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Savannah River National Laboratory®

SRNL EPC Installation Report

Ian Webb

Klaehn Burkes

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Savannah River National Laboratory®

1.0 Summary

During the week of August 25th, 2021, three Electric Phenomenon Cluster (EPC) sensors were installed at the Savannah River Site (SRS) owned, Dominion Energy (DE) operated 504-2G substation, shown in the figure below.

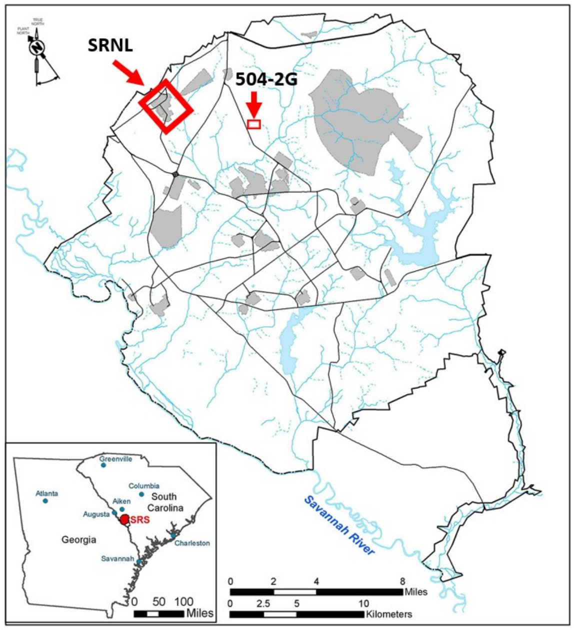

Figure 1-1. Location of EPC Installation within SRS

This substation is one of the primary feeds for the 115 kV transmission grid at SRS, serving as one of the few interfaces between the outside grid and the SRS grid. Within the substation, the 115 kV outside feed is broken into a variety of different 115 kV lines to feed different sections of the SRS grid. For this installation, the EPC sensors were installed on the line that feeds directly into the Savannah River Tritium Enterprise, a major link in the nuclear supply chain.

The installation of the sensors took place in two separate parts: one part for the physical mounting of the sensor, conduit, and fiber optic cables performed by DE, and the other part for the connection of the EPC to the Optical Processing Unit (OPU) via specialty fiber optic cables performed jointly by SmartSenseCom (SSC), DE, and qualified SRNL personnel. The finalized connection diagram is shown in Figure 1-2 below. After the EPC sensors were connected to the OPU, remote access was configured between the Savannah River National Lab Critical Infrastructure and Industrial Control System Cyber Security lab (S-CIIC), using a cellular radio transmitter system between the substation and the SRNL campus. The installation activities concluded on September 3rd.

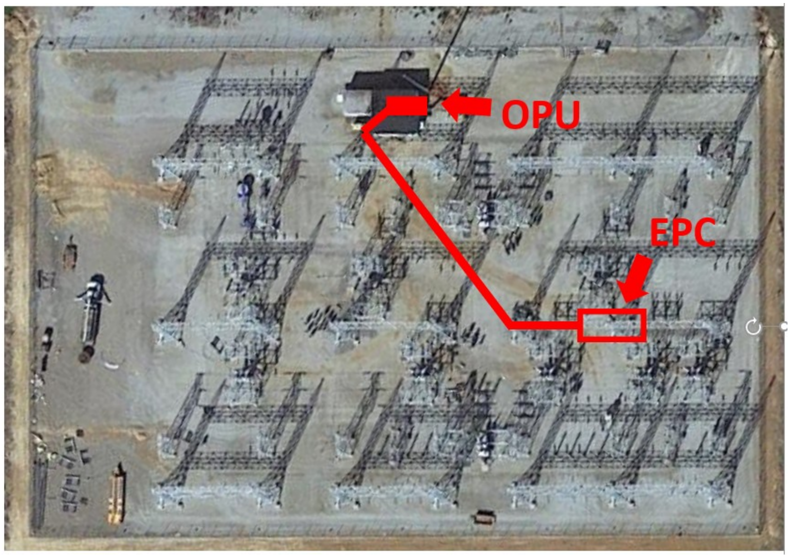

Figure 1-2. EPC Installation at 504-2G

2.0 Installation Synopsis

Starting the week of August 23rd, Dominion Energy began the process of installing the three 115kV rated EPC sensors. These sensors were installed at the top of the 60 ft substation structure, with fiber optic cables coming from the bottom of the sensor mounting box running through a rigid conduit down the side of the structure, which then was buried through the switchyard until the conduit terminated at the switch house. A picture showing the hoisting of the sensors to the top of the substation truss structure is shown below.

