PECAN STREET

# Product Performance Testing Results: Detection of Electrical Faults, Bi-directional Current Flow, and Current Variability

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Athena Power UFD 1000

## Product Description

Athena Power's UFD 1000 Fault Current Indicator (FCI) is a self-powered, wireless, and submersible sensor for underground distribution circuits. The UFD 1000 can be connected to electrical gear, such as transformers, reclosers, or pad-mounted switchgears, vaults or manholes. Per Athena Power, the UFD 1000 could find faults more quickly by providing real-time information directly to the utility's SCADA systems. Due to the wireless capabilities of the UFD 1000 device, Athena Power believes that their product can capture predictive data for future failures in underground circuits.

## Product Application

When faults occur in the distribution system – whether because of faulty equipment, environmental, or other reasons – they should be immediately isolated to prevent hazards to the general public or utility personnel. Unfortunately, in underground lines, detecting a fault is difficult since visually inspecting a feeder is not possible. Although there are means of detecting ground faults underground, they are not efficient in determining the faulted element or location along the distribution feeder. As a result, utility personnel are required to manually disconnect every feeder in a substation to troubleshoot and find the fault.

For underground circuits, it is important that devices such as Fault Current Indicators (FCIs) are readily available for utilities to use and install. Having FCI sensors can help utilities find underground faults rapidly and efficiently without increasing the number and length of outages. Some of the largest manufacturers of fault sensors and grid protection devices are Siemens, Schweitzer Energy Laboratories, GE, and others.

FCIs are constantly measuring current on a circuit to know when a fault occurs. Therefore, some of these sensors can also be used as data loggers that are monitoring current at real time and reduce issues related to power congestion. These sensors, connected to the SCADA systems via WI-FI or fiber glass, can be extremely useful in the industry as the penetration of DERs on the grid increases.

## Analysis and Results

This section summarizes the results for the tests agreed upon between Pecan Street and Athena Power. These tests aimed to reflect how well the UFD 1000 performs under the following tests. The tests were done on a UFD 1000 capable of detecting current and voltage for three phases.

1. **Fault Detection**

The fault detection test was performed in order to see how long it would take for the UFD 1000 to respond to a fault condition. Pecan Street noticed that when setting the UFD 1000 to respond to a fault of 10A, the device's CTs picked up a lot of noise. After discussing this with Athena Power, Pecan Street modified the test to have a 100A setpoint for a fault, instead of 10A.

The test ran for 15 minutes. Every five minutes the current was increased as shown in Table 1. As soon as the current was set to 100A (the fault setpoint), the three phases (A, B, C) of the devices detected a fault within five seconds. Table 1 shows the results for this test.

The UFD 1000 device faults after detecting peak values, not RMS values. However, when setting the UFD 1000 to detect a fault, one must set an RMS value. As a result, in this section, the results tables have both the RMS value and the peak value to see when the device detects the fault.

*Table 1Results for Fault Detection tests*

| 100A Fault | RMS Current (Load) | Peak Current | Phase A (RMS) | Phase B (RMS) | Phase C (RMS) |
|---|---|---|---|---|---|
| **Time** | | | | | |
| **4:00** | 80 | 113.12 | 80 | 81 | 80 |
| **4:05** | 92 | 130.088 | 92 | 94 | 92 |
| **4:10** | 100 | 141.4 | Faults within 5 seconds | Faults within 5 seconds | Faults within 5 seconds |

**2. Bi-Directional Power Flow**

For the bi-directional power flow tests, Pecan Street initially aimed to use a battery and an inverter to measure current charging and discharging from the AC side of the inverter. However, the UFD 1000 picked up noise and harmonics with small currents, so Pecan Street was not able to test the device under the condition described in the test plan.

To achieve bi-directional measurement, Pecan Street used the same setup as the other tests with the programmable Chroma load, measuring the currents from a wire wrapped 40 times around the Rogowski CTs. To get bi-directional flow, the CTs were flipped. The UFD 1000 measured the current correctly in both flow directions. The percent error was slightly larger with reverse flow, but not significant enough to limit the performance of the device. The results for phase A, B, and C are shown in Table 2-4.

*Table 2 Results for Bi-directional measurements (Phase A)*

| Phase A | Total Current | CT measured current | CT measured current (reverse flow) | % Error | % Error (reverse flow) | Pass/Fail |
|---|---|---|---|---|---|---|
| **4:45** | 100 | 101 | 101 | 1 | 1 | Pass |
| **4:50** | 250 | 252 | 253 | 0.8 | 1.2 | Pass |
| **4:55** | 500 | 502 | 504 | 0.4 | 0.8 | Pass |

*Table 3 Results for Bi-directional measurements (Phase B)*

| Phase B | Total Current | CT measured current | CT measured current (reverse flow) | % Error | % Error (reverse flow) | Pass/Fail |
|---|---|---|---|---|---|---|
| **4:45** | 100 | 102 | 102 | 2 | 2 | Pass |
| **4:50** | 250 | 255 | 254 | 2 | 1.6 | Pass |
| **4:55** | 500 | 508 | 507 | 1.6 | 1.4 | Pass |

*Table 4 Results for Bi-directional measurements (Phase C)*

| Phase C | Total Current | CT measured current | CT measured current (reverse flow) | % Error | % Error (reverse flow) | Pass/Fail |
|---|---|---|---|---|---|---|
| **4:45** | 100 | 100 | 101 | 0 | 1 | Pass |
| **4:50** | 250 | 251 | 253 | 0.4 | 1.2 | Pass |
| **4:55** | 500 | 500 | 508 | 0 | 1.6 | Pass |

## 3. Current Variability Tests

The current variability tests evaluated how well the UFD 1000 device measured current. The device measured currents of 100A, 250A, and 500A with less than 2% error margins. The results for phase A, B, and C are shown in Table 5-7.

*Table 5 Results for current variability (Phase A)*

| A<br>Time | Load Current | Total Current | CT measured current | % Error | Pass/Fail |
|---|---|---|---|---|---|
| **4:25** | 2.5 | 100 | 101 | 1 | Pass |
| **4:30** | 6.25 | 250 | 252 | 0.8 | Pass |
| **4:35** | 12.5 | 500 | 502 | 0.4 | Pass |

*Table 6 Results for current variability (Phase B)*

| B<br>Time | Load Current | Total Current | CT measured current | % Error | Pass/Fail |
|---|---|---|---|---|---|
| **4:25** | 2.5 | 100 | 102 | 2 | Pass |
| **4:30** | 6.25 | 250 | 255 | 2 | Pass |
| **4:35** | 12.5 | 500 | 508 | 1.6 | Pass |

*Table 7 Results for current variability (Phase C)*

| C<br>Time | Load Current | Total Current | CT measured current | % Error | Pass/Fail |
|---|---|---|---|---|---|
| **4:25** | 2.5 | 100 | 100 | 0 | Pass |
| **4:30** | 6.25 | 250 | 251 | 0.4 | Pass |
| **4:35** | 12.5 | 500 | 500 | 0 | Pass |

## Conclusion

Pecan Street Inc. conducted the testing for the UFD 1000 under the DOE Platform Project. The UFD 1000 performed well under fault conditions, where the device detected a fault within five seconds. It also measured bi-directional current, although the percent error was slightly larger with reverse flow, but not significant enough to limit the performance of the device. Lastly, the device measured currents of 100A, 250A, and 500A with less than 2% error margins. The device successfully passed the majority of performance validation test protocols outlined in the test plan.