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Interconnection Standard for Small Generating Facilities No Larger Than 25kW and 600VAC

Introduction

This document provides a standard for interconnection of distributed resources within the Highline Electric Association (HEA) electric power system with aggregate capacity that is no larger than 25kW and 600VAC. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.

This standard is established to assist the generating facility in understanding the requirements involved in planning and designing an electrical interconnection with the HEA electric system. This standard is a general guideline and may not cover all of the details of the installation. If deviations occur from this standard the changes must be approved by HEA or their designated representative.

All costs associated with the interconnection will be paid by the generating facility including, but not limited to, technical review and analysis by HEA and/or their designated representative.

2.0 General Requirements for Interconnection

2.1 Codes and Standards

The generating facility and its associated equipment must meet all applicable national, state and local construction and safety codes.

The interconnection shall conform to latest revision but not limited to the following:

- Colorado Department of Regulatory Agencies Public Utilities Commission's 4 Code of Colorado Regulations (CCR) 723-3, Part 3, "Rules Regulating Electric Utilities," Section 3665, "Small Generation Interconnection Procedures."
- IEEE Standard 1547, "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems."
- IEEE Standard 1453, "IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems."
- IEEE Standard 519, "IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems."
- IEEE Standard 141(Red Book), "IEEE Recommended Practice for Electric Power Distribution for Industrial Plants."
- IEEE Standard 142 (Green Book), "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems."
- IEEE STD 929-2000, "Recommended Practice for Utility Interface of Photovoltaic Systems."
- UL 1741, "Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources."
- IEEE C-2 (NESC), "National Electric Safety Code."
- NFPA-70 (NEC), "National Electrical Code."

In the event of conflict between these documents, the requirements of this Specification shall take precedence or the more stringent requirement shall be followed. If clarification is necessary, HEA shall be notified for resolution.

2.2 Interconnection Review

The small generating facility should provide HEA with electrical drawings for review prior to equipment procurement. As a minimum a single-line diagram is required indicating the point-of-interconnection, size/type/rating of power conversion device (generator, inverter/kW, kVA, etc.), voltage (single-phase or three-phase), frequency, size/type/rating of fault interrupting device, size/type/rating of manual disconnecting switch, and energy source (solar, wind, hydro, diesel, natural gas, propane, fuel oil, etc.) being used.

If protective relays are used, the drawing package should consist of meter and relay diagrams; three-line diagrams (AC) showing connectivity of relays; and, schematics (DC) indicating tripping schemes for any relays. The single-line meter and relay diagram listing major equipment should be provided to HEA prior to ordering relays. The three-line diagrams and DC schematics should be provided before fabricating panels with protective relays. These may come from the manufacturer and need not be re-drawn.

If protective relays are used, relay settings for the interconnection are to be submitted to HEA for review. HEA will review the settings and may include changes or additions to the settings as warranted by the application.

Within three business days HEA will notify by email or fax provided by the small generating facility that the interconnection request was received.

Within ten business days HEA will notify the small generating facility as to whether the interconnection request is complete or incomplete. If the interconnection request is incomplete a notice that the interconnection request is incomplete will be provided by HEA. The notice will contain a written list detailing information that must be provided to complete the interconnection request. The small generating facility will have ten business days after receipt of the notice to submit the listed information or to request an extension. If the information or a request for extension is not received within the ten business days the interconnection request will be deemed withdrawn.

Within 15 days HEA will conduct an initial review and determine which screening criteria will be used in accordance with CCR 723-3, Part 3, Section 3665, "Small Generation Interconnection Procedures."

Prior to parallel operation, HEA may inspect the small generating facility for compliance with standards, which may include a witness test, and may schedule appropriate metering replacement, if necessary.

2.3 Connection Voltage

Under this standard, small generating units shall be connected on the secondary low voltage (600VAC and less) side of the HEA electrical system, and shall not be connected directly onto the distribution circuit. On the HEA system this is typically 480VAC and less.

