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1 FOREWORD

The information contained in this document was prepared by PPL Electric. This information represents the minimum design requirements needed to ensure the safe and reliable operation of facilities to protect PPL Electric's system and personnel. However, this shall not relieve the customer from sole and complete responsibility for all aspects of design, installation, maintenance, and operation of their facilities. Neither PPL Electric nor any person acting on behalf of PPL Electric; (a) makes any warranty with respect to the use of information disclosed in this document or that such use may not infringe on privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information disclosed in this document.

To ensure that all proposed installations are handled uniformly and to minimize the possibility of misinterpreting PPL Electric requirements, this document outlines the protection requirements for parallel operation of distributed energy resources (DER). These requirements will also ensure the safety of the general public and PPL Electric personnel and minimize possible damage to PPL Electric equipment and that of PPL Electric customers. The amount of protection applied to a particular DER will vary with the specific location on PPL Electric's system. It must be clearly understood that the protection identified in this document is for PPL Electric's distribution system protection, not protection of the customers' DER or generating equipment.

For NEW applicable installations, this document is to be used in conjunction with the "PPL ELECTRIC PCC REQUIREMENTS FOR DISTRIBUTION VOLTAGE FACILITIES" document which covers Point of Common Coupling (PCC) installation requirements and the "SCADA Requirements for Parallel Operation of Distributed Energy Resources" document as applicable.



2 SCOPE

This document is intended for DER installations on the PPL Electric distribution system (12.47 kV and below). The intended installations will be connected to PPL Electric circuits and are subject to isolation from the PPL Electric system if the upstream protective device (circuit breaker, recloser, fuse, disconnect, etc.) opens for any reason.

The installation of the DER equipment shall not cause any deterioration in the quality of service to PPL Electric customers.

The Pennsylvania Public Utility Commission (PUC) has enacted rules for net metering installations sized at 3 MW or less that are NOT covered by the PJM or FERC processes. In general, these will be small installations connected at distribution voltage levels 12.47 kV and below. The current PA PUC rules can be found on the Pennsylvania Commonwealth website.

Typically, installations between 3 MVA and 20 MVA will fall under the PJM Interconnection process, specifically in PJM Manual 14G, Section 5 "Small Generator Interconnection Requests." These facilities will generally be connected to transmission facilities at 69 kV or 138 kV but may be connected to PPL Electric distribution facilities.

In addition to this document when applicable, DER installations will be covered by a combination of the REMSI (Rules for Electric Meter Service Installation) document, PA PUC and PJM rules as noted above.



3 ACRONYMS AND ABBREVIATIONS

The following defined acronyms and abbreviations are used in this document:

AC	Alternating Current
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
BIL	Basic Insulation Level
BOM	Bill of Materials
CTs	Current Transformers
DC	Direct Current
DFAG	Double-fed Asynchronous Generator
DFIG	Double-fed Induction Generator
DER	Distributed Energy Resource
DG	Distributed Generation
DTT	Direct Transfer Trip
EDC	Electric Distribution Company
EMI	Electromagnetic Interference
EPS	Electric Power System
EUT	Equipment Under Test
FDDA	Fully Differential Difference Amplifier
FID	Fault Interrupting Device (a circuit breaker or fuse)
ICS	Industrial and Commercial Services
IEEE	Institute of Electrical and Electronics Engineers
IMR	Interconnection Monitor Relaying
IPP	Independent Power Producer
IPR	Intertie Protective Relay
KI	Kirk Key Interlock
NEC	National Electrical Code
NESC	National Electrical Safety Code
MVA	Mega Volt Amperes
MVA _r	Mega Volt Amperes Reactive
MW	Mega Watts
MWh	Megawatt hour
NUG	Non-Utility Generator
PCC	Point of Common Coupling
PCS	PPL Control Switch
PLC	Programmable Logic Controller
POC	Point of DER Connection (formerly Point of Contact)
POI	Point of Interconnection
PPL	PPL Electric
PRDA	Path-based Recursive Decomposition Algorithm



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PTs	Potential Transformers
PURPA	Public Utility Regulatory Policies Act of 1978
PWM	Pulse-Width Modulation
REMSI	Rules for Electric Meter and Service Installations
RTU	Remote Terminal Unit (SCADA)
SCADA	Supervisory Control And Data Acquisition
TCM	Trip Circuit Monitor
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply



4 OVERVIEW

4.1 INTERCONNECTING DER WITH THE UTILITY SYSTEM

This document is intended to serve as a reference for PPL Electric engineers and DER sponsors when planning protection for the parallel operation of a DER facility on the PPL Electric's distribution system. *NOTE: the term DER will be used throughout this document to designate ANY form of generation or energy storage system. This would include traditional PURPA installations, as well as newer Merchant Power Installations (MPI), Independent Power Producers (IPP) and Distributed Generation (DG).* Minimum interconnection and certification requirements for DER intertie are identified to provide safe and effective operation of the PPL Electric system. Some installations may be required to install relaying equipment and additional protection after a review of the proposed generation installation.

This document is intended to be used for all DER connected to the PPL Electric distribution system as applicable. Furthermore, this document will also apply in situations where there are multiple Authorities Having Jurisdiction (AHJ) as it relates to the operation of a DER.

Where feasible, DER equipment built and certified to IEEE standards will be permitted to be installed with no additional protection requirements at the site of the installation. However, multiple installations on a single line or substation, or the installation of a large DER unit, may have substantial impact that will require additional protection.

All inverters to be used for proposed DER shall be certified to be compliant with the latest versions of UL 1741 and IEEE 1547 standards. The term certified is understood to indicate that a Nationally Recognized Testing Laboratory (NRTL) has tested the device to the appropriate standard. Any inverter not meeting the NRTL certification will either not be allowed to connect to the PPL Electric system or will be required to install suitable external protection equipment to provide the same level of protection. Further, the inverter vendor must provide copies of the certification of the inverter equipment from the NRTL. Self-certification or certification by a third party that is not listed on the OSHA web site will not be accepted.

For all DER installations, it shall be the customer and their engineer/electricians' responsibility to determine if the operational voltage limits of the inverter might exceed the maximum operational output of the DER during normal operation of the PPL Electric system. It should be recognized that at certain times of the year, the PPL Electric system voltage will approach the maximum limit as measured at the meter base of 126 or 252 volts. The addition of DER can cause this voltage to increase, or if there is a sufficiently long branch circuit to the DER equipment, the voltage at the inverters may be high enough for the inverters to trip off on over voltage. It shall be the customer's responsibility to take the possible voltage rise into consideration in the design of their facility.

DER will not be permitted to connect to a PPL Electric "Low Tension" network system, without prior detailed review. Installation of DER equipment on a low-tension network can have a negative impact on the operation of the network. Under no circumstances will the PPL Electric network protector be used to isolate the DER from the PPL Electric system. The installation of DER on PPL Electric network system must not result in operation of the network protectors for reverse flow conditions. See IEEE 1547 Section 8.1.4.2.

Under no circumstances shall two or more PPL Electric lines of differing voltages (12.47 kV and 69 kV, for example) be paralleled through DER facilities. Where one or more sources is intended to back-up the primary supply to a DER facility, the electrical circuit to the primary supply must be interrupted before the circuit to the back-up is



closed. (Trapped Key Interlock Switches or break-before-make transfer switches are suitable devices for this type of transfer. Multiple sources at the same voltage level will be handled on a case-by-case basis.

4.2 INITIATING A REQUEST TO INSTALL OR CHANGE OPERATION OF DER EQUIPMENT

All projects to add or modify a connection to the PPL Electric system should start with a call to the PPL Electric Business Account Services (BAS) Group at 1-888-220-9991 or email at businessaccounts@pplweb.com to contact a BAS representative, who will be able to respond to your inquiry. Alternatively, you may initiate a contact to BAS via the PPL website at: www.pplelectric.com.

Any deviation from PPL Electric's approved design, without notifying PPL Electric and acquiring new approval shall be considered a violation of PPL Electric requirements, which may result in immediate disconnection of the customer's facility from the PPL Electric system.

4.3 POINT OF COMMON COUPLING (PCC), INTERCONNECTION MONITOR RELAYING (IMR), and INTERTIE PROTECTIVE RELAYING (IPR)

This document defines specific practices required for the interconnection of DER to the utility system at voltages 12.47 kV and below. Proposed customer DER may require either a Point of Common Coupling (PCC) recloser, Interconnection Monitor Relaying (IMR), or Intertie Protective Relaying (IPR) or a combination of either to provide optimal protection to PPL Electric's system, personnel and customers.

In this document, the term "Point of Common Coupling" (PCC) will be used when specifically referring to fuses or reclosers that act as a protective point of connection between PPL Electric and the customer's facility. The use of this term is consistent with its use in the IEEE 1547 standard. Prior to 2023, PPL Electric referred to the point of connection between the Electric Distribution Company (EDC) and the customer's facility as the Point of Contact (formerly POC). PPL has departed from the aforementioned practice and instead uses the term "POC" as used in IEEE 1547 to refer to the "Point of DER Connection" as the electrical point of connection between the DER and rest of the customer's facility. Typically, POC will be used in reference to the DER isolation breaker that the IPR would interface with. The term "Point of Interconnection" (POI) will be used when referring to the electrical connection point where PPL Electric's service conductors meet the customers service conductors.

The PCC, IMR, and IPR protective relay functions should be in separate protective relays and must be for PPL Electric use only. If the PCC and IPR protection must be combined this will be handled on a case-by-case basis, and PPL Electric may require additional protection beyond what is normal to ensure redundancy of both schemes. Under no circumstances will IPR or PCC relays be used for customer functions or logic. Where practical, separate CTs should be used for these functions, see [Section 5.2.3 Current and Voltage Transformers](#).

Refer to "PPL ELECTRIC PCC REQUIREMENTS FOR DISTRIBUTION VOLTAGE FACILITIES" for specific PCC protection requirements.



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4.4 CUSTOMER DER RESPONSIBILITIES

The list of Customer Responsibilities covered in this Section provides a list of activities that must be completed before the DER equipment can be operated in parallel with the utility system. ***This should not be considered as project sequence.***

<u>Description</u>	<u>Reference</u>
<input type="checkbox"/> Complete and submit Application for Parallel DER.	PPL Electric Application for Parallel DER
<input type="checkbox"/> Submit preliminary site drawings, including site plan and elevation views showing desired location and orientation of facilities, electrical one-line diagram, and equipment specification sheets to PPL Electric	
<input type="checkbox"/> Return signed Letter of Authorization (LOA) to begin PPL Electric Engineering.	
<input type="checkbox"/> Return signed Electric Service Contract (may be required)	
<input type="checkbox"/> Submit customer proposed one-line diagram as described in the Section 8.2.1, include PCC protection installations.	Point of Common Coupling Requirements for Distribution Voltage Facilities, REMSI sketches, Relay and Control Requirements for Parallel Operation of DER, section 5.
<input type="checkbox"/> Submit preliminary control drawings and specifications for PPL Electric approval prior to ordering equipment.	Point of Common Coupling Requirements for Distribution Voltage Facilities and Relay and Control Requirements for Parallel Operation of DER, section 5.
<input type="checkbox"/> Submit final control drawings incorporating required PPL Electric changes for PCC protection prior to ordering equipment.	Point of Common Coupling Requirements for Distribution Voltage Facilities.
<input type="checkbox"/> For Underground Services: Submit switchgear drawings for approval - must comply with reference	PPL Drawing 6-09-199 & REMSI Rules 8 & 18.
1. Termination cubicle	6-09-199.
2. Metering cubicle	6-09-199.
<input type="checkbox"/> For Overhead Services: Switch & Meter poles must comply with reference	Specifications 6-09-194, 6-09-197 & REMSI Sketches #30-#34 & REMSI Rules 7, 8, & 18.
<input type="checkbox"/> Submit CT/PT/Meter location and drawings for Approval	REMSI Rules 3, 7, 8, 13, 18.



