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Measuring Geomagnetically-Induced Currents in each Phase of an Auto Transformer Bank

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2021 CIGRE Grid of the Future Symposium
Providence, RI
October 18th, 2021

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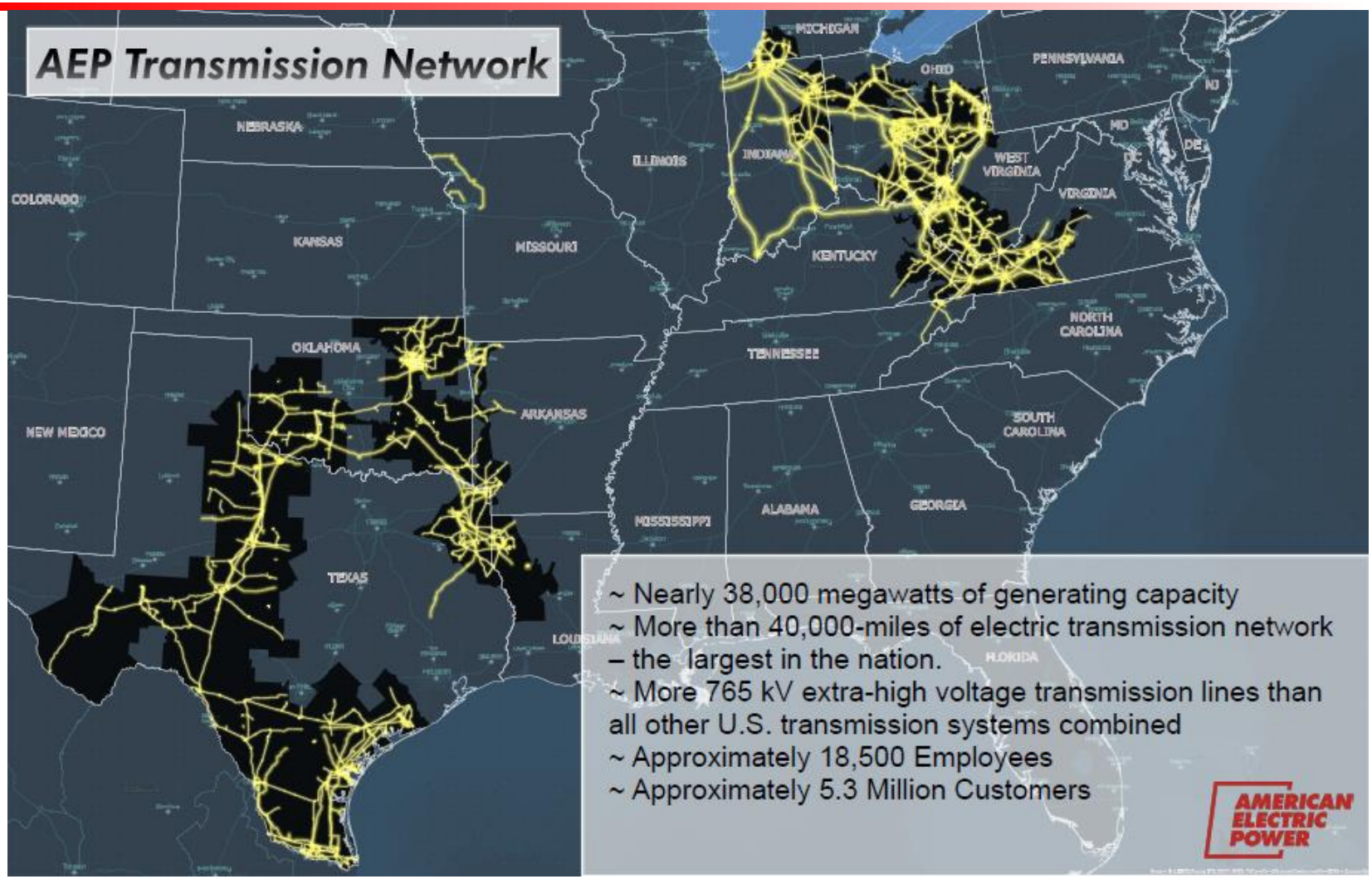
About AEP



