DISTRIBUTED GENERATION INTERCONNECTIONS: PROTECTION, MONITORING, AND CONTROL OPPORTUNITIES

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INTRODUCTION

Paralleling a Distributed Generation Supply to an Electric Power System (EPS) involves protection, monitoring and control of the interconnection for the mutual benefit of both parties to the Interconnection. Standards exist that cover the various practices for the types of distributed energy technologies, sizes, and configurations of the interconnection. Appendix I is a list of these standards and codes.

Ten-point action plan for reducing barriers to distributed generation

A. Reduce technical barriers
- (1) Adopt uniform technical standards for interconnecting distributed power to the grid.
- (2) Adopt testing and certification procedures for interconnection equipment.
- (3) Accelerate development of distributed power control technology and systems.

B. Reduce business practice barriers
- (4) Adopt standard commercial practices for any required utility review of interconnection.
- (5) Establish standard business terms for interconnection agreements.
- (6) Develop tools for utilities to assess the value and impact of distributed power at any point on the grid.

C. Reduce regulatory barriers
- (7) Develop new regulatory principles compatible with distributed power choices in both competitive and utility markets.
- (8) Adopt regulatory tariffs and utility incentives to fit the new distributed power model.
- (9) Establish expedited dispute resolution processes for distributed generation project proposals.
- (10) Define the conditions necessary for a right to interconnect.

Standards are under development that cover the various practices for the types of distributed energy technologies, sizes, and configurations of the interconnection The blackouts and shortfalls in central power station capacity since 1996 in California, Illinois, New York, and other regions brings the Distributed Generation (DG) solution to the forefront. The production of electrical energy from a customer's site has significant economic effects on the transmission and distribution systems of the electric utility provider. Small drop-and-run power plants such as microturbines, fuel cells, solar, wind, reciprocating engines, and gas turbines can provide substantial additional power to meet the provider's peak loads. The hurdles to DG continue to be the resolution of important policy issues including interconnection interfaces, standby charges, stranded costs, siting and permitting for the DG.

The main technical interconnection question today is how to interface DG energy resources with existing electric power systems in a reliable, safe, and cost-effective manner. Figure 1 illustrates the complexity and the interaction between DG and the interconnected electric power system. The four areas are as follows:

1. Isolated, no grid source
2. Isolated with automatic transfer
3. Grid interconnection, no power export
4. Grid interconnection, bi-directional power flow

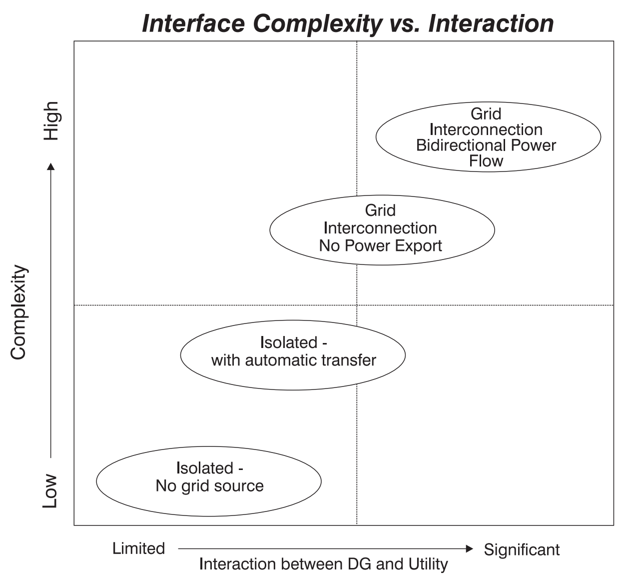


Figure 1: Complexity and interaction between DG and interconnected electric power system

Figure 2 is a typical single line diagram of an interconnection. The major power apparatus is shown. Figure 3 lays out the complexity of five different configurations of interconnections, relating the type of interconnection with the least complex to the most complex.

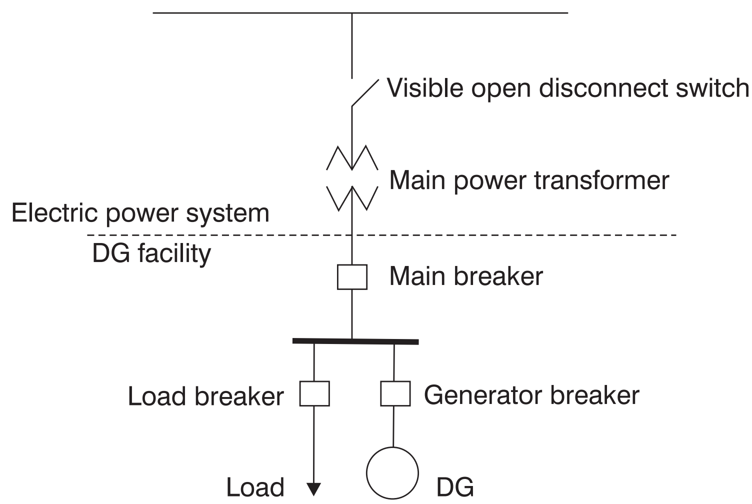


Figure 2: Typical interconnection one-line diagram

The interconnection concerns from the electric utility point of view, as illustrated by recent surveys, include the reliability of the existing grid, the safety of electric power system personnel, and quality control. The key to achieving a working implementation of DG will be the introduction of universal technical standards that permit standardized grid interconnection while maintaining power system stability and worker safety. In the winter of 1999, the Institute of Electrical and Electronic Engineers (IEEE) began devising a universal interconnection standard, currently called IEEE P1547. Its purpose is to set forth a uniform standard for interconnection of distributed resources 10 Mva or smaller with electric power systems. The requirements relevant to performance, operation, testing, safety, and maintenance of the interconnection are also included in the emerging standard. This document is presently scheduled for the IEEE Standards Board review in early 2002. The states of California, Texas, New York, and others have set forth their own interconnection requirements that presently are being implemented.

