Dominion Energy's Experience with Optical Sensors

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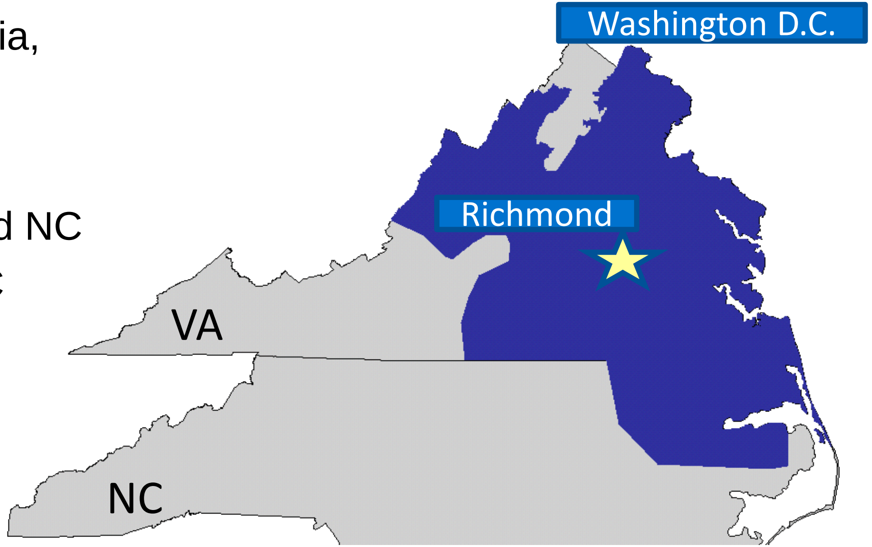
Dominion Energy Virginia

Electric Transmission

- 6,600 miles of transmission lines in Virginia, North Carolina, and West Virginia

Electric Distribution

- 57,600 miles of distribution lines in VA and NC
- Serve 2.6 million customers in VA and NC



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Dominion Energy Applications with Optical Sensors

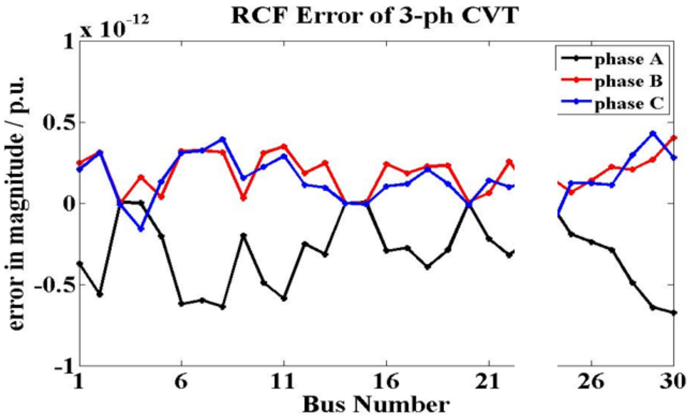
- Our experience with Optical Sensors started with our initial deployment of PMUs and PMU Applications as part of the DOE Smart Grid Investment Grants
    - The initial application requiring optical sensors was for Calibrating Instrument Transformers across the system

- Using Optical CTs for a specific protection application with a physical constraint
    - Long distance CT secondary cable run

- Using Optical Sensors for Revenue Metering applications

Using Optical Sensors for Calibrating Instrument Txs

- Voltage and Current Transformers are installed on all high voltage transmission lines and transformers. They are what provide all measurements made in power systems, whether for SCADA monitoring, PMUs, Meters, or protection systems.
- These devices are subject to errors in their performance, usually expressed as Ratio Correction Factors (RCFs).
    - We can estimate and calibrate these RCFs using synchrophasor measurements made from a high accuracy Optical Voltage Transformer, in conjunction with measurements made with traditional less-precise current and voltage transformers.
- Using a sufficient number of measurement sets over a period of several hours as the system load changes, the technique can obtain and calibrate RCFs of all imprecise instrument transformers