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- Complete transformer data sheet and submit transformer drawings for review *prior* to ordering (kVA, connection, taps, impedance, primary/secondary voltages).
Transformer Requirements (Section 6.6.1) and Physical & Electrical Design Requirements.
- If applicable, inform PPL Electric when relaying is available for testing/setting.
- Supply slide bar lock on substation gate and disconnecting device.
NOTE: PPL Electric might need to remove these relays for bench testing.
- Submit switch, interlock schematic & details.
Physical & Electrical Design Requirements.
- Return signed Electric Service Contract prior to the start of PPL Electric construction.
- Provide payment of costs to PPL Electric for 12 kV or lower service.
- Submit final substation site location and orientation, horizontal and vertical survey control points, and phase orientation of transformer.
Physical & Electrical Design Requirements.
- Provide power transformer certified test reports for compensated metering (%) exciting current, % impedance, core loss, full load copper loss.
Physical & Electrical Design Requirements.
- Provide Bill of Material (major electrical equipment only)
Physical & Electrical Design Requirements.
- Call PPL Electric when ready for PPL Electric billing metering (Separate from PCC equipment) CT/PT delivery.
- Install PPL Electric billing metering CTs and PTs per PPL Specifications.
REMSI & Supervisor – Large Power Metering
- Provide substation ground grid resistance test report per IEEE Std. 81.
Physical & Electrical Design Requirements.
- Complete inspection requirements – independent electrical final one-line diagram. This includes all PPL Electric required station and equipment inspections.
REMSI Rule 19
- Provide as-built drawings for PPL Electric file.
- Provide proof that all PCC and relaying is functional and tested prior to the energization of the facility.

* REMSI (Rules for Electric Metering & Service Installation).



5 INTERCONNECTION MONITOR RELAYING (IMR) AND INTERTIE PROTECTION RELAYING (IPR) REQUIREMENTS

5.1 BACKGROUND

5.1.1 Scope

The scope of section 5 is limited to the Interconnection Monitor Relaying (IMR) and Intertie Protective Relaying (IPR) requirements and design features. This document does not cover the relaying's specific settings, nor the settings of any other equipment installed for the monitoring and protection of the DER. Specific settings for the IPR system can be found in the Intertie Protective Relay SEL -751 document which can be provided by PPL Electric.

Neither IMR nor IPR will be required for inverter-based DER smaller than 500 kW since inverters' built-in anti-islanding features are relied upon to disconnect the DER when abnormal grid conditions arise. IMR will be required for any large inverter-based DER greater than 500 kW. IPR will be evaluated for any DER greater than 500 kW and required only if it is determined that the interconnection creates a high risk of islanding.

The customer is responsible for design, installation, and testing of the relays. The customer is also responsible for periodic maintenance of the relays (10 years unless more specific guidelines are provided in the customer contract). PPL Electric Relay Test must be on-site to witness successful testing of the relaying and proof of successful testing must be submitted. This includes CT accuracy testing during commissioning.

5.1.2 IMR and IPR Functional Requirements

The primary function of the IMR is to monitor and obtain data related to the performance of large DER systems and facilitate the review of that data when abnormal feeder conditions arise. This data will enable PPL Electric to evaluate operations on the customer's DER system and to determine whether there is adequate anti-islanding protection on the feeder.

The primary function of the IPR is to isolate a DER and/or any ground source (if present) from the PPL Electric system for faults on the PPL Electric system or whenever continued operation would be detrimental to PPL Electric or PPL Electric customers. This is accomplished via the operation of a POC isolation breaker. The secondary function of the IPR is to block closing of all circuit breakers that can be used to parallel the DER whenever the PPL Electric source is unavailable or abnormal.

As defined in the latest version of IEEE 1547, the following are the required functional characteristics to be performed by DER systems. In addition, the IPR schemes will perform similar functions for DER systems connected to the 12 kV distribution system with a high risk of islanding:

- Fast operation by undervoltage relay to disconnect the DER facility for a supply line fault and isolate it prior to the first reclosure operation. This is required to prevent the generation from possibly sustaining the fault and thus causing the PPL Electric line potential test to be unsuccessful or to minimize the chance of an out-of-phase reclosure.
- Fast operation on overvoltage if overexcitation, ferro-resonance, or ground fault overvoltage (GFOV) causes a rapid, severe voltage rise.
- Fast or delayed operation for the various levels of underfrequency/overfrequency detected on the distribution system.



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- To prevent false trips, the IPR should be capable of obtaining selectivity for system faults not on the source line.
- Large units, while interconnected, can have a significant impact on system voltage levels. Customers need to make sure the DER facility shall not actively regulate the voltage levels at the Point of Interconnection (POI) unless permitted to do so through participation in PPL Electric's DER Management Pilot Program.
- Large units can impact a significant portion of the power system, and therefore, a high assurance is required for such large generation facilities that they will not operate in island mode while connected to the PPL Electric System unless permitted to do so through participation in PPL Electric's DER Management Pilot Program.
- The interconnection relay system shall have the capability to withstand electromagnetic interference (EMI) environments (as per IEEE C37.90.2 – 2004 or latest revision) so that the influence of EMI shall not result in a change in state or mis operation of the interconnection system.

NOTE: Under no circumstance should the IPR relays trip the POC isolation breaker through a PLC or other programmable device. The breaker must be tripped directly to avoid any additional time delay from an interposing programmable device. Auxiliary relay(s) can be used only if necessary. The trip signal may be monitored by a PLC or other programmable device to facilitate control functions at the IPP facility. The trip coil will be monitored through the IPR.

NOTE: For all IMR and IPR installations, the approved SEL-751 relays are microprocessor-based units which can provide multiple protection and control functions. These relays provide multiple functions in one device as well as oscillography and sequence of events capability. ALL microprocessor-based relays must be supplied with suitable communication software to allow the transfer of data and settings from a computer and must derive control power from a DC source. AC power supply to microprocessor-based relays from the grid is not acceptable.

Use of a single microprocessor-based relay has the potential to lose ALL monitor and protection features upon failure. Therefore, if only one (1) microprocessor-based relay is installed, the relay failure (or health) contact must be connected to isolate the DER from the PPL Electric system upon failure of the relay. Installation of a second or backup relay eliminates the need for this trip and is strongly recommended.

5.1.3 Interconnected Inverter-based Generators

Inverters convert DC power to AC by means of electronic switching. Switching can be controlled by the AC voltage of the supply system (line-commutated) or by internal electronic circuitry (forced-commutated), or the newest type PWM (Pulse Width Modulation). Line-commutated inverters are generally not capable of operating independently of the AC supply system and, as such, cannot supply fault current or isolated loads. Forced-commutated and PWM inverters are capable of supplying fault current and may supply load independent of the AC supply system. All inverters will be expected to conform to the latest version of IEEE 1547 and UL 1741.

Equipment like Solar arrays (photovoltaic), certain wind turbines, microturbines, and energy storage systems for example, supply their power at DC or high frequency AC and use inverters to convert this power to 60 Hz AC at a suitable voltage level. DER systems below 500 kW, which are compliant with IEEE 1547 and UL-1741, can be connected to the PPL Electric system without any other additional protection. Facilities with more than 500 kW capacity or locations using multiple inverters will be subject to PPL Electric review and may require additional external monitoring and/or protection equipment such as POC protection, IMR, IPR and devices capable of synchronization checks.



5.1.4 Interconnected Synchronous and Induction Generators

Induction generation facilities will require a dedicated parallel IPR. If a capacitor is used to serve as the excitation source for an induction generator the capacitor must not be capable of remaining on the system with the generator(s) offline. Where a customer facility has inverters in combination with synchronous or induction generation, additional protection and interlock schemes may be required due to the possibility of the inverters supporting the rotating generation and making an island more likely to form. This will be handled on a case-by-case basis.

5.1.5 Classification of Installations

The following general classifications are done based on major operating characteristics and protection requirements for different types of generation installations. Each classification gives a general view of different types of DER facilities expected to be installed on the PPL Electric system (12kV or below). A summary of these classifications is shown below:

- TYPE 1D** Single phase, any type of DER, up to 150 kW.
- TYPE 2D** Three phase, any type of DER, up to 3,000 kW.
- TYPE 3D** Three phase, any type of DER, limit on generation shall be based on system impacts.
- TYPE 5D** Three phase, any type of DER, momentary parallel for less than 5 minutes, and limit on DER capacity shall be based on system impacts.
- TYPE 6D** Three phase, campus type installations, with no intentional power flow into the PPL Electric system. Limit on DER capacity shall be based on system impacts.
- TYPE 7D** Direct substations or switchyard connected facilities – typically large facilities at 12 kV.

NOTES: Following requirements shall be applicable to all TYPES:

- NOTE 1** The safety switch (G), as mentioned in Section 5.2.17, must be lockable in the open position, and must be located between the generator and the PPL Electric metering point, and provide a visible break.
- NOTE 2** Contact PPL Electric for specific metering requirements.
- NOTE 3** When more than one (1) breaker is installed between the DER(s) and the PPL Point of Interconnection, the IPR must trip one of the breakers which must isolate all DER units from PPL Electric system. The choice of breaker to be tripped shall be determined by the operation of the plant and PPL Electric reclosing practice, as per Section 5.8.
- NOTE 4** For all installations, the required relays are microprocessor-based relays which is currently the SEL-751 relay. These relays provide multiple functions in one device as well as oscillography and sequence of events capability. All microprocessor-based relays shall be ordered with suitable communication software to allow relay settings and other data transfer to and from a computer.



5.1.5.1 TYPE 1D

A Type 1D installation, shown in Figure 1, covers single-phase inverter, synchronous, induction generators and energy storage systems up to 150 kVA on a distribution circuit. These installations are characterized as:

- Having a fuse (D) specified by PPL Electric as the Point of Interconnection device, which also provides the visible break for safety.
- Having a safety switch (G) lockable in the open position, to block the generator from operation.

RELAY REQUIREMENTS

For Induction and Synchronous generation protection will be required to meet IEEE 1547 requirements. At a minimum this will include over/under voltage (59/27), over/under frequency (81), directional power (32) and synchronism check functions (25).

Inverter based generation and energy storage systems meeting the latest IEEE 1547 and UL 1741 are acceptable, up to the 150 kVA limit, without additional protection.

The relays are to be in the IMR/IPR cabinet. The preferred location for the current and voltage transformers is on the high side of the power transformer. However, connection to the low side of the power transformer may be possible, subject to PPL Electric review.

GUIDELINES

- See REMSI rules #7 and #8 for details on fused disconnect/disconnect switch.
- AC powered shunt trips are not acceptable for tripping/isolating the generator unless an appropriate UPS unit is installed.
- An AC undervoltage trip should be included on the POC isolation breaker if normal tripping is by a DC shunt trip.
- The main transformer must have a fully insulated WYE-WYE transformer winding suitable for impedance grounding.
- Refer to the REMSI documents for metering requirements.



5.1.5.2 TYPE 2D

A Type 2D installation, shown in Figure 2, covers three-phase inverter, synchronous, induction generators and energy storage systems up to 3000 kVA (aggregated capacity), connected to a distribution circuit. These installations are characterized as:

- Being connected through a three-phase transformer.
- Having fuses or a recloser as the Point of Common Coupling device.
- Having a safety switch (G), lockable in the open position, to isolate the DER from PPL Electric system.

RELAY REQUIREMENTS

For Induction and Synchronous generation, protection will be required to meet IEEE 1547 requirements. At a minimum, this will include over/under voltage (59/27), over/under frequency (81), directional power (32) and synchronism check (25) functions.

