Interconnection Guidelines for Generation

VEC-006 Control Document
Interconnection Guidelines for Generation

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1 Introduction

1.1 Purpose

These guidelines provide preliminary technical information to parties seeking to interconnect new generation facilities or materially modifying existing generating facilities connected to Southern Indiana Gas & Electric Company d/b/a CenterPoint Energy Indiana South (SIGE) electric system. As a Transmission Owner, SIGE makes transmission facility interconnection requirements available upon request to entities seeking to interconnect.

These guidelines state general SIGE recommendations to ensure that the interconnection of generation to the SIGE electric system does not adversely impact reliability or quality of electric service to SIGE or its customers.

SIGE's facility connection requirements are organized into two separate documents, **VEC-007 - Requirements for Transmission or End User Facilities Interconnection to the SIGE Electric Transmission System** and **VEC-006 - Interconnection Guidelines for Generation** (this document).

When a proposed facility includes both generation and **End-User** or **Transmission Interconnection** facilities, the **Requestor** will need to consult both documents.

For new installations or modifications impacting SIGE's transmission system, notification should be made per **VEC-007 Requirements for Transmission and End-User Facilities Interconnection to the SIGE Electric Transmission System, Section 1.6 Initiating a Facility Connection or Facility Change**. VEC-007, provides general requirements for the transmission facilities needed to interconnect the Producer's generating facility to the SIGE electric transmission system.

The Producer must also comply with any NERC Reliability Standards, regional and Transmission Owner planning criteria, and Facility interconnection requirements.

1.2 Terms

Throughout this document, the term "Producer" refers to the owner of the customer-owned generating facility, any Independent Power Producer interconnected to SIGE's electric system, and any Generator Owner/Generator Operator connected to SIGE's system to include Power Supply/Power Supply Services.

1.3 SIGE and MISO Contacts

The table below outlines the MISO and SIGE personnel to contact for any request.

Type pf Request	Name	Email	Phone Number
DER (i.e., Excess Distributed Generation or EDG) & Customer Owned Application Submittal	New Service Department	newservice@centerpointenergy.com	812-464-4600
DER & Customer Owned Questions	Ryan Snyder, Manager of Indiana Planning and Protection	Ryan.Snyder@centerpointenergy.com	812-491-5877
Transmission Application Submittal	MISO GI Online Application Tool	https://www.misoenergy.org/planning/generator-interconnection	N/A
Transmission Application Questions	MISO GI Interconnection Team	ginterconnection@misoenergy.org	N/A
Transmission Technical Questions	Ryan Snyder, Manager of Indiana Planning and Protection or Allen Collins, Manager of High Voltage Project Engineering	Ryan.Snyder@centerpointenergy.com Allen.Collins@centerpointenergy.com	812-491-5877 812-491-4629
NERC Compliance Questions	Electric Reliability Compliance Department	NERCCompliance@CenterPointEnergy.com	812-491-4012

1.4 Indemnification

These guidelines are recommendations only and do not dismiss the Producer from independently evaluating the customer-owned generating system's performance, compliance, and safety. It is the Producer's sole responsibility to evaluate and ensure safety with respect to its facilities and employees. SIGE assumes no liability or responsibility with respect to the accuracy or completeness of these guideline recommendations contained herein.

2 General Guidelines

2.1 Generating System Sources

The Producer may elect to use any of a variety of energy sources including solar, wind, hydro or other types of sources, in addition to conventional fossil fuels. For interconnection to the SIGE electric system, the generating system shall generate 60 Hz sinusoidal alternating current at a SIGE standard voltage and phase rotation.

2.2 Operational Communications

2.2.1 Operational Communication Methods

Requestor shall provide a primary and alternative contact phone number(s) to SIGE. The contact information supplied shall be the Requestor's 24/7 response contacts (such as a 24/7 control center) to respond to normal and emergency operational concerns. Requestor is responsible for providing any updates to contact information.

All primary voice communication concerning facility operations shall be conducted through the primary network to the Transmission System Operations (TSO) phone number(s) issued by SIGE. Alternative methods of communication will be used if primary voice communications are unavailable.

Other communication modes (email, web-based, etc.) may be required by SIGE and/or MISO.

2.2.2 Emergency Operational Communication

In the event of an electric transmission facility emergency, the primary contact phone number(s) shall be used. If primary contact phone number is inoperable, alternative communication methods will be utilized.

It is the **Requestor's** responsibility to take prudent steps when an area or system-wide capacity or transmission emergency is declared. 3-Part Communication Protocols shall be used in all emergency communication situations with TSO.

Examples of emergency situations:

- Suspect or identify a physical threat that may impact the operation of the BES
- System condition burdening other areas or is reducing the reliability of the Interconnection
- Line loading and voltage/reactive levels are such that a single contingency could threaten the reliability of the Interconnection
- Anticipation of 3% or greater voltage reduction and/or public appeals due to a capacity or transmission emergency

3-Part Communications Protocol:

1. **Instruction:** Issuer issues an operating instruction/situation
2. **Confirmation:** Receiver states back their understanding of the instruction/situation
3. **Acknowledgement:** Issuer is confirmers Receivers understanding is correct

End-Users shall be provided a direct contact phone number to be used for emergency or routine operations. Operational emergencies, including customer-owned equipment issues, warrant a direct call to SIGE. TSO will advise the SIGE representative of problems that they should handle directly with the **End-Users**.

2.3 Coordination with Other Codes, Standards and Agencies

These guidelines are for informational purposes only and do not relieve the Producer from complying with the National Electrical Safety Code, the National Electrical Code, Indiana Administrative Code (IAC) 170, RF and NERC standards, requirements and recommendations and all relevant IEEE Standards, including IEEE 1547 - IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.

Additionally, these guidelines do not address federal or state regulatory requirements, transmission access, or other commercial terms and conditions to transport or sell energy.

3 Customer-Owned and Distributed Energy Resource (DER)

3.1 Initiating a Request

Producer and SIGE personnel are to use these guidelines when planning installations or modifications for customer-owned generation to identify proper design, analysis and coordination in the pursuit of a comprehensive, interconnection feasibility study.

SIGE personnel reviews all proposed material modifications to the interconnected electric systems to determine the level of impact. The Producer must notify SIGE of any planned generation installations or material modifications so that all entities responsible for the reliability of the distribution systems and the interconnected transmission systems can also be notified as soon as feasible.

Applicable interconnection costs will be billed to Producer per IAC 170. These costs may include, but not limited to, the following: design and installation, communications, protective and safety devices, network upgrades, and power system studies.

3.2 SIGE Policy on Customer-Owned Generation

SIGE permits any Producer to operate generating equipment in parallel with the SIGE electric system with an executed Interconnection Agreement and without adverse effects to SIGE personnel, equipment, or its customers. Protective devices, such as relays, circuit breakers, etc., specified by SIGE, may be required at any location where a Producer desires to operate generation in parallel with the SIGE electric system. The purpose of these devices is to promptly disconnect the Producer's generating system from the SIGE electric system whenever electrical faults or abnormal operating conditions occur.

3.2.1 Hot Transfer Standby Generation

Hot Transfer Standby Generation, often referred to as “closed transition”, is when the Producer’s generation can be interconnected to the SIGE electric system on a short-term basis to prevent interruption of the Producer’s critical load. In this configuration, the Producer’s load is transferred from the SIGE electric system to the Producer’s generating system and back again without an interruption. The duration of the interconnection is to be minimal and negotiated in the Paralleling Agreement. Power flow from the Producer’s generating system to the SIGE electric system may be prevented by other design or equipment solutions.

3.2.2 Demand Reducing Generation

Demand Reducing Generation is when the customer-owned generator is interconnected to the SIGE electric system; however, no power is intentionally transferred to or purchased by SIGE. The local demand is reduced, i.e. "peak shaving." Since the Producer’s rate may not permit peak shaving, the SIGE Field Sales and/or Rate departments shall be contacted for initial approval. If approved, the interconnection requirements shall be based on the inverter or generator rating. Refer to Sections 3.9.1 through 3.9.6.

3.2.3 Excess Distributed Generation (EDG)

Excess Distributed Generation (EDG) is available to SIGE electric customers as described in Rider EDG (excess distributed generation rider) within SIGE’s Tariff for Electric Service. Customers must meet the availability and applicability listed in SIGE’s EDG Rider as well as the rules of Net Metering specified in the Indiana Administrative Code (170 IAC, Article 4, Rule 4.3). For more information see Customer Generation page of the SIGE website.

3.3 Requirements for Interconnection

The operation of a customer-owned generator, interconnected to the SIGE electric system, presents several points of concern for the SIGE electric system. These concerns include: safety, reliability, quality of service, protection planning and operations problems. SIGE must maintain the integrity of its system to ensure a reliable supply of electricity to its customers and the bulk electric system. Therefore, any interconnected generating system must include equipment dedicated to protecting the electric system from problems that originate within the interconnected generating system. These concerns and problems are evaluated by completing steady state, short circuit, dynamics, and other studies as described in **VEC-008 Electric Generation and Transmission Planning Criteria.**

The Customer-Owned Producer must verify with SIGE the specific point of interconnection to ensure that it is within SIGE's Balancing Authority metered boundaries, if connected to the transmission system.

Producers requesting to connect generators to the electric distribution system must also meet the Customer-Generator Interconnection Standards as specified in Indiana Administrative Code (170 IAC, Article 4, Rule 4.3) and the conditions listed in the SIGE Tariff.

If the existing distribution transformer is unacceptable, the generator owner shall be responsible for costs associated with installing a dedicated transformer for the generator. All generator requests are reviewed to determine if a dedicated step-up transformer is required.

After interconnecting, SIGE requires the Producer to notify SIGE of any proposed modifications to facilities to determine the impact on the reliability of the interconnected electric system.

3.3.1 System Modeling Data Requirements

As mentioned above and described in VEC-008 Electric Generation and Transmission Planning Criteria, steady state, dynamics, short circuit, and other system studies may be required to ensure reliability, integrity, and quality of service on SIGE's electric system. To ensure the accuracy of these studies and their results, SIGE requires Producers to provide various modeling information or facility data that can be converted to needed modeling information. Since the studies are required to be completed before the interconnection is approved, there is the potential that this data as provided will be preliminary, in which case Producer is required to submit updated final data prior to commercial operation. Also, any changes made to Producer's generating facilities in the future are required to be communicated to SIGE and updated data is required to be submitted.

For installations less than 200 kW that are connecting directly to SIGE's distribution (12.47 kV and below) system, this data includes the AC output of the generator or inverter and the impedance of the generator step-up (GSU) transformer.

Installations larger than 200 kW connecting to the distribution system or any installation connecting directly to SIGE's transmission (69 kV and above) system or substation may require more in-depth system impact studies and therefor more data. The type of data can generally be grouped by the three main study types, steady state, dynamics (or transient stability), and short circuit. The type of data required will correspond to the type of study required, as determined by SIGE.

Steady state, or load flow, studies are used to determine the impacts on SIGE's electric system during continuous operation through normal and abnormal (whether due to fault conditions or maintenance outages) system operating conditions. The data needed for these studies includes:

- Maximum continuous AC output of the generator or inverter
- AC terminal voltage of the generator or inverter
- Positive sequence impedance of transformers and conductors
- Continuous current ratings of transformers and conductors
- Transformers tap settings
- Power factor at point of interconnection
- Station service load for synchronous machines
- Reactive capability of any power factor correction devices (such as capacitor banks)
- Voltage control settings
- Other data as specified by SIGE

Dynamics, or transient stability, studies are used to determine the generator and associated equipment's behavior during and immediately after a fault condition to ensure the electric system remains stable. The modeling needed for these studies incudes detailed data on the below components.

- Generator
- Inverter
- Exciter
- Governor
- Power system stabilizer
- Compensator
- Outer loop controller
- Inverter controller
- Under/over voltage and frequency relays
- Station service loads
- Power factor correction devices (such as capacitor banks)
- Other installation dependent equipment as determined by SIGE

Short circuit studies are used to evaluate the system under fault conditions, validate circuit breaker duty requirements, and for setting and coordinating relay settings. The data needed for these studies includes:

- Zero sequence impedances of transformers and conductors
- Negative sequence impedances of transformers and conductors (if different from positive sequence)
- Unit neutral impedance
- Number of inverters
- Load and no-load losses for transformers
- Excitation and thermal limits
- Relay settings
- Other data as specified by SIGE

Additional modeling data, including electromagnetic transient modeling (ETM) modeling data, may be required based on the size and type of the proposed installation. SIGE will coordinate with Producer on needed data during the data submittal and system impact portions of the interconnection process.

3.4 Points of Concern

The following sub-sections will introduce, at a high-level, potential concerns that will be addressed between the Producer and SIGE during the design phase of the Customer-owned interconnection project.

These concerns will be further detailed in later sections.

3.4.1 Safety Concerns

Safety concerns focus first on isolating the interconnected generator from the SIGE electric system when a SIGE electric system line is opened. Isolation shall be both automatic and manual. The method for accomplishing automatic isolation may vary depending on size, electrical characteristics, and other factors of the interconnected generating system and the SIGE electric system. A lockable, manually operated switch or disconnect with visible breaks between the SIGE electric system and all customer-owned energy sources is required. This switch or disconnect shall be subject to SIGE lock-out and tag-out procedures. One exception to this rule is for installations with a total capacity of 10 kW or less interconnected to the SIGE electric distribution system and meets IEEE 1547 requirements and the requirements of 170 Indiana Administrative Code (IAC) Rule 4.3 Level 1 review. For these installations a disconnect switch is recommended but not required.

Another concern with isolating an interconnected generator is self-excitation of the generator, which can cause damage to customer's equipment and create public safety issues. Voltage and frequency relays and automatic interrupting devices shall be used to protect the customer's equipment, SIGE employees, and the public.

An additional concern is preventing the isolated generator from energizing a de-energized SIGE electric system circuit. Energizing a de-energized circuit can endanger the public, rescue workers, SIGE employees and others who may have determined that the circuit is de-energized and were in contact with the circuit. In this situation, energizing a de-energized circuit shall be blocked for all automatic and manual isolation schemes.

3.4.2 Reliability Concerns

The Producer shall ensure that the interconnected generating system does not adversely impact the reliability of the electric system. This consideration may influence the equipment protection scheme designs, discussed later. Protective relay settings shall be coordinated so that the safety and reliability of electric service for all SIGE customers are not compromised.

Other factors that could affect the reliability of SIGE electric system and require additional protective relay considerations, include but are not limited to:

- The location of the interconnected generating system on the SIGE electric system; if the interconnection location is at a transmission level, then interruptions of service have a greater impact to the SIGE electric system than when located at a distribution level.
- The generator size compared to the interconnected generating system load and the load on the SIGE electric system line.

3.4.3 Quality of Service Concerns

SIGE is required to meet certain tolerances of voltage, frequency, and duration to their customers. Power supplied to the SIGE electric system by an interconnected generating system shall also be within certain tolerances so that the overall power quality of the SIGE electric system remains satisfactory.

The following list of quality of service concerns may need to be addressed between the Producer and SIGE. The associated cost with resolving these concerns may be the responsibility of the Producer.

- Lagging or leading power factor (pf). Capacitors can be used to correct lagging power factor.

- Harmonic currents. Harmonic currents occur at frequencies other than the desired 60 Hz of the power signal. Harmonic currents can cause improper operation of protective relays, communication systems, and sensitive electronic equipment.

- Voltage Flicker. Voltage variations "flicker" can occur when there are sudden changes of current flowing in a circuit. Voltage flicker can cause misoperation of sensitive equipment or visual irritation.

3.4.4 Protection Concerns

Both the Producer and SIGE must protect their respective personnel and systems from injury or damage, which may be the result of the interconnection of a customer-owned generator. This protection often utilizes automatic equipment to detect and isolate faulted sections of a system so that the remainder of the system can continue to operate without interruption.

3.4.5 Planning and Operations Concerns

Customer-owned generators create unique challenges for system planning that may need to be studied; therefore, the Producer may be required to provide detailed modeling information for their generator and associated systems to facilitate these studies.

Operation of the SIGE electric system may be affected by customer-owned generation.

The Producer shall be required to pay for any increased costs resulting from changes in SIGE operating procedures.

3.5 Generating System Operation

The Producer may elect to operate the generator as a separate system with the capability of non-parallel load transfer between the two independent systems or in parallel with the SIGE electric system. These two methods of system operation are discussed below.

3.5.1 Separate System Operation

A separate system is a system to which there is no possibility of interconnecting the Producer's generating system in parallel with the SIGE electric system. Un-interruptible Power Supply Systems (UPS) may not meet the separate system operating criteria and should not be considered unless they are designed for and meet the separate system operating criteria.

For this design to be acceptable, the Producer must verify the system is capable of transferring load in an "open transition," or non-parallel mode, between the Producer's generating system and the SIGE electric system. This can be accomplished by either an electrical or mechanical "fail safe" interlocked switching arrangement, which prevents operation of both switches in the closed position simultaneously.

If the Producer has a separate system, SIGE requires verification that a transfer scheme exists and meets non-parallel mode requirements. Verification will be accomplished by the approval of drawings by SIGE in writing and, if SIGE so chooses, by field inspection of the transfer scheme.

SIGE shall not be responsible for approving the Producer's generating system equipment and assumes no responsibility for its design, operation or effects on the Producer's loads.

3.5.2 Parallel System Operation

A parallel system is a system to which the Producer's generating system can be connected to the SIGE electric system.

The SIGE electric system is subject to a variety of system disturbances. A parallel system operated generator shall have adequate protective devices installed, which will detect fault conditions on the SIGE electric system and will operate to disconnect the generator. The protective devices must be properly designed and sized appropriately by the Producer to withstand the fault levels and voltage surges that may occur. This is discussed in more detail in Section 3.9.2 of this document.

Parallel system operated generation can cause a condition known as "islanding" where a portion of the SIGE electric system load becomes isolated from the SIGE electric system source and remains interconnected to the paralleled generator. In this condition, the isolated system can continue to operate independently from the SIGE electric system and develop abnormal voltage or frequency.

In order to properly parallel the Producer's equipment with the SIGE electric system, the Producer must incorporate automatic synchronizing equipment that can smoothly interconnect the Producer's generating equipment with the SIGE electric system.

