

**CUSTOMER GUIDE**

**FOR THE**

**INTERCONNECTION**

**OF**

**DISTRIBUTED RESOURCES**

**TO THE**

**AMERICAN ELECTRIC POWER**

**DISTRIBUTION SYSTEM**



*An **AEP** Company*

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*BOUNDLESS ENERGY<sup>SM</sup>*

**April 27, 2018**



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## **Introduction**

This Customer Guide to the Interconnection of Distributed Resources to the American Electric Power (AEP) Distribution System

- Explains the basic process used to interconnect Distributed Resources
- Provides information on the technical requirements for Distributed Resources and the potential system impact a Distributed Resource may have when interconnecting to the AEP Distribution System.

For specific requirements please refer to the tariffs or rules governing interconnection within a given jurisdiction (Federal or State) based upon the location, type, size and intended use of the proposed generator.

The electric power distribution systems operating today were not designed to accommodate the interconnection of Distributed Resources. The voltage regulation practices, overcurrent protection approaches, switching techniques and maintenance and power restoration practices used for distribution systems have been based on the fundamental assumption that there are no generation sources on the distribution system. Generation sources on the distribution system can create operating conditions that cannot be managed in conventional ways and may require special equipment, changes to the protection and control provisions, and other system modifications to operate safely and effectively without adversely affecting system performance.

The Distributed Resources Interconnection Process is intended to efficiently:

- 1) determine if the proposed Distributed Resource is compatible with the electric power system at the proposed interconnection point, and
- 2) identify and make any additions or modifications to the electric power system or modifications to the proposed Distributed Resource installation necessary for compatibility.

## **Applicability**

This document provides guidance on the interconnection of Distributed Resources to the AEP Distribution System. Distributed Resources includes both generators and energy storage technologies.

The rules covering the interconnection of Distributed Resources to the Distribution System vary among the State Regulatory Commissions and the Federal Energy Regulatory Commission (FERC). For further information on the specific rules and tariffs covering the use of Distributed Resources or other generators please contact:

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A generator used in an automatic or manual transfer scheme in which electrical load is transferred between the AEP Distribution System and the generator, but never paralleled with the AEP Distribution System is not considered to be a Distributed Resource in most jurisdictions. Such a generator should have an approved double-throw double-pole transfer switch installed by a qualified electrician so that the generator and AEP's service conductors cannot be paralleled.

A generator using a make-before-break transfer scheme where the generator is paralleled less than 100 milliseconds with the AEP Distribution System does not fall under the interconnection rules for Distributed Resources in most jurisdictions. However, proposed make-before-break transfer scheme generator equipment packages must be reviewed and approved by AEP. The package must meet the requirements of Underwriters Laboratories Standard 1008 and be listed by a nationally recognized testing laboratory.<sup>1</sup>

This guide covers the issues directly relating to the interconnection of a Distributed Resource. It does not cover other issues a customer will need to consider when planning to install a Distributed Resource, such as the terms and conditions relating to any purchase or sale of electric energy, environmental permitting, local ordinances, and fuel supply. Arrangements for purchase or sale of electric energy are handled separately from interconnection. The interconnection process only provides for the safe interconnection of the proposed Distributed Resource without degradation in the power quality or reliability of the AEP Distribution System. Interconnection with the AEP Distribution System does not provide an Interconnection Customer any rights to utilize AEP's Distribution System for the transmission, distribution or wheeling of electric power, nor does it limit those rights.

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<sup>1</sup> UL publications are available from Underwriters Laboratories, Inc. (<http://www.ul.com/>)

This guide does not cover self protection of the Distributed Resource or all operating requirements for the Distributed Resource. AEP's review and authorization for parallel operation shall not be construed as confirming or endorsing the Interconnection Customer's design or as warranting the Distributed Resource and interconnection systems' safety, durability or reliability. AEP shall not, by reason of such review or lack of review, be responsible for the strength, adequacy or capacity of such equipment.

## **Definitions**

AEP Distribution System – Facilities owned, leased or controlled by AEP that deliver electric power at primary voltages ranging from 4 to 34.5 kV three phase and at secondary voltages ranging from 120/240 volts single phase to 277/480 volts three phase to retail and wholesale customers.

Distributed Resources – Sources of electric power including both generators and energy storage technologies operated in parallel with the power system and not directly connected to a bulk power transmission system.

Distributed Generation – Electric power generators operated in parallel with the power system and not directly connected to a bulk power transmission system. Distributed Generation is a subset of Distributed Resources.

Interconnection – The result of adding a Distributed Resource to the AEP Distribution or Transmission System so the Distributed Resource can operate in parallel.

Interconnection Agreement – An agreement between AEP and the owner of a Distributed Resource covering the terms and conditions under which the owner's Distributed Resource can be installed and operated in parallel with the AEP System.

