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# Measuring the Earth's Magnetic Field Variations – AEP's Experience with the Design and Commissioning of a Magnetometer Measurement System


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CIGRE Grid of the Future
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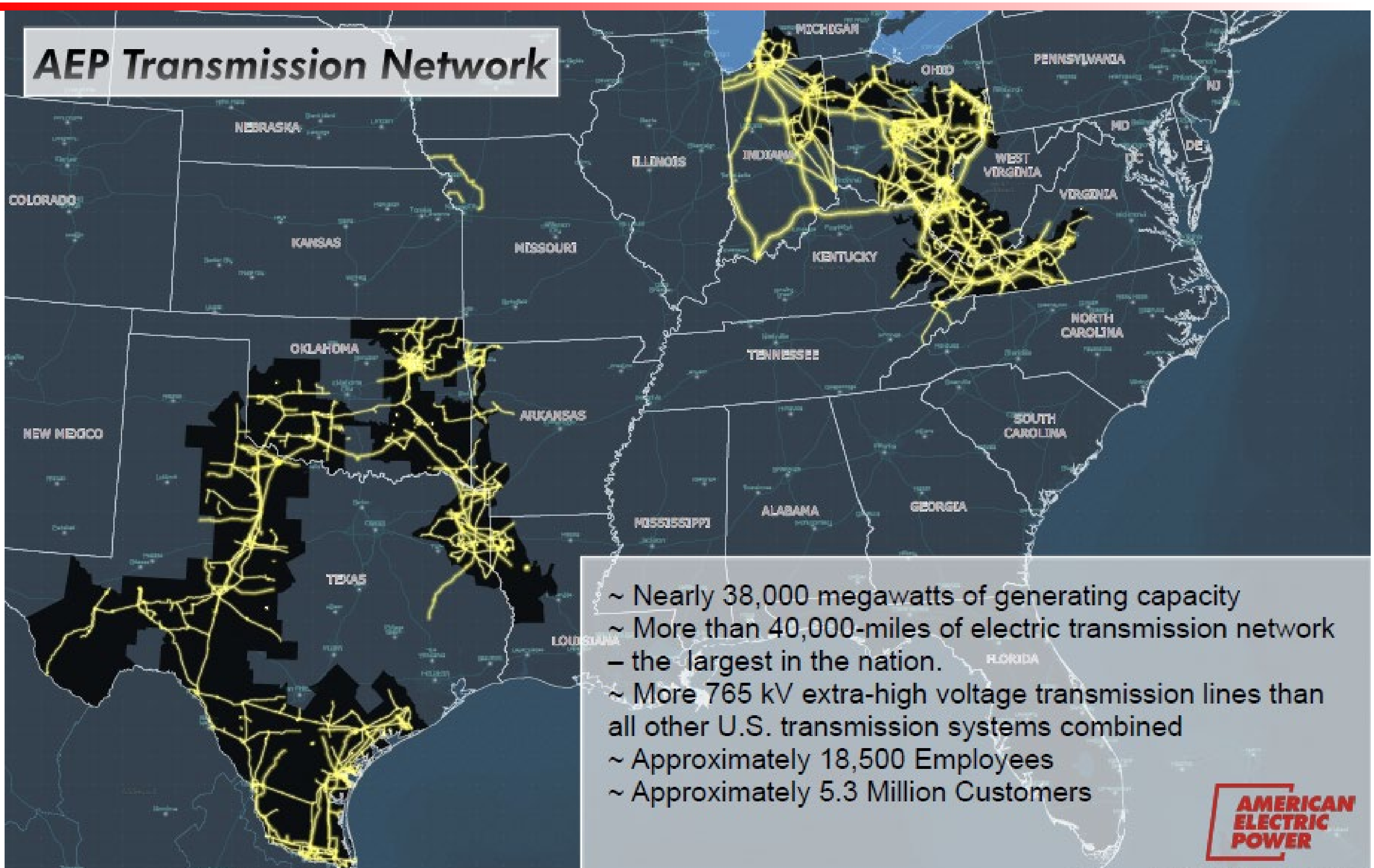
# About AEP




