

San Diego Gas & Electric Company Generation Interconnection Handbook

For Generators Interconnecting to SDG&E-Owned Transmission Facilities¹

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¹ For generators interconnecting to SDG&E-owned Distribution Facilities, please refer to the Distribution Generator Interconnection Handbook

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SECTION 1

METERING REQUIREMENTS

FOR GENERATING UNITS INTERCONNECTING TO THE SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE:

This section specifies the metering requirements for Generating Units interconnecting to SDG&E-owned transmission facilities.

APPLICABILITY:

All wholesale generators (generators who make sales for resale) connected to SDG&E-owned transmission facilities must meet both SDG&E and California Independent System Operator (CAISO) metering requirements. SDG&E metering is required for retail standby service. All other generators (not providing wholesale service) must meet SDG&E's retail metering requirements. Furthermore, all generators 1 MW and above must meet all applicable Western Electricity Coordinating Council (WECC) metering standards.

1.1 BASIC METERING REQUIREMENTS

SDG&E meter(s) shall be installed to measure auxiliary load per SDG&E metering standards and requirements.

For each generator, or bank of generators, one CAISO meter shall be installed to measure net generation and, in addition, CAISO meter(s) shall be installed to measure other quantities required by the CAISO per CAISO metering standards and requirements (e.g. auxiliary load, generator output).

The CAISO meter type(s) shall be specified by the CAISO and shall meet CAISO metering standards and requirements.

1.2 LOCATION OF METERING

It is preferred that the auxiliary load metering instrument transformers are located on the transmission side of the facility. The alternative is to place the auxiliary load metering instrument transformers on the low voltage side of the main Generating Facility transformer bank. If located on the low voltage side of the main Generating Facility transformer bank the Generation Facility Developer shall provide certified transformer test reports that indicate transformer losses, used to program the meter(s) which will account for transformer losses. No metering instrument transformers (used for SDG&E metering purposes) shall be located behind any other transformers other than the main Generating Facility transformer bank.

The Developer shall provide the transmission line section parameters that will be required and used to program the meter(s) to account for losses associated with the Interconnection Customer's (IC) transmission line.

The preferred and typically most cost effective method of metering the Generating Facility is to utilize one set of instrument transformers for both the CAISO meter and SDG&E meter where the SDG&E meter also serves to measure auxiliary load, i.e. bi-directional metering. Specialized extended range Current Transformers (CT's) are required for this type of installation. Refer to Section 1.5, Instrument Transformers, for extended range CT requirements. If the high voltage side facility circuit breaker is on the SDG&E service side of the metering CT's and Potential Transformers (PT's), a separate set of dry contacts must be provided to each SDG&E meter whose open/close status indicates whether the facility is energized. See Figure 1 for a typical layout utilizing this arrangement type.

The alternative method of metering the Generating Facility is to utilize one set of instrument transformers for the CAISO meter and SDG&E meter and one, or up to a maximum of two, SDG&E metering points to measure auxiliary load. At each auxiliary load metering point the CT/PT enclosure, meter panel, pull section, disconnect switches, etc. shall meet all SDG&E service standards and requirements. If the high voltage side facility circuit breaker is on the SDG&E service side of the metering CT's/PT's used for net generation metering, a set of dry contacts must be provided to each auxiliary load meter whose open/close status indicates if the facility is energized. In addition, a set of dry contacts must be supplied to each SDG&E auxiliary load meter indicating whether the generator output breaker is in the closed or open position. Given this metering configuration, the meter assumes that when the generator output breaker is closed, the generator is operating, and auxiliary load is being provided to the generating facility. See Figure 2 for a typical layout utilizing this arrangement type.

1.3 METERING SPECIFICS

SDG&E and CAISO meters will be form 9, class 20 meters per American National Standards Institute (ANSI) C12 standards. The CAISO meters shall meet all CAISO standards and requirements.

Each meter shall utilize its own dedicated test switch. SDG&E will supply a test switch for each SDG&E meter.

A suitably sized cabinet or wall plate shall contain the SDG&E meter(s). Refer to Figure 3 for the typical metering layout indicated and Figure 4 and 5 for the dimensions of SDG&E metering equipment.

The metering cabinet or wall plate shall have a ground strap or suitably sized copper wire connected to ground. In addition, for metering cabinets with doors, the doors shall have a ground strap or suitably sized copper wire connecting the ground of the cabinet to the door.

If a wall plate is utilized to affix metering equipment, its material shall be aluminum and braced by uni-strut, i.e. not mounted directly to a wall. Wall plates and cabinet back-plates used to affix metering equipment shall accommodate sheet metal screws of at least ½" length for use in attaching the metering equipment.

National Electrical Manufacturer Association (NEMA) 3R type (or a higher rated NEMA water-tightness rating) enclosures shall be used for outside metering installations.

All SDG&E-owned meters (i.e. CAISO back-up and/or auxiliary load meters) shall require an uninterruptible 120VAC or 125VDC power supply (UPS) to keep them energized in the event the facility has an outage. A separately fused position or breaker position from the uninterruptible power supply shall be provided to each SDG&E meter.

Each SDG&E meter shall be provided a separate set of dry A-finger contacts that indicate the open/close status of the main facility circuit breaker. The exception is if the metering PT's/CT's are on the SDG&E supply side of the of the main facility circuit breaker then the SDG&E meter doesn't require this interface.

The uninterruptible power supply wiring shall terminate to a terminal strip in the metering cabinet or on the wall plate. This terminal strip may be the same as that used for the PT and CT secondary leads. A separate terminal strip shall be installed to accommodate the main breaker A-finger contact wires.

A standard 120VAC receptacle, heater strip and a light with a switch shall be provided and installed in outdoor metering cabinets.

1.4 METER COMMUNICATIONS

SDG&E shall supply a wireless communications module that will be used to support data transfer from the meter to SDG&E's meter data storage center. Refer to Figure 5 for the dimensions of the wireless communications module. SDG&E shall also supply the associated wireless module antenna that will be mounted outside with a clear line of sight to receive/transmit a cellular signal.

The Developer shall provide an open area close to the meter for the wireless communications module to be mounted and a path to route communication wiring between the wireless communications module and the SDG&E meter. The Developer shall consult with SDG&E to determine the most suitable location for the wireless communications module.

The Developer shall supply a 120VAC source to provide power to the wireless communications module or, if the meter is in close proximity to the wireless device, the supplied 120VAC UPS source to the meter can be shared with the wireless communications module with the UPS source split by two fused disconnects. The wireless module cannot be supplied with a DC power source. With outdoor metering cabinets, the 120VAC receptacle can be used to power the wireless module.

The Developer shall be responsible for mounting the wireless module antenna in a suitable location (typically on the roof of a control house) and routing the antenna cord between the wireless communication module and the antenna. The Developer shall consult with SDG&E to determine the most suitable location for the antenna. In the event that there is inadequate cellular coverage at the facility, an activated dial-up phone line shall be provided to each SDG&E meter by the Developer.

1.5 INSTRUMENT TRANSFORMERS

The metering PT's and CT's shall be 0.3% ANSI accuracy class, or higher, metering devices. If the instrument transformers used for auxiliary load metering are located on the transmission side of the facility, special extended range CT's are required, i.e. guaranteed and tested to accurately measure current down to at least 0.5% of CT rating.

The metering unit CT's shall have a minimum B-1.8 ANSI burden rating and the PT's shall have a minimum Z rated ANSI burden.

The metering CT's shall be sized in accordance to good metering practices and shall always be within meter accuracy class range during generation cycles and/or auxiliary load cycles.

If the alternative method of metering auxiliary power is utilized (i.e. metering auxiliary load on the low voltage side of the main Generator Facility transformer bank in addition to metering at the net-generation point), the CT/PT enclosure, meter panel, pull section, disconnect switches, etc. at each auxiliary load metering point shall meet all SDG&E service standards and requirements. These standards and requirements are referenced in SDG&E's Service Standards and Guide (Sections 670 and 680) and are available upon request.

Associated PT's and CT's shall be located electrically at the same location. No appreciable capacitance, inductance, or resistance shall be located between the devices.

Disconnect switches shall be located on both sides of transmission level metering PT's and CT's. It is permissible to locate the main breaker between one of these disconnect switches and the metering PT's and CT's.

Generally, all transmission voltage-level metering CT's and PT's shall be freestanding. Any exceptions must be reviewed and approved by SDG&E.

The primary side of the metering units shall not be fused and shall not have any sort of switch or disconnect capable of de-energizing the metering units without de-energizing the circuit being metered.

There should be no means or possibility of by-passing metering CT's except by use of temporary high voltage jumpers.

No unmetered auxiliary load is permissible on the source side of the SDG&E metering. PT's (or CCVT's) used for protection, monitoring and/or synching purposes may be located upstream of the SDG&E metering with the condition that no appreciable load will be drawn from it. Under this circumstance, the Developer will provide SDG&E applicable specifications, drawings, and wiring diagrams for verification that the PT's (or CCVT's) will not draw any appreciable load.

The metering unit CT's and PT's shall be inductive type. CCVT types can only be used if SDG&E Meter Engineering reviews and approves the specific model and type.

Spare metering CT's and PT's shall either be stored on site or be installed redundantly.

All metering CT's shall be utilized for revenue metering, which includes SDG&E meter(s) and CAISO meter(s).

The PT voltage coils shall be utilized for revenue metering, which includes SDG&E meter(s) and CAISO meter(s). If the metering PT has a second set of coils, it may be used for protection, monitoring, and/or synching purposes with the condition that no appreciable load will be drawn from it. The Developer will provide SDG&E applicable specifications, drawings, and wiring diagrams for verification that the second set of PT voltage coils will not draw any appreciable load.

All CT and PT secondary leads shall be terminated to a termination strip located in or near the metering cabinet. This may be the same terminal strip required to terminate the UPS wires. A separate terminal strip is required for the main breaker status and/or generator output breaker leads if there is a breaker status going to the metering.

PT secondary fused disconnect switches must be installed in close proximity to the metering PT's. Each SDG&E meter shall have a dedicated fused disconnect switch that is readily accessible (i.e., no ladder required to access) and clearly labeled.

CT shorting blocks must be installed in close proximity to the metering CT's switch that is readily accessible (i.e., no ladder required to access) and clearly labeled. They will be available to isolate the CT's from all load-side (downstream) metering.

All CT secondary non-polarity leads shall be tied together and grounded as close to the CT's as practical. One common wire shall emerge from this point which extends to the appropriate position on the metering connection terminal strip. This is in addition to the 3 CT secondary polarity leads that also extend to the appropriate positions on the metering connection terminal strip next to each SDG&E meter.

All PT secondary non-polarity leads shall be tied together and grounded as close to the PT's as practical. One common wire shall emerge from this point which extends to the appropriate position on the metering connection terminal strip. This is in addition to the 3 PT secondary polarity leads that also extend to the appropriate positions on the metering connection terminal strip.

There shall only be one grounding point for the PT secondary neutral and CT secondary non-polarity wires. The PT secondary neutral and CT secondary non-polarity leads can connect to separate grounding points or a common grounding point.

CT and PT neutral common wires shall not be shared.

1.6 PROJECT ROLES AND RESPONSIBILITIES

The Developer shall procure the primary CAISO meter and manage/implement all aspects to program and install the CAISO primary meter per CAISO requirements and practices.

The Developer shall procure and manage/implement all aspects of the programming for, and installation of, ancillary CAISO meter equipment such as remote intelligent gateways (RIG), data processing gateways (DPG), routers, and cabling per CAISO requirements and practices.

The Developer shall provide to SDG&E Meter Engineering, in writing, projected load and generation information including projected maximum and minimum current levels, in-rush current, harmonic content level, load/generation profile and any other pertinent data.

The Developer shall provide to SDG&E Meter Engineering all preliminary meter related electrical and structural design drawings.

The Developer shall provide to SDG&E Meter Engineering all preliminary metering equipment specifications and attributes (i.e. CT secondary wire sizes, lengths, and calculated burden).

Only upon SDG&E Meter Engineering's approval of preliminary drawings and metering equipment specifications may final design drawings be issued for construction and metering equipment purchased by the Developer. The Developer shall provide to SDG&E Meter Engineering two copies each of the final design drawings, CT/PT test reports, other meter related equipment test reports/specifications, the main transformer test report (if applicable), and all other metering related information.

The Developer shall notify SDG&E Meter Engineering of any proposed upgrades or changes to the SDG&E meter or metering scheme, and SDG&E Meter Engineering shall be responsible for approval of any aforementioned upgrades or changes.

The Developer shall comply with all CAISO requirements and obtain all necessary CAISO approvals before the facility can begin generating power.

SDG&E Meter Electricians shall procure, wire and install the SDG&E meter(s), meter test switches, A-base adapters, and all equipment beyond a termination block located in or near the metering cabinet (or wall plate).

The installation of CAISO meters shall be performed by a certified CAISO meter installer.

Prior to initial generation testing, SDG&E must inspect, verify, and test all SDG&E meter-related wiring, connections, terminations, and metering PT's/CT's. The generating facility may not be energized until SDG&E has provided written notice that all metering components and wiring have been checked and verified as being acceptable by the SDG&E inspector.