Point of Common Coupling – The point at which the distributed generation facility is connected to the shared portion of the utility system or where an electrical system connects to the AEP System.

Pre-certified – A Distributed Resource equipment package, submitted by a manufacturer or an entity that assembles an equipment package, tested as per IEEE 1547 Clause 5 by a nationally recognized testing laboratory and found after testing to be in compliance with the requirements of IEEE 1547 Clause 4.

Queue – The time ordered collection of pending valid interconnection requests maintained to assure that interconnection requests are processed on a first-in first-out basis.

Screening Criteria – A set of technical criterion used to evaluate Distributed Resource interconnection requests in order to determine if a request can be approved for interconnection with no further study or if the request requires more study to determine its system impact.

System Impact – Negative effects due to technical or operational limits on conductors or equipment being exceeded that may compromise the safety, reliability or power quality of the electric system.

Technical Requirements – The specific criteria and specifications relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection of Distributed Resources with the AEP Distribution System. A Distributed Resource may comply with all of the Technical Requirements and still have significant System Impact.

## **Overview of the Interconnection Process**

AEP is committed to providing safe reliable service to our customers at the lowest practical cost. This means that AEP will perform as efficiently as practical the work necessary and appropriate to assure the continued safety of its employees and the public and continued reliable electric service to our customers.

Improper connection and operation of any source of electrical power, such as a Distributed Resource, in parallel with the AEP Distribution System could jeopardize the safety of AEP employees and the public and could degrade the reliability and quality of the electric service provided to our customers. Therefore, no source of electrical power shall be operated in parallel with the AEP Distribution System without the express written approval of AEP.

Customers may obtain AEP approval to operate a Distributed Resource in parallel with its system by applying for interconnection and following the appropriate interconnection process. The specific application form and interconnection process to be followed is dictated by the regulatory agency having jurisdiction and can vary based upon the location, type, size and proposed use of the Distributed Resource. Significant variations in the application forms and interconnection processes exist for interconnection to the AEP Distribution System since any one of twelve regulatory agencies may have jurisdiction (1 Federal and 11 State Commissions) and some jurisdictions have multiple tariffs relating to Distributed Resource interconnection. AEP desires to minimize the time and expense involved in each interconnection process consistent with maintenance of system safety and reliability, compliance with the applicable regulatory requirements and customer satisfaction.



An overview of the general interconnection process is outlined below.

**Step 1: The customer contacts AEP.**

The customer contacts AEP by telephone, e-mail or U.S. mail. Based upon the customer's request and preliminary plans, AEP sends the customer the interconnection application form and provides information on the required interconnection process. The correct application form to use depends upon the location, type, size and proposed use of the planned Distributed Resource.

Customers who plan to sell electricity produced by their planned electrical generating facility at wholesale in interstate commerce may need to use an application form approved for use as part of a Federal Energy Regulatory Commission (FERC) approved Open Access Transmission Tariff. Customers whose planned Distributed Resource does not fall under FERC jurisdiction must use the application form approved for use by the state regulatory commission based upon the location, type, size and proposed use of the Distributed Resource.

For customers whose planned Distributed Resource does not fall under FERC jurisdiction and the state regulatory commission does not have an approved tariff applicable to the planned Distributed Resource, the customer should obtain/submit a state specific Interconnection Application from the local AEP operating company (e.g. Kentucky Power, AEP Ohio, etc.).

**Step 2: Customer submits a completed application.**

Any customer who proposes to operate any type of Distributed Resource in parallel with the AEP Distribution System must first submit a completed application to request review and approval of the proposed Distributed Resource interconnection. For the application to be considered complete, the request must be submitted on the proper application form and must include all information requested and payment of monies due at the time of application.

**Step 3: AEP reviews the application form for completeness.**

In order for AEP to process a customer request for Distributed Resource interconnection, the submitted application form must be complete. Upon receipt of an application form, AEP will review the application for completeness. If AEP determines the application form is incorrect and/or is incomplete, AEP will notify the customer and provide the correct form and/or a description of the information needed to complete the application form. The interconnection request will be placed in Queue based upon the date and time of receipt of the completed application form unless the rules established by the regulatory authority having jurisdiction differ.

**Step 4: AEP performs a limited study to determine compliance with the Technical Requirements and the potential system impact of the Distributed Resource.**

Based upon an interconnection request's position in the Queue and the applicable time limits established by the regulatory authority having jurisdiction, AEP will perform a limited engineering study to determine compliance with the Technical Requirements and to evaluate the System Impact of the proposed Distributed Resource.

The study time limits and study scope vary depending upon the rules established by the regulatory authority having jurisdiction and may vary by the type, size and proposed use of the Distributed Resource. In many jurisdictions, specific screening criteria are utilized to minimize the time and expense involved to evaluate pre-certified Distributed Resources. Additional time is generally required to evaluate Distributed Resources that are not pre-certified to determine if they meet the Technical Requirements.

