City of Fort Collins Utility Services

# INTERCONNECTION STANDARDS FOR GENERATING FACILITIES (GF) CONNECTED TO THE FORT COLLINS DISTRIBUTION SYSTEM

**July 2011**

UPDATED STANDARDS

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# Scope and General Requirements

## 1.1 Scope and Intent

The requirements contained in this document apply to all generation sources connected to the FCU distribution system 5MW and below at any one location. Any and all connections to the FCU distribution system and any aspect of such connection are subject to FCU review and such connections shall not be permitted unless approved by FCU. The operation and design of any GF must meet all of the requirements contained in this document, any written agreement between FCU and the Operator, as well as any applicable requirements contained in Chapter 26 of the Fort Collins Municipal Code and Fort Collins Utilities Electric Service Rules and Regulations.

Any location where the aggregate total generation exceeds 5MW may require additional study by FCU. This study will consider the specific feeder where the GF is proposed to be connected. If the addition of any GF causes the total amount of generation by all sources on that feeder to exceed 50% of the minimum load on that feeder, additional study by FCU is required and the requirements produced as a result of that study may exceed those in this document. If the GF source to be added is highly variable such as wind or solar, and the total amount of wind or solar generation by all sources on that feeder exceeds 13.3% of the feeder capacity, or if the total of all the wind or solar generation on any substation exceeds 13.3% of the substation transformer size, additional study by FCU is required and the requirements produced as a result of that study may exceed those in this document.

Protection and safety devices are intended to provide protection for the FCU distribution system, FCU utility workers, FCU customers and the general public. Protective devices installed on the GF are designed to ensure that the fault current supplied by the GF will be interrupted in the event a fault occurs on the FCU distribution system. When a fault occurs, the GF must be designed to automatically disconnect from the FCU distribution system until the distribution system is restored to normal operation.

Any source not explicitly described in this document will require special study before it is allowed to interconnect to FCU.

## 1.2 System Phase and Voltage

The GF may interconnect to the system at any service voltage available at the site. Additional voltages may be arranged with FCU on a case-by-case basis, subject to FCU approval. If the site contains a three-phase system the GF equipment must be three-phase. If only a single phase service is available, a single-phase GF may be allowed. The maximum nameplate rating of all the single-phase generators at any GF shall not exceed 20 kVA if connected line-line. When the site contains a center-tapped single-phase service, machines may be connected between phase and the center-tapped neutral providing the maximum nameplate rating of the generator connected does not exceed 5 kVA.

## 1.3 System Reclosing

Automatic reclosing is generally not utilized on the FCU distribution systems to clear temporary faults; however, in the cases and locations where automatic reclosing is used, the GF must be designed to ensure that the GF will disconnect from the distribution system in the event an automatic reclose occurs. Normally the GF will not be allowed to interfere with automatic reclosing where it exists; however, industry standards require that a GF must automatically disconnect from an islanded system within two seconds. If the existing reclosing interval is faster than two seconds FCU will reset it to accommodate the GF.

## 1.4 Islanding

Islanding occurs when a GF becomes separated from the main generation source on a distribution system, but continues to independently serve a portion of the distribution system. GF's shall be

equipped with protective devices and controls designed to prevent the generator from being connected to a de-energized distribution system. Islanding is not permitted on the FCU distribution system.

### 1.5 Synchronizing

Synchronization of the GF with the FCU system must be done automatically. Any proposal to allow manual synchronization is subject to review and approval by FCU. All GF's must use protective devices that prevent electrically closing a GF that is out of synchronization with the distribution system. FCU will under no circumstances be responsible or liable for any damage done due to an out of synchronization closure of a GF onto the system. Additionally, the Operator is responsible and liable for any damage done to the FCU system by any type of improper closing onto the system.

### 1.6 Improper Operation of the GF

Operation and design of the GF must meet all the requirements contained in this document as well as any applicable requirements contained in the Fort Collins Municipal Code and the Fort Collins Utilities Electric Service Rules and Regulations and any written agreement between FCU and the Operator. Also, no GF operation will at any time be allowed to adversely impact the operation of the FCU system in any way. The GF must not produce adverse amounts of unbalanced currents or voltages; produce high or low voltages, or unacceptable frequencies; it must not inject DC or harmonics into the system beyond what is allowed by this document; or cause excessive operations of system voltage regulating devices such as load tap changers and voltage regulators. The GF must not adversely affect system grounding or ground fault protection.

FCU will not normally interfere with the operation of any GF. However, when requested by FCU by telephone, in person, or in writing, the Operator must immediately stop operation and not resume operation until cleared by FCU to do so. If the Operator begins to operate the GF out of the ranges or conditions listed herein, the Operator must agree to cease operation until such a time as the GF Operator can demonstrate to FCU that it has remedied the problem and can once again operate the GF in compliance with these requirements.

If usage of the GF causes unusual fluctuations or disturbances on, or interference with FCU's system or other FCU customers, FCU shall have the right to require the GF to install suitable apparatus to reasonably correct or limit such fluctuation, disturbance or interference at not expense to FCU or other customers.

### 1.7 System Capacity Limitations

The equipment installed by FCU to distribute power is limited in size and is normally sized for safe and efficient delivery of power. Adding generation to this system, especially generation supplied by renewable sources which normally have low capacity factors, may quickly overload the existing equipment. Care must be taken when adding generation to avoid damaging FCU equipment. Also, when system penetration levels of distributed generation becomes large enough, accidental islanding of sections of the system becomes possible, and additional protective devices or systems, such as transfer trip equipment, may be needed for safe operation of the FCU system. Whenever one or more of the following limitations are exceeded, FCU may need to conduct an additional study and FCU may require additional equipment. Additional study is required if:

a) The rated aggregate generation kVA on any distribution transformer after the addition of the new GF equals or exceeds 100% of the rating of the transformer
b) The rated aggregate generation kVA on any protective device or feeder from the point of interconnection to the substation transformer exceeds 13.3% of the rating of that protective device or feeder
c) The rated aggregate generation kVA on any feeder or portion of a feeder equals or exceeds 50% of the existing annual minimum load on that feeder or feeder section

d) The proposed GF results in more than 90kW of single-phase generation on one phase of a feeder when both the new and existing generation are included
e) The proposed GF includes an induction machine 300kW or greater, or an aggregate of 300kW of induction generators

### 1.8 Submittal Requirement

The Operator shall submit in a timely manner, sufficient design and specification information relating to the facilities to be installed by the Operator. FCU shall be entitled to review and approve or disapprove these facilities prior to their installation and energization. The Operator agrees to incorporate any reasonable design changes requested by FCU prior to, during, or after installation of the GF's facilities. FCU's approval or acceptance of any design and specification information related to the GF to be installed shall not be construed as an endorsement of such engineering plans, specifications, or other information.

The following drawings and other documents must be submitted to FCU for approval before any construction is begun.

a) Single-line diagram of the facility showing the sizes of all equipment and the system protection planned
b) Cut sheets on all equipment planned including inverters, generators, fuses, circuit breakers, switches, etc.
c) Capability curves on all synchronous and doubly fed induction generators.
d) Short circuit calculations.