Improper synchronizing can cause significant damage to the Producer's equipment, and possibly SIGE and other customers' equipment. The Producer will be held liable for any damage caused by improper synchronizing of Producer's equipment.

3.6 SIGE Electric System Information

3.6.1 Voltage

The SIGE electric transmission system nominal voltages are: 345 kV, 138 kV, and 69 kV. SIGE's nominal distribution voltage is 12.47 kV.

SIGE operates the electric system voltage between 95% and 105% of nominal under normal and single transmission element outage conditions.

Under multiple element outage conditions, system voltage may range between 90% and 105% of nominal. If the **Producer's** supply voltage requirements are more restrictive than the range of 90% to 105%, SIGE recommends that the **Producer** consider the addition of voltage regulation equipment to their facility.

Under certain emergency conditions, the SIGE electric system may operate for a period of time outside of the 90% to 105% range. The **Producer** is responsible for providing any voltage sensing equipment required to protect their equipment during abnormal voltage operation.

3.6.2 Circuit Restoration

It is the responsibility of the Producer to install necessary equipment to ensure a proper disconnection exists before reclosing occurs. SIGE and the Producer shall coordinate to ensure that all Producer-generation disconnects prior to SIGE's system reclosing operation.

Large customer-owned generation may be asked to ride through electrical disturbances, including faults and other transients. This will be coordinated on a case-by-case basis.

SIGE's practice is to reclose circuit breakers on transmission and distribution lines after they have automatically tripped. Protective relays are intended to disconnect the generator from faulted or isolated lines before reclosing occurs. On-site relaying is not always adequate to ensure separation when the Producer's generator is capable of supplying most or all of the line or line segment load; therefore, remote relaying may be required.

SIGE costs for installing, maintaining, and/or modifying such equipment shall be borne by the Producer.

3.6.3 Effective Grounding

SIGE requires effective grounding on its distribution system. SIGE may require customer to effectively ground their equipment as well by installing a grounding transformer or other means.
A general definition for an effectively grounded system is where the ratio of zero-sequence reactance to positive- sequence reactance is less than or equal to three ($X_0/X_1 \leq 3.0$), and the ratio of zero-sequence resistance to positive-sequence reactance is less than or equal to one ($R_0/X_1 \leq 1.0$), for any condition of operation and for any amount of generator capacity.

SIGE uses effective grounding to limit the range of voltage rise on un-faulted phases during fault conditions and to provide a source of ground current to operate protective relays. This is done to protect SIGE's and all customers' phase-to-ground equipment and load.

3.7 SIGE Electric System Integrity and Power Quality

3.7.1 General

Interconnection of the Producer's generating equipment to the SIGE electric system shall not cause any reduction in the quality of service provided to SIGE customers. No abnormal voltages, frequencies, or interruptions caused by customer-owned generation shall be permitted. If steady state or transient voltage irregularities result from operation of Producer generation, such generating equipment shall be disconnected until the problem is resolved at the Producer's expense.

3.7.2 Harmonic Distortion

Voltage and current harmonic distortion and other power quality disturbances on a power system, from any source, shall be kept to a minimum. Current Total Harmonic Distortion (I_{THD}) and Voltage Total Harmonic Distortion (V_{THD}) may be measured by SIGE at the Producer's point of common coupling, the SIGE metering point. Under no circumstances, shall V_{THD} of the voltage waveform or I_{THD} of the current waveform be allowed to exceed levels established in **ANSI/IEEE 519**, **Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems**.

If a Producer's generating system is found to be interfering with other customers, Producers, SIGE, or public communications equipment, the Producer shall be required to install corrective measures such as harmonic filtering. The Producer shall bring the harmonic output of the generating system to an acceptable level and shall be resolved at the Producer's expense.

3.7.3 Frequency

Operation of the Producer's generator shall not adversely affect frequency stability on the SIGE electric system.
For installations connecting to SIGE's Distribution System (12 kV), the Producer shall follow the frequency ride-through guidelines of the most current IEEE 1547 Standard.

For installations connecting to SIGE's Transmission System (69 kV and above) or an electric substation, Producer shall follow the frequency ride-through guidelines of the most current NERC Standard PRC-024.

3.7.4 Voltage

Operation of the Producer's generator shall not adversely affect voltage stability on the SIGE electric system. Adequate voltage control may be required to minimize voltage regulation on the SIGE electric system caused by changing generator loading conditions. Automatic power factor or reactive power (VAR) controllers may be required for installations utilizing synchronous generators.

All generator installations over 10 kW shall maintain at least a power factor of 0.9 leading (VARs going into the machine) over an operating range of 25% to 100% of the generators rating. Inverter connected and synchronous machines shall maintain a power factor of 1.0 at their terminals unless otherwise directed by SIGE. All synchronous machines shall be capable of operating at between 0.9 leading to 0.9 lagging power factor.

For synchronous generators, sufficient generator reactive power capability shall be provided to withstand normal operating voltage changes on the SIGE electric system. The generator voltage-VAR schedule, voltage regulation settings, and transformer tap position shall be jointly determined by SIGE and the Producer to ensure proper coordination of voltages and regulator action.

No synchronous generator shall regulate the voltage at its terminals on the distribution system unless agreed to by SIGE. All synchronous generators on the distribution system shall be operated in power factor control mode unless a study determines voltage control is advantageous and will not cause problems with voltage regulation equipment and tap changers in SIGE's system.

All induction generators shall match speed to within 5% of synchronous speed before their breakers are closed. Exceptions to this requirement must be agreed to by SIGE.

In cases where starting or load changing on induction generators will have an adverse impact on SIGE electric system voltage, step-switched capacitors or other techniques may be required, at the Producer's expense, to bring voltage changes to synchronous speed before connecting to the SIGE electric system. In some cases, a closer speed match will be required.

3.8 Generating System Operating Requirements

3.8.1 De-Energized Circuits

The Producer shall not be permitted to energize a de-energized SIGE circuit under any circumstances without prior SIGE permission. Failure to observe this requirement is cause for immediate and permanent disconnection of the generating system. In addition, the Producer shall be held responsible for all damages and injuries resulting from such actions.

3.8.2 Operational Log

Operational log indicating changes in operating status, available or unavailable, maintenance outages, trip indications or other unusual conditions found upon inspection may be required by SIGE. The operational log shall be available for inspection upon request by SIGE.

3.8.3 Discontinuation of Operation

The Producer shall discontinue paralleled system operation when requested by SIGE for the following reasons:

- To facilitate maintenance, testing or repair of the SIGE electric system.
- During any emergency condition.
- When the Producer's generating equipment is interfering with other customers connected to the SIGE electric system.
- When it's determined that the Producer's generating system equipment reveals a condition hazardous to the SIGE electric system or a lack of scheduled maintenance or maintenance records for equipment necessary to protect the SIGE electric system.

3.8.4 Synchronous Generators

Producers with synchronous generators may be requested to provide the following:

- 24x7 voice communications capability to SIGE's operating center. Provide name(s) and telephone number(s) to SIGE's operating center.

- Name and telephone number of the designated operating agent. Designated operating agent and other operating personnel shall communicate with SIGE personnel with respect to line clearance and operating procedures.

- Notification to SIGE's designated operating center prior to bringing the generator on line and time of interconnection.

- Notification to SIGE's designated operating center at the time the generator is disconnected from the SIGE electric system.

- A droop setting on the governor of 5% is required.

- All machines shall be capable of operating at between 0.9 leading to 0.9 lagging power factor.

3.8.5 Telemetry (i.e. telecommunications)

Telemetering is required for sites over 1 MW and may be required for less than 1 MW.

Producer shall provide telemetering to SIGE's designated operating center (and MISO if applicable) for continuous kilowatt, kilovar, hourly generation values in kilowatt-hours, and breaker/inverter status.

The design, purchase, installation, testing, maintenance, and replacement of telemetry equipment and circuits from the Producer's generating system to the designated Point of Interconnection with SIGE shall be the responsibility of the Producer and must be approved by SIGE to ensure correct operation and system compatibility.

3.9 Generating System Design Requirements

3.9.1 Codes

Producer installations shall meet Indiana Utility Regulatory Commission rules for customer-owned generation systems and all applicable national, state and local construction and safety codes including the National Electrical Safety Code, the National Electrical Code, and all relevant IEEE Standards.

3.9.2 Protective Devices

Protective devices such as relays, circuit breakers, etc. used for the protection of SIGE's system, metering equipment and synchronizing equipment shall be provided by the Producer as required by SIGE. Protective devices differ with the size and type of the generating system. Producer shall ensure that the equipment ratings are sufficient to operate under normal and contingency states. Consideration must be given to maximum continuous operating voltage, continuous current ratings, over current duty ratings. Refer to **Section 3.11 "Protective Relaying Requirements"** for information concerning protective relaying requirements.

A manual-disconnecting device, capable of interrupting the generator and/or rated load current may be required per SIGE's Tariff. If required, the device shall be provided by the Producer and approved by SIGE. The device type will vary with the service voltage and capacity. This disconnecting device shall be accessible to SIGE personnel during emergency situations as described in the SIGE tariff. The device shall be of a design that can be locked open for line clearances.

If it is determined that system protection is required on the high voltage side of the interconnecting transformer, a 3-phase interrupting device shall be installed on the transformer high-voltage side. This device will be supplied and installed by SIGE at the expense of the generator owner.

The Producer will provide surge protection for its equipment. This surge protection equipment is to be coordinated with SIGE's equipment to ensure protection against voltage surges on both the Producer's and SIGE's systems.

3.9.3 Effective Grounding

All systems shall maintain effective grounding. Refer to **Section 3.6.3, "Effective Grounding"**.

Induction and synchronous generation systems shall have an X_0/X_1 ratio within the range of 2.5 to 3.0 during conditions resulting in unintentional islanding or a loss of the SIGE source. Inverter based generation systems shall have the appropriate anti-islanding measures per the IEEE 1547 standard. Intentional islanding is not permitted on the distribution system.

For systems over 1 MW, a delta-grounded wye step-up transformer with the grounded-wye winding connected on the distribution feeder side is required in order to maintain proper voltage for line-to-ground equipment. Other interconnecting transformer configurations could be considered but must be approved by SIGE. There could be situations where a grounding transformer or a Direct Transfer Trip (DTT) scheme may be required. SIGE has internal standards maintained by system protection personnel that can be referenced.

For systems less than 1 MW, a grounded-wye/grounded-wye or an ungrounded-wye/grounded-wye (utility side) interconnecting transformer can be acceptable.

Other interconnecting transformer configurations could be considered but must be approved by SIGE. There could be situations where a grounding transformer or a Direct Transfer Trip (DTT) scheme may be required. SIGE has internal standards maintained by system protection personnel that can be referenced.

Regarding synchronous and induction generation systems, if a generator neutral reactor is used, it shall be sized in accordance with the X_0/X_1 ratio mentioned above. If a generator neutral resistor is used, it shall be sized to limit the overvoltage on un-faulted phases to 120% of nominal, during single line-to-ground faults.

The reactor or resistor will limit fault current due to single line-to-ground faults as well as minimize the effect on SIGE grounding. The reactor, resistor, or grounding transformer shall be capable of carrying at least 20% of generator rated current on a continuous basis. Since generators may create excessive harmonics if their neutral is grounded, care must be exercised in generator selection or a grounding transformer should be used. If the generator cannot tolerate severe phase current unbalance, a grounding transformer is recommended.

3.9.4 Insulation

The insulation of the Producer's equipment shall be of suitable design to ensure that all equipment is properly protected against lightning, switching, and fundamental-frequency over-voltages and coordinated with SIGE's system.

3.9.5 Design Specifications

The Producer shall submit detailed design specifications and engineering information as soon as feasible and in accordance with IAC 170, as applicable. The design specifications shall include the following:

- The service voltage and location of the point of interconnection.
- An electrical one-line diagram of the Producer's generating system, beginning at the interconnection point, and the AC and DC schematics.
- A detailed description of how and where the Producer's load and generation will be connected and disconnected.
- The capacity and ownership of all equipment and circuits.
- Capacity and interrupting ratings for all equipment and safety devices, including detailed information of all protective relaying.

- A detailed description of any special control equipment required.
- Sufficient information to establish all necessary rights-of-way and easements to install, operate, maintain, replace, and remove SIGE's system.
- Machine characteristics, ratings and other technical information specified in the Appendix 1 and 2 of this document.

3.9.6 Induction Generators

SIGE may supply the VAR requirements from general system sources without a specific charge to the Producer. Installations may require capacitors to be installed to maintain a power factor of at least 0.9. See **Section 3.8.4, "Synchronous Generators"**. Such capacitor installations shall be at the Producer's expense.

The self-excited induction generator can produce abnormally high voltages that can cause damage to SIGE and customer equipment. Modern protective relaying can limit the duration of such over-voltages. Because of these problems, the reactive power supply for large induction generators must be studied on an individual basis. Where self-excitation problems appear likely, special service arrangements will be required. Especially during self-excitation, effective grounding is important to restrict the range of voltage unbalance. Refer to **Section 3.9.3, "Effective Grounding"**.

3.9.7 Inverter Systems

Total harmonic distortion (THD) from the generating system will be measured at the interconnection metering point. Under no circumstances, shall V_{THD} of the voltage waveform or I_{THD} of the current waveform be allowed to exceed levels established in **ANSI/IEEE 519**, **Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems**. If a Producer's inverter system is found to be interfering with other customers, Producers, SIGE, or public communications, the Producer shall be required to install filtering or other corrective measures to bring the harmonic output of the inverter to an acceptable level and shall be resolved at the Producer's expense.

3.9.8 Design Review

SIGE shall review submitted plans in compliance with regulating agency requirements (such as IAC 170) and either accept or deny the plans. A denied plan may be modified based on SIGE's response and re-submitted for review.

SIGE's responsibility is to protect its system and customers from damage or hazards due to the operation of interconnected generation. It is the Producer's responsibility to protect their generator and associated equipment from short circuits, overload, equipment failures or other malfunctions.

3.10 Metering Requirements

3.10.1 General

Metering installation requirements, for each interconnected generating system category, are outlined in the **SIGE Electric Service Manual** and in the MISO Open Access Transmission Tariff, if applicable. Unless agreed to otherwise, SIGE will furnish, install and own the meter for the registration of all electrical energy. The Producer shall provide a suitable place for the installation of the metering equipment and shall consult SIGE regarding the location of the metering equipment. For facilities exceeding 10 kW, SIGE may require customer to install a disconnect switch. The Producer shall provide SIGE employees access to the metering installation to modify, operate, maintain and read the metering equipment.

When the Producer owns the interconnection transformer, transformer high-side metering or loss-compensated metering shall be used, as required by SIGE. When SIGE owns the interconnection transformer, transformer low-side metering with transformer loss compensation shall be utilized for power deliveries to SIGE.

Two metering scheme options are available for Producers who have contracted to sell power to SIGE with generating systems greater than 10 kW:

- **Option "A"** shall be used when the Producer's load requirements are served directly by the Producer's generator. This metering option will use a single meter that measures both the power leaving the Producer's facility (outflow) and the power entering the Producer's facility (inflow).

- **Option "B"** shall be used when SIGE serves the Producer's load requirements. This option will meter the net output of the generator, which is the gross output of the generator minus the power consumed by the power production process and station service. All other loads not associated with the power production process will be metered separately.

3.10.2 Generation 10 KW & Under

Metering option "A" shall be applied for this category and located as shown in **Figure 5.1, "Relaying and Metering 10kW & Under".** Installation requirements as outlined in the **SIGE Electric Service Manual** are applicable.

3.10.3 Generation Over 10 KW to Less Than 100 KW

Metering options "A" or "B" shall be applied for this category as shown in **Figure 5.2, "Relaying and Metering Over 10kW to Less Than 100kW"**. Installation requirements as outlined in the **SIGE Electric Service Manual** are applicable.

3.10.4 Generation 100 KW to Less Than 1 MW

Metering options "A" or "B" shall be applied for this category as shown in **Figure 5.3, "Relaying and Metering From 100kW to less than 1 MW"**. Most of these meters will require dedicated instrument transformers and installation requirements shall conform to the **SIGE Electric Service Manual**.

If the nominal voltage of the metered circuit exceeds 480 volts, a transformer type primary meter installation, using both current and voltage transformers, is required, regardless of the load current. This is referred to as a primary meter and may be installed either in the Producer-owned switchgear, indoor or outdoor, or on a Producer-owned pole, outdoor. Such installations require coordination between the Producer and SIGE regarding accuracy class, technical details and locations.

For metering option "A", "generation" metering shall be connected so that energy from the generator is measured, and energy to the generator, from the SIGE electric system, is measured. For metering option "B", "load" metering shall be measured in addition to "generation" metering.

3.10.5 Generation 1 MW and Above

Metering options "A" or "B" shall be applied for this category as shown in **Figure 5.4, "Relaying and Metering From 1 MW to less than 10 MW"**. The Producer must coordinate with SIGE for units or systems larger than 10 MW. In general, these meters shall require dedicated instrument transformers and the installation requirements shall conform to the **SIGE Electric Service Manual**.

If the nominal voltage of the metered circuit exceeds 480 volts, a transformer-type primary meter installation, using both current and voltage transformers, is required, regardless of the load current. This is referred to as a primary meter and may be installed either in Producer-owned switchgear, indoor or outdoor, or on a Producer-owned pole, outdoor. Such installations require coordination between the Producer and SIGE regarding accuracy class, technical details and locations.

For metering option "A", "generation" metering shall be connected so that energy from the generator is measured, and energy to the generator, from the SIGE electric system, is measured. For metering option "B", "load" metering shall be measured in addition to "generation" metering. For metering option "B", the Producer shall consult SIGE regarding metering requirements.

The generating system in this category shall provide telemetering to SIGE's designated operating center (and the MISO if applicable) for continuous kilowatt, kilovar, and hourly generation values in kilowatt-hours.