**Step 5: AEP informs the customer of the results of the limited study.**

The results of the limited study are provided to the customer within the applicable time limits established by the regulatory authority having jurisdiction.

AEP will first determine if the proposed Distributed Resource meets the Technical Requirements. If it is determined that the proposed Distributed Resource does not meet the Technical Requirements, AEP will notify the customer and provide a list of specific changes necessary for the proposed Distributed Resource to meet the Technical Requirements. If the customer decides to make the necessary changes to comply with the Technical Requirements, AEP will complete the limited study.

If the limited study shows that the proposed Distributed Resource meets the Technical Requirements and that interconnection of the proposed Distributed Resource will not cause System Impact, AEP will notify the customer of the study results and provide the customer with a proposed interconnection agreement.

If the limited study shows that the proposed Distributed Resource meets the Technical Requirements but that interconnection of the proposed Distributed Resource will cause System Impact and it is determined that changes in the customer's proposed generating facilities or minor AEP system modifications can be made to accommodate the proposed Distributed Resource, AEP will notify the customer of these study results. If the customer then elects to make the necessary changes and/or pay for minor AEP system modifications, AEP will provide the customer with a proposed interconnection agreement.

If the limited study shows that the proposed Distributed Resource meets the Technical Requirements and additional study is required to determine if interconnection of the proposed Distributed Resource will cause System Impact, AEP will provide the customer with the results of the limited study and provide an estimate of the cost of the additional study required to determine the System Impact of the proposed Distributed Resource. If the customer then elects to pay for the additional study and subsequently agrees to pay for any necessary changes, minor system modifications and/or system upgrades determined necessary by the additional study, AEP will provide the customer with a proposed interconnection agreement.

**Step 6: The customer signs and returns the proposed interconnection agreement and any necessary study and facility changes are completed.**

The customer signs and returns the proposed interconnection agreement. Upon receipt of the customer's payment and completion of any necessary study, minor system modifications and system upgrades by AEP and the completion of customer facility changes necessary to accommodate the customer's Distributed Resource, the customer can proceed to complete their Distributed Resource installation in preparation for final checkout and commissioning tests.

**Step 7: The customer notifies AEP of final checkout schedule, performs the final Checkout, successfully completes all commissioning tests and sets up periodic interconnection test procedures.**

The customer completes their Distributed Resource installation and notifies AEP of their schedule for final checkout and the plan for commissioning tests. AEP may inspect the customer's Distributed Resource installation and observe the customer performing the required commissioning tests. Upon successful completion of the commissioning tests, the customer will give or send AEP a copy of their final inspection checkout and the results of the commissioning tests and the written periodic interconnection test procedures proposed by the customer.

**Step 8: AEP authorizes operation of the proposed Distributed Resource in parallel with the AEP Distribution System.**

Based upon its review of the customer's proposed Distributed Resource facility, the final inspection checkout and the results of the commissioning tests, AEP notifies the customer in writing of its authorization for the customer to operate the generating facility in parallel with the AEP Distribution system under the terms of its interconnection agreement.

If AEP identifies problems with the inspection, if the commissioning test results are unsatisfactory, or if AEP does not agree with the customer's periodic test procedures, AEP will notify the customer in writing with the deficiencies clearly identified. AEP may withhold authorization for parallel operation until such deficiencies have been properly corrected.

For specific interconnection process requirements, please refer to the tariffs or rules governing interconnection within a given jurisdiction (Federal or State) based upon the location, type, size and intended use of the proposed Distributed Resource.

## **Technical Requirements for Interconnection**

IEEE Standard 1547-2003 "Standard for Interconnecting Distributed Resources with Electric Power Systems" (IEEE 1547)<sup>2</sup> is the basis for interconnection Technical Requirements for most jurisdictions. These Technical Requirements apply to all Distributed Resource technologies including synchronous machines, induction machines, or static power inverters/converters.

The interconnection system hardware and software used by a Distributed Resource to meet these Technical Requirements do not have to be located at the Point of Common Coupling. However, the Technical Requirements shall be met at the Point of Common Coupling.

A table summarizing the Distributed Resource Technical Requirements is attached as Appendix 1. The pertinent IEEE 1547 clause number(s) are shown in this table.

Basic Technical Requirements - The Technical Requirements in IEEE 1547 cover the following areas, Voltage Regulation, Voltage Disturbances, Harmonic Current Injection, Direct Current Injection, Grounding Scheme Compatibility, Inadvertent Energization, Monitoring Operation, Isolation Device, Withstand Performance, Paralleling Device, Response to Area EPS Faults, Reclosing Coordination, Unintentional Islanding, Voltage and Frequency Detection, Abnormal Voltage or Frequency, Reconnection Following a Disturbance, Secondary Grid and Spot Network Systems, and Testing and Maintenance.