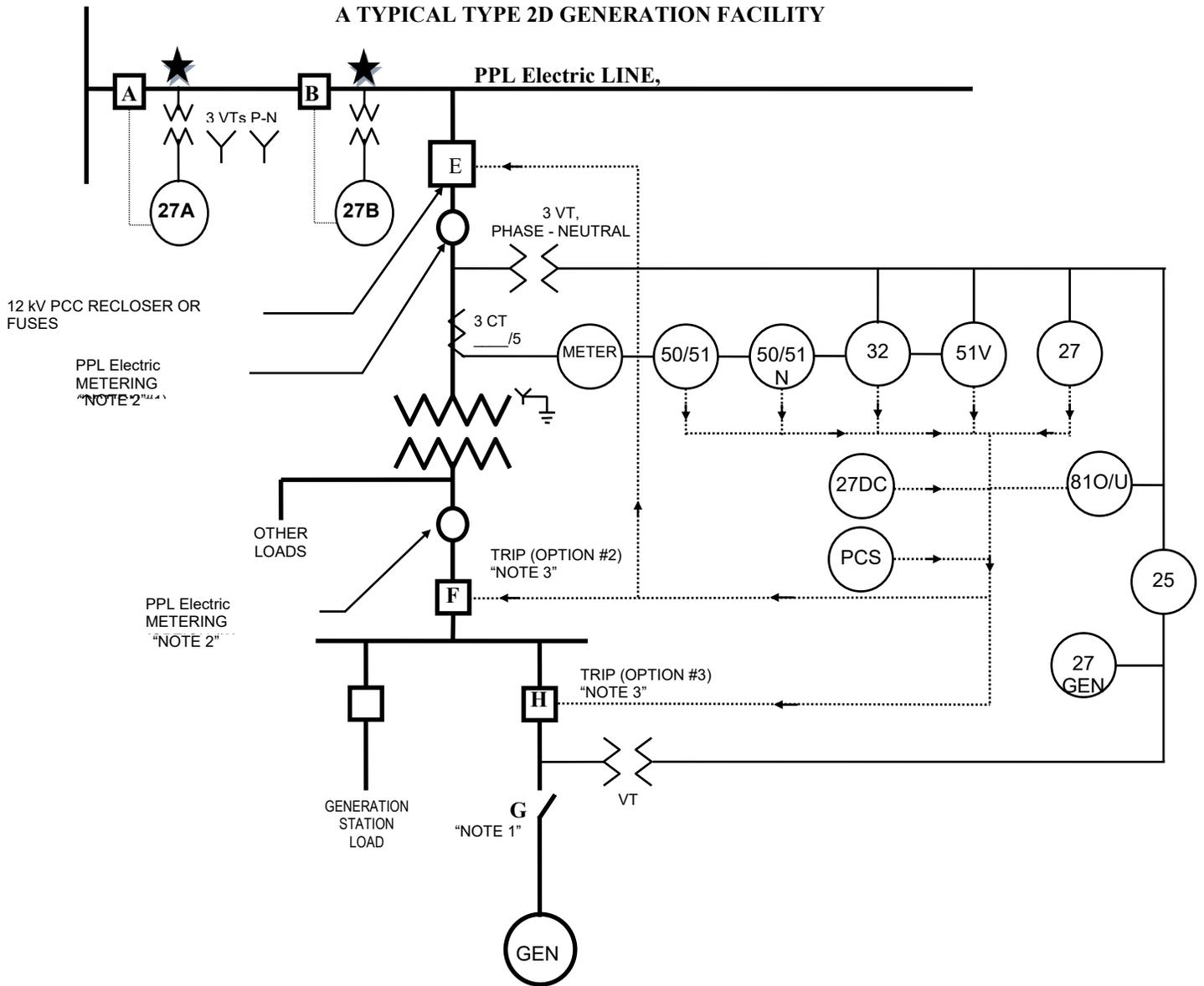
Inverter based generation unit meeting the latest IEEE 1547 and UL 1741 is acceptable up to the 500 kVA limit without additional relaying or protection. IMR will be required for any large inverter-based DER greater than 500 kW. IPR will be evaluated for any DER greater than 500 kW and required only if it is determined that the interconnection creates a high risk of islanding.

The required relays shall be in the IMR/IPR cabinet. The preferred location for the current and voltage transformers is on the high side of the power transformer. However, connection to the low side of the power transformer may be possible, subject to PPL Electric review.

GUIDELINES

- The protective relays shall trip the appropriate POC isolation breaker between the DER and PPL Electric point of interconnection.
- A circuit breaker must be utilized as the POC isolation device that the IPR would interface with, it can be utilized to provide the visible break for safety, if it is lockable in the racked-out position.
- See REMSI rules #7 and #8 for details on fused disconnect/disconnect switch.
- AC powered shunt trips shall not be acceptable for tripping the POC isolation breaker unless an appropriate UPS unit is installed to supply AC power.
- An AC powered undervoltage trip should be included on the POC isolation breaker if normal tripping is by a DC shunt trip.
- The main transformer must have a fully insulated WYE-WYE transformer winding suitable for impedance grounding.

TYPE 2D INSTALLATION



★ Fuses must be installed on customer VTs on the PPL side of the PCC Recloser.

FIGURE 2 TYPE 2D GENERATION INTERTIE REQUIREMENTS



5.1.5.3 TYPE 3D

A Type 3D installation, shown in Figure 3, covers three-phase inverter, synchronous, induction generators and energy storage systems greater than 3000 kVA (aggregated capacity), connected to a distribution circuit. These installations are characterized as:

- Being connected through a three-phase transformer.
- Having a high-side circuit breaker.
- Having a safety disconnect switch, lockable in the open position, to isolate DER from the PPL Electric system.

RELAY REQUIREMENTS

IPR and SCADA are required at these installations to enable PPL Electric to remotely monitor electrical conditions at the DER facility and provide a means for PPL Electric to remotely disconnect the DER from the PPL Electric system in the event of a system emergency.

GUIDELINES

- A three-phase synchronism check relay (25) supervises reclosing of substation circuit breaker “A” (This will stall reclosing until the DER is isolated for an adjustable time delay.
- The protective relays shall trip the appropriate POC isolation breaker between the DER and PPL Electric point of interconnection.
- A circuit breaker must be utilized as the POC isolation device that the IPR would interface with, it can be utilized to provide the visible break for safety, if it is lockable in the racked-out position.
- See REMSI rules #7 and #8 for details on fused disconnect/disconnect switch.
- AC powered shunt trips shall not be acceptable for tripping the POC isolation breaker unless an appropriate UPS unit is installed to supply AC power.
- An AC powered undervoltage trip should be included on the POC isolation breaker if normal tripping is by a DC shunt trip.
- The main transformer must have a fully insulated WYE-WYE transformer winding suitable for impedance grounding.
- A SCADA trip from PPL Electric to the DER facility will be required. Any of the following devices may be operated (tripped) by SCADA trip signal:
 - The high side breaker
 - The low side breaker
 - The generator synchronizing breaker (if different from 1 or 2 above).



5.1.5.4 TYPE 5D

In a Type 5 installation, the DER is allowed to parallel with the PPL Electric system **for a limited period (not greater than 5 minutes)**, but not inject any power to PPL Electric system. Generally, load of this type of facility is larger than the installed DER capacity, and therefore, there is no excess power to send to PPL Electric system.

NOTE: This type is different from a make-before-break transfer switch. A make-before-break transfer switch is expected to parallel for less than 100 milliseconds and does not have a mode that will maintain the parallel operation position of the switch. For applications involving transfer switches, please contact PPL Electric for approval of the proposed transfer switch.

For TYPE 5D installation, following requirements must be met (at a minimum):

1. The DER will be required to supply an IPR cabinet with (at a minimum):
 - i. Synchronism check relay (25) which supervises closing of CB used to parallel customer facilities with PPL Electric system when the generator is operating. A microprocessor based three-phase relay with over/undervoltage (59/27), over/underfrequency (81) protection available, and a sensitive reverse power relay (32) connected to measure power **into** the PPL Electric system at the utility/customer point of common coupling (or PPL PCC).
 - ii. The reverse power relay (32) shall have a timer activation when the DER is paralleled with the PPL Electric system and shall trip the POC isolation breaker if paralleling time exceeds 5 minutes or a predetermined duration to separate the DER from PPL Electric system. Timer logic must be hardwired or hardcoded (not controlled by any intermediate device such as a programmable logic controller).
 - i. PPL Electric control switch (as mentioned in Section 5.2.7) and associated indication lights.

NOTE: Depending on the exact location, size, and type of DER, additional relay(s) may be required. Intertie relays that initiate tripping of the DER need to be in service when the DER is paralleled with the PPL Electric system.

2. Due to the minimal relaying, PPL Electric will require a “Fail-Safe” AC powered undervoltage trip control scheme or a DC powered control shunt trip scheme with a backup AC undervoltage trip.
3. The DER will not be allowed to send any power into the PPL Electric system.
4. The DER must supply a complete set of drawings and system information for PPL Electric review and approval.
5. PPL Electric will assume operational control, but not ownership, of the relay(s), control switch, etc. in the IPR cabinet.
6. PPL Electric will specify the amount of time for which the DER is allowed to operate in parallel with the PPL Electric system if less than five minutes.



5.1.5.5 TYPE 6D

Campus type installations where one or more generators are installed at various locations within a facility

The TYPE 6D installation may be like any of the previously discussed types of installations, *with a condition of no power flow back to PPL Electric system*. These installations will contain one or more reverse power relays that will be programmed to detect power flow into the PPL Electric system. If reverse flow is detected, a suitable device shall operate to immediately isolate DER from the PPL Electric system.

This installation tends to be part of campus style facilities, and therefore do not lend them to a standard design. The customer is required to submit detailed one line drawing(s) to discuss which devices should operate to isolate the DER from PPL Electric system, and the appropriate locations of the various sensing components (CTs, VTs (PTs), and the relaying). PPL Electric will review the proposed design and shall comment as necessary.

The device to be used to isolate the DER shall be proposed by the customer depending on the operation of their facility.

Depending on the possible impact of the DER on the PPL Electric system, additional functions may be required to supplement the reverse power relay.



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5.1.5.6 TYPE 7D

Large Units connected directly to distribution substations, via express distribution feeder(s), where DER can be isolated from the PPL Electric system at substation level.

This type of installation shall be assessed on a case-by-case basis. Please contact PPL Electric for further details with proposed DER facility design.



5.1.6 Temporary Installations

Temporary installations are those installations where the DER is rented or installed for a specific period, with the possibility of being removed and replaced with different equipment and is not permanently connected to the PPL Electric system. These DER systems are usually installed in campus type facilities, usually limited to less than 200 hours of operation per year. The following items should be considered for these applications:

1. The relaying should be installed in such a manner that it will NOT need to be removed or re-installed with the DER.
1. Consideration should be given to limiting or eliminating the connections between the DER controls (tripping, closing, and auxiliary switches), and the use of a single POC isolation breaker to isolate multiple DER units.
2. IEEE 1547 requirements should be met by the relaying, independent of the type of DER installed.
3. For installations above 2.0 MVA, PPL Electric will generally need to know when the DER is operating via SCADA, revenue metering, or a PJM Internet based SCADA system.
4. The entire design of the facility should take into consideration the probability of changing out the DER equipment on a yearly basis WITHOUT the need to make changes to the PPL Electric required relaying cabinet.



5.2 IMR AND IPR SYSTEM DESIGN REQUIREMENTS

5.2.1 General

All relays shall use phase-to-neutral potential and phase-current (from WYE connected VTs and CTs) unless otherwise specified. Proper phasing and polarities must be followed as indicated in the manufacturers' instruction books. **ALL IMR/IPR and SCADA transducers are to be connected according to PPL Electric phase designations.**

All relays must incorporate an isolation device to isolate ALL inputs and ALL outputs of the IPR relaying for testing. Typically test switches mounted on the IMR/IPR panel are utilized.

Contact the PPL Electric assigned Project Manager for any questions related to the approved list of isolation switches which can also be found in the IPR SEL-751 document which can be provided by PPL Electric.

5.2.2 Drawing Acceptance

All IMR/IPR related drawings shall be reviewed by PPL Electric for acceptance. The elementary diagrams (potential, current, and control) and the physical layout drawing must be ACCEPTED by PPL Electric before the facility can be placed in service. The customer is expected and required to submit ALL drawings required to complete the review of the IMR/IPR design, VT and CT inputs, the DC supplies, trip/close coils of the controlled equipment as well as any and all interlock devices. This includes any manufacturers or subcontractor drawings. *NOTE:* all drawings submitted electronically must be scalable to the original size for plotting. See "Drawing Requirements" for further information.