3.11 Protective Relaying Requirements

3.11.1 Protection Classes

SIGE has established seven different classes of protective relaying for interconnected customer-owned generation. These classes are:

1) 0 - 10 kW
2) 10 kW - 100 kW
3) 100 kW - 1 MW
4) 1 MW - 10 MW
5) Over 10 MW
6) Hot Transfer Standby Generation
7) Demand Reduction Generation

Typical protective relaying schemes are shown in **Figure 5.1** through **Figure 5.5** within this document. The installation must be permanently wired within a suitable load center and a lockable disconnect switch shall be provided which is readily accessible to SIGE personnel at all times. This switch shall be located at the meter unless an alternate location is readily accessible and easily identifiable. The alternate location must be approved by SIGE. One exception to this rule is for installations with a total capacity of 10 kW or less interconnected to the SIGE electric distribution system and meet IEEE 1547 requirements and the requirements of 170 IAC Rule 4.3 Level 1 review. For these installations a disconnect switch is recommended but not required.

The Producer's protective relaying schemes must be coordinated with SIGE's schemes.

Relay protection classes are based upon the generator or inverter nameplate ratings. When multiple generators are connected to the SIGE electric system through a single service point, the class shall be determined by the sum of the generator ratings.

These classes have been established for convenience and are based on circuits with normal load density. The final decision as to the requirements for each installation will be made depending on concerns such as the Producer's generating system's load magnitude, the magnitude of other loads connected to that circuit, available short circuit contribution, source substation size and line conductor size.

SIGE cost for installing, maintaining, and/or rearranging such relaying equipment shall be borne by the Producer.

3.11.2 Generation 10 kW & Under

All installations in this class shall require a review by SIGE personnel. Those installations that are a standard package will be reviewed once. No further package review will be required for additional installations provided no changes in configuration or equipment are made to the package. Installations that are not a standard package shall be reviewed individually.

3.11.3 Generation Over 10 kW to Less Than 100 kW

All installations in this class shall require a review by SIGE personnel. Those installations that are a standard package shall be reviewed once. No further package review will be required for additional installations provided no changes in configuration or equipment are made to the package. Installations that are not a standard package shall be reviewed individually.

The protective relaying schemes are shown in **Figure 5.2, Relaying and Metering Over 10kW to Less than 100kW"**. The larger installations in this class shall use industrial grade relays or utility grade relays. The larger installations may vary somewhat from the layout shown in Figure 5.2. Some variation in the specifics, but not of the intent of the requirements, will be allowed. All variations shall be approved by SIGE.

3.11.4 Generation 100 kW to Less Than 1 MW

All installations in this class shall require a full protective relaying and site review by SIGE personnel. The protective relaying schemes are shown in **Figure 5.3, "Relaying and Metering From 100kW to Less than 1 MW"**. For some of the larger installations, the transformer and associated equipment may be owned by the Producer instead of SIGE. Utility grade protective relays, such as those normally found in utility switchgear and utility grade equipment shall be required. The following manufacturers, as well as some others, produce utility grade protective relays: Schweitzer Engineering Laboratories, General Electric, ABB Power T & D Company, Inc. and Basler Electric.

3.11.5 Generation 1 MW to Less Than 10 MW

All installations in this class shall require a full protective relaying and site review by SIGE personnel. The protective relaying schemes are shown in **Figure 5.4, "Relaying and Metering From 1 MW to less than 10 MW"**. For some of the larger installations, the transformer and associated equipment may be owned by the Producer instead of SIGE. Utility grade protective relays, such as those normally found in utility switchgear and utility grade equipment shall be required. The following manufacturers, as well as some others, produce utility grade protective relays: Schweitzer Engineering Laboratories, General Electric, ABB Power T & D Company, and Basler Electric.

Many rural systems will not accept this class of generation and, as such, shall be treated in the same manner as the over 10 MW class. Most circuits will most likely require modifications to be compatible with this class of installation.

3.11.6 Generation Over 10 MW

In general, the SIGE distribution system is designed to handle load and generation up to 10 MW. Generation in excess of 10 MW shall be served from the transmission system. Each installation is unique so that no general requirements are possible. Each installation shall be discussed and reviewed by SIGE personnel on an individual basis. SIGE shall be contacted, by the Producer, to determine the feasibility of any proposal, due to the restrictive nature and cost of interconnection to the SIGE electric system.

3.11.7 Battery Power & DC Fusing

A battery power system may be required to provide DC for powering control systems, breaker control, and powering protective relays if determined to be needed for proper system protection by SIGE. The cost of this system is the responsibility of the Producer.

Adequate protection for the loss of a DC fuse shall be provided. Figure 10.6 illustrates an example of a DC fusing scheme utilizing a loss of potential relay to trip the breaker. A loss of potential relaying scheme shall be required when there is no relaying redundancy. In installations where relaying redundancy exists, the DC fusing scheme shall prevent common mode failure of the sensing, tripping and interruption equipment. The entire tripping scheme shall not become disabled by a single DC fuse operation. Relay redundancy can be achieved through a combination of relays or an exact duplication of relays.

3.11.8 Direct Transfer Trip

SIGE may require a Direct Transfer Trip (DTT) scheme to be installed at the point of common coupling with Producer's facility as the result of system studies. The costs associated with the DTT scheme shall be borne by the Producer.

3.12 Demonstrations/Inspections of Protective Devices

3.12.1 General

The Producer shall demonstrate to SIGE personnel the correct operation of all protective devices when requested by SIGE. SIGE shall not be responsible for performing these demonstrations. The Producer shall provide qualified personnel to perform these demonstrations/inspections. Demonstrations/inspections shall be performed on all new equipment and modified equipment, and on existing equipment as circumstances warrant or when requested by SIGE.

These demonstrations shall be divided into three sections: Bench Testing/Calibration, Trip Checks and On-Line Testing. The Bench Testing/Calibration section shall demonstrate that agreed upon settings, between the Producer and SIGE, are used on each of the relays required by SIGE. This section also demonstrates that the relays are functional and calibrated to their manufacturer's tolerances. The Trip Checks section shall demonstrate that both the required relays and their interlocks correctly operate. The On-Line Tests section shall demonstrate the expected operation of relays and interlocks specific to the interconnection interface.

The following Bench Testing/Calibration, Trip Checks and On-Line Testing sections are intended to serve as guidelines. These demonstrations are designed to be non-destructive; however, SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. It shall be the Producer's responsibility to demonstrate operation of all protective devices in a safe manner. These demonstrations should not adversely affect the generator or any equipment associated with the interconnection.

Producer shall provide all test records and any additional documentation requested by SIGE.

3.12.2 Bench Testing/Calibration

Proper testing and verification of CTs and VTs and relay settings shall be demonstrated to SIGE personnel in the following manner:

- Four tests shall be performed for CT verification in accordance with the latest version of **ANSI/IEEE C57.13.1** and are as follows:

  1) Ratio check.

  2) Polarity check

3) Excitation Test, Saturation Test, reports from the manufacturer or in lieu of the reports.

4) Insulation Resistance Test

- Two tests shall be performed for VT verification in accordance with the latest version of **ANSI/IEEE C57.13.1** and are as follows:

1) Ratio Check using voltage method.

2) Polarity Check using DC or AC voltage tests

- Relays shall be tested as follows:

1) Tested according to their manufacturer's acceptance specifications.

2) Tested at on-line setting values to verify calibration. If possible, this can be completed as part of the relay acceptance test.

All testing and calibration of CTs, VTs and relays shall be performed with test equipment of current calibration according to manufacturer's calibration specifications and intervals. Proof of test equipment calibration must be produced upon request from SIGE prior to relay calibration. All systems over 1 MW must have SIGE's designated personnel witness the synchronizing and sync-check function, calibration and operation.

3.12.3 Trip Checks

All required DC trip circuitry shall be functionally checked to demonstrate proper voltage and continuity from the DC source to the breaker trip coil. Additionally, all required relays shall be functionally operated to demonstrate correct operation. Tests can be performed off-line if possible. Tests that cannot be performed off-line shall be demonstrated to functionally operate on-line. Trip outputs from the relay may be either by manually operating all appropriate contacts, dictated by design, or by injecting an electrical signal to cause a trip output. If a lockout device is used with a blocking relay, then the relay(s) shall be tripped a minimum of one time through the entire scheme. All other trips may then be performed in such a manner so only the lockout device trips.

- Verify that breaker(s) cannot be manually or automatically closed with the trip relay in the latched or trip position.

- Demonstrate that the synchronism check and synchronizing relays wiring is correct and interlocks operate correctly.

- Demonstrate that interlocks between the generator and SIGE breaker(s) operate properly; i.e., the Producer cannot re-energize a de-energized SIGE electric system supply and can only tie to an energized SIGE electric system supply via a synchronizing device.

- Demonstrate that the breaker cannot be closed either manually or automatically without resetting the lockout device.

- Demonstrate proper operation of anti-islanding, synch check, and other embedded protection functions for inverter-based generation systems.

3.12.4 On-Line Tests

Testing requirements for proposed facilities will be identified by SIGE during the review of the application. Typical testing requirements are provided in **Appendix 3.1 "Synchronous/Induction On-Line Testing"** and **Appendix 3.2 "Inverter-based Generation On-Line Testing"**.

3.13 Periodic Demonstrations/Inspections of Protective Devices

3.13.1 Maintenance

The Producer shall maintain its equipment in good order. SIGE reserves the right to inspect the Producer's generating system, at the Producer's expense, whenever it appears that the generating system is operating in a manner detrimental to the integrity of the SIGE electric system. The Producer shall annually perform functional testing of all breakers, relays, and transformers. Installations must have protection systems tests performed every three years and certified test reports shall be forwarded to SIGE.

Interface protective devices shall be tested and may or may not have to be demonstrated to SIGE. The Producer shall provide qualified personnel to perform the demonstrations. SIGE costs for the demonstration shall be borne by the Producer.

Maintenance of the Producer's generating system shall be coordinated with SIGE and, if required, with the MISO. The Producer shall schedule with SIGE (and MISO if applicable) all planned maintenance which would impact the output of the Producer's facilities. The Producer shall contact the provided SIGE contact as soon as practical should an unscheduled outage be needed or if one should occur.

3.13.2 Annual Demonstrations/Inspections

It shall be the Producer's responsibility to conduct an annual demonstration/inspection of interconnection trip schemes and generator synchronization, if required by SIGE. The Producer shall provide qualified personnel to perform these demonstrations. These demonstrations are designed to be non-destructive, and it shall be the Producer's responsibility to conduct these demonstrations in a safe manner. SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. These demonstrations should not adversely affect the generator or any equipment associated with the interconnection.

These annual demonstrations shall consist of the following:

1) All interconnection trip schemes and interlocks shall be demonstrated for proper operation. All interface protective devices shall be trip tested in such a manner so that a trip signal originates from the protecting device. The trip command can be simulated by closing a mechanical contact, or relay device secondary circuit injection of voltage, current, or frequency to cause a trip, or by the removal or change of a protective device's sensing circuit input, without lifting wiring, to cause a trip.

2) Anti-islanding protection shall be tested.

3) If an 86 device is used with a blocking relay, then the relay(s) shall be tripped a minimum of one time through the entire scheme. All other trips may then be performed in such a manner so that only the 86 device trips.

4) Synchronizing shall be demonstrated annually in automatic and manual mode, if applicable. With the breaker in the test position, verify that close is blocked for an out-of-phase condition, allows close in an in-phase condition and blocks close on a dead bus condition.

All test results shall be forwarded to SIGE.

3.13.3 Three-Year Demonstrations/Inspections

In addition to the annual demonstrations/inspections, it shall be the Producer's responsibility to conduct three-year demonstrations of relay operation and generator VAR capacity performance. The Producer shall provide qualified personnel to perform these demonstrations. These demonstrations are designed to be non-destructive, and it shall be the Producer's responsibility to conduct these demonstrations in a safe manner. SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. These demonstrations should not adversely affect the generator or any equipment associated with the interconnection.

These annual demonstrations shall consist of the following:

1) Relays are functional and calibrated at approved settings and within their manufacturer's tolerances. Refer to manufacturer's literature for test procedures.

2) The VAR capacity test shall be demonstrated on generators that have adjustable voltage regulation. Operation at 90% leading and lagging power factor shall be performed. Tests shall be conducted at 25%, 50%, 75%, and 100% of rated generator output. With SIGE approval, the capacity tests may be limited or waived because of operational limitations due to manufacturer's design criteria or stator end turn heating concerns

3.13.4 Design Changes After Commercial Operation

Design changes of the interconnection protection and synchronizing schemes shall be reviewed and approved by SIGE, at the Producer's expense. Demonstrations/inspections of relay calibration, trip tests and on-line testing may be required depending on the extent of the design change. Changes to the SIGE electric system can be necessary and may be extensive. The cost of these changes shall be borne by the Producer.

Setting changes of any interconnection protection or synchronizing device, or any "Field Modification" or "As Built" protection and synchronizing schematics associated with any interconnection device shall be reviewed and approved by SIGE, at the Producer's expense.

4 Transmission

As a Generator Owner, SIGE requires a fully executed agreement with a third-party planning to interconnect to a SIGE generation facility prior to providing the respective facility interconnection requirements. Upon request, SIGE provides interconnection requirements within 45 calendar days of the fully executed agreement. The agreement states SIGE conducts a study on the reliability impact of the interconnection.

Any request over 10MW must be connected to the transmission system.

4.1 Initiating a Request

Producer and SIGE personnel are to use these guidelines when planning installations or modifications for generation to identify proper design, analysis and coordination in the pursuit of a comprehensive, interconnection feasibility study.

SIGE personnel reviews all proposed material modifications to the interconnected electric systems to determine the level of impact. The Producer must notify SIGE of any planned generation installations or material modifications so that all entities responsible for the reliability of the distribution systems and the interconnected transmission systems can also be notified as soon as feasible.

Applicable interconnection costs will be billed to Producer per IAC 170 and/or MISO Tariff. These costs may include, but not limited to, the following: design and installation, metering and communications, protective and safety devices, network upgrades, and power system studies.

4.2 Requirements for Interconnection

The operation of a generator interconnected to the SIGE electric system presents several issues of concern for the SIGE electric system. These concerns include: safety, reliability, quality of service, protection planning and operations problems. SIGE must maintain the integrity of its system to ensure a reliable supply of electricity to its customers and the bulk electric system. Therefore, any interconnected generating system must include equipment dedicated to protecting the electric system from problems that originate within the interconnected generating system. These concerns and problems are evaluated by completing steady state, short circuit, dynamics, and effected system studies as described in **VEC-008 Electric Generation and Transmission Planning Criteria**.

Producers requesting to connect generators to the electric transmission system must also meet applicable IEEE, NERC, and MISO requirements. Any generator connected to the SIGE transmission system shall be connected using a dedicated generator step-up transformer. Exceptions will be evaluated on a case-by-case basis.

The Producer must verify with SIGE the specific point of interconnection to ensure that it is within SIGE's Balancing Authority metered boundaries.

SIGE is a member of the Midcontinent Independent System Operator, Inc. (MISO), which performs as SIGE's Transmission Provider, Planning Coordinator, and Reliability Coordinator. The Producer must first file a request with MISO for an interconnection to the SIGE electric transmission system. MISO notifies transmission owners who may be impacted by the generation addition or modification. MISO also performs coordinated joint studies to evaluate the impact of the generation addition or material modification and identify any upgrade requirements. In addition, these studies address plans to achieve the required system performance throughout the planning horizon.

After interconnecting, SIGE and MISO require the Producer to notify them of any proposed modifications to facilities.

4.2.1 Modeling Requirements

As mentioned above and described in VEC-008 Electric Generation and Transmission Planning Criteria, steady state, dynamics, short circuit, and other system studies may be required to ensure reliability, integrity, and quality of service on SIGE's electric system. To ensure the accuracy of these studies and their results, SIGE requires Producers to provide various modeling information or facility data that can be converted to needed modeling information. Since the studies are required to be completed before the interconnection is approved, there is the potential that this data as provided will be preliminary, in which case Producer is required to submit updated final data prior to commercial operation. Also, any changes made to Producer's generating facilities in the future are required to be communicated to SIGE and updated data is required to be submitted.

The type of data can generally be grouped by the three main study types, steady state, dynamics (or transient stability), and short circuit. The type of data required will correspond to the type of study required, as determined by SIGE and MISO.

Steady state, or load flow, studies are used to determine the impacts on SIGE's electric system during continuous operation through normal and abnormal (whether due to fault conditions or maintenance outages) system operating conditions. The data needed for these studies includes:

- Maximum continuous AC output of the generator or inverter
- AC terminal voltage of the generator or inverter
- Positive sequence impedance of transformers and conductors
- Continuous current ratings of transformers and conductors

- Transformers tap settings
- Power factor at point of interconnection
- Station service load for synchronous machines
- Reactive capability of any power factor correction devices (such as capacitor banks)
- Voltage control settings
- Other data as specified by SIGE and MISO

Dynamics, or transient stability, studies are used to determine the generator and associated equipment's behavior during and immediately after a fault condition to ensure the electric system remains stable. The modeling needed for these studies incudes detailed data on the below components.

- Generator
- Inverter
- Exciter
- Governor
- Power system stabilizer
- Compensator
- Outer loop controller
- Inverter controller
- Under/over voltage and frequency relays
- Station service loads
- Power factor correction devices (such as capacitor banks)
- Other installation dependent equipment as determined by SIGE and MISO

Short circuit studies are used to evaluate the system under fault conditions, validate circuit breaker duty requirements, and for setting and coordinating relay settings. The data needed for these studies includes:

- Zero sequence impedances of transformers and conductors
- Negative sequence impedances of transformers and conductors (if different from positive sequence)
- Unit neutral impedance
- Number of inverters
- Load and no-load losses for transformers
- Excitation and thermal limits
- Relay settings
- Other data as specified by SIGE

Additional modeling data, including electromagnetic transient modeling (ETM) modeling data, may be required based on the size and type of the proposed installation. SIGE will coordinate with Producer on needed data during the data submittal and system impact portions of the interconnection process.

4.3 Points of Concern

4.3.1 Safety Concerns

Safety concerns focus first on isolating the interconnected generator from the SIGE electric system when a SIGE electric system line is opened. Isolation shall be both automatic and manual. The method for accomplishing automatic isolation may vary depending on size, electrical characteristics, and other factors of the interconnected generating system and the SIGE electric system. A lockable, manually operated switch or breaker disconnect with visible breaks between the SIGE electric system and all customer-owned energy sources is required. This switch or breaker disconnect shall be subject to SIGE lock-out and tag-out procedures.