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Presentation Outline

- Geomagnetic Disturbances
- AEP Efforts on GIC Monitoring
- Why measure Line GIC
- Line GIC system Design
  - FOCS System
  - Merging Unit
  - Measuring unit
  - Data Transfer
- Data Acquisition
- Data Validation
- GIC Distribution
- Concluding Remarks

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Geomagnetic Disturbances

- Geomagnetic Disturbances (GMD) are a result of the interaction of the earth's magnetic field and the particles discharged from the sun during a solar storm
- Changes in the Earth's magnetic field will induce a quasi dc voltage, which will result in the flow of Geomagnetically Induced Currents (GIC) through grounded transformers and transmission lines
- Measuring GIC magnitude, direction, and distribution is important to assess the possible impact on large transformers and on the bulk electric power system

Source: NASA

AEP Efforts on GIC Monitoring

- Working with transformer manufacturers and research institutions to study the impact of GIC on large EHV power transformers
- Installed permanent GIC monitors across the system to detect and evaluate GMD impacts on large transformers
- Commissioned Off station magnetometer system to detect changes in earth magnetic field

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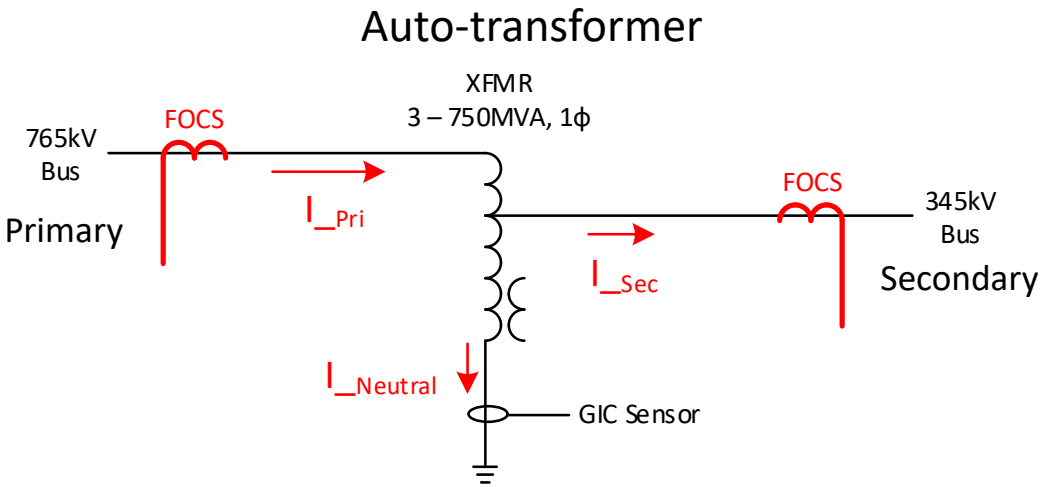
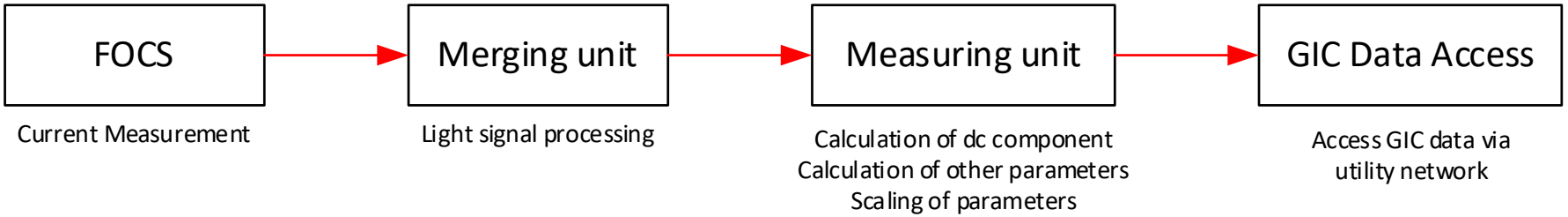
Why Measure Line GIC