Testing – A Distributed Resource proposing to interconnect with the AEP Distribution System must be tested as per IEEE 1547 Clause 5 to demonstrate that the interconnection system meets the requirements of IEEE 1547 Clause 4. Documentation of the results of the Design Test and Production Tests shall be provided to AEP at the time of application unless such tests are to be conducted as part of the Commissioning Tests.

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<sup>2</sup> IEEE publications are available from the Institute of Electrical and Electronics Engineers, 443 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 (<http://standards.ieee.org/>).

When the interconnection system of the Distributed Resource uses an assembly of discrete components, documentation of testing must be provided to AEP at the time of application to confirm the compatibility of the discrete components to properly function together. Otherwise AEP may require the Design Test to be conducted as part of the Commissioning Tests.

Written test procedures shall be approved by AEP for all tests to be performed as Commissioning Tests. To avoid delay, these test procedures should be submitted to AEP well in advance of the scheduled date of the Commissioning Tests.

#### Additional Technical Requirements:

**Circuit Breaker** - If a main circuit breaker (or circuit switcher) between the interconnection transformer and the Distribution System is required, the device must comply with the applicable current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.

**Main Disconnect Switch (Voltages exceeding 480 volts)** – A gang operated disconnecting device must be located at the Point of Common Coupling for all three phase interconnections. In all cases the disconnecting device must be clearly labeled, accessible to AEP personnel, must be suitable for use by AEP personnel at all times and must be suitable for use by AEP as a protective tagging location. The disconnecting device shall have a visible open gap when in the open position and be capable of being locked in the open position. The disconnecting device must have a ground grid designed in accordance with specifications to be provided by AEP. Operation of the device must be restricted to AEP personnel and properly trained operators designated by the interconnection customer. The disconnecting device must comply with the applicable current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.

**Terminating Structure** – When a new interconnection line is required, the interconnection customer shall provide a suitable structure to terminate the interconnection line. The customer is responsible for ensuring that terminating structure or substation structural material strengths are adequate for all requirements, incorporating appropriate safety factors. AEP will provide line tension information for maximum dead-end. The structure must be designed for the maximum line tension along with an adequate margin of safety.

Substation electrical clearances shall meet or exceed the requirements of the National Electrical Safety Code. Installation of disconnect switches, bus support insulators and other equipment shall comply with accepted industry practices.

Surge arresters shall be selected to coordinate with the BIL rating of major equipment components and shall comply with recommendations set forth in the applicable current ANSI Standard C62.2 that specifies the requirements for surge arresters and other surge protection devices.

Momentary Paralleling – For situations where the proposed Distributed Resource will only be operated in parallel with the AEP system for a short duration (less than 100 milliseconds), as in a make-before-break automatic transfer scheme, the requirements of IEEE 1547 do not apply except as noted in Clause 4.1.4. All make-before-break automatic transfer switch systems proposed by the interconnection customer must comply with UL 1008 and be listed by a nationally recognized testing laboratory.

Voltage Unbalance – The interconnection customer is responsible for operating the proposed Distributed Resource such that the voltage unbalance attributable to the Distributed Resource does not exceed 2.5% at the Point of Common Coupling.

Power Factor - Each Distributed Resource shall be capable of operating at some point within a power factor range from 0.9 leading to 0.9 lagging. Operation outside this range is acceptable provided the reactive power of the Distributed Resource is used to meet the reactive power needs of the electrical loads within the interconnection customer's facility or that reactive power is otherwise provided under tariff by AEP. The interconnection customer shall notify AEP if it is using the Distributed Resource for power factor correction.

System Stability – AEP may require a stability study for Distributed Resources if the aggregate generation is greater than 10 MW and in an area where there are known or posted stability limitations to generation located in the general electrical vicinity (e.g., three or four Transmission voltage level busses from the Transmission voltage bus serving the distribution circuit where the Distributed Resource proposes to interconnect.

Maintenance and Testing – The interconnection customer is responsible for the periodic scheduled maintenance on the interconnection system of the Distributed Resource (relays, interrupting devices, control schemes, and batteries that involve the protection of the AEP system). Unless the equipment manufacturer provides study results that demonstrate the need for less frequency, interconnection systems that depend upon a battery for proper function shall be checked and logged once per month for proper voltage. At least once every four years, the battery must be either replaced or a discharge test performed.

A periodic maintenance program is to be established in accordance with the requirements of IEEE 1547. AEP may examine copies of the periodic test reports or inspection logs associated with the periodic maintenance program. Upon request, AEP shall be informed of the next scheduled maintenance and be able to witness the maintenance performed and any associated testing.

Monitoring – AEP reserves the right, at AEP's initial expense, to install special test equipment as may be required to perform a disturbance analysis and monitor the operation and control of the Distributed Resource to evaluate the quality of power produced by the Distributed Resource.

