Sub-Transmission DER Interconnection Witness Test

Testing Requirements & Procedure

1.0 Purpose

This document provides the requirements, test cases, and test procedures for completing a witness test of inverter based Distributed Energy Resource (DER) systems that interconnect with the Ameren Illinois (AIC) sub-transmission system. The AIC sub-transmission system consists of networked and radial lines operated at 34.5 kV and 69 kV and is operated by and under the jurisdiction of the AIC Distribution Control organization.

2.0 Test Requirements

Requirements 2 through 7 below apply at the Reference Point of Applicability as defined in Section 4.2 of the IEEE 1547-2018 standard. In most cases, the RPA is the Ameren Illinois revenue meter location. If any deviation from this is needed, the modified RPA location will be identified in the Interconnection Agreement.

Requirement 7 below only applies to sites that implement a power plant control (PPC) system.

1. **DER Disconnect Switch Testing**

   The customer owned air-break switch must be demonstrated to operate through a full close-open-close cycle, and it must be demonstrated how AIC line personnel will have access to the switch to operate it and lock it out. If the switch is normally motor operated, it must be demonstrated how it can be manually operated.

2. **Anti-Islanding Protection**

   The DER site must adhere to the IEEE 1547-2018 specifications for anti-islanding protection for the loss of utility source as defined in Section 8.1 of the standard.

3. **Loss of Phase Detection**

   At the discretion of AIC, the site may be required to detect and react to open phase conditions as described in Section 6.2.2 of the IEEE 1547-2018 standard. If this requirement is mandated, it will be communicated to the site owner/developer/operator in advance of the date of initial energization of the site.

4. **Plant Start-Up (Enter Service) Wait Time**

   When starting up after an intended or unintended shutdown of the plant inverters, the plant shall enter service per the IEEE 1547-2018 standard Section 4, with an enter service delay (Section 4.10.3) of **300 seconds.**

5. **Plant Start-Up Ramp Rate**

When starting up after an intended or unintended shutdown of the plant inverters, the plant shall ramp its active power output per the IEEE 1547-2018 standard Section 4.10.3 at a rate no faster than **2% per second** of the site's contracted AC capacity.

6. **Power Quality**

   At the discretion of AIC, the site may be subject to power quality testing to validate its compliance with section 7 of the IEEE 1547-2018 standard.

7. **Plant Steady State Performance**

   Steady state tests will be conducted to verify compliance with any plant operating parameters defined in the Interconnection Agreement. This will consist of set point testing on the day of the witness test. Automatic voltage regulation (AVR) and constant power factor control modes are both subject to testing, regardless of the in-force operating mode for the plant. Criteria for successful plant response during these tests is provided in Section 3.3 (On-Site Test Procedure) of this document.

   Once the plant begins commercial operation, AIC reserves the right to monitor the site performance in an ongoing manner in accordance with the Interconnection Agreement. Any monitoring will be with respect to the in-force operating mode for the plant and the contracted maximum plant active or apparent power output.

3.0 Test Procedure

3.1 On-Site Test Requirements

Prior to scheduling the on-site witness test, the site must have received permission for initial energization and have submitted all necessary documentation, which must be reviewed and approved by AIC. Permission for initial energization is coordinated through either the AIC Project Manager or the assigned Region Engineer. During the initial energization period, the site will be allowed to export real power to the grid at a level no greater than 30% of the site's contracted AC capacity. During the initial energization period, the site will be energized only during regular business hours. Requests for additional consecutive hours of energization will be handled through the AIC Project Manager or Region Engineer.

At the time of the on-site testing, the DER site must meet the following requirements:

1. **Minimum Output Level**

   The site must be able to achieve a minimum of **30% of its contracted AC output capacity**. On the day of the on-site testing, the site will be allowed to export up to its full contracted AC capacity.

2. **Inverter and Plant Controller Operation**

   During the testing, all site inverters must be operational and must be under the control of the site's plant controller for steady state and disturbance ride-through operations. The settings to enforce the inverter start-up wait time and ramp rate must be configured on the plant inverters.

3. **PV Array Tracking**

   If the site employs PV array tracking, the arrays should remain fixed on loss of utility power or should be capable of being locked in a fixed position. This is to ensure that the panels are in an optimal position during start-up ramp rate testing. Note that this tracking array behavior is only needed during the on-site witness testing.

4. **Site Loads**

   No temporary load banks, capacitive or inductive devices are to be connected to the customer side of the plant during testing. All permanent site loads must be closed in.

3.2 On-Site Test Procedure

During this test, AIC personnel will be on-site as needed to observe, support the collection of data, and address any operational needs. An industry standard recording power quality (PQ) meter will be installed at the AIC revenue meter location for the purpose of data collection and analysis. For all tests, data will be collected on 1

second intervals.

Tests 3 & 4 below are only required for sites that are required to implement a plant control system.

1. **DER Disconnect Test**

   The customer's on-site operations personnel will operate the customer owned air-break switch through a full operational cycle while the plant is energized under minimum load. The customer will demonstrate how an AIC operations resource (lineman) should access and operate this switch and how it can be locked out with a standard padlock. If the switch is motor operated, the customer will demonstrate how the switch can be de-coupled from the motor to facilitate manual operation.

2. **Anti-Islanding Test (and Optional Phase Loss Test)**

   The site will be allowed to ramp up to full output as available based on the available solar irradiance. Once the site is deemed to be at a stable output, AIC will create a loss of all utility phases using its closest device on the utility side of the revenue meter. Any protective devices on the customer's system that trip during this test shall be closed in prior to closing the AIC device. If interlocks or other protections on the customer system prevent closing of tripped devices in the absence of the utility feed, this shall be disclosed to AIC prior to testing.

