

A. Introduction

1. Title: Duke Energy System Protection Standard – Distribution Connected Distributed Energy Resources

2. Purpose: Establish system protection requirements that will allow voltage and frequency ride-through for Distributed Energy Resources (DER) while still ensuring the detection of faulted conditions and the expeditious clearing of all sources of fault current. Additionally, such a solution will ensure that unintentional islanding by DER does not occur.

3. Applicability: DER interconnecting to the distribution system owned by Duke Energy Carolinas, LLC, Duke Energy Florida, LLC, Duke Energy Progress, LLC, Duke Energy Indiana, LLC, Duke Energy Ohio, Inc. and Duke Energy Kentucky, Inc. (collectively, “Duke Energy”).

4. Effective Date: October 14, 2016

5. Background:

The primary objectives of protective systems are to ensure the detection of faulted conditions and to safely remove all sources of energy supplying the fault current. Conventional distribution system protection philosophy is designed to directly detect overcurrent faults and to clearly distinguish them from load current. This is possible due to the ability of the utility system to deliver significant energy to a fault from the highly interconnected generation and transmission system.

In a typical distribution system, the magnitude of fault current is significantly higher than typical load current levels. The range of fault current magnitude expected in a protective zone can be very accurately modeled, as can the maximum load current. Effective distribution system protection practices rely on (1) a significant difference between the fault current and load current at any protective device and (2) the ability to accurately calculate the expected magnitudes through system modeling. Most importantly, in order to minimize human exposure and to reduce damage to equipment, the expedited clearing time for the protective devices installed for interruption of faults is required. Implementing an effective system protection philosophy requires well placed protective devices with the targeted responsibility of detecting and clearing faulted conditions within predetermined zones of protection.

The interconnection of DER onto the distribution system has added significant challenges to existing protection system design practices. It has been well-established within the system protection community for many decades that the use of simple and effective non-directional time-overcurrent elements, as is common in most distribution system protection devices, is not an effective means to clear DER generators from feeder circuits when faults occur. This is because DER generators cannot deliver the large magnitude of sustained fault current when compared with the utility system.

To meet the protection challenges presented by DER interconnections, Duke Energy's existing protection practices for DER rely heavily upon both Duke Energy-owned and Customer-owned passive voltage and frequency protection elements, in addition to the overcurrent elements typically utilized, being sensitive and fast. The voltage and frequency elements must quickly detect and respond to over- and under-voltage and/or over- and under-frequency excursions normally found at the DER interconnection during a localized system fault. These voltage and/or frequency excursions may not vary significantly from nominal system conditions, and cannot always be accurately determined within system modeling. The passive under/over-frequency and under/over-voltage elements, when used to detect and clear these faults, are required to meet the same expedited practices that are captured within the existing system protection policies employed today.

The passive elements used today will typically separate a DER facility from the utility system in less than 10 cycles for most faulted conditions and allow the feeder protection scheme to return to a radial fed case. DER should not disconnect unnecessarily from the distribution system during over- and under-voltage and/or over- and under-frequency excursions in the presence of a system wide fault or load flow event. However, de-sensitizing and/or removing this type of protection without providing an alternative protective solution would seriously degrade the effectiveness of the protection system and hence introduce unacceptable risk for inadequate clearing of DER sources during localized system faults.

Sensitive passive settings also play an integral role in most inverter anti-islanding algorithms in use today. In addition to passive elements, Duke Energy's protection philosophy relies on customer-owned active anti-islanding protection which has been designed to meet requirements in UL1741, Utility Interactive Anti-Islanding per IEEE 1547-2003. Adverse impacts, such as eliminating or rendering these protection features ineffective, increase the probability of unintentional islanding. The responsibility of unintentional islanding detection then shifts from the DER back to the utility.

For generation connecting to the transmission system, Duke Energy developed a protection scheme that would allow transmission-connected generation to ride-through, as defined by NERC reliability standard PRC-024, while still ensuring each generator could quickly trip offline in the event of a fault or unintentional island. These sites contain less sensitive over/under-voltage and frequency settings that are commonly referred to as "PRC-024 ride-through settings" but are dependent upon communications-based Direct Transfer Trip to be in service. Direct Transfer Trip is a protection system capability that communicates a trip signal from one location to another. For example, if a utility substation relay detects a fault on a circuit with DER, Direct Transfer Trip can send a signal to a circuit breaker at the DER location to trip the DER offline.