A transformer is used by HEA to step-down the distribution voltage to the utilization voltage of the facility. The transformer also allows isolation between the generating facility and other HEA customers when a three-phase inverter is installed. The impedance of the step-down transformer limits fault currents on the generator bus from the HEA electric power system and limits fault currents on the HEA electric power system from the generator. Hence, it reduces the potential damage to both parties due to faults.

Lightning arrestors may be required at the point of interconnection.

2.4 Fault-Interrupting Devices

A low voltage (less than 600VAC) three-phase/single-phase circuit breaker or contactor at the point of interconnection shall automatically separate the small generation facility from the HEA electric power system upon detection of a circuit fault. Additional breakers and protective relays may be installed in the small generation facility for ease in operating and protecting the facility, but they are not required for the purpose of interconnection. The interconnection breaker or contactor shall have sufficient capacity to interrupt the maximum available fault current at its location.

Generally, the interconnection must meet the requirements and latest version of NEC, Article 705, "Interconnected Electric Power Production Sources" and the following specifications apply:

- Normally a low voltage thermal-magnetic circuit breaker is all that is required, however, it is up to the small generating facility to size and determine the fault interrupting capability for the application.
- A fused disconnect switch may be used and will be reviewed on a case by case basis.
- Contactors may be installed and will be reviewed on a case by case basis.
- An external trip signal (shunt trip) may be required to trip the breaker and will be reviewed on a case by case basis.

- For three-phase interconnections, a three-pole device is required due to its simultaneous three-phase operation and ability to coordinate with HEA transformer high-side protection.

2.5 Manual Disconnect Switch

A manual disconnect switch is required for the small generation facility. An HEA-operated disconnect device must be provided as a means of electrically isolating the HEA electric power system from the generator. This device shall be used to establish visually open working clearance for maintenance and repair work in accordance with HEA safety rules and practices. A separate disconnect device must be located at any and all points of interconnection with HEA. The disconnect switch shall be a gang-operated, single-pole, double-pole or three-pole lockable switch as determined by the type of interconnection: single-phase or three-phase. All switch devices must be approved by HEA. HEA will inspect and approve the installation before parallel operation is permitted.

In general, the following specifications apply:

- Disconnect switches shall be furnished and installed by the small generation facility.
- Disconnect switches shall be physically located for ease of access and visibility to HEA personnel.
- Disconnect switches shall be rated for the voltage and current requirements of the particular installation.
- Disconnect switches shall be gang-operated (for other than single-pole switches).
- Disconnect switches shall be weatherproof and designed to withstand exposure to weather and ice.
- Disconnect switches shall be lockable in both the open/closed positions with a standard HEA pad lock.
- Disconnect switches may be fused and will be reviewed on a case by case basis.
- Disconnect switches shall not be used to make or break parallel operation between the HEA electric power system and the generator(s).

2.6 Protective Equipment

Protective Equipment specified in this standard, 4 CCR 723-3, and IEEE 1547 must be installed at locations where the generating facility wishes to operate in parallel with the HEA electric power system. This equipment is used to ensure safe and reliable power system operation and to allow disconnection of the facility's generation in the event of a short circuit or other malfunction. The protection equipment for a small generation facility must protect against faults within that facility and faults on the HEA electric power system. A small generation facility must also trip off-line (disconnect from the HEA electric power system automatically) when power is disconnected from the line into which the unit is generating. HEA uses line-protective equipment to either; 1) automatically clear a fault and restore power, or 2) rapidly isolate only the faulted section so that a minimum number of customers are affected by any outages.

HEA protection requirements are designed and intended to protect the HEA electric power system only. As a general rule, neither party should depend on the other for the protection of its own equipment.

Additional protective relays may be needed to protect the generating facility adequately. It is the generating facility's responsibility to protect its own system and equipment from faults or interruptions originating on both HEA side and the small generating facility's side of the Interconnection. The small generating facility's system protection shall be designed, operated, and maintained to isolate any fault or abnormality that would adversely affect the HEA electric power system or the systems of other entities connected to the HEA electric power system.