## 2.0 Standards and Definitions

### 2.1 Standards

In all cases the current edition of the following standards should be referred to in design of the power plant, choice of equipment, and interconnection design.

a) ANSI C84.1 American National Standard for Electric Power Systems and Equipment-Voltage ratings (60 Hertz)
b) IEEE Std. 18 IEEE Standard for Shunt Capacitors
c) IEEE Std. 32 IEEE Standard Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
d) IEEE Std. 141: IEEE Recommended Practice for Electric Power Distribution for Industrial Plants
e) IEEE Std. 142: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
f) IEEE Std. 242: IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
g) IEEE Std. 519: Recommended Practices and Requirements for Harmonic Control in Electric Power Systems
h) IEEE Std. 665: IEEE Standard for Generation Station Grounding
i) IEEE Std. 1015: IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems
j) IEEE Std. 1036: IEEE Standard for Application of Shunt Power Capacitors
k) IEEE 1547 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
l) IEEE 1547.1 IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
m) IEEE 1547.2 IEEE Application Guide for IEEE Std. 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
n) IEEE Std. C2: National Electrical Safety Code

o) IEEE Std. C37.06: IEEE Standard for AC High-Voltage Circuit Breakers rated on a Symmetrical Current Basis-Preferred Ratings and Required Capabilities.
p) IEEE C37.012: IEEE Application Guide for Capacitor Current Switching for AC High-Voltage Circuit Breakers
q) IEEE C37.66: IEEE Standard Requirements for Capacitor Switches for AC Systems (1kV thru 38kV).
r) IEEE C37.90 IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
s) IEEE C37.90.1 IEEE Standard for Surge Withstand capability (SWC) Tests for Relay and Relay Systems Associated with Electric Power Apparatus.
t) IEEE C37.90.2 IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
u) IEEE C37.90.3 IEEE Standard Electrostatic Discharge Tests for Protective Relays
v) IEEE C37.95 IEEE Guide for Protective Relaying of Utility-Consumer Interconnections
w) IEEE Std. C37.102 IEEE Guide for AC Generator Protection
x) IEEE Std C62.41: IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
y) NERC PRC-024-1: Generator Frequency and Voltage Protective Relays
z) NFPA 70: National Electrical Code
aa) UL 1741: Inverters, Converters, Controllers and Interconnection System Equipment for use with Distributed Energy Resources

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### 2.2 Definitions

The following definitions will be used throughout this document.

- ANSI-American National Standards Institute
- FCU-Fort Collins Utility Services
- GF-Generating facility
- IEEE-Institute of Electrical and Electronic Engineers
- KVA-Kilovolt-amps
- KW-Kilowatt
- MW-Megawatt
- NEC-National Electrical Code
- NEMA-National Electrical Manufacturers Association
- NESC-National Electrical Safety Code
- Operator-Generating facility owner and operator, successors, heirs, agents, employees, and assigns
- PCC-Point of common coupling
- UL-Underwriters Laboratories
- VAR-Volt-Amps reactive (reactive power)

## 3.0 GF Equipment and Installation Requirements

### 3.1 General Requirements

The installation of any GF shall meet the relevant requirements of the National Electrical Code (NEC) and the National Electrical Safety Code (NESC). Where required by the municipality, the Operator cleared to move forward with the installation must obtain all necessary building permits, pass all applicable building department inspections, and meet other applicable requirements including but not limited to municipal code and Fort Collins Electric Service Rules and Regulations.

Unless otherwise modified in this document, the interconnection must meet the requirements of IEEE Std. 1547. Where the requirements of this document vary from the requirements of IEEE Std. 1547, this document governs.

The Operator shall be solely responsible for protecting the GF and all associated equipment from abnormal distribution system conditions such as outages, short circuits, voltage or frequency variations, or other disturbances. FCU will not install equipment for the protection of the GF generator or other equipment. The GF equipment must be designed and operated so that it is capable of properly synchronizing the generator to the system, maintaining safe operation of the generation equipment, detecting any unusual operating condition, and disconnecting the generator from the system anytime damage to the generator or other equipment may occur. The equipment protection provided by the Operator will prevent the GF from adversely affecting the distribution system's capability of providing reliable service to other FCU customers. The GF must automatically disconnect itself from the system anytime system conditions are outside the ranges described in this document and is not permitted to reconnect to the system until system conditions return to normal and are maintained within the normal range for a minimum of five (5) minutes.

### 3.2 Interconnection Disconnect Switch

Each GF installation must include a manually operated, lockable, disconnect switch with a visual break. The disconnect switch must be visible and accessible at all times by FCU personnel to allow the GF to be disconnected safely during maintenance or outage conditions. In the case of a PV system this disconnect switch must be located next to the FCU electric meter. In all cases the disconnect switch must be rated to interrupt the maximum output of the generator and must be rated for the voltage and fault current requirements of the GF and must meet all applicable NEMA, UL, ANSI, IEEE, and NEC standards as well as local and state electrical codes. The disconnect switch shall be permanently labeled with text indicating that the switch is for the GF. The labeling shall also clearly indicate the open and closed position of the switch. The disconnect switch must be located on the output or load side of the GF such that the entire GF can be isolated from FCU distribution system. If the site contains several generators, a single disconnect switch may be used providing its rating is sufficient for all generators and opening it produces a visible open point between all generators and the FCU system.

Other devices such as circuit breakers or fuses may be considered as a substitute for a disconnect switch if each of the following conditions is met:

a) If a circuit breaker is used it is draw-out and capable of being locked into the disconnected position
b) If a fuse is used it is capable of being removed from the bus to provide a visual open point
c) The Operator or Operator’s agents are available at all times to disconnect and remove this breaker or fuses whenever requested by FCU

All lock-out and tag-out capabilities must also be available for the devices used and must be assessable to FCU personnel.

### 3.3 Dedicated Transformer and Additional Primary Protection

If the GF rating is greater than 50kW the GF must be connected to the FCU by a dedicated transformer. The transformer must meet FCU standards and design criteria. The transformer must be labeled according to FCU practices.

Most interconnecting transformers on the FCU system are protected with fuses. However, if a GF is rated at 1500 kVA or above, FCU may determine the fuse protection is insufficient to properly protect the FCU system. In this case, FCU may require that a dedicated three-phase interrupting device such as a recloser must be added to the transformer high-voltage side along with necessary relaying.. Moreover, any GF whose connection to the FCU distribution system increases the aggregate generation on any feeder, transformer, or portion of a feeder to 1500 kVA or above is subject to a separate study by FCU, and FCU may require the addition of a three-phase protective device on the primary side of the system.

### 3.4 Interrupting Devices Required

Circuit breakers or other interrupting devices located at the Point of Common Coupling (PCC) must be certified or "Listed" (as defined in Article 100, the Definitions Section of the National Electrical Code) as suitable for their intended application. This includes being capable of interrupting the maximum available fault current expected at their location. The Operator's GF Facility and associated interconnection equipment must be designed so that the failure of any single device will not potentially compromise the safety and reliability of FCU's distribution system.

### 3.5 System Protective Functions

The protective functions and requirements contained in this document are designed to protect FCU's distribution system and not specifically the Operator's GF. The Operator is solely responsible for providing adequate protection for the GF and all associated equipment. The Operator's protective devices must not impact the operation of other protective devices utilized on the FCU distribution system in a manner that would affect FCU's ability to provide reliable service to its customers.

The GF's protective functions must sense abnormal conditions and disconnect the GF from the FCU distribution system during abnormal conditions. All GFs must be capable of sensing line-line-line, line-line, and line-ground faults on the distribution feeder supplying the GF and must disconnect from the line to protect both the line from further damage and the generator from damage due to excessive currents or unusual voltages. The settings of these relays will be coordinated with FCU substation relaying.

For induction machines speed matching must be done automatically and shall match speed to less that 5% before closing the associated breaker.

The minimum protective functions needed for various types of generators, and other requirements for system protection are shown below. Any machine that is not included in one of the following categories must be individually considered by FCU.

#### 3.5.1 Synchronous Machines above 50kW to 100kW

a) Over and under voltage functions (27/59)
b) Over current trip functions. (50/51) which may be included in a breaker trip-unit or a fuse.
c) Ground fault protection (50/51G)
d) Over and under frequency functions. (81O/U)
e) Sync Check (25)
f) Phase-sequence or negative sequence voltage (47)
g) A function to prevent the GF from contributing to the formation of an unintended island and to prevent the GF from reconnecting with the distribution system under abnormal conditions is required.
h) Relay settings and test reports will be submitted to FCU for review. FCU will determine if an on-site inspection is required.