~ Nearly 38,000 megawatts of generating capacity
~ More than 40,000-miles of electric transmission network – the largest in the nation.
~ More 765 kV extra-high voltage transmission lines than all other U.S. transmission systems combined
~ Approximately 18,500 Employees
~ Approximately 5.3 Million Customers

# Presentation Outline

- Why Measure Earth's Magnetic Field ?
- AEP Efforts on GIC Monitoring
- Magnetometer System Design and Installation
- Data Acquisition and Communication
- Power Supply Requirements
- Laboratory Testing
- Commissioning Experience
- Data Validation
- Concluding Remarks

# Why Measure Earth’s Magnetic Field ?

- 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

Source: NASA

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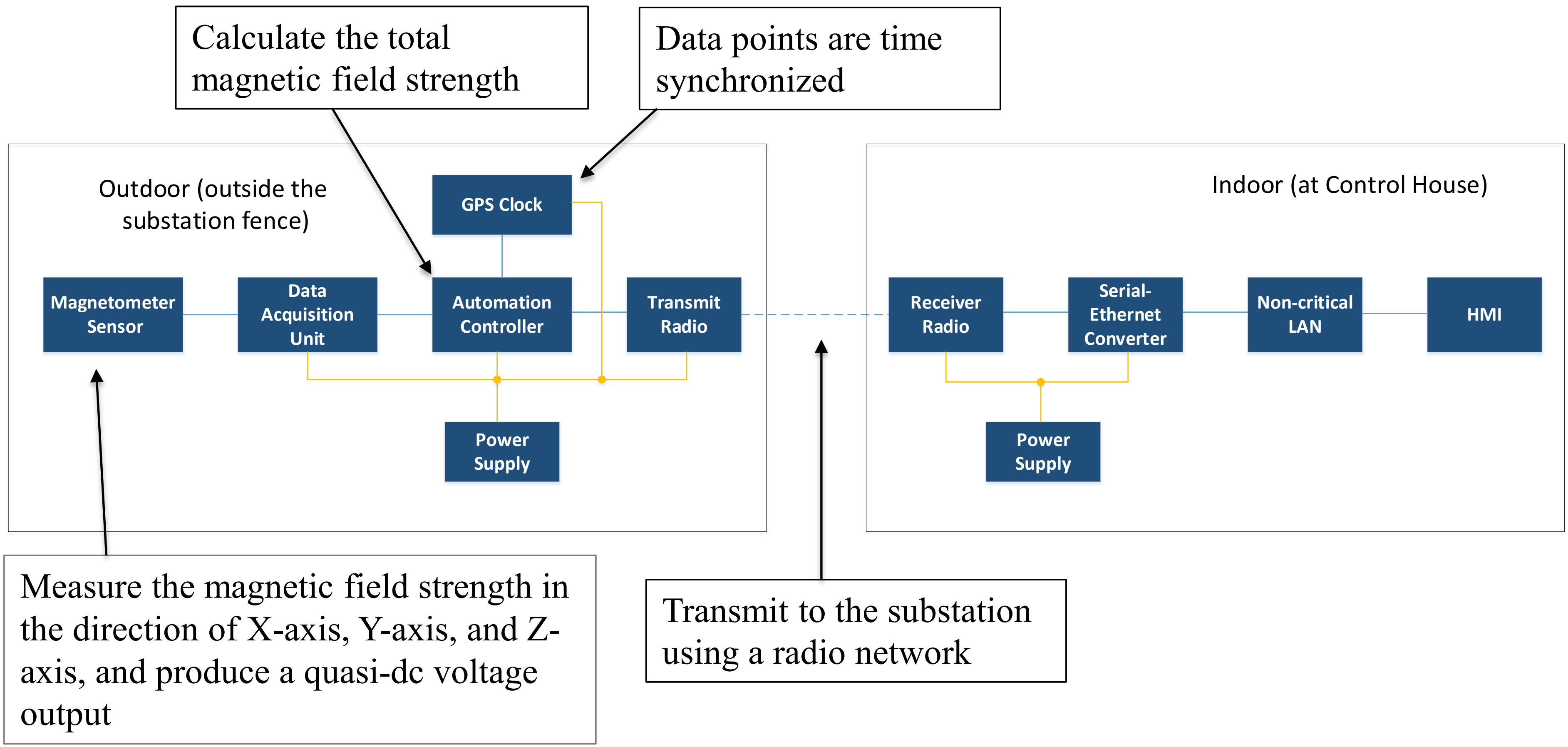
# AEP Efforts on GIC Monitoring

