

SDG&E Electric Distribution System Interconnection Handbook

<Revised as of 10/21/2015>



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1 Introduction

1.1 Purposes

This handbook has been prepared to provide an overview of the technical requirements to interconnect Generating Facilities (includes all generators located at an interconnection point) to operate in parallel with SDG&E's distribution system. The requirements are necessary to ensure safe and reliable operation of SDG&E's electric system. The handbook shall serve as a guideline to SDG&E personnel and customer generation owners in completing generation to distribution interconnections that conform to SDG&E reliability requirements.

The interconnections include facility additions and modifications on generation and distribution systems necessary to accommodate the interconnection of generation to SDG&E distribution system. For generation interconnection to the transmission system, refer to ***SDG&E Generation Interconnection Handbook***, which can be found on the SDG&E website, link below.

<http://www.sdge.com/generation-interconnection-handbook>

1.2 Applicability and Related Tariffs

All generators connected to the distribution system must meet the technical requirements of this handbook. The handbook is not intended to supersede

Interconnection Agreements required by SDG&E's Electric Rule 21 and/or the Wholesale Distribution Open Access Tariff (WDAT), particularly the Large Generator Interconnection Agreement (LGIA) and Small Generator Interconnection Agreement (SGIA).

1.3 Interconnection Agreement Required

The Owner/Operator must execute an Interconnection Agreement with SDG&E, and receive SDG&E's express written permission before parallel operation of its generating facility with SDG&E's Distribution System. SDG&E shall treat all requests in a non-discriminatory manner and shall not unreasonably withhold its permission for Parallel Operation of Owner/Operator's Generating Facility with SDG&E's Distribution System.

1.4 Technical Requirement

The technical requirements are organized in five (5) categories:

- Metering
- Protection and Control

- Operating Requirements
- Operating Procedures
- Energization and Synchronization

2 Metering Requirements

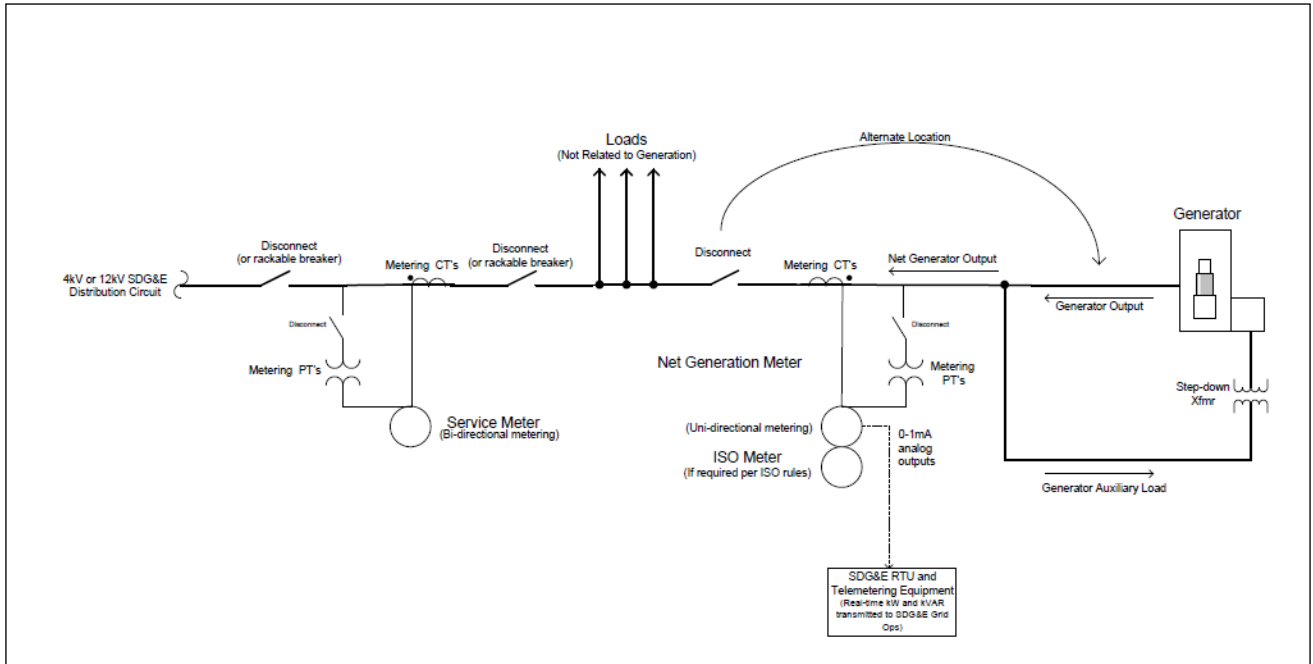
2.1 *Basic Metering Requirements*

- On generating facilities < 1 MW, it is recommended that SDG&E metering be installed to measure net generator output (generator output minus auxiliary loads associated with the generator) per SDG&E metering standards and requirements.
- On generating facilities \geq 1MW, SDG&E metering shall be installed to measure net generator output (generator output minus auxiliary loads associated with the generator) in addition to SDG&E telemetering.
- SDG&E metering shall be installed to meter import and export at the SDG&E service point(s) regardless of Generating Facility size.
- If the facility is a generating facility serving only auxiliary load with one SDG&E service point, the SDG&E service point is also considered to be the net generator output point, so no additional net generation output meter is required or recommended.
- For a generating facility that requires CAISO (California Independent System Operator) metering, a CAISO meter(s) shall be installed at the SDG&E service point or at the net-generation point(s) per CAISO requirements and policies.

2.2 *Metering Equipment Layout*

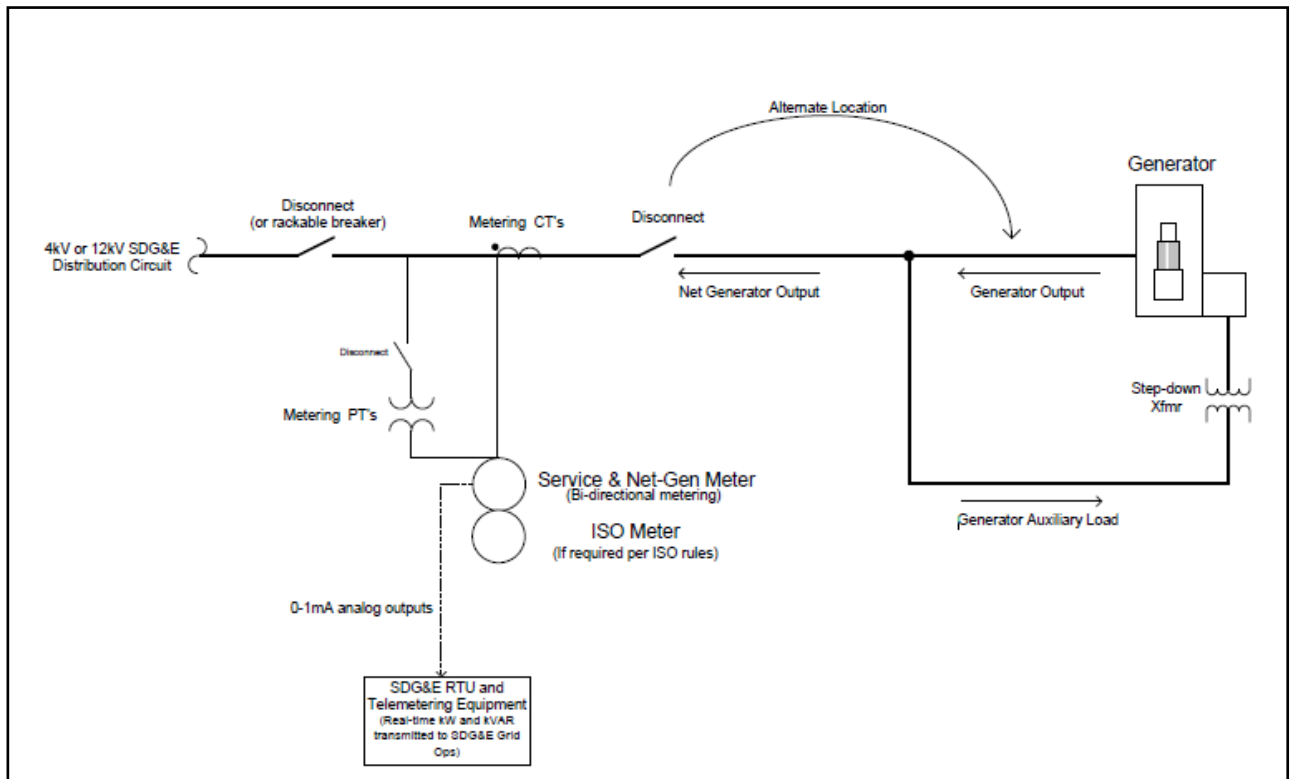
A typical metering layout of a generating facility containing load that is not directly associated with generation is illustrated in Figure 1.