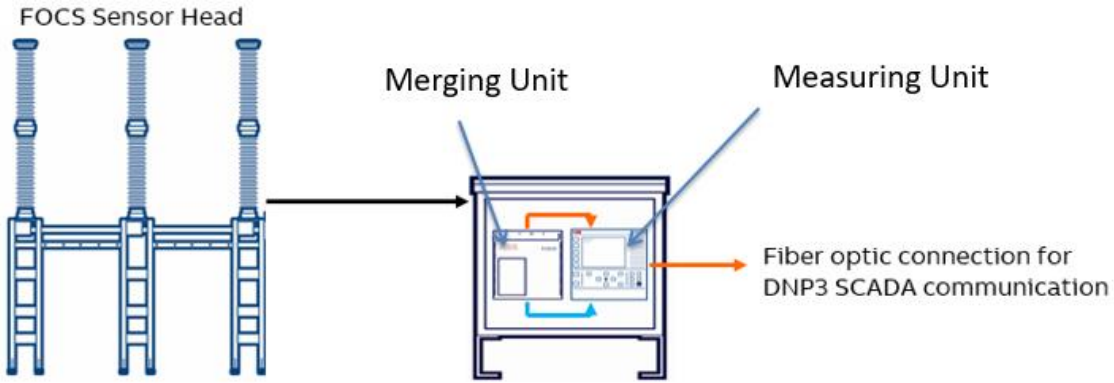
- During a GMD event, GIC flowing towards the transformer could split between the neutral and secondary sides
- Measuring at least 2 out of the 3 current components, the 3rd current component can be calculated
- GIC neutral sensor will only measure the GIC component flowing through the neutral, which will not provide the complete GIC distribution



$$I_{Pri} = I_{Sec} + I_{Neutral}$$

Line GIC System Design

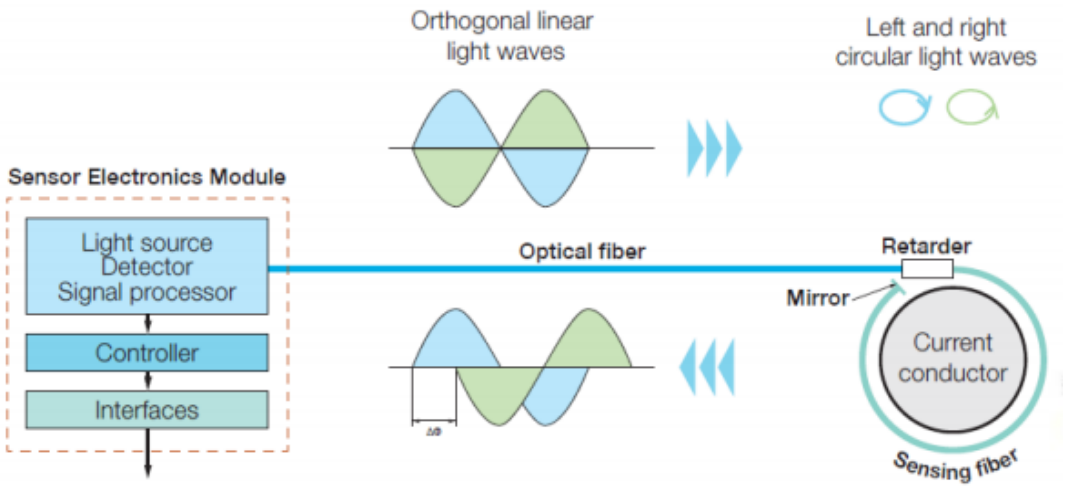




Source : Introduction of FOCS and FOCS based applications, ABB HVIT presentation, 24th February, 2017