   AIC will hold its device open for a minimum of 6 minutes before closing it.

   If the loss of phase test is applicable for the site, the procedure listed above will be repeated, with AIC tripping one phase of its device. The process will be repeated for each of the three phases.

3. **Plant Steady State Performance – Voltage Control Mode**

   The Voltage Control Mode Test verifies that the site has the capability of maintaining a voltage schedule at the RPA and that the site responds to deviations within specified limits. The Voltage Control Mode Test will be performed, while the plant is in voltage control mode, by changing the voltage reference setpoint of the site controller. AIC will record voltage, reactive power, and active power during the Voltage Control Mode Test. Results of the test will be used to determine damping ratio, reaction time, and step response time.

   A. With the site energized, connected to the grid, and operating in a voltage control mode, record quantities for 2 minutes.
   B. Site operator increases the voltage reference point by 2%
   C. Record quantities for a minimum of 10 minutes.
   D. Site operator to update the voltage reference point to the original voltage reference point.
   E. Record quantities for a minimum of 10 minutes.
   F. Site operator to decrease the voltage reference point by 2%
   G. Record quantities for a minimum of 10 minutes.
   H. Site operator to update the voltage reference point to the original voltage reference point.
   I. Record quantities for a minimum of 10 minutes.

J. With the recorded test data, the damping ratio, reaction time, and step response time will be determined. The damping ratio will be determined using the methods described in IEEE 2800 – 2022. A site will pass the voltage control mode test with the following conditions:
   i. Damping Ratio is greater than 0.3
   ii. Reaction Time is less than 30 secs.
   iii. Total step response time to meet the voltage reference point of each step is 300 seconds or less.
   iv. After the step response, the site will maintain the voltage at the RPA within 1% of the voltage reference point.

4. **Plant Steady State Performance – Power Factor Control**

The Power Factor Control Mode Test is to verify that a site has the capability of maintaining a power factor schedule at the RPA. The Power Factor Control Mode Test will be performed, while the plant is in power factor control mode, by changing the power factor setpoint of the site's controller. Ameren will record voltage, reactive power, and active power during the Power Factor Control Mode Test. The site is expected to maintain the power factor schedule with changes in active power output. Note that if the plant's required steady-state operating mode is power factor control (as specified by the Interconnection Agreement), then the test power factor values shown below may be altered. Any deviation from the listed values will be communicated to the developer prior to the day of witness testing.

A. With the site energized, connected to the grid, and operating in power factor control mode at unity, record quantities for a minimum of 10 minutes.
B. Site operator increases the power factor by 0.02 p.u. for 0.98 p.u. lagging (capacitive for a generator).
C. Record quantities for a minimum of 10 minutes.
D. Site operator to update the power factor setpoint to the original power factor setpoint of unity.
E. Record quantities for a minimum of 10 minutes.
F. Site operator decreases the power factor setpoint point by 0.02 p.u. for 0.98 p.u. leading (inductive for a generator)
G. Record quantities for a minimum of 10 minutes.
H. Site operator to update the power factor setpoint to the original power factor setpoint of unity.
I. Record quantities for a minimum of 10 minutes.

The data collected will be analyzed using the following criteria to determine the success of this test:

A. The first 60 seconds after a set point change and the last 20 seconds prior to the next set point change will be ignored to account for the time during which the controller is ramping to the desired set point and any inaccuracies in the exact timing of the set point becoming effective in the PPC.
B. For each set point, the remaining data points will be evaluated, with the average PF (PFavg) calculated.

C. If no more than 10% of the PF data points vary from the average PF (PFavg) by more than ± 0.005, the test will be considered to pass provided that PFavg does not vary from the PF set point by more than 0.01.

3.3 On-Site Test Wrap-Up and Data Analysis

In most cases, when the on-site testing has completed, the site will be left in a de-energized state, with the AIC protective device open and the customer air-break switch open. The site will remain in this state until the on-site test data analysis is complete. The data analysis may take up to 10 business days. The test data analysis will typically result in any of the following 3 outcomes.

1. **On-Site Test Results Pass**

   In this case, the site will be granted Conditional Permission to Operate (PTO). This is a verbal agreement that the site is allowed to generate at full output capacity. AIC will close in its protective device and the customer will then close in their device to energize the site. The site will operate in this mode for a period of at least seven (7) days while AIC collects steady state performance data from the site's revenue meter. This data will be analyzed and if satisfactory, full PTO will be offered in writing from AIC to the applicant.

2. **On-Site Test Results Fail**

   If analysis of the collected data indicates a failed test, this will be communicated in writing to the developer and will include an explanation of the failed test(s). The developer will then be required to mitigate any issues prior to requesting a re-test. In the interim, the site will be allowed to temporarily energize using the same procedures that were in place prior to the day of the witness test. The developer and AIC will work together to schedule a new test date once any issues have been mitigated.

3. **Additional Data Collection Needed**

   If AIC determines that additional on-site testing is needed, this will be communicated to the developer and a new date for the additional testing will be scheduled as soon as possible. Instructions for allowed site operation for the interim period will also be provided.

3.4 Site Steady-State Test

At the conclusion of the on-site testing, after confirmation of success for all test cases, the site will be issued a formal Permission to Operate (PTO) letter. Once the plant begins commercial operation, AIC reserves the right to monitor the site performance in an ongoing manner in accordance with the Interconnection Agreement. Any monitoring will be with respect to the in-force operating mode for the plant and the contracted maximum plant active or apparent power output. Any identified issues or any changes in the default operating mode will be communicated in writing to the site owner of record.