- 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

# Magnetometer System Design

- Magnetometer location was selected close to, but outside of a 765 kV substation
- Sensor was installed on a non-metallic enclosure, below ground level, and outside of the substation fence to reduce interference from :
  - current carrying conductors
  - metallic structures
  - moving objects
  - minimize the impact of seasonal temperature variations
- System is powered by an isolated solar panel and a battery unit

# Magnetometer System Design



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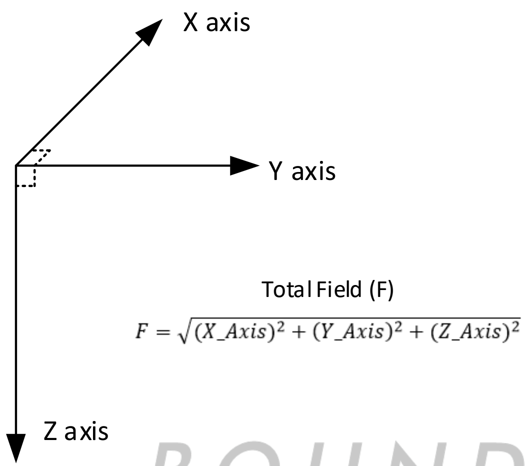
# Magnetometer installed within an Underground Enclosure

- Fiberglass enclosure
- Mounted on a wooden platform with plastic brackets and screws
- Open bottom enclosure, sitting on a gravel bed
- Drainage to avoid flooding
- X, Y, and Z Axis magnetic field measurements

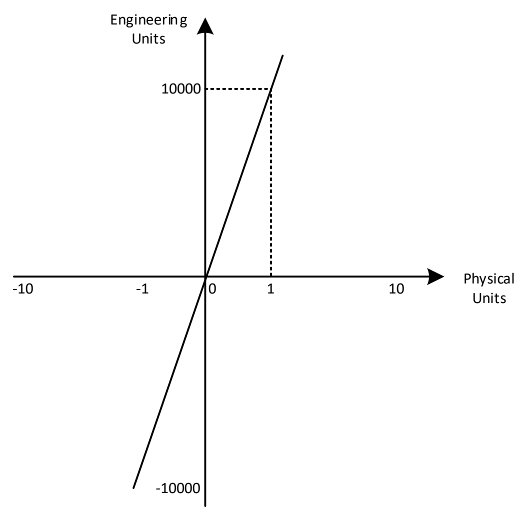
# Data Acquisition

- Measured Parameters
  - X-Axis magnetic field measurement
  - Y-Axis magnetic field measurement
  - Z-Axis magnetic field measurement
- Calculated Parameters
  - Total magnetic field strength (F) :

$$F = \sqrt{(X\_Axis)^2 + (Y\_Axis)^2 + (Z\_Axis)^2}$$




- Magnetometer measuring range
  +100 µT to - 100 µT
- Sensor scaling factor : 0.1V / µT
- Automation controller scales the measured signal (+10V to -10V) to a nano Tesla range