Fiber Optic Current Sensor (FOCS)

- Need to calculate the dc component of individual phase currents
- Regular wire-wound CTs are not capable of providing the dc component
- FOCS, together with a merging and measuring units, will calculate the directional dc component

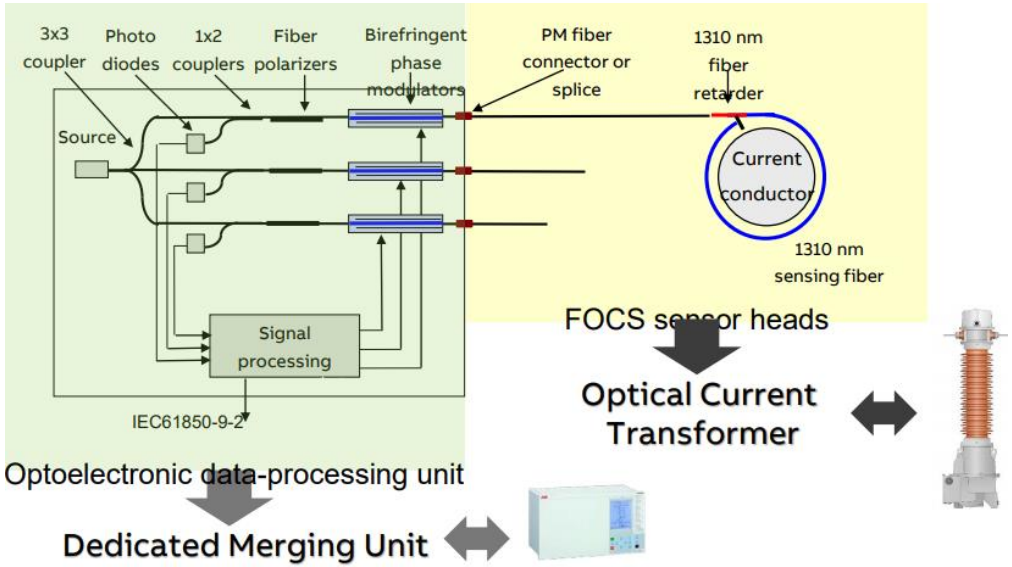


Source : AEP GIC Measuring Project, ABB RTM Presentation, 2nd February, 2018

- Sending and receiving light signals will travel through the fiber optic cables at the same speed when there is no magnetic field present
- When the current flows in the primary conductor, sending and receiving light signals will travel at different speeds and will induce an optical phase shift, which is proportional to the instantaneous primary current

Merging Unit

- The merging unit is designed to control the sending and receiving light signals to and from FOCS units, using closed loop detection circuits with integrated optic phase modulators
- One merging unit will process the optoelectronics data from each FOCS for all three phases
- Measured and scaled optical phase shift data will be transferred to the measuring unit which is installed in the same kiosk



Source: AEP GIC Measuring Project, ABB RTM Presentation, 2nd February, 2018

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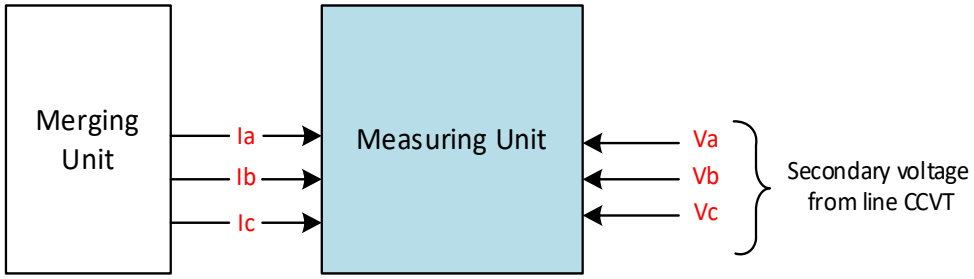
Measuring Unit