Figure 1: Typical Generation Facility Metering Layout (w/ loads not related to generation)



A typical metering layout of a generating facility with only loads associated with generation is illustrated in Figure 2.

Figure 2: Typical Generation Facility Metering Layout (w/ only loads associated with generation)



2.3 ***Metering Sections***

- At all points where SDG&E meters are to be installed, the Owner/Operator shall acquire and install a metering section. The metering section includes cable pull sections, bus bars for metering CT/PT insertion; disconnect switches, a metering panel, a meter socket(s), and accommodations for test switches/test blocks. Please refer to pages 676 and 677 of SDG&E's Electric Service Standards & Guide Manual for a typical metering section.
- Detailed information on all new proposed metering sections for the project shall be provided to SDG&E as part of the review and approval process described in the applicable tariff. This includes (but is not limited to) clearances from the metering section and details of the standing surface of the metering section.
- A set of disconnect switches or a rackable breaker shall be placed directly on the line side of each metering section as well as a set of disconnect switches for the metering PT's (accessible by SDG&E personnel only) per SDG&E service requirements. In addition, a set of disconnect switches shall be placed on the load side of the meter or at the point of generator output.
- Locations of these disconnect switches (or rackable breakers) are illustrated in Figures 1 and 2 above.
- The required disconnect switches (or rackable breakers) shall allow visible verification that separation has occurred.
- Disconnect switches are required to be gang operated.
- Disconnect switches and rack-out breakers must accommodate locking devices to allow SDG&E to lock-out services or net-generation points when necessary.
- Suitable locations shall be selected for all SDG&E metering sections per requirement outlined on page 602 of SDG&E's Electric Service Standards & Guide Manual.
- CAISO meters shall be located on the same metering panel plate as SDG&E meters that serve to meter the same point (e.g. net-generation point, SDG&E service point). Both meters will tap off the same metering PT's/CT's with the enclosure/panel having two sockets and test switches. See page 678 of SDG&E's Electric Service Standards & Guide Manual for a typical layout of this panel configuration.
- Any load that precedes point of service metering must be metered by an SDG&E self-contained meter on the same meter panel as that of the SDG&E meter. Typically, this load consists of customer owned PT's feeding control, protection, and monitoring devices. A typical panel layout showing this self-contained metering is shown on pages 679 and 680 of SDG&E's Electric Service Standards & Guide Manual.
- For self-contained meters, the Owner/Operator is required to acquire and install test blocks that meet SDG&E service requirements.

- The Electric Service Standards & Guide Manual can be found at:

<http://www.sdge.com/electric-service-standards-guide-manual>

2.4 Other Metering Requirements

- An activated dial-up phone line shall be provided to each SDG&E meter.
- This phone line shall be routed to the associated meter panel with the SDG&E meter where SDG&E can plug an RJ-11 connector to obtain phone service to the meter. The RJ-11 connection point shall be within 12" of the meter socket.
- Monthly costs and maintenance of the phone lines to SDG&E meters are the responsibility of the Owner/Operator.
- At all SDG&E metering locations where voltage potential may be lost (except in the event of a planned or forced SDG&E outage), the Owner/Operator shall supply each SDG&E meter with a 120VAC uninterruptible power supply (UPS).
- A dedicated breaker position in the UPS breaker panel shall be utilized to supply each meter with UPS power and shall be clearly marked as feeding an SDG&E meter.
- The Owner/Operator may request KYZ outputs from any SDG&E meter for a one-time cost. See Figure 3 shown in Section 2.6 of this handbook for a typical KYZ output configuration.