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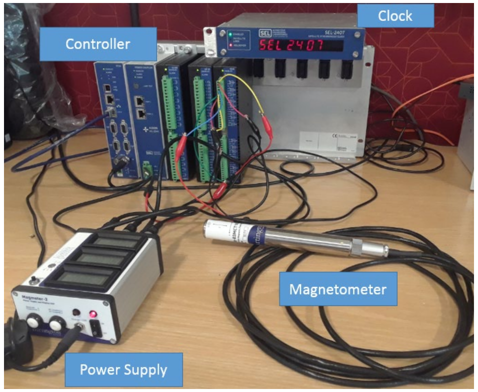
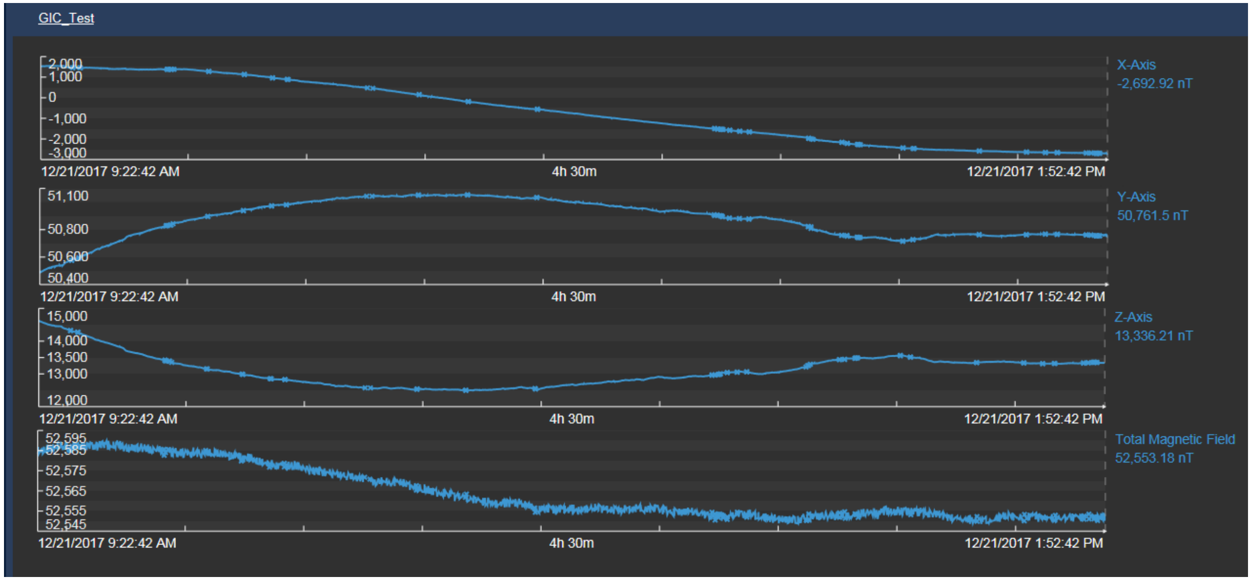
# Power Supply Requirements

- Isolated power supply was required based on its location and to reduce any interference
- System was powered by a solar array with a 12 Vdc battery
- Solar array capacity was selected based on the **average winter sun hours** available per day for the area
- Battery Amp-hour capacity was selected based on the total power consumption of the sensor, data acquisition unit, automation controller, GPS clock, and the serial radio
- Solar array will charge the battery through a solar charge controller which uses Maximum Power Tracking (MPPT) technology to extract maximum power from the solar panel

# Laboratory Testing

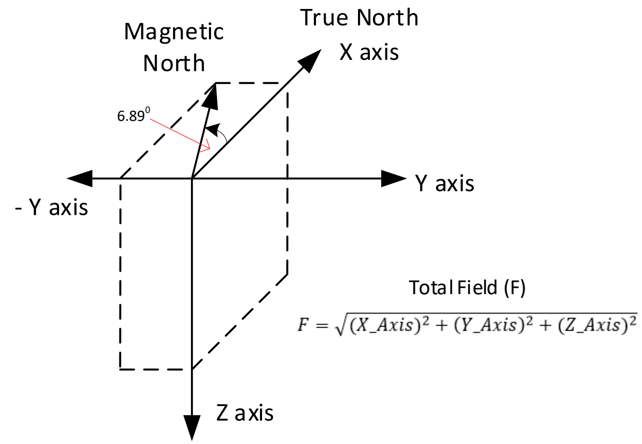
- Lab test performed with identical equipment and settings
- Radio network established for testing
- Sensor calibrated per World Magnetic Model data for the location