Another concern with isolating an interconnected generator is self-excitation of the generator, which can cause damage to customer and SIGE-owned equipment and create public safety issues. Voltage and frequency relays and automatic interrupting devices shall be used to protect the equipment, SIGE employees, and the public.

An additional safety concern is preventing the isolated generator from energizing a de-energized SIGE electric system circuit. Energizing a de-energized circuit can endanger the public, rescue workers, SIGE employees and others who may have determined that the circuit is de-energized and were in contact with the circuit. In this situation, energizing a de-energized circuit shall be blocked for all automatic and manual closing schemes.

4.3.2 Reliability Concerns

The Producer shall ensure that the interconnected generating system does not adversely impact the reliability of the electric system. This consideration may influence the equipment protection scheme designs, discussed later. Protective relay settings shall be coordinated so that the safety and reliability of electric service for all SIGE customers are not compromised.

Other factors that could affect the reliability of SIGE electric system and require additional protective relay considerations, include but are not limited to:

- The location of the interconnected generating system on the SIGE electric system; if the interconnection location is at a transmission level, then interruptions of service have a greater impact to the SIGE electric system than when located at a distribution level.
- The generator size compared to the interconnected generating system load and the load on the SIGE electric system line.

4.3.3 Quality of Service Concerns

SIGE is required to meet certain tolerances of voltage, frequency, and duration to their customers. Power supplied to the SIGE electric system by an interconnected generating system shall also be within certain tolerances so that the overall power quality of the SIGE electric system remains satisfactory.

The following list of quality-of-service concerns may need to be addressed between the Producer and SIGE. The associated cost with resolving these concerns may be the responsibility of the Producer.

- Lagging or leading power factor (pf). Capacitors can be used to correct lagging power factor.

- Harmonic currents. Harmonic currents occur at frequencies other than the desired 60 Hz of the power signal. Harmonic currents can cause improper operation of protective relays, communication systems, and sensitive electronic equipment.

- Voltage Transient. Voltage variations can occur when there are sudden changes of current flowing in a circuit. Voltage transient can cause misoperation of sensitive equipment.

4.3.4 Protection Concerns

Both the Producer and SIGE must protect their respective personnel and systems from injury or damage, which may be the result of the interconnection of a customer-owned generator. This protection often utilizes automatic equipment to detect and isolate faulted sections of a system so that the remainder of the system can continue to operate without interruption.

4.3.5 Planning and Operations Concerns

Where customer-owned generators are present, several areas of SIGE electric system planning can be affected for two reasons: first, is that a dispersed generator exists, as opposed to centralized generators, and second, is the assumption of unidirectional power flow from the SIGE electric system to customers may no longer be valid.

SIGE accounts for deviations from expected load surveys and load factors caused by dispersed generation. Both of these are affected by dispersed generation. Load surveys are done to determine electrical demands SIGE must meet for the present and for the future. Load factors reflect the utilization of SIGE electric system equipment, the ratio of average usage to the peak usage. The Producer shall be required to pay for any increased costs resulting from changes in SIGE operating procedures.

Operations, for both the interconnected generating system and the SIGE electric system, is affected by the customer-owned generator. The impact on SIGE electric system operations may include extra records and communications required to work safely on circuits with dispersed generation and increased time to do repair work. If the customer-owned generator is very large, SIGE may choose to include the generator in its dispatch of generating units and retain some control over the generator operation. The control system may use telemetering. Also, very large generators can impact the SIGE electric system stability, the ability of the system to stay synchronized after any disturbance, and SIGE may require even more stringent protection requirements or special equipment to maintain stability margins.

4.4 SIGE Electric System Information

4.4.1 Voltage

The SIGE electric transmission system nominal voltages are: 345 kV, 138 kV, and 69 kV. SIGE's nominal distribution voltage is 12.47 kV. The Producer should contact SIGE for information on specific circuit voltages available to the Producer's generating system.

SIGE operates the electric system voltage between 95% and 105% of nominal under normal and single transmission element outage conditions.

Under multiple element outage conditions, system voltage may range between 90% and 105% of nominal. If the **Producer's** supply voltage requirements are more restrictive than the range of 90% to 105%, SIGE recommends that the **Producer** consider the addition of voltage regulation equipment to their facility.

Under certain emergency conditions, the SIGE electric transmission system may operate for a period of time outside of the 90% to 105% range. The **Producer** is responsible for providing any voltage sensing equipment required to protect their equipment during abnormal voltage operation.

4.4.2 Circuit Restoration

It is the responsibility of the Producer to install necessary equipment to ensure a proper disconnection exists before reclosing occurs. SIGE and the Producer shall coordinate to ensure that all Producer-generation disconnects prior to SIGE's system reclosing operation.

Generation facilities connected to the SIGE transmission system are required to ride through electrical disturbances, including remote faults (those not occurring within generator/unit zone of protection) and other transients.

Protective relays on the unit/generation system are intended to disconnect the generator from internal generator/unit zone of protection faults. Although SIGE's practice is to automatically reclose circuit breakers on transmission lines after they have tripped, this is not allowed for generator/unit zone of protection faults.

SIGE costs for installing, maintaining, and/or modifying relaying equipment at the point of interconnection shall be borne by the Producer.

4.4.3 Effective Grounding

SIGE maintains effective grounding on its electric system.

A general definition for an effectively grounded system is where the ratio of zero-sequence reactance to positive- sequence reactance is less than or equal to three ($X_0/X_1 \leq 3.0$), and the ratio of zero-sequence resistance to positive-sequence reactance is less than or equal to one ($R_0/X_1 \leq 1.0$), for any condition of operation and for any amount of generator capacity.

SIGE requires an effective ground source to the transmission system such that it provides a source of ground current to operate protective relays. This can be accomplished via the proper transformer interconnection. Typical interconnecting transformer configurations would be a grounded wye-grounded wye with a delta tertiary or delta-grounded wye (transmission side) GSU connection.

4.5 SIGE Electric System Integrity

4.5.1 General

Interconnection of the Producer's generating equipment to the SIGE electric system shall not cause any reduction in the quality of service provided to SIGE customers. No abnormal voltages, frequencies, or interruptions shall be permitted. If steady state or transient voltage irregularities result from operation of Producer generation, such generating equipment shall be disconnected until the problem is resolved at the Producer's expense.

4.5.2 Harmonic Distortion and Power Quality

Voltage and current harmonic distortion and other power quality disturbances on a power system, from any source, shall be kept to a minimum. Periodically, Current Total Harmonic Distortion (I_{THD}), generated by the Producer's generating system, and Voltage Total Harmonic Distortion (V_{THD})) may be measured by SIGE at the Producer's point of common coupling, the SIGE metering point. Under no circumstances, shall V_{THD} of the voltage waveform or I_{THD} of the current waveform be allowed to exceed levels established in **ANSI/IEEE 519**, **Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems**.

If a Producer's generating system is found to be interfering with other customers, Producers, SIGE, or public communications equipment, the Producer shall be required to install corrective measures such as harmonic filtering. The Producer shall bring the harmonic output of the generating system to an acceptable level and shall be resolved at the Producer's expense.

4.5.3 Frequency

Operation of the Producer's generator shall not adversely affect frequency stability on the SIGE electric system.
For installations connecting to SIGE's Transmission System (69 kV and above) or an electric substation, Producer shall follow the frequency ride-through guidelines of the most current NERC Standard PRC-024.

4.5.4 Voltage

Operation of the Producer's generator shall not adversely affect voltage stability on the SIGE electric system. Adequate voltage control may be required to minimize voltage regulation on the SIGE electric system caused by changing generator loading conditions. Automatic power factor or reactive power (VAR) controllers may be required for installations utilizing synchronous generators.

All generator installations over 10 kW shall maintain at least a power factor of 0.9 leading (VARs going into the machine) over an operating range of 25% to 100% of the generators rating. Inverter connected and synchronous machines shall maintain a power factor of 1.0 at their terminals unless otherwise directed by SIGE. All synchronous machines shall be capable of operating at between 0.9 leading to 0.9 lagging power factor. All nonsynchronous resources to provide dynamic reactive power within a minimum power factor range of 0.95 leading to 0.95 lagging. If additional reactive power capability is available from the inverter-based resources for a specific active power output, that capability should not be artificially limited.

The reactive capability of the Producers generation installation shall be dynamic and able to supply and absorb reactive current to control voltage at the Point of Measurement. Static reactive compensation, such as capacitor banks, shall only be used for compensating losses in the collector system. The active and reactive capability of all resources shall be provided in the form of a P-Q graph which represents the capability of the overall system at the Point of Measurement at nominal voltage. For inverter-based resources, P-Q graphs may be required for individual inverters to verify the aggregate capability.

For synchronous generators, sufficient generator reactive power capability shall be provided to withstand normal operating voltage changes on the SIGE electric system. The generator voltage-VAR schedule, voltage regulation settings, and transformer tap position shall be jointly determined by SIGE and the Producer to ensure proper coordination of voltages and regulator action.

Inverter-based resources shall maintain the voltage schedule determined by SIGE by controlling voltage at the Point of Measurement with a closed-loop, automatic voltage control mode. Inverter base resources should have capability to meet or exceed the performance specified in **Appendices 4.1** and **4.2**.

All induction generators shall match speed to within 5% of synchronous speed before their breakers are closed. Across the line starting and electrically accelerating of induction generators, without first accelerating the machine to within 5% of synchronous speed using the prime mover before closing the breaker shall be permitted only when agreed to by SIGE.

In cases where starting or load changing on induction generators will have an adverse impact on SIGE electric system voltage, step-switched capacitors or other techniques may be required, at the Producer's expense, to bring voltage changes to synchronous speed before connecting to the SIGE electric system. In some cases, a closer speed match will be required.

4.5.5 Momentary Cessation

Momentary cessation is a mode of operation during which no current is injected into the grid by the inverter during low or high voltage conditions outside the continuous operating range. This leads to no current injection from the inverter and therefore no active or reactive current (and no active or reactive power). Note that during momentary cessation, the inverter remains electrically connected to the grid.

Based on data gathered from the NERC Alerts following the Blue Cut Fire and Canyon 2 Fire disturbances, the use of momentary cessation outside of the continuous operating range was implemented in the majority of solar PV inverters connected to the Bulk Electric System. The ERO, while working with industry stakeholders, identified that the continued use of momentary cessation for connected inverter-based resources with these settings is a potential reliability risk.

Newly interconnecting inverter-based resources shall be designed and configured to continuously inject current within the "No Trip Zone" of the currently effective version of PRC-024. Momentary cessation should only be approved as an exception based on system studies performed by the utility or MISO to mitigate potential local reliability or controls-related stability issues.

4.5.6 Phase Jump Requirement

The inverter continually monitors the phase angle difference between the inverter ac voltage command and the grid-side ac voltage.
Producer shall provide the means in which the inverters may trip on instantaneous change in phase (magnitude and angle) either due to fault events or line switching events.
SIGE may perform system studies to identify possible worst-case phase jump at the point of interconnection (POI) of the interconnecting resources. SIGE may also identify worst-case balanced phase jump limits. Inverter-based resources should not trip for studied credible contingency events, such as switching, faults, disturbances, or other anomalies.

4.6 Generating System Operating Requirements

4.6.1 Return to Service Following Tripping

The Producer shall not be permitted to energize a de-energized SIGE circuit under any circumstances without direction from SIGE or MISO. Failure to observe this requirement is cause for immediate and permanent disconnection of the generating system. In addition, the Producer shall be held responsible for all damages and injuries resulting from such actions.

Following "system black" conditions, inverter-based resources should not attempt to automatically reconnect to the grid (unless directed by the MISO) to not interfere with blackstart procedures.

Any Transmission connected resource (69kV and above) that trips offline shall reconnect based on the reconnection requirements provided by SIGE's control center and MISO.

4.6.2 Discontinuation of Operation

The Producer shall discontinue paralleled system operation when directed by MISO or SIGE for the following reasons:

- To facilitate maintenance, testing or repair of the SIGE electric system.
- During any emergency condition.

- When the Producer's generating equipment is interfering with other customers connected to the SIGE electric system.

- When a SIGE inspection of the Producer's generating system equipment reveals a condition hazardous to the SIGE electric system or a lack of scheduled maintenance or maintenance records for equipment necessary to protect the SIGE electric system.

4.6.3 Synchronous Generators

Producers with synchronous generators shall provide the following:

- 24x7 voice communications capability to SIGE's operating center. Provide name(s) and telephone number(s) to SIGE's operating center.

- Name and telephone number of the designated operating agent. Designated operating agent and other operating personnel shall communicate with SIGE personnel with respect to line clearance and operating procedures

- Notification to SIGE's designated operating center prior to bringing the generator on line and time of interconnection.

- Notification to SIGE's designated operating center at the time the generator is disconnected from the SIGE electric system.

- A droop setting on the governor of 5% is required.

- All machines shall be capable of operating at between 0.9 leading to 0.9 lagging power factor.

4.7 Generating System Design Requirements

4.7.1 Codes

Producer installations shall comply with all applicable NERC Standards and requirements, as well as national, state and local construction and safety codes including the National Electrical Safety Code, the National Electrical Code, and all relevant IEEE Standards.

4.7.2 Protective Devices

Protective devices such as relays, circuit breakers, etc. used for the protection of SIGE's system, metering equipment and synchronizing equipment shall be provided by the Producer as required by SIGE. Protective devices differ with the size and type of the generating system. Producer shall ensure that the equipment ratings are sufficient to operate under normal and contingency states. Consideration must be given to maximum continuous operating voltage, continuous current ratings, over current duty ratings. Refer to **Section 4.10, SCADA/Telemetry** for information concerning protective relaying requirements.

A lockable, manually operated switch or breaker disconnect with visible breaks between the SIGE electric system and all customer-owned energy sources is required. The form of this device will vary with the service voltage and capacity. This disconnecting device shall always be accessible to SIGE personnel. The device shall be of a design that can be locked open for line clearances.

If it is determined that system protection is required on the high voltage side of the interconnecting transformer, a 3-phase interrupting device shall be installed on the transformer high-voltage side. This device will be supplied and installed by SIGE at the expense of the Producer.

The Producer will provide surge protection for its equipment. This surge protection equipment is to be coordinated with SIGE's equipment to ensure protection against voltage surges on both the Producer's and SIGE's systems.

4.7.3 Effective Grounding

All systems shall maintain effective grounding. Refer to **Section 4.4.3, "Effective Grounding**".

Induction and synchronous generation systems shall have an X_0/X_1 ratio within the range of 2.5 to 3.0 for loss of SIGE source conditions.

For induction and synchronous generation systems, a delta-grounded wye step-up transformer with the grounded-wye winding connected on the transmission system side is required in order to maintain proper voltage for line-to-ground equipment and provide a ground source of fault current to aid in the operation of protection systems.

For any generator step up transformer configuration, the system X_0/X_1 ratio should take into account the sum of zero-sequence reactances of the step-up transformer, generator sub-transient and any generator or step-up transformer neutral grounding and grounding bank and shall be between 2.5 and 3.0 during islanding conditions.

Regarding synchronous and induction generation system, if a generator neutral reactor is used, it shall be sized in accordance with this formula. If a generator neutral resistor is used, it shall be sized to limit the overvoltage on un-faulted phases to 120% of nominal, during single line-to-ground faults.

The reactor or resistor will limit generator damage due to single line-to-ground faults as well as minimize the effect on SIGE grounding. The reactor, resistor, or grounding transformer shall be capable of carrying at least 20% of generator rated current on a continuous basis. Since many generators create excessive harmonics if their neutral is grounded, care must be exercised in generator selection or a grounding transformer should be used. If the generator cannot tolerate severe phase current unbalance, a grounding transformer is recommended.

For inverter-based generation systems, a grounded wye-grounded wye with a delta tertiary step up transformer is required in order to maintain proper voltage for line-to-ground equipment and provide a ground source of fault current to aid in the operation of protection systems, although ground fault current could be minimal in some cases. Due to the lack of ground fault current or zero-sequence current, SIGE may elect to require inverter-based generation to provide additional positive and negative sequence current injection to the system for fault conditions as required for reliable operation of protection systems on the transmission system.

Inverter based generation systems shall have the appropriate ride-through measures in the event of system disturbances and transients. NERC PRC standards and IEEE standards should be referenced.

4.7.4 Insulation

The insulation of the Producer’s equipment shall be in accordance with IEEE Standards, at a minimum, to ensure that all equipment is properly protected against lightning, switching, and fundamental-frequency over-voltages and coordinated with SIGE’s system. This will be coordinated during interconnection facilities study.

4.7.5 Design Specifications

The Producer shall submit detailed design specifications and engineering information per the MISO Generation Interconnection process. The design specifications shall include the following:

- The service voltage and location of the point of interconnection.

- An electrical one-line diagram of the Producer's generating system, beginning at the interconnection point, and the AC and DC schematics.

- A detailed description of how and where the Producer's load will be connected and disconnected.

- The capacity and ownership of all equipment and circuits.

- Capacity and interrupting ratings for all equipment and safety devices, including detailed information of all protective relaying.

- A detailed description of any special control equipment required.

- Sufficient information to establish all necessary rights-of-way and easements to install, operate, maintain, replace, and remove SIGE's system.

- Machine characteristics, ratings and other technical information specified in the **Appendix 1** and **2** of this document.

- Grid forming technology information, if supported by inverters

- Blackstart capability information, if supported by inverters

- Technical information and data for the exciter, governor, power system stabilizer, reactive line drop compensation, and any other equipment required.

- Nameplate data, including ratings and impedances, for the main generator step-up (GSU) transformer.

- Conductor size, type, length, rating, and impedance for tie line between the generator station and the POI (gen-tie line).

- Test results or certifications related to inverter current during fault conditions, including current magnitude, phase relationship of current with respect to voltage, and timing of injection.

4.7.6 Low Short-Circuit Strength Networks

Short circuit strength is needed for protection systems to reliably operate.