**For specific interconnection Technical Requirements within a given jurisdiction (Federal or State), please refer to the tariffs or rules governing interconnection for that jurisdiction based upon the location, type, size and intended use of the proposed generator.**

## Evaluation of System Impact

A Distributed Resource proposing to interconnect to the AEP Distribution System may have significant impact on the safety and reliability of one or more of the following portions of the electrical power system; the AEP Distribution System, the AEP Transmission System, the Distribution or Transmission System of a third party (called an Affected System) and the electrical system where the Distributed Resource is to be connected. AEP shall not be responsible for the evaluation of the safety and reliability impacts on the electrical system where the Distributed Resource is to be connected. AEP approval of a Distributed Resource interconnection should not be construed as an endorsement, confirmation, warranty, guarantee, or representation concerning the safety, operating characteristics, durability, or reliability of the Distributed Resource facility and the electrical system where it is connected.

### Distribution System Impact –

AEP Distribution is responsible for evaluating the system impact of a proposed Distributed Resource interconnection based upon the information provided in the interconnection application once the application is considered complete.

A study to determine system impact will be performed based upon the interconnection request's position in the Queue and the applicable time limits established by the regulatory authority having jurisdiction. The study time limits and study scope vary depending upon the regulatory authority and the type, size and proposed use of the Distributed Resource.

AEP supports limited study and the use of a screening process to expeditiously identify and approve Distributed Resources that can be interconnected without significant system impact. Many jurisdictions specify the screening criteria to be utilized and restrict the use of the screening criteria to pre-certified Distributed Resources. In jurisdictions where screening criteria is not specified, the screening criteria in Appendix 2 may be used.

Additional study time is generally required to evaluate Distributed Resources that are not pre-certified. The exception may be for Distributed Resources that have been evaluated previously by AEP and were found to meet the Technical Requirements including the necessary testing.

The possible outcomes of the system impact study could include the following:

- 1) The proposed Distributed Resource interconnection meets the Technical Requirements and there are no system impacts that would require modification or upgrade to either AEP facilities or the Distributed Resource installation;
- 2) The proposed Distributed Resource interconnection does not meet the Technical Requirements and modifications or changes are required to either AEP facilities or the Distributed Resource installation;

3) The proposed Distributed Resource interconnection would result in negative system impact and modifications or changes are required to either AEP facilities or the Distributed Resource installation;

4) The proposed Distributed Resource interconnection requires new AEP facilities.

The potential Distribution system impacts listed in Appendix 3 may need to be examined as part of the impact study.

#### Transmission System Impact –

The AEP Transmission organization is informed of all requests for interconnection to the AEP Distribution System. The Transmission organization reviews each request and determines if there may be a Transmission System impact (including any system stability impact) or an impact to a third party's system.

If the request needs to be studied to determine if there is significant Transmission System impact, the Transmission organization will notify the Distribution organization accordingly. The Distribution organization will coordinate the processing of the interconnection request to help assure that the proper process is followed and all required milestones are met.

#### Affected System Impact –

The Distribution organization will review each request for interconnection to the AEP Distribution System to determine if the potential exists for impact to a third party's system. For example, the distribution systems of several Rural Electric Cooperatives (REC's) are interconnected to AEP Distribution feeders. The interconnection of a Distributed Resource to an AEP Distribution feeder with an REC interconnection could result in significant impact to the REC system.

If the potential exists for impact, the AEP Distribution organization will notify the third party of the proposed interconnection request and coordinate the processing of the interconnection request to help assure that the proper process is followed and all required milestones are met.