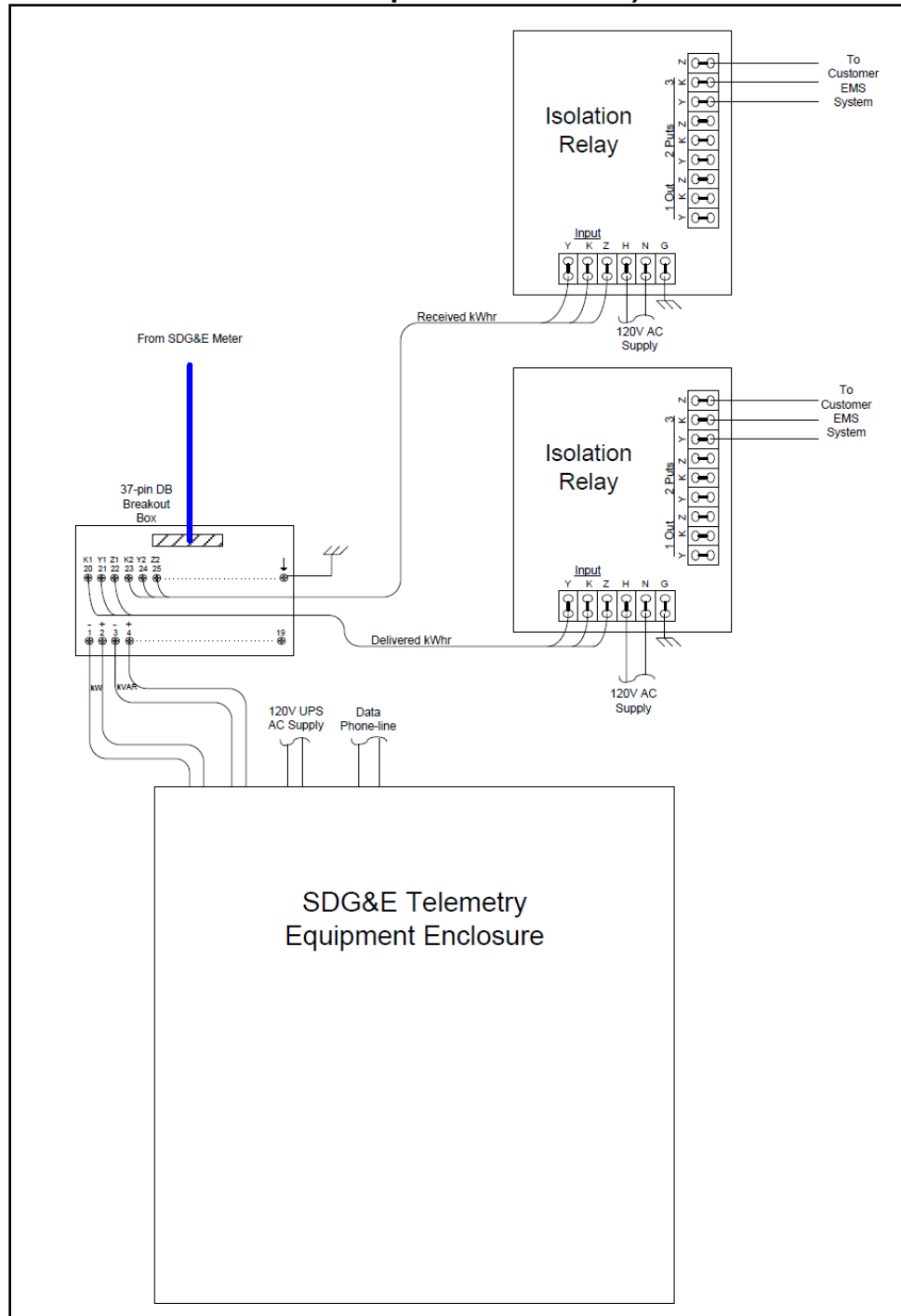
2.5 Metering Equipment Installation

- All metering sections shall be installed by the Owner/Operator.
- Upon final approval of the metering sections, layout, and overall facility, SDG&E personnel will provide, install and wire the metering CT's/PT's, telemetry equipment (if applicable), and test switches in preparation for the installation of SDG&E meters.
- If a CAISO meter is required, SDG&E will wire all CAISO metering. However, an ISO certified contractor is required to perform installs of CAISO meters per arrangements made by the Owner/Operator with the CAISO.

2.6 Telemetering Equipment

- SDG&E telemetering equipment located at net generation output metering points for generators ≥ 1 MW utilize outputs from SDG&E meters located at the same metering points. See Figure 3 below for typical telemetering configuration.

Figure 3: Typical Telemetry Interface with SDG&E Metering (w/ KYZ outputs to customer)



- Telemetry requires a dedicated 120VAC UPS source. The telemetry equipment enclosure should be placed on or close to the meter panel but is not required to be on the meter panel. A suitable conduit can be used to interconnect the telemetry equipment with the SDG&E meter.
- The telemetry requires a high speed dedicated data line to SDG&E's Grid Operations center.
- Costs associated with the set-up requirements of telemetry equipment (e.g., conduit runs, activated data line) are borne by the Owner/Operator. There is a one-time cost to the Owner/Operator for the SDG&E telemetry equipment.

2.7 Meter Reading/Maintenance/Testing

- SDG&E will own, install, maintain, read, and test all SDG&E meters, telemetry equipment, metering PT's/CT's, and associated wiring installed at the facility.
- 24hr/7day unrestricted and unescorted access to all metering equipment and metering associated devices shall be provided to SDG&E metering personnel. All locked doors and gates SDG&E metering personnel must pass through to gain access shall each contain a SDG&E Schlage restricted VTQP quad lock supplied and installed by the Owner/Operator. A list of locksmiths authorized by SDG&E to sell Schlage restricted VTQP quad locks is listed on page 005.1 of SDG&E's Electric Service Standards & Guide Manual.
- If required, the Owner/Operator shall be responsible for installing, maintaining, reading, and testing the CAISO meter(s) per CAISO requirements. It is the responsibility of the facility Owner/Operator to comply with all applicable CAISO metering standards and requirements.
- Per SDG&E request, the Owner/Operator of the Generating Facility shall make all necessary arrangements with the CAISO for SDG&E to obtain all 5 min interval data reads from the CAISO meter. SDG&E will in-turn, upon reasonable notification, supply the CAISO with meter data from the SDG&E meter in the event of a CASIO meter failure within a reasonable time-frame, and with the understanding that most SDG&E meters only record IDR data on a 15min basis per SDG&E tariffs.
- The format of these reads must be compatible with SDG&E's meter reading system (MV90) using a Hand-Held Files (HHF) format. SDG&E shall supply the CAISO with meter data in this same HHF format.
- All metering sections and associated equipment are maintained by the Owner/Operator. In the event of a failure or malfunction of this equipment, the Owner/Operator is responsible for all replacements and repairs.
- The metering PT's/CT's, SDG&E meters, and SDG&E telemetry equipment is owned and therefore maintained by SDG&E.
- Repairs and replacements of CAISO meters are the Owner/Operator's responsibility and not the responsibility of SDG&E.

- Upon reasonable advanced notification by SDG&E, the Owner/Operator shall operate disconnect switches and/or rack-out breakers in order for SDG&E to perform maintenance on metering CT/PT's, telemetering equipment, or inspection of the metering section.
- Upon a failure or malfunction of a metering section or SDG&E equipment, the Owner/Operator shall accommodate immediate arrangements with SDG&E to operate disconnects or rack-out breakers.

3 Protection and Control Requirements

3.1 Purpose

This section specifies the requirements for protection and control devices for Generating Facilities interconnecting to the SDG&E Distribution System.

The applicable protective standards of this section apply to all Generating Facilities interconnecting to any portion of SDG&E's Distribution System. These standards, which govern the design, construction, inspection and testing of protective devices, have been developed to be consistent with SDG&E's Rule 21, *Interconnection Standards for Non-Utility Owned Generation*, and IEEE 1547, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*.

3.2 General Interconnection and Protective Function Requirements

The Protective Functions and requirements of this Section are designed to protect SDG&E's Distribution System and not the Generating Facility. An Owner/Operator shall be solely responsible for providing adequate protection for its Generating Facility and Interconnection Facilities. The Owner/Operator's protective equipment shall not impact the operation of other protective equipment utilized on SDG&E's Distribution System in a manner that would affect SDG&E's capability of providing reliable service to its Customers.

Protective Equipment Required - Generating Facilities operating in parallel with SDG&E's Distribution System shall be equipped with protective devices that will sense abnormal conditions on SDG&E's Distribution System and will: cause the Generating Facility to automatically disconnect from SDG&E's Distribution System, or will prevent the Generating Facility from being connected to SDG&E's Distribution System inappropriately. These protective functions include:

- 1) Over and under voltage trip functions and over and under frequency trip functions;
- 2) A voltage and frequency sensing and time-delay function that will prevent the Generating Facility from energizing a de-energized Distribution System circuit, and will prevent the Generating Facility from reconnecting with SDG&E's Distribution System unless SDG&E's Distribution System service voltage and frequency is: a) within the ANSI C84.1-1995 Table 1 Range B Voltage Range of 106V to 127V (on a 120V basis), inclusive, and b) within a frequency range of 59.7 Hz to 60.5 Hz inclusive, and is stable for at least 60 seconds.
- 3) A function to prevent the Generating Facility from contributing to the formation of an Unintended Island, and cease to energize SDG&E's Distribution System within two seconds of the formation of an Unintended Island.

The Generating Facility shall cease to energize SDG&E's Distribution System for faults on SDG&E's Distribution System circuit to which it is connected (IEEE1547-4.2.1). The Generating Facility shall cease to energize SDG&E's Distribution circuit prior to reclosure by SDG&E's Distribution System equipment (IEEE1547-4.2.2).

Momentary Paralleling Generating Facilities - With SDG&E's approval, the transfer switch or scheme used to transfer the Owner/Operator's loads from SDG&E's Distribution System to Owner/Operator's Generating Facility may be used in lieu of the protective functions required for Parallel Operation.

Suitable Equipment Required - Circuit breakers or other interrupting equipment 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. Owner/Operator's Generating Facility and Interconnection Facilities shall be designed so that the failure of any single device or component shall not potentially compromise the safety and reliability of SDG&E's Distribution System. The Generating Facility paralleling-device shall be capable of withstanding 220% of the Interconnection Facility rated voltage (IEEE1547-4.1.8.3). The Interconnection Facility shall have the capability to withstand voltage and current surges in accordance with the environments defined in IEEE Std C62.41.2-2002 or IEEE Std C37.90.1-2002 as applicable and as described in Rule 21 Section J.3.e (IEEE1547-4.1.8.2).