#### 3.5.2 Synchronous Machines 100kW to and including 1000kW

a) Interrupting devices must be 3-phase circuit breakers with electrical operation.
b) Relays must be utility grade (must meet IEEE Std.C37.90, C37.91, C37.92 and C37.93) and must be independent from the generator control devices.
c) Over and under voltage functions (27/59)
d) Voltage restrained over current trip functions. (50/51V)
e) Ground fault protection (50/51G)
f) Over and under frequency functions. (81O/U)
g) Sync Check (25)
h) Phase-sequence or negative sequence voltage (47)

i) Reverse power (32)
j) A function to prevent the GF from contributing to the formation of an unintended island and to prevent the GF from reconnecting with the distribution system under abnormal conditions is required.
k) Relay settings and test reports will be submitted to FCU for review. FCU will determine if an on-site inspection is required.

### 3.5.3 Synchronous Machines 1000kW to and including 5000kW

a) Interrupting devices must be 3-phase circuit breakers with electrical operation.
b) Relays must be utility grade (must meet IEEE Std.C37.90, C37.91, C37.92 and C37.93) and must be independent from the generator control devices.
c) Over and under voltage functions (27/59)
d) Voltage restrained over current trip functions. (50/51V)
e) Ground fault protection (50/51G)
f) Over and under frequency functions. (81O/U)
g) Negative Sequence Current (46)
h) Loss of Field (40)
i) Sync Check (25)
j) Phase-sequence or negative sequence voltage (47)
k) Reverse power (32)
l) A function to prevent the GF from contributing to the formation of an unintended island and to prevent the GF from reconnecting with the distribution system under abnormal conditions is required.
m) Relay settings and test reports will be submitted to FCU for review.

### 3.5.4 Doubly-Fed Induction Machines above 50kW to 100kW

a) Over and under voltage functions (27/59)
b) Over current trip functions. (50/51) which may be included in a breaker trip-unit or a fuse.
c) Ground fault protection (50/51G) which may be included in a breaker trip-unit or a fuse
d) Phase-sequence or negative sequence voltage (47)
e) Speed matching to within 5% (15)
f) If it is determined that it is possible for the machine to self-excite in this installation, the GF must include a function to prevent the GF from contributing to the formation of an unintended island and to prevent the GF from reconnecting with the distribution system under abnormal conditions. If it is determined that the machine cannot self-excite, evidence must be provided to FCU proving that this is the case and anti-islanding protection is not required. If such evidence does not meet FCU approval, anti-islanding protection is required.
g) Relay settings and test reports must be submitted to FCU for review. FCU will determine if an on-site inspection is required.

### 3.5.5 Doubly-Fed Induction Machines 100kW to 5000kW

a) Interrupting devices must be 3-phase circuit breakers with electrical operation.
b) Relays must be utility grade (must meet IEEE Std.C37.90, C37.91, C37.92 and C37.93) and must be independent from the generator control devices.
c) Over and under voltage functions (27/59)
d) Over current trip functions. (50/51) which may be included in a breaker trip-unit or a fuse.
e) Ground fault protection (50/51G) which may be included in a breaker trip-unit or a fuse
f) Phase-sequence or negative sequence voltage (47)
g) Negative sequence current (46)
h) Over and under frequency (81 O/U)
i) Reverse power (32)
j) Speed matching to within 5% (15)

k) If it is determined that it is possible for the machine to self-excite in this installation the GF must include a function to prevent the GF from contributing to the formation of an unintended island and to prevent the GF from reconnecting with the distribution system under abnormal conditions. If it is determined that the machine cannot self-excite, evidence must be provided to FCU proving that this is the case and anti-islanding protection is not required. If such evidence does not meet FCU approval, anti-islanding protection is required.
l) Relay settings and test reports must be submitted to FCU for review. FCU will determine if an on-site inspection is required.

### 3.5.6 Induction Machines above 50kW to 100kW

a) Over and under voltage functions (27/59)
b) Over current trip functions. (50/51) which may be included in a breaker trip-unit or a fuse.
c) Ground fault protection (50/51G) which may be included in a breaker trip-unit or a fuse
d) Phase-sequence or negative sequence voltage (47)
e) Speed matching to within 5% (15)
f) If it is determined that it is possible for the machine to self-excite in this installation the GF must include a function to detect and trip the unit during a self excited condition. This will prevent system over voltages and also prevent the GF from contributing to the formation of an unintended island. If it is determined that the machine cannot self-excite, evidence must be provided to FCU proving that this is the case and this protection is not required. If such evidence does not meet FCU approval, anti-islanding protection is required.
g) Relay settings and test reports must be submitted to FCU for approval. FCU will determine if an on-site inspection is required.

### 3.5.7 Induction Machines 100kW to 5000kW

a) Interrupting devices must be 3-phase circuit breakers with electrical operation.
b) Relays must be utility grade (must meet IEEE Std.C37.90, C37.91, C37.92 and C37.93) and must be independent from the generator control devices.
c) Over and under voltage functions (27/59)
d) Over current trip functions. (50/51) which may be included in a breaker trip-unit or a fuse.
e) Ground fault protection (50/51G) which may be included in a breaker trip-unit or a fuse
f) Phase-sequence or negative sequence voltage (47)
g) Negative sequence current (46)
h) Over and under frequency (81 O/U)
i) Reverse power (32)
j) Speed matching to within 5% (15)
k) If it is determined that it is possible for the machine to self-excite in this installation the GF must include a function to detect and trip the unit during a self excited condition. This will prevent system over voltages and also prevent the GF from contributing to the formation of an unintended island. If it is determined that the machine cannot self-excite, evidence must be provided to FCU proving that this is the case and this protection is not required. If such evidence does not meet FCU approval, anti-islanding protection is required.
l) Relay settings and test reports will be submitted to FCU for review. FCU will determine if an on-site inspection is required.

### 3.5.8 Inverter Connected Systems 1000 kW and Below

This may include photovoltaic systems (PV), some wind turbines, fuel cells, microturbines and all other machines that deliver their power to the utility system via an inverter or converter utilizing power electronics.

a) The Inverter must be tested to meet IEEE 1547, and IEEE 1547.1. One way to meet this requirement is to be tested to UL1741. However, it is not required that this testing be done by Underwriters Laboratories. Any recognized testing lab which confirms that the inverter meets IEEE 1547, and IEEE 1547.1 is satisfactory. If the inverter does not carry a UL sticker, FCU must be supplied with a letter from the manufacturer or an independent testing laboratory stating the inverter has been tested and meets the above IEEE standards.
b) FCU will require over current trip functions (50/51) which may be included in a breaker trip-unit or a fuse. This device must be separate from the inverter control system and internal disconnect device.
c) FCU will determine if an on-site inspection is required to observe calibration and testing of the inverter functions.

#### 3.5.9 Inverter Connected Systems above 1000 kW to 5000kW

This may include photovoltaic systems (PV) some wind turbines, fuel cells, microturbines and all other machines that deliver their power to the utility system via an inverter or converter utilizing power electronics.

a) The Inverter must be tested to meet IEEE 1547, and IEEE 1547.1. One way to meet this requirement is to be tested to UL1741. However, it is not required that this testing be done by Underwriters Laboratories. Any recognized testing lab which confirms that the inverter meets IEEE 1547, and IEEE 1547.1 is satisfactory. If the inverter does not carry a UL sticker, FCU must be supplied with a letter from the manufacturer or an independent testing laboratory stating the inverter has been tested and meets the above IEEE standards.
b) FCU will require over current trip functions (50/51) which may be included in a breaker trip-unit or a fuse. This device must be separate from the inverter control system and internal disconnect device.
c) Ground fault protection (50/51G) which may be included in a breaker trip unit. This device must be separate from the inverter control system and internal disconnect device.
d) Over and under frequency (81 O/U). This device must be separate from the inverter control system and internal disconnect device.
e) Over and under voltage functions (27/59). This device must be separate from the inverter control system and internal disconnect device.
f) FCU will determine if an on-site inspection is required to observe calibration and testing of the inverter and relay functions.

#### 3.5.10 All machines above 5000kW

Any type of GF of this size must be studied and considered individually by FCU.

### 3.6 Momentary Paralleling Generation Facilities

At times an Operator may decide to install a system that may operate parallel to the FCU system only momentarily (normally less than 0.1 seconds). With FCU's approval, the transfer switch or system used to transfer the Operator's loads from FCU's distribution system to the Operator's GF may be used in lieu of the protective functions required for parallel operation.