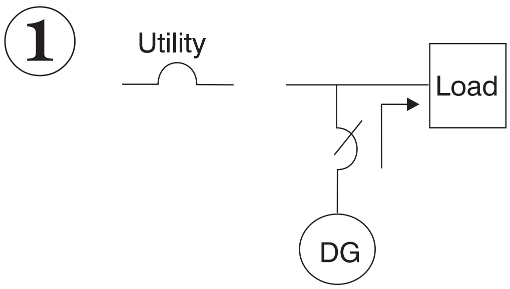
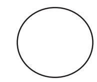
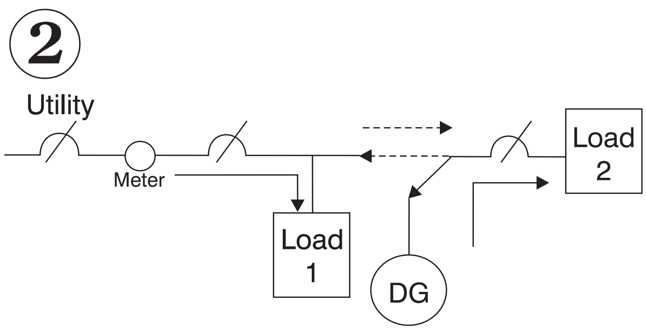
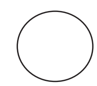
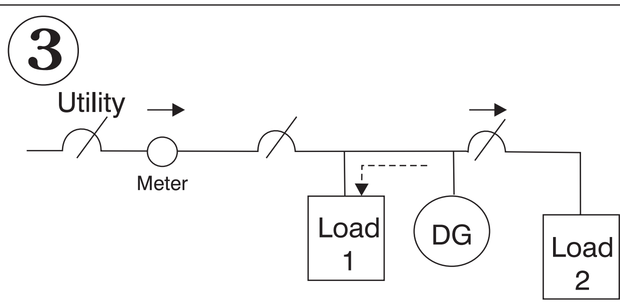
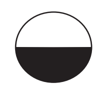
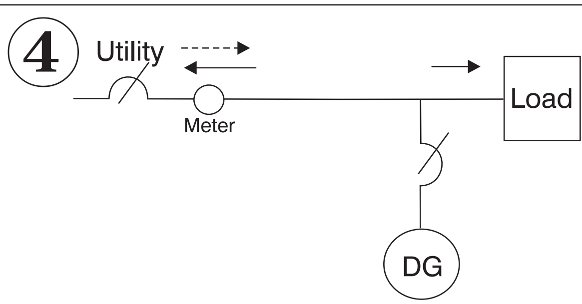
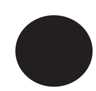
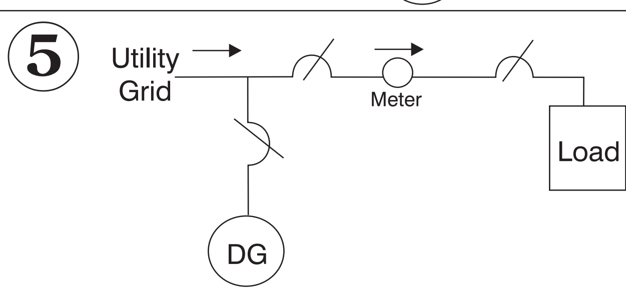
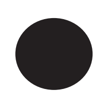
CONFIGURATION	TYPE	COMPLEXITY
	Grid-disconnected - DG provides power for all loads completely isolated from grid. - Utility provides no backup or supplemental power.	
	Grid-connected/ Not parallel - DG provides power to Load 2 for peaking, baseload, or backup power. - Utility provides power to Load 1 and occasionally Load 2.	
	Grid-connected/parallel/ Without Export - DG provides peaking or baseload power to all or some loads. - DG does not export power to the grid. - Utility provides any supplemental or back up power.	
	Grid-connected/parallel/ With Power Export - DG provides peaking, or baseload power to load and exports power to grid. - Utility may provide supplemental and backup power.	
	Utility-Side DG - DG provides peaking, baseload, or backup power for utility to provide to customer.	

Figure 3: Five different interconnection configurations

Figure 4 is a schematic of the interconnection system illustrating the approach taken in the development of the IEEE P1547 Draft standard for the interconnection system between a DG and a Wires Owner's Electric Power Systems.

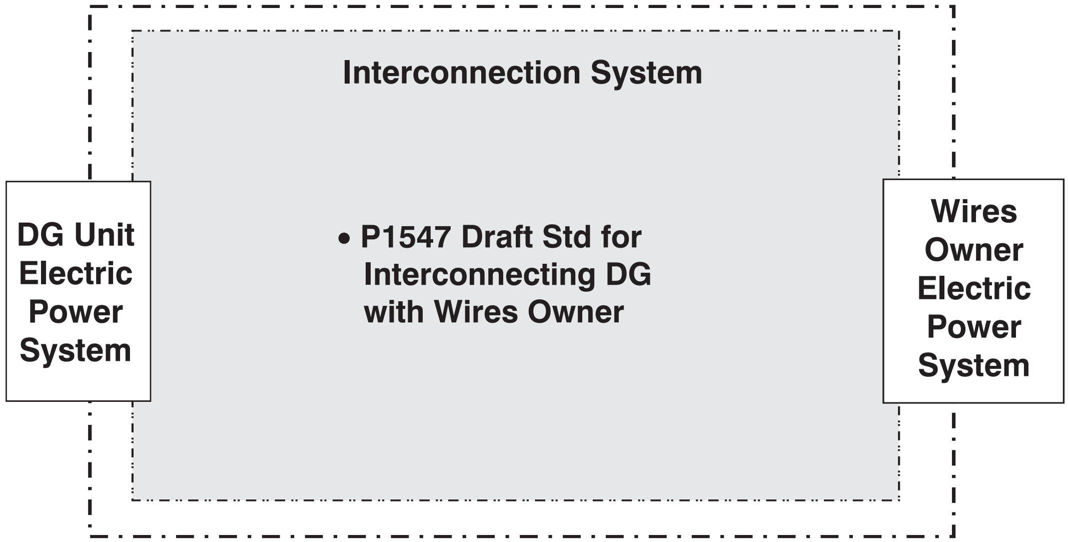


Figure 4: Schematic of Interconnection system

TYPICAL DG INTERCONNECTION REQUIREMENTS

PURPOSE

A typical interconnection standard for DG establishes the criteria and requirements for the interconnection of distributed resources with distribution systems. It may conform to the emerging IEEE P1547 interconnection Standard, now a work in progress and close to completion. Specifically this document describes the design and testing requirements of generator interconnection to the electric utility distribution system. The requirements established in this document cover a broad spectrum of interests. The addition of a distributed resource to the distribution system may change the system and its response. Attaining a technically sound and robust interconnection among distributed resources and the distribution system mandates diligence on the part of everyone involved in the inter-connection,including designers, manufacturers, users, owners, and operators of both electric power systems as part of the interconnection requirements. This requirement needs to be understood cooperatively among the aforementioned groups and met.

LIMITATIONS

The criteria and requirements are applicable to all distributed resource technologies and to the primary and secondary voltages of the electric Power systems. Installation of DGs on the radial primary and secondary electric power systems is the main emphasis of the IEEE. The requirements may be met at the Point of Common Coupling (PCC), although the location of protective devices may not be at the PCC.

Figure 5 illustrates the relationship of the interconnection system terms for the purpose of this typical DG interconnection requirements.

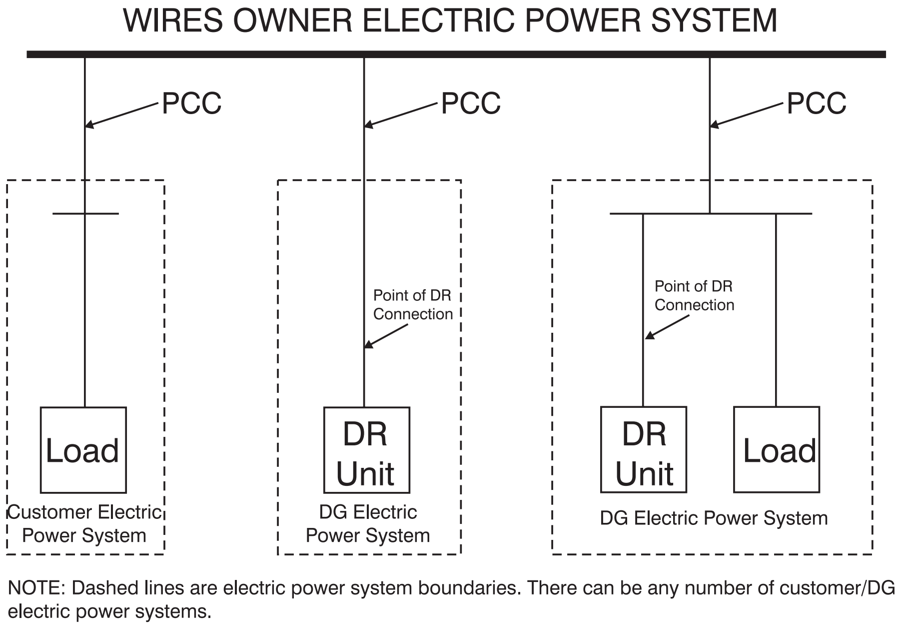


Figure 5: Relationship of interconnection terms

DEFINITIONS

Distributed Generation (DG)—Electric generation facilities connected to a Distribution System through the Point of Common Coupling. Distributed Generation is a subset of Distributed Resources.