When FERC Order No. 828 was issued on July 21, 2016, the *pro forma* Small Generation Interconnection Agreement (SGIA) was modified to require ride-through for all FERC-jurisdictional small generator interconnections (< 20 MW). Although generators under 20 megawatts typically connect to the distribution system, Duke Energy will require a supplemental communications-based protection, as detailed in the “Requirement” section below, to avoid the additional risk presented by de-sensitizing the voltage and frequency settings at these sites.

In the event that any of the states within Duke Energy service territories adopt the FERC *pro forma* SGIA changes to require ride-through, generators under 20 MW whose interconnections are state-jurisdictional will also be subject to the protection scheme as detailed in the “Requirement” section below.

While improvements related to ride-through capability are likely upcoming for UL1741 and IEEE1547, the anticipated changes to such standards do not provide an adequate basis for relaxing protection requirements associated with the detection and clearing of faults. Implementation of ride-through must continue to be accompanied by protection system schemes that prevent islanding by prompt detection and clearing of faults.

B. Requirement:

Duke Energy requires installation of Direct Transfer Trip for interconnection of any DER, including both inverter-based and rotating generation, where protection system settings are established to enable the DER to ride through voltage and/or frequency excursions in the presence of a system wide event.

With Direct Transfer Trip communications in place, voltage/frequency settings would no longer be the sole means of detecting localized faults and/or islanding conditions, and could be effectively converted to PRC-024 ride-through settings. This solution will typically require a utility-owned protective device, an electronic recloser for example, at the DER site and fiber optics for the communication path. Other communication media are being researched as alternatives to fiber optics.

With Direct Transfer Trip in place, the inverter site is not required to identify an islanded condition since connection to the grid is validated thru the communication scheme with upstream protective devices. This Direct Transfer Trip solution also ensures that the inverter will not remain connected through the upstream reclose interval(s) of the station circuit breaker. This is very important when ride-through settings are applied that may allow the DER to remain connected during the shorter reclose open intervals, which would result in an “out-of-sync” reclose condition. In fact, this solution becomes completely independent of station reclose intervals and will not require recloser open interval time coordination at all.

Any loss of the Direct Transfer Trip availability, such as a communications failure, must result in either an instantaneous trip of the DER or an automatic change from the less sensitive ride-through settings to more sensitive voltage and frequency settings that meet or exceed the requirements of IEEE-1547-2003 for some period of time before the trip is initiated for a loss of the Direct Transfer Trip. Similarly, a hot line tag applied at the utility station could trip or convert the DER site protection to more sensitive passive settings. Automatic reconfiguration of the circuit due to a “self-healing” switching event will also require additional protection evaluation. The DER site may be required to trip for the duration of an abnormal circuit reconfiguration. Enabling tighter passive elements, in lieu of ride-through settings, in a temporary configuration may be considered. If Direct Transfer Trip availability is lost, or if self-healing results in an abnormal reconfiguration, the inverter should always operate in the active anti-islanding mode to perturb the system to the point that is detected by the more sensitive settings implemented by the Duke Energy protective device. Some inverters on the Duke Energy system are currently incapable of simultaneous operation in both active anti-islanding and ride-through modes.

There are additional criteria for Direct Transfer Trip which could be invoked at a DER site due to requirements at the feeder or station level that are not related to ride-through requirements and not discussed in detail within these standard requirements. They include, but are not limited to, unacceptable load to generation ratios, unacceptable rotating to inverter driven generation ratios, multiple inverter types on the same circuit or substation, etc., which all can contribute to an unacceptable increase in the probability of unintentional islanding.

It is extremely important to note that DER sites with a need for ride-through settings shall also be required to meet requirements to be “effectively grounded.” This will necessitate particular transformer connections at the site, certain changes in local interconnection protection equipment, and could also impact generator grounding design. This is in addition to Direct Transfer Trip requirements.