## 4.0 Facility Grounding

In all cases the GF grounding system must not adversely impact FCU grounding or ground fault protective relaying. The GF grounding must not cause high voltages to occur under any condition either normally occurring or occurring during a system fault such as allowing high voltages to exist on the un-faulted phases during a single-line-to-ground fault.

### 4.1 Equipment Bonding Conductor

The Operator must install an equipment-grounding conductor, in addition to the ungrounded conductors and grounded conductor (neutral), between the GF and the distribution system. The grounding conductor must be permanent, electrically continuous, and must be capable of safely carrying the maximum fault current that could be imposed it by the systems to which it is connected. Additionally, the equipment-grounding conductor must be of sufficiently low impedance to facilitate the operation of over current protection devices under fault conditions. All conductors shall comply with the National Electrical Code (NEC). The GF must not be designed or implemented such that the earth becomes the sole fault current path.

### 4.2 Surge Protection

It is strongly recommended but not required that a surge protective device (SPD) be utilized to protect GF equipment.

### 4.3 System Grounding

FCU maintains an effectively grounded distribution system and requires that all GFs be designed to contribute to an effectively grounded system. Effective grounding prevents the occurrence of excessively high voltages during ground faults and protects existing FCU equipment. Effective grounding of the GF may desensitize existing FCU ground fault protection, which could require FCU ground fault relay settings changes or modifications in the design of the GF. The transformer supplied to interconnect the GF voltage to the FCU system will normally be a grounded-wye to grounded-wye transformer. This connection will not provide a grounding source by itself and will not provide an effectively grounded system from the GF side of the interconnection unless effective grounding of GF is provided. When designing the grounding system for the GF, the designer should consider the condition that will result when a ground fault occurs on the line serving the GF. This ground fault would be cleared on the FCU side of the line by opening a breaker or recloser in the FCU substation. This will result in momentarily islanding the line on the GF until it opens its breaker. Under this condition, where the line is islanded and being supplied by the GF, the system must remain effectively grounded.

Effective grounding shall be defined by IEEE Std.142 which states that to be considered effectively grounded both of the following two conditions must be met:

a) The ratio of zero-sequence reactance to positive-sequence reactance ($X_0/X_1$) must be positive and three or less.
b) The ratio of zero-sequence resistance to positive-sequence reactance ($R_0/X_1$) must be positive and less than 1.

The GF system equivalent (Thevenin equivalent) impedance must meet the criteria for effective grounding stated above. The networks used in determining this impedance, and other fault current calculations for the plant, will include the positive, negative, and zero sequence networks of the step-up transformer connected to the FCU system, all other transformers between the generator and the point of common coupling, the generator subtransient, positive, negative and zero sequence values, the neutral grounding device for the generator, the grounding transformer and neutral grounding device (if used) and any significant cable runs. The GF shall maintain an effectively grounded system under normal operating conditions while operating in connection with FCU lines.

The short circuit contribution ratio (SCCR) of the GF is defined as the ratio of the GF short circuit contribution to FCU's contribution to a short circuit ($I_{scGF}/I_{scFCU}$) for either a three-phase or single-line-to ground fault measured at the high voltage side of the transformer stepping up from the generation voltage to the FCU voltage.

The GF must be grounded in such a way that the SCCR for a line-ground fault calculated at the high voltage side of the transformer connecting the GF to FCU is less than 3% while still achieving effective grounding as defined above. If this SCCR ratio is greater than 3% FCU must do a study to

determine if re-setting ground fault relays on the existing FCU system is required. In rare cases connecting a certain GF to a particular feeder may not be practical due to protection issues or special protection techniques may be needed to make the connection safe.

Proper grounding of the GF can be achieved in a number of ways. FCU may at its discretion accept any of the following methods:

a) Solidly grounding the generator or installing a solidly grounded grounding transformer (zig-zag or grounded wye-delta transformer). While a solidly grounded generator is acceptable to FCU if all other requirements are met, it must be used with care. ANSI standards generally require that for a synchronous generator the ground fault current must be limited to the three-phase fault current. This usually requires a resistance or reactance be used for grounding the generator neutral. Also, a solidly grounded generator may conduct large amounts of harmonic currents. There may be some unbalanced voltage at the terminals of the generator. This can cause circulating current through the generator if it is solidly grounded which may make de-rating of the generator necessary. If a solidly grounded system is used the designer must consider and plan for all issues that may result.
b) Resistance grounding. A resistance grounded generator or grounding transformer with a resistance placed between neutral and ground may be used if it meets the requirements of effective grounding.
c) Reactance grounding. A reactance grounded generator or grounding transformer with a reactor between the transformer neutral and ground may be used if it meets the requirements of effective grounding.
d) Other methods may be suggested for consideration by FCU.

If the Operator desires to generate at the FCU primary voltage and to connect the generators directly to the FCU system without the use of an interconnecting transformer, FCU must first conduct a study of the connection. FCU will determine, as a result of the study, the grounding and other requirements necessary for this type of connection.

## 5.0 Prevention of Interference and Unacceptable Operating Conditions

The Operator must not operate the GF in any way that causes a system disturbance or that superimposes a voltage or current upon FCU's distribution system that results in interference with FCU operations, service to FCU's customers, or other FCU equipment and facilities. When FCU suspects that interference with electric service to other FCU customers is occurring, and such interference exceeds FCU Standards, FCU reserves the right at its expense to install special test equipment as may be required to perform a disturbance analysis and monitor the operation of the GF to evaluate the quality of power produced. If the GF is demonstrated to be the source of the interference, and it is demonstrated that the interference produced exceeds FCU Standards or generally accepted industry standards, FCU may, without liability, disconnect the GF from the FCU distribution system.It shall be the responsibility of the Operator to eliminate any interference caused by the GF and the Operator must diligently pursue and take corrective action, at the Operator's own expense, to eliminate undesirable interference caused by the GF. The GF will be reconnected to the FCU system only after the Operator demonstrates to the satisfaction of FCU that the cause of the interference has been remedied.

The Operator's protective devices must prevent the GFs from contributing to an island. If the FCU feeder to which the GF is connected is de-energized for any reason, the GF must sense this and disconnect itself within 2 seconds of the de-energization of the feeder.

### 5.1 Voltage Regulation

The GF shall not actively regulate the voltage at the point of common coupling (PCC) unless the effects of this are first reviewed and approved by FCU. If a study has been done by FCU which determines that it is advantageous for a GF to actively control its voltage, FCU will inform the Operator and the Operator will be required to control the GF's terminal voltage.

### 5.2 System Voltage

The voltage operating range limits for GFs shall be used as a protection function that responds to abnormal conditions on FCU's distribution system. The FCU voltage operating range is normally - 95% to 105% of the nominal voltage at the electrical service point, and 92% to 105% of nominal voltage at the utilization point, as required by ANSI C84.1. All GFs must be capable of operating within the voltage range normally experienced on FCU's distribution system. Ocassional excursions outside this range may occur, and tripping of the GF is not suggested until the voltage range is less than 88% or more than 110% of the nominal voltage. The operating range and GF protection shall be selected in a manner that minimizes nuisance tripping between 88% and 110% of nominal voltage. GFs must not energize or, after a trip, re-energize FCU's circuits whenever the voltage at the PCC deviates from the allowable voltage operating range allowed by ANSI C84.1 Table 1 voltage range (95-105% of nominal voltage at the service or 92-105% of nominal voltage at the utilization point).

Whenever the FCU distribution system voltage at the PCC varies from normal (nominally 120 volts) by the amounts as set forth in Table 5-1 the GF's protective functions shall disconnect the generator(s) from the FCU distribution system with delay times no longer than those shown.