- The measuring unit is a protection relay platform which will receive :
  - 3-ph currents from the merging unit
  - Secondary voltages from line CCVTs
- The dc components of the received current signals are calculated by performing a Fast Fourier Transform (FFT) to the input current signals, utilizing a customized harmonic measurement module
- Following parameters are calculated for each phase, which will then be scaled to proper engineering units



- DC current magnitude with polarity (Amps)
- AC current magnitude (Amps)
- AC current angle (degrees)
- Line voltage (kV)
- Line voltage angle (degrees)
- Active power (MW)
- Reactive power (MVAr)
- Apparent power (kVA)

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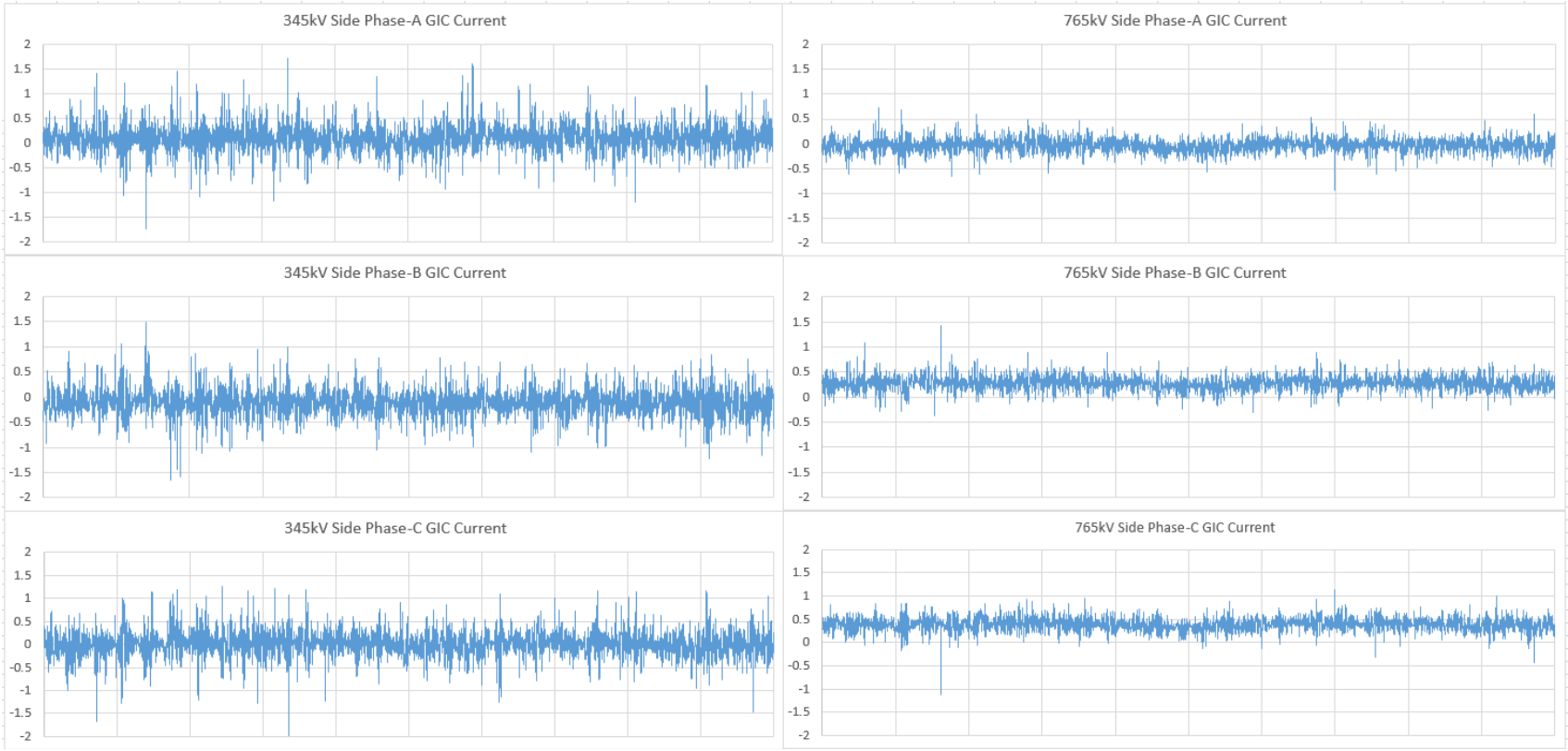
Data Transfer