The protective relays used for isolating the small generation facility from the HEA electric power system at the Point of Interconnection must be reviewed and approved by HEA. Additional requirements, as to the exact type and style of the protective devices, may be imposed on the generating facility based on the proposed configuration or the type of interrupting device closest to the point of common coupling on the HEA system. Any additional protective equipment required will be at the generating facility's cost. A summary of protective relaying that may be required by the small generating facility is included in Appendix 1.

> Note: Inverters that comply with IEEE STD 929-2000, "Recommended Practice for Utility Interface of Photovoltaic Systems," and UL 1741, "Inverters, Converters, Controllers, and Interconnection System

Equipment for Use with Distributed Energy Resources," have built-in protective relay functions and may not require additional protection. These systems will be reviewed on case by case basis. See Appendix 2 for more information on inverter based systems.

HEA recommends that the generating facility acquire the services of a qualified electrical engineer to review the electrical design of the proposed small generation facility and ensure that it will be adequately protected.

2.7 Safety, Reliability and Power Quality

The small generating facility must design, construct and operate its equipment in a manner that will not degrade the quality of electric service to other HEA customers. HEA reserves the right to specify the quality and determine the adequacy of the small generating facility's equipment, installation and operation in any respect that affects safety, reliability and quality of service.

The generating facility is expected to operate within the limits of voltage, frequency and harmonic distortion outlined in the latest revision of IEEE Standard 1547, IEEE Standard 1453, IEEE Standard 519 and IEEE Standard 141 (Red Book).

Studies, such as a System Impact Study and associated excitation equipment settings shall be at the generating facility's expense.

2.8 Isolated Operation

HEA does not allow isolated operation of the HEA distribution system by a distributed resource under any circumstances. To prevent isolated operation, HEA requires devices to detect and disconnect the distributed resource in the event of a loss of electrical power at the point of interconnection. If the control system of the small generating facility is not capable of detecting faults on the utility system, relays may be required so that the distributed resource can be disconnected when the HEA breaker or recloser opens. In rare cases, transfer tripping equipment may be required and will be reviewed on a case by case basis.

The small generating system is allowed to disconnect and operate independent of the HEA distribution system. Proper synchronizing devices must be in place when the small generating facility parallels back to the HEA electrical system while energized.

2.9 Facility System Disturbances

The small generating facility must disconnect in the event of a disturbance or malfunction of facility equipment to prevent loss of service to other HEA customers.

2.10 Utility System Disturbances

The small generating facility must promptly disconnect from the HEA electric power system in the event of a utility system disturbance. HEA protective relaying will act to promptly disconnect the affected line. The small generating facility on this affected line represents an additional source of power to energize the line. Therefore the generating facility must provide a means to automatically disconnect its generator to avoid isolated operation and protect equipment and personnel.

3.0 <u>Commissioning Test</u>

3.1 Commissioning Testing

Commissioning testing shall be performed on-site to verify functionality and when used, protective relay settings. HEA has the right to witness the commissioning test, and may also require written certification by the installer describing which tests were performed and their results.

In some cases testing may be verified by a certified factory test. In such cases copies of all factory tests shall be submitted for review by HEA. HEA will review the factory test reports and determine if they are acceptable commissioning tests or if more testing is required. Test reports will be reviewed on case by case basis.

Testing shall include visual inspections of the interconnection equipment and when used, protective settings to confirm compliance with the interconnection requirements. The generating facility shall provide HEA with copies of test reports for the particular types of protective devices applied before the generating facility will be allowed to parallel. The cost of performing commissioning testing is the responsibility of the generating facility. Once complete and accepted the commissioning tests do not have to be repeated unless set points are changed.