The Developer shall accommodate and ensure that SDG&E meter personnel have unrestricted 24hr/7day access to the SDG&E meters, metering PT's/CT's, and associated wiring/terminations/enclosures. Locked doors and gates (which SDG&E personnel must pass through to access the SDG&E metering and associated equipment) shall be keyed with Schlage restricted Quad VQTP cylinders. A list of locksmiths that provide these cylinders for door locks, padlocks, and gate controllers is available upon request and is shown in SDG&E's Service Standards and Guide on page 005.1.

FIGURE 1
Typical Generation Metering Layout
(Preferred Method)

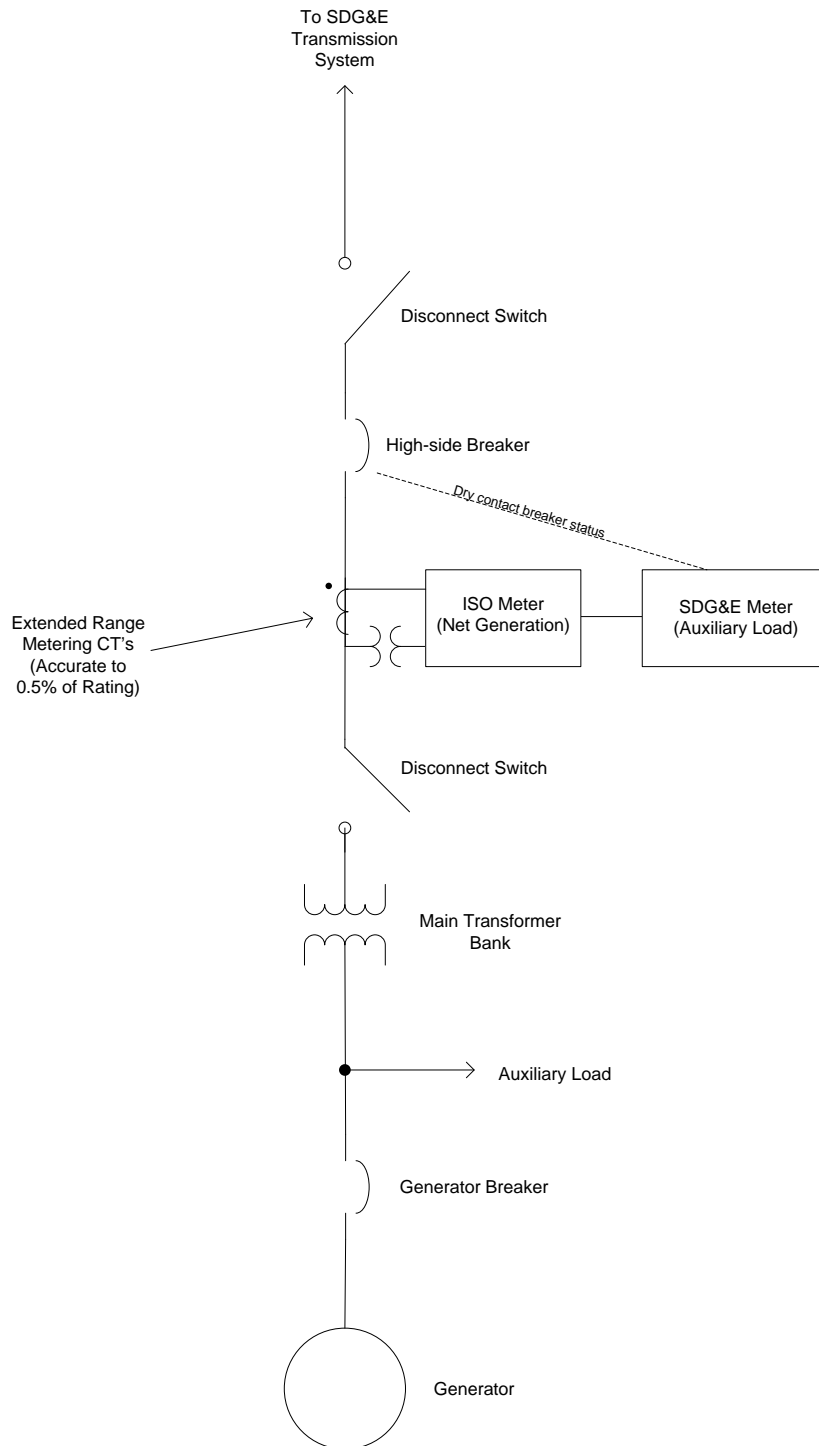


FIGURE 2 Typical Generation Metering Layout (Alternate Method)

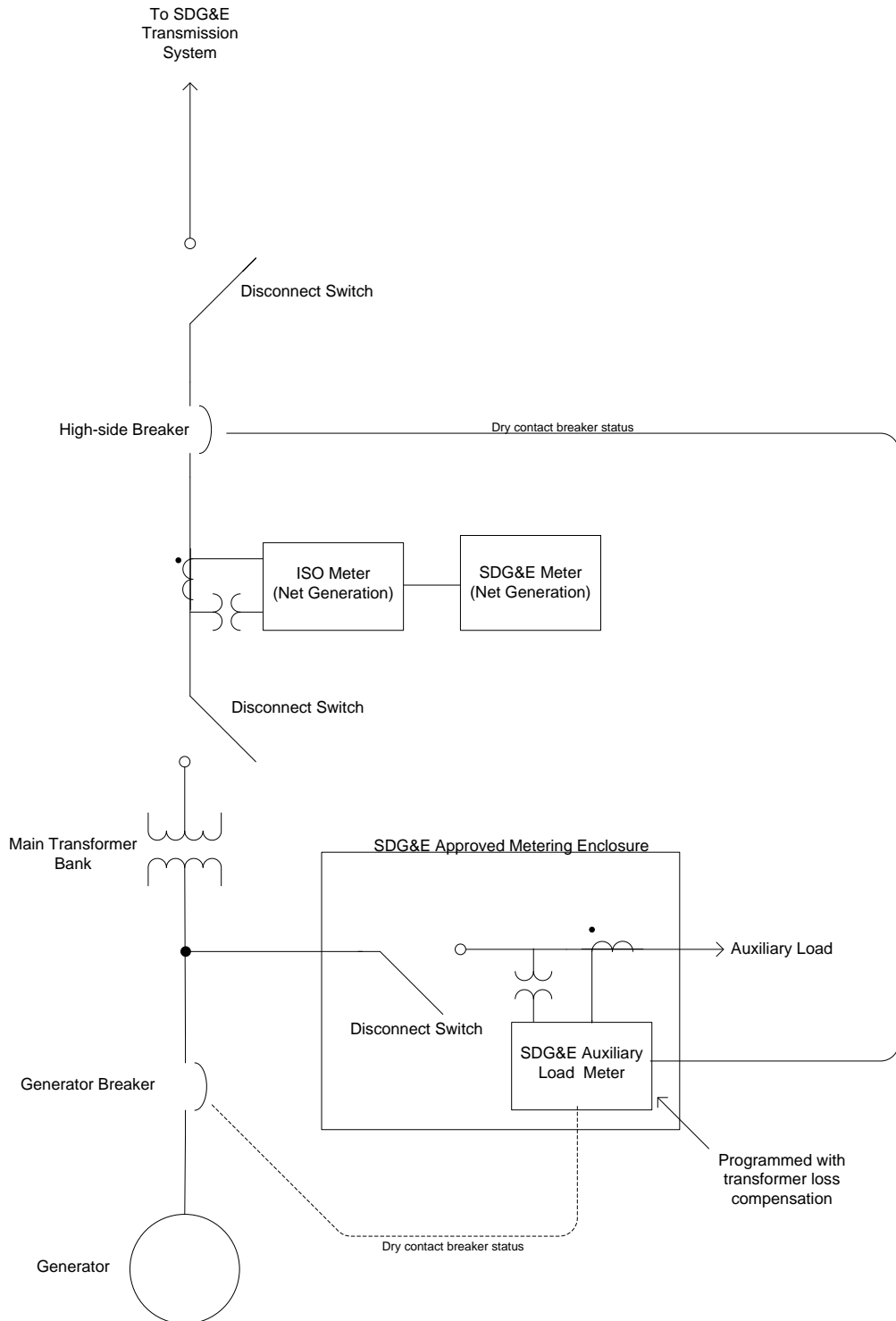


FIGURE 3
Typical Meter Layout
(Not to Scale)

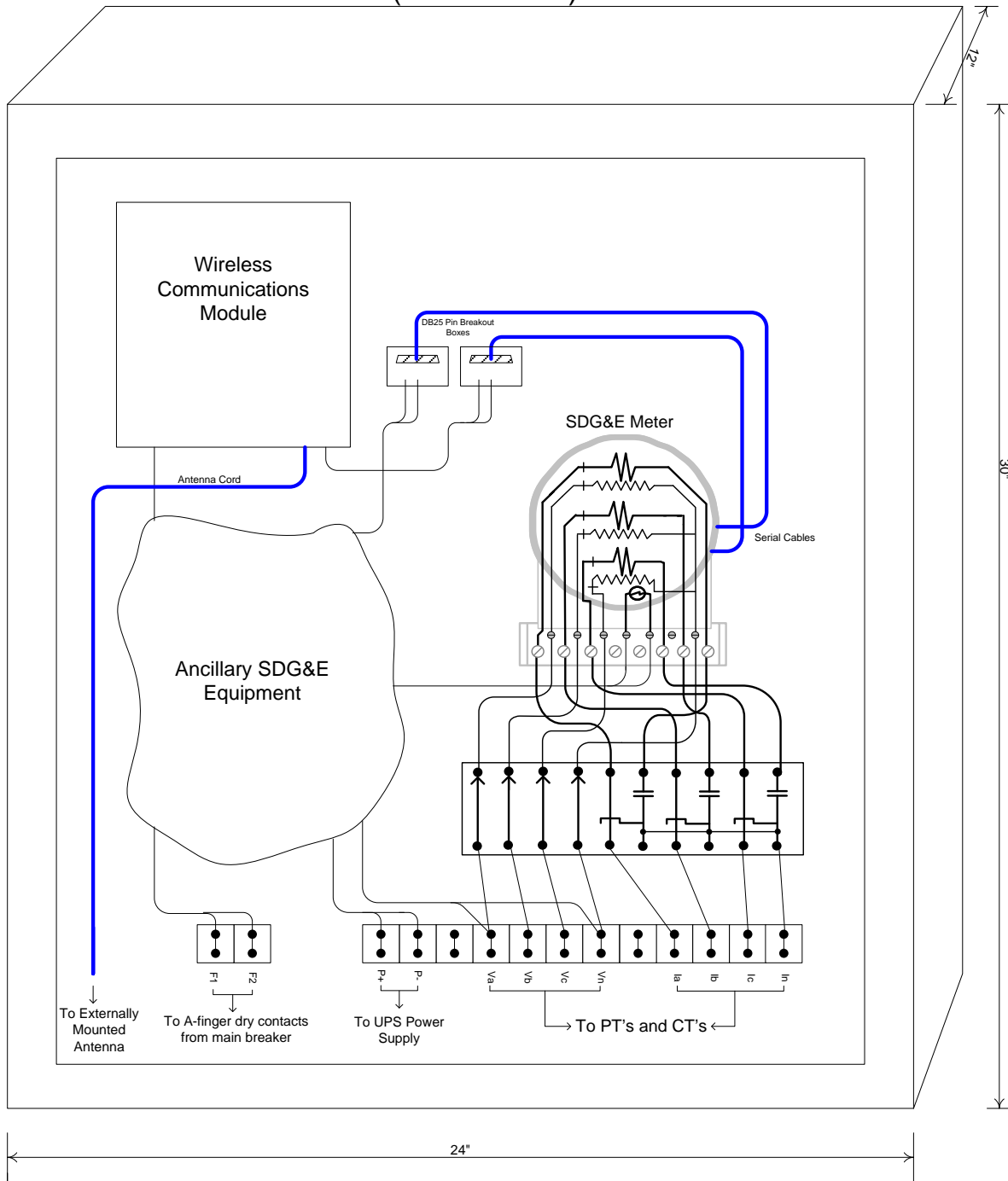


FIGURE 4
Dimensions of Metering Equipment
(Not to Scale)