Studies analyzing system short-circuit strength are performed for interconnecting generating resources, and typically include a determination of an SCR (short circuit ratio) based metric.
These studies may be performed by MISO, SIGE, or a designated third party.

Low short-circuit strength issues are typically site-specific and the studies are performed under expected outage conditions with the inverter-based resources off-line to determine the short-circuit MVA capacity for these conditions.

SCR-based analysis does not model inverter-based resources as on-line since lower short-circuit capacity results in a lower SCR value.
Short circuit analysis is performed under expected N-2 conditions (or conditions which MISO defines) with the inverter-based resources off-line to determine the short-circuit MVA capacity for these conditions.

If SIGE or MISO considers the interconnection area to be "weak," then the interconnecting Producer shall provide the information mentioned below to the inverter manufacturer(s) and that the Producer submit documentation demonstrating that the interconnecting inverter-based resource can reliably and stably operate under similar low short-circuit strength conditions.
SIGE will provide the modeling data around the interconnecting resource, including system equivalent impedance data.

a. The documentation submitted by the Producer should include data showing stable and correct operation which meets the performance requirements established by MISO or SIGE used in the studies process for expected grid conditions, including outage conditions.
b. Any identified instability conditions or issues meeting performance requirements should be addressed by the interconnecting Producer in cooperation with the SIGE. This may include, but is not limited to the following:
    i. Controls modifications to ensure reliable operation under low short-circuit strength conditions.
    ii. Adding equipment or network enhancements to improve short-circuit strength (e.g., synchronous condensers or transmission reinforcements).
    iii. Reduction of proposed maximum generating capacity, where applicable.

Once a mutually agreed upon solution has been identified, SIGE or MISO will require that an updated positive sequence stability model and short circuit model be studied based on the proposed solution.

4.7.7 Induction Generators

Installations shall maintain a power factor of at least 0.95 lagging and 0.95 leading. See Section 4.6.3. It is the Producer's responsibility to provide power factor correction equipment to maintain the required power factor. Such installations shall be at the Producer's expense.

The self-excited induction generator can produce abnormally high voltages that can cause damage to SIGE and customer equipment. Modern protective relaying can limit the duration of such over-voltages. Because of these problems, the reactive power supply for large induction generators must be studied on an individual basis. Where self-excitation problems appear likely, special service arrangements will be required. Especially during self-excitation, effective grounding is important to restrict the range of voltage unbalance. Refer to **Section 4.6.3, "Synchronous Generators"**.

4.7.8 Inverter Systems

Total harmonic distortion (THD) from the generating system will be measured at the interconnection metering point. Under no circumstances, shall V_{THD} of the voltage waveform or I_{THD} of the current waveform be allowed to exceed levels established in **ANSI/IEEE 519**, **Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems**. If a Producer's inverter system is found to be interfering with other customers, Producers, SIGE, or public communications, the Producer shall be required to install filtering or other corrective measures to bring the harmonic output of the inverter to an acceptable level and shall be resolved at the Producer's expense.

4.7.9 Design Review

Producer submits preliminary plans to MISO per the MISO Generator Interconnection process. MISO provides the plans to SIGE for review and feedback. MISO will either accept the plans or outline specific additional functions which must be provided along with supportive data within the specified timeframe.

Producer shall provide the most up to date technical data and design to SIGE during the facility studies process and generation interconnection agreement negotiation. Prior to SIGE commencing detail design of the interconnection, Producer shall provide final technical data and design.

SIGE's responsibility is to protect its system and customers from damage or hazards due to the operation of interconnected generation. It is the Producer's responsibility to protect their generator and associated equipment from short circuits, overload, equipment failures or other malfunctions.

4.8 Metering Requirements

4.8.1 General

Metering installation requirements, for each interconnected generating system category, are outlined in the SIGE standards and in the MISO Open Access Transmission Tariff, if applicable. Unless agreed to otherwise, SIGE will furnish, install and own the meter for the registration of all electrical energy. Typically, the revenue class metering is installed at the point of interconnection at a SIGE-owned substation. The Producer may consult with SIGE if the Producer wishes to install the metering equipment at their location. The Producer shall provide SIGE employees access, at all times, to the metering installation to modify, operate, maintain and read the metering equipment. Transformer and line loss compensation may be required.

Metering configuration will be discussed during the facility studies phase. A typical configuration can be found in **Section 5, "Figures"**.

4.9 Protective Relaying Requirements

4.9.1 Protection Schemes

SIGE has established typical protective relaying for interconnected transmission generation. The protective relaying schemes are shown in **Section 5, "Figures"** and **Section 6, "Interconnection Figures"**.

Unit protection schemes are based upon the generator or inverter nameplate ratings as well as the interconnecting transformer rating.

The Producer's protective relaying schemes must be coordinated with SIGE's schemes. During the facility interconnection study, SIGE provides the preliminary site-specific line protection scheme for coordination. This is finalized during the detailed engineering phase after the Interconnection Agreement is executed.

Protection and control equipment must be reviewed and approved by SIGE.

SIGE cost for installing, maintaining, and/or rearranging protection and control equipment shall be borne by the Producer.

4.9.2 Protection Settings

The Producer's protective relaying settings must be coordinated with SIGE's protective settings to ensure safe and reliable operation during transient conditions. Protection and control settings of the generating system must be reviewed and approved by SIGE. Adherence to SIGE's procedures for the PRC-027 standard must be followed.

- Key findings from grid disturbance analyses involving inverter-based resources have led to recommendations for inverter-based resource protection and controls:
- The area outside of the "No Trip Zone" of the voltage and frequency ride-through curves of the currently effective PRC-024 should not be interpreted as a "Must Trip Zone," and should be considered a "May Trip Zone." Tripping should be based on physical equipment limitations and protection should be set to the widest range of voltage and frequency deviations possible while still ensuring equipment safety and reliability.
- Any instantaneous tripping without filtering or time delay for protection functions should be avoided, unless necessary for the safety and integrity of the inverter-based resource facility. Note that filtering inherently adds a time delay to protective functions.
- Any tripping on calculated frequency should be based on an accurately calculated and filtered frequency measurement over a time window (e.g., six cycles), and should not use an instantaneously calculated value.
- Inverter overvoltage protection should be set as wide as possible, within equipment limitations. The PRC-024 curve uses a filtered RMS voltage measurement, and should not be applied for transient, sub-cycle overvoltages. Refer to Figure A.1 and Table A.1 in NERC Reliability Guideline on BPS-Connected Inverter-Based Resource Performance. The table refers to any individual phase voltage quantities.
- Any dc reverse current protection should be coordinated with the PV module ratings, set to operate for short-circuits on the dc side, and should not operate for transient ac overvoltages or for ac-side faults.
- Inverter-based resources connected to the transmission system should not use rate-of-change-of-frequency (ROCOF) protection, unless an equipment limitation exists that requires the inverter to trip on high ROCOF. However, in most instances, ROCOF protection should not be used for transmission-connected resources.
- Inverter phase lock-loop (PLL) loss of synchronism should not cause the inverter to trip or enter momentary cessation within the voltage and frequency ride-through curves of PRC-024. Inverters should be capable of continuing to inject current to the system within the PRC-024 curves. If the PLL loses synchronism, the inverter-based resource should be able to regain synchronism and resume stable current injection without causing a trip or using momentary cessation.
- Any limitations regarding the need to use momentary cessation within the "No Trip Zone" of the currently effective version of PRC-024 should

be identified by the GO and provided to the utility and MISO per Requirement R3 of PRC-024-2.

4.9.3 Fault Ride-Through (FRT) Capability

FRT is the capability of a plant to remain connected to the grid, continue injecting some form of active and reactive current, and meet a set of performance requirements during and following a system fault event.

Since NERC PRC-024 focuses only on the voltage and frequency protective relaying aspects of generator protection, and is not a comprehensive FRT standard, more stringent requirements on meeting FRT specifications for a predefined set of contingency events may be needed. These requirements apply to both synchronous and nonsynchronous generating resources.

Regarding the overall ride-through for expected transmission disturbances, generating resources may be required to have FRT capability for all expected single contingency events (e.g., NERC TPL-001 standard P1 and P2 events) unless the plant is consequentially isolated due to the fault, the plant is part of a remedial action scheme, or the plant is allowed to trip by exception from the result of system studies. These types of requirements are applied during the FAC-002 interconnection studies process, where MISO and/or the utility would perform stability analyses for the set of expected contingencies and identify any situations where the generating facility is unable to meet the FRT or performance requirements. From a transmission perspective, having assurance that generating resources will remain connected and supporting system reliability during grid disturbances is critical.

Interconnection studies, grid codes, Reliability Standards, and other factors may lead to various requirements to ensure grid reliability (FRT capability). These requirements ensure that the resources, particularly inverter-based resources, are unlikely to operate in a mode that has not been studied. Examples of these performance requirements include, but are not limited to, the following:

- Pre-fault and post-fault short circuit strength for worst case contingency conditions
- RMS low voltage ride-through and high voltage ride-through
- Instantaneous transient voltage
- Instantaneous change in phase angle
- Low frequency ride-through and high frequency ride-through
- No use of momentary cessation (used by exception only) – refer to **Section 4.5.5, “Momentary Cessation”**

4.9.4 Battery Power & DC Redundancy

1) A battery power system may be required to provide DC for powering control systems, breaker control, and powering protective relays if determined to be needed for proper system protection by SIGE. The cost of this system is the responsibility of the Producer.

2) Adequate protection for the loss of a DC circuit shall be provided by the Producer. DC circuits will be redundant and will coincide with the primary and secondary protection schemes. Additional details will be discussed during the engineering phase.

4.10 SCADA/Telemetry

Producer shall provide telemetering to SIGE's designated operating center and MISO (if required) for the following values:

- continuous megawatt
- continuous megavar
- hourly generation values in megawatt-hours
- breaker/inverter status
- voltage set point
- frequency
- sequence of events recording data
- other data as specified by SIGE

This telemetry data shall be provided by Producer via fiber or other approved communication method to SIGE's Remote Terminal Unit (RTU) at the interconnecting station. From there it will be sent to SIGE's operating control center through SIGE's standard SCADA communication network.

The design, purchase, installation, testing, maintenance, and replacement of telemetry equipment and circuits from the Producer's generating system to the designated Point of Interconnection with SIGE shall be the responsibility of the Producer and must be approved by SIGE to ensure correct operation and system compatibility.

4.11 Demonstrations/Inspections of Protective Devices

4.11.1 General

The Producer shall demonstrate to SIGE personnel the correct operation of all protective devices. SIGE shall not be responsible for performing these demonstrations. The Producer shall provide qualified personnel to perform these demonstrations/inspections. Demonstrations/inspections shall be performed on all new equipment and modified equipment, and on existing equipment as circumstances warrant or when requested by SIGE.

Demonstrations/testing shall be conducted in accordance with the testing guidelines in latest revision of the NERC Standard PRC-005. Inverter-based generation shall comply with NERC's reliability guidelines for inverter-based resource.

These demonstrations shall be divided into three sections: Bench Testing/Calibration, Trip Checks and On-Line Testing. The Bench Testing/Calibration section shall demonstrate that agreed upon settings, between the Producer and SIGE, are used on each of the relays required by SIGE. This section also demonstrates that the relays are functional and calibrated to their manufacturer's tolerances. The Trip Checks section shall demonstrate that both the required relays and their interlocks correctly operate. The On-Line Tests section shall demonstrate the expected operation of relays and interlocks specific to the interconnection interface.

The following Bench Testing/Calibration, Trip Checks and On-Line Testing sections are intended to serve as guidelines. These demonstrations are designed to be non-destructive; however, SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. It shall be the Producer's responsibility to demonstrate operation of all protective devices in a safe manner. These demonstrations should not adversely affect the generator, or any equipment associated with the interconnection. SIGE costs for witnessing these demonstrations shall be borne by the Producer.

Producer shall provide all test records and any additional documentation requested by SIGE to ensure compliance with NERC Standard PRC-005.

4.11.2 Bench Testing/Calibration

Proper testing and verification of CTs and VTs and relay settings shall be demonstrated to SIGE personnel in the following manner:

* Four tests shall be performed for CT verification in accordance with the latest version of **ANSI/IEEE C57.13.1** and are as follows:

  1) Ratio check

  2) Polarity check

  3) Excitation Test, Saturation Test, reports from the manufacturer or in lieu of the reports

4) Insulation Resistance Test

* Two tests shall be performed for VT verification in accordance with the latest version of **ANSI/IEEE C57.13.1** and are as follows:

1) Ratio Check using voltage method.

2) Polarity Check using DC or AC voltage tests

* Relays shall be tested as follows:

1) Tested according to their manufacturer's acceptance specifications.

2) Tested at on-line setting values to verify calibration. If possible, this can be completed as part of the relay acceptance test.

All testing and calibration of CTs, VTs and relays shall be performed with test equipment of current calibration according to manufacturer's calibration specifications and intervals. Proof of test equipment calibration must be produced upon request from SIGE prior to relay calibration. All systems over 1 MW must have SIGE's designated personnel witness the synchronizing relay and sync-check relay calibration and operation.

4.11.3 Trip Checks

All required DC trip circuitry shall be functionally checked to demonstrate proper voltage and continuity from the DC source to the breaker trip coil. Additionally, all required relays shall be functionally operated to demonstrate correct operation. Tests can be performed off-line if possible. Tests that cannot be performed off-line shall be demonstrated to functionally operate on-line. Trip outputs from the relay may be either by manually operating all appropriate contacts, dictated by design, or by injecting an electrical signal to cause a trip output. If a lockout device is used with a blocking relay, then the relay(s) shall be tripped a minimum of one time through the entire scheme. All other trips may then be performed in such a manner so only the lockout device trips.

* Verify that breaker(s) cannot be manually or automatically closed with the trip relay in the latched or trip position.

* Demonstrate that the synchronism check and synchronizing relay wiring is correct, and interlocks operate correctly.

* Demonstrate that interlocks between the generator and SIGE breaker(s) operate properly; i.e., the Producer cannot re-energize a de-energized the SIGE electric system supply and can only tie to an energized the SIGE electric system supply via a synchronizing device.

* Demonstrate that the breaker cannot be closed either manually or automatically without resetting the lockout device.

* Demonstrate proper operation of anti-islanding, synch check, and other embedded protection functions for inverter-based generation systems.

4.11.4 OnLine Tests

Testing requirements for proposed facilities will be identified by SIGE during the review of the application. Typical testing requirements are provided in **Appendix 3.1 "Synchronous/Induction On-Line Testing"** and **Appendix 3.2 "Inverter-based Generation On-Line Testing"**.

4.12 Periodic Demonstrations/Inspections of Protective Devices

4.12.1 Maintenance

The Producer shall maintain its equipment in good order. SIGE reserves the right to inspect the Producer's generating system, at the Producer's expense, whenever it appears that the generating system is operating in a manner detrimental to the integrity of the SIGE electric system. The Producer shall annually perform functional testing of all breakers, relays, and transformers. Installations must have protection systems tests performed every three years and certified test reports shall be forwarded to SIGE.

Protection system testing shall be conducted in accordance with the testing guidelines in latest revision of the NERC Standard PRC-005.

Interface protective devices shall be tested and may or may not have to be demonstrated to SIGE. The Producer shall provide qualified personnel to perform the demonstrations. SIGE costs for the demonstration shall be borne by the Producer.

Maintenance of the Producer's generating system shall be coordinated with SIGE and, if required, with the MISO. The Producer shall schedule with SIGE (and MISO if applicable) all planned maintenance which would impact the output of the Producer's facilities. The Producer shall contact the provided SIGE contact as soon as practical should an unscheduled outage be needed or if one should occur.

4.12.2 Annual Demonstrations/Inspections

It shall be the Producer's responsibility to conduct an annual demonstration/inspection of interconnection trip schemes and generator synchronization, if required by SIGE. The Producer shall provide qualified personnel to perform these demonstrations. These demonstrations are designed to be non-destructive, and it shall be the Producer's responsibility to conduct these demonstrations in a safe manner. SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. These demonstrations should not adversely affect the generator, or any equipment associated with the interconnection.

These annual demonstrations shall consist of the following:

1) All interconnection trip schemes and interlocks shall be demonstrated for proper operation. All interface protective devices shall be trip tested in such a manner so that a trip signal originates from the protecting device. The trip command can be simulated by closing a mechanical contact, or relay device secondary circuit injection of voltage, current, or frequency to cause a trip, or by the removal or change of a protective device's sensing circuit input, without lifting wiring, to cause a trip.

2) Anti-islanding protection shall be tested.

3) If an 86 device is used with a blocking relay, then the relay(s) shall be tripped a minimum of one time through the entire scheme. All other trips may then be performed in such a manner so that only the 86 device trips.

4) Synchronizing shall be demonstrated annually in automatic and manual mode, if applicable. With the breaker in the test position, verify that close is blocked for an out-of-phase condition, allows close in an in-phase condition and blocks close on a dead bus condition.

All test results shall be forwarded to SIGE.

4.12.3 Three-Year Demonstrations/Inspections

In addition to the annual demonstrations/inspections, it shall be the Producer's responsibility to conduct three-year demonstrations of relay operation and generator VAR capacity performance. The Producer shall provide qualified personnel to perform these demonstrations. These demonstrations are designed to be non-destructive, and it shall be the Producer's responsibility to conduct these demonstrations in a safe manner. SIGE shall not be responsible for any equipment damage or injury resulting from these demonstrations. These demonstrations should not adversely affect the generator, or any equipment associated with the interconnection. SIGE costs for witnessing these demonstrations shall be borne by the Producer.

These annual demonstrations shall consist of the following:

1) Relays are functional and calibrated at approved settings and within their manufacturer's tolerances. Refer to manufacturer's literature for test procedures.

2) The VAR capacity test shall be demonstrated on generators that have adjustable voltage regulation. Operation at 90% leading and lagging power factor shall be performed. Tests shall be conducted at 25%, 50%, 75%, and 100% of rated generator output. With SIGE approval, the capacity tests may be limited or waived because of operational limitations due to manufacturer's design criteria or stator end turn heating concerns.

Testing shall be conducted in accordance with the testing guidelines in latest revision of the NERC Standard PRC-005.