ALL drawings submitted to PPL Electric for the DER facility above 150 kVA must be signed by a licensed Professional Engineer in good standing in the Commonwealth of Pennsylvania.

All drawings are reviewed subject to this NOTICE:

This information was prepared from a review of customer drawings by PPL Electric. Drawing review applies only to the general arrangement of the facilities and the primary and the control equipment associated with the Interconnection Monitor Relaying and Intertie Protection Relaying Equipment. Neither PPL Electric nor any person acting on behalf of PPL Electric (a) assumes any responsibility for the correctness of design, drawings, installation or operation: or (b) assumes any liabilities with respect to the use of, or for damages of any kind resulting from the use of, any comments disclosed in the review document.

NOTE: It is suggested that panel construction should not begin until PPL Electric approval has been obtained on the IPR drawings. Any work done prior to approval of the drawings may need to be redone based on approved drawings.

5.2.3 Current and Voltage Transformers

PPL Electric shall review the voltage transformer (VT), also known as a potential transformer (PT) and current transformer (CT) ratios and accuracy class. WYE-grounded VTs and WYE-grounded CTs are required. These VTs and CTs must be relaying class accuracy and be able to support the connected burden during normal load and fault conditions. Typically, 200 VA VTs (or PTs) and class C400 CTs at the approved tap ratio will be acceptable for facilities using discrete relays. IEEE 1547 compliant equipment using remote mounted CTs and VTs will be required to supply equipment compatible with the IEEE 1547 manufacturer's specifications. Equipment with lower ratings must be reviewed and accepted by PPL Electric.

The preferred location for the source of relay potentials and currents is the high side of the DER power transformer. For all single phase and three-phase installations up to 150 kVA where use of high-side VTs and CTs is uneconomical



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or impractical, these devices may be located on the low-side of the DER power transformer. This configuration must be reviewed and approved by PPL Electric and, in general, will only be permitted if service to other PPL Electric customers will not be impacted.

All installations must include:

- An ammeter (for single-phase installations), or an ammeter and a switch to monitor all three phases (for three-phase installations), or suitable 3 phase digital display.
- A digital multi-function meter, transducer, or relay, where a PPL Electric SCADA is to be installed. This device will be used to collect the analog data for the SCADA, and to provide local readings. Contact PPL Electric for current equipment requirements.
- A visible SEMAPHORE on each of the breakers between the DER and the PPL Electric system to determine the actual status of the breaker (open or close).

To prevent a possible undesirable out of phase connection of the DER to the PPL Electric system, synchronous generators shall require a synchronization check relay (25), and induction generators or inverters shall require a voltage check relay (27). These devices must be in the IPR cabinet and connected to prevent closing of the POC circuit breaker, or other breaker as agreed upon by PPL Electric, for:

- An out-of-phase condition.
- A de-energized line condition (PPL Electric supply breaker open).

Where synchronism check (25) is required, a red indicating LED and nameplate shall be placed in series with the VT relay input fuse. The light shall be lit red when the VT is energized and not lit when the VT is de-energized.

If there is substantial distance or other equipment between the generation equipment and PPL Electric, it may be necessary to have the sensing CTs and VTs located at the Point of Common Coupling (PCC). Also in this case, the DER operator may desire to have the IMR/IPR relaying operate a breaker other than the POC isolation breaker. When the CTs, VTs, or controlled breaker are remote (exceeds a distance of 200 ft) from the IEEE 1547 compliant equipment, then the protection and drawings need to be reviewed and approved by PPL Electric.

PPL will supply fault current data at the point of interconnection to facilitate the proper sizing of protective equipment.

CTs and VTs (relay windings) are NOT to be shared with any customer or DER relaying, or revenue metering, without prior PPL Electric approval.

Voltage Transformers at 12.47 kV, on the PPL Electric side of the PCC recloser/POC isolation breaker must have adequate high-side voltage fusing to protect PPL Electric system from equipment failure.

5.2.4 Manufacturer Firmware

When purchasing SEL 751 relays from the manufacturer, the customer must request the Special Specification SS-1566 version of the relay in order to ensure firmware compatible with PPL Electric's distribution system is applied.

5.2.5 DER Relay Settings

PPL Electric will request specific setting information on generation relays which will act to trip the DER. The purpose of this request is to review the protection settings to ensure proper coordination of the generation relays with PPL



Electric operating practices. It is, however, the responsibility of the DER owner to apply DER protective relay settings that must provide adequate protection to meet IEEE guidelines and other regulatory body requirements.

NOTE: Changes in the IPR settings might be required in the future if PPL Electric's network configuration or fault level change.

5.2.6 IPR Tripping Relays

The SEL-751 Relay is PPL Electric's approved microprocessor relay for IPR installations. The current microprocessor based protective relays typically provide multiple trips and block close contacts. It is expected that these contacts will be connected directly to the required breaker(s) for trip and block close functions.

The customer must install suitable equipment to monitor continuity of the lockout relay coil without affecting operation. The circuit breaker trip coil will be monitored through the IPR and closing will not be permitted if the trip coil has failed.

5.2.7 IPR Control Switches

The PPL Control Switch (PCS) shall be in the IPR Cabinet for PPL Electric use. This switch will provide the capability to locally disconnect the DER from the PPL Electric system when circumstances require manual disconnection. This PCS switch shall provide the close permissive signal but will not close the breaker directly.

A standard PPL Electric control switch (General Electric Company Type SB-1, Model 16SB1B2X2) or equivalent with flag, sliding contacts, etc. must be used for the PPL Electric control switch. Alternative suppliers for this equipment will be considered if the functional requirements are met.

The PPL Electric control switch shall be a three-position switch with spring return from close to normal and from trip to normal. (The "close" position shall be to the right of "Normal" and the "Trip" position shall be to the left of "Normal." This will maintain compatibility with standard PPL Electric controls.)

The PPL Electric switch shall be able to trip but NOT close the POC isolation breaker. The PPL Electric control switch will provide an interlock to block closing of the POC isolation circuit breaker unless the PPL Electric control switch is in the Normal After Close (NAC) position. This switch is required to be pad-lockable to prevent unauthorized access. The exception to this requirement is for facilities under PJM agreements and subject to PJM rules and regulations.

5.2.8 Breaker Status

PPL Electric must be able to determine the actual status of the DER (online or offline) before any switching is attempted on the safety switch or POC isolation breaker. Indicating lamps (driven by circuit breaker auxiliary switches) and a means of sensing actual current flow (CTs and an ammeter) or a physical indication (breaker semaphore) must be available to PPL Electric switchman to verify the DER is not in parallel operation.

5.2.9 Indicating LED

Two indicating LEDs should be located within 6" of the PPL Electric control switch: A red LED (labeled CLOSED) to indicate when the generator isolation circuit breaker is closed, and a green LED (labeled OPEN) to indicate when the circuit breaker is open.

5.2.10 Control Systems

The DER customer has the option to use either an AC or DC control system as described in Section 5.2.11 and Section 5.2.12. **Capacitor trip devices shall not be allowed.**



5.2.11 AC System

Typically, AC control schemes will be used on very small generation projects. The AC control system supply must use 60 Hz power derived from the PPL Electric line. The system must be designed to be fail-safe, and the failure of any single component must result in a trip of the DER isolation circuit breaker.

NOTE: The AC system should use continuously energized auxiliary relays with contacts to trip the DER circuit breaker whenever the relays drop out. If a molded case circuit breaker (or equal) is used, it must be equipped with an undervoltage trip option.

All installations must isolate (trip) the DER in such a manner that return of the generation (i.e., closure of the generator or POC breaker) can only occur by:

- A manual operation under the direct control of the PPL Electric System Operator
- Or
- A time-delayed synchronization check or supervised voltage-check operation after the PPL Electric source has returned to normal.

Under no circumstances shall the POC isolation breaker be closed immediately upon restoration of the PPL Electric source. Automatic operation of these facilities must be discussed with PPL Electric.

White light indication lamps and nameplate must be provided to monitor the AC source.

5.2.12 DC System

This system will use a battery to supply tripping energy to the circuit breaker. This DC source must be continuously monitored by the undervoltage relay (27/DC) which will trip the circuit breaker if the DC source voltage falls below 10% of nominal. In general, the DC system should use normally de-energized relays.

All such installations must isolate (trip) the DER in such a manner that uncontrolled automatic reclosing of the POC isolation breaker cannot occur for:

- A manual tripping operation
- Or
- An automatic (protective relay initiated) operation. In such situations, a time-delayed automatic synchronization check or voltage check supervised operation is required to close the generator breaker after the PPL Electric source has returned to normal.

The POC isolation breaker must not close immediately upon restoration of the PPL Electric source. An automatic reclosing operation of these facilities must be discussed with PPL Electric prior to implementation.

An amber or yellow indication lamp, with a nameplate, must be provided to monitor the DC source.

5.2.13 PPL Electric Reclosing

PPL Electric will review the line loading in various line sections to determine the probability of forming an unintentional island with the proposed DER. The result of this study will be a list of reclosers and/or the feeder circuit breaker that do or do not need to be modified due to the proposed DER.



Synchronization Check (25) and voltage supervised closing of the POC isolation breaker is required to protect PPL Electric's system and the equipment of PPL Electric customers. Unsupervised reclosing with parallel DER could cause damage to customer's equipment. It is the customer's responsibility to evaluate the potential impact of PPL Electric reclosing practices on the DER system, and to install suitable protection for their equipment.

PPL Electric normally provides automatic reclosing on all 12 kV line circuit breakers. Additionally, automatic sectionalizing for faults is provided on the distribution system with electronic and hydraulic reclosers. To protect both PPL Electric and customer's equipment from possible damage due to out-of-phase reclosing, the substation 12 kV line circuit breaker and the line reclosers may have to be modified to have synchronism check relays (25).

5.2.14 Targets

Individual Intertie Protective Relays (IPR) must be equipped with targets that indicate operations. These targets shall operate only when the associated relays trip the POC isolation circuit breaker. Microprocessor based relays will have internal targets (typically LED indicators) to indicate the type of fault, and trip status.

5.2.15 Indicating Meters

Where required, the customer shall install an ammeter to indicate the flow of current in the POC switch.

For three-phase installations, an ammeter switch (General Electric Company, Westinghouse, or Electro Switch) must be installed to allow ALL phase currents to be read.

NOTE: If SCADA is to be installed, the above ammeters should be replaced with suitable IEDs (Intelligent Electronic Devices). This meter will be directly connected to the PPL Electric SCADA to supply the required analog data, equipment position, and can supply local indication of current.

5.2.16 Current and Potential Neutral Circuits Grounding

Neutral circuits should not be confused with the ground circuit. All current and potential neutrals shall be isolated from all other circuits and be grounded at one point only. The preferred grounding location will be at the IMR/IPR cabinet, on the cable side of the isolating links. Other locations can be considered if the safety of PPL Electric personnel is not compromised.

5.2.17 Visible Break Safety Switch (or visible breaker disconnect switch)

DEFINITION

A switch that, when in the open position, allows the physical contacts to be viewed and provides electrical isolation of DER from PPL Electric system.

ACCEPTABLE DEVICES

Devices in compliance with IEEE 1547, designated for use as 'Visible Break Disconnect' include the following:

- Fused disconnect switches.
- Circuit breakers that can be physically removed from switchgear and locked on the removed position.



NON-ACCEPTABLE DEVICES

Following devices are not acceptable as visible break safety/disconnect switch:

- Load-break switches with arc chutes that obscure a direct view of the contacts with the switch in the open position.
- Molded case circuit breakers.
- Any device with hidden or non-observable contacts.

A "racked out" breaker can be considered as a visible break if it is capable of being locked in the "racked out" position. However, if the facility requires load-break capability, then a second device must be installed in series with the visible break safety switch to provide the load breaking capability.