- Measured and calculated quantities were configured and scaled to transfer to the AEP SCADA network for remote access and long term archiving
- Watch dog (faulty device) alarms were hard wired to monitor the status of merging unit and the measuring unit
- Two sets of data streams were configured for the high and low side of the transformer

Data Acquisition

- Transformer low side and high side calculated GIC currents with direction
- for 24 hr period without any significant geomagnetic activity



The sign convention indicates positive numbers for current flow into the transformer on both windings

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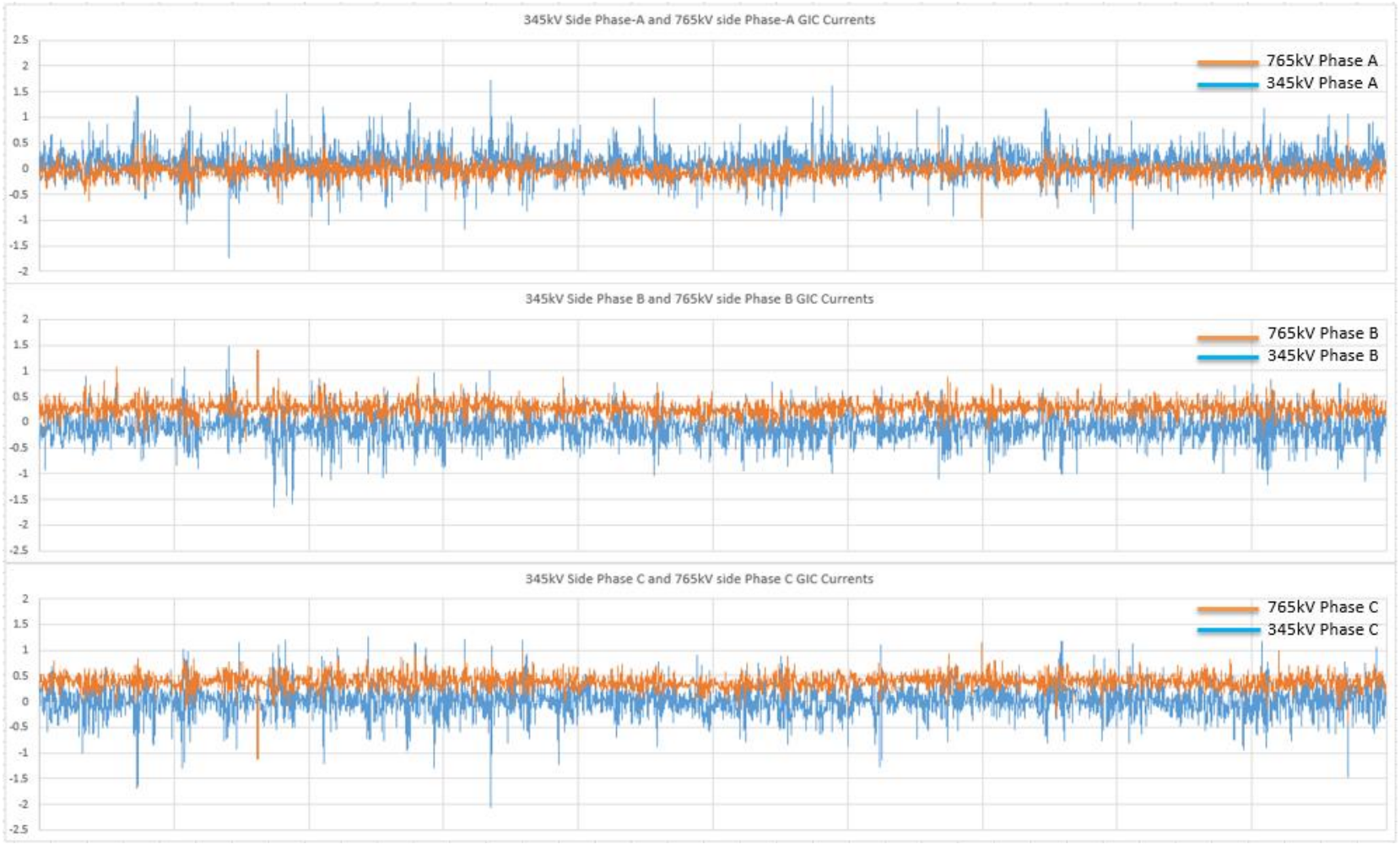
Per phase GIC data