3.2 Scheduled Testing

After commissioning, the generating facility should perform periodic testing to demonstrating the functionality of the system. The interval between testing is usually specified by the manufacturer of the equipment. Copies of any testing shall be kept by the small generating facility and made available to HEA if requested.

If used, protective relays should be checked and tested every five years. These tests shall demonstrate that the protective relays are functional and within calibration.

HEA will not test the generating facility's equipment, but reserves the right to witness the testing performed by a qualified testing firm retained by the generating facility.

3.3 Testing Qualifications

Individuals qualified in testing protective equipment (professional engineer, factory-certified technician, or licensed electrician with experience in testing protective equipment) must perform commissioning and scheduled testing.

4.0 References

1) Interconnection Standards for Qualifying Facilities, Tri-State Generation and Transmission Association, Inc. September, 1992.
2) IEEE Standard 1547, "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems".
3) Colorado Department of Regulatory Agencies, Public Utilities Commission, 4 Code of Colorado Regulations (CCR) 723-3, Part 3, "Rules Regulating Electric Utilities."
4) IEEE Standard P1547.2, "Draft Application Guide for IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems", Draft 9, September, 2007.
5) PG&E GENERATION INTERCONNECTION HANDBOOK, Section G2, Protection and Control Requirements for Generation Entities, August 6, 2007.
6) IEEE Standard 929-2000, "Recommended Practice for Utility Interface of Photovoltaic Systems."
7) UL 1741, "Inverters, Converters, Controllers, and Interconnection System Equipment for Use With Distributed Energy Resources,"

Appendix 1

A Summary of Protective Relaying

1.0 Protective Relaying

1.1 General requirements

As stated in Section 2.6 (Protective Equipment) of this standard, HEA may require additional equipment if the individual application warrants the use of such equipment. The following is intended as a guide that represents the minimum requirements to provide a safe and reliable interconnection.

If required, protective relays shall be utility grade and must be submitted to HEA for approval. Industrial grade protective relays for interconnection may be acceptable on a case by case basis; however, utility grade relays are preferred. Utility grade relays, used by electric utilities, have much higher reliability and accuracy than industrial grade relays. All utility grade relays must include resettable relay targets, and have 5A nominal AC input current. All utility grade relay power supplies should be powered by battery DC voltage, and the battery system should include a DC undervoltage detection device and alarm.

1.2 Line Protection

If required, line-protection relays must coordinate with the protective relays at the HEA recloser/breaker for the line on which the generating facility is connected. HEA operates a 12.47/7.2kV grounded-wye distribution system. Typical HEA protection is for a long radial line where current can flow in one direction only; typical protective relays for this type of line need to be coordinated in only one direction and may not be directional elements. However, there may be instances where current may flow in either direction depending on system conditions. Relays on these portions of the HEA electric power system must be directional. Such modifications to existing relays will be at the generating facility's cost.

The line protection schemes must be able to distinguish between generation, load, inrush and fault currents. HEA's existing relay schemes may have to be reset, replaced, or augmented with additional relays at the small generation facility's expense, to coordinate with the new generation facility. The minimum protection that HEA typically uses on its own installation is phase overcurrent, ground overcurrent, and reclosing.

If required, relays must be located so that a fault on any phase of HEA's interconnected line(s) shall be detected. If transfer trip protection is required by HEA, the small generation facility shall provide all required communication circuits at its expense.

Some portions of the HEA electric power system have provisions for an alternate feed. In some of these locations, generation may not be allowed on line while being fed from an alternate source due to protection coordination issues. Whenever possible, the small generation facility will be given the option of:

1. Paying for any required upgrades so as to stay on line while transferred to the alternate source, or
2. Accepting shutdowns when transferred to the alternate source and not incurring costs for upgrades to the existing system.

1.3 Generator/Intertie Protection and Control

Single-phase generators should be connected in groups so that an equal amount of generation capacity is applied to each phase of a three-phase circuit. Synchronous generators of any size will require: a) synchronizing relays (Device 15/25), synch check (Device 25), or auto synchronizer to supervise generator breaker closing, and b) reclose blocking at the HEA side of the line to which the generator is connected (applies to substation breaker/recloser and line reclosers).