This visible break disconnect switch is a safety device and must be reviewed by PPL Electric Engineering for correct application, position, and type, prior to the start of construction.

Customer facilities where multiple generators are installed, one designated visible break disconnect switch must disconnect all generators from PPL Electric system.

A warning sign must be placed for visible break disconnect switches to state "BOTH SIDES ENERGIZED IN CLOSED AND OPEN POSITION".

Please contact PPL Electric Engineering for the latest specification, possible switch locations, and types of acceptable switches.

5.3 IMR and IPR CABINET

The IMR/IPR cabinet or panel shall contain all relays and controls specified by PPL Electric for a particular installation, except for the Voltage Check and Synchronization Check functions which may be applied on a per generator basis for multiple generator installations.

PPL Electric is responsible for the initial programming and requires continued access and control of the relaying. The customer is responsible for installation and maintenance of the relaying. This can be provided by a dedicated padlockable cabinet, with a PPL Electric lock, or using passwords on the relays, or both. PPL Electric will specify relaying requirements and any special metering for the generation installation.

PPL Electric prefers a dedicated cabinet suitable for a PPL Electric padlock. However, if this is not practical, passwords can be enabled on the microprocessor-based protection relays to limit access. The IPR protection equipment is installed to protect the PPL Electric system from adverse effects of the generation. For this reason, controls of this equipment shall remain with PPL Electric. This can be in the form of a locked cabinet (PPL Electric lock), suitable passwords on the protective equipment, or a combination of both forms of control.

This cabinet is expected to be located inside a suitable building to protect the sensitive electronic equipment from weather, and to provide shelter during maintenance activities. **Locating the IMR/IPR equipment in a pole mounted cabinet, along a distribution line, is not acceptable.** Locating this in a metal enclosed switchgear facility would be acceptable.

Following specifications must be followed as closely as possible for all proposed generation installation:



5.3.1 General

- Only IMR/IPR as detailed by PPL Electric shall be installed in the cabinet unless passwords have been implemented to limit access to the IPR relay(s). The IMR/IPR relay(s) will NOT contain any customer generation logic, interlocks, alarms, or controls.
- The customer shall furnish all equipment required for the IMR/IPR cabinet, except the special metering equipment, and the SCADA protocol converter, if required.
- All component (relay, resistor, fuse, etc.) ratings and ranges must be reviewed by PPL Electric.
- The customer is requested to identify PPL Electric as the end user to all suppliers of protective relays and switches. PPL Electric requests access to firmware updates or manufacturers' service bulletins.
- The maximum voltages allowed in the cabinet are 140V_{DC} and 240V_{AC} nominal. Any voltages above this level must be barricaded and labeled.
- All relays must be current production utility grade relays and must be reviewed and approved by PPL Electric.
- PPL will inspect the cabinet prior to assuming operational control; any deficiencies must be corrected by the customer before acceptance.
- The customer shall be responsible to mount the cabinet in an easily accessible location. The customer shall provide an access procedure for PPL Electric access to any PPL Electric owned, maintained, or controlled equipment (IMR, IPR, or SCADA).
- The customer shall supply copies of the drawings listed in Section 5.3.2 for PPL Electric review and acceptance. Contact PPL Electric for the specific quantity required. AutoCAD is the preferred electronic format; however, PDF is also acceptable. The drawings will be assigned a PPL Electric drawing number and entered into the PPL Electric drawing system and re-issued as the 'drawings of record' for the customer generation installation.
- ALL drawings must be suitable to be scaled to "D" size (24 inches by 36 inches), except for reports, word or excel documents. Reduced size drawings are NOT acceptable.

5.3.2 Required Drawings and Instructions

- Potential/current elementary diagram(s) – showing the IMR/IPR equipment.
- Control elementary diagram(s) – showing the POC isolation circuit breaker controls.
- Wiring diagram(s) or wire list – for the Intertie protective relay cabinet.
- Bill of Material showing the instrument transformers and relays.
- Description of operation explaining the generator control scheme.
- PPL will review elementary diagram(s) typically within 30 days of receipt. Wiring diagram(s) or list will not be reviewed. Panel construction should not begin until PPL Electric has reviewed and approved the drawings.
- The customer is responsible for the accuracy of all drawings.
- The customer shall supply copies of all "As Built" drawings and instruction books for relay switches, auxiliary relays, VTs (PTs), CTs and any other devices as requested by PPL Electric, prior to final acceptance of facility. Contact PPL Electric for the number of copies required.

5.3.3 Equipment Housing



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For outdoor installations, there must be a minimum three (3) feet of clearance between the IMR/IPR cabinet and any fence or other structure that might interfere with the opening of the door(s) or access to the cabinet. The IMR/IPR can be installed in a switchgear type line up of cabinets provided that sufficient clearances have been provided as per NEC and NESC standards.

For indoor installations all walkways around the IMR/IPR cabinet must be at least three (3) feet wide. Any other structures or cabinets must not obstruct doors.

PPL Electric strongly recommends that two (2) relays be provided, such that the failure of one will allow continued operation of the generation facility until the failure can be repaired. Failure of a single relay installation shall require the immediate disconnection of the generation from the PPL Electric system. This is typically accomplished by wiring the relay fail contact to the CB trip coil, such that the CB will be tripped immediately upon a failure of the single relay.

Following are the guidelines for IMR/IPR cabinet equipment housing:

5.3.3.1 General Construction

The cabinet minimum size must allow easy access to all components and if equipped, must not restrict motion of internal swing panel.

1. IMR/IPR cabinets, which will be subjected to an outdoor environment, shall conform to specifications for a NEMA Type 3R - Ventilated Enclosure. Indoor cabinets shall conform to specifications for a NEMA Type 4 Enclosure. Specifications for these enclosures are contained in NEMA Standard ICS 6-1978.
2. Single door cabinets will need the following:
 - I. A latch handle on the door with provisions for PPL Electric's padlock (3/8" hole).
 - II. A hinged panel, opening in the same direction as the door.
 - III. A handle to facilitate opening and closing of the hinged panel.
 - IV. A latch or equivalent to keep the panel in the open position or the fully closed position and hold it there.
 - V. All components and wiring must be accessible from the front door.
3. For double door cabinets all components and wiring must be accessible from the front (and/or rear) doors. If all components are not accessible from the doors, then the cabinet shall have a continuously hinged panel opening in the same direction as the front access door.
4. IMR/IPR relays may be mounted on the doors of cabinets not exposed to weather. The PPL Electric control switch must be mounted in a convenient location to allow easy access if switching is required. The intended use of this switch is for PPL Electric use. The customer must not change the position of this switch without contacting PPL Electric.
5. The IMR/IPR controls and indication lamps may be mounted on the door provided that the components subjected to an outdoor environment are for weatherproof construction.
6. Space shall be provided near the terminal blocks to allow connection of conduits.
7. Hinges exposed to the weather shall be stainless steel or equivalent non-rusting material.
8. One duplex 120V_{AC}, 15 amps receptacle must be located in the cabinet or within 10 feet of the cabinet, and must be accessible for PPL Electric use. This circuit cannot be supplied by the PT's or VT's used for relaying.



9. Cabinet is to be labeled "Generation name control cabinet" in black letters with a yellow background and a minimum height of 1".

5.3.3.2 Heaters

1. Heaters are required in all outdoor cabinets to control condensation, and shall operate at 120V_{AC}, and rated at 125V_{AC}.
2. Heaters shall not be located near a device whose performance is dependent on ambient temperature.
3. A protective screen or shield shall enclose all heaters.
4. Humidistats and thermostats may be installed, subject to PPL Electric review, to control heat during summer months and maintain an adequate temperature differential if there is sufficient heat provided by other components.

5.3.3.3 Grounding

1. Cabinet and duplex receptacle must be solidly grounded.

5.3.4 *Wiring and Identification Guidelines*

Following are the guidelines for wiring and identification of cabinet equipment:

5.3.4.1 General

1. Cabinet wiring shall meet current NEC and industry standards, and suitable for operation up to and including 90°C.
2. Cabinet wiring should be free from abrasions and tool marks, and all bends of wires shall have a minimum of 1/4" radius.
3. All wires should be anchored to the cabinet or bundled when running between devices. Wiring should be installed so that it can be visually traced and checked.
4. Wiring should be installed to avoid damage to the cable and its insulation. Movement of the hinged panel shall not damage the cable or its insulation or cause stress to the termination points on the panel or on the door.
5. Wiring and device location should not prevent the removal of any equipment or block access to equipment for inspection and maintenance.
6. All equipment should be mounted and wired in such a manner that no energized terminals or connections are exposed with cabinet swing panels and doors closed.
7. All relays or IEDs (Intelligent Electronic Devices) which are not equipped with internal isolation devices must be connected through an external test device (i.e., WHSE FT-1 or similar as determined and approved by PPL Electric). ALL inputs and outputs for protective relays and IEDs are to be connected through suitable test switches. Further the switches are to be connected to allow the isolation of the device and the injection of current or voltage WITHOUT disturbing other devices that may be connected to the same CTs or VTs.
8. All incoming and outgoing cables/conductors will terminate on sliding link terminal blocks located in the IPR cabinet.



5.3.4.2 Terminal Blocks

1. Terminal blocks shall be mounted such that the connections and links are accessible and not blocked by projecting equipment.
2. Terminal blocks shall be mounted with a minimum separation of 6" from sidewalls and adjacent equipment and a minimum of 4" separation from the bottom of the housing.
3. Terminal blocks shall be mounted such that the sliding link:
 - ii. Falls closed when loosened, if mounted in horizontal rows.
 - iii. Moves toward the front of the cabinet when opened, if mounted in vertical rows on side panels.
 - iv. Moves away from the panel centerline when opened, if mounted on the rear panel.
4. There shall be a minimum of 10% or 2, whichever is a greater, spare terminal included in the cabinet for modifications.

5.3.4.3 Terminal Connections

Suitable connections or connectors are to be used for the applications. PPL Electric prefers Ring Tongue Lugs, which completely encircle the screw or the stud. The crimping tool should be suitable for the connectors used. Soldered terminals or connections should generally be avoided.

5.3.4.4 Identification

A suitable means of identifying the conductors or wiring should be employed to provide a method to trace the wiring.

5.3.4.5 Nameplates

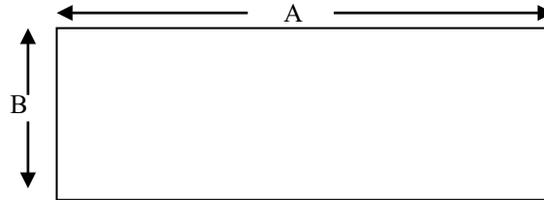
Suitable nameplates should be applied to the various pieces of equipment to avoid confusion or switching errors. The actual text on the nameplates should be shown on the drawings for PPL Electric review.

The same wording on these nameplates should be referenced in any operational instructions.



Below is a typical list of nameplate schedules.

NAMEPLATE SCHEDULE



NOTE: All dimensions in inches.

FIG	DIM A	DIM B	HEIGHT OF LETTERS	WHERE USED
1	2-1/2	1	7/32	All primary circuits on generating or substation switchboards (up to two lines)
2	2	3/4	1/8	Equipment on switchboards or in cabinets (up to 3 lines)
3	-	-	-	-
4	-	-	-	-
5	2-1/4	1-1/2	1/8	Equipment on switch boards or in cabinets (up to 3 lines)
6	-	-	-	-
7	4	1	1/8	Equipment on switch boards or in cabinets (up to 4 lines)
8	-	-	-	-
9	3-5/8	3/4	1/8	3 gang fuses and indicating lights (up to 3 lines)
10	2-3/4	1-1/4	1/8	Equipment on switch boards or in cabinets (up to 5 lines)
11	1-5/8	13/16	1/8	SCADA
12	4-1/2	1	7/32	Small cabinet doors (up to 2 lines)
13	8	2	1/2	Large cabinet doors (up to 2 lines)
14	3-1/2	1-1/4	7/32	Identification on front and back of switchboards (up to 3 lines)

5.4 POWER TRANSFORMER CONNECTIONS AND VECTOR DIAGRAMS

5.4.1 New Transformers

All three phase DER must be isolated from PPL Electric customers by a power transformer. For new three phase installations the **preferred** isolation transformer is WYE-grounded high side (PPL Electric). If a wye-wye configuration is used, the transformer must be solidly grounded on the low side. The transformer high side winding is to be specified for proper insulation to allow neutral impedance grounding. The need for neutral impedance grounding depends on the impact of the generation to the PPL Electric system. It will not be necessary in all cases.