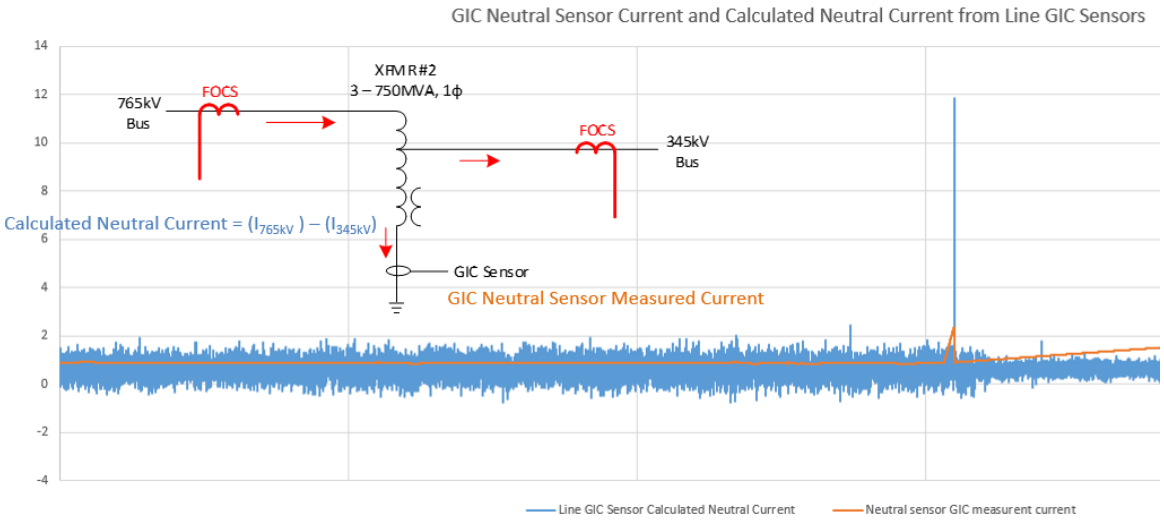


Data Validation

- Neutral GIC flow could be calculated from subtracting the low side GIC from high side GIC for each phase
- Add the components to get the total neutral GIC

$$Ia_{\_Calc} = (Ia_{\_765kV}) - (Ia_{\_345kV})$$
$$Ib_{\_Calc} = (Ib_{\_765kV}) - (Ib_{\_345kV})$$
$$Ic_{\_Calc} = (Ic_{\_765kV}) - (Ic_{\_345kV})$$

$$I_{\_Calc} = Ia_{\_Calc} + Ib_{\_Calc} + Ic_{\_Calc}$$



- Calculated GIC component (blue plot) could be compared against the measured GIC (orange plot) from the neutral sensor
- Data for fifteen days
- Calculated GIC data for the transformer neutral is consistent with the measured neutral GIC from the sensor
- The outlier toward the end of the plot is related to a station line reactor switching event