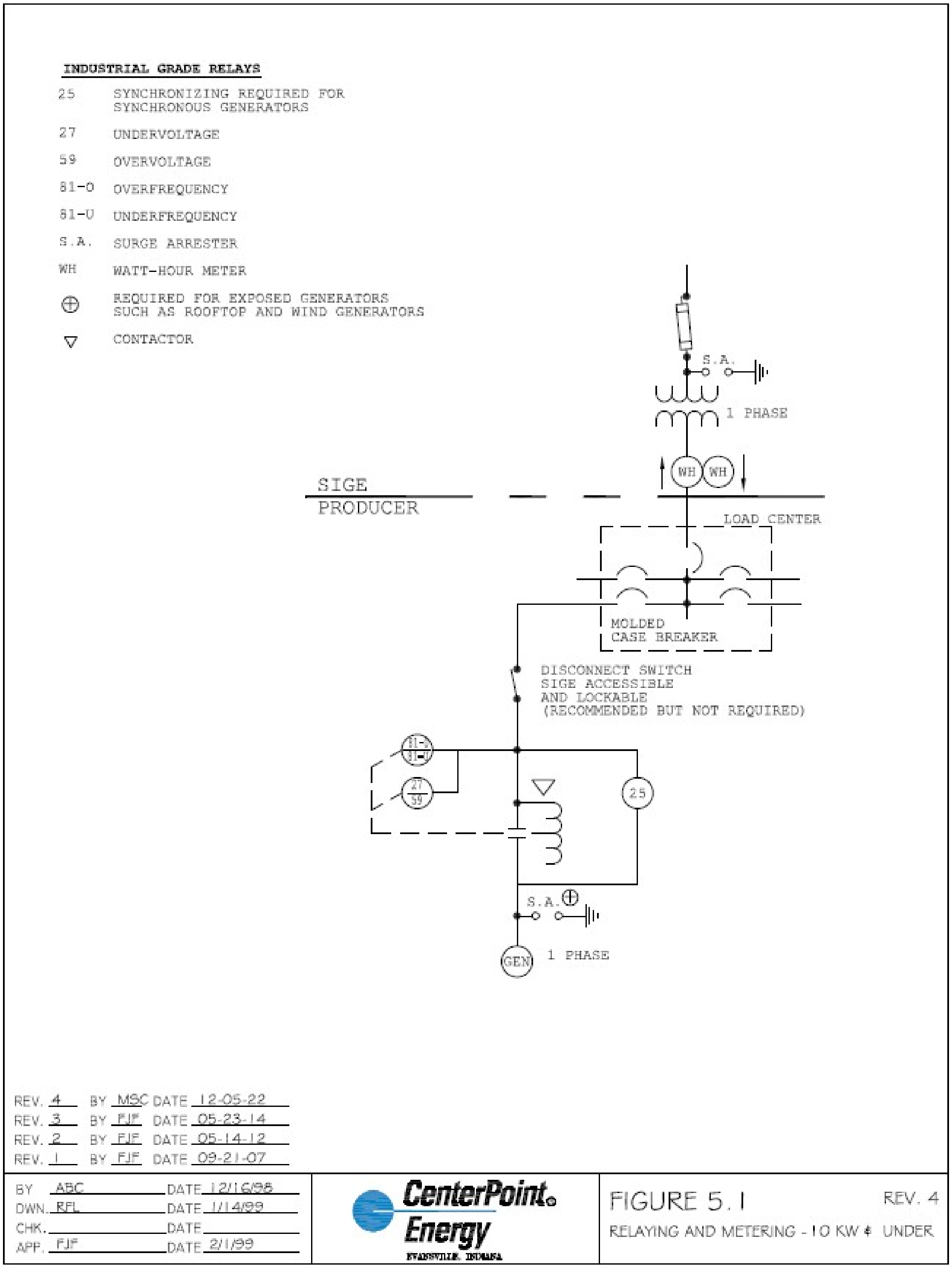
4.12.4 Design Changes After Commercial Operation

Design changes of the interconnection protection and synchronizing schemes shall be reviewed and approved by SIGE, at the Producer's expense. Demonstrations/inspections of relay calibration, trip tests and on-line testing may be required depending on the extent of the design change. Changes to the SIGE electric system can be necessary and may be extensive. The cost of these changes shall be borne by the Producer.

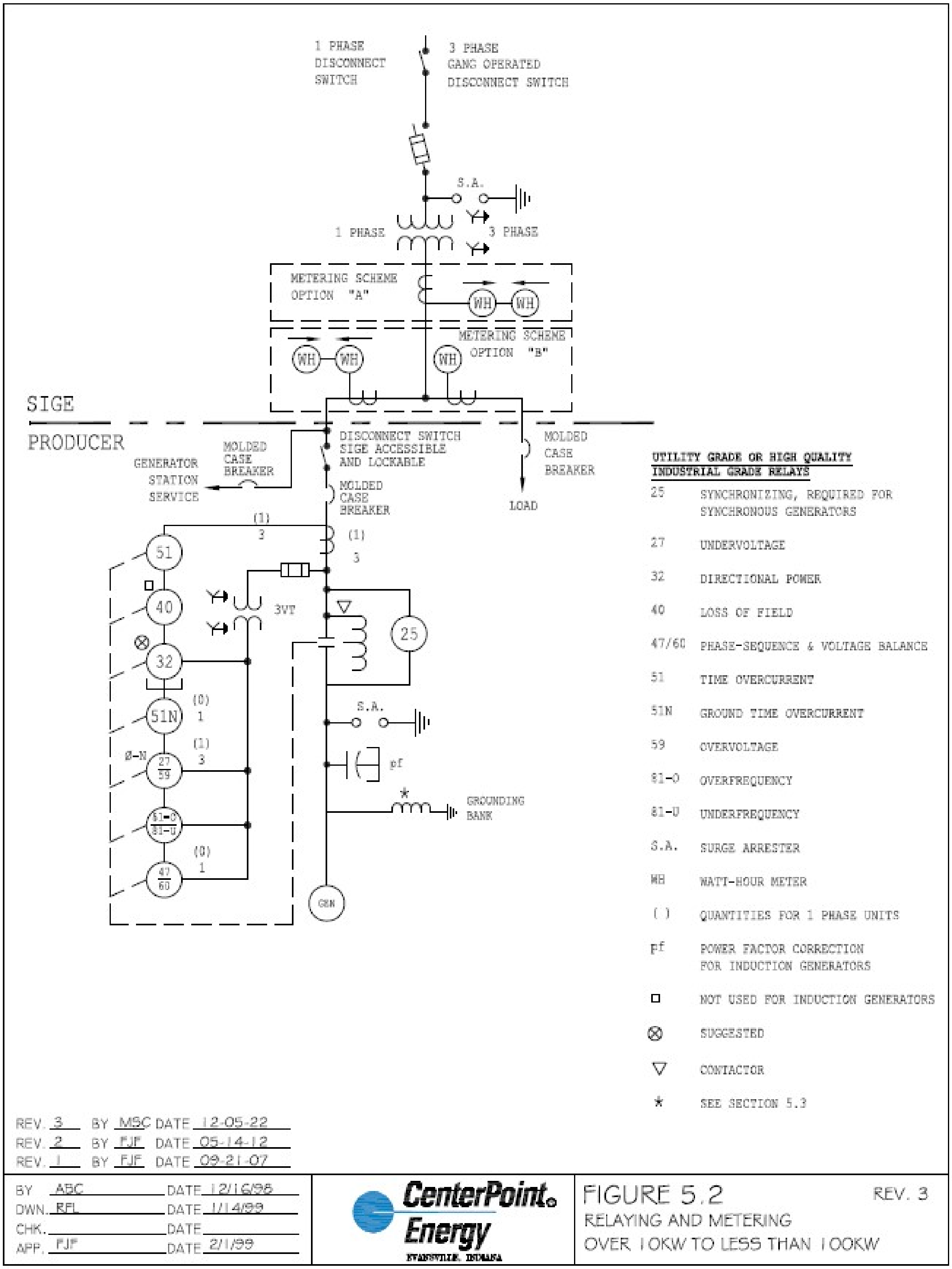
Setting changes of any interconnection protection or synchronizing device, or any "Field Modification" or "As Built" protection and synchronizing schematics associated with any interconnection device shall be reviewed and approved by SIGE, at the Producer's expense.

5 Figures

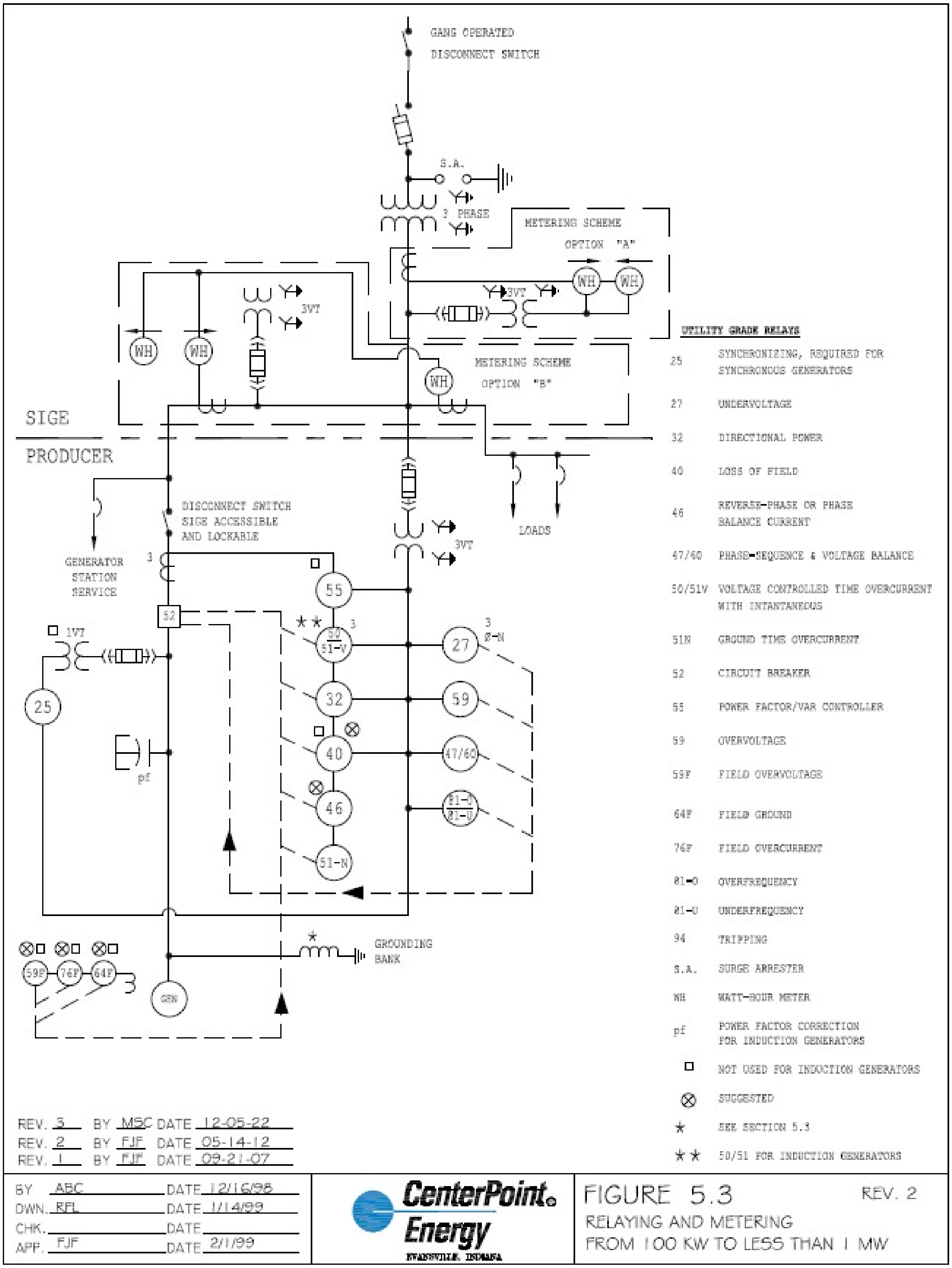
5.1 Relaying and Metering 10 kW & Under: Customer-Owned



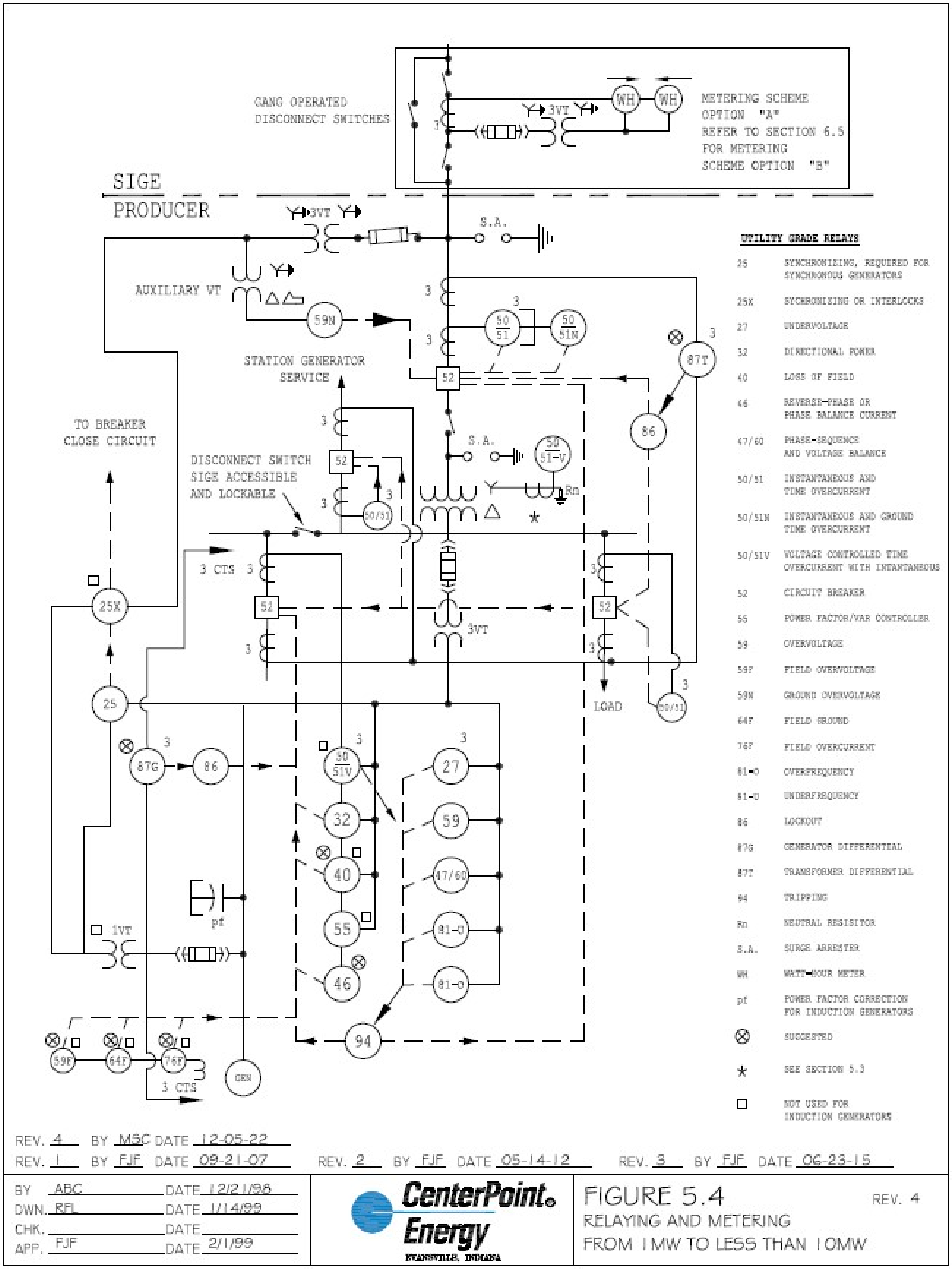
5.2 Relaying and Metering Over 10 kW to Less Than 100 kW: Customer-Owned



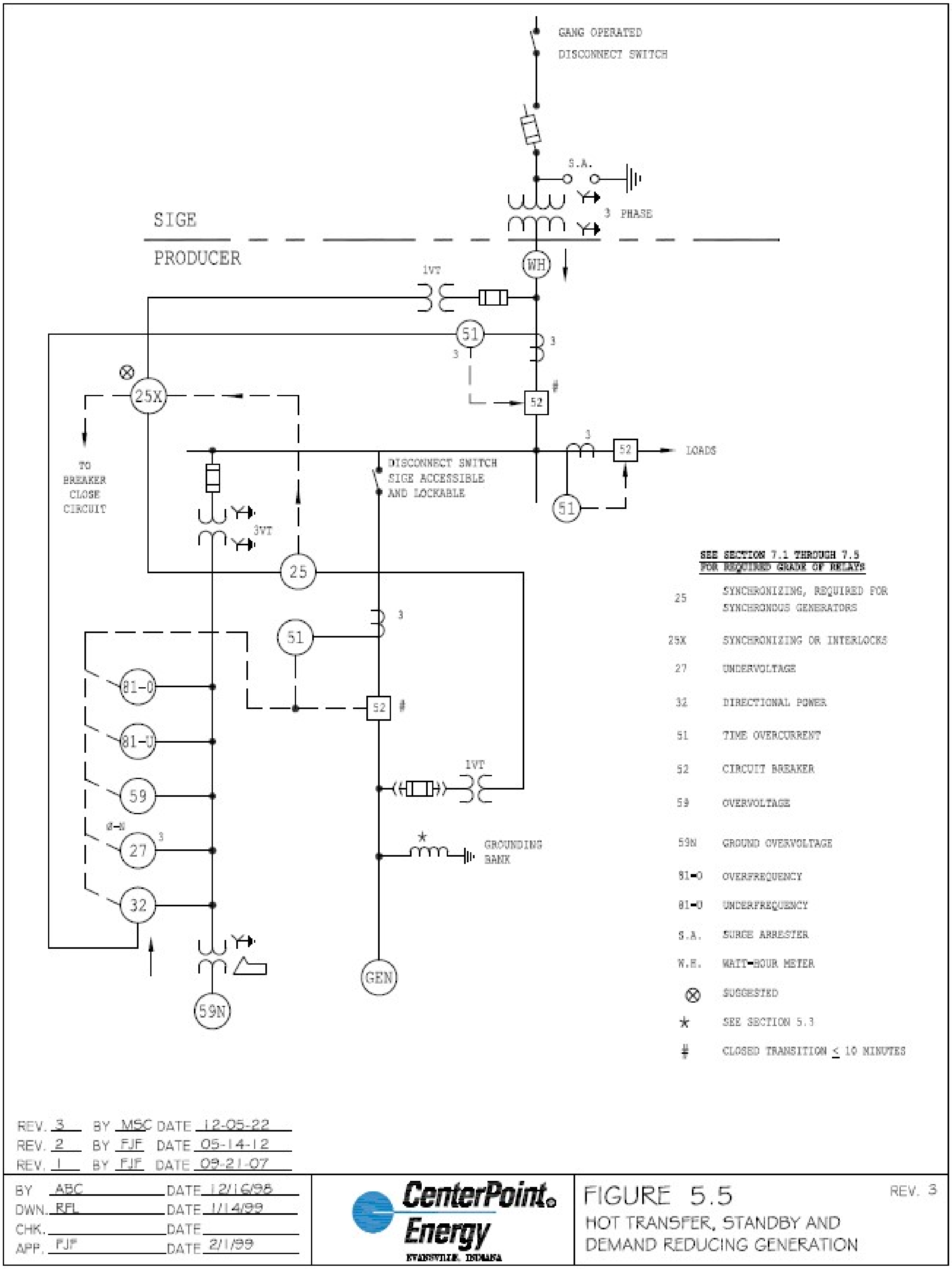
5.3 Relaying and Metering From 100 kW to Less Than 1 MW: Customer-Owned