Customer DER, operating in parallel with PPL's distribution system, may not be served by an open delta transformer configuration. The power transformer(s) connections must be reviewed and approved by PPL Electric prior to purchase.

5.4.2 Existing Transformers

Existing facilities which install DER will typically have a Delta high side and WYE low side transformer. Those will be accepted by PPL Electric; however, additional high voltage protection will be required but may cause excessive



customer momentary interruptions. Further, the generator sponsor should review the transformer connection and the impact on the connection of the generation equipment to the existing plant.

5.4.3 Vector Diagrams

PPL Electric System - 12 kV and Below

PPL Electric employs a "C-B-A" phase sequence at voltage levels of 12 kV and below. Most references cite an "A-B-C" or "1-2-3" sequence. For PPL, the equivalent would be "C-B-A" or "1-2-3".

PPL Electric chose to connect the high side of delta-wye power transformers in the following manner in all divisions except the Lancaster Division:

A phase - H1 Bushing
B phase - H2 Bushing
C phase - H3 Bushing

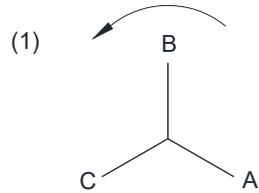
For the Lancaster Division:

C phase - H1 Bushing
B phase - H2 Bushing
A phase - H3 Bushing

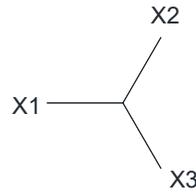
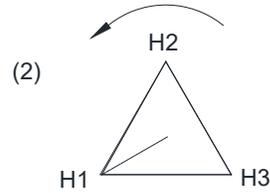
For all PPL Electric divisions except Lancaster, the transformer connections noted above and the standard phase relationships and transformer terminal designations for three-phase power transformers as outlined in IEEE Standard C57.12.00-1993 result in a non-standard phase displacement of the low side voltage leading the high side voltage by 30 degrees.

For Lancaster Division, the transformer connections noted above and the standard phase relationships and transformer terminal designations for three-phase power transformers as outlined in IEEE Standard C57.12.00-1993 result in the low side voltage lagging the high side voltage by 30 degrees.

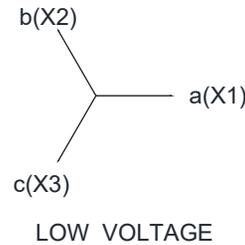
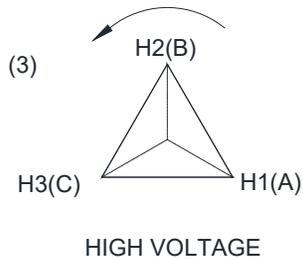
The below mentioned diagrams illustrate the transformer connections and angular displacements:



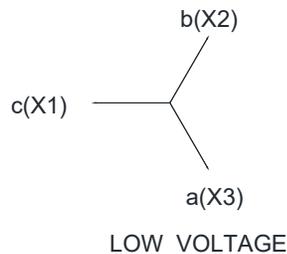
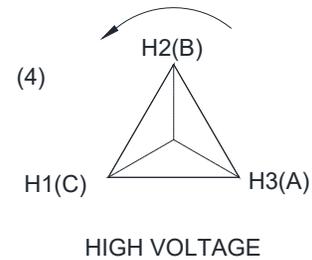
PPL 12 kV AND BELOW
C-B-A ROTATION



INDUSTRY STANDARD



LOW VOLTAGE LEADS
HIGH VOLTAGE BY 30°
(SYSTEM).



LOW VOLTAGE LAGS
HIGH VOLTAGE BY 30°
(LANCASTER).



5.5 BASIC INSULATION LEVELS AND CLEARANCES

Customer equipment’s BIL is expected to coordinate with established PPL Electric designs. In addition, NESC clearances are to be maintained. Minimum insulation levels for service voltage (higher levels are customer's option):

12 kV system = 110 kV BIL (open air)
= 95 kV BIL (switchgear)

Electrical clearances (phase-to-phase, phase-to-ground, elevation above grade/road, etc.) of bus conductor and equipment in a substation shall, at a minimum, be designed to the National Electrical Code (NEC) and National Electrical Safety Code (NESC) requirements, latest code revisions, for the BIL insulation levels chosen.

Minimum phase-to-phase (centerline) spacing of point-of-contact air switches and tie air switches (if installed):

Nominal System Voltage (kV)	Basic Impulse Level (kV BIL)	Disconnecting Vertical Break (inch)	Switches Side Break (inch)	All Horn Gap Switches* (inch)
12	95	30	-	-

5.6 VOLTAGE LEVELS AND VARIATION

The primary voltage levels on the PPL distribution system are as noted below:

Nominal System Voltage (kV)	Voltage Range at Point of Interconnection High - Low (kV)
12.47	13.1 – 11.8
13.2 (Hershey Area – Check with PPL Electric)	13.8 – 12.5

5.7 INSTALLATIONS INVOLVING 15 KV CLASS SWITCHGEAR

For Installations involving only 15 kV class switchgear (12 kV supply) with underground connections and fused POC protection, please refer to the REMSI instructions at website: REMSI (Rules for Electric Metering and Service Installation) and PPL Specification 6-09-199, titled “Installation Instructions for 12 kV 3-Phase Service Termination and Metering Compartments in Customer-Owned Switchgear Cubicles, Underground Supply”, for requirements. If fuses are used as the POC protection, an IPR may still required if the customer has generation.

5.8 POINT OF DER CONNECTION (POC) ISOLATION BREAKER

This breaker is typically the main device that isolates the generation from the PPL Electric system; this breaker could be the generator breaker, or any other appropriate breaker (subject to PPL Electric review) between PPL Electric point of interconnection and generator. It must be able to withstand 2 per unit voltage (minimum) across



the open contacts. It should be equipped with breaker failure protection to provide an alternate means of isolation should the breaker fail to trip. It may be necessary to coordinate the breaker failure relaying with PPL Electric protective relaying. SF-6 breakers require special consideration since loss of SF-6 gas pressure will reduce the breaker's dielectric capability and the ability to interrupt current. Consequently, loss of SF-6 gas shall initiate a local and a PPL Electric SCADA alarm, and then trip the breaker before the gas pressure is too low to operate the breaker. The manufacturer's recommendations for the specific breaker will be carefully reviewed to determine if the suggested operation on loss of SF-6 gas will be acceptable on the PPL Electric system.

5.9 SCADA AND TELEPROTECTION

5.9.1 COMMUNICATION REQUIREMENTS

Communication requirements for generation installations vary depending on the size of the generator and how it is connected to the PPL Electric power system. Any of the following may be implemented for any generation installation:

All communications systems (DTT and/or SCADA) must be available approximately one month prior to synchronization date (generally only larger systems of 2.5 MW and greater), following are the requirements:

- SCADA – Requires a cellular modem, provided by PPL Electric and invoiced to customer
- DTT – Requires a dedicated T1 or fiber-optic line for each dual channel application.
 - PPL Electric will provide specific information on the type and quantity of lines to be provided and typical protection requirements for the lines for each project. The local telephone company may have additional requirements.

5.9.2 TELEPHONE CIRCUITS

(ONLY APPLIES TO EXISTING CUSTOMERS WITH TELEPHONE CIRCUITS. NO NEW CUSTOMERS WILL BE ALLOWED TO INSTALL TELEPHONE CIRCUITS)

- SCADA – Requires a dedicated 4-wire line (type FDDA).
- DTT – Requires a dedicated 4-wire line for each dual channel application (type PRDA).
- Voice grade - A voice grade phone line is required. In addition, PPL Electric needs to be able to read the revenue meters daily. Therefore, a **shared voice grade** phone line is suitable for this function.

All copper phone circuits, required by PPL Electric (SCADA and/or DTT), must be equipped with **telephone company approved** high voltage isolating devices. See IEEE 487 latest version, and the local telephone company specific requirements. **NOTE:** these specialized phone lines tend to be long lead items and **may not be available in all locations**. PPL Electric may decide at the initial study phase to see if the required telephone services are available and suggest alternatives if they are not.

In addition, telephone companies may have their own specific requirements. Some *typical* requirements are:

- IEEE 487 – “The dedicated cable should be routed in a well-drained insulated conduit, e.g., polyvinylchloride (PVC), within the station ground grid area.”
- IEEE 789 – “In the case of the dedicated communications cable leaving the station, it is recommended that this cable be installed in a continuous PVC conduit within the station and for at least 3 m (10 ft.) beyond the ground grid or the power station perimeter fence.”



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- IEEE 789 – “It is important that metallic conduits should not be used or extended outside the station grid.”
- Customer shall provide required site data to allow the telephone company to calculate the maximum Ground Potential Rise (GPR) voltage and the Zone of Influence (ZOI) at their High Voltage site and enable the telephone company to complete their design. Those calculations will also determine if customer site will be serviced by a copper entrance cable or a fiber optic cable. Telephone companies may request more information based on specific project details.
- Specific telephone company requirements at power stations (customer handout) – “Schedule 80 PVC conduit (suitable for cable pulling) from the HVP (High Voltage Protection) location to a point 10 feet (3 m) beyond the substation fence or ground grid.”
- Some telephone companies also specify the use of lightning arrestors for these installations.

5.9.3 SCADA

A PPL Electric **SCADA remote monitoring shall be required for generation installations equal to or above 2.5 MW.** Refer to the “PPL Electric SCADA Requirements for Parallel Operation of Distributed Energy Resources” (EU00568250).

5.9.4 DTT COMMUNICATIONS

DTT may be required under certain circumstances which will be specified by PPL Electric after generator impact study and review is completed.



6 SUBSTATION PHYSICAL ELECTRICAL AND EQUIPMENT REQUIREMENTS

6.1 SUBSTATION ORIENTATION

The location and orientation of the customer-owned substation must be coordinated with PPL Electric before site layout.

6.2 SUBSTATION LINE DEAD-END STRUCTURE

The customer shall provide a suitable free-standing or guyed structure to terminate PPL Electric's line(s). The structure can be steel, aluminum or wood and shall be designed to accommodate the tension and clearance requirements of the distribution facilities. The structure must meet the National Electrical Code (NEC), National Electrical Safety Code (NESC) and PPL Electric strength and safety requirements.

6.3 GROUNDING REQUIREMENTS

The customer's outdoor substation facilities must have an adequate grounding system to prevent hazardous step and touch potentials. The grounding system shall be designed in accordance with IEEE Standard 80, "Guide for Safety in AC Substation Grounding," latest revision, and shall include the following:

1. Substation shall have a perimeter ground ring approximately 3 feet outside the fence line.
2. All gate entrances, man and vehicular, shall have their stationary posts bonded to each other and to the swing panels. Stationary post bonding by connections to the perimeter ground ring is acceptable.
3. The perimeter ground ring shall be designed to accommodate the swing of the entrance gate.
4. All air switch operating mechanisms shall be bonded to the substation structure by a suitable flexible braid connection from the operating pipe (near the operating mechanism) to the structure. A connection shall be made from the structure (near the operating mechanism) to the ground grid.
5. Each mechanism shall also have an ABOVE-GRADE steel platform/grating bonded to both the operating pipe and the ground grid.
6. Substation yard surfacing (4-inch minimum layer of crushed stone or macadam) shall extend 5 feet beyond the substation fence line along all sides.
7. Transformer high side should be solidly grounded Wye. No impedance grounding will be permitted for new transformers.
8. Substation ground grid should be 5 ohms or less for 138 kV and 69 kV transmission circuits.