The protection classes for generator interconnection under this standard are:

- 5 kW and below
- 6-25 kW

The following represents the minimum protection that should be used to provide a safe and reliable interconnection. HEA may require additional equipment if the individual application warrants the use of such equipment. Additional generator protection may be determined by HEA on a case-by-case basis.

- Protective Relaying, 5 kW and below:
    - Short Circuit Protection:
        - Thermal-magnetic circuit breaker
        - Devices 50/51 and 51V as applicable on case by case basis.
        - Device 51V not required on induction machines.
    - Isolation Protection:
        - Devices 27, 32, 59, 81O, 81U
        - Device 32 is required for peak shaving and no-sale applications where the generating facility is operating in parallel with the HEA electric power system.
        - May be only protection required on inverters.
    - Breaker Closing/Reclosing Control:
        - Devices 25, 27R on any synchronous machine.
        - Device 25 not required on induction machines.
    - Ground Fault Protection:
        - Devices 51N or 51G as applicable on case by case basis.
    - Overspeed protection if applicable.

- Protective Relaying, 6-25 kW:
    - Short Circuit Protection
        - Thermal-magnetic circuit breaker
        - Devices 50/51 and 51V as applicable on case by case basis.
        - Device 51V not required on induction machines.
    - Isolation Protection
        - Devices 27, 59, 81O, 81U.
        - Device 32 is required for peak shaving and no-sale applications where the generating facility is operating in parallel with the HEA electric power system.
        - Only protection required on inverters.
    - Breaker Closing/Reclosing Control
        - Devices 25, 27R on any synchronous machine.
        - Device 25 not required on induction machines.
    - Ground Fault Protection
        - Devices 51N or 51G as applicable on case by case basis.
    - Over/under-speed control for induction generators
        - Device 15

1.4 Circuit Breaker/Circuit Switcher (Device 52)

A three-phase, three-pole, single-phase one-or two-pole circuit breaker is the preferred fault-interruption device at the point of interconnection due to its simultaneous operation and ability to coordinate with HEA line-side devices.

1.5 Phase Overcurrent (Device 50/51)

A phase overcurrent device provides tripping of the circuit breaker in the event of a phase fault. Phase overcurrent relays are to be coordinated with HEA line-side devices. Overcurrent protection can also be used to detect a line-end fault condition. A phase instantaneous overcurrent relay that can see a line fault under sub-transient conditions may also be used. A phase instantaneous overcurrent relay is generally not required if a 51V relay is used.

1.6 Phase Overcurrent Relay with Voltage Restraint/Voltage Control (Device 51V)

These relays are used to detect multi-phase faults and initiate a generator circuit breaker trip. These relays are located on the individual generator feeder. An overcurrent relay with voltage control may also be acceptable if it can be set to adequately detect end-of-line faults as verified by HEA protection studies.

- Phase Overcurrent with Voltage Restraint (51V) – suggested settings:
  - Pickup: 125-150% of generator FLA @ 100% Voltage Restraint.
  - Time: Above the knee of the generator decrement curve with constant excitation and coordinated with the downstream HEA feeder relay setting.
- Phase Overcurrent with Voltage Control (51V) – suggested settings:
  - Pickup: 80-90% of generator $I_d = 1/X_d$.
  - Time: Above the knee of the generator decrement curve with constant excitation and coordinated with the downstream HEA feeder relay setting.

Note: The 51V function is not useful for induction generators since, if the voltage is low enough to enable overcurrent protection, the generator excitation will not be sustained.

1.7 Under/Overvoltage Relay (Device 27/59)

This protection is used to trip the circuit breaker when the voltage is above or below HEA's normal operating level. Relays will operate for generator protection and backup protection in the event that the generator is carrying load that has become isolated from the HEA electric power system.