Distributed Resources (DR)—Sources of real electric power that are not directly connected to the bulk power system. It includes both generators and energy storage technologies.

Distribution System—Any facilities that allow electric power to be delivered to a load regardless of ownership.

Island—A condition in which a portion of the Wires Owner's system is energized by one or more power producer generators through their PCC(s) while electrically separated from the rest of the Wires Owner system.

Parallel (Operation)—With the Wire Owner will be used to refer to any electrical condition between the Wire Owner and the Power Producer's generation equipment.

Point of Common Coupling (PCC)—Will be used to refer to the point where the electrical facilities or conductors of the Wires Owner are connected to the Power Producer's facilities or conductors, and where any transfer of electric power between the Power Producer and the Wire Owner takes place.

Power Producer—Will be used to refer to anyone interconnected to the Wires Owner System for the purpose of generating power.

Stabilized—Will be used to refer to the Wires Owner's distribution system returning to a normal range of voltage and frequency for 5 minutes or a time coordinated with the Wires Owner, following a disturbance.

Target (Operation Indicator)—A supplementary device operated either mechanically or electrically to visibly indicate that a relay or device has operated or completed its function.

Telemetering—Transmission of measurable quantities using telecommunications techniques.

Visible-break Disconnect—A disconnect switch or circuit breaker by means of which the generator and all protective devices and control apparatus can be simultaneously disconnected entirely under full load from circuits supplied by the generator. The switch or breaker shall be provided with the means for adequate visible inspection of all contacts in the open position, and the blades or moving contacts shall be connected to the generator side.

Wires—The Host Utility's distribution system below 25kV to which the generation equipment is interconnected.

Wires Owner—The Host Utility owning the Utility System.

GENERAL INTERCONNECTION REQUIREMENTS

When a customer desires to establish a parallel interconnection with the utility, there are formal procedures to follow that will ensure a sound technical basis for the proposed interconnection asset. These technical and application procedures are summarized in the following table.

1. Planning for the interconnection asset
2. Designing the interconnection asset
3. Constructing the interconnection asset according to the planning and design drawings agreed to during the application phase of the project.
4. Verification testing and commissioning testing of the completed construction phase.
5. Initial operation of the parallel interconnection, operations training, and recording the performance of the interconnection system.
6. Operation and maintenance of the interconnection asset for the life of the asset.

Any customer may operate 60 Hertz, three phase or single phase generating equipment in parallel with an electric utility system in accordance with the utility's interconnection and operating agreement, provided the equipment of the customer meets or exceeds the requirements of the utility.

PROTECTION AND CONTROL REQUIREMENTS

Refer to Table 1 and Figure 6 for Summary Table and Single Line Diagram showing typical interconnection requirements.

Control, Protection and Safety Equipment
Three Phase connected to Secondary or Primary system

Device Number	Generator size classifications:		Small	Small	Small / Medium	Medium	Medium	Large
			10kW or less	11kW-200kW	200kW-500kW 500kVA-1000kVA<600V	500-2,000kW	2001-10,000kW	12,500-50,000kVA
	Interconnect Disconnect Device		**X**	**X**	**X**	**X**	**X**	**X**
	Generator Disconnect Device		**X**	**X**	**X**	**X**	**X**	**X**
25	Synchronizing Check		Y-manual/auto	Y-manual/auto	Y-manual/auto	Y-automatic	Y-automatic	Y-automatic
		Qty.:	(1)	(1)	(1)	(1)	(1)	(1)
27	Undervoltage Trip		Y	Y	Y	Y	Y	Y
		Qty:	(3)	(3)	(3)	(3)	(3)	(3)
32	Power direction/Reverse power		Y	Y	Y	**X**	**X**	
		Qty:	(1)	(1)	(1)	(1)	(1)	
46	Negative Phase Seq Overcurrent				X	**X**	**X**	**X**
	(Phase unbalance, rev ph seq)					(1)	(1)	(1)
51V	Overcurrent, voltage restrained		**X**	**X**	**X**	**X**	**X**	**X**
	(Opt: to prevent nuisance trips)	Qty:	(1)	(1)	(1)	(3)	(3)	(3)
50/51	Instantaneous/Timed O/current		**X**	**X**	**X**	**X**	**X**	**X**
		Qty:	(3)	(3)	(3)	(3)	(3)	(3)
50N	Instantaneous Neutral O/current				**X**	**X**	**X**	**X**
		Qty:			(1)	(1)	(1)	(1)
51G	**Ground Overvoltage Trip or**				**X**	**X**	**X**	**X**
	Ground Overcurrent Trip	Qty:			(1)	(1)	(1)	(1)
TT	Transfer Trip				Y	Y	Y	Y
	(Based on Feeder Load)							
	Telemetry data communication				Y	Y	Y	Y
	Auto Voltage Regulation						X	X
		Qty:					(1)	(1)
59	Instantaneous Overvoltage Trip		Y	Y	Y	Y	Y	Y
	(for ferroresonance conditions)	Qty:	(3)	(3)	(3)	(3)	(3)	(3)
59T	Overvoltage Trip		Y	Y	Y	Y	Y	Y
		Qty:	(3)	(3)	(3)	(3)	(3)	(3)
60	Voltage Balance Relay							**X**
								(1)
67/67N	Directional Overcurrent		Y	Y	Y	Y	Y	Y
		Qty:	(3)	(3)	(3)	(3)	(3)	(3)
81O, 81U	Over/Underfrequency Trip		Y	Y	Y	Y	Y	Y
		Qty:	(3)	(3)	(3)	(3)	(3)	(3)
	Anti-islanding for inverters		Y	Y	Y	Y	Y	Y
	IEEE 929 AND UL 1741							

Table 1: Protection functions versus generator size for three phase synchronous generators

Notes for Table 1:

1. For synchronous and other types of generators with standalone capability.
2. Only required on synchronous generators that are for on-site load only. If NOT exporting and generator is less than minimum load of customer, or if always exporting, then relay not required except as noted.
3. If exporting, frequency blocks under trip with agreement of Host Utility.
4. May be required as part of a transfer tripping/blocking protective scheme.
5. Exporting to the Wire Owner may require additional operational/protection devices and will require coordination of operations with the Wire Owner.
6. Selection depends on grounding system, if required by Wire Owner.
7. Quantity shown in brackets below, e.g. (3).
8. Bold X is IEEE Std. 242 protection requirement.
9. Three Directional Overcurrent relays may be substituted for Reverse Power relay.
10. Transfer Trip required for synchronous machines.
11. Above to be in accordance with Electrical Codes.