6.4 GROUND GRID TESTING

The customer shall have the substation grounding system tested for "resistance to remote earth" prior to making connections to the PPL lines and energizing the facility. The customer is responsible for arranging the test(s) and costs associated with such work. The tests shall be made in accordance with the "Fall of Potential" method as outlined in IEEE Standard 81, "Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System," latest revision.



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All tests shall be conducted before any PPL shield wires, counterpoises and/or system neutrals and any other external ground wires (i.e., sewer lines, water pipes, telephone circuits, railroad tracks) are connected to the facility. If any external neutrals are connected before conducting ground testing, the results will yield false, lower value readings. Neutral(s) of any temporary construction power services must be properly isolated from the substation grounding system before tests are performed. The test circuit configuration shall be so arranged that no "sneak circuits" exist while performing the test.

The reference "current probe" (C2) must be driven at a point beyond the "extent" of the ground system under test to obtain meaningful results.

All ground resistance test results must be submitted to PPL for approval, and must include:

- Geometry of the test circuit showing relative positions/directions and distances between test and reference electrodes. An accurate sketch or field-marked location plan drawing is acceptable.
- Actual resistance measurements at several reference points including the "theoretical 62% point." Measurements shall be submitted as tabled values and graphically to illustrate the "plateau" and inflection points in the resistance curve.

PPL requires the effective resistance to remote earth of the customer's substation ground grid to be **five (5) ohms or less**.

6.5 POINT OF COMMON COUPLING SWITCHING DIAGRAMS AND NOTES

Please refer to "PPL Electric PCC REQUIREMENTS" for additional information.

6.6 EQUIPMENT AND MATERIAL

6.6.1 Power Transformers

All three-phase DER must be isolated from PPL Electric customers by a power transformer. For new three phase installations the *preferred* isolation transformer is WYE-grounded high side (PPL Electric). If a wye-wye configuration is used, the transformer must be solidly grounded on the low side. The transformer high side winding is to be specified for proper insulation to allow neutral impedance grounding. The need for neutral impedance grounding depends on the impact of the generation to the PPL Electric system. It will not be necessary in all cases.

Customer DER, operating in parallel with PPL's distribution system, may not be served by an open delta transformer configuration. The power transformer(s) connections must be reviewed and approved by PPL Electric prior to purchase.

Existing facilities which install generation will typically have a Delta high side and WYE low side transformer. Those will be accepted by PPL Electric; however, additional high voltage protection will be required but may cause excessive customer momentary interruptions. Further, the generator sponsor should review the transformer connection and the impact on the connection of the generation equipment to the existing plant.

Customer must contact PPL Electric prior to ordering or specifying the main power transformer. Depending on the size, location on the PPL system, or other concerns, alternate winding configuration may be required.

The voltage taps should accommodate the voltage criteria discussed in Section 5.6. A PPL Electric representative may be contacted to provide transformer tap recommendations prior to purchase and a desired tap setting at the specific location given the customer's load characteristics.



Please refer to the REMSI customer reference specification for any additional information, which can be found at: REMSI (Rules for Electric Metering and Service Installation).

6.6.2 Circuit Interrupting Devices (CID) - Switches and Interrupter Accessories

The provided CID equipment must be capable of interrupting expected current flows. The following devices provide the physical means to disconnect and provide a visible break between customer-owned substation and PPL Electric system:

6.6.2.1 Air switch – Gang Operated

Air switch; three-pole, gang-operated, with horn gap; manual swing handle, worm gear drive or motor-operated mechanism.

Please refer to the REMSI customer reference specification for any additional information, which can be found at: REMSI (Rules for Electric Metering and Service Installation).

6.6.2.2 Switch Interrupter Accessories

Interrupter accessories shall be installed on the point-of-contact switches as appropriate for the installation. These include, but are not limited to:

- Interrupter attachment (with whip interrupter) loop sectionalizing, line (bus) de-energizing, and transformer magnetizing current switching applications.
- Interrupter attachment (without whip interrupter) for loop sectionalizing (parallel switching) applications.

6.6.3 Fault Interrupting Devices (FID)

PPL Electric 138-12 kV and 69-12 kV substations are designed to withstand fault currents of 20 kA at 12.47 kV, symmetrical. PPL recommends that customer switchgear and equipment be designed to handle this amount of fault current at a minimum. Prior to the purchase of any equipment, the customer must contact PPL Electric Engineering for the actual fault duties at the customer's supply location and the PPL Electric substation bus.

If the customer elects to design their equipment to meet a lower maximum fault current than the recommended design level, then the customer must meet the calculated fault duties supplied by PPL for their location, plus a suitable safety margin of 120%. Future system changes to the supply system may increase the fault duties at the customer's location and any upgrades required to meet these increased fault duties will be at the customer's expense.

The following devices are approved for generation interconnection protection in customer-owned facilities:

- Power Circuit Breaker – 12 kV vacuum or SF6 insulating medium, single or three-tank style. Interrupting rating to be determined based on PPL Electric's criteria for the particular proposed installation.
- Circuit Switcher – 12 kV, three pole, 1,200 ampere continuous and 64 kA momentary ratings, 20 kA at 12.47 kV primary and 4 kA inherent-secondary interrupting ratings.

6.6.4 Insulator and Surge Arrester

Surge arresters must be connected to the LOAD side of the point-of-contact interrupting device. Location and quantity are to be determined by customer's engineering representative. Other locations must be reviewed with



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PPL Electric before implementation. In all situations, such equipment must comply with PPL Electric Insulator coordination and Surge Arrester protection requirements. Please refer to the REMSI customer reference specification for any additional information, which can be found at: REMSI (Rules for Electric Metering and Service Installation).



7 RELAY TEST PROCEDURES

The Relay Test Department at PPL Electric provides technical field support for all customer IMR/IPR installations involving DER systems. They should be included in the early review of customer drawings, along with other key PPL groups, to help the customer to develop an optimal and effective design.

As the work progresses to the physical construction stage, the following documentation/testing are required as listed below:

Task/Deliverable	Timeline	Responsibility
Commissioning Test Procedure*	Submitted to PPL Electric Relay Test for approval 3 weeks prior to performing tests outlined below	Customer
Current Transformer test	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
Current Transformer saturation tests	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
Current circuit verification	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
Potential circuit verification	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
Control circuit tests	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
In-service verification tests	Submitted to PPL Electric Relay Test for approval prior to site visit	Customer
Any other issues related to the POC and IPR systems	As needed if PPL Electric requires additional information dependent on the results of the tests listed above.	Customer
Relay Settings	Issued after approval of all customer's submitted drawings (typically day before site visit).	Applied by PPL Electric Relay Test during site visit for final relay acceptance testing.
Relay Acceptance Tests	Scheduled once above tasks are completed.	Performed by Customer. Witnessed by PPL Electric Relay Test.

*PPL Electric Relay Test personnel will require a written commissioning test procedure proposed by the customers' contractor. This procedure should cover a step-by-step listing of the tests required to ensure that the DER's schemes operate properly. This commissioning procedure should be supplied to PPL Electric at least three weeks prior to the scheduled in-service testing process. The customer shall provide a detailed procedure of the initial phase-out and synchronization to PPL Electric, which must be reviewed and approved by PPL Electric prior to actual synchronization.



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PPL Electric Witness testing is done during normal working business hours. If the customer wishes to perform work outside of these normal business hours, there will be fees associated with the work which can be discussed further.

The generator operator is to verify the phase rotation of the generator. Please note that in MOST cases the PPL Electric system rotation is C-B-A. The generator is expected to verify the specific rotation at their facility, with PPL Electric.



8 DRAWING REQUIREMENTS

ALL drawings must be suitable to be scaled to “D” size (24 inches by 36 inches), except for reports, word or excel documents. Reduced size drawings are NOT acceptable.

8.1 DRAWINGS AND INFORMATION FOR REVIEW

It is expected that most of the required protection will be built into the generation equipment. Under these circumstances, PPL Electric will request copies of the manufacturer’s drawings, and any drawings showing external inputs to the protective equipment, for example CTs or VTs. If the DER operator has decided to operate a different breaker than that supplied with the generation equipment, the drawing showing the controls and interlocks to this breaker will also be requested.

PPL Electric will require the following drawings/information for review and acceptance:

NOTE: A final set of “as built” drawings are required to be submitted to PPL Electric within 90 days of initial synchronization of the generation. Failure to submit such drawings may result in the generator not being able to interconnect with the PPL Electric system until the “as built” drawings are received.

- One-Line Diagram
- Three-Line Diagram
- Distribution Line Dead-end Structure (proposed/final)
- Plan and Elevation Views (electrical arrangements only)
- Grounding Plan and Details
- Ground Test Report (when customer substation is complete but before PPL supplies are connected)
- Bill of Material (major electrical equipment only, including switch, protective device, transformer, surge arresters, relays, etc.)
- Switch Interlock Schematic and Details
- Three-Line Potential Elementary
- Three-Line Current Elementary
- Control Elementary Diagram(s) of each FID (Breaker or Circuit Switcher)
- Power Transformer Certified Test Report(s)
- Front view showing IPR Relay(s) and Control Equipment
- A detailed written description of Point of DER Connection (POC) relay if used, Interconnection Monitor Relaying (IMR) and Intertie Protective Relaying (IPR), as well as control functions and description of operation. The drawing is to provide a description of operation of the facility including:
 - Point of DER connection breaker or low side circuit breaker
 - Generator circuit breaker
 - Controls associated with the above circuit breakers
 - Any other equipment that connects to the above breakers



- System interlocks
- Direct transfer Trip equipment, if required
- General description of the operation of the facility, including operational modes [parallel, isolated, peak shaving, etc.]
- Any other unique facilities or operational modes
- High side breaker isolation procedure if a SF-6 high side breaker is used
- Commissioning procedure
- IMR/IPR instruction book
- IMR/IPR firmware (specified in BOM)
- IMR/IPR part number (specified in BOM)
- IMR/IPR CT saturation study if accuracy class less than C400
- Auto transfer switch make and model (if customer-owned backup generation is installed)

8.2 CONTENTS OF DRAWINGS

The customer's IPR drawings shall contain the following information:

8.2.1 One-line Relay Diagrams

This diagram shows the customer's substation functional arrangement. All the equipment shall be shown using single-line diagram and standard symbol notations (per latest ANSI/IEEE Standard 315; titled Graphic Symbols for Electrical and Electronic Diagrams). This diagram shall include:

- Equipment names and/or numerical designations for main Fault Interrupting Devices (FIDs), air switches, power transformers, and associated POC/ IPR relays and control devices shall be shown to match with PPL line designation. (Note: The required information will be provided by PPL after the customer submits a preliminary one-line diagram.)
- Power Transformers - Nominal kVA, nominal primary/secondary and tertiary voltages, vector diagram and impedance.
- Instrument Transformers - Voltage and Current that supply the POC/IPR relaying.
- Lightning Arresters/Spill Gaps/Surge Capacitors - Ratings.
- Air Switches - Indicate status normally open with a (N.O), normally closed with a (N.C.) and type of operation manual or motor.
- Safety Switch - Continuous ampere and interrupting ratings.
- FIDs - Interrupting rating, continuous rating, operating times.
- Transformer Fuses - Size, type, manufacturer, location.
- Grounding.
- Generator(s) - Include type, connection, kVA, voltage, current, phasing, rotation, PF, sub-transient, transient, and steady-state reactance, etc.