Visible Disconnect Required - When required by SDG&E's operating practices, the Owner/Operator shall furnish and install a ganged, manually-operated isolating switch (or a comparable device mutually agreed upon by SDG&E and the Owner/Operator) near the Point of Interconnection to isolate the Generating Facility from SDG&E's Distribution System. The device does not have to be rated for load break nor provide over-current protection. The device must:

- 1) Allow visible verification that separation has been accomplished. (This requirement may be met by opening the enclosure to observe contact separation.)
- 2) Include markings or signage that clearly indicates open and closed positions.
- 3) Be capable of being reached quickly and conveniently 24 hours a day by SDG&E personnel for construction, operation, maintenance, inspection, and testing or reading without: a) obstacles, b) a requirement to seek access to climb over or remove obstacles, or c) a requirement to obtain keys, special permission, or security clearances.
- 4) Be capable of being locked in the open position.
- 5) Be clearly marked on the submitted single line diagram and its type and location approved by SDG&E prior to installation. If the device is not

adjacent to the PCC, permanent signage must be installed at an SDG&E approved location providing a clear description of the location of the device.

Generating Facilities with Non-Islanding inverters totaling one (1) kilovolt-ampere (kVA) or less are exempt from this requirement.

Drawings Required - Prior to Parallel Operation or Momentary Parallel Operation of the Generating Facility, SDG&E shall approve the Owner/Operator's protective function and control diagrams. Generating Facilities equipped with protective functions and a control scheme previously approved by SDG&E for system-wide application or only Certified Equipment may satisfy this requirement by reference to previously approved drawings and diagrams.

3.3 *Prevention of Interference*

The Owner/Operator shall not operate Generating or Interconnection Facilities that superimpose a voltage or current upon SDG&E's Distribution System, or that interferes with SDG&E operations, service to SDG&E customers, or communication facilities. If such interference occurs, the Owner/Operator must diligently pursue and take corrective action at its own expense after being given notice and reasonable time to do so by SDG&E. If the Owner/Operator does not take corrective action in a timely manner, or continues to operate the facilities causing interference without restriction or limit, SDG&E may, without liability, disconnect the Owner/Operator's facilities from SDG&E's Distribution System, in accordance with Section 3.4 of the Wholesale Open Access Distribution Tariff Small Generator Interconnection Agreement (WDAT SGIA). Below is a link to the WDAT SGIA:

<http://www.sdge.com/generation-interconnections/wholesale-generator-transmission-interconnections>

To eliminate undesirable interference caused by its operation, each Generating Facility (GF) shall meet the following criteria:

Voltage Regulation - The GF shall not actively regulate the voltage at the PCC while in parallel with SDG&E's Distribution System. The GF shall not cause the service voltage at other customers to go outside the requirements of ANSI C84.1-1995, Range A (IEEE1547-4.1.1).

Operating Voltage Range - The voltage ranges in Table 1 below define protective trip limits for the protective function and are not intended to define or imply a voltage regulation function. Generating Facilities shall cease to energize SDG&E's Distribution System within the prescribed trip time whenever the voltage at the PCC deviates from the allowable voltage operating range. The protective function shall detect and respond to voltage on all phases to which the Generating Facility is connected.

- 1) **Generating Facilities (30 kVA or less)** - Generating Facilities with a Gross Nameplate Rating of 30 kVA or less shall be capable of operating within the

voltage range normally experienced on SDG&E’s Distribution System from 114V to 126V on a 120V base, at the service panel or PCC. The trip settings at the generator terminals may be selected in a manner that minimizes nuisance tripping between 106 volts and 132 volts on a 120-volt base (88%-110% of nominal voltage) to compensate for voltage drop between the generator terminals and the PCC. Voltage may be detected at either the PCC or the Point of Interconnection. However, the normal operating voltage range at the PCC, with the generator on-line, shall stay within +/- 5% of nominal voltage.

- 2) **Generating Facilities (greater than 30 kVA)** - SDG&E may have specific operating voltage ranges for Generating Facilities with Gross Nameplate Ratings greater than 30 kVA, and may require adjustable operating voltage settings. In the absence of such requirements, the Generating Facility shall operate at a range between 88% and 110% of the applicable interconnection voltage. Voltage shall be detected at either the PCC or the Point of Interconnection, with settings compensated to account for the voltage at the PCC. However, the normal operating voltage range at the PCC, with the generator on-line, shall stay within +/- 5% of nominal voltage.
- 3) **Voltage Disturbances** - Whenever SDG&E’s Distribution System voltage at the Point of Common Coupling varies from and remains outside normal (nominally 120 volts) by the predetermined amounts set forth in Table 1, the Generating Facility’s protective functions shall cause the Generator(s) to become isolated from SDG&E’s Distribution System.

Table 1: Voltage Trip Settings

Voltage at Generator Terminal or Point of Common Coupling (the ranges below are used to trip the generator during abnormal conditions)		Maximum Trip Time [1]	
Assuming 120 V Base	% of Nominal Voltage	# of Cycles (Assuming 60Hz Nominal)	Seconds
Less than 60 Volts	Less than 50%	10 Cycles	0.16 Seconds
Greater than or equal to 60 Volts but less than 106 Volts	Greater than or equal to 50% but less than 88%	120 Cycles	2 Seconds
Greater than 132 Volts but less than or equal to 144 Volts	Greater than 110% but less than or equal to 120%	60 Cycles	1 Second
Greater than 144 Volts	Greater than 120%	10 Cycles	0.16 Seconds

[1] -"Maximum Trip time" refers to the time between the onset of the abnormal condition and the Generating Facility ceasing to energize SDG&E’s Distribution System. Protective function sensing equipment and circuits may remain connected to SDG&E’s Distribution System to allow sensing of electrical conditions for use by the "reconnect" feature. The purpose of the allowed time delay is to allow a Generating Facility to "ride through" short-term disturbances to avoid nuisance tripping. Set

points shall not be user adjustable (though they may be field adjustable by qualified personnel). For Generating Facilities with a Gross Nameplate Rating greater than 30 kVA, set points shall be field adjustable and different voltage set points and trip times from those in Table 1 may be negotiated with SDG&E.

Paralleling - The Generating Facility shall parallel with SDG&E's Distribution System without causing a voltage fluctuation at the PCC greater than $\pm 5\%$ of the prevailing voltage level of SDG&E's Distribution System, and meet the flicker requirements of this section. (IEEE1547-4.1.3)

Flicker - The Generating Facility shall not create objectionable flicker for other customers on SDG&E's Distribution System. To minimize the adverse voltage effects experienced by other customers (IEEE1547-4.3.2), flicker at the Point of Common Coupling caused by the Generating Facility should not exceed the limits defined by the "Maximum Borderline of Irritation Curve" identified in IEEE 519-1992 (IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems, IEEE STD 519-1992, Institute of Electrical and Electronic Engineers, Piscataway, NJ). This requirement is necessary to minimize the adverse voltage effects experienced by other customers on SDG&E's Distribution System. Generators may be connected and brought up to synchronous speed (as an induction motor) provided these flicker limits are not exceeded.

Integration with SDG&E's Distribution System Grounding - The grounding scheme of the Generating Facility interconnection shall not cause overvoltages that exceed the rating of the equipment connected to SDG&E's Distribution System, and shall not disrupt the coordination of the ground fault protection on the SDG&E's Distribution System (IEEE1547-4.1.2) (See Section 1.3.h). The gas standard must be followed where electrical equipment is in the vicinity of the gas meter assembly. Any electrical connection to SDG&E's gas equipment is a violation of the Code and is unsafe. Electric bonding to SDG&E's gas service pipes, gas riser, or gas meter assembly is not permitted (Gas Standard page 1003).

