6
Reactive Power Requirement for 20MW increase	9.7
Total Reactive Requirement	519.3
Generator New Gross	1282
MVAr Capability at New Gross	456.9
Total Reactive Deficiency (Unit 1)	62.3

Notes: Transformer losses were ignored during this study.

Additional compensation

To operate at the designated output of 1282 MW winter gross, and meet the power factor requirement, queue project V4-048 must install 62.3 MVAr power factor correction equipment at the plant or provide an additional 62.3 MVAr dynamic reactive capability to meet the reactive power requirement as shown in Table I.