- Point of Interconnection to PPL Electric (12 kV) and phase identification. NOTE: if the generation phase sequence is different than the PPL Electric phase sequence, both must be shown on this diagram.
- Energy Storage Systems - type, connection, kVA, voltage, current, energy capacity

8.2.2 Current Elementary Diagrams

This diagram shall include:

- Terminal designations of all devices - Relay coils and contacts, switches, transducers, etc.
- Relay Functional Designation – Per ANSI/IEEE standard C-37.2-1991. The same functional designation shall be used on all the drawings showing the relay.
- Complete relay type such as "SEL 321", etc., and the relay range.
- Range and settings of timing relays.
- Switch developments and escutcheons shall be shown on the drawing where most contacts are used. Where contacts of a switch are used on a separate drawing, that drawing should be referenced adjacent to the contacts in the switch development. Any contacts not used should be referenced as spare.
- All switch contacts are to be shown in the open position with each labeled to indicate the positions in which the contacts will be closed.
- Switch contacts shall be referenced to the switch development if development is shown on a separate drawing.
- Isolating points (States sliding links, test switches, etc.).
- Grounding of CT cables.
- All other circuit elements and components with device designation, rating, and setting where applicable.
- Current Transformers - Polarity marks, rating, tap, ratio, class, and connection.
- Auxiliary CT ratios, connections, polarity, winding current rating, and arrows to indicate assumed current flow.
- Phase designations and rotation of both PPL and customer.
- Cable connection number or wire designation.

8.2.3 Potential Elementary Diagrams

This diagram shall include:

- Terminal designations of all devices – relay coils/contacts, switches, transducers, etc.
- Relay functional designation – per ANSI/IEEE standard C-37.2-1991. The same functional designation shall be used on all the drawings showing the relay.
- Complete relay type such as "SEL 321", etc., and the relay range.
- Relay contacts shall be referenced to the drawing where coils are shown, provided coil are shown on a separate drawing.
- Relay contacts should be shown with each referenced to the drawing where they are used. Contacts not used should be referenced as spare.



- Range and settings of timing relays.
- Switch developments and escutcheons shall be shown on the drawing where most contacts are used. Where contacts of a switch are used on a separate drawing, that drawing should be referenced adjacent to the contacts in the switch development. Any contacts not used should be referenced as spare.
- All switch contacts are to be shown in the open position with each labeled to indicate the positions in which the contacts will be closed.
- Switch contacts shall be referenced to the switch development if development is shown on a separate drawing.
- Isolating points (States links, test switches, etc.).
- Grounding of cables.
- All other circuit elements and components with device designation, rating, and setting where applicable.
- Coil voltage for all auxiliary relays.
- Voltage transformer – nameplate ratio, polarity marks, rating, primary and secondary connections.
- Phase designations and rotation of both the utility and customer.
- Current ratings and designation of all fuses.

8.2.4 Control Elementary Diagram

Control elementary diagrams are to be functionally complete schematics. They should be as simple and uncluttered as possible, and shall contain the following information:

- Terminal designations of all devices – relay coils and contacts, switches, transducers, etc.
- Relay functional designation – per ANSI/IEEE standard C-37.2-1991. The same functional designation shall be used on all the drawings showing the relay.
- Complete relay type such as "SEL 321", etc., and the relay range.
- Range and settings of timing relays.
- Switch developments and escutcheons shall be shown on the drawing where most contacts are used. Where contacts of a switch are used on a separate drawing, that drawing should be referenced adjacent to the contacts in the switch development. Any contacts not used should be referenced as spare.
- All switch contacts are to be shown in the open position with each labeled to indicate the positions in which the contacts will be closed.
- Switch contacts shall be referenced to the switch development if development is shown on a separate drawing.
- Isolating points (States links, test switches, etc.)
- All other circuit elements and components with device designation, rating, and setting where applicable.
- Cable connection number or wire designation.
- Device auxiliary switches (FIDs, contactors) should be referenced to the drawings where they are used.
- Any interlocks; electromechanical, key, etc.
- Coil target ratings: on dual ratings underline the appropriate tap setting.



- Complete internals for electromechanical protective relays. Solid-state relays may be shown as a “black box,” with power supply and output connections, but manufacturer’s instruction book number shall be referenced, and terminal designations shown.
- DC fuses protecting the relaying and FID’s control circuit shall be monitored for blown fuse or open circuit with a yellow indicating light.
- The trip coils of lockout relays should be monitored.
- If the IPR trips the CB directly, the CB trip coil will be monitored through the IPR in addition to the lockout relay trip coil.
- The coils and contacts of all timers and lockout relays shall be wired through States links or equivalent terminal blocks to provide isolation for testing.

8.2.5 Front View Diagrams

This diagram will show the physical arrangement of all the control and protective equipment for the IPR relaying and shall contain the following information: `

- Nameplates shall be provided for all switches, lights and hand reset lockout relays for the purpose of identification.
- The IPR relaying shall be mounted and grouped in such a way as to be clearly differentiated from the other customer’s relaying. The IPR relaying may be located on a separate area within a relay panel housing other customer relays.
- The IPR relaying shall be mounted on the switchboards in such an order that equipment associated with the various phases will be in A-B-C (PPL phase names) order from top to bottom or from left to right when facing front of panel on which they are mounted.

8.3 DRAWING APPROVAL PROCEDURES

- The customer must submit preliminary IPR relay(s) drawings for PPL review and acceptance. These drawings must be submitted before the customer’s equipment is ordered to ensure that it meets PPL Electric requirements.
- The customer must submit final IPR relay(s) drawings for PPL review and acceptance before customer’s facilities connect to the PPL Electric system, and placed in-service. PPL Electric will not be held responsible for possible delayed connection of customer’s facilities if drawings are not received in time for review.
- The type of drawings submitted must be according to the list described in Section 8.1.
- All drawings submitted to PPL for acceptance must contain complete information as outlined in Section 8.2.
- PPL will review customer’s drawings and provide comments within **30 working days** from the day a complete set of required drawings and information are received by PPL Electric.
- Specific Grading Plan, Foundation Plan, Foundation Details, Conduit Plan, Structural Steel Assembly, and Structural Steel Fabrication Detail drawings do not require PPL Electric review.
- The responsibility of detail and correct design lies with the customer. Neither PPL nor any person acting on behalf of PPL:
 - Assumes any responsibility for correctness of design, drawings, installation, or operations.



- Assumes any liability with respect to the use of, or damages resulting from the use of, any comments disclosed in this document or in any other PPL correspondence with the customer.

8.4 FINAL AS-BUILT DRAWINGS

The customer must provide two (2) copies of the As-Built drawings listed in Section 8.1. Also include copies of all inspection certificates with the copies.

The 'Final as Built' drawings can be provided in:

- Hard copy
- Auto CAD format
- PDF format

The text must be legible. For example, a 'D' size Drawing (22x34 inches) cannot be submitted as a 'C' or 'B' size final drawing.

NOTE: final "as built" drawings shall be required to be completed within 60 days of the initial synchronization of the generation.



9 APPENDIX

9.1 LIST OF APPLICABLE STANDARDS

This document will be applied in conjunction with latest versions of the following industry standards pertaining to generation and PPL Electric intertie installations:

- ANSI C2, National Electrical Safety Code.
- ANSI/IEEE C37.010 (R1988), Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
- ANSI/IEEE C37.2, Standard Electrical Power System Device Function Numbers.
- ANSI/IEEE C37.5, Guide for Calculation of Fault Current for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis.
- ANSI/IEEE C37.90 (R1994), Relays and Relay Systems Associated with Electric Power Apparatus.
- IEEE standard C62.41.2, IEEE recommended Practice on Characterization of Surges in Low Voltage (1000 V or less) AC Power Circuits.
- IEEE standard C62.45, IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits.
- IEEE Standard C37.90.1, IEEE Standard Surge Voltage Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
- IEEE Standard C37.90.2, IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.
- ANSI/IEEE C37.91 (R1990), Guide for Protective Relay Applications to Power Transformers.
- ANSI/IEEE C37.93 (R1992), Guide for Power System Protective Relay Applications of Audio Tones over Telephone Channels.
- ANSI/IEEE C37.99 (R1994), Guide for Protection of Shunt Capacitor Banks.
- ANSI/IEEE C37.101, Guide for Generator Ground Protection.
- ANSI/IEEE C57.13, Standard Requirements for Instrument Transformers.
- ANSI C84.1, Electric Power Systems and Equipment – Voltage Ratings
- ANSI/IEEE Std. 141, Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).
- ANSI/IEEE Std. 241, Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book).
- ANSI/IEEE Std. 242 (R1991), Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).
- ANSI/IEEE Std. 315 (R1989), Graphic Symbols for Electrical and Electronics Diagrams.
- ANSI/IEEE Std. 446, Recommended Practice for Emergency and Standby Power for Industrial and Commercial Applications (IEEE Orange Book).
- ANSI/IEEE Std. 493, Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book).
- ANSI/IEEE Std. 519 IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.
- ANSI/NFPA 70, National Electrical Code.
- IEEE Std. 80 (R1991), Guide for Safety in AC Substation Grounding.
- ANSI/IEEE 37.102, Guide for AC Generator Protection.
- IEEE Std. C37.110, IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes.



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- IEEE Standard 929 [Recommended Practice for Utility Interface of Photovoltaic (PV) Systems] and UL 1741 Publication [“Power Conditioning Units for Use in Residential Photovoltaic Power System”], latest version.
- ANSI/IEEE C57.105 (R1992), IEEE Guide for Application of Transformer Connections in Three-Phase Distribution Systems
- IEEE Standard 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems, latest version.
- IEEE Standard 1547.1, Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.
- Generation installations certified to be compliant with IEEE 1547.1 will generally be accepted as designed. In these cases, an IPR (Intertie Protective Relay) cabinet will not be required, as the required protective functions will be included in the generation package. IEEE 1547 is limited to Distributed Resource [generation] installations of 10 MVA or less for a single installation and 10 MVA or less for multiple generator installations on a single line or substation. For the PPL Electric system, most of these installations will be at 12 kV. PPL Electric will accept IEEE 1547.1 certified generators for parallel operation on its system up to 2.0 MW, with no additional system modifications. However, installations above this limit will be reviewed to determine if additional protection, beyond that provided by IEEE 1547 is required.
- The PJM Small Generation (0 to 2.0 MW) interconnection requirements will be used in place of the PPL Electric for facilities in this range *AND UNDER THE JURISDICTION OF PJM*. Units in this range, but not under PJM jurisdiction will be classified as TYPE 1, 2, 3 or 4 as appropriate.
- CERTIFIED equipment will be tested and certified by a NRTL (Nationally Recognized Testing Laboratory) to IEEE 1547.1. All inverters to be used for connecting generation to the PPL Electric system are required to be certified to UL1741 and IEEE 1547. The term certified is understood to indicate a NRTL has tested the device to the appropriate standard, in this case UL1741 and IEEE 1547. Any inverter not meeting the NRTL certification will either not be allowed to connect to the PPL Electric system or will be required to install suitable external protection equipment to provide the same level of protection. Further, the inverter vendor must provide upon request copies of the certification of the inverter equipment from the NRTL. Self-certification or certification by a third party that is not listed on the OSHA web site will not be accepted.
- NEMA MG-1, Motors and Generators.
- NEC 2005.
- NFPA 70 National Electrical Code.
- IEEE standard 519, IEEE recommended Practice and Requirements for Harmonic Control in Electrical Power Systems.



10 Revision History

Revision 0 11/01/2018	Initial Procedure Release
Prepared by:	Deepak Sharma
	Senior Engineer, Distribution Substation Design
Reviewed by:	Thien Hoang
	Supervising Engineer, Distribution Design and Standards
Approved by:	Michael J. Wolf
	Supervising Engineer, Distribution Substation Design

Revision 1 08/01/2022	Updated IPR Requirements and Comprehensive Review of Document
Prepared by:	Mohamad A. Kanbari
	Senior Engineer, Distribution Interconnection and Tariff Rules
	Mychal Kistler
	Senior Engineer, Distribution Protection and Control
Reviewed by:	Ricardo Romero
	Distribution Protection and Control
	Niall Pascal
	Distribution Interconnection and Tariff Rules
Approved by:	Kimberly Gauntner
	Supervisor, Distribution Interconnection and Tariff Rules
	John Bannon
	Supervisor, Distribution Protection and Control