- Overvoltage (59) – settings:
  - 110%< Voltage < 120% of nominal @ 1.0 sec (60 cycles)
  - Voltage > 120% of nominal @ 0.16 sec (9.6 cycles)
- Undervoltage (27) – settings:
  - Voltage < 50% of nominal @ 0.16 sec (9.6 cycles)
  - 50% < Voltage < 88% of nominal @ 2.0 sec (120 cycles)

Note: Inverters that comply with IEEE STD 929-2000, "Recommended Practice for Utility Interface of Photovoltaic Systems," and UL 1741, "Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources," have built-in 27/59 functions. If an inverter lacks these functions, then 27/59 relay protection must be installed. See Appendix 2 for more information on inverter based systems.

1.8 Reverse Power Relay (Device 32)

The reverse power relay is used when the small generating facility is operating in parallel with the HEA electric power system and power export is not allowed. A directional power element may be set to look either forward or reverse. When set to detect power export (reverse power), the relay may be set to trip at a level below the expected minimum utility feeder load that the small generating facility would supply if islanded. When set to detect power import (forward power), the relay may be set to trip at a level below the minimum expected power import level. This relay is not used for fault protection, but can prevent damage to other HEA customers.

1.9 Over/Under Frequency Relay (Device 81 O/U)

This protection is used to trip the circuit breaker when the frequency is above or below HEA's normal operating level. It is used for generator/turbine protection and backup protection. Generator underfrequency relay settings are coordinated with other utilities in the Western Electricity Coordinating Council (WECC) to maintain generation on line during system disturbances. Relays shall not be set for a higher frequency or shorter time delay than specified without prior written approval by HEA.

- Less than 25kW – settings:
  - Over Frequency (81O)
    - 60.5 Hz @ 0.16 sec (9.6 cycles).
  - Under Frequency (81U)
    - 59.3 Hz @ 0.16 sec (9.6 cycles).

  Note: Inverters that comply with IEEE STD 929-2000, "Recommended Practice for Utility Interface of Photovoltaic Systems," and UL 1741, "Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources," have built-in 81O/U functions. If an inverter lacks these functions, then 81O/U relay protection must be installed.

1.10 Synchronizing (Device 15/25) and Synch-Check (Device 25)

The application of synchronizing devices attempts to ensure that a synchronous generator will parallel with the utility electric system without causing a disturbance to other customers and facilities (present and in the future) connected to the same system. The protection also works to ensure that the generator itself will not be damaged due to an improper parallel action. Synchronous generators and other generators with stand-alone capability should use one of the following methods to synchronize with the HEA electric power system:

- Automatic synchronization (Device 15/25) supervised by a synch-check relay (Device 25) to synchronize with the HEA electric power system. The synch-check relay must have the characteristics listed below.

- Manual synchronization with supervision from a synch-check relay (Device 25) to synchronize with the HEA electric power system. The synch-check relay must have the characteristics listed below.

- Manual synchronization with synchroscope and synch-check (Device 25) relay supervision. The synch-check relay must have the characteristics listed below.

- The synch-check relay must have all of the following characteristics:
  - Slip frequency matching window of 0.3 Hz or less
  - Voltage matching window of ± 10 percent or less
  - Phase angle acceptance window of ± 20 degrees or less

  Note: A synch-check function is not needed on induction generators. Unlike synchronous generators, induction generators are not synchronized before paralleling to the electric utility system.

1.11 Ground Fault Sensing Scheme (Device 51G)

The ground fault sensing scheme detects HEA electric power system ground faults and trips the generator breaker or the generating facility's main circuit breaker, thus preventing the small generation facility's generator from continuously contributing to a ground fault. This scheme should detect faults between the HEA system side of the dedicated transformer and the end of HEA's line. The following transformer connections, along with appropriate relaying equipment, are commonly used to detect system ground faults:

- System side - grounded wye; generator side - delta
- System side - grounded wye; generator side - wye; tertiary - delta

In general, a ground overcurrent relay (Device 51G) is installed in the step-up transformer neutral (primary voltage side).