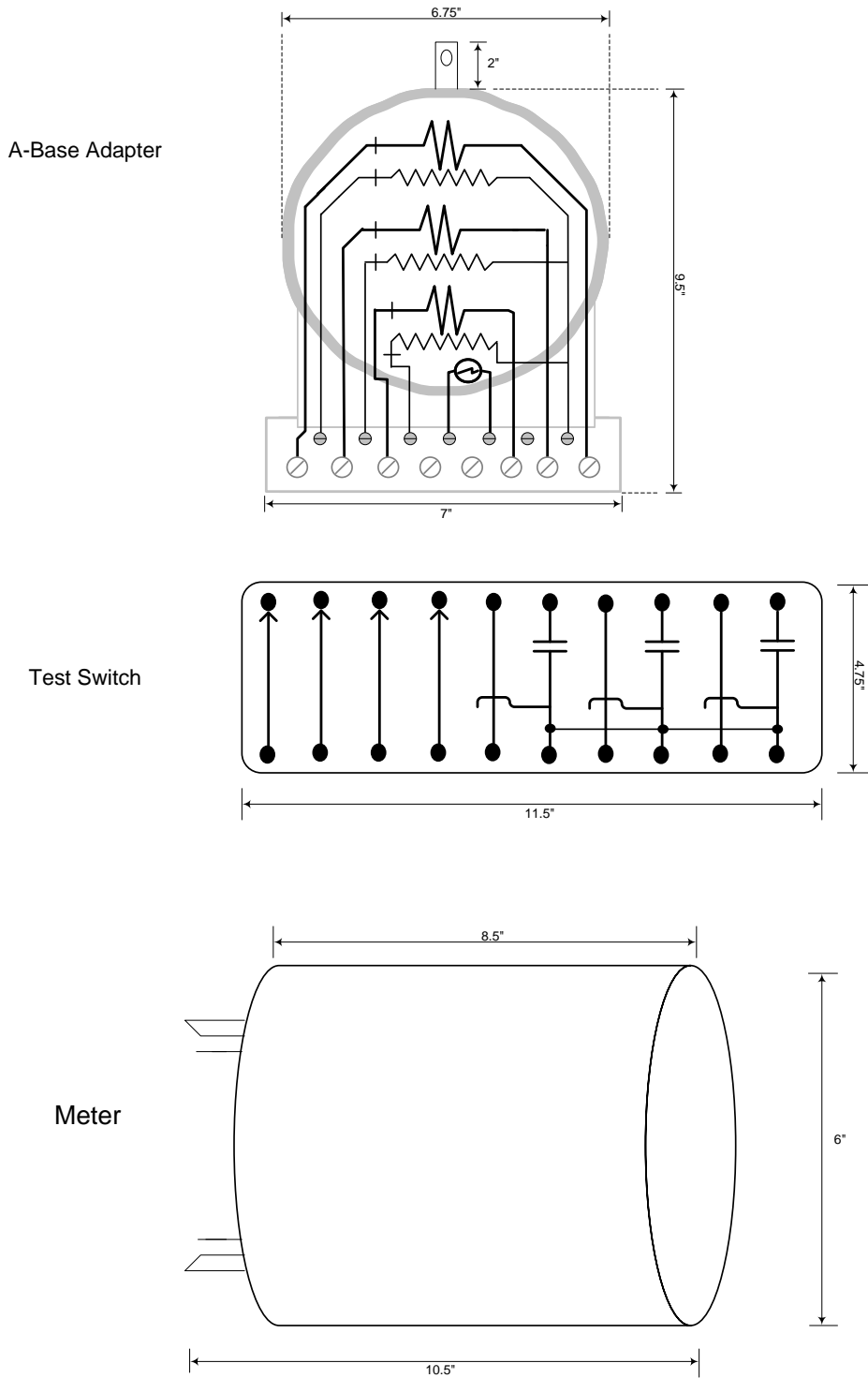
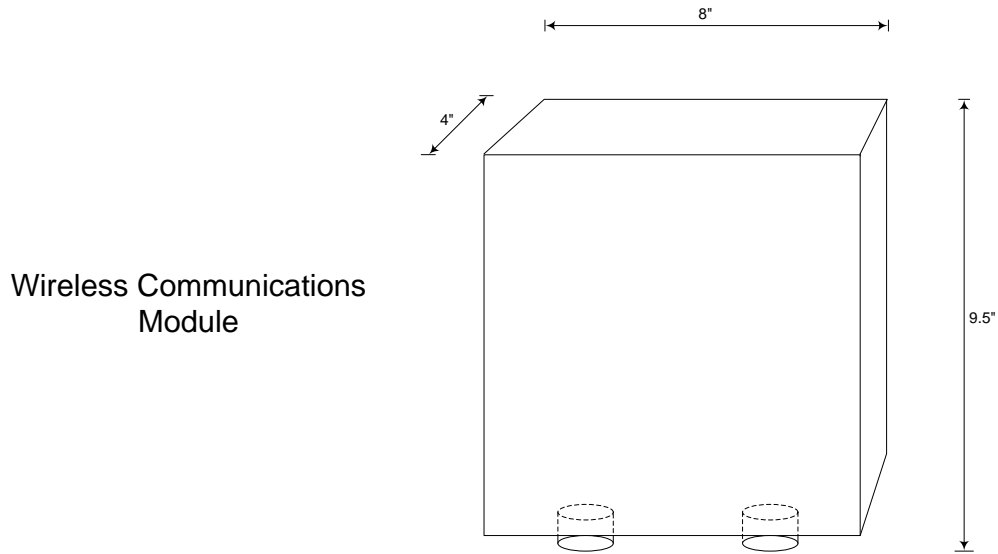


FIGURE 5
Dimensions of Metering Equipment
(Not to Scale)



SECTION 2

PROTECTION AND CONTROL REQUIREMENTS FOR GENERATING UNITS INTERCONNECTING TO SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE:

This section specifies the requirements for protective relays and control devices for Generating Units interconnecting to SDG&E-owned transmission facilities.

APPLICABILITY:

The applicable protective standards of this section apply to all Generating Units interconnecting to any portion of SDG&E-owned transmission facilities. These standards, which govern the design, construction, inspection and testing of protective devices, have been developed by SDG&E to be consistent with applicable regional reliability criteria and to include appropriate CAISO consultation. The CAISO, in consultation with SDG&E, may designate certain new or existing protective devices as CAISO Grid Critical Protective Systems. Such systems have special CAISO requirements, e.g., for installation and maintenance, as described in the CAISO Tariff Section 5 and the TCA Section 8.

In addition, for Generating Units connecting directly to a non SDG&E owned-transmission facility: The non-SDG&E-owned entity must coordinate with the CAISO, SDG&E (as the Transmission Owner), and the Generator, as needed, to ensure that any CAISO Controlled Grid Critical Protective Systems, including relay systems, are installed and maintained in order to function on a coordinated and complementary basis with the protective systems of the Generating Unit and the SDG&E power system in the accordance with the CAISO Tariff Section 4 and the CAISO-UDC Agreement, both available on the CAISO website (www.caiso.com).

2.1 PROTECTIVE RELAY REQUIREMENTS

An important objective in the interconnection facilities to the SDG&E Power System is minimizing the potential hazard to life and property. A primary safety requirement is the ability to disconnect immediately when a fault is detected.

The protection equipment for a Generating Facility must protect against faults within that facility, faults on the SDG&E Power Systems and on any nearby or intervening systems. A Generating Facility must also trip off-line (disconnect automatically) when power is disconnected from the line into which the unit generates.

Due to the high energy capacity of the transmission system, high-speed fault clearing may be required, to minimize equipment damage and potential impact to system stability. The requirement of high-speed fault clearing will be determined

by SDG&E on a case-by-case basis. Some protection requirements can be standardized; however, most line relaying depends on Generating Unit size and type, number of Generating Units, line characteristics (i.e. voltage, impedance, and ampacity), and the existing protection equipment connected to the SDG&E System.

SDG&E protection requirements are designed and intended to protect the SDG&E Power System only. As a general rule, neither party should depend on the other for the protection of its own equipment.

The Generator shall install at the Point of Interconnection, at a minimum, a disconnecting device or switch with generation interrupting capability. Additional protective relays are typically needed to protect Generator's facility adequately. It is the Generator's responsibility to protect its own system and equipment from faults or interruptions originating on both SDG&E's side and the Generator's side of the Interconnection. The Generator's system protection facilities shall be designed, operated, and maintained to isolate any fault or abnormality that would adversely affect the SDG&E Power System or the systems of other entities connected to the SDG&E Power System. The Generator shall, at its expense, install, operate, and maintain system protection facilities in accordance with applicable CAISO, WECC and North American Electric Reliability Corporation (NERC) requirements and in accordance with design and application requirements of this Generation Interconnection Handbook.

The protective relays used in isolating the Generating Facility from the SDG&E power system at the Point of Interconnection must be set to coordinate with the protective relays at the SDG&E line breaker terminals for the line on which the Generating Facility is connected. Additional requirements, as to the exact type and style of the protective devices, may be imposed on the Generator based on the proposed station configuration or the type of interrupting device closest to the point of common coupling to SDG&E's facility. **Note:** *There may be additional protective equipment requirements, at the Generator's cost, which SDG&E will coordinate with the Generator or its representatives.*

SDG&E recommends that the entity acquire the services of a qualified electrical engineer to review the electrical design of the proposed Generating Facility and ensure that it will be adequately protected.

Generally, fault-interrupting equipment should be located as close to the interconnection point as possible – typically within one span of overhead line or 200 feet of non-spliced underground cable.

The Generator should provide SDG&E with electrical drawings for review prior to equipment procurement. The drawings provided should consist of Single Line Meter and Relay Diagrams, schematic drawings detailing connectivity (3-Line AC (Alternating Current)) and tripping schemes (Direct Current (DC)) for all SDG&E

required relays. The Single Line Meter and Relay Diagrams listing the major protective equipment should be provided for review prior to ordering relays. The 3-Line AC and the DC schematics should be provided before fabricating relay panels. The following documents must be submitted by the Interconnection Customer for review by SDG&E's Systems Protection and Control Engineering Department (SPACE) before any agreements are executed: Single Line Diagram, Single Line Meter and Relay Diagrams.

The Generator must provide SDG&E with test reports for the particular types of protection devices, including verification of all protective functionality, before SDG&E will allow the facility to parallel. Where tele-protection is utilized, the communication circuits must be tested and the scheme operation functionally verified prior to release for commercial operation. The Generator must submit written test reports for qualified testing to SDG&E upon request by SDG&E, that demonstrate that the relays are operable and within calibration. SDG&E will not test the entity's equipment, but may witness the testing performed by a qualified testing firm retained by the entity.

On-site power (typically 120 volts) is required for the test equipment. Circuit breakers must be tested on a schedule consistent with the equipment manufacturer's instruction manual or Good Utility Practice after the pre-parallel inspection. It is also in the Generator's best interest to make sure all of its protective equipment is operating properly, since significant equipment damage and liability can result from failures of the entity's protective equipment.

2.2 RELIABILITY AND REDUNDANCY

The Generator shall design the protection system with sufficient redundancy that the failure of any one component will still permit the Generating Facility to be isolated in the required clearing time from the SDG&E power system under a fault condition. Multi-function three-phase protective relays used for line protection must have redundant relay(s) for backup. The required breakers must be trip tested by the Generator at least once a year.

2.3 RELAY GRADES

Only utility grade relays can be used for interconnection protection, and must meet the following specifications:

- The minimum and maximum operating temperatures are the range of -40° to 70° C.
- Must be certified to meet ANSI/IEEE (Institute of Electrical and Electronics Engineers, Inc.) C37.90 dielectric testing requirements.
- Must be certified to meet ANSI/IEEE 37.90.1 Surge Withstand Capability (SWC) and Fast Transient testing.
- Must be certified to meet Radio Frequency Interference (RFI) with stand capability in accordance with ANSI/IEEE C37.90.2.

- Must meet Power Frequency Magnetic Field Immunity (ANSI/IEEE 1308-1994 (R2001) and International Electrotechnical Commission (IEC) 61000-4-8).
- Must meet Underwriters Laboratory (UL) and Federal Communications Commission (FCC) test requirements as necessary.
- Must be certified for output contact Load Break Capability tests- through an inductive network (UL-1054, ANSI C37.90).
- Airborne Arcing Noise susceptibility (IEEE C62.41.2, C62.45 and IEEE 896.5).
- Must be certified for DC Hi-pot Test or Megger with no leakage or breakdown of the components (IEC 61000-4-11 and 60255-11).
- Electrostatic Discharge Immunity (ANSI/IEEE C37.90).
- Must be certified to meet IEC 60255-21-1 Class 1 Vibration test (sinusoidal) or equivalent tests and IEC 60255-21-2 Class 1 Shock and bump or equivalent tests.

2.4 LINE PROTECTION

Line protection relays must coordinate with the protective relays at the SDG&E breakers for the line on which the Generating Facility is connected. The typical protective zone is a two-terminal line section with a breaker on each end. In the simplest case of a load on a radial line, current can flow in one direction only, so protective relays need to be coordinated in one direction and do not need directional elements. However, on the typical transmission system, where current may flow in either direction depending on system conditions, relays must be directional. Also, the complexity and the required number of protective devices increase dramatically with increase in the number of terminals in each protective zone.

The SDG&E-required relays must be located so that a fault on any phase of the SDG&E-owned transmission facility shall be detected. If transfer trip protection is required by SDG&E, the Generator shall provide all required communication circuits at its expense. A communication circuit may be a leased line from the telephone company, a dedicated cable, microwave, or a fiber optic circuit and shall be designed with sufficient levels of monitoring of critical communication channels and associated equipment. SDG&E will determine the appropriate communication medium to be used on a case-by-case basis. The leased phone line or dedicated communication network must have high-voltage protection equipment on the entering cable so the transfer trip equipment will operate properly during fault conditions.

SDG&E-owned transmission and distribution facilities are designed for high reliability by having multiple sources and paths to serve customers. Due to the multiple sources and paths, complex protection schemes are required to properly detect and isolate faults. The addition of any new Generating Facility to the SDG&E-owned transmission facilities must not degrade the existing protection and

control schemes, create safety concerns or cause service reliability to drop to levels that violate minimum reliability standards. See California Public Utility Commission (CPUC) Electric [Rule 2](#).

2.4.1 No Tapped Transmission Lines Practice

Tapped transmission lines “increase the number of terminals in each protective zone” and are subject to the strictures of the above language.