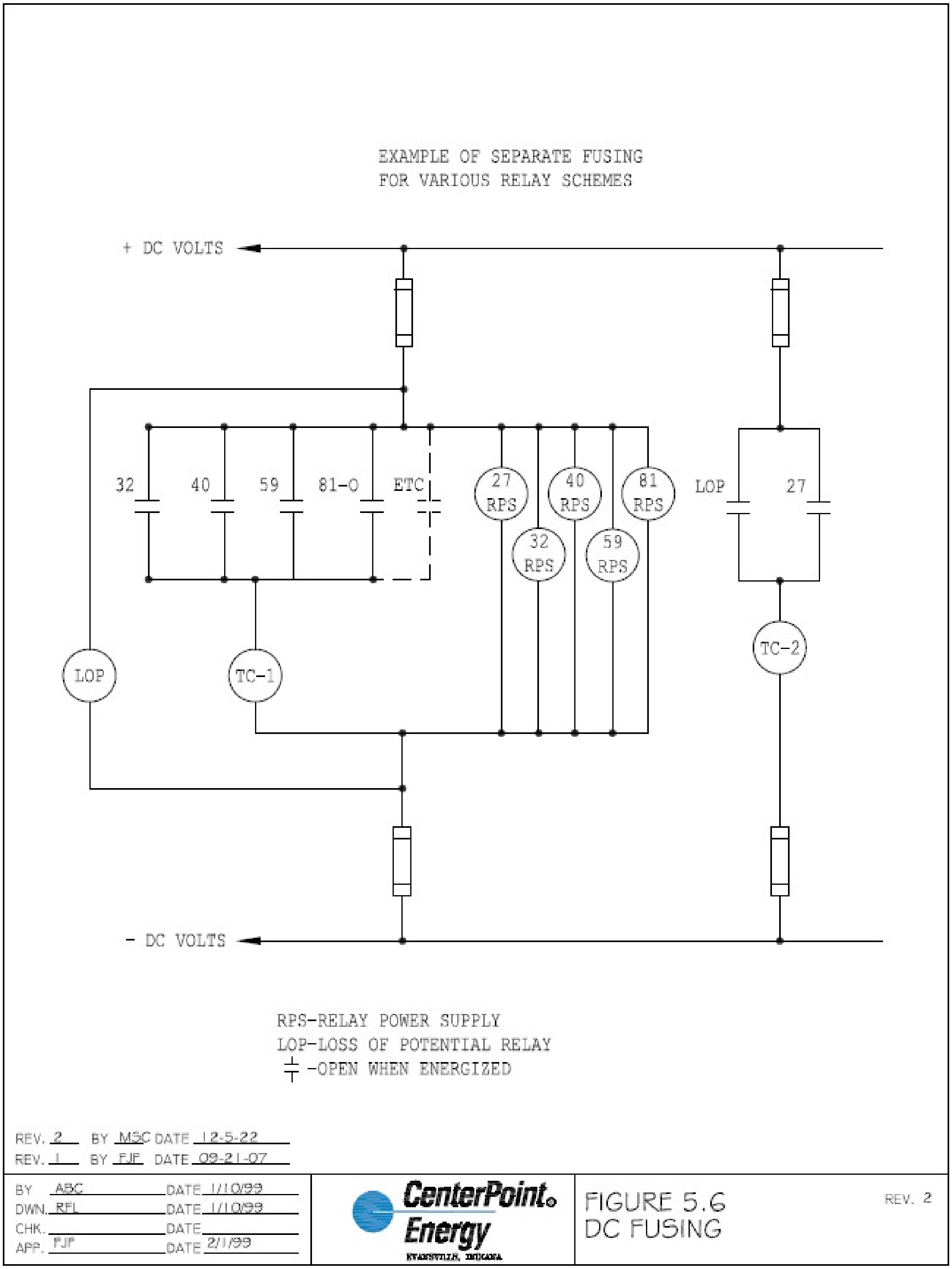
5.4 Relaying and Metering From 1 MW to Less Than 10 MW: Customer-Owned



5.5 Hot Transfer, Standby, and Demand Reducing Generation

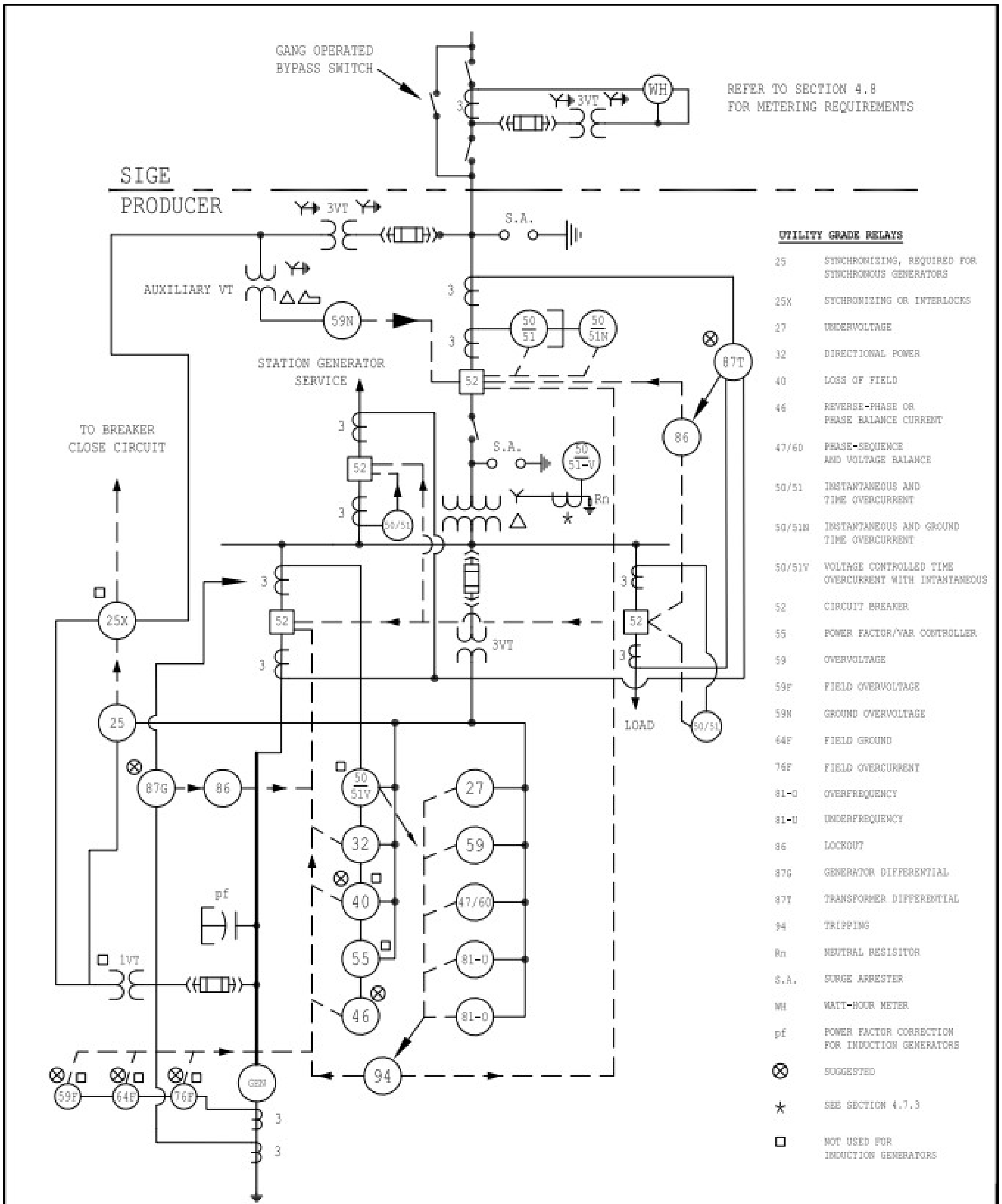


5.6 DC Fusing


EXAMPLE OF SEPARATE FUSING
FOR VARIOUS RELAY SCHEMES
+ DC VOLTS
32
40
59
81-O
ETC
27 RPS
40 RPS
81 RPS
32 RPS
59 RPS
LOP
27
LOP
TC-1
TC-2
- DC VOLTS
RPS-RELAY POWER SUPPLY
LOP-LOSS OF POTENTIAL RELAY
-OPEN WHEN ENERGIZED
REV. 2 BY MSC DATE 12-5-22
REV. 1 BY FJF DATE 09-21-07
BY ABC DATE 1/10/99
DWN. RFL DATE 1/10/99
CHK. DATE
APP. FJF DATE 2/1/99
CenterPoint Energy
EVANSVILLE, INDIANA
FIGURE 5.6
DC FUSING
REV. 2

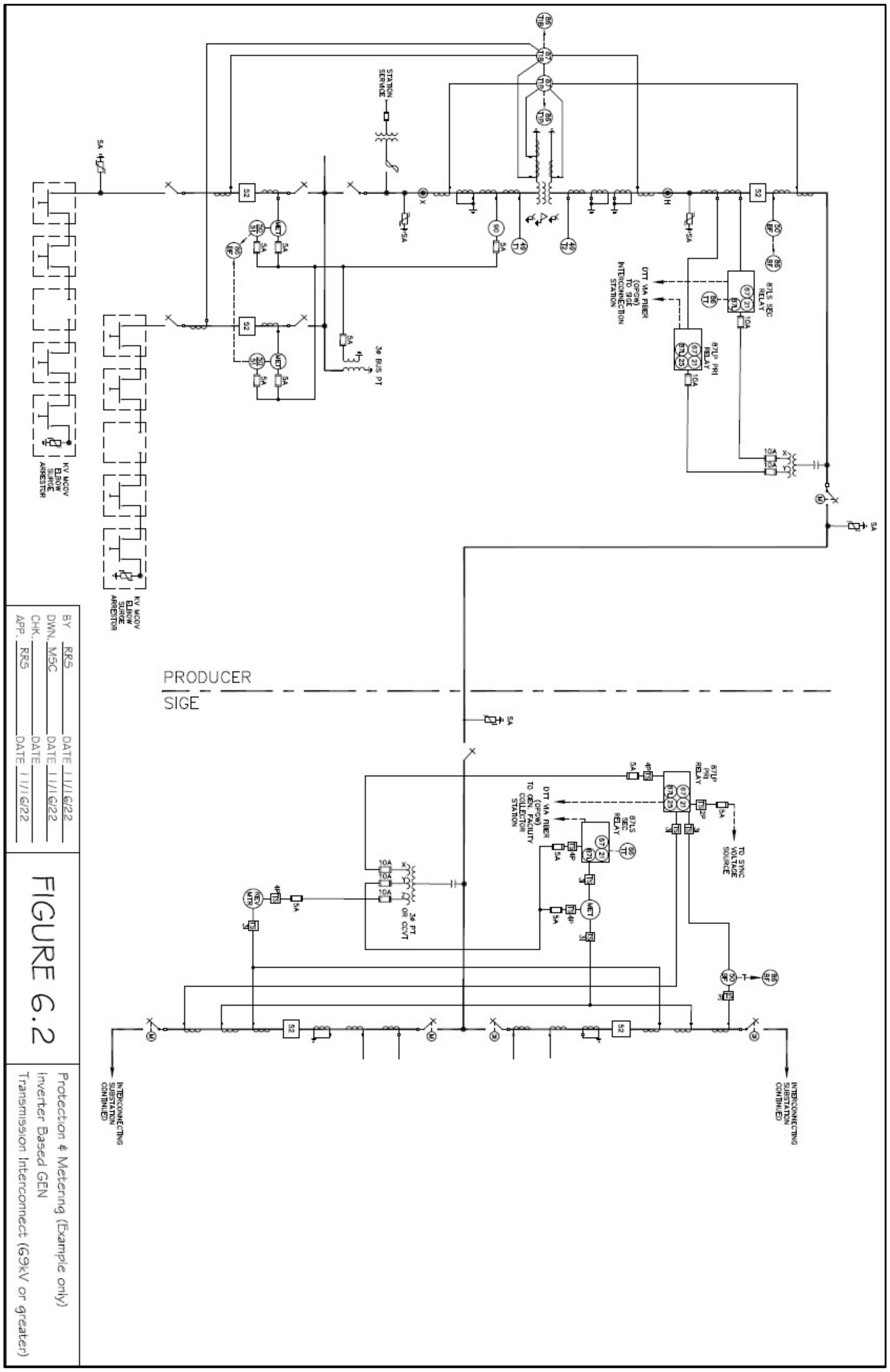
6 Interconnection Figures

6.1 Typical Generation Protection Scheme (Induction and Synchronous)



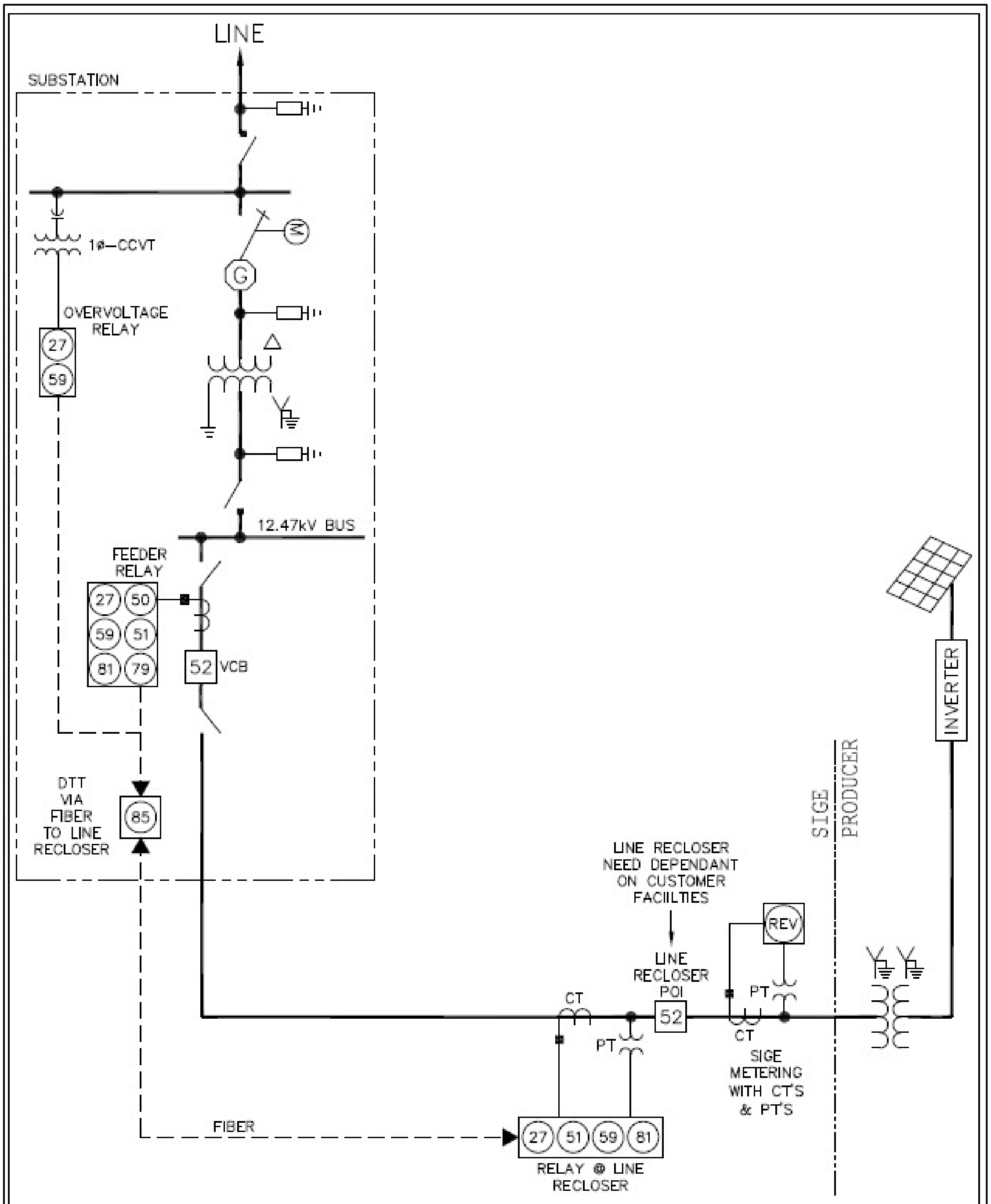
BY RRS DATE 10/28/20 DWN. RRS DATE 10/28/20 CHK. DATE APP. RRS DATE 10/28/20	FIGURE 6.1	Protection & Metering (Example only) Synchronous and Induction Based GEN Transmission Interconnect (69kV or greater)