NOTES:

1. Use one or other for simultaneous 3 phase switching. Simultaneous 3 phase switching is not required for non-export static power converters or induction generators not susceptible to self-excitation.
2. Required only if ferroresonance is possible.
3. Required if 27 operating time is too slow for feeder faults.
4. Use one or other only if feeder unbalance can cause transformer overloading.
5. For export only: For synchronous generators and generator susceptible to self-excitation (induction and static power converters).
6. For non-export only: Must sense both real and reactive power. Three 67 relays and one 67N relay also may be required.
7. To suppress a possible ferroresonance condition when the low voltage system is operated ungrounded.
8. Number and location of the metering points by commercial parameters.
9. Required if feeder load unbalance will overload transformer.
10. Also can be solidly grounded.
11. Breaker "B" may be used as breaker failure backup to interconnecting breaker "A".

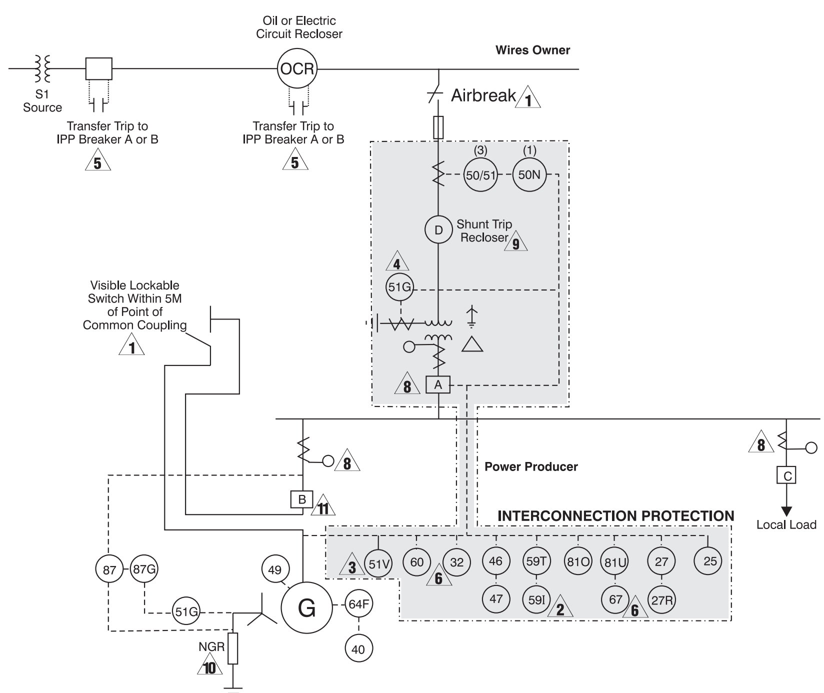


Figure 6: Wye-Delta Interconnection Transformer Connection Single Line Diagram -Protection and Control Requirements

Typical Implementation, DG Interconnection, Protection, Monitoring, and Control Opportunities

A. SCOPE

The project is to implement a parallel interconnection between a Power Producer and a Wires Owner. The steps required to implement the interconnection includes the following:

1. Make Application to the Wires Owner for a parallel interconnection
2. Prepare the required Single Line Diagrams, Proposed Design, Type of Generator, Fuel Source, and Type of Service desired.
3. Receive approval of the Wires Owner to proceed with the Interconnection.
4. Finalize the Design, Construction, Testing, Interconnection Agreement, and Operation and Maintenance Agreement between the Power Producer and the Wires Owner.
5. Proceed with the construction of the generator and the interconnection.
6. Inspect the installation periodically during construction.
7. Review Type Testing submittals and witness them where necessary.
8. After completion of construction begin Start-up and Design Verification Testing.
9. Energize Generation and Interconnection Facilities
10. Document all functional testing using modern technology such as Numerical Protection Systems as recorders and event loggers before loading and after loading the generator and the interconnection facility.
11. Place in operation and begin maintenance planning for the asset.

B. INTERCONNECTION PROTECTION SINGLE LINES

To review the required protection for the reliability and performance of the proposed facility, there are four increasingly complex levels to get the job done:

- Level 1 - **Protection requirements for operating the interconnection system for system disturbances that occur when the two electric power systems are operating in parallel.**
- Level 2 - **Additional protective functions to increase the level of protective elements to enhance the detection of harmful currents while operating in parallel.**
- Level 3 - **Additional protective functions enhance control during normal operation.**
- Level 4 - **Additional control functions.**

Figure 7 is the single line diagram illustrating the performance capability of the least complex alternative - Level 1.

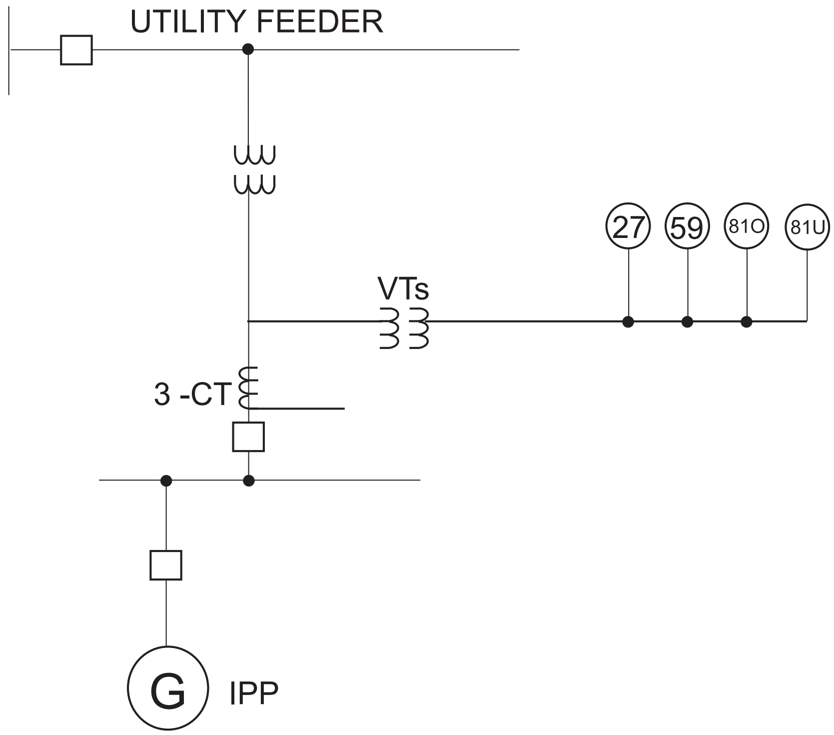


Figure 7: Level 1 (Least complex alternative)

The purpose of the 27/59 and 81U/O functions shown in Figure 7 is to separate the two electric power systems and allow the system with the disturbance to recover to its steady state conditions before restoring the systems to parallel operation. Recording of the system conditions before, during and after the disturbance by the interconnection protection systems available today is a must. The recording of targets, fault current levels, sequence of events, and oscillographic information removes all doubt as to why the tie line tripped. Older technology did not have this capability at a reasonable cost.

Figure 8 is the single line diagram for Level 2 and increases the performance capability for protection, however it also adds complexity due to closer interaction between the operating systems. Additions include Overcurrent Protection for system fault conditions and unbalance voltage and current (51C or 51V, 67, 46) and additional voltage protection (59N/G, 27N, and 47).