Frequency - SDG&E controls system frequency, and the Generating Facility shall operate in synchronism with the SDG&E's Distribution System. Whenever SDG&E's Distribution System frequency at the Point of Common Coupling varies from and remains outside normal (nominally 60 Hz) by the predetermined amounts set forth in Table 2 below, the Generating Facility's protective functions shall cease to energize SDG&E's Distribution System within the stated maximum trip time.

Table 2: Frequency Trip Settings

Generating Facility Rating:	Frequency Rating (60Hz Nominal)	Maximum Trip Time [1] (Assuming 60 Cycles per Second)
Less or equal to 30kW	Less than 59.3 Hz	10 Cycles
	Greater than 60.5 Hz	10 Cycles
Greater than 30kW	Less than 57.0 Hz	10 cycles
	Less than an adjustable value between 59.8 Hz and 57 Hz but greater than 57 Hz. [2]	Adjustable between 10 and 18,000 Cycles. [2, 3]
	Greater than 60.5 Hz	10 Cycles

[1] - "Maximum Trip time" refers to the time between the onset of the abnormal condition and the Generating Facility ceasing to energize SDG&E's Distribution System. Protective function sensing equipment and circuits may remain connected to SDG&E's Distribution System to allow sensing of electrical conditions for use by the "reconnect" feature. The purpose of the allowed time delay is to allow a Generating Facility to "ride through" short-term disturbances to avoid nuisance tripping. Set points shall not be user adjustable (though they may be field adjustable by qualified personnel). For Generating Facilities with a Gross Nameplate Rating greater than 30 kVA, set points shall be field adjustable and different voltage set points and trip times from those in Table 2 may be negotiated with SDG&E.

[2] - Unless otherwise required by SDG&E, a trip frequency of 59.3 Hz and a maximum trip time of 10 cycles shall be used.

[3] - When a 10 cycle Maximum trip time is used, a second under frequency trip setting is not required.

Harmonics - When the Generating Facility is serving balanced linear loads, harmonic current injection into SDG&E’s Distribution System at the PCC shall not exceed the limits stated below in Table 3 below. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in SDG&E’s Distribution System without the Generating Facility connected (IEEE1547-4.3.3). The harmonic distortion of a Generating Facility located at a Customer's site shall be evaluated using the same criteria as for the Host Loads.

Table 3: Maximum harmonic current distortion in percent of current (I) [1,2]

Individual harmonic order, h (odd harmonics) [1]	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	Total demand distortion (TDD)
Max Distortion (%)	4.0	2.0	1.5	0.6	0.3	5.0

[1] - Even harmonics are limited to 25% of the odd harmonic limits above.

Direct Current Injection - Generating Facilities should not inject direct current greater than 0.5% of rated output current into SDG&E’s Distribution System.

Power Factor - Each Generator in a Generating Facility shall be capable of operating at some point within a power factor range from 0.90 leading to 0.90 lagging. Operation outside this range is acceptable provided the reactive power of the Generating Facility is used to meet the reactive power needs of the Host Loads, or that reactive power is otherwise provided under tariff by SDG&E. The Owner/Operator shall notify SDG&E if it is using the Generating Facility for power factor correction. Unless otherwise agreed upon by the Owner/Operator and SDG&E, Generating Facilities shall automatically regulate power factor, not voltage, while operating in parallel with SDG&E’s Distribution System.

3.4 Technology Specific Requirements

Three-Phase Synchronous Generators - For three-phase Generators, the Generating Facility circuit breakers shall be three-phase devices with electronic or electromechanical control. The Owner/Operator shall be responsible for properly synchronizing its Generating Facility with SDG&E’s Distribution System by means of either manual or automatic synchronizing equipment. Automatic synchronizing is required for all synchronous Generators that have a Short Circuit Contribution Ratio (SCCR) exceeding 0.05. Loss of synchronism protection is not required except as may be necessary to meet flicker requirements (IEEE1547-4.2.5). Unless otherwise agreed upon by the Owner/Operator and SDG&E, synchronous Generators shall automatically regulate power factor, not voltage, while operating in parallel with SDG&E’s Distribution System. A power system stabilization function is

specifically not required for Generating Facilities under 10 MW Net Nameplate Rating.

Induction Generators - Induction Generators (except self-excited Induction Generators) do not require a synchronizing function. Starting or rapid load fluctuations on induction generators can adversely impact SDG&E's Distribution System's voltage. Corrective step-switched capacitors or other techniques may be necessary and may cause undesirable ferro-resonance. When these counter measures (e.g., additional capacitors) are installed on the Owner/Operator's side of the Point of Common Coupling, SDG&E must review these measures. Additional equipment may be required as determined in an interconnection review or an Interconnection Study.

Inverters - Utility-interactive inverters do not require separate synchronizing equipment. Non-utility-interactive or "stand-alone" inverters shall not be used for Parallel Operation with SDG&E's Distribution System.

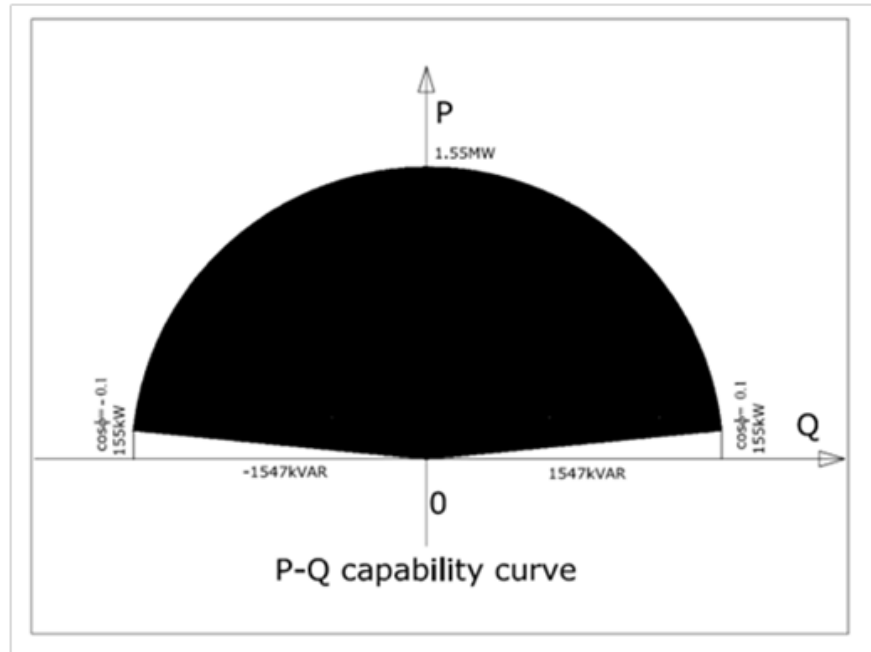
Single-Phase Generators - For single-phase Generators connected to a shared single-phase secondary system, the maximum Net Nameplate Rating of the Generating Facilities shall be 20 kVA. Generators connected to a center-tapped neutral 240-volt service must be installed such that no more than 6 kVA of imbalanced power is applied to the two "legs" of the 240-volt service. For Dedicated Distribution Transformer services, the maximum Net Nameplate Rating of a single-phase Generating Facility shall be the transformer nameplate rating.