- Ground overcurrent (51G):
  - Pickup: must be set above the HEA electric power system unbalance.
  - Time: set above feeder relays and coordinated with the slowest downstream feeder relay ground setting.

For induction generators less than 25kW covered under this standard, ground fault detection is not required.

Appendix 2

Generation and Power Conversion Technologies

1.0 <u>Generation and Power Conversion Technologies</u>

1.1 Synchronous Generators

The generating unit should meet all applicable American National Standards Institute (ANSI) and Institute of Electrical and Electronic Engineers (IEEE) standards. The prime mover and the generator should operate within the nominal range of voltage and frequency excursions that may occur on the HEA electric power system without damage to them. The generating unit should be able to operate through the specified frequency ranges for the time durations in this standard, to enhance system stability during a system disturbance.

1.2 Asynchronous (Induction) Generators

Conventional induction generators and other generators with no inherent VAR (reactive power) control capability require an amount of reactive power to maintain power factor between 90 percent lagging and 95 percent leading to maintain the required voltage on the HEA electric power system. They may also be required to follow a HEA-specified voltage or VAR schedule on an hourly, daily or seasonal basis, depending on the location of the installation.

Note: Double-fed asynchronous machines, also known as double-fed induction generators (DFIGs), are a distinct class of asynchronous generators, employing wound rotor induction machines with static power converters to drive the rotor field currents. The physical rotational speed of the machine can be varied over a wide range, both faster and slower than the synchronous speed. Unlike an ordinary induction machine, a double-fed asynchronous generator can supply or absorb reactive power, which allows power factor or net reactive flow to be easily and quickly controlled. In general, DFIG technology is widely used in wind generation.

1.2.1 Excitation

Conventional induction machines will not be allowed to be self-excited by nearby distribution capacitors, or as the result of capacitive voltage on the distribution network. Entities utilizing conventional induction machines shall provide their own excitation VARs such that the generating facility will not normally demand reactive power from, nor supply reactive power to, the HEA electric power system. Power factor correction capacitors (switched or fixed), power electronics designed to supply a level of reactive capability, or a combination of devices used for excitation shall be provided and installed at the generating facility's expense. The generating facility shall not disable power factor equipment while induction machines are in operation.

1.2.2 Voltage Regulation

Speed matching may be by any means such that voltage regulation and voltage flicker are held within tolerance.

1.2.3 Dynamic Voltage Support

Wind farms or other induction technologies shall also be able to provide sufficient dynamic voltage support and automatic voltage regulation at the generator excitation system if it is determined that voltage support is required for system safety and reliability.

1.2.4 Crowbar

In some double-fed induction generators (DFIG), a "crowbar" circuit can be added to the rotor side of the frequency converter to provide overcurrent protection and overvoltage control to the rotor winding. The crowbar circuit limits the transient current in the stator and the rotor to less than 1 per unit for close-in and multiple-phase faults. It consists of a protection circuit that rapidly short-circuits (or "crowbars") the supply line if the voltage or current exceeds defined limits.

1.3 DC Generators

Static power converters (inverters) convert DC electricity into AC electricity and offer additional electronic power conversion. They are sometimes referred to as power conditioning systems. Their fundamental role is to convert DC or non-synchronous AC electricity from a prime mover energy source into a synchronous AC system of voltages that can be smoothly and easily interconnected with the electric power system.

1.3.1 Inverters Capable of Stand-Alone Operation

Inverters capable of stand-alone operation are capable of islanding operation and shall have similar functional requirements as synchronous generators. For units less than 25 kW, usually it is acceptable to have the frequency and voltage functions built into the electronics of the inverter if the set points of these built-in protective functions are tamper-proof and can be easily and reliably tested. These relay functions must receive HEA approval before they can be used to interconnect with the HEA electric power system. The total harmonic distortion in the output current of the inverters will be required to meet ANSI/IEEE 519 requirements.