Figure 2-1. EPC Installation on Substation Structure

Due to contractual verbiage in the initial contract document between SRNL and SSC, SSC representatives were not authorized to perform hands-on work while within the SRS boundary. Because of this, after the EPC sensors and the fiber optic cables were installed (but not connected), a representative from SSC came onto SRS and trained qualified SRNL personnel to perform the hands-on work involving the preparing, splicing and connecting of the specialty fiber cables. After the SSC had trained the SRNL representative and was comfortable with their skill level, the optical processing unit (OPU) that was to be installed at the 504-2G substation was field acceptance tested using SRNL's High Current Lab (HCL). A diagram depicting the test set-up is shown below.

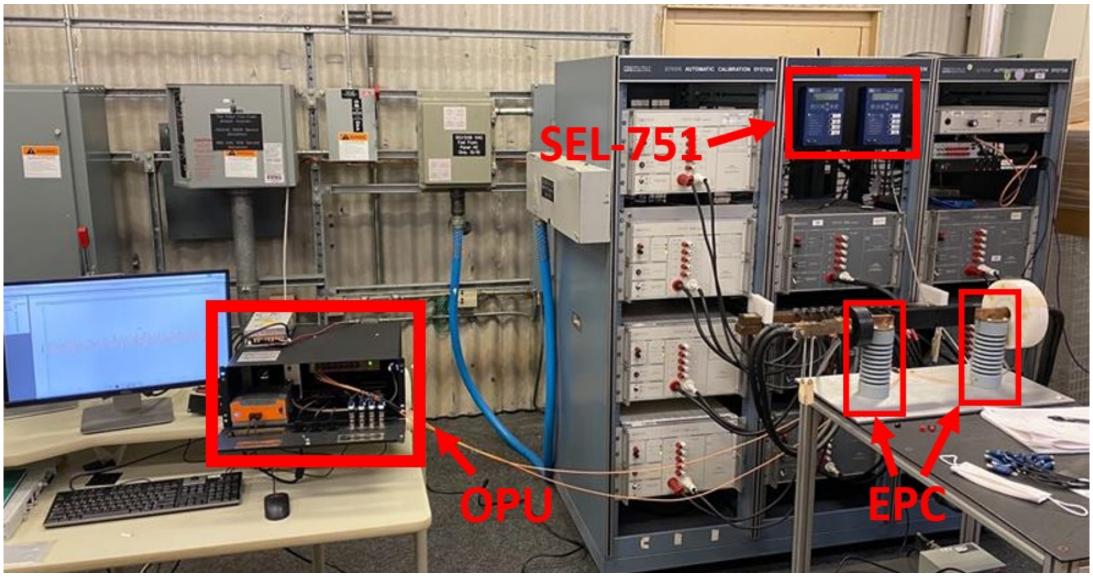

Figure 2-2. High Current Lab OPU Field Acceptance Test Set-Up

Pictured in the figure above is a rack of 10 current amplifiers with a combined capability of outputting accurate waveforms at the 1000 A level through a copper bus bar shown connected to the EPCs in the figure above. Also included in the figure are 2 SEL-751 protective relays, which were used for low-level input evaluation. The primary purpose of this test was to ensure that the OPU was still in functioning order after shipment. This test was done by connecting the fiber optic cables from the EPC sensors to the OPU and sending a large amount of current through the sensors to observe how the EPC displayed the information.

After the OPU was determined to be in working order, the low level signal outputs on the front ports of the OPU were tested. The 8 coaxial ports on the front of the OPU enclosure serve as the signal output to be fed into monitoring equipment, such as protective relays or other data acquisition equipment. It was determined previously that in both an experimental test set-up within SRNL's HCL and the EPC installation in Fork Union, Virginia that the OPU has incorrect output signal grounding within the circuit board that produces the output signal that goes to the coaxial ports. This issue (as mentioned in previous installation reports), was discovered by connecting the outputs from the OPU to the low level inputs on an SEL-351 protective relay and observing the following behaviors:

1. There was a large amount of signal induced on other channels when just one signal (coaxial plug) wire was plugged in
2. Touching the chassis ground (the panel itself, the metal chassis ground on the coaxial connectors, touching internally into the SEL-351) resulted in a change in the displayed values on the relay
3. Generally high noise levels

To recreate and test for this behavior in the test set-up shown above, the output signals from the coaxial connectors on the OPU were connected to an SEL-751 relay via the low-level interface on the SEL-751. It was observed that when connected, the OPU displayed a low-light received error, which is normally triggered when a transmit LED has either died or the signal coming back is too weak to be read accurately. However, whenever the output signal from the OPU was disconnected from the low-level inputs on the relay, the OPU began reading accurately again without error. From this, it was postulated that each of the signal leads coming from the OPU had a common leg, meaning that one of the wires for each signal pair were connected to the system ground. This is a crucial detail, because the signal coming from the circuit board within the OPU is a differential signal, requiring two separate wires to be not connected to ground in any form.