3.5 *Inverter Specifications*

Reactive Power - The inverter shall be capable of operating in the following reactive power modes:

- Dynamic power factor: Inverter shall be capable of operating dynamically at a minimum power factor range of +/- .85 PF for larger systems (>15 kW), +/- 0.90 PF for smaller systems (\leq 15 kW), and a preferred power factor range of +/- 0.10 PF. Figure 4 below illustrates the preferred power factor range of +/- 0.10 PF.

Figure 4: P-Q Capability Curve

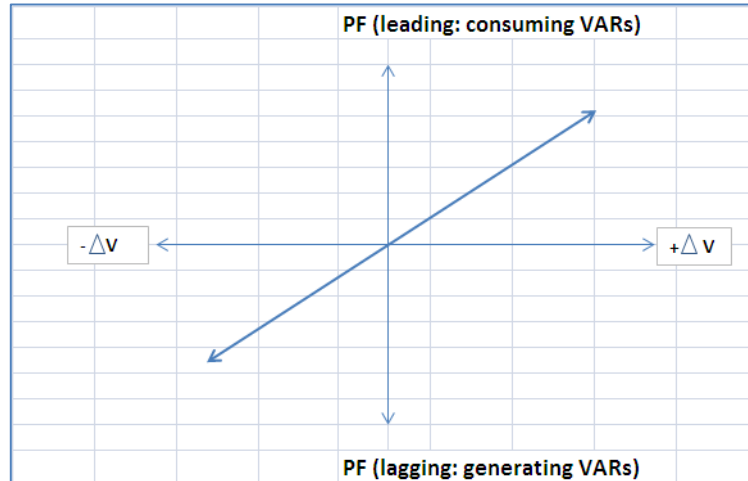


- Dynamic VAR output or input:
 - Inverter shall autonomously prevent line voltage changes from exceeding 2% at the point of common coupling (PCC) due to a loss of generation, or due to an increase in generation output. Inverter output shall not cause the line voltage at the point of common coupling to go outside the requirements of the latest version of ANSI C84.1, Range A.
 - Dynamic VAR output/input function shall not operate within a total deadband of 2% (i.e. a range of +/-1%) of line voltage at the PCC.
- Autonomous operations described above may be superseded by an external signal issued by distribution system operator.

The reactive power output of the inverter must be dynamic and adjustable. It must be possible to provide the prescribed reactive power compensation within the following time constraints:

- Within 10 seconds if reactive power setting is prescribed by autonomous control
- Within 5 seconds if reactive power setting is prescribed by external signal which will supersede autonomous settings.
- No change in reactive compensation shall occur unless the voltage changes outside the deadband range of 2% (+/-1%)

The inverter shall consume reactive power in response to an increase in line voltage, and generate reactive power in response to a decrease in line voltage. An example of the desired correlation between reactive power output and changes in line voltage is shown below.

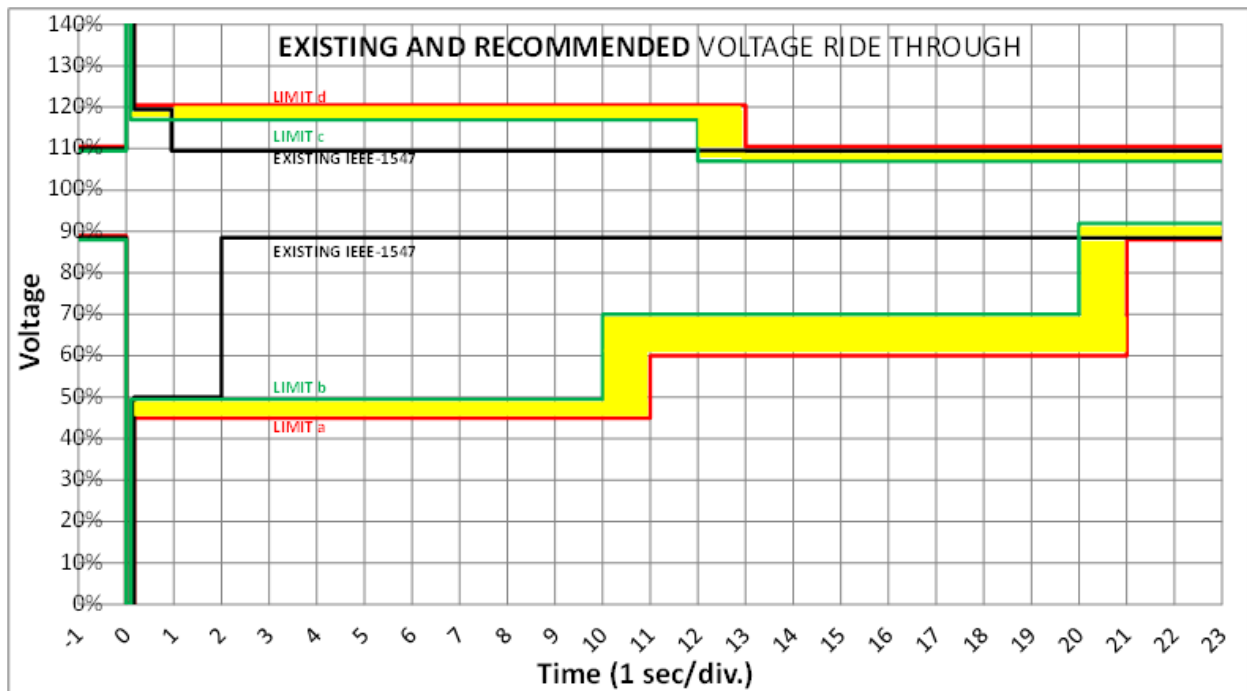


Low Voltage Ride-Through:

Inverters shall stay connected to the electric grid, and shall disconnect from the electric grid during a high or low voltage event, in compliance with the parameters shown in the following table and graph:

Table 4: Low Voltage Ride-Through Percent of Nominal

Voltage Level	Stay Connected Until	Voltage level	Disconnect by
>1.17	0.1 sec	>1.2	0.16
1.07-1.17	12 sec.	1.1 - 1.2	13 sec
0.92-1.07	Indefinite	0.6 – 0.88	21 sec
0.7 – 0.92	20 sec	0.45 – 0.6	11 sec
0.5 – 0.7	10 sec	0 – 0.45	0.16 sec
0 – 0.5	0.1 sec		



Randomization of Inverter Disconnect and Reconnect

If voltage limits are exceeded and inverter disconnection is imminent, disconnection shall employ timing randomization so that multiple inverters do not disconnect simultaneously for the same system voltage disturbance. And after such disconnection, inverters shall reconnect using timing randomization to avoid multiple inverters connecting simultaneously after a system disturbance. The randomization of timing for disconnection and reconnection scenarios shall be:

- **Disconnection:** If voltage limits are exceeded, inverters shall disconnect at a random time during a window of an additional 0 to 10% beyond the elapsed time from initial fault.
- **Reconnection:** After an inverter has disconnected due to a system disturbance, it will reconnect at a random time during a window of an additional 0 to 10 seconds beyond the earliest allowable reconnection time.

Extended Frequency Ride-Through:

Inverters shall accommodate, at a minimum, underfrequency and overfrequency operation in compliance with the WECC Off Nominal Frequency Load Shedding Plan, as provided in the table below. In general the inverter would not trip off line at any frequency greater than 57 Hz or less than 60.3 Hz.

WECC Off Nominal Frequency Load Shedding Limits

Underfrequency Limit	Overfrequency Limit	Minimum Time*
>59.4 Hz	< 60.6 Hz	N/A (continuous operation)
≤59.4 Hz	≥60.6 Hz	3 minutes
≤58.4 Hz	≥61.6 Hz	30 seconds
≤57.8 Hz		7.5 seconds
≤57.3 Hz		45 cycles
≤57.0 Hz	≥61.7 Hz	Instantaneous trip

* Minimum Time is the time the inverter should stay interconnected with the PV generator power being supplied to the grid.