**Table 5-1: Voltage trip settings.**
**(Adapted from IEEE 1547-2003 and ANSI C84.1-2006)**

| Voltage at Point of Common Coupling (% of base Voltage) | Maximum Tripping Time Delay (seconds/cycles) |
|---|---|
| V-PCC < 50% | 0.16 / 10 |
| 50% < V-PCC < 88% | 2.0 / 120 |
| 92% < V-PCC < / 105% | Normal operating range |
| 110% < V-PCC < 120% | 1.0 / 60 |
| 120% < V-PCC | 0.16 / 10 |

### 5.3 System Frequency

The GF shall operate in synchronism with the FCU distribution system. Whenever FCU's distribution system frequency at the PCC varies from normal (nominally 60 Hertz) by the amounts as set forth in Table 5-2 the GF's protective functions shall disconnect the generator(s) from the FCU distribution system with delay times no longer than those shown.

**Table 5-2: Frequency Settings**
**(Adapted from IEEE 1547-2003 and NERC PRC-024-1)**

| GF Facility Size | Frequency (Hz) | Maximum Tripping Time Delay (sec./cycles) |
|---|---|---|
| GF 30kW or Less | GF<59.3 | 0.16/10 |
| | 59.3 ≤ GF ≤ 60.5 | Continuous Operation |
| | GF>60.5 | 0.16/10 |
| | | |
| GF > 30kW | | |
| | GF<57.8 | 0.16/10 |
| | 57.8 ≤ GF ≤ 58.0 | 4/240 |
| | 58.0 < GF ≤ 58.5 | 40/2,400 |
| | 58.5 < GF ≤ 59.0 | 200/12,000 |

| | | |
|---|---|---|
| | **59.0 < GF < 59.5** | **1,800/108,000** |
| | **59.5 ≤ GF ≤ 60.5** | **Continuous Operation** |
| | **60.5 < GF ≤ 61.5** | **600/36,000** |
| | **61.5 < GF** | **0.16/10** |

Unless some other anti-islanding scheme is employed, the GF should disconnect due to low frequency resulting from islanding the feeder load on the GF. The frequency settings must be adjusted to insure that, during the lowest loading level on the feeder, the resulting frequency change of the GF when it is islanded with those feeder loads , should cause the under frequency relaying to disconnect the the generators within two seconds.

### 5.4 Synchronization

Synchronous machine automatic synchronizers and sync-check relays must be set as shown in Table 5-3.

**Table 5-3: Synchronizer/sync check relay settings.**
**(Adapted from IEEE 1547-2003)**

| Rating of GF (kVA) | Maximum Slip Rate (Hz) | Maximum Voltage Difference (%V) | Maximum Phase Angle Difference (deg). |
|---|---|---|---|
| 0-500 | 0.3 | 10 | 20 |
| 500-1500 | 0.2 | 5 | 10 |
| 1500 and above | 0.1 | 3 | 10 |

### 5.5 Flicker

Any voltage flicker at the PCC caused by the GF should not exceed the limits defined by the “Maximum Borderline of Irritation Curve” identified in IEEE 519, IEEE 141, and IEE 1453. This limit is shown in Figure 5-1. This requirement is necessary to minimize the adverse voltage effects which may be experienced by other customers on the FCU distribution system due to the operation of the GF. Induction generators may only be connected to the system and brought up to synchronous speed (as an induction motor) if these flicker limits are not exceeded.

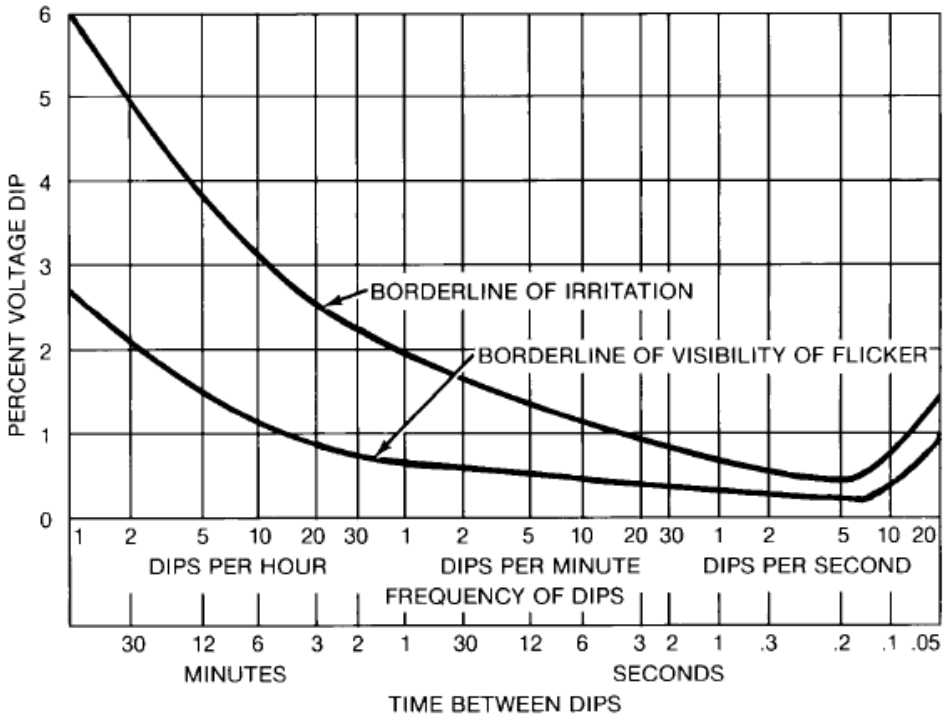


**Figure 5-1: Allowable voltage flicker vs. time (reproduced from IEEE Std. 141).**

### 5.6 Harmonics

Harmonic distortion measured at the PCC must be in compliance with IEEE 519 and IEEE 1547. Harmonic current injection limits are shown in Table 5-4.

**Table 5-4: Maximum harmonic current distortion as a percentage of fundamental frequency at the point of common coupling.**
**(Adapted from IEEE 1547-2003)**

| Individual Harmonic Order h (Odd Harmonics Only) | | | | | |
|---|---|---|---|---|---|
| h<11 | 11≤h<17 | 17≤h<23 | 23≤h<35 | 35≤h | TDD |
| 4.0 | 2.0 | 1.5 | 0.6 | 0.3 | 5.0 |

The even harmonic limits must be 25% of those shown in Table 5-4.

GF's must not inject direct current greater than 0.5% of rated output into the FCU distribution system. Any device causing a DC offset such as a half-wave converter shall not be allowed.

### 5.7 Power Factor

The power factor at the point of common coupling (PCC) with FCU (the low voltage terminals of the transformer connecting the GF to FCU) shall always remain within 0.95 lagging (VARs going into the site) to 0.95 leading (Vars going out of the site). The only exception to this requirement is a GF consisting of an inverter connected generator 10 kW or less. For this exception it is expected that the site power factor will deteriorate anytime the GF is operating, and FCU will provide the VARs needed at the site. However the site power factor must be maintained such that it would remain within the limits stated above if the GF was not operating and, as a result, the power factor was allowed to revert to the value it had before the GF was added.

a)

Each synchronous generator in a GF shall be capable of operating at any point within a power factor range of 0.95 leading (Vars going into the generator) to 0.95 lagging (Vars going out of the generator). Synchronous generators should automatically control power factor and should be set to deliver VARs to the system as needed to keep the power factor at the PCC with FCU to the range required by this section.

For generators other than synchronous generators, operation outside this power factor range is acceptable provided the cumulative power factor of the customer's entire facility is kept within the range noted. This may be done using capacitor banks, controlling the inverter settings, adding static VAR compensators (SVC) or synchronous condensers, or other means agreeable to both the GF and FCU. If capacitor banks are used they shall be sized and installed per IEEE Stds. 18, 1036, C37.012, C37.06, C37.66, and 1015. Capacitors may need to be stepped and switched to meet the power factor requirements above. Before the addition of capacitors the GF should completely study the effects of the capacitor additions on the resonance conditions and harmonic values that will result. If the GF's addition of capacitors causes adverse resonance or harmonics effects on FCU's system, the GF shall be required to pay for any modifications needed to mitigate the problem.

## 6.0 Monitoring Provisions

The following monitoring and metering requirements must be met by any Operator connecting a GF to the FCU system.

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### 6.1 Metering

GFs larger than 10kW and less than or equal to 100 kW require a minimum of a form 9s metering installation.