To test this theory, the cathode of the coaxial connectors going into the front face of the OPU were tested with a continuity meter to test if there is any form of appreciable electrical connection between each cathode. This test showed that there was in fact an electrical connection between the cathodes of the coaxial terminals on the front face of the OPU. This implies that each of the signal pairs on the internal circuit board have a common leg in each of the signal wire pairs. This demonstration was done in conjunction with SSC personnel, and they are currently working on a fix for the next generation of the OPU hardware.

Figure 2-3. Front Panel of OPU

Another minor hardware issue that was discovered in these tests was the chassis grounding of the coaxial connectors. As shown in the figure above, the coaxial ports that are used to interface with the differential output signal do not have electrical insolation between the chassis and the cathode. This essentially chassis grounded one of the signal wires in the differential pair and caused small signals to be induced on other connected coaxial connectors. This issue has been explained to SSC, and they are currently working on a fix for the next generation of the OPU hardware.

After the field acceptance test, the OPU was installed into a rack of data acquisition equipment, shown in the figure below.

Figure 2-4. OPU Rack of Equipment in 504-2G

This rack included (starting from the top going down) a screen, keyboard and mouse, a National Instruments PXI chassis, an SEL-351 protective relay, an interface board to interface between the OPU signal outputs and relay low level inputs, the OPU, a GPS signal-based clock, and a Juniper cellular gateway. After the OPU was installed, remote access was configured and tested by connecting the OPU to the Juniper cellular gateway and utilizing TightVNC (a free, open-source remote desktop software server and client application) to remote desktop into the OPU.

Once remote access was configured, the calibration of the EPC sensors took place. This process involved DE and qualified SRNL personnel going up to the EPC sensor installation at the top of the truss structure in a bucket lift and connecting a CPC-100 calibration device to the sensors. The CPC-100 is a power calibration device that is used in the initial calibration of the EPC to inject 100 amps for current calibration and 2000 volts for the voltage calibration. The calibrating process requires a person at the sensor to inject the current and voltage using the CPC-100, and a person at the OPU to calibrate the values displayed on the OPU HMI. The CPC-100 was placed into the bucket lift with the DE and SRNL personnel, and the SSC representative was on the ground with the OPU.

3.0 Important Notes and Lessons Learned

- It should be noted that the EPC sensors are normally meant to be installed on some form of flat pedestal, with a bottom plate covering the bottom face of the mounting box. For this installation, the EPC was mounted on a truss-based structure, which does not have a solid bottom mounting base. This in turn left the interior of the EPC base box unsealed and exposed the interior of the EPC base box from the bottom. This is not an issue in this case due to all cables and interior components being weather rated, however in future truss-based installations, a bottom plate would be advised to ensure complete protection of the interior components of the EPC. A figure depicting DE personnel accessing the inside of the EPC base box using the unprotected bottom face is shown below.

Figure 3-1. DE Personnel Accessing EPC Interior via Bottom Face

- Previously, when the OPU was being prepared for substation installation at SRNL, SRNL personnel attempted to change the IP addresses of the internal networked components inside the OPU. The re-numbering of the address set from the default was done as a good cyber-hygiene practice, as well as the fact that the OPU was to be installed in a rack of other networked equipment that was to be integrated into an existing laboratory-based network with its own IP addressing scheme. Changing the IP addresses within the OPU resulted in a general failure of the functions of the OPU, causing the SSC application to not connect to the signal input boards. SSC personnel were notified of this issue, and the OPU was sent back to SSC for repair. After discussions with SSC on this issue, it was determined that currently, the only way to change the IP addresses within the OPU would be to change it at the SSC lab, requiring the IP schema to be determined and communicated to SSC before OPU shipment to the customer.
    - It has been communicated to SSC that in future OPU updates, an added function of being able to change IP addresses freely from the user end in the field would be very useful.