## Appendix 1

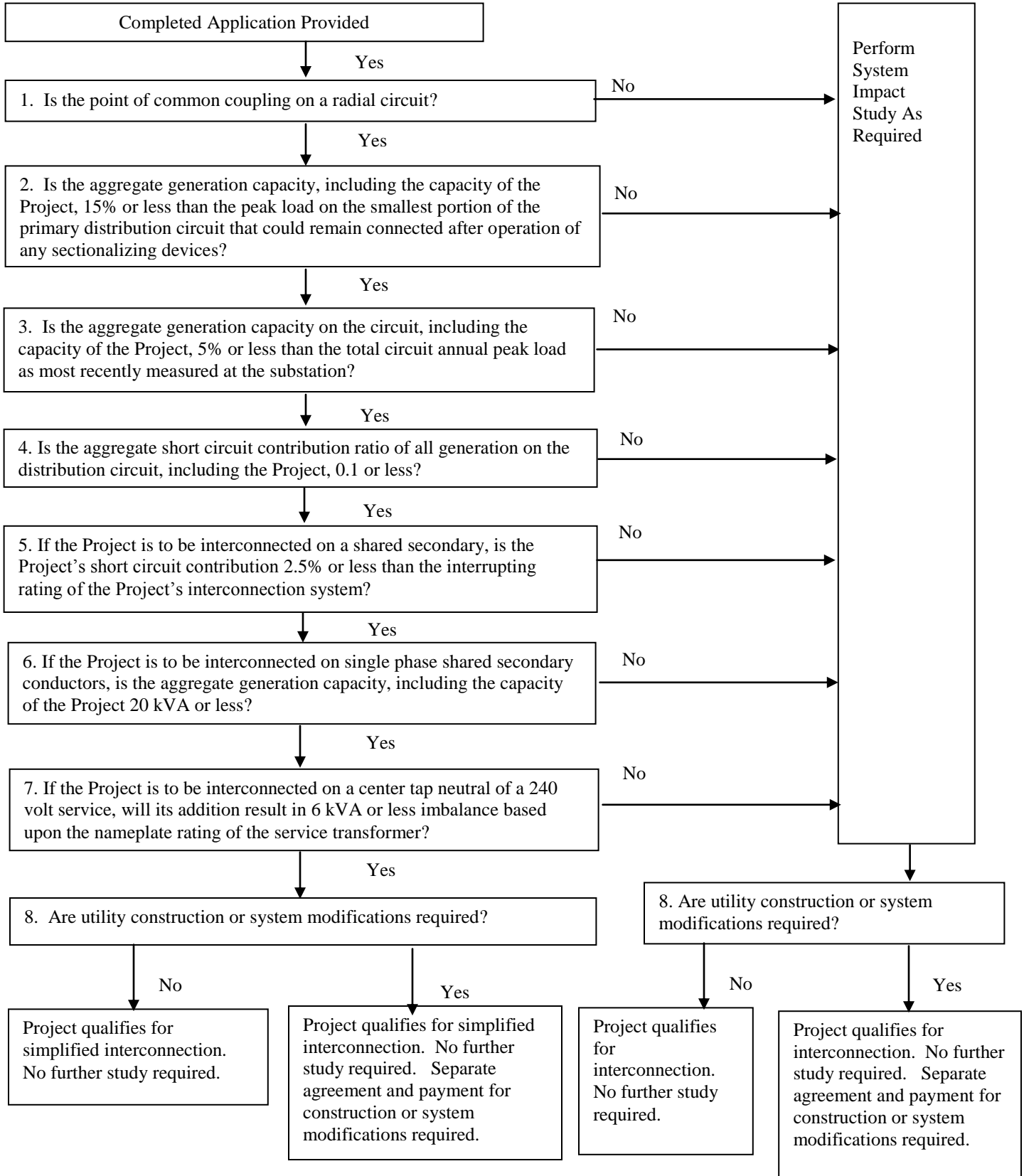
# Distributed Resource Technical Requirements

<b>Attribute</b>	<b>Requirement</b>
Voltage Regulation	IEEE 1547 - Clause 4.1.1
Voltage Disturbances	IEEE 1547 - Clause 4.3.2
Harmonic Current Injection	IEEE 1547 - Clause 4.3.3
Direct Current Injection	IEEE 1547 - Clause 4.3.1
Grounding Scheme Compatibility	IEEE 1547 - Clause 4.1.2
Inadvertent Energization	IEEE 1547 - Clause 4.1.5
Monitoring Provisions	IEEE 1547 - Clause 4.1.6
Isolation Device	IEEE 1547 - Clause 4.1.7
Withstand Performance	IEEE 1547 - Clause 4.1.8.1 and Clause 4.1.8.2
Paralleling Device	IEEE 1547 - Clause 4.1.8.3
Response to Area EPS Faults	IEEE 1547 - Clause 4.2.1
Reclosing Coordination	IEEE 1547 - Clause 4.2.2
Unintentional Islanding	IEEE 1547 - Clause 4.4.1
Abnormal Voltage	IEEE 1547 - Clause 4.2.3
Abnormal Frequency	IEEE 1547 - Clause 4.2.4
Reconnection Following a Disturbance	IEEE 1547 - Clause 4.2.6
Secondary Grid and Spot Network Systems	IEEE 1547 - Clause 4.1.4
Testing	IEEE 1547 - Clause 5
Periodic Interconnection Tests	IEEE 1547 - Clause 5.5
Circuit Breaker	Meet appropriate ANSI C37 standard
Disconnect Switch	Three phase unit gang operated at Point of Common Coupling
Terminating Structure	Adequate structural material strength suitable to terminate line
Surge Arresters	Meet applicable ANSI C62.2 standard
Momentary Paralleling	Comply with Underwriter's Laboratories Standard 1008 and IEEE 1547 – Clause 1.3
Voltage Unbalance	Unbalance attributable to Distributed Resource 2.5% or less
System Stability	Study required for units greater than 10 MW when limitations exist



## Appendix 2

# INTERCONNECTION APPLICATION SCREENING CRITERIA



## Significance of Screens:

### **1. Is the point of common coupling on a radial circuit?**

If the point of common coupling is not on a radial distribution circuit, special considerations must be taken because of the design, protection and operational aspects of network distribution systems.