GFs larger than 100 kW will require revenue metering capable of recording the following components:

a) Time of use (TOU)
b) Harmonic measuring capability
c) Four quadrant capability
d) MV90 capable
e) Form 9S
f) The revenue meter must measure the aggregate load of the Operator's facility including the GF.

### 6.2 Monitoring and Control Requirements

Each non-inverter connected generating facility of 100 kW or larger shall be required, at the discretion of FCU, to have FCU supplied equipment that will be used for monitoring and control of the facility. The Operator shall be responsible for all hardware, software, and any installation costs of FCU provided equipment associated with the co-gen installation. FCU will provide a remote monitoring and control equipment enclosure containing the following equipment at the Operator's expense:

- 900 MHZ spread spectrum radio
- SEL 351 relay
- Terminal blocks as required
- Various control switches, CT blocks, etc as required

- UPS power supply with battery backup

A YAGI antenna will be provided and shall be installed by the Operator at a location designated by FCU. The Operator will be responsible for installing the antenna coax specified by FCU. The Operator must use a certified installer to terminate the coax. The Operator shall also be responsible for mounting the equipment enclosure.

The monitoring and control system shall be designed to allow FCU to perform the following:

- Trip the generator breaker for unstable system conditions such as frequency, voltage and fault conditions
- Place a HOT LINE TAG on the generator breaker that would block its close circuit to prevent its closing
- Initiate a generator startup thru SCADA for future power dispatching by FCU (This would normally be blocked locally unless requested by the Operator.)
- Monitor the generator breaker status to determine if the generator is on or off line
- Monitor generator output power(real and reactive), voltage, harmonics etc. (This will require current and voltage inputs from the GF equipment.)

The GF Operator must provide all the necessary interface design to accomplish the functions listed above. The GF Operator must submit drawings of the proposed design to FCU for review.

## 7.0 Testing

### 7.1 Commissioning Tests

In addition to any commissioning tests required by the owner of the GF or manufacturer of equipment used, the following tests must be performed before operation of the GF. The Operator must notify FCU two weeks in advance of the time of the testing so that a FCU representative may observe any tests required by FCU.

a) Visual inspection to ensure proper grounding.
b) Visual inspection shall confirm the presence of the isolation device described in section 3.2 and the device shall be tested for operation.
c) Trip tests must be performed to prove each device which is required to trip any breaker is capable of doing so.
d) Relays or protective functions provided by the generator manufacture must be tested and relay test reports must be made available to FCU. All of the functions required in Section 3.5 must be tested. Inverter connected devices tested by an independent testing laboratory as required in Section 3.5 are not be required to perform this test.
e) In the case of a synchronous generator the Operator must prove that the generator is connected to the system with the proper phase rotation and that all three phases of generator voltage match those of the system at the same instant in time. This test is commonly known as “phasing out” the generator.
f) In the case of a synchronous generator the Operator must prove that the generator synchronizer and sync check relay is capable of connecting the generator to the system properly and in synchronism. This test must be done before the generator is allowed to actually connect to the system.
g) The ability of the control system to disconnect the generator within two seconds in the event of islanding must be tested.

### 7.2 Periodic Maintenance Tests

An Operator must maintain his or her equipment in good order and in compliance with all manufacturers suggested periodic maintenance. If it is discovered that an Operator is not properly maintaining his or her equipment, FCU may disconnect the GF until such time that the Operator can prove that he or she has provided all required maintenance needed to allow the GF to operate properly and safely.

FCU reserves the right to inspect the GF equipment whenever it appears the GF is operating in a manner that is hazardous to the FCU system.

Functional testing must be performed every year to prove the proper operation of the isolation device and all breakers and relays. For all GFs consisting of synchronous machines with aggregate ratings of larger than 1000kW, no less than once every three years all protective functions must be re-tested and calibrated to prove their operation complies with the requirements contained in this document. The Operator must maintain written records of these tests and these records will be made available to FCU on request.

Battery systems used for generator control or protective relaying must be maintained and periodically tested as suggested by the battery manufacturer.

### 7.3 Qualified Personnel

All testing and calibration shall be done by qualified personnel. FCU will provide a list of contractors qualified to provide this service.

## 8.0 Design Changes

After the GF begins operation any design changes, such as the addition of more generation, must be submitted to FCU for review. Protective devices or any other requirements listed in this document must not be modified or their settings changed without approval of FCU.

## 9.0 Liability and Insurance

In no event shall FCU be held responsible for the safety, reliability, design, or protection of the GF. Compliance with these interconnection standards does not mean the GF is safe to operate and the Operator is solely responsible for making a determination about whether the GF is safe to operate.

Nothing herein shall be construed to create any duty to, any standard of care with reference to, or any liability to any person who is not a party to an arrangement or agreement between FCU and the Operator pursuant to these requirements. FCU is not liable for damages caused to the facilities, improvements or equipment of the Operator by reason of the operation, faulty operation or non-operation of FCU facilities.

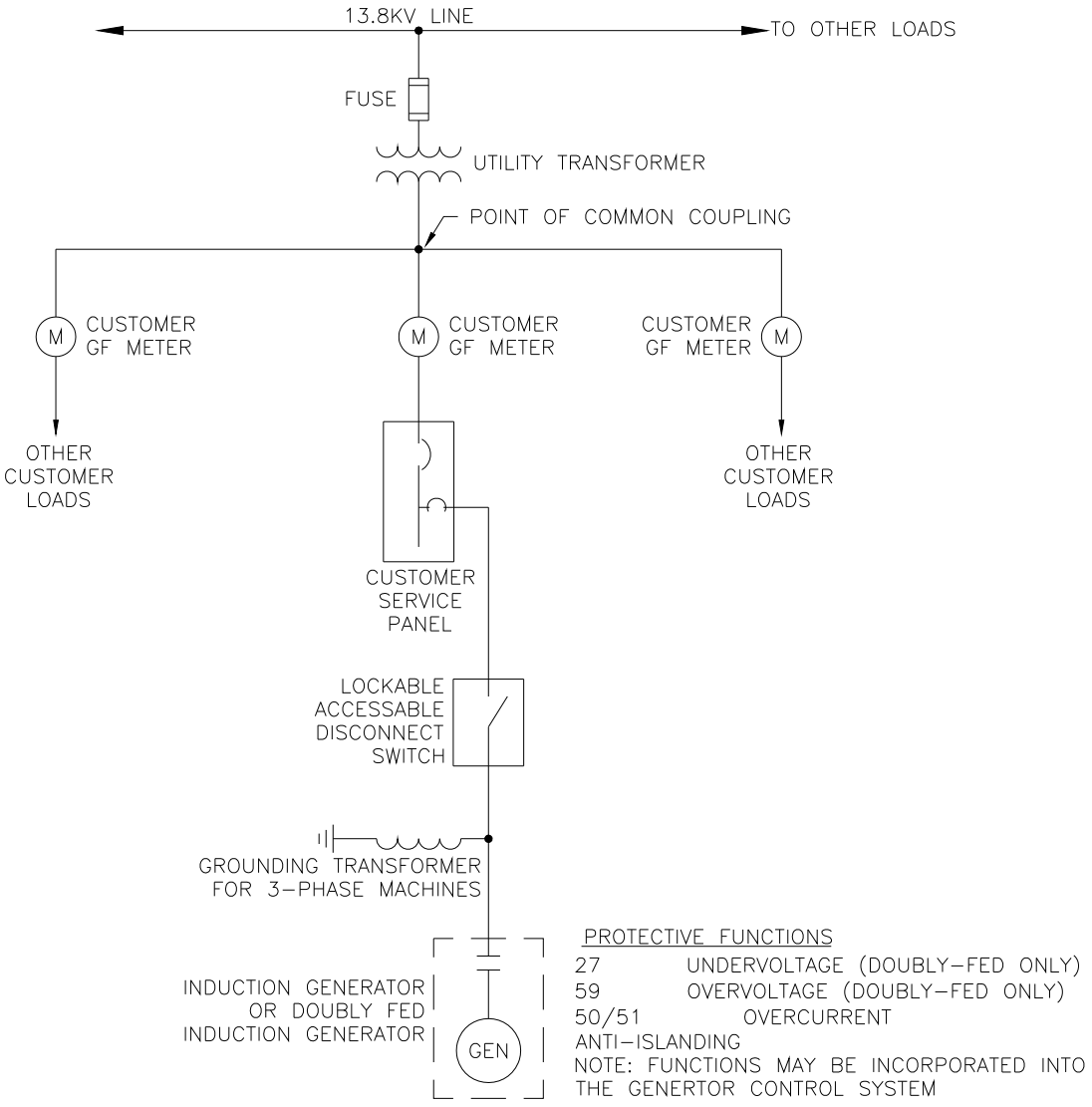
To the extent permitted by law, the Operator shall be solely responsible for and shall defend, indemnify and hold FCU harmless from and against any and all claims or causes of action for personal injury, death, property damage, loss or violation of governmental laws, regulations or orders, which injury, death, damage, loss or violations occurs on or is caused by operation of equipment or facilities on the Operator's side of the point of connection. Notwithstanding the above and to the extent permitted by law, the Operator shall be solely responsible for and shall defend, indemnify and hold harmless FCU from and against any and all claims or causes of action for personal injury, death, property damage or loss or violation of governmental laws, regulations or orders, wherever occurring, which injury, death, damage, loss or violation is due solely to the acts of omissions of such Operator, including but not limited to the use of defective equipment or faulty installation or maintenance or equipment by such party. However, nothing contained in this section shall be construed as relieving or releasing either party from liability or personal injury, death, property damage or loss, or violation of governmental laws, regulations or orders, wherever occurring, resulting from its own negligence or the negligence of any of its officers, servants, agents or employees. In the event of concurrent negligence, liability shall be apportioned between the parties according to each party's respective fault. Neither the Operator nor FCU shall be liable to the other or any other third party, in contract or in tort or otherwise, for loss of use of equipment and