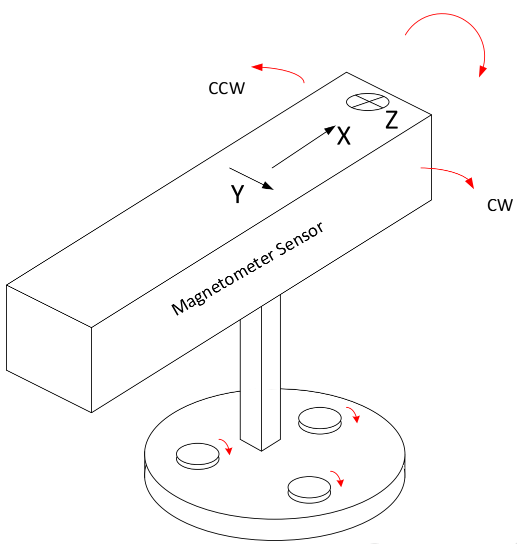


# Commissioning Experience – Installation and Calibration

- Sensor calibrated per World Magnetic Model data for the location
- Sensor X-axis was directed to the true north ( 6.89$^0$ CW from Compus north )
- Sensor could be rotated, turned clockwise (CW), turned counterclockwise (CCW) or level adjusted using leveling screws.



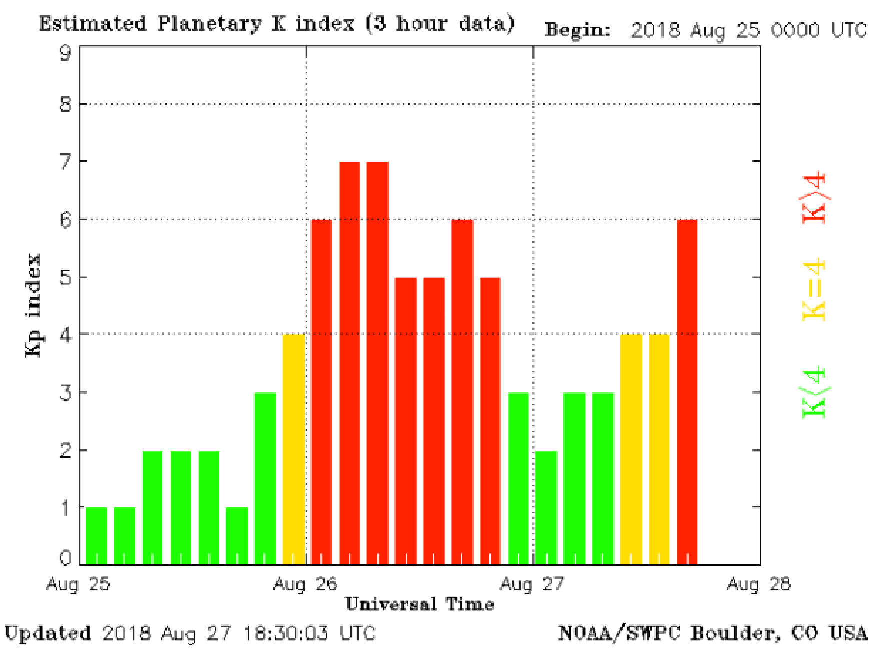



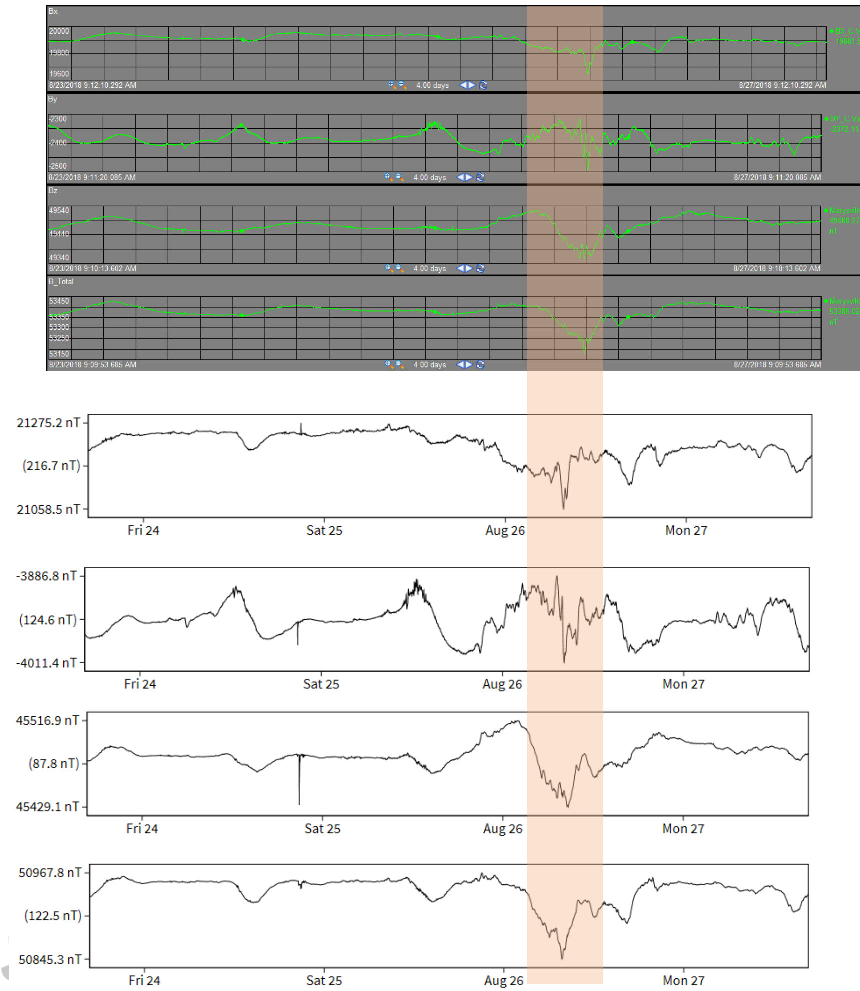

| Fields | Values | Changes/yr | Uncertainty |
|---|---|---|---|
| D (deg) | -6.89$^0$ | -0.04$^0$ | 0.36$^0$ |
| I (deg) | 67.6$^0$ | -0.08$^0$ | 0.22$^0$ |