### **2. Is the aggregate generation capacity, including the capacity of the Project, 15% or less than the peak load on the smallest portion of the primary distribution circuit that could remain connected after operation of any sectionalizing devices?**

The 15% of line section peak load screen is a catchall for a variety of potential problems (Unintentional islanding, voltage regulation, equipment rating, cold load pickup and protective device coordination) that can occur as the level of penetration of generation within a line section on the distribution system increases. Low penetration of generation will have a minimal impact on operation and load restoration. As the penetration increases the cumulative impact must be reviewed.

### **3. Is the aggregate generation capacity on the circuit, including the capacity of the Project, 5% or less than the total circuit annual peak load as most recently measured at the substation?**

The 5% of total circuit annual peak load screen is a catchall for a variety of potential problems (Unintentional islanding, voltage regulation, equipment rating, cold load pickup and protective device coordination) that can occur as the level of penetration of generation on a circuit increases. Low penetration of generation will have a minimal impact on operation and load restoration. As the penetration increases the cumulative impact must be reviewed.

### **4. Is the aggregate short circuit contribution ratio of all generation on the distribution circuit (including the Project) 0.1 or less?** (The short circuit contribution ratio for a generator is the ratio of the generator's short circuit contribution to the utility's short circuit contribution for a three phase fault at the primary voltage level nearest the point of common coupling. The aggregate short circuit contribution ratio is the sum of the individual generator short circuit contribution ratios for all the generators connected to the circuit.)

If the short circuit current contribution from the proposed generation is small compared to the available fault current without the generation connected, there will be no significant impact on the distribution system's short circuit duty, fault detection sensitivity and protective device coordination schemes.

**5. If the Project is to be interconnected on a shared secondary, is the short circuit contribution of the Project 2.5% or less than the interrupting rating of the Project's interconnection system?**

If the short circuit current contribution from the proposed generation is small compared to the interrupting rating of the interconnection system, there will be no significant impact on the distribution system's short circuit duty, fault detection sensitivity and protective device coordination schemes.

**6. If the Project is to be interconnected on single phase shared secondary conductors, is the aggregate generation capacity (including the capacity of the Project) 20 kVA or less?**

If the aggregate generation capacity is in excess of 20 kVA, the voltage supplied to other customers who share the secondary conductors could exceed acceptable limits.

**7. If the Project is to be interconnected on a center tap neutral of a 240 volt service, will its addition result in 6 kVA or more imbalance based upon the nameplate rating of the service transformer?**

If an imbalance of more than 6 kVA is created on a 240 volt service, the voltage could exceed acceptable limits.

**8. Are utility construction or system modifications required?**

Any required utility construction or system modifications would require agreement on the scope, the cost and the schedule for the work.



## Appendix 3

### Potential Distribution System Impacts

**Voltage Regulation** - With the addition of the Distributed Resource, the voltage level on both the primary and secondary must be maintained within acceptable limits for both on peak and off peak conditions.

- 1) Reverse power flow through voltage regulators or load tap changers may cause the regulator or load tap changer to incorrectly regulate the voltage.
- 2) Improper settings of the Distributed Resource controls may result in the steady state voltage straying outside the + or - 5% limits at the point of common coupling on a 120 volt basis.
- 3) Low voltage may be experienced after a temporary fault or when restoring service after a permanent fault if the presence of the Distributed Resource is essential to the maintenance of adequate voltage.
- 4) The loss of Distributed Resource synchronous machine exciters may cause excessive reactive power losses and low voltages on a circuit.
- 5) The presence of Distributed Resources with varying output (e.g. wind turbines, photovoltaic cells, etc.) may cause excessive switching of capacitor banks and/or an excessive number of regulator or load tap changer operations.
- 6) When line drop compensators are used on a circuit, the presence of Distributed Resources may significantly alter the intended regulation scheme.
- 7) The presence of Distributed Resources on a secondary system may cause the off peak voltage level to exceed its upper limit.
- 8) The Distributed Resource owner could experience periods when his unit(s) trips off line from overvoltage due to system voltage excursions.

**Voltage Flicker** - Several Distributed Resource technologies have the potential for creating objectionable voltage flicker. In extreme cases the size of the Distributed Resource may need to be limited to prevent objectionable flicker or system improvements may be necessary to limit the voltage flicker. Possible flicker sources include:

- 1) Wind turbines may produce rapidly varying output due to changes in wind speed, wind turbulence, intensity, tower shadowing effects and blade pitching.
- 2) Photovoltaic (PV) installations may produce rapidly varying output due to intermittent cloud cover over the cells.
- 3) Reciprocating engine Distributed Resources may be produce rapid output fluctuations caused by engine misfiring due to low quality fuel.