related expenses, expense involving cost of capital, claims of customers of FCU or the Operator, as applicable, loss of profits or revenues, cost of purchase or replacement power, or any indirect, incidental or consequential loss or damage whatsoever.

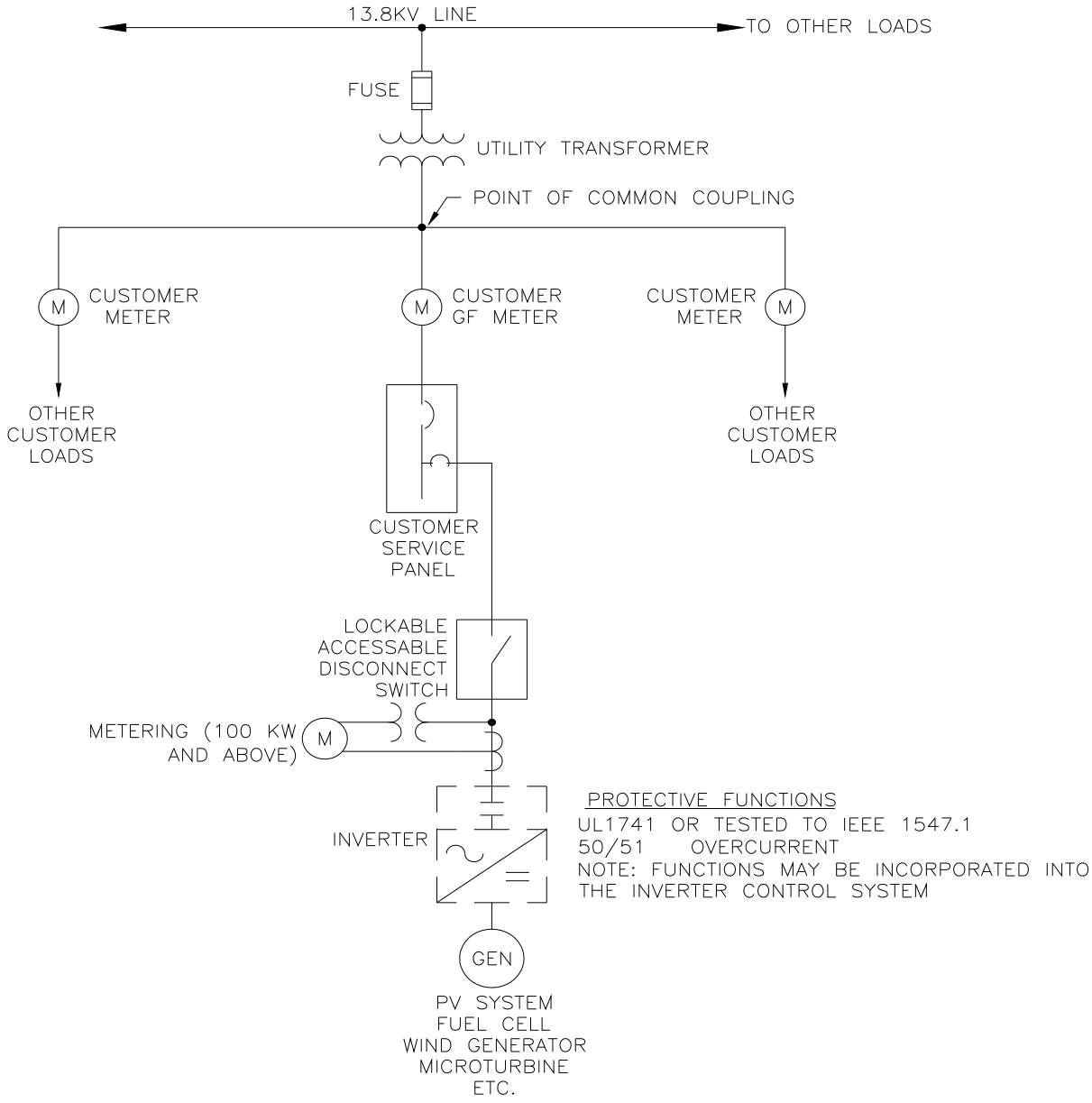
The Operator shall pay all costs that may be incurred by FCU in enforcing the indemnity described herein. Each party's liability to the other party for any loss, cost, claim, injury, liability, or expense, including reasonable attorney's fees, relating to or arising from any act or omission in its performance of this agreement, shall be limited to the amount of direct damage actually incurred. In no event shall either party be liable to the other party for any indirect, incidental, special, consequential, or punitive damages of any kind whatsoever.

For systems of ten kW or more, the Operator, at its own expense, except when the Operator is a governmental entity that self-insures in accordance with Colorado law, shall secure and maintain in effect during connection of its GF to the FCU system, liability insurance with a combined single limit for bodily injury and property damage of not less than $300,000 (Three Hundred Thousand Dollars) each occurrence. Such liability insurance shall not exclude coverage for any incident related to the subject GF or its operation. Except when the Operator is a governmental entity that self-insures in accordance with Colorado law, FCU shall be named as an additional insured under the liability policy. For systems above 500 kW and up to one megawatt, the Operator, at its own expense, except when the Operator is a governmental entity that self-insures in accordance with Colorado law, shall secure and maintain in effect during connection of its GC to the FCU system, liability insurance with a combined single limit for bodily injury and property damage of not less than $2,000,000 (Two Million Dollars) for each occurrence. Insurance coverage for systems greater than one megawatt shall be determined on a case-by-case basis by FCU and shall reflect the size of the installation and the potential for system damage. Any insurance policy required herein shall include that written notice be given to FCU at least 30 days prior to any cancellation or reduction of any coverage. Such liability insurance shall provide, by endorsement to the policy, that FCU shall not by reason of its inclusion as an additional insured incur liability to the insurance carrier for the payment of premium of such insurance. A copy of the liability insurance certificate must be received by FCU prior to GF operation. Certificates of insurance evidencing the requisite coverage and provision(s) shall be furnished to FCU prior to date of interconnection of the generation system. FCU shall be permitted to periodically obtain proof of current insurance coverage from the Operator in order to verify proper liability insurance coverage. The Operator will not be allowed to commence or continue interconnected operations unless evidence is provided that satisfactory insurance coverage is in effect at all times.