Communications:

Inverters will have communications capabilities and security control mechanism that will comply with all applicable System Requirements (SRs) of standard ISA 99.03.03 for Security for Industrial Automation and Control Systems: System Security Requirements and Security Assurance Levels, Draft 2, Edit 30, published September 2010. It is also desirable (but not required) that the inverter and its associated computing components shall be ISA-099 certified/accredited.

3.6 Supplemental Generating Facility Requirements

Fault Detection - A Generating Facility with an SCCR exceeding 0.1 or one that does not cease to energize SDG&E’s Distribution System within two seconds of the formation of an Unintended Island shall be equipped with protective functions designed to detect Distribution System faults, both line-to-line and line-to-ground, and shall cease to energize SDG&E’s Distribution System within two seconds of the initiation of a fault.

Transfer Trip - For a Generating Facility that cannot detect Distribution System faults (both line-to-line and line-to-ground) or the formation of an Unintended Island, the facility must cease to energize SDG&E's Distribution System within two seconds. SDG&E may require a Transfer Trip system or an equivalent Protective Function.

Reclose Blocking - Where the aggregate Generating Facility capacity exceeds 15% of the maximum rating of any automatic reclosing device, SDG&E may require additional protective functions, including, but not limited to, reclose-blocking on some of the automatic reclosing devices.

4 Operating Requirements

4.1 Generator Step-up Transformer

The available voltage taps of a Generating Unit's step-up transformer must be reviewed by SDG&E for their suitability with SDG&E's system. The Generator is to request this review before acquiring the transformer.

SDG&E shall determine which voltage taps would be suitable for a step-up transformer for the Generator's proposed project. Suitable taps are required to give the transformer the essential capacity for the generator to:

- Deliver maximum reactive power to SDG&E's system at the point of interconnection (generator operating at 90 percent lagging power factor) and,
- Absorb maximum reactive power from SDG&E's system (generator operating at 95 percent leading power factor).

The Generating Unit's transformer, with correct voltage taps, helps maintain a specified voltage profile on SDG&E's system for varying operating conditions. Actual voltage tap settings can be different for transformers connected at the same voltage level, depending upon their geographic location.

4.2 Power Quality Requirements

Voltage Fluctuation Limits - A generator connected to the SDG&E system must not cause harmful voltage fluctuations or interference with service and communication facilities. Any generating facility that does so is subject to being disconnected from the SDG&E system until the condition has been corrected.

Harmonics Limits - All generators shall comply with the voltage and current harmonic limits specified in IEEE Standard 519-1992, "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems".

- The harmonic content of the voltage and current waveforms in the SDG&E system must be restricted to levels which do not cause interference or equipment-operating problems for SDG&E or its customers.
- Many methods may be used to restrict harmonics. The preferred method is to install a transformer with at least one delta connection between the generator and the SDG&E system. This method significantly limits the amount of voltage and current harmonics entering the SDG&E system. Generation system configuration with a wye-grounded generator and a two-winding (both wye-grounded) transformer shall not be allowed.
- When the Generating Facility is serving balanced linear loads, harmonic current injection into SDG&E's Distribution System at the PCC shall not exceed the limits stated in Table 3 shown in Section 3.3 of this handbook. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in SDG&E's Distribution System

without the Generating Facility connected (IEEE 1547-4.3.3). The harmonic distortion of a Generating Facility located at a Customer's site shall be evaluated using the same criteria as for the Host Loads.

4.3 *Under-frequency Operation*

SDG&E controls system frequency, and the Generating Facility shall operate in synchronism with SDG&E's Distribution System. Whenever SDG&E's Distribution System frequency at the PCC varies from and remains outside of the normal (nominally 60 Hz) by the predetermined amounts set forth in Table 2 shown in Section 3.3, the Generating Facility's Protective Functions shall cease to energize SDG&E's Distribution System within the stated maximum trip time.

5 Operating Procedures

5.1 CVR Standards

In 1977, the CPUC mandated the Conservation Voltage Reduction (CVR) standards. Approximately 95% of SDG&E substations are CVR and the remaining are NON-CVR. For CVR substations, the voltage maximum limit is 12.3kV and the adjustable voltage range shall be 11.9kV to 12.3kV. For NON-CVR substations, the voltage maximum limit is 12.6kV and the adjustable voltage range shall be 12.1kV to 12.6kV. The specific voltage set point will be provided to the interconnect customer after completion of load flow modeling with the generator on the distribution circuit.

5.2 Voltage Control Operation and Other Service Requirements

The Generating facility operator shall operate any voltage control (i.e., generator controls, shunt capacitors) at the direction of the SDG&E Designated Control Center and in accordance with applicable provisions of applicable agreements, applicable tariff(s), CAISO requirements if required and other electric service schedules. The facility operator shall insure the orders are understood and passed on to subsequent shift operator as appropriate to insure that any relief or backup operator is aware of the current SDG&E voltage instruction. The Generator is responsible for the safe operation and interruption and de-energization of the customer-owned voltage control devices when required.

Whenever primary relays or protective devices are out of service, backup or secondary relays must be available to clear faults. When restoring any relays that have been out of service, the Generator's designated representative shall verify that the contacts of any such relays, which are normally open, are in fact open. The Generator must ensure that relays do not have standing trip output.

5.3 Unusual or System Emergency Conditions

SDG&E is responsible for complying with all directions from the CAISO regarding management and alleviation of the System Emergency, unless such compliance would impair the Health and Safety of personnel or the general public. As directed by the CAISO, SDG&E will be responsible for communicating with Generating Facilities regarding emergencies. Unusual operating conditions or other factors that have affected or may affect SDG&E's electric system (e.g., abnormal voltages or loading or unbalanced loading) must be reported to the SDG&E Designated Control Center as soon as possible. Conditions imperiling life or property shall be reported to the SDG&E Designated Control Center immediately.

6 Energization and Synchronization Requirements

6.1 Purpose

The following is SDG&E's procedure for performing pre-parallel inspections and preparing to energize and synchronize the generator to SDG&E's Distribution System. All time requirements must be met for SDG&E to provide the Generating Units with timely service.

Any inspections required by local government agencies must be completed and permits signed off prior to the pre-parallel date. Failure to meet the succeeding requirements within the timeframes specified may result in a delay to successful operations parallel to the SDG&E system.

6.2 Design Review and Interconnection Facilities Inspection

SDG&E shall have the right to review the design of an Owner/Operator's Generating and Interconnection Facilities and to inspect an Owner/Operator's Generating and/or Interconnection Facilities prior to the commencement of Parallel Operation with SDG&E's Distribution System. SDG&E may require an Owner/Operator to make modifications as necessary to comply with the requirements of this Handbook. SDG&E's review and authorization for Parallel Operation shall not be construed as confirming or endorsing the Owner/Operator's design, nor as warranting the Generating and/or Interconnection Facility's safety, durability or reliability. SDG&E shall not, by reason of such review or lack of review, be responsible for the strength, adequacy, or capacity of such equipment.

6.3 Pre-parallel Testing

Commissioning Testing, where required, will be performed on-site to verify protective settings and functionality. Upon initial Parallel Operation of a Generating Facility, or any time interface hardware or software is changed that may affect the functions listed below, a Commissioning Test must be performed. An individual qualified in testing protective equipment (professional engineer, factory-certified technician, or licensed electrician with experience in testing protective equipment) must perform Commissioning Testing in accordance with the manufacturer's recommended test procedure to verify the settings and requirements per this handbook.