Typical errors of estimation of RCFs

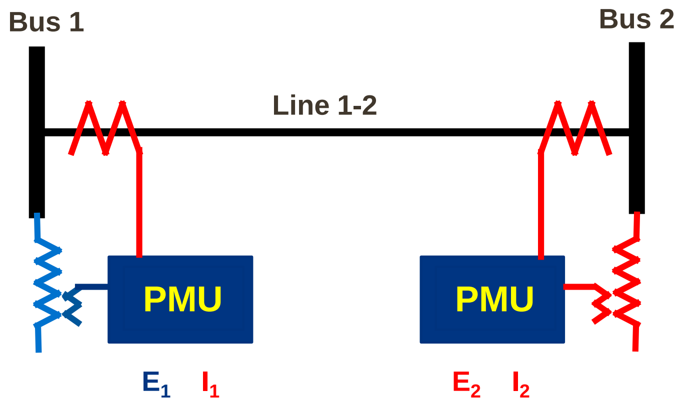
Using Optical Sensors for Calibrating Instrument Txs

The voltage transformer at Bus 1 is the Optical PT, with the most accurate measurements available

The voltage transformer at Bus 2 and current transformers at Bus 1 and Bus 2 are imperfect and have RCFs which need to be determined.

The unknown quantities are

- RCF-E2
- RCF-I1
- RCF-I2



The PMUs at two ends of the line provide 4 sets of measurements: E_1, E_2, I_1, and I_2 .
Using multiple sets of these measurements obtained over several hours of system load variations, the unknown RCFs can be determined.

Future research is needed to investigate the addition of Optical CTs to Bus 1, which may allow for line impedance estimation.

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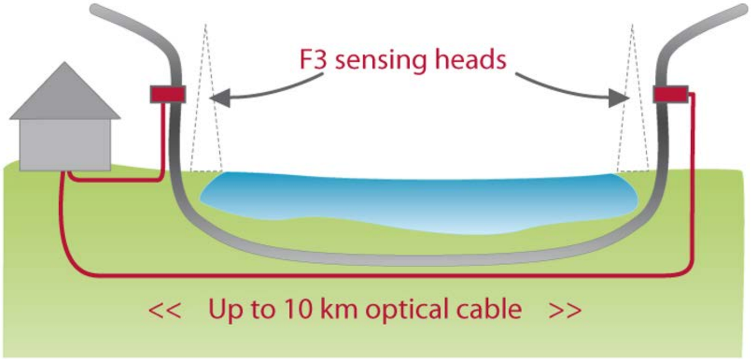
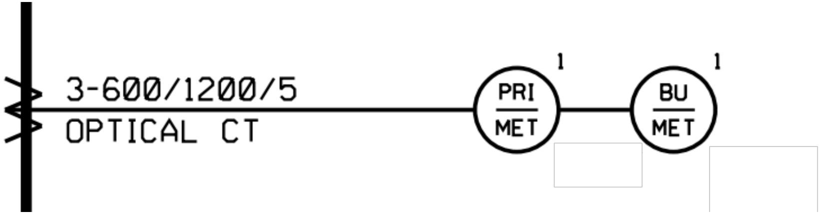
Using Optical CTs for Protection Application

- Have a transmission line with an underground section, and needed to determine when faults were inside the underground section or outside the underground section
- To do this, we needed current signals from both ends of the UG section, but one end did not allow for a substation to be built.
- Distance to the other end with the substation was too long for traditional 5A secondary CT signals
- Optical CTs were used instead of traditional CTs because the current signals could be run the long distance without any degradation in signal



Revenue Metering with Optical CTs

- Due to high accuracy of Optical CTs, our metering team piloted the use of Optical CTs for a revenue metering application
- The team used these new Optical CTs to gather revenue metering data (energy output from a plant and station service load usage), and compared the data to our existing traditional primary and backup revenue meters



- Found the components performed well, and comparison of revenue meter data is ongoing
- Additionally, loading limits of Optical CTs must be considered

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Experience/Issues with the Optical Sensors

- Requires training of technicians and engineers with the new systems, components, and functionality

- Even though they are optical sensors, they still do have a loading limit on the primary components and possibly the secondary systems

- If using a conversion system to convert the optical sensors to traditional 115V / 5A secondary signals, get detailed training and design information from vendors and understand these secondary systems in detail

- Experienced some failures of the optical sensors in the field

Future of Optical Sensors

- Explore alternatives to converting the optical signal to our traditional 115V / 5A secondary signals
  - Lose some of the benefits from the optical signals, can introduce more complexity and inaccuracies
  - Directly feeding the fiber optic signals to relays and meters would be valuable, but requires new devices and changes from our traditional copper inputs
- Further integration with IEC-61850 components and features like process bus and merging units
- Additional voltage-level and current-levels needed, including combination voltage and current units
- High quality components with very high load ratings
  - These should be mostly passive devices with low risk
  - High load ratings essential, do not want these to be limiting factors on lines and transformers

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