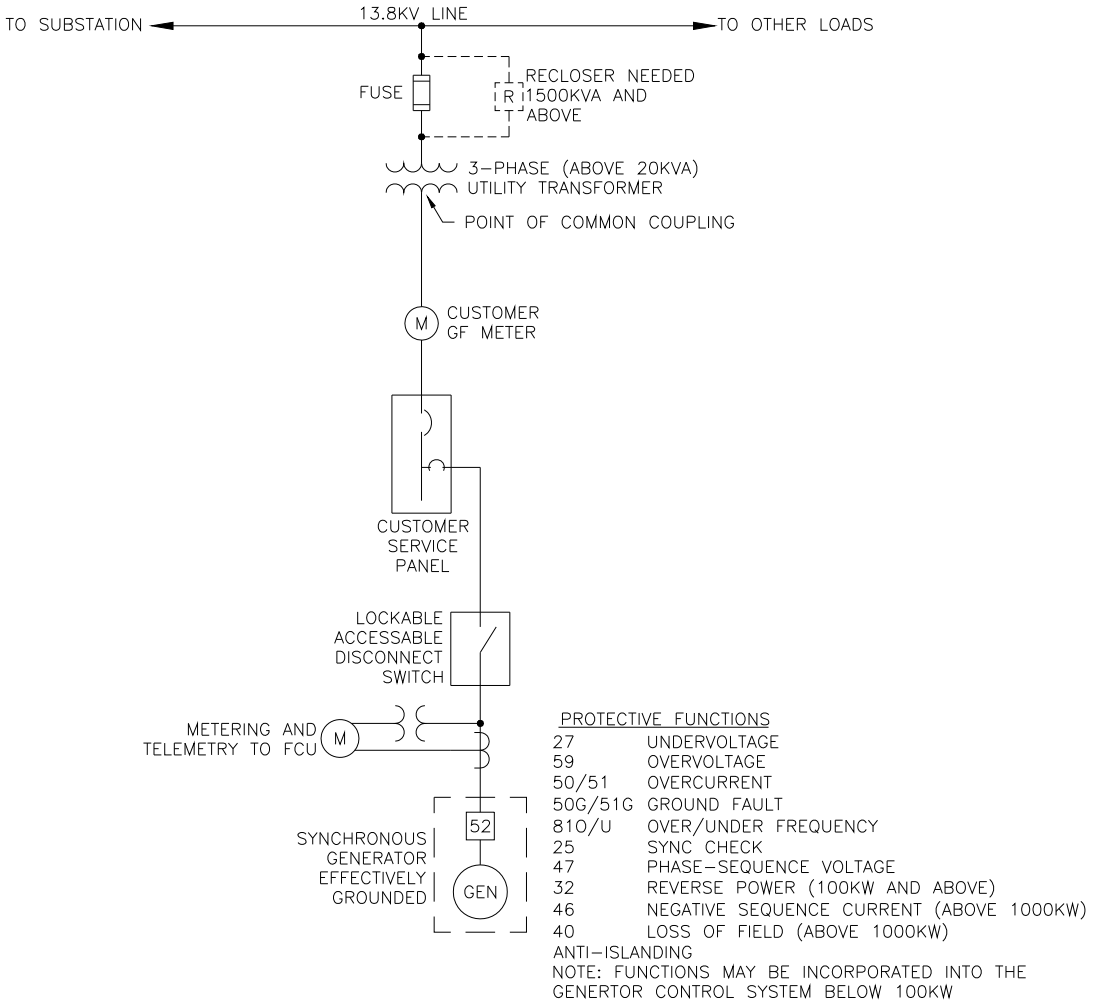
## APPENDIX A-TYPICAL ONE-LINE INDUCTION GENERATOR BETWEEN 50KW AND 100KW



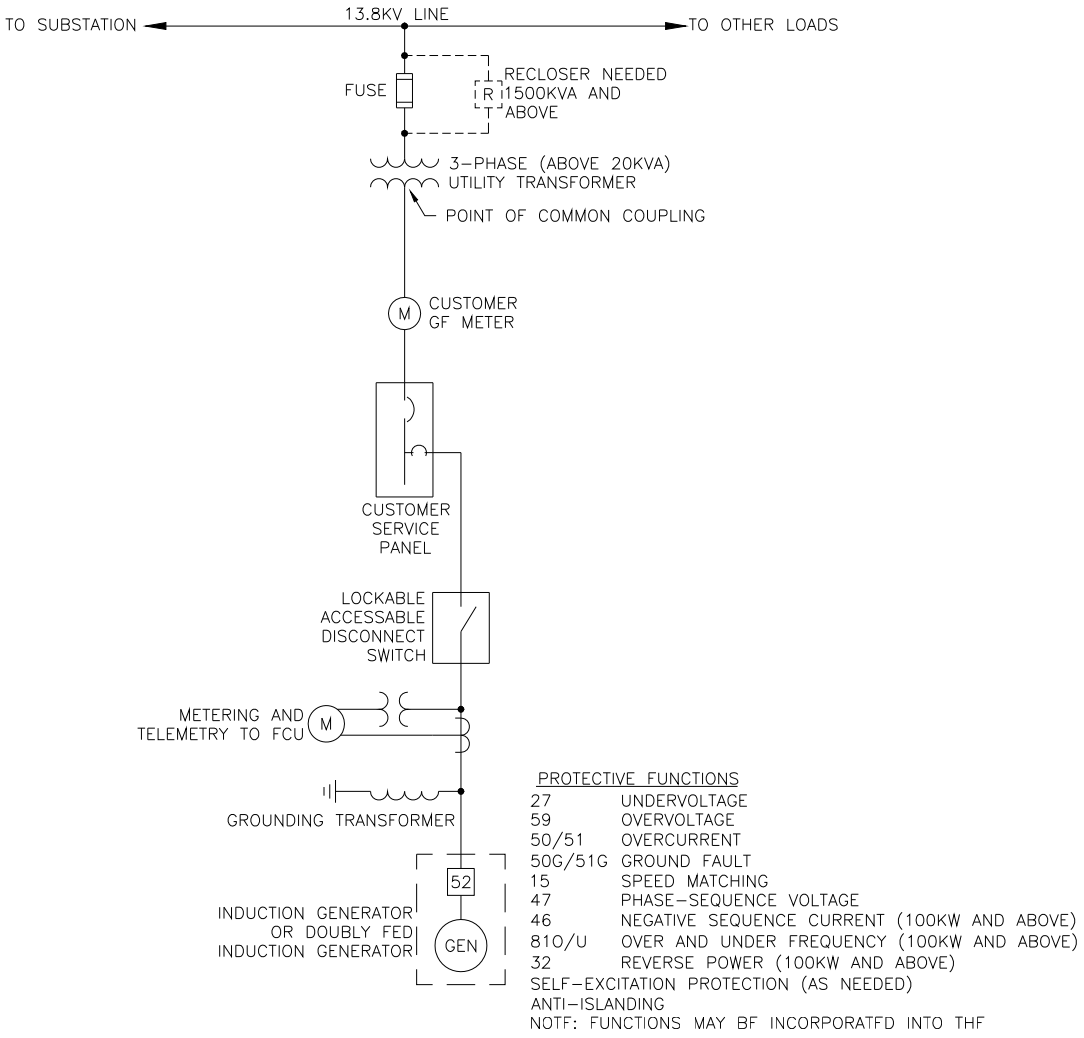
**APPENDIX B-TYPICAL ONE-LINE INVERTER CONNECTED GENERATOR BELOW 1000KW.**



## APPENDIX C-TYPICAL ONE-LINE SYNCHRONOUS GENERATOR 50KW AND ABOVE



## APPENDIX D-TYPICAL ONE-LINE INDUCTION GENERATOR LARGER THAN 100KW



## APPENDIX E-TYPICAL ONE-LINE INVERTER CONNECTED GENERATOR LARGER THAN 1000KW