6.2 Typical Generation Protection Scheme (Inverter-based)



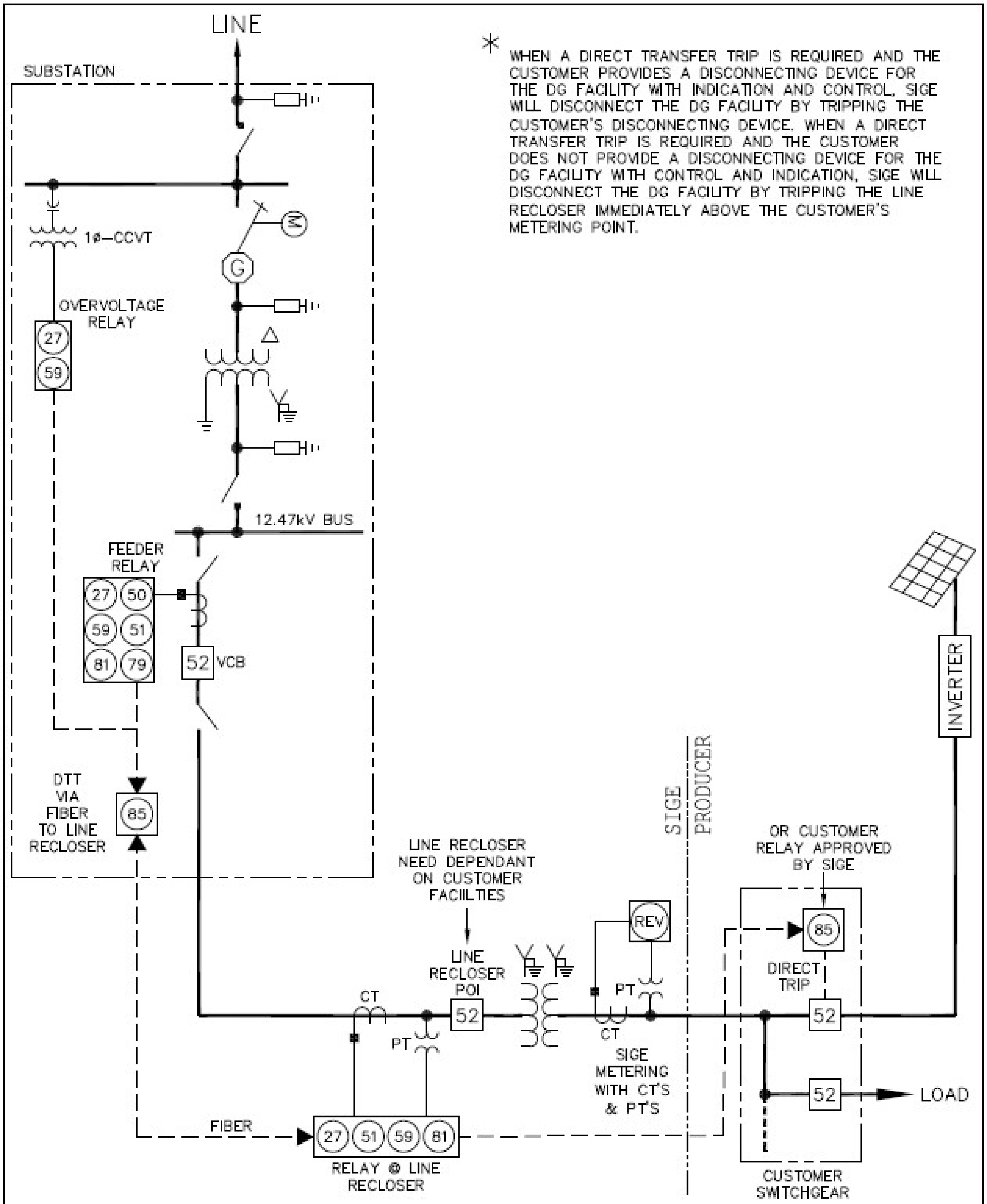
6.3 Typical Inverter Generation Protection Scheme (Distribution)

6.3.1 Inverter Generation - No Customer Load



BY RRS DATE 11/28/22 DWN. MSC DATE 11/28/22 CHK. DATE APP. RRS DATE 11/28/22	FIGURE 6.3.1	Protection & Metering (Example only) Inverter Based GEN (No Load) Distribution Interconnect (12.47kV)

6.3.2 Inverter Generation - With Customer Load



BY RRS DATE 11/28/22 DWN. MSC DATE 11/28/22 CHK. DATE APP. RRS DATE 11/28/22	FIGURE 6.3.2	Protection & Metering (Example only) Inverter Based GEN (With Customer Load) Distribution Interconnect (12.47kV)

7 Appendix 1

7.1 Induction Generator Characteristics Survey

Name of Project ______________________________

Manufacture ______________________________

Type ____________________
Model ____________________
Number of Phases ____________________
Rater KW Output ____________________
Rated KVA Output ____________________
Rated Voltage (line to line) ____________________
Rated Current ____________________
Maximum KW Output (prime mover & Generator) ____________________
Power Factor or Rated Load (KVAR):

At maximum KW Output ____________________
At 100 % of Rated Output ____________________
At 75 % of Rated Output ____________________
At 50 % of Rated Output ____________________
At 25 % of Rated Output ____________________

Connection (wye or delta) ____________________
Is the wye point grounded? ____________________
Impedance in ground connection ____________________
Rotor Resistance (R_r) ____________________
Rotor Reactance (X_r) ____________________
Stator Resistance (R_s) ____________________
Stator Reactance (X_s) ____________________
Magnetizing Branch Reactance (X_m) ____________________
Short Circuit Time Constant (T) ____________________
Slip at Rated Output (s) ____________________
Synchronous Speed ____________________
Inertia of Combined Machine ____________________

8 Appendix 2

8.1 Synchronous Generator Characteristics Survey

Name of Project ________________________________

Manufacture ________________________________

Type		____________
Model		____________
Number of Phases		____________
Rater KW Output		____________
Rated KVA Output		____________
Rated Voltage (line to line)		____________
Rated Current		____________
Rated Power Factor:	leading	____________
Rated Power Factor:	lagging	____________
Maximum KW Output (prime mover & Generator)		____________
Maximum KW Output (prime mover & Generator)		____________

With generator at this maximum KW,

What is the maximum leading power factor? ____________

What is the maximum lagging power factor? ____________

Connection (wye or delta) ____________

Is the wye point grounded?		____________
Impedance in ground connection		____________
Synchronous Reactance	(X_d)	____________
Transient Reactance	(X'_d)	____________
Sub-Transient Reactance	(X''_d)	____________
Negative-Sequence Reactance	(X_2)	____________
Zero-Sequence Reactance	(X_0)	____________
Transient Time Constant	(T'_d)	____________
Sub-Transient Time Constant	(T''_d)	____________
Inertia Constant	($W\ r^2$)	____________
Synchronous Speed		____________

9 Appendix 3.1: Synchronous/Induction On-Line Testing

Items "1" through "6" shall be performed with the generator breaker racked out in the test position and the line breaker closed, energizing the transformer.

1. Under-voltage Relay - Device 27: Prior to putting the generator on-line, lift the potential to the relay. Expected result is the operation of Device 27 after the specified time delay.

2. Ground Overvoltage Relay - Device 59N: Verify proper voltage present at relay input (relay may not be used on smaller generation units).

3. Frequency Relay - Device 81 O/U: Verify proper voltage present at relay input.

4. Phase-Sequence and Voltage Balance Relay - Device 47/60 or 47/27: Interchange two of the potential inputs to this relay to simulate a negative-phase sequence condition. Expected result is the operation of this relay after the specified time delay. Also, lift one potential lead and observe relay trip output. Once testing of this device is completed, restore the potential input connections to their original polarities.

5. Synchronous generators - Phase out and check the rotation of the primary potential on both incoming and running sides of the generator breaker with the generator running unloaded, i.e. between the generator and the SIGE electric system. While performing the phase out and rotation check, test phasing and rotation across the open generator breaker using synchroscope and voltmeter for VT secondary verification. Verify a single sync path through the sync-select switch on multi-unit operations. Verify correct phase and polarity of VT inputs to sync-check relay. Verify proper synchronizing potential sources.

6. Induction generators - Allow the prime mover to rotate the generator with generator breaker open. Then, with the prime mover removed, briefly "motor" the generator by closing the generator breaker. Expected result is the same direction of rotation. Upon completion of "4.", with the generator breaker still racked out in the test position, verify that the synchronizer/sync-check or speed relays give a breaker close output signal at the appropriate synchronized conditions, proper voltage magnitude match, phase rotation, phase angle match, and proper slip rate.

7. Flicker and Harmonics test - With the generator breaker open, close the SIGE line breaker, start up the generator and synchronize the generator to the SIGE-energized transformer. Verify that acceptable minimal flicker of room lights occurs at the close of the generator breaker and that the generator runs in a stable unloaded condition in parallel with the SIGE electric system. Synchronizing should normally take place while the synch-scope is moving in the "fast" direction, clockwise. An oscillograph shall be used to verify proper breaker pole alignment and the absence of harmonics.

8. Directional Power Relay – Device 32: With the generator on-line, cause the generator to motor. The expected result is the operation of 32 device after the specified time delay. An alternate test is to phase check, under load, at the directional relay, with a phase angle meter.

9. Voltage Supervised or Directional Overcurrent Relay - Device 51V: With the generator on-line, run the generator above zero voltage current pick-up level with voltage applied; lift the potential. Expected result is the operation of 51V device after the specified time delay.

10. Power Factor Controller Test shall be done with a plant load that can be interrupted during test procedures:

    a. With the generator off-line, measure the power factor of the full house power kW load. The measured value will usually be lagging, not unity.

    b. Set the generator power factor controller to a more leading pf, usually unity. This creates a var mismatch between the load and generator. Also, block the 81 O/U relay.

    c. Bring the generator on-line. The station service load shall be served by the generator.

    d. Match the generator kW to the house power load.

    e. Trip the SIGE line breaker.

    f. The generator should trip on low voltage, due to power factor mismatch, by means of the under-voltage relay. A Producer-provided oscillograph will monitor all three-phase currents, bus voltages, neutral current or generator neutral current, and a contact off the generator and SIGE line breakers.

11. A demonstration of compliance with contracted power factor shall be performed for induction generators.

    a. VAR Capacity Tests: For generators which possess adjustable voltage regulation, a demonstration that the generator is capable of operation at a 90% leading and lagging power factor shall be performed. These tests shall be conducted at 25%, 50%, 75%, and 100% of rated generator load. With SIGE approval, the capacity tests may be limited or waived because of operational limitations due to manufacturer's design criteria or stator end turn heating concerns.

10 Appendix 3.2: Inverter-based Generation On-Line Testing

1) Trip on Sudden Loss of Power Supply/ Two Second Shutdown Test:
   a. The Customer shall simulate a loss of power supply and demonstrate that the relay trips the interrupting device in a fail-safe manner (for each individual phase and for three-phase, as per IEEE 1547a, 5.4.2). The interrupting device is required to trip within 2 seconds (IEEE 1547a, 4.4.1). Also demonstrate that the interrupting device cannot be closed back in when the relay has failed or is otherwise out of service. The customer shall specify the test switches to be opened for this step
      i. Testing for over-voltage and under-voltage shall be performed per the IEEE Standard, ensuring the interconnection equipment trips off-line within the Clearing Times listed in IEEE 1547a, Table 1 - Interconnection System Response to Abnormal Voltages.

2) DG Operational Only if Ground Source in Service:
   a. For DG that requires a grounding transformer to interconnect, the Customer shall demonstrate that the inverters or other DG cannot operate if the grounding transformer is not closed in. Customer shall provide the steps needed to prove this statement.

3) Inverter/Generator Five Minute Reconnect Test (IEEE 1547-2003 4.2.6)
   a. The customer shall demonstrate that when the breaker/disconnect switch (representing restoration of utility power) is closed back in, that the inverter/generator does not start for a minimum of 5 minutes.

4) Visual Inspection
   a. SIGE will perform a visual inspection of the equipment being tested along with reviewing the one-line diagram, reviewing applicable settings, and inspecting the isolation and/or disconnection device(s)

11 Appendix 4: Reactive Power-Voltage Performance

11.1 Appendix 4.1: Small Disturbance Reactive Power-Voltage Performance

Small disturbances are disturbances that cause voltage to stay within the continuous operating range of the plan.

The overall response of the plant should have response times and characteristics to support BPS voltage schedules, post-contingency voltage recovery, and voltage stability. Inverter-based resource should be flexible and have the capability to adjust control settings and tuning based on changing grid conditions.

Inverter-based resources should have the capability to meet or exceed the performance characteristics shown in the table below.

For a step change in voltage at the POM of the inverter-based resource, the inverter reactive power response should meet the following performance specifications:

Small Disturbance Reactive Power-Voltage Performance Table		
Parameter	**Description**	**Performance Target**
Reaction Time	Time between the step change in voltage and when the resource reactive power output begins responding to the change	< 500 ms*
Rise Time	Time between a step change in control signal input (reference voltage or POM voltage) and when the reactive power output changes by 90% of its final value****	< 1-30 sec**
Overshoot	Percentage of rated reactive current output that the resource can exceed while reaching the settling band	< 5%***

** Reactive power response to change in POM voltage should occur with no intentional time delay.*

*** Depends on whether local inverter terminal voltage control is enabled, any local requirements, and system strength (response should be stable for the lowest possible grid strength). Response time may be modified based on studied system characteristics.*

**** Any overshoot in reactive power response should not cause BPS voltages to exceed acceptable voltage limits.*

***** See Appendix F of NERC Reliability Guideline: BPS-Connected Inverter-Based Resource Performance. Final value is the final settled (steady-state) value of reactive power following the change in voltage set point value.*

11.2 Appendix 4.2: Large Disturbance Reactive Current-Voltage Performance

Large disturbances are disturbances that cause voltage to fall outside the continuous operating range of the plant (i.e., "ride-through mode").

Inverter-based resources should adhere to the following:

- **Stable Response:** The response of each generating resource over its full operating range, and for all expected BPS grid conditions, should be stable. The dynamic performance should be tuned to provide stable response. The performance specifications in the table below may need to be modified during the study process to ensure a stable response.
- **Local Control and Faster Response Time:** Large disturbance behavior, where local inverter controls take priority, should operate with significantly faster response times compared to the outer loop plant-level controls.
- **Current Limiting:** Large changes in terminal voltage will likely cause the inverter to reach a current limit. Any current limiters should be coordinated with inverter protection.

For a larger disturbance step change in voltage, measured at the inverter terminals, where voltage falls outside the continuous range, the positive sequence component of the inverter reactive current response should meet the following performance specifications:

Large Disturbance Reactive Current-Voltage Performance Table		
Parameter	**Description**	**Performance Target**
Reaction Time	Time between the step change in voltage and when the resource reactive current output begins responding to the change	< 16 ms*
Rise Time	Time between a step change in control signal input (reference voltage or POM voltage) and when the reactive current output changes by 90% of its final value	< 100 ms**
Overshoot	Percentage of rated reactive current output that the resource can exceed while reaching the settling band	Determined by the TP/PC***

** For very low voltages (e.g., less than around 0.2 pu), the inverter PLL may lose its lock and be unable to track the voltage waveform. In this case, rather than trip or inject a large unknown amount of active and reactive current, the output current of the inverter(s)may be limited or reduced to avoid or mitigate any potentially unstable conditions.*

*** Varying grid conditions (i.e., grid strength) should be considered, and behavior should be stable for the range of plausible driving point impedances. Stable behavior and response should be prioritized over speed of response.*

**** Any overshoot in reactive power response should not cause BPS voltages to exceed acceptable voltage limits. The magnitude of the dynamic response may be requested to be reduced by the TP or PC based on stability studies.*

12 References

Documents Cross Referenced Documents Table

Document Name
MISO BPM-015 Generation Interconnection
VEC-007 Requirements for Transmission or End-User Facilities Interconnection to the SIGE Electric Transmission System
ANSI/IEEE 519, **Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems**
SIGE Electric Service Manual
ANSI/IEEE C57.13.1, Sections 5,6,7,7.1,7.2,9
IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

13 Revision Table

Revision Number	Revision Date	Effective Date	Revised By	Summary of Changes
0	05/08/08	05/08/08	R. Tabor	Revised document in new format
1	03/10/09	03/31/09	R. Tabor	▪ Updated Annual Review Table ▪ Standardized document formatting.
2	05/19/10	06/28/10	M. Rose	▪ Annual Review. See Redline.
3	06/01/11	07/06/11	R. Collins	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
4	03/01/12	07/16/12	R. Collins	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
5	10/31/13	12/17/13	K. Barr	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
6	05/27/14	08/05/14	F. Frederick	▪ Made content changes concerning disconnect switch requirements for installations on the electric distribution system of 10 KW or less.
7	04/27/15	07/07/15	K. Barr	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
8	10/06/15	12/14/15	K. Barr	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
9	07/06/16	10/26/16	K. Barr	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
10	08/09/17	11/02/17	K. Barr	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.

11	08/22/18	11/12/18	L. Hamby	▪ Made content changes based on annual or self-certification review. See redline(s) and summary of document changes.
12	11/22/19	12/13/19	L. Hamby	▪ Made content changes based on annual review. See redline(s)
13	3/23/20	12/30/20	L. Hamby	▪ Made content changes based on annual review. See redline(s).
14	01/19/21	04/01/21	K. Barr	▪ Non-material change, logo updated and 'Vectren' changed to 'SIGE', included revisions per FAC-002-3; previous signatures maintained. See redline(s)
15	3/31/21	04/22/21	K. Barr	▪ Made content changes based on Excess Distributed Generation (EDG) filing with IURC. See redline(s).
16	11/11/21	12/15/21	L. Hamby	▪ Made content changes based on annual review. See redline(s).
17	10/01/22	12/12/22	L. Hamby	▪ Non-material formatting changes ▪ Made content changes based on annual review. See redline(s).