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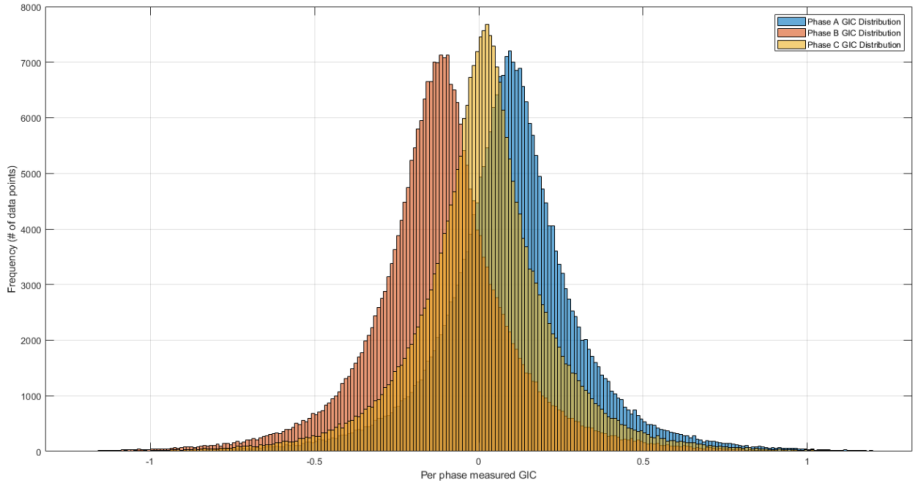
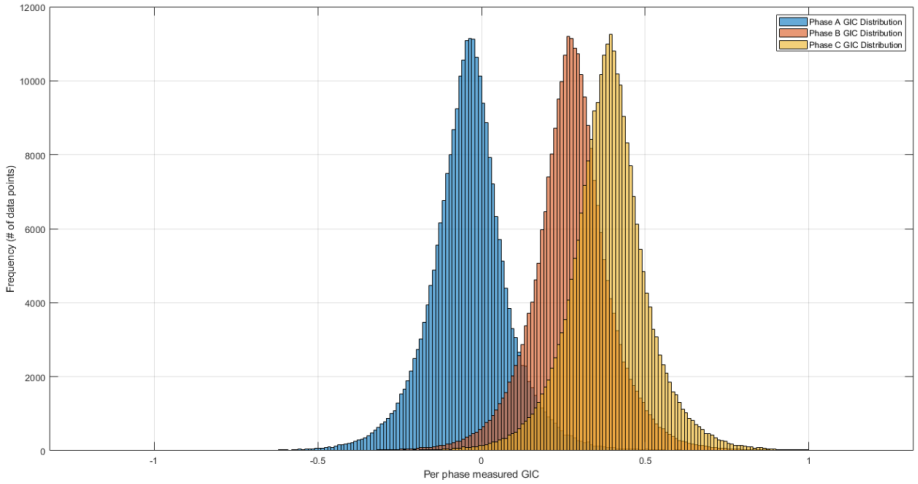
GIC Distribution

- Measured data demonstrates that GIC will not equally distribute among three phases
- histograms of GIC data for a fifteen day period, which did not have any significant geomagnetic activity



Transformer low side measured GIC dispersion



Transformer high side measured GIC dispersion

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Concluding Remarks and Future work

- AEP successfully designed and commissioned a line GIC system to measure the direction and distribution of the GIC within an EHV transformer's windings
- AEP will use this data along with transformer neutral GIC and magnetometer measurements to help in the validation of GIC system models
- This will enable AEP to understand the impacts of GMD events and take possible mitigating actions in the future
- Future work for this project includes further analysis of the GIC data for significant GMD events and correlation with magnetometer data, to evaluate the possible impact on the EHV transformers

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Questions?