SDG&E strongly discourages Generating Facility taps to existing transmission lines. SDG&E’s position is founded on prudent practice. SDG&E’s practice is not strictly associated with protection concerns; it is also based on the ability to reliably restore the line/system following a protection event. SDG&E’s practice of connecting a Generating Facility to an SDG&E substation bus via a radial line allows for straightforward line protection and assurance that 1) only SDG&E can re-energize a transmission line following a line trip, and 2) a generator closure out-of-synchronism cannot occur.

Additionally, connecting a Generating Facility to SDG&E facilities via a tapped line increases the consequences of outages since a fault on any of the tapped line segments will remove all line segments from service. In contrast, a fault on the radial line connecting a Generating Facility to an SDG&E substation bus will remove only the radial line from service; and a fault on any other transmission line will not remove the radial line from service.

2.5 GENERATOR PROTECTION AND CONTROL

Generator protection shall include:

2.5.1 Over/Under-voltage Relay

This protection is used to trip the circuit breaker when the voltage is above or below an acceptable operating range, specified by SDG&E. It is used for generator protection and backup protection in the event that the generator is carrying load that has become isolated from the SDG&E-owned transmission system.

2.5.2 Over/Under-frequency Relay

This protection is used to trip the circuit breaker when the frequency is above or below an acceptable frequency range as specified by SDG&E. It is used for generator and/or turbine protection and back-up protection.

2.5.3 Low/High Voltage and Frequency Ride Through

Generator relay settings (for voltage and frequency) are coordinated with other utilities in the Western Electricity Coordinating Council (WECC) and the CAISO to maintain generation on-line during system disturbances (also known as “ride through”). Relay settings should not be set for a higher frequency/voltage or shorter time delay than specified in the NERC standard PRC-024 without prior written approval by SDG&E and the CAISO.

2.5.4 Ground Fault Sensing Scheme

2.5.4.1 General:

The ground fault sensing scheme detects ground faults on SDG&E-owned transmission facilities and trips the generator breaker or the generating facility’s main circuit breaker, thus preventing the generating unit from contributing to a ground fault. This scheme must be able to detect faults between SDG&E’s side of the dedicated transformer and the end of SDG&E’s line segment. The following transformer connections, along with appropriate relaying equipment, are commonly used to detect system ground faults:

- System side - ground wye: generator side -delta
- System side – ground wye: generator side – wye; tertiary – delta

2.5.4.2 Ground Grid Requirements

Transformers connected to the transmission system at 69 kV and higher must have a grounded wye connection on the system side, and a ground current sensing scheme must be used to detect ground faults on the SDG&E Power System.

For any substations and/or generating facility built by other entities but subsequently owned and/or operated by SDG&E, the ground grid must meet the minimum design and safety requirements used in SDG&E substations.

Additionally, when generating facilities (operated by Generator personnel) need to be connected to the ground grid of an existing or new SDG&E substation (i.e. when they are located inside or immediately adjacent to SDG&E substation or switching stations OR when system protection requires solid ground interconnection for relay operation), the ground grid must meet the minimum design and safety requirements used in SDG&E substations.

When Generating Facilities are not in any way connected to the SDG&E ground grid or neutral system, the Generator will be solely responsible for establishing design and safety limits for their grounding system.

2.6 MANUAL DISCONNECT SWITCH

2.6.1 General

A SDG&E-operated disconnect device must be provided as a means of electrically isolating the SDG&E Power System from the Generating Facilities. This device shall be used to establish visually open working clearance for maintenance and repair work in accordance with SDG&E safety rules and practices. A disconnect device must be located at all points of interconnection with SDG&E. This disconnect switch should be gang-operated, three-pole lockable switch.

If the switch is to be located on the SDG&E side of the Point of Change of Ownership, SDG&E will install the switch at the Generator's expense. If the device is to be located on the entity's side, it must be furnished and installed by the Generator. All switch installations must be approved by SDG&E. SDG&E personnel shall inspect and approve the installation before parallel operation is permitted.

2.7 FAULT-INTERRUPTING DEVICES

The fault-interrupting device selected by the Generator must be reviewed and approved by SDG&E for each particular application.

There are two basic types of fault-interrupting devices:

- Circuit Breakers
- Circuit Switchers

SDG&E will determine the type of fault-interrupting device required for a Generating Facility based on the size and type of generation, the available fault duty, the local circuit configuration, and the existing SDG&E protection equipment.

2.7.1 Circuit Breakers

A three-phase circuit breaker at the point of interconnection automatically separates the Generating Facility from the SDG&E Power System upon detection of a fault. Additional breakers and protective relays may be installed in the Generating Facility for ease in operating and protecting the facility, but they are not required for the purpose of interconnection. The interconnection breaker must have sufficient capacity to interrupt maximum available fault current at its location and be equipped with accessories to:

- Trip the breaker with an external trip signal supplied through a battery (shunt trip)
- Telemeter the breaker status when it is required
- Lock-out if operated by protective relays required for interconnection

Generally, a three-phase circuit breaker is the required fault-interruption device at the point of interconnection, due to its simultaneous three-phase operation and ability to coordinate with SDG&E line-side devices.

2.7.2 Circuit Switchers

A circuit switcher is a three-phase fault-interrupter with limited fault interrupting capability. These devices may substitute for circuit breakers when the fault duty is within the interrupting rating of the circuit switcher. With SDG&E approval, some circuit switchers with blades can double as the visual open disconnect switch between the metering transformers and the main transformer. Since circuit switchers do not have integral current transformers, they must be installed within 30 feet of the associated current transformers to minimize the length of the unprotected line/ bus disturbance.

2.8 GENERATORS

The Generating Unit must meet all applicable ANSI and IEEE standards. This prime mover and the Generating Unit should also be able to operate within the full range of voltage and frequency excursions that may exist on the SDG&E Power System without damage to the prime mover or Generating Unit. The Generating Unit must be able to operate through the specified frequency ranges for the time durations listed in the WECC Off-Frequency standard (PRC-006-WECC-CRT-2) to enhance system stability during a system disturbance.

2.8.1 Synchronizing Relays

The application of synchronizing devices attempts to assure that a synchronous generator will parallel with the utility electric system without causing an unacceptable disturbance to other customers and facilities (present and in the future) connected to the same system. It also attempts to assure that the Generating Unit itself will not be damaged due to an improper parallel action.

Synchronous generators and other generators with stand-alone capability must use one of the following methods to synchronize with the SDG&E Power System:

2.8.1.1 Automatic Synchronizer

Automatic synchronization with automatic synchronizer (ANSI Device 15/25) to synchronize with the SDG&E Power System:

The automatic synchronizer must be approved by SDG&E and have all of the following characteristics:

- Slip frequency matching window of 0.1 Hz or less
- Voltage matching window of ± 3 percent or less
- Phase angle acceptance window of ± 10 degrees or less
- Breaker closure time compensation. For an automatic synchronizer that does not have this feature, a tighter phase angle window (± 5 degrees) with one second time acceptance window shall be used to achieve synchronization with ± 10 degree phase angle

Note: The automatic synchronizer has the ability to adjust generator voltage and frequency automatically to match system voltage and frequency, in addition to having the above characteristics.

2.8.1.2 Manual Synchronization Supervised by a Synchronizing Relay

Manual synchronization with supervision from a synchronizing relay (ANSI Device 25) to synchronize with the SDG&E Power System:

The synchronizing relay must have all of the following characteristics:

- Slip frequency matching window of 0.1 Hz or less
- Voltage matching window of ± 3 percent or less
- Phase angle acceptance window of ± 10 degrees or less
- Breaker closure time compensation

Note: The synchronizing relay closes a supervisory contact, after the above conditions are met, allowing the breaker to close.

2.8.2 Frequency/Speed Control

Please refer to Section 4.1.1.1.

2.8.3 Excitation System Requirements

An excitation system is required to regulate generator output voltage.

Excitation systems shall have a minimum ceiling voltage of 150 percent of rated full load field voltage and be classified as a high response excitation system as defined in IEEE 421.1. Static Systems shall meet these criteria with 70 percent of generator terminal voltage. The offline generator terminal voltage response shall have an overshoot limited to 20 percent and a band width of at least 0.1 to 4 hertz. However, in no case shall the bandwidth upper limit be less than

local mode frequency. All systems shall be suitable to utilize a Power Stabilizer as described in SECTION 2.8.4

Ceiling current shall have a transient time capability equal to or greater than the short time overload capability of the generator. See ANSI C50.12, 13, or 14.

A means shall be provided to quickly remove excitation from the generator field to minimize contributions to faults. The preferred method is to reverse generator field voltage to drive the current to zero.

Excitation system shall respond to system disturbances equally in both the buck and boost directions. All bridges that govern excitation responses shall be full wave type. Bridges feeding a pilot exciter shall have negative forcing capability.

2.8.4 Voltage Regulator

Voltage control is required for all Generating Units interconnected at transmission level voltages.

The unit should be able to operate in Automatic Voltage Control Mode with its automatic voltage regulator (AVR) in service and controlling voltage continuously; except when instructed otherwise by the Transmission Operator (TOP), or it is in starting, shutting down or testing mode. If the Voltage Control equipment is out of service, the generator operator shall have an alternative method to control generator voltage and reactive output to meet the voltage or reactive power schedule directed by the SDG&E Designated Control Center (per applicable NERC Reliability Standard: NERC Reliability Standard VAR-002-4 or any future revisions) and as directed by the CAISO. The regulator must be acting continuously and be able to maintain the specified voltage or reactive power schedule at the interconnection point under steady-state and contingency conditions without hunting and within ± 0.5 percent of any voltage level between 95 percent and 105 percent of the nominal voltage at the point of interconnection.

Voltage regulators for synchronous generators shall have a minimum of the following signal modifiers:

- Reactive current compensator capable of line drop or droop characteristic
- Minimum and maximum excitation limiter
- Volts per Hertz limiter
- Two levels of over-excitation protection. The first level should provide a forcing alarm and trip the voltage regulator after a time delay. The second level shall have an inverse time characteristic such that the time-

- current relationship may be coordinated with the generator short time thermal requirements (ANSI C50.13 or C50.14).
- A two input Power System Stabilizer (PSS) utilizing Integral of Accelerating Power to produce a stabilizing signal to modify regulator output. The PSS shall be an integral part of the voltage regulator and be incorporated into the excitation system for all generation units greater than 30 MVA and connected to the transmission system at 69 kV and greater. The PSS shall provide a positive contribution to damping for a frequency range from 0.1 hertz through local mode frequency.

2.8.5 Power Factor Controller

The controller must be able to maintain a power factor setting within ± 1 percent of the setting at full load at any set point within the capability of generator. However, in no case shall control limits be greater than the following: Between 90 percent lagging and 95 percent leading. Per Appendix V, Section 9.6.1 of the CAISO's conformed Tariff [CAISO's Standard Large Generator Interconnection Agreement (LGIA)], the Interconnection Customer shall design the Large Generating Facility to maintain a composite power delivery at continuous rated power output at the terminals of the Electric Generating Unit at a power factor within the range of 0.95 leading to 0.90 lagging, unless the CAISO has established different requirements that apply to all generators in the Control Area on a comparable basis. Power factor design criteria can be found in Section 4.1.

Wind Generating Units and other Generating Units of the induction type must install enough equipment to maintain at least unity power factor and the voltage within criteria at the point of interconnection, under normal and extreme system conditions. This compensating equipment must have dynamic characteristics as determined by the interconnection studies.

2.8.6 Inverter-based Generators (Solar, Wind, Battery and others)

Inverter based generation must comply and meet the latest applicable IEEE 1547 and UL 1741 standards. The harmonic generated by these inverters must be less than 1% for single harmonic and less than 5% for total harmonic. At SDG&E's request, all voltages, frequencies, and set points must be verified by providing calibration test reports showing pass/fail indication.

2.9 Remedial Action Schemes

As stated in the NERC and WECC Planning Standards, the function of a Remedial Action Scheme (RAS), also referred to as a Special Protection System (SPS), is to "detect abnormal system conditions and take pre-planned, corrective action (other than the isolation of faulted elements) to provide acceptable system

performance.” In the context of new generation projects, the primary action of a RAS would be to detect a transmission facility outage or an overloaded transmission facility and then trip or run back (reduce) generation output to prevent damage to the overloaded facilities, protect against potential overloads, and/or avoid other criteria violations.

The output of electric Generating Units will flow over the entire interconnected transmission system. A Generating Facility is therefore required to participate, at any point in time, in RAS’s to protect local transmission facilities and the entire system as SDG&E and the CAISO determines necessary.

A typical disturbance, as it is considered in the planning and design of the electric transmission system, is the sudden loss of one or more critical transmission lines or transformers. A widely applied corrective measure is to instantaneously drop a sufficient amount of generation on the sending end of the lost transmission facility. This is known as *generation dropping*, and a Generating Facility may be disconnected from the transmission by the automatic RAS controller, in much the same way as by a transfer-trip scheme. A Generating Facility should therefore have full load-rejection capability as needed both for local line protection and RAS.

The RAS design must be such that any single-point failure will not prevent the effective operation of the scheme.

Whether RAS shall be required will depend on the overall location and size of the generator and load, the nature, consequences and expected frequency of disturbances and the nature of potential transmission reinforcements. Interconnection customers may be required to implement new or expanded RASs at any time

Any RAS proposal must be approved by both SDG&E and CAISO and must comply with the applicable CAISO Planning Standards and Good Utility Practice.