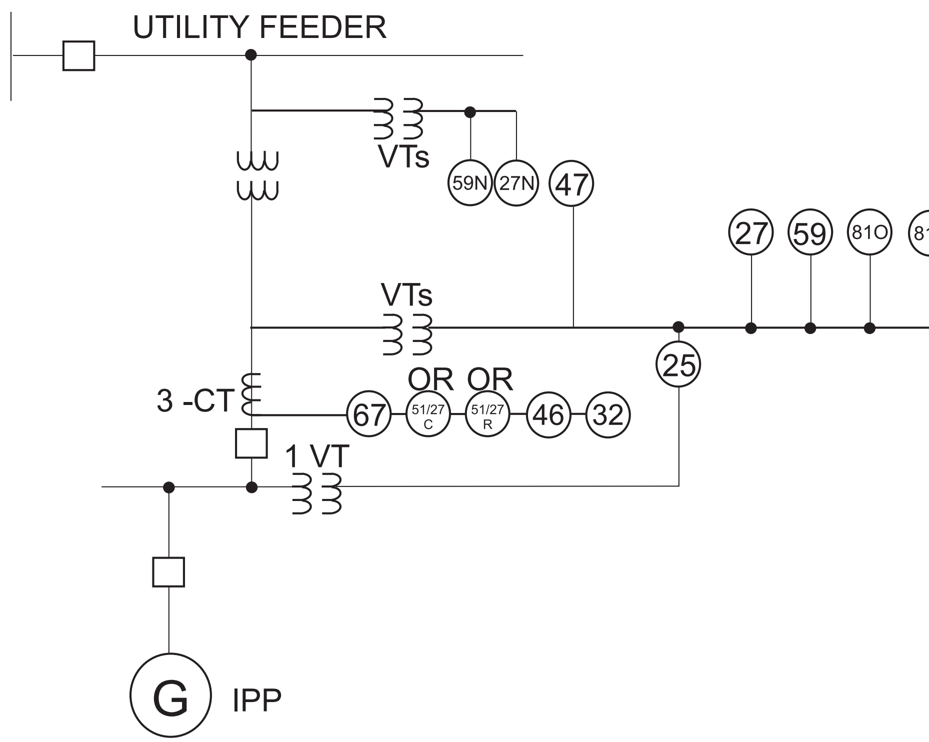


Figure 8: Level 2 (Increased performance capability)

The addition of time overcurrent with voltage controller or voltage restrained control allows for more selectivity to differentiate fault current from overload current when system fault current levels and overload levels are close, due to a low system stiffness ratio. The addition of directional overcurrent adds increase selectivity for fault detection of phase faults. The addition of current unbalance (Function 46) will assist in preventing unbalance currents from damaging the interconnection equipment. The addition of the unbalanced voltage (Function 47) will add protection for open or high impedance grounded phases. The addition of the 59N and 27N functions on the high side of a Delta-Wye transformer adds fault detection for phase to ground faults.

Figure 9 is the single line diagram for Level 3 and adds additional protection to Level 2 (Protection 32 overpower forward or reverse).

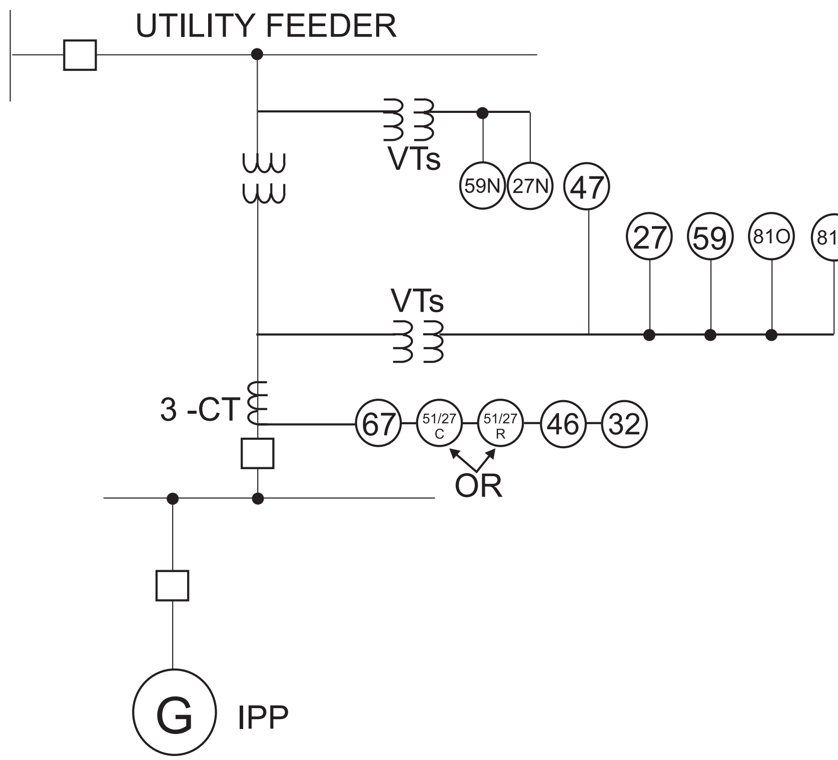


Figure 9: Level 3 (additional protection)

The addition of an overpower device 32 to the interconnection gives the capability of controlling the import or export of power during normal operation. Figure 8 shows this additional element and directionality is controlled by the polarity of the CT connections. Dual element overpower - forward and reverse allows the Wires Owner to determine if the Power Producer has lost load or lost generation when coupled with a time delay function 62.

Figure 10 is the single line diagram for Level 4 and adds control functions to Level 3. (25 w/voltage monitoring)

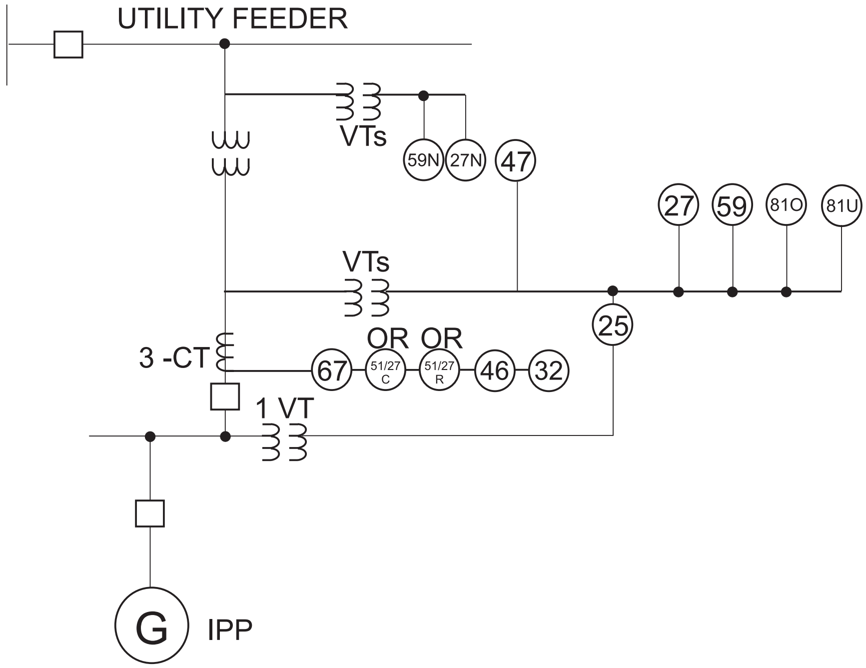


Figure 10: Level 4 (adds control function)

When an interconnection is closed, there must be supervision of the closing of the Interconnection/Generator Breaker. Monitoring of the voltage across the open breaker for the following four conditions will set up the closing logic scheme chosen:

a. Live bus - Live line
b. Live bus - Dead line
c. Dead bus - Live line
d. Dead bus - Dead line

A 25 sync-check device must only permit the closing of the open breaker when the voltage, frequency and phase angle between the electric systems are within certain differential limits. These limits are Delta V, Delta F and Delta Phase Angle. This function is required any time the interconnection is manually or automatically closed. Otherwise, there are potentially damaging transients to the equipment.