SDG&E may require that a written commissioning test procedure be submitted at least 10 working days prior to the performance of the commissioning test. SDG&E has the right to witness Commissioning Tests. SDG&E may also require written Certification by the installer describing which tests were performed and their results. Protective Functions to be tested during commissioning, particularly with respect to non-Certified Equipment, may consist of the following:

- Over and under voltage
- Over and under frequency

- Anti-Islanding Function (if applicable)
- Non-Export Function (if applicable)
- Inability to energize dead line
- Time delay on restart after utility source is stable
- Utility system fault detection (if used)
- Synchronizing controls (if applicable)
- Other Interconnection Protective Functions that may be required as part of the Interconnection Agreement

Commissioning Test shall include visual inspections of the interconnection equipment and protective settings to confirm compliance with the interconnection requirements.

Other checks and tests that may need to be performed include:

- Verifying final Protective Function settings
- Trip test
- In-service test

6.3.1 Certified Equipment

Generating Facilities qualifying for Simplified Interconnection must incorporate Certified Equipment that has, at a minimum, passed the Type Tests and Production Tests described in this handbook and are judged to have little or no potential impact on SDG&E's Distribution System. For such Generating Facilities, it is necessary to perform the following tests:

- 1) Protective function settings that have been changed after Production Testing will require field verification. Tests shall be performed using injected secondary frequencies, voltages and currents, applied waveforms, a test connection using a Generator to simulate abnormal utility voltage or frequency, or varying the set points to show that the device trips at the measured (actual) utility voltage or frequency.
- 2) The Non-Islanding Function will be checked by operating a load break disconnect switch to verify the Interconnection equipment ceases to energize SDG&E's Distribution System and does not re-energize it for the required time delay after the switch is closed.
- 3) The Non-Exporting Function shall be checked using secondary injection techniques. This function may also be tested by adjusting the Generating

Facility output and local loads to verify that the applicable Non-Exporting criteria (i.e., reverse power or under power) are met.

The Supplemental Review or an Interconnection Study may impose additional components or additional testing.

6.3.2 Non-Certified Equipment

Non-Certified Equipment shall be subjected to the appropriate tests described in Rule 21 under Type Testing (Section J.3.) as well as those described in Certified Equipment Commissioning Tests (Section J.5.c.). With SDG&E's approval, these tests may be performed in the factory, in the field as part of commissioning, or a combination of both. SDG&E, at its discretion, may also approve a reduced set of tests for a particular Generating Facility or, for example, if it determines it has sufficient experience with the equipment.

6.3.3 Verification of Settings

At the completion of Commissioning testing, the Owner/Operator shall confirm all devices are set to SDG&E-approved settings. Verification shall be documented in the Commissioning Test Certification.

6.4 Requirements for Commercial (Parallel) Operation

An Owner/Operator's Generating Facility and Interconnection Facilities shall be reasonably accessible to SDG&E personnel as necessary for SDG&E to perform its duties and exercise its rights under its tariffs approved by the Commission, and any Interconnection Agreement between SDG&E and the Owner/Operator.

An Owner/Operator shall operate and maintain its Generating Facility and Interconnection Facilities in accordance with Prudent Electrical Practices and shall maintain compliance with this Handbook.

SDG&E may limit the operation, disconnect, or require the disconnection of an Owner/Operator's Generating Facility from SDG&E's Distribution System at any time, with or without notice, in the event of an Emergency, or to correct Unsafe Operating Conditions. SDG&E may also limit the operation, disconnect, or require the disconnection of an Owner/Operator's Generating Facility from SDG&E's Distribution System upon the provision of reasonable written notice: 1) to allow for routine maintenance, repairs or modifications to SDG&E's Distribution System; 2) upon SDG&E's determination that a Owner/Operator's Generating Facility is not in compliance with this Handbook and any applicable tariffs or rules that apply to the interconnection; or 3) upon termination of the Interconnection Agreement. Upon the Owner/Operator's written request, SDG&E shall provide a written explanation of the reason for such curtailment or disconnection.

6.4.1 Trip Tests

Interconnection Protective Functions and devices (e.g., reverse power relays) that have not previously been tested as part of the Interconnection Facilities with their associated interrupting devices (e.g. contactor or circuit breaker) shall be trip tested during commissioning. The trip test shall be adequate to prove that the associated interrupting devices open when the protective devices operate. Interlocking circuits between Protective Function devices or between interrupting devices shall be similarly tested unless they are part of a system that has been tested and approved during manufacturing.

6.4.2 In-service Tests

Interconnection Protective Functions and devices that have not previously been tested as part of the Interconnection Facilities with their associated instrument transformers or that are wired in the field shall be given an in-service test during commissioning. This test will verify proper wiring, polarity, CT/PT ratios, and proper operation of the measuring circuits. The in-service test shall be made with the power system energized and carrying a known level of current. A measurement of the magnitude and phase angle of each Alternating Current (AC) voltage and current connected to the protective device shall be made and the results shall be compared to expected values. For protective devices with built-in Metering Functions that report current and voltage magnitudes and phase angles, or magnitudes of current, voltage, and real and reactive power, the metered values may be used for in-service testing. Otherwise, portable ammeters, voltmeters, and phase-angle meters shall be used.

6.4.3 Periodic Testing

Periodic Testing of Interconnection-related Protective Functions shall be performed as specified by the manufacturer, or at least every four years. All periodic tests prescribed by the manufacturer shall be performed. The Owner/Operator shall maintain periodic test reports or a log for inspection by SDG&E. Periodic Testing conforming to SDG&E test intervals for the particular Line Section may be specified by SDG&E under special circumstances, such as high fire hazard areas. Batteries used to activate any Protective Function shall be checked and logged once per month for proper voltage. Once every four years, these batteries must be replaced or a discharge test must be performed.

7 Attachments

7.1 Tariffs

SDG&E offers open access, wholesale distribution service to eligible customers, under the rates, terms and conditions set forth by the CPUC, California Public Utilities Commission. Below is the link to the SDG&E Wholesale Distribution Open Access Tariff (WDAT) outlining integration of Distribution SGIP, Small Generator Interconnection Procedures, and Distribution LGIP, Large Generator Interconnection Procedures, to the WDAT.

<http://www.sdge.com/rates-regulations/tariff-information/open-access-ferc-tariffs>

7.2 Interconnection Applications

For an interconnection to the distribution system for a project that *does not* intend to resell the power generated back to the market, a Rule 21 Interconnection Application is required to be completed and issued to SDG&E. Upon receipt of the application, SDG&E will review the request as outlined in Rule 21. Below is an internet link to the application document and other information about interconnection.

<http://www.sdge.com/rates-regulations/tariff-information/open-access-ferc-tariffs>

For an interconnection to the distribution system that intends to resell the power generated back to the market and the project is no larger than 20 MW in size, a Small Generation Interconnection Procedures (SGIP) Interconnection Application from SDG&E's Wholesale Distribution Open Access Tariff (WDAT) is required to be completed and submitted to SDG&E. Upon receipt of the application, SDG&E will review the request as outlined in the SGIP WDAT tariff.

For an interconnection to the distribution system for a project that intends to resell the power generated back to the market and is larger than 20 MW in size, a Large Generation Interconnection Procedures (LGIP) Interconnection Application from SDG&E's Wholesale Distribution Open Access Tariff (WDAT) is required to be completed and submitted to SDG&E. Upon receipt of the application, SDG&E will review the request as outlined in the LGIP WDAT tariff.

Below, and as shown in section 7.1, is an internet link that contains the WDAT application documents and summaries as well as other information about generation interconnections to SDG&E's system.

<http://www.sdge.com/rates-regulations/tariff-information/open-access-ferc-tariffs>