| F (nT) | 52576.5 | -115.05 | 152 |
| H (nT) | 20033.6 | 23.65 | 133 |
| X (nT) | 19888.8 | 21.67 | 138 |
| Y (nT) | -2404 | -17.76 | 89 |
| Z (nT) | 48610.1 | -134.18 | 165 |

# Data Validation Case #1

## Geomagnetic Event on 8/26/2018 at 7.38 AM (UTC)

- Space weather prediction center (SWPC) issued an alert for a geomagnetic storm with a k-index of 7
- Data profiles were consistent with magnetic field data for the same event from USGS (Fredericksburg, VA observatory)



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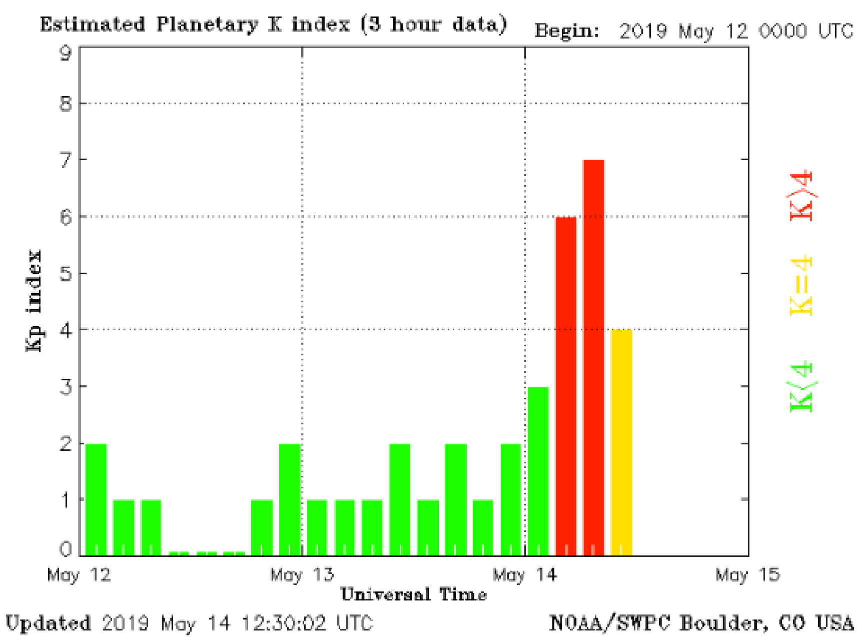