DG OPPORTUNITIES TO ENHANCE CUSTOMER SATISFACTION

Case #1: Given a local hospital with cogeneration needs for hot water for the hospital laundry. The addition of five 75kW Induction Generators (325kW) is a cost effective use of combined heat and power running in parallel with the hospital's 277/480V electric power system. Figure 11 is a one line diagram of this application. The facility has been in operation since early 1991.

The designer used a zig-zag transformer connection to provide a ground source to trip the DG breaker for ground faults on the hospital's electric power system.

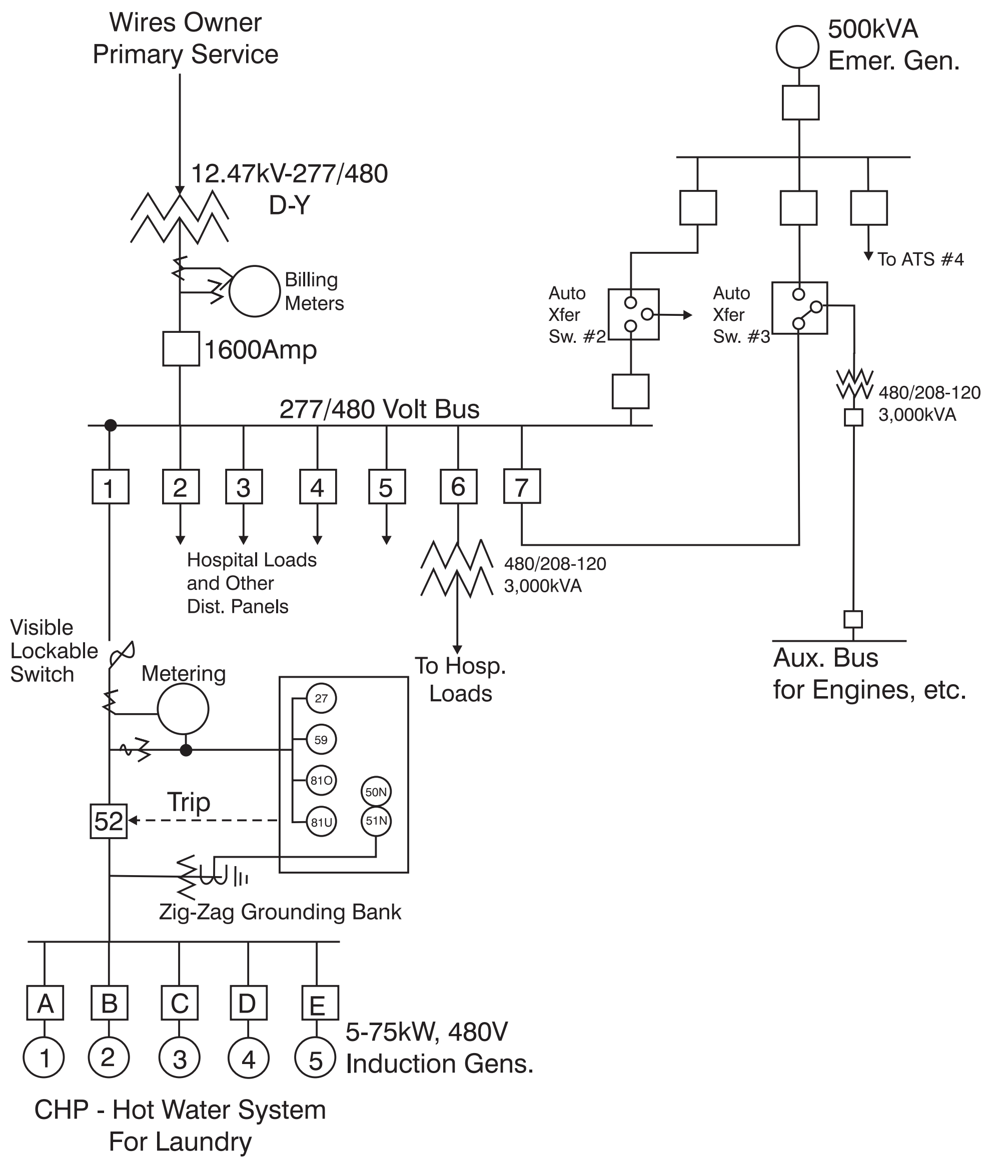


Figure 11: Typical DG opportunity - Combined heat and power

A possible new application opportunity for this facility is to convert the 500kVA emergency generator to run in parallel with the hospital's electric power system continuously without exporting power to the Wires Owner's electric power system.

Case #2: This case is an application whereby existing interconnected electric power systems installed a 24MW diesel power plant. The purpose was for one party to install and operate the 24MW facilities to relieve imported power and energy during peak loads and periods of curtailment within the bulk power systems.

Case #3: This case has applied the fuel cell technology to a United States Postal Service facility using five natural gas fueled 200kW phosphoric acid fuel cells. These prepackaged and self-contained fuel cells feed a 480V common bus. The bus is connected to 600V metal-clad circuit breaker switchgear. A site management protection and control system consisting of circuit breakers for the fuel cell side and the grid side, along with a high speed solid state automatic switch between the Post Office 480V switchboard and the grid side circuit breaker. The high speed automatic switch controller provides for detection of grid transients and transfers the fuel cell power plant output from grid parallel mode to grid independent operation. The shift from full plant output to load matching/following is accomplished in one-quarter cycle. The 1MW fuel cell power plant provides electricity and heat to the U.S. Postal facility.

Case #4: This application has applied a 6MW diesel power plant at a customer's 35mW Chip Plant manufacturing process in cases of load curtailments. The agreement provides that, upon notification by the Wires Owner, the customer will manually start the three 2MW unit power plant and place the 6MW on line. The process of synchronizing and paralleling with the power grid is fully automated. The objective of paralleling is a seamless transfer to and from the Wires Owner's grid.

FUTURE OPPORTUNITIES - DISTRIBUTED GENERATION AGGREGATION

Power supply planning is being challenged by continuously growing needs for more capacity in supply, wholesale for retail delivery systems (bulk power supply grid/network) and retail delivery systems (subtransmission and distribution systems).

Planners are searching for additional energy sources that can be brought on line quickly and economically to satisfy peaking and mid-range energy demand needs. A key source already exists. Distributed generation units now used for emergency standby or cogeneration purposes already exist. One survey suggests that more than 90,000MW of DG capacity currently exists.

Tapping this resource will require some novel approaches to providing system solutions to system opportunities.

For instance, suppose a regional wastewater utility has an environmental problem with flaring methane gas to the atmosphere from the digesting process. What if the emergency standby generators could be retrofitted or upgraded with equipment to allow parallel interconnected operation with the Wires Owner system?