Inverter-type generators that have been pre-approved by HEA can be connected to the HEA electric power system. For units over 10 kW, a dedicated transformer may be required to minimize the harmonics entering into the HEA electric power system.

1.4 Emergency Generator Requirements

There are two methods of transferring electric power supply between the HEA source and the emergency generator system: open transition (break before make) and closed transition (make before break).

1.4.1 Break Before Make

This method can be accomplished via a double throw transfer switch or an interlock scheme that prevents the two systems from operating in parallel. The small generation facility's main breaker shall not be allowed to close until the generator breaker opens. This open transition method does not require any additional protection equipment; however, it does cause the small generation facility's load to experience an outage while transferring back to HEA. The length of this transfer depends on the transfer equipment.

The “break before make” transfer switch must be of a design, or have an interlock, that prevents the transfer switch from closing and connecting the customer’s system with HEA unless the emergency generator is already removed from the system.

1.4.2 Make Before Break

This method is used when the customer wants to minimize any loss of power or disturbance to the electric load. With this scheme, the customer's generator and the HEA electric power system are in parallel for a very short time interval during which the customer's load is being transferred between the HEA source and the emergency generator. Both the transfer from HEA to the emergency source and the transfer back can be accomplished without an outage.

“Make before break” transfer switches:

- The transfer switch is rated for the maximum available fault duty in the event that the transfer switch closes into a fault condition.
- Have an interlock that will trip the main breaker or generator in the event of a failure of the transfer switch so that the unit will not remain paralleled to the HEA electric power system. One way to accomplish this function is with a “failure-to-open” timer.
- The controls for the transfer switch prevent a parallel condition of the customer generator and the HEA electric power system from existing for an extended time period. Any system that allows a parallel condition to exist for greater than 100 milliseconds (6 cycles) on the distribution system will be subject to the additional parallel operation guidelines outlined in this standard.

Disconnect switches:

- The customer provided manual disconnect is located at the point of interconnection, which will establish a visually open safety clearance for HEA personnel working on the HEA electric power system.
- The disconnect is lockable in either the open or closed positions and operated only by HEA.
- The disconnect is easily accessible, preferably located adjacent to the electric meter.
- The disconnect has full load break capability.

The make before break transfer scheme must have adequate control and protection to ensure the HEA and customer electric systems are in synchronism prior to making the parallel connection. Synchronization is accomplished through the use of an auto-synchronizer (Device 15/25) or a synchronizing relay supervised by a synch-check relay (Device 25).

Since the emergency generators are paralleled with the HEA electric power system, protective devices are installed that will prevent the customer’s generator from remaining connected in the event of a fault on the HEA electric power system during the transition.

In some installations, the protection requirement may be satisfied through the installation of the reverse power relay (Device 32R). This relay should be installed on the customer’s side of the service transformer that is connected to the HEA electric power system. The relay should trip the customer’s main breaker and must be able to detect transformer core magnetizing power. In this manner, reverse power flow is detected before it actually enters the HEA electric power system and other customers’ equipment. This can be accomplished by setting the current level pick up equivalent to 60 percent of the transformer bank magnetizing current. Because this current value will be small, the current transformers associated with the relay must be capable of accurately providing these small currents to the relay.

When transferring the customer’s load back to the HEA electric power system, it is possible to have incidental power flow back to HEA’s system. By properly setting the synchronizing and/or generator control, this reverse flow can be avoided. However, a short time delay may be required on the reverse power relay to prevent it from tripping the generator unnecessarily each time a transfer is attempted. At no time should this time delay exceed 100 milliseconds (6 cycles).

Again, since the emergency generator is briefly connected in parallel with the HEA electric power system, all transfer schemes of this type must have a dedicated transformer to reduce the possibility that any transfer activities will affect other HEA customers. A dedicated transformer is also necessary to allow the installation of the reverse power relay scheme.