- 4) Induction machine Distributed Resources may produce voltage flicker due to current inrush when they are connected.
- 5) Synchronous machine Distributed Resources may produce voltage flicker due to poor voltage matching and phase angle synchronization at contact closure.
- 6) Power inverter based Distributed Resources may not have soft start technology to limit the rate of change of power output at starting.
- 7) Interaction of Distributed Resources with other devices such as voltage regulators, load tap changers and switched capacitor banks may produce objectionable voltage flicker.

**Overcurrent Protection and Protective Device Coordination** - With the addition of a Distributed Resource on a circuit, another source of fault current is introduced. The available fault current at any location on the feeder will depend upon the type of fault (e.g. line-to-ground, three phase, double-line-to-ground, etc.), the fault impedance, and the status of the Distributed Resource on the feeder (i.e. on or off line). Each Distributed Resource technology has its own unique fault current characteristics.

The presence of Distributed Resources may create several problems with overcurrent protection and the coordination of protective devices. Some of the problems include:

- 1) The “reach” of overcurrent protective devices may be reduced due to a reduction in the fault current contribution from the station source with Distributed Resources on a feeder. For faults located downstream from a Distributed Resource, the fault current contribution from the station source will be reduced when the Distributed Resource unit is on line.
- 2) Recloser to fuse coordination may no longer exist with the introduction of a Distributed Resource on the feeder so fuses may blow for temporary faults.
- 3) Sectionalizers may misoperate if the Distributed Resource maintains voltage when the sectionalizer should be "counting" an operation.
- 4) Nuisance tripping of a circuit recloser or station breaker may occur from a fault located on an adjacent feeder due to the fault current contribution from the Distributed Resource.
- 5) The presence of an interconnection transformer with a primary voltage wye grounded winding connection and a secondary voltage delta connection at the Distributed Resource can desensitize ground fault relays and the ground fault settings on recloser controls.
- 6) The introduction of Distributed Resource to a secondary spot or grid network system can cause nuisance trips of protectors and protector cycling and may lead to out of phase protector closing resulting in equipment damage.



- 7) The presence of a Distributed Resource may exacerbate cold load pickup problems following a feeder outage.
- 8) The addition of a Distributed Resource may increase the available fault current to the point where utility system or customer owned protective device fault interrupting ratings are exceeded.
- 9) If the Distributed Resource remains on the feeder after a protective device opens for any reason, then the protective device may reclose with the system voltage and the Distributed Resource voltage out of synchronism.
- 10) Distribution automation schemes may be adversely affected by the introduction of Distributed Resources.
- 11) System under frequency conditions may result in feeder or transformer overload conditions.

**Harmonic Current Injection** - Several Distributed Resource technologies have the potential for introducing harmonic distortion. Possible harmonic issues include:

- 1) Rotating machines produce 3rd harmonic distortion. Machines having a pitch of either  $5/6$  and  $11/16$  introduce the most distortion with  $2/3$  pitch being the preferred pitch to minimize distortion.
- 2) Inverter based Distributed Resources may inject harmonic voltages and currents into the utility grid or may serve as a system sink for harmonics.
- 3) Wye-wye transformer connected Distributed Resources and single phase Distributed Resources have the potential for being the worst harmonic sources.

**Other Issues** - Several other issues relating to the interconnection of Distributed Resources need to be considered. Potential problems to look for include:

- 1) Voltage on unfaulted phases may approach 1.73 times nominal during single line to ground faults when delta-wye or delta-delta connected transformer banks are used for the Distributed Resource transformation.
- 2) Resonant overvoltages can occur if a synchronous or induction generator Distributed Resource is isolated with capacitors during line to ground faults.
- 3) Single phase switching of a delta connected Distributed Resource transformer bank may create ferroresonant overvoltage conditions.
- 4) Distributed Resources may present utility worker and public safety concerns by inadvertently re-energizing the electric power system during abnormal system conditions.

- 5) The addition of Distributed Resource may overload conductors or equipment.
- 6) The presence of a Distributed Resource may defeat attempts to clear fault conditions by continuing to energize the feeder during fault events.
- 7) Induction and synchronous machine Distributed Resources may be over excited by the presence of a capacitor bank in an unintentional islanding situation and produce high voltages in the island.
- 8) Inverter based Distributed Resources may inject direct current onto the feeder causing transformer saturation.
- 9) When a grounded-wye high-side/delta low-side connected transformer bank is used to connect a Distributed Resource, circulating current in the delta winding may result in transformer overloading. This transformer connection allows zero sequence current to circulate in the delta winding.
- 10) When feeders are switched from their normal configuration to effect load transfers or to restore power to customers during outage situations, the presence of a Distributed Resource may create voltage regulation problems, objectionable voltage flicker, improper protective device operation and coordination or other problems.