2.10 PERMISSIVE CLOSE FOR INTERRUPTING DEVICE AT POINT OF INTERCONNECTION

SDG&E will provide a Permissive Close Control Signal to enable closing of the Generation Entity’s interrupting device at or near the Point of Interconnection, which is typically the circuit breaker(s) at the SDG&E bus position. The intent of this control is to ensure that SDG&E is ready for the Generating Facility to be energized from the SDG&E power system, and to prevent the closing of the Generator’s interrupting device when the SDG&E facility is de-energized. The Generator must incorporate the interface to SDG&E’s Permissive Close Control Signal communication interface in the design of the associated interrupting device close circuit(s). In addition, the Generator must provide status of the interrupting device (open or closed) to SDG&E via the communication control interface.

SECTION 3

SUBSTATION REQUIREMENTS FOR GENERATION ENTITIES CONNECTING TO SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE

The purpose of this section is to help all generators satisfy applicable SDG&E substation requirements. In addition to the operating requirements in this handbook, a more detailed description may be found in the Conformed CAISO Tariff, which may be obtained from the CAISO [website](http://www.caiso.com) at www.caiso.com.

This document provides guidelines for:

- The determination of breaker duty and surge protection for generation, transmission or end-user facilities connecting to SDG&E-owned transmission facilities.
- Engineering and design of grounding systems for generation, transmission or end-user electric facilities connecting to SDG&E-owned transmission facilities.
- Establishing the methodology used by SDG&E to determine equipment ratings. These equipment ratings will be used in determining ratings of Electric Facilities on SDG&E-owned transmission facilities. Conductors, equipment, and material should be selected to prevent substation elements from being the most limiting element of a facility.
- The selection of substation insulation for generation, transmission or end-user electric facilities connecting to SDG&E-owned transmission facilities.

APPLICABILITY

The substation requirements of this section apply to all generators interconnecting with the SDG&E-owned transmission facilities. All Generators must meet applicable WECC and NERC standards.

REFERENCES

- San Diego Gas & Electric Company FERC Electric Tariff
- SES-3801 – Substation Arrestor Selection Requirements
- SE-1301 – Substation and Transmission Equipment Rating Methodology
- SE-1302 – Substation Conductor Rating Methodology
- IEEE C62.22 Guide to the Application of Metal-Oxide Surge Arrestors for Alternation Current Systems
- IEEE 80 Guide for Safety in AC Substation Grounding

- IEEE Std C62.82.1, IEEE Standard insulation Coordination-Definitions, Principles and Rules
- IEEE 1313.2, IEEE Guide for the Application of Insulation Coordination

DEFINITIONS

- Surge – A transient wave of current, potential or power in an electric circuit.
- Breaker Fault Duty – The highest value of the symmetrical component of the three-phase, short-circuit current in RMS amperes measured from the envelope of the current wave at the instant of primary arcing contact separation that the circuit breaker shall be required to interrupt at rated maximum voltage and on the standard operating duty.
- Grounding Study – A study to determine the long term performance of differing types of commonly used grounding electrodes in diverse geographical locations and soil types.
- Basic Lightning Impulse Insulation Level (BIL) – The electrical strength of insulation expressed in terms of the crest value of a standard lightning impulse under standard atmospheric conditions. BIL may be expressed as either statistical or conventional.
- Crest Value – The maximum absolute value of a function when such a maximum exists.
- Insulation Coordination – The selection of insulation strength consistent with expected over-voltages to obtain an acceptable risk of failure.

3.1 BREAKER DUTY AND SURGE PROTECTION

- 3.1.1 Breaker Duty:** The breaker duty for facilities connecting to SDG&E-owned transmission facilities should meet the requirements stated in the section 2.7.1 or 2.7.2 of this handbook depending on which device will be used. The fault duty for the device used depends on the physical connection to the system. A System Impact Study will be needed in order to determine fault duty. The System Impact Study is executed in accordance to the San Diego Gas & Electric Company FERC Electric Tariff (Section 10.7) and the results will be used to determine the specified circuit breaker fault duty rating. These requirements also extend to transmission facilities and end-user facilities interconnecting to SDG&E-owned transmission facilities.
- 3.1.2 Surge Protection:** Facilities connecting to the SDG&E-owned transmission facilities via underground cables will require surge protection. This applies to all transmission voltage levels 69 kV and above. Furthermore, any new

transmission-level transformer connecting to an SDG&E facility will require surge protection.

The minimum surge protection varies depending on the voltage level of the third party's connecting facility. San Diego Gas & Electric has opted to use metal oxide type surge arrestors for substation surge protection. Third-party owned facilities connecting to an SDG&E-owned substation are required to use the latest revision of IEEE C62.22, Guide to the Application of Metal-Oxide Surge Arrestors for Alternation Current Systems, in order to determine the appropriate surge protection. In addition to using IEEE C62.22 for the application of surge arresters, any new connecting facility must meet the equipment requirements for surge arrester as dictated in Substation Engineering Standard SES-3801. SES-3801 describes and quantifies standard station class, metal oxide surge arrestors for 69 kV to 500 kV (Please see Table 4.7 under section 4.6.19).

3.2 GROUNDING AND SAFETY

3.2.1 Grounding: Any new facility connecting to the SDG&E grid, regardless of its business functionality, will require an independent grounding study. That study will require the modeling and engineering of the grounding system based on the latest revision of IEEE 80, "Guide for Safety in AC Substation Grounding".

3.3 EQUIPMENT RATING

3.3.1 The ratings of Electric Facilities on SDG&E's transmission system are derived from the individual ratings of the equipment, or elements, which comprise that electric facility. Specifically, a Facility Rating will be equal to the most limiting applicable Equipment Rating of the individual equipment that comprises that Facility.

3.3.2 Please see Rating Methodology detailed in SE-1301 Sections 6.2 – 6.12.

3.3.3 Please see Conductor Rating Methodology detailed in SE-1302 Section 4.

3.4 INSULATION AND INSULATION COORDINATION

3.4.1 Insulation and Insulation Coordination: Third-party owned facilities connecting to SDG&E-owned transmission facilities will be required to coordinate with the insulation strength of the facility to which interconnection is made. A system transient analysis will be performed to determine the amplitude, waveform and duration of the over-stress voltages and generally done using software such as Electromagnetic Transient Program (EMTP). The insulation level will be in accordance with the latest revision of IEEE Std C62.82.1, "IEEE Standard insulation Coordination-Definitions, Principles and

Rules” and IEEE 1313.2, “IEEE Guide for the Application of Insulation Coordination”.

- 3.4.2** All equipment will adhere to the chosen basic lightning impulse insulation level with the exception of the transformer windings, which are protected by surge arrestors.

3.5 SUBSYNCHRONOUS OSCILLATION (SSO)

- 3.5.1** Turbine generators or inverter based generators using power-electronic devices installed near series compensated lines may be exposed to Sub-synchronous Oscillation (SSO) conditions. Subsynchronous Oscillation includes Subsynchronous Resonance (SSR) and Subsynchronous Torsional Interactions (SSTI) for conventional generation units and Type-3 wind turbines, as well as Subsynchronous Control Instability (SSCI) for inverter based generators using power electronic devices (e.g. solar PV and wind turbines).

If a generating project is at risk of SSO instability, a SSO study may be required prior to interconnection. It is the generation developer’s responsibility to select, purchase, and install turbine/inverter based generators that are compatible with the series compensation in the area and to provide the CAISO with documentation that conclusively establishes that the generator will not cause SSO problems.

For at risk projects, the PTO will provide the Interconnection Customer (IC) with information regarding series compensation in the area that will allow the IC to run its studies and provide the necessary documentation. The report must be provided to both CAISO and SDG&E prior to interconnection of the generator to the CAISO system and sufficiently in advance of the generator’s In-Service Date to permit review by CAISO and SDG&E. All costs of the SSO study will be borne by the generation developer.

- 3.5.2** Appendix A describes a process that may be useful in identifying whether a generating project is at risk of SSO instability. Based on the criteria that are discussed in this Appendix, generation projects may be selected by SDG&E to perform a detailed PSCAD study. Alternatively, for its own protection, a generating project may elect to perform a detailed PSCAD study. Some details on the mechanics of the studies and the requirements for reporting are explained in the Appendix.
- 3.5.3** The report must include a detailed (PSCAD) model of its Generating Facility and associated control systems, along with the manufacturer representative’s contact information. In the event the study reveals instability in violation of reliability standards, the report must also identify appropriate mitigation

measures that must be implemented prior to initial synchronization (In-Service Date) of the Generating Facility.

3.6 PHASOR MEASUREMENT UNIT

3.6.1 As a Balancing Authority under NERC reliability standards, the CAISO has an obligation to match (i) the actual dynamic response of the system to disturbances, to (ii) the simulated dynamic response of the system to the same disturbances under similar system conditions. To allow the CAISO to match actual and simulated performance, individual generators larger than 10 MVA², and generating facilities with a maximum facility output equal or greater than 20 MVA² are required to provide Transmission Providers with dynamic models that simulate the generator's dynamic response to disturbances on the system.

Under NERC reliability standards, SDG&E is a Transmission Planner within the CAISO Balancing Authority. SDG&E thereby has an obligation to provide to the CAISO dynamic models that will allow the CAISO to demonstrate a match between actual and simulated dynamic performance. Accordingly, each individual generator that is larger than 10 MVA², or generating facility that has a maximum facility output equal or greater than 20 MVA², shall install and maintain, at its expense, phasor measurement units (PMUs).

These PMUs must be capable of capturing real-time data sufficient to allow SDG&E to either (i) validate, or (ii) identify errors or inaccuracies in, the dynamic models provided by the generator to SDG&E³.

3.6.2 PMUs shall be installed on the Customer Facility low side of the generator step-up transformer, unless it is a non-synchronous generation facility, in which case the PMUs shall be installed on the Customer Facility side of the Point of Interconnection.

3.6.3 Installed PMU must be capable of a minimum of 30 samples per second and synchronized via a high-accuracy satellite clock.

3.6.4 Phasor Data Concentrator (PDC) Requirements

PMU equipment which includes the communication circuit should be capable of carrying the PMU data to a local data concentrator, and then transporting

² <http://www.caiso.com/Documents/ISO-SDGEMOD-032-01Requirements.pdf>

³ <http://www.nerc.com/pa/Stand/Reliability%20Standards/MOD-032-1.pdf> (R3)

the information continuously to SDG&E, as well as storing the PMU data locally for thirty days.

3.6.5 Network Requirements

SDG&E will install and provide for ongoing support and maintenance of the network communications linking the data concentrator to SDG&E.

3.6.6 Data Exchange and Management Requirements

Interconnection Customer shall provide to SDG&E all necessary and requested information through the SDG&E synchro-phasor system, including:

- (a) Gross MW and MVAR measured at the Customer Facility side of the generator step-up transformer (or, for a non-synchronous generation facility, to be measured at the Customer Facility side of the Point of Interconnection);
- (b) Generator terminal voltage;
- (c) Generator terminal frequency; and
- (d) Generator field voltage and current, where available.

SECTION 4

OPERATING REQUIREMENTS

FOR GENERATION ENTITIES CONNECTING TO SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE

This section specifies operating requirements that generators connected to SDG&E-owned facilities must adhere to. In addition to the operating requirements in this handbook, the CAISO Tariff, Protocols and Business Practices Manual may set forth additional operating requirements. The CAISO [website](http://www.caiso.com) is at www.caiso.com.

APPLICABILITY

The operating requirements of this section apply to all generators interconnecting with SDG&E-owned transmission facilities. All Generators must meet applicable WECC and NERC standards. Generators are obligated to install, operate and maintain Power Factor, Voltage, and Power Delivery control equipment.

Participating Generators shall operate, or cause their facilities to be operated, in accordance with the CAISO Tariff and Protocols, and are required to have signed applicable Agreements with the CAISO. Distribution-connected generators making sales for resale (i.e., participating in wholesale markets) are subject to the provisions of SDG&E's Wholesale Distribution Access Tariff (WDAT). Participating Generators are required to schedule energy or Ancillary Services through a designated Scheduling Coordinator.

In the absence of specific CAISO Protocols, the Participating Generator shall abide by the CAISO Tariff and SDG&E's operating requirements. If conflicts arise between the SDG&E's operating requirements and the CAISO Tariff or Protocols, the CAISO Tariff and Protocols shall take precedent subject to resolution through the Alternative Dispute Resolution ("ADR") processes.

4.1 REACTIVE, VOLTAGE AND POWER DELIVERY CONTROL REQUIREMENTS FOR GENERATORS

SDG&E transmission voltage levels will fluctuate depending on plant operation, load levels or other system conditions. If the generating unit is synchronous, the power factor at the point of Interconnection must meet or exceed a minimum bandwidth from 0.90 lag (producing reactive power) to 0.95 lead (absorbing reactive power) at continuous rated power output. The power factor at the Point of Interconnection must meet or exceed a minimum bandwidth from 0.95 lag to 0.95 lead at continuous rated power output per [FERC's Reactive Power Requirements](#). For more details see Appendix H of the Large Generator Interconnection Agreement (LGIA) and Attachment 7 of the Small Generator

Interconnection Agreement (SGIA). Generating Units should utilize fast acting dynamic reactive power support subject to demonstration of acceptable performance over the power factor range. If studies show a need for a wider power factor range, the Generating Unit will be required to provide this wider range and the controls necessary to operate anywhere within this range.

Each Generator shall install, own, operate and maintain the necessary equipment (e.g., “Voltage Ride Through” package) for uninterrupted power delivery based upon SDG&E and CAISO specifications, as may be modified from time-to-time consistent with good utility practice, to limit tripping of the Generating Facilities for temporary low voltage conditions caused by remote faults.

Unless otherwise instructed by the CAISO or SDG&E, the Generating Facility will be operated in an Automatic Voltage Regulating (AVR) mode being properly responsive to changes in transmission voltage and shall follow the voltage schedule provided by the SDG&E Designated Control Center.

Reactive power and voltage control are vital components of safe and reliable system operation. It is essential that interconnected generators have reactive power capability. If a generator is unable to furnish reactive power support and voltage control during steady state, transient and post-transient conditions (due to interconnection limitations, type of generator, the generator loading or other reasons), the Generator shall install reactive support and voltage control equipment at the Generator’s expense. If due to unexpected temporary circumstances, the Generator is unable to furnish reactive power support and voltage control, the Generator should contact SDG&E with a plan to mitigate the situation. SDG&E will perform studies to determine if the mitigation is adequate. For Generating Facilities larger than 20 MW, this provision is pursuant to LGIA Articles 9.3 and 9.6.1 and 10. For Generating Facilities less than or equal to 20 MW, this provision is pursuant to SGIA Articles 1.6 and 1.8.1 and 3.4.

How a Generating Unit meets reactive requirements will depend on its type and size. Synchronous generators have an inherent reactive flexibility that allows them to operate within a range to either produce or absorb reactive power. However, induction generators operate at a power factor wherein reactive power is absorbed and require local corrective reactive power support in order to comply with reactive power, voltage and power delivery control requirements. See section 2.8.4 and 2.8.5 for the voltage regulator and power factor controller requirements.

4.1.1 Synchronous Generator Control

4.1.1.1 Frequency/Speed Control

To enhance system stability, a governor is required on the prime mover. The governor shall be set to provide a droop characteristic consistent with

NERC, WECC and CAISO requirements. Governors shall be operated unrestrained to regulate system frequency.

4.1.1.2 Voltage and Power Factor Control

Imports into the SDG&E system are thermally limited and post-transient voltage limited. For this reason, Generating Units are vital in maintaining system voltage stability. SDG&E operating studies count on Generating Units being operated under AVR control continuously. Failure to operate under AVR control may cause a system collapse depending on system conditions. The commitment of generating units connected to SDG&E-owned transmission facilities is frequently done based on voltage stability, which makes it critical that the generator have adequate voltage control under steady state, transient and post-transient conditions.

Generating Units connected to SDG&E-owned transmission facilities must have both, voltage and power factor modes available on the controller system, and shall be set on automatic voltage regulating (AVR) mode unless otherwise instructed by the CAISO or Designated SDG&E Control Center. The voltage schedule will typically be provided in a procedure form, but may also be provided orally from the Designated SDG&E Control Center. SDG&E Grid Control Center operators may use their judgment in directing a specific generator(s) to operate on power factor control mode or in operating at a different voltage level than the specified voltage schedule. The voltage schedule may be changed by the CAISO or SDG&E as required by system conditions, system configuration changes, high or low voltages at the customer level, criteria violations, and optimization of losses, among others.

Generator voltage regulators must be capable of maintaining the voltage schedule at the point of interconnection (POI) under steady-state and contingency conditions. Typically, the schedule or target voltage is within 5% of nominal voltage, in some cases a tolerance band for NERC reporting purposes is also specified. This tolerance band will at best be, ± 5 percent of the nominal voltage at the point of interconnection. See Section 2.8.4 Voltage Regulator Requirements and also refer to NERC/WECC Reliability Standards VAR-001 and VAR-002.

4.1.1.3 Power System Stabilizer (PSS) Operating Requirements for Generators

SDG&E and the CAISO are responsible for the safe and reliable operation of the electric system. Generating Units with properly tuned and calibrated PSS provide damping to electric power oscillations. Such damping improves stability in the electrical system and may also prevent an individual generator from unnecessary tripping. The PSS must be calibrated and

operated in accordance with the latest standard procedures for calibration, testing and operation of such equipment.

4.1.2 Non-Synchronous Generator Control (without Reactive Power/Voltage Control)

Induction generators or other generators without Reactive Power/Voltage control typically absorb VARs and therefore require local reactive power support so as not to burden the transmission system or adversely impact customers. Even though typically these facilities require reactive power, there are cases when the facilities are located remotely and generate high voltages. In these high voltage cases, the corrective action required may be installation of reactors. Therefore, in general, all generating facilities require power factor compensation and voltage control. If the compensation or corrective action is designed (based on a study employing all-facilities-in-service and applicable contingencies under heavy and light load conditions) to adequately operate within voltage limits (for facilities operated by SDG&E or facilities operated by the generator), then no generation curtailment is expected from the SDG&E Designated Control Center. However, if voltage limit exceedance arises and can be mitigated by adjusting generation, then the SDG&E Designated Control Center will notify the CAISO to curtail generation. If the frequency and duration of voltage limit exceedance continues, the SDG&E Designated Control Center will notify the CAISO to coordinate with SDG&E and the generator to implement additional compensation or corrective action. This equipment may include capacitors, reactors and Static Var Compensators (SVCs). For Generating Units larger than 20 MW, this provision is pursuant to LGIA Articles 9.3 and 9.6.1 and 10.5. Care must be exercised by the Generator in connecting capacitors and/or reactors and other similar equipment directly to the generator terminals to avoid problems such as self-excitation. The reactive Power and/or Voltage control equipment must be set on automatic voltage control mode unless otherwise instructed by the Designated Control Center. Failure of the control or reactive power compensating equipment must be reported immediately to the Designated Control Center, which will give directives on how to proceed.

4.2 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.

4.3 POWER QUALITY REQUIREMENTS

4.3.1 RMS Voltage

A generator connected to SDG&E-owned transmission facilities shall not cause RMS voltage to exceed the Maximum Service Voltage allowed per ANSI C84.1-2011, Table 1, Voltage Range A, where RMS voltage is defined as the average voltage over a 10 minute interval.

4.3.2 VOLTAGE FLICKER CRITERIA

Random voltage fluctuations (flicker) occurring at the POI directly attributable to the Generator shall remain within the limits specified in latest revision of IEEE Standard 1453 ("IEEE Recommended Practice for the Analysis of Fluctuating Installations on Power Systems").

Under no circumstances will a generator permit voltage flicker to exceed SDG&E's voltage flicker criteria as set forth in the preceding paragraph. This obligation exists whether or not complaints are received or service/operational problems are experienced on the SDG&E Grid. Should complaints be received by the SDG&E or should other operating problems arise, or should the Generator flicker exceed the SDG&E criteria, the Generator agrees to take immediate action to reduce its flicker to a level at which flicker complaints and service/operational problems are eliminated.

Corrective measures could include, but are not limited to, modifying production methods/materials or installing, at the Generator's expense, voltage flicker mitigation equipment such as a static DVAR, VAR compensator or another device. SDG&E will work collaboratively with the Generator to assess problems, identify solutions and implement mutually agreed corrective measures.

If the Generator fails to take corrective action after notice by the SDG&E, SDG&E will take corrective action as allowed by law, tariff or regulation, which may include discontinuing service, until such time as the problem is corrected

4.3.3 HARMONIC DISTORTION CRITERIA

SDG&E also requires that the Generator's operation be in compliance with SDG&E's Harmonic Distortion Guidelines based on the latest revision of IEEE Standard 519 ("IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems").

The Generator will immediately remedy, at Generator's expense, the operation of motors, appliances, devices or apparatus served by its facility that result in harmonic distortions in violation of SDG&E's Harmonic Distortion Criteria as set forth in the preceding paragraph.

The SDG&E will work collaboratively with the Generator to assess problems, identify solutions, and implement mutually agreed corrective measures.

If the Generator fails to take corrective action after notice by the SDG&E, SDG&E will take corrective action as allowed by law, tariff or regulation, which may include discontinuing service, until such time as the problem is corrected.

4.4 UNDER-FREQUENCY OPERATING REQUIREMENTS

All generators greater than 10 MW connecting to the grid must conform with WECC Standard PRC-024 and disclose the same information provided to WECC to SDG&E. Minimum supplied information shall be as indicated in Table 1 below.

Table 1. Generator Off-Nominal Frequency Survey

Generator (Facility/Owner)	Pickup #	Relay Frequency Trip Under and Over frequency (Hz)	Definite Time Delay (seconds)	Relay Type
Example plant/ unit #1	1	59.4	180	
	2	58.4	30	
	3	57.8	7.5	
	4	57.3	5	
	5	61.6	45 cycles	
	6	no more settings		
	7			
	8			
	9			
	10			
Plant Name/ unit # 2	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
Plant Name/ unit # (etc)	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			

The WECC Off-Nominal Frequency Load Shedding Plan ([link](#)) requires that generators connected to the grid that protect for off-nominal frequency operation have relaying protection that accommodates, as a minimum, under-frequency and over-frequency operation for specific time frames. The requirement is shown on Table 2 below. SDG&E provides this table for information purposes only. The requirement may be changed from time-to-time. Please check with the WECC for updates.

Table 2. WECC Off-Nominal Frequency Limits

Under-frequency Limit	Over-frequency Limit	WECC Minimum Time
> 59.4 Hz	60 Hz to < 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 Hz	> 61.7 Hz	Instantaneous trip

4.5 GENERATOR OPERATING PARAMETERS

Generators connecting to SDG&E-owned transmission facilities must supply SDG&E with the following minimum operating data:

4.5.1 Generators connecting at 69kV or higher:

1. Net Maximum operating level MW
2. Net Minimum continuous operating level MW
3. Ramp rate (MW/Minimum), normal and emergency (Load pick-up capability of Generating Unit)
4. Gross MW capability of Generating Unit
5. Time to have Generating Unit prepared to close into bus following notification (minutes). Please provide information for hot, warm and cold starts.
6. Maximum and Minimum reactive capability (MVAR). Provide generator capability curve (D Curve).
7. Step-up transformer modelling and Tap Changer characteristics (NLTC or TCUL, and the different tap positions).

8. Time to reach rated power following synchronization (minutes);
9. Single line diagrams showing connections to the Grid and required switching steps needed to connect to the Grid.
10. Blackstart capable (yes/no)
11. Isochronous capability (yes/no)
12. Types of fuel used and onsite storage capacity.
13. WECC dynamic testing results or dynamic testing plan per [WECC requirements](#). Once the WECC dynamic testing has been performed and the required PSLF modeling has been developed, the dynamic model is to be submitted to SDG&E. Test results must be submitted to SDG&E within 180 days of beginning commercial operation.

4.5.2 Generators connecting at 12kV or lower:

Refer to the Distribution Generation Interconnection Handbook for interconnection requirements.

SECTION 5

OPERATING PROCEDURES FOR GENERATING UNITS CONNECTING TO THE SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE

The purpose of this section is to provide Generators with a general understanding of applicable SDG&E and CAISO operating procedures.

APPLICABILITY

The operating procedures of this section apply to all Generating Units interconnecting with the CAISO-controlled grid. For all other Generating Units, including Participating Generators, the SDG&E Large Generation Interconnection Agreement (LGIA) may not include certain provisions of this section, such as energy reporting, paralleling and/or separating, and Ancillary Services (handled by Scheduling Coordinators), and maintenance scheduling (handled by the CAISO). Such provisions, which are described in the CAISO Tariff, will be covered under separate agreements. In the future, and subject to appropriate regulatory approval, the CAISO may develop revised or new operating procedures applicable to the interconnection of certain generators. If conflicts arise between SDG&E's operating procedures and the CAISO's procedures, then SDG&E and the CAISO shall negotiate the difference(s) and use the CAISO's Alternative Dispute Resolution ("ADR") processes identified as part of the Agreement. If the conflict requires a resolution during real-time operations, the most conservative parameters shall be used.

5.1 JURISDICTION OF THE CAISO AND THE SDG&E DESIGNATED CONTROL CENTER

On March 31, 1998, the CAISO assumed operational control over most of the SDG&E's 69 kV and above transmission grid. Notwithstanding the operational jurisdiction of the CAISO over most of SDG&E's transmission system, the CAISO Protocols delegate certain operational activities to SDG&E on selected parts of the CAISO Controlled Grid. Under the CAISO's control and instruction, SDG&E performs all physical switching operations, including de-energization and restoration of SDG&E-owned facilities.

Both SDG&E and the CAISO serve as points of contact for Generating Facilities that are connected to SDG&E-owned transmission facilities that are part of the CAISO-controlled grid. These Generating Facilities will communicate and coordinate with the CAISO and SDG&E as specified in the CAISO's Protocols, Operating Procedures, and tariffs.

The Generator, while operating its facility interconnected with the CAISO Controlled Grid or with SDG&E-owned transmission facilities, shall at all times follow the operating instructions of the CAISO and SDG&E. The SDG&E Designated Control Center shall be responsible for implementing the CAISO's orders, protocols, and operating procedures.

5.2 COMMUNICATIONS

The Generator shall maintain telephone service at the Generating Facility. If the facility is remote or unattended, telephone service shall be provided to the nearest location normally occupied by the responsible Generator (acting on its own behalf or through its designated Generating Facility operator). SDG&E and the Generating Facility operator shall maintain operating communications through the SDG&E Designated Control Center. The Generation Facility operator shall be accessible at all times and shall provide to the SDG&E Designated Control Center a 24-hour phone number where the facility operator may be reached. For each Generating Facility, 20 MW or greater (or of any size when connecting to the transmission grid at 69 kV and higher), an operating agreement shall be mutually developed (between the Generating Facility, CAISO and SDG&E) to facilitate scheduled and forced operating activities.

5.2.1 Daily Capacity and Energy Reports

A Generator whose facilities may produce 10 MW or more, must provide data via telemetry to the CAISO according to the requirements of the CAISO Tariff. SDG&E may also require telemetry of data depending on the number of generators and the complexity of the transmission configuration. The Generation Facility operator shall provide and maintain the data circuits required to telemeter units greater than or equal to 20 MW. When such telemetering is inoperative, the facility operator shall report to the SDG&E Designated Control Center on an hourly basis the voltage reading and the real and reactive power flows at the generator's Point of Interconnection.

5.2.2 Voltage Control Operation and Other Service Requirements

The Generation 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 and other electric service schedules. The facility operator shall ensure 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 voltage instruction. The Generator is responsible for the safe operation and interruption and de-energization of the customer-owned voltage control devices.

SDG&E's voltage schedules and power factor schedules shall treat all sources of reactive power in the service area in an equitable and non-discriminatory manner. The SDG&E Designated Control Center shall endeavor to provide the Generator with voltage schedules and power factor (reactive power) schedules, if possible, at least one (1) day in advance, and may make changes to such schedules as necessary to maintain the reliability of the SDG&E electric system. The Generator shall operate their generating facility to maintain the specified voltage set-point (or power factor). If the Generator is unable to maintain the specified voltage set point (or power factor), it shall promptly notify the SDG&E Designated Control Center. If the Generating Unit's voltage or power factors, at the point of interconnection, are outside of the specified values, SDG&E shall have the right to order a reduction or increase in output, or to disconnect the Generating Unit from the grid, if the plant's operation is adversely affecting the SDG&E electric system.

Prime movers for Generating Units with power system stabilizers shall be operated on unrestrained governor control, unless the Generation Facility operator and the CAISO system dispatcher otherwise agree for a temporary period. The standard governor droop setting shall meet WECC requirement PRC-001-WECC-CRT-1.1.

Where identified in the interconnection study, the Generating Facility may be required to participate in a RAS to maintain or enhance the operating capability or performance of the SDG&E electric system.

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. **Note: The CAISO may have additional requirements for systems designated as CAISO Grid Critical Protective Systems. Refer to the CAISO Tariff available on the CAISO website (www.aiso.com).**

5.2.3 Paralleling To and Separating From SDG&E

The Generator's designated representative shall notify the SDG&E Designated Control Center prior to paralleling or separating from the SDG&E system. For unexpected separations, the Generator's designated representative will inform the SDG&E Designated Control Center of the nature of the problem (e.g., over-voltage, under-frequency, ground fault, remedial action) and report on any relay target operations. For safety and reliability, a mutually developed set of operating procedures between SDG&E and the generator must be documented prior to paralleling and before the facilities connecting the generator to SDG&E-owned transmission facilities is energized.

5.2.4 Work Authorizations and Switching Requests

The Generating Facility operator must request a work authorization from SDG&E a minimum of ten calendar days in advance of commencement of the requested work. SDG&E shall notify the Generator at least three (3) workdays in advance of any plans by SDG&E to take a clearance, which affects the Generating Facility.

Each interconnected facility shall have installed an approved disconnect or other switching device for operation by the Generating Facility as an isolating point. The disconnect must be capable of being locked open and accessible to SDG&E personnel.

5.2.5 Unusual or System Emergency Conditions

For all System Emergencies, the CAISO is responsible for managing the emergency and for restoration as specified in the CAISO Tariff. All Generating Units and System Resources that are owned or controlled by a Participating Generator are (without limitation to the CAISO's other rights under the CAISO Tariff) subject to control by the CAISO during a System Emergency and in circumstances in which the CAISO considers that a System Emergency is imminent or a threat. The CAISO shall, subject to applicable CAISO Tariff provisions, have the authority to instruct a Participating Generator to bring its Generating Unit on-line, off-line, or increase or curtail the output of the Generating Unit and to alter scheduled deliveries of Energy and Ancillary Services into or out of the CAISO Controlled Grid, if such an instruction is reasonably necessary to prevent an imminent or threatened System Emergency or to retain Operational Control over the CAISO Controlled Grid during an actual System Emergency.

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 the CAISO Controlled Grid or 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. The SDG&E Designated Control Center shall be notified of any forced outage. The SDG&E Designated Control Center shall notify the Generator of any unusual CAISO Controlled Grid or SDG&E conditions that may affect the Generator's facility. During any emergency, the facility operator shall follow the instructions of the SDG&E Designated Control Center

5.2.6 Other Communications

The Generating Facility operator shall notify the SDG&E Designated Control Center of any replacement, modification or removal of any interconnection facilities (e.g., transformer, breaker), changes in EMS/SCADA, (Emergency Management System/Supervisory Control and Data Acquisition), disconnects, relays, special protection equipment).

Note: Regardless of generator size, protective equipment designated as CAISO Grid Critical Protective devices utilize special CAISO procedures, as specified in the CAISO Tariff.

For the Interconnection Facilities listed above, the Generating Facility operator shall follow the manufacturer's minimum maintenance requirements on file for audit by the SDG&E Designated Substation Maintenance Supervisor

- Results of four-year bench tests on all SDG&E-required relays (see SECTION 2.1).
- Results of recommended maintenance tests on interconnection circuit breakers and transformers.

The Generating Facility operator shall notify the SDG&E Designated Control Center:

- The time of any relay operations and targets of the relay that caused the Generating Facility to separate, if applicable.
- The time of any paralleling with and separations from the SDG&E system.
- The time of the change in voltage-control device set points (if applicable) and the time of change in the operating status (i.e., opened or closed) of any other voltage-control device (i.e., shunt capacitors or reactors).

5.2.7 Event Recorder

All generation facilities connecting to SDG&E-owned transmission facilities must have an event recorder that will enable SDG&E to make an after-the-fact determination of the status of the Generating Facility at the time of a system disturbance, should such a determination be required. The events should be recorded to sub-cycle resolution. The Generating Facility shall ensure the time reading is correct and synchronized via a high accuracy satellite clock.

SECTION 6

ENERGIZATION AND SYNCHRONIZATION REQUIREMENTS FOR GENERATION ENTITIES CONNECTING TO THE SDG&E-OWNED TRANSMISSION FACILITIES

PURPOSE:

The following is SDG&E's procedure for performing pre-parallel inspections and preparing to energize and synchronize the generator to SDG&E-owned transmission facilities. 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 successfully paralleling to the SDG&E system.

The Interconnection Customer (IC) must comply with the CAISO's "[New resource implementation process and requirements](#)". This webpage contains guidelines, deliverables and activities needed during the final 203 days of the project's interconnection. This will allow for a successful and complete resource interconnection to the ISO grid.

6.1 TEST RESULTS AND/OR INFORMATION REQUIRED PRIOR TO PRE-PARALLEL TESTING

All tests outlined below must be complete and two (2) copies of the test reports submitted to a SDG&E representative a minimum of fifteen (15) business days before the requested energize date. Test reports must be approved by SDG&E at least three (3) business days before the requested pre-parallel date. Failure to meet SDG&E-approved test requirements will result in delay of energizing and testing of Generator's equipment.

6.1.1 Proving Insulation

For any of the megger tests referred to below a 2,500 volt DC megger or a hi-pot is preferred, but a 1,000 volt DC megger is acceptable.

- All transformers connected to the primary bus and the main transformer must be meggered winding to winding and each winding to ground. For purposes of this document, "primary bus" is defined as the source-side bus or conductor from the primary interrupting device to the generating plant.
- All circuit breakers and circuit switchers connected to the primary bus and at the interconnection point must be meggered in the following manner: Breaker open - each pole to ground, pole 1-2, pole 3-4, pole 5-

6; breaker closed - pole 1-ground, pole 3-ground, pole 5-ground and if the poles are in common tank or cell, pole 1-3, pole 3-5, pole 5-1.

- All buses and cables shall be meggered phase-to-phase and phase-to-ground.
- The main transformer(s) and main breaker(s) shall have a dielectric test performed on the insulating medium (gas or oil). This does not apply to factory-sealed circuit switcher interrupters.
- The Generating Unit(s) must be meggered or hi-pot tested phase-to-phase and phase-to-ground.

6.1.2 Proving Ratios

All ratios of transformers connected to the primary bus must be proven using either a turns ratio tester or a voltage ratio test. The main transformer must be tested on the final operating tap as determined by SDG&E according to Section 3.2.

6.1.3 Circuit Breakers and Circuit Switchers

- A minimum to trip at 70 volts (assuming a nominal 125 VDC battery system) must be performed on all circuit breakers and/or circuit switchers that are operated by SDG&E-required relays.
- A Micro-Ohm test must be performed on all circuit breakers and circuit switchers.
- A timing test showing the time from trip initiation to main poles opening is required.
- A timing test showing the time from close initiation to main poles closing is required.

6.1.4 Current Transformers and Current Circuits

- A saturation check must be made on all current transformers (CTs) associated with the required SDG&E relays.
- The ratio of all CTs must be proven.
- CT circuits must be checked for proper connections and continuity by applying primary or secondary current and reading in the relays. Each test (primary or secondary) must be performed in all combinations to prove proper connections to all phase and ground relays. Current must be applied or injected to achieve a secondary reading of 0.5 amps in each relay to ensure that no loose wiring or parallel current paths exist.

- A check of the total circuit with the ground wire lifted must be done to prove that only one ground exists.

6.1.5 Relays

All relays must be field tested on site to their specified settings to verify the following:

- Minimum operating point at which relay picks up (minimum pickup)
- Time delay at three different current test points, in integral multiples of minimum pickup that closely characterize the relay time-current curve
- Phase angle characteristic of directional relay
- Pickup points at maximum torque angle (MTA) and 30 degrees of MTA on impedance relays using the approved settings
- Slip frequency, voltage matching, phase angle acceptance and breaker compensation time on synchronizing relays
- SDG&E tolerances are listed below:

Current/Voltage/Time \pm 3 to 5 percent
Impedance/Phase Angle \pm 0.05 degrees
Frequency \pm 0.05 Hz

If a pilot relay system is required by SDG&E, signal level checks must be performed.

6.1.6 Primary Disconnect Switch

The primary disconnect switch at the point of interconnection shall be clearly labeled and lockable in the open position.

6.1.7 RTU/RIG/DPU

The final remote intelligent gateway (RIG), data processing gateway (DPG) and remote terminal unit (RIG/DPG/RTU) database shall be provided to SDG&E at least thirty (30) calendar days prior to scheduled energization date.

6.1.8 Metering

Subsequent to SDG&E Engineering approval of the metering design and receipt/approval of applicable equipment test reports and documentation, SDG&E shall be provided at least thirty (30) business days notice to perform

an inspection of the facility. This inspection includes, but is not limited to, verifying wire impedances, ratio checking of CT's, and inspecting the metering cabinet and associated hardware.

Upon a satisfactory inspection by SDG&E of the facility, the SDG&E meters and ancillary equipment shall be installed by SDG&E. The facility may not be energized before the installation of the SDG&E meters.

6.1.9 STATION BATTERY

When a battery is installed, proof of discharge testing is required to ensure that the battery has the capacity to support the load and trip.

6.2 PRE-PARALLEL TEST

The Generator is responsible for ensuring that all relays, data telemetry and other protective devices are adjusted and working properly prior to the pre-parallel inspection. If problems arise with equipment during testing, the SDG&E protection representative may elect to cancel the test and reschedule.

All pre-parallel tests should only be scheduled to begin at 8:00 AM and completed by 6:00 PM Monday through Friday. Functional tests shall be performed by the Generator and all tests shall be observed by SDG&E as outlined below. The Generator shall provide all test equipment and qualified personnel to perform the required tests. SDG&E shall be included strictly as an observer.

6.2.1 Functional Tests

The following functional tests shall be performed after the equipment has been energized, but before the Generating Unit is paralleled with SDG&E's system:

- Check that each protective relay trips the appropriate generator breaker and/or main breaker. This may require injecting a signal. Jumpering across a contact on the back of the relay is not acceptable.
- When first energized, check that proper secondary potential is applied to all voltage and frequency relays.
- Check the synchronizing meter, synchronizing equipment and phasing panel (if used) with the paralleling breaker closed and the generator off-line. This typically requires lifting the generator leads. The equipment should show an "in-phase" condition.
- Check the generator phase rotation. (SDG&E's phase rotation is A-B-C clockwise). All three phases must be checked using hot sticks with a phasing tool or a phasing panel provided by the Generator. The

synchronizing equipment typically checks one phase only. Any other method of demonstrating correct phasing and phase rotation shall be approved by SDG&E in writing prior to conducting the test. Alternative methodologies to check phasing and phase rotations must be submitted to SDG&E fifteen (15) business days in advance of scheduled pre-parallel test. SDG&E must approve the methodology three business days in advance of pre-parallel test date.

6.2.2 Impedance and Directional Relay Tests

Direction-check all impedance and directional relays.