Technical business practices and regulatory barriers could be overcome with the following concept: Aggregation of these 1 to 10MVA sources could be possible and economical if system solutions were planned, designed, built, tested, and maintained and operated for the life of the asset.

The components of the solution would include the following:

1. Integrated and adaptive protection and control systems, i.e. a transparent interconnection system.
2. Integrated command and control systems to dispatch these resources in a real time environment.
3. Integrated monitoring and control systems to log and alarm when DG components need attention or routine maintenance, i.e. reliability centered maintenance.
4. Data logging and real time pricing to control the real time economics of firm and non-firm power commitments between the parties operating in parallel.

Figure 12 illustrates how an aggregated DG might be implemented. Functional requirements would include, but not be limited to, the following functions.

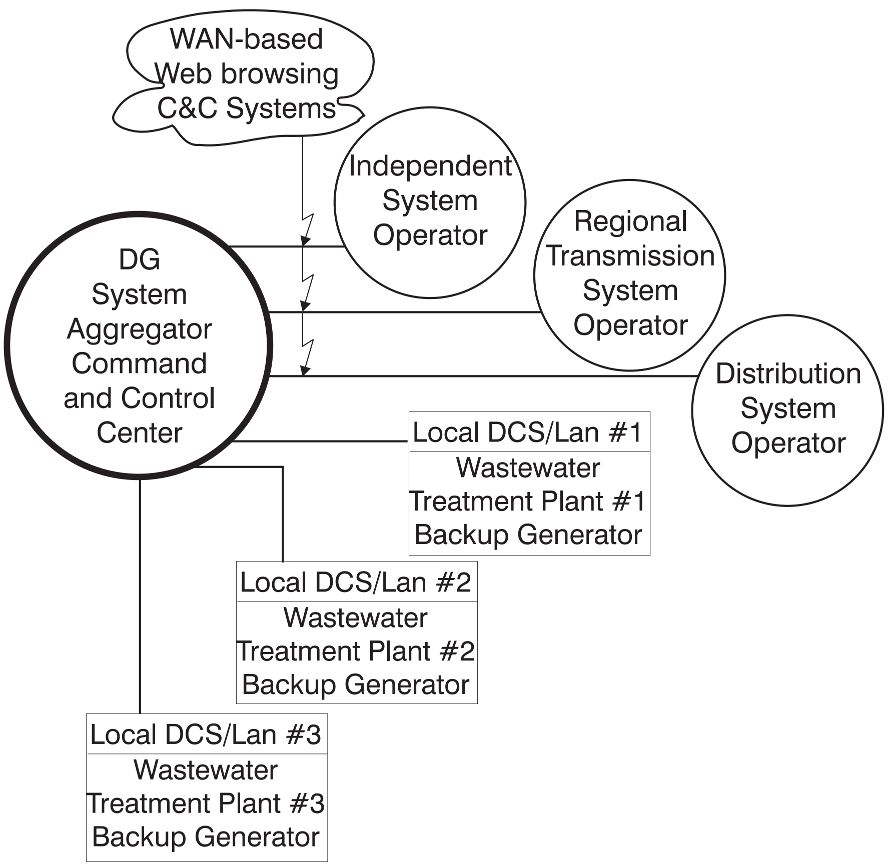


Figure 12: Economic dispatching of DG resources

1. DG system aggregator would monitor the DG assets from each wastewater facility.
2. Under emergency conditions or in times of peak pricing, a request is made by the ISO, RTO, or distributed system operator to meet system demand.
3. The aggregated DG command and control system automatically communicates to each remote generator that is available to come on line and parallel with the grid. This would, thereby, reduce the ISO load and ensure uninterrupted operation of the facility.
4. With real time pricing, both parties could elect to buy or sell off peak power on a "when and if available" basis at a "split the savings" economy interchange service. Figure 13 illustrates this principle.

Benefit: DG equipment placed in operation and under load, saving marginal costs

$$\text{Economy Exchange Transaction Price (\$)} = \text{Hourly Scheduled Transaction (MWHr)} * \left[\frac{\underset{\$/\text{MWHr}}{\text{(Party A's cost to produce)}} + \underset{\$/\text{MWHr}}{\text{(Party B's avoided cost to produce)}}}{2} \right]$$

Substituting Typical Numbers:

$$= 10\text{MWHr} * \left[\frac{(\$30/\text{MWHr}) + (\$60/\text{MWHr})}{2} \right]$$

$$= 10\text{MWHr} * \$45/\text{MWHr}$$

$$= \$450.00$$

Each party saves incrementally (marginal costs of $15/MWHr).
If transactions last for 100 hours/month, total savings are $1,500.00.

Figure 13: Split the savings economy exchange transactions

SUMMARY and CONCLUSIONS

The implementation of a DG and its associated parallel interconnection is based on a long history of satisfactory performance relating to:

- Increases in the reliability of the interconnected electric power system
- Mutual economic benefits brought to the parties belonging to the interconnection.
- Protection of the safety of the parties involved in interconnected operation.
- Providing flexibility for emergency, short term firm, long term firm and when and if available energy services that reduce the exposure to step changes in supply and demand economics.
- Improvement in the quality of electric service to wholesale and retail customers.
- Provides access to other markets for customers.
- Future work required for successful implementation and understanding of the interconnection of DG is illustrated in Figure 14.

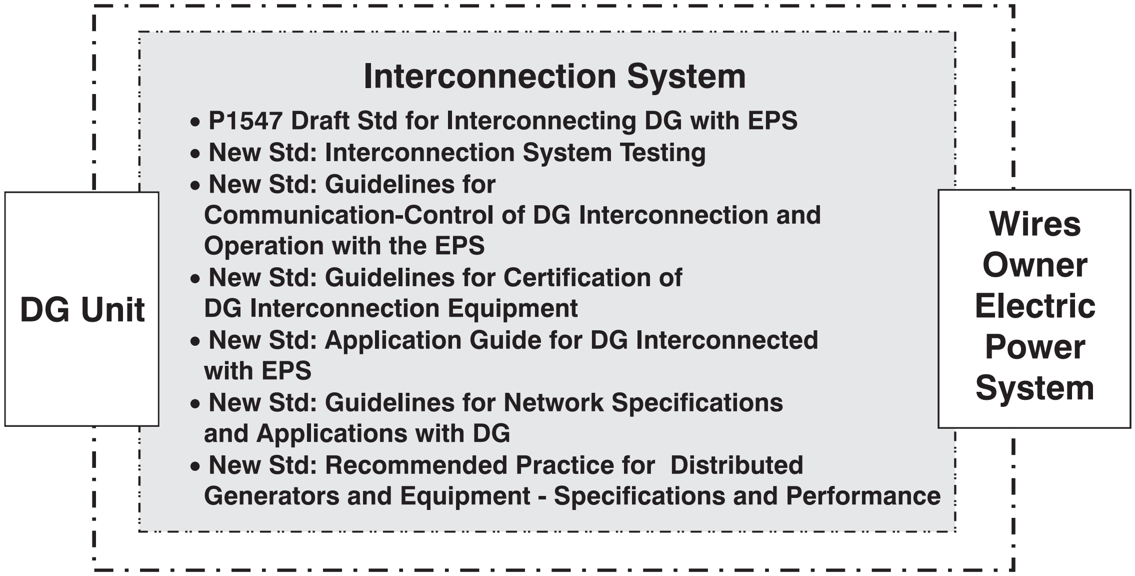


Figure 14: Future work required covering interconnection of DG

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BIOGRAPHICAL INFORMATION

Don Hornak has more than 40 years' experience in the Electric Power Industry. He has worked in the fields of System Planning, System Operations, Substation Design, Construction, Operations and Maintenance, Power Generation Facilities, and Corporate Management. He has served on the System Planning Committee, System Operating Committee, and Technical Advisory Group for the Florida Region of the Southeastern Reliability Council (SERC). Don has actively participated in the formation of the Florida Energy Broker System. He graduated from the University of Florida in 1962 with a BS in EE. He is a registered Professional Engineer (Florida). Don is a Senior Member of the IEEE, PES, IAS, and a member of IEEE working group P1547. He has written technical papers for various power system conferences on protection and control applications. Mr. Hornak is a Senior Application Engineer with Basler Electric. Don is a member of the IEEE Working Group P1547.

N. H. "Joe" Chau is graduated from Georgia Tech in 1973 with a BS in EE. He worked with Simons Eastern Company as Electrical Engineer in the pulp and paper industries from 1973 to 1984. Joe received is MSEE from Georgia Tech in Power System in 1984. He worked with GE in 1984 and Florida Power and Light from 1987 to the present, as Principal Engineer in Power Systems - Protection and Control. Joe is a member of the IEEE working groups IEEE929, and P1547.

APPENDIX 1

Applicable Codes and Standards

The generator or distributed resource interconnection shall conform to this guideline and to the applicable sections of the following codes and standards:

When the stated version of the following standards is superseded by an approved revision, then that revision shall apply.

Specific types of interconnection schemes, DR technologies, and Distribution Systems may have additional requirements, standards, recommended practices, or guideline documents external to this guideline. The applicability and hierarchy of those with respect to the requirements herein are beyond the scope of this guideline. Users of this guideline shall address those concerns. This list of standards is, therefore, not to be regarded as all-inclusive.

Power Quality Standards

- ANSI C84.1-1989 American National Standards for Electric Power Systems and Equip- ment ratings (60 Hertz). Establishes nominal voltage ratings and operating tolerances for 60Hz electric power systems from 100V through 230kV.
- IEEE Std. 493-1900 IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book). Chapter 9 deals specifically with voltage sags analysis and methods of reporting sag characteristics graphically and statistically.
- IEEE Std 519-1992 IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems.
- IEEE Std 1100-1992 IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book).
- IEEE Std 1159-1995 IEEE Recommended Practice for Monitoring Electric Power Quality.
- IEEE Std 1250-1995 IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances.

In addition to the power quality standards, the following standards are applicable to the interconnection of distributed generation resources on the Wires Owner system:

- IEEE Std 100-1997 IEEE Standard Dictionary of Electrical and Electronics Terms
- IEEE Std 315-1975 (Reaffirmed 1993) ANSI Y32.3-1975 (Reaffirmed 1989) CSA Z99-1975 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters)
- IEEE Std 929-1988 IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems
- C37.1 ANSI/IEEE Standard Definitions, Specifications and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control
- C37.2 IEEE Standard Electrical Power System Device Function Numbers
- C37.18 ANSI/IEEE Standard Enclosed Field Discharge Circuit Breakers for Rotating Electric Machinery
- C37.20.1 ANSI/IEEE Standard for Metal-Enclosed Low-voltage Power Circuit Breakers Switchgear

- C37.20.3 ANSI/IEEE Standard for Metal-Enclosed Interrupter Switchgear
- C37.24 ANSI/IEEE Standard for Radiation on Outdoor Metal-Enclosed Switchgear
- C37.27 ANSI/IEEE Standard Application Guide for Low-voltage AC Nonintegrally Fused Power Circuit Breakers (Using Separately Mounted Current-Limiting Fuses)
- C37.50 ANSI Standard Test Procedures for Low-voltage AC Circuit Breakers Use In Enclosures
- C37.51 ANSI Standard Conformance Test Procedure for Metal Enclosed Low-voltage AC Power Circuit-Breaker Switchgear Assemblies
- C37.52 ANSI Standard Test Procedures for Low-voltage AC Power Circuit Protectors Used in Enclosures
- C57.12 IEEE Standard General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers
- C57.12.13 Conformance Requirements for Liquid Filled Transformers Used in Unit Installations including Unit Substations
- C57.13.1 IEEE Guide for Field Testing of Relaying Current Transformers
- C57.13.2 IEEE Standard Conformance Test Procedures for Instrument Transformers
- C37.58 ANSI Standard Conformance Test Procedures for Indoor AC Medium Voltage Switches for use in Metal-Enclosed Switchgear
- C37.90 ANSI/IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
- C37.90.1 ANSI/IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
- C37.90.2 ANSI/IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
- C37.95 IEEE Guide for Protective Relaying of Utility Consumer Interconnections
- C37.98 ANSI/IEEE Standard for Seismic Testing of Relays
- IEC 1000-3-3 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current less than 16A
- IEC1000-3-5 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current greater than 16A
- UL1008 Transfer Switch Equipment
- IEEE P1547, DRAFT Standard for Distributed Resources Interconnected with Electric Power Systems
- Canadian Electrical Code, CSA no. C22-1, latest version
- C22.2 No. 31-M89 (R1995) - Switchgear Assemblies
- Can/CSA - C22.2 No. 107.1-95 - Commercial and Industrial Power Supplies
- Can/CSA - C22.2 No. 1010.1-92 - Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
- Can/CSA - C22.2 No. 144-M91 (R1997) - Ground Fault Circuit Interrupters
- C22.2 No. 193-M1983 (R1992) - High Voltage Full-load Interrupter Switches
- C22.2 No. 201-M1984 (R1992) - Metal Enclosed High Voltage Busways
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- C37.015-1993 IEEE Application Guide for Shunt Reactor Switching
- C37.081-1981 (Reaff 1988) Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current basis
- C37.11-1997 IEEE Standard Requirements for Electrical Control for High-Voltage Circuit Breakers Rated on a Symmetrical Current basis
- C37.13-1990 (R1995) IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
- C37.14-1992 IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures
- C37.16-1997 American National Standard for Switchgear - Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements, and Application Recommendations
- C37.20.2-1999 IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear
- C37.20.2b-1994 Supplement to IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear: Current Transformer Accuracies
- C37.20.6-1997 IEEE Standard for 4.76 to 38kV Rated Grounding and Testing Devices used in Enclosures
- C37.23-1987 (R1991) IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus
- C37.30-1997 IEEE Standard Requirements for High-Voltage Switches
- C37.32-1996 American National Standard for Switchgear -- High-Voltage Air Switches, Bus Supports, and Switch Accessories -- Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide
- C37.34-1994 IEEE Standard Test Code for High-Voltage Air Switches
- C37.35-1995 IEEE Guide for the Application, Installation, Operating, and Maintenance of High-Voltage Air Disconnecting and Load Interrupter Switches
- C37.36b-1990 IEEE Guide to Current Interruption with Horn-Gap Air Switches

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- C37.38-1989 IEEE Standard for Gas-Insulated, Metal-Enclosed Disconnecting, Interrupter, and Grounding Switches
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- NEMA CC-1 - Electric Power Connectors for Substations
- NEMA LA-1 - Surge Arresters
- NEMA MG-1 - Motors

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