6.2.3 Generator Load Tests

For Generators, the following load tests shall be performed after the Generating Unit picks up load:

- Verify operation of the Generating Unit at 90 percent lagging power factor and at 95 percent leading power factor at rated output.
- Verify operation of the Generating Unit at 95 percent and 105 percent of per unit voltage while delivering rated output.
- Load check all SDG&E required differential relays. The load current must balance to zero in all differential relays.
- Load check voltage restraint over-current relays to prove correct connection of currents and potentials.
- The Generating Unit(s) may have to be paralleled temporarily with SDG&E's system to run the load tests. Permission to do this shall be given by the SDG&E Operations representative observing the test.

6.2.4 Data Telemetry Tests

SDG&E Operations must verify the following prior to Pre-Parallel Operations:

- Communications circuits meet SDG&E's telecommunication specifications and are functioning properly
- RIG/DPG/RTU data is mapped correctly to SDG&E EMS and SCADA systems
 - Scaling on all analog data points is correct

- Point-to-Point check on all status points is verified at SDG&E designated control centers

Typically, pre-parallel inspections can be performed within a normal working day.

SDG&E shall dedicate one full work day to observe the test. If a test cannot be completed by 6:00 PM, the SDG&E representative may cancel the remainder of the test and reschedule it. In this case the Generator shall incur additional costs for the pre-parallel inspection.

6.3 REQUIREMENTS FOR COMMERCIAL (PARALLEL) OPERATION

6.3.1 Clearance for Parallel Operation (For Testing Purposes Only)

The Generator shall certify that it has met all pre-parallel requirements ten (10) business days before commencing Commercial Operation. The Generator shall provide SDG&E with a “Turn-Over” letter, stating that their equipment installation and testing is complete, all relay and control systems have been tested between the generator and SDG&E, and the equipment is ready for service. The Turn-Over letter will provide that the Generator is aware, and that their personnel have been informed (and/or trained), that SDG&E facilities up to their Generating Facilities will be energized. The SDG&E representative shall notify the CAISO in writing that the Generator has met all the requirements to synchronize to the grid at least seven (7) calendar days before the pre-parallel test and prior to obtaining a clearance for parallel operation.

The SDG&E representative shall contact the Designated SDG&E Energy Control Center at least seventy-two (72) hours before the pre-parallel test and obtain a clearance for parallel operation. The SDG&E representative shall provide the Designated SDG&E Energy Control Center a drawing indicating which SDG&E circuit the Generating Facility will be connected to, and which SDG&E-operated disconnect will be identified with a SDG&E-designated number. When the pre-parallel test is passed, the Generating Unit may at SDG&E’s discretion be allowed to operate in parallel with SDG&E for testing purposes only. This should not be mistaken as an official release for parallel operation.

Once this testing-only permission is granted, the Generator may operate the Generating Unit in accordance with the previously executed Interconnection Agreement for a maximum of fourteen (14) days, or a period previously approved by SDG&E.

If applicable, firm capacity performance testing of new generators cannot begin until the Generator receives written permission from SDG&E.

6.3.2 Power System Stabilizer (PSS)

During the Parallel Operation for Testing period, the Power System Stabilizer shall be calibrated and tested in accordance with the latest WECC standard calibration and test procedures.

Adequate testing of the PSS can only occur on the generating unit(s) after pre-parallel inspection has been satisfactorily completed and the units are paralleled and supplying load. The generation facility shall not be considered officially operational until this PSS calibration and testing has been done to SDG&E's satisfaction.

Failure of the Generator to maintain its PSS could adversely impact system operation. SDG&E reserves the right either to disconnect from, or refuse to parallel with, any Generator that does not operate and maintain its generator control systems in accordance with applicable reliability criteria.

6.3.3 Model Testing and Validation Report

Following WECC guidelines, generation equipment shall be tested to verify that data submitted for steady-state and dynamics modeling in planning and operating studies is consistent with the actual physical characteristics of the equipment. The data to be verified and provided shall include generator gross and net dependable capability, gross and net reactive power capability, voltage regulator controls, speed and/or load governor controls, and excitation systems.

6.3.4 Permission for Parallel Operation

At the end of this period, if the Generator has not received written permission from SDG&E to operate in parallel, the entity must isolate from SDG&E until written permission is received. Written permission to parallel shall be sent to the Generator via U.S. First Class Mail after SDG&E has verified the following:

- All proper contracts and documents have been executed and are in place.
- The pre-parallel test has been passed.
- The Power System Stabilizer tests and calibration have been completed.
- All other outstanding issues have been resolved, including rights-of-way, deeds of conveyance, insurance verification and operating agreements.

- SDG&E has received final copies of the single line diagram and elementary diagrams that show "As-Built" changes made during construction, as well as a completed finalized generator data sheet.
- The Generator has provided a Turn-over letter to SDG&E (see section 5.3.1) affirming that all testing has been completed, and the Generating Facility is ready to be energized from the SDG&E transmission system.

If applicable, firm capacity performance testing of new generators cannot begin until the Generator receives written permission from SDG&E to parallel.

6.4 GENERAL NOTES

- The SDG&E system has A-B-C clockwise rotation
- Any changes to SDG&E-required protection equipment or major substation equipment (e.g., transformers and breakers) must be submitted to SDG&E for review and approval by the appropriate SDG&E engineer prior to the changes being made.
- Protective Relays: Routine maintenance on SDG&E-required protective relays and the breaker(s) must meet SDG&E's maintenance and test practices. After completion of these tests, test reports must be submitted to SDG&E (protection specialist) for review and approval by the appropriate SDG&E engineer. A SDG&E technical representative shall then come to the customer's Generating Facilities and verify the settings.

Attachment

GENERATOR CONTROL AND PROTECTION CHECKLIST FOR GENERATION ENTITIES CONNECTING TO THE SDG&E-OWNED TRANSMISSION FACILITIES

GENERATOR CONTROL & PROTECTION CHECK LIST

Substation or Switchyard at which Generator is Interconnecting to SDG&E-
Owned Transmission Facilities _____

A. Site Drawings

1. Relay Functional 1-line
2. 3-line AC Schematic
3. Circuit breaker control schematic
4. Transformer protection schematic
5. Generator protection schematic(s)
6. Generator breaker control schematic(s)
7. Site Plan

B. Relay Settings

1. Transmission interconnection line relay settings (SDG&E must approve)
2. Step-up Transformer relay settings (SDG&E must approve over-current settings)
3. Generator relay settings (review only)

C. Apparatus Testing (In accordance with Manufacturer's Instructions or Good Utility Practice which may include but not be limited to the following:)

1. Transmission voltage circuit breaker(s)
 - a. Power factor
 - b. Contact resistance
 - c. Timing
 - d. Gas pressure switches
2. Relay circuit CTs
 - a. Ratio

- b. Polarity
- c. Saturation
- 3. Transformer(s)
 - a. Test report
 - b. Power factor test (Doble)
 - c. Insulation test (Megger)
 - d. Transformer Turns Ratio test (TTR)
 - e. Oil Quality/DGA
 - f. Oil Fill Results (log, dewpoint etc.)
- 4. Generating Unit(s)
 - a. Test Reports
 - b. Neutral resistor rating (if used)

D. Control & Protection Testing

- 1. Protective relays
 - a. Calibration reports
 - b. Verify as-left settings
- 2. Protection trip test
 - a. Transmission voltage Circuit Breaker(s)
 - b. Generating Unit Circuit Breaker(s)
- 3. Verify close circuit controls, including synchronizing controls

E. In-service Testing

- 1. High voltage interconnection relays
- 2. Backup interconnection relays

F. Security

- 1. Substation fence installed and locked.

Version History

SDG&E Generation Interconnection Handbook

Update	Section(s)	Date
Original		July 2000
Updated and reformatted the entire handbook	All	August 21, 2008
<ul style="list-style-type: none"> • Inserted reference that optical metering unit CT's and PT's can be used under special circumstances • Inserted web- link to California Public Utility Commission (CPUC) Electric Rule 2 • Inserted reference to reactive power support and voltage control requirements for Small Generator 	1.4 2.4 3.1	August 24, 2010
Deleted reference to California Public Utilities Commission (CPUC) Rule 21 interconnection requirements	3.5.2	June 22, 2011
<ul style="list-style-type: none"> • Updated Section 2.4.1 to include the SDG&E Addendum for the “no taps practice” • Updated the applicability portion of Section 4 • Added version history • Formatting Changes 	2.4.1 4 All	January 22, 2016
<ul style="list-style-type: none"> • Added a new Section 3 titled “Substation Requirements” • Updated Sections 1, 2, 4, 5 and 6 	All	November 30, 2016
<ul style="list-style-type: none"> • Updated Section 2.5.3 • Changed terminology from “SPS” to “RAS” when applicable 	All	December 18, 2017

Appendix A

SDG&E's Screening Criteria for Identifying Existing and Planned Generators that are at Potential Risk for Sub-Synchronous Resonance (SSR) or Sub-Synchronous Control Interaction (SSCI) Oscillation⁴

Background

A capacitor in series with a transmission line creates a resonant frequency. This is not a problem as long as energy is not injected at the resonant frequency. However, a generator which injects power at the resonant frequency can lead to facility damage.

Types of Sub Synchronous Resonance (SSR)

- Torsional Interaction (TI)
 - Torsional interaction between the turbine-generator shaft and the electrical grid.
 - An example of the consequences of unacceptable TI is the damage that occurred to the now-retired Mohave generating station in Arizona.

- Sub-Synchronous Control Interaction (SSCI)
 - The feedback-based control systems of some generators, particularly type 3 wind turbines, can interact with series compensation to produce positive feedback and current amplification at sub-synchronous frequencies.
 - The first instance of SSCI was observed in ERCOT system in October, 2009. The tripping of a 345 kV transmission line resulted in wind generators being radially connected to series capacitors. The undamped oscillations at 22 Hz resulted in voltages at the generator terminals doubling in ~150 milliseconds. Both wind generators and the series capacitors were damaged.

- Induction Generator Effect (IGE)
 - A purely electrical phenomenon due to the flow of sub-synchronous currents in the armature of a synchronous generator creating the appearance of a negative resistance looking in; effectively leading to amplification.

Screening Criteria

- Unacceptable SSR/SSCI may exist where generation is connected with series-capacitors through a susceptible electrical network. A susceptible electrical network may exist if any combination of up to five transmission facility

⁴ Based on "Planning Guide concepts for dealing with Sub Synchronous Resonance in ERCOT & other issues," (ERCOT, Sept 14, 2012 by John Adams)

contingencies would result in the generator being radially connected to a transmission line with series-compensation. Note that this is not meant to imply that a generator has to be radially connected with series compensation for there to be unacceptable SSR/SSCI; the five-contingency test is solely for the purpose of identifying which portions of electrical may be susceptible.

- Identify which N-1, N-2, N-3, N-4 or N-5 contingency conditions could result in a generator being radially-connected to a transmission line with series compensation, in which case the generator is deemed to be connected to a susceptible network and could be subject to unacceptable SSR/SSCI.
 - If connected to a susceptible network, it is recommended that a Level 1 screening study be performed.
- Level 1 screening
 - Grid-side frequency-scan: Inject varying frequencies from generator terminals into the grid model looking for resonant frequencies under the identified contingency conditions in which the generator becomes radially connected with the series compensation. If no resonant frequencies are identified, no SSR/SSCI risk exists. Again, note that this does not mean that the generator actually has to be radially connected with the series compensation in order for unacceptable SSR/SSCI to exist; this is simply an approach for identifying when a risk of unacceptable SSR/SSCI is present.
 - Level 2 screening
 - Machine-side frequency-scan: If Level 1 screening indicates that an unacceptable SSR/SSCI may be present, it is recommended that a machine-side scan be performed. In this technique, varying frequencies below 60 Hertz are injected into a very detailed generator model.
 - Full SSR/SSCI study
 - If Level 2 screening indicates the presence of complementary mechanical resonance frequencies, it could be an indication of SSR/SSCI issues; however it is not absolutely assured. And conversely, the absence of complementary resonance frequencies is not a definite indication of no SSR/SSCI issues. For all cases that Level 1 and 2 screening are not sufficient to demonstrate the risk is negligible -- i.e., some resonance frequencies are identified both in level 1 and level 2 screening -- time domain studies are required. A full time domain SSR/SSCI study requires detailed 3-phase modeling in PSCAD software. SDG&E accepts studies that are only performed in PSCAD.

Series-Compensated lines owned by SDG&E

- 500 kV ECO-Miguel transmission line, 500 kV Ocotillo-Suncrest transmission line, and 500 kV North Gila-Imperial Valley transmission line.

Locations of Generators Connected to SDG&E-Owned Transmission Facilities that may be at Risk of Unacceptable SSR/SSCI

- Based on the N-5 criteria discussed above, generators that may be connected to a susceptible electrical network would be those generators connecting to (i) the ECO 500/230 kV bus, (ii) the Boulevard 138 kV bus, (iii) the Ocotillo 500 kV bus, (iv) the Hoodoo Wash 500 kV bus, or (v) loop-ins of any transmission line connecting these buses.
- It is recommended that synchronous and asynchronous generators connected at these locations undertake the screening discussed above. Generators with rotating mass should be tested for unacceptable SSR (synchronous or type 3 wind turbine generators). Type 4 wind turbine generators and solar PV facilities should test for unacceptable SSCI. If indicated by study results, mitigation should be implemented to protect against the possibility of facility damage based on unacceptable SSR/SSCI.
- SDG&E requests that SSR/SSCI studies conducted by generators be documented in a report and that the report and the underlying model (in PSCAD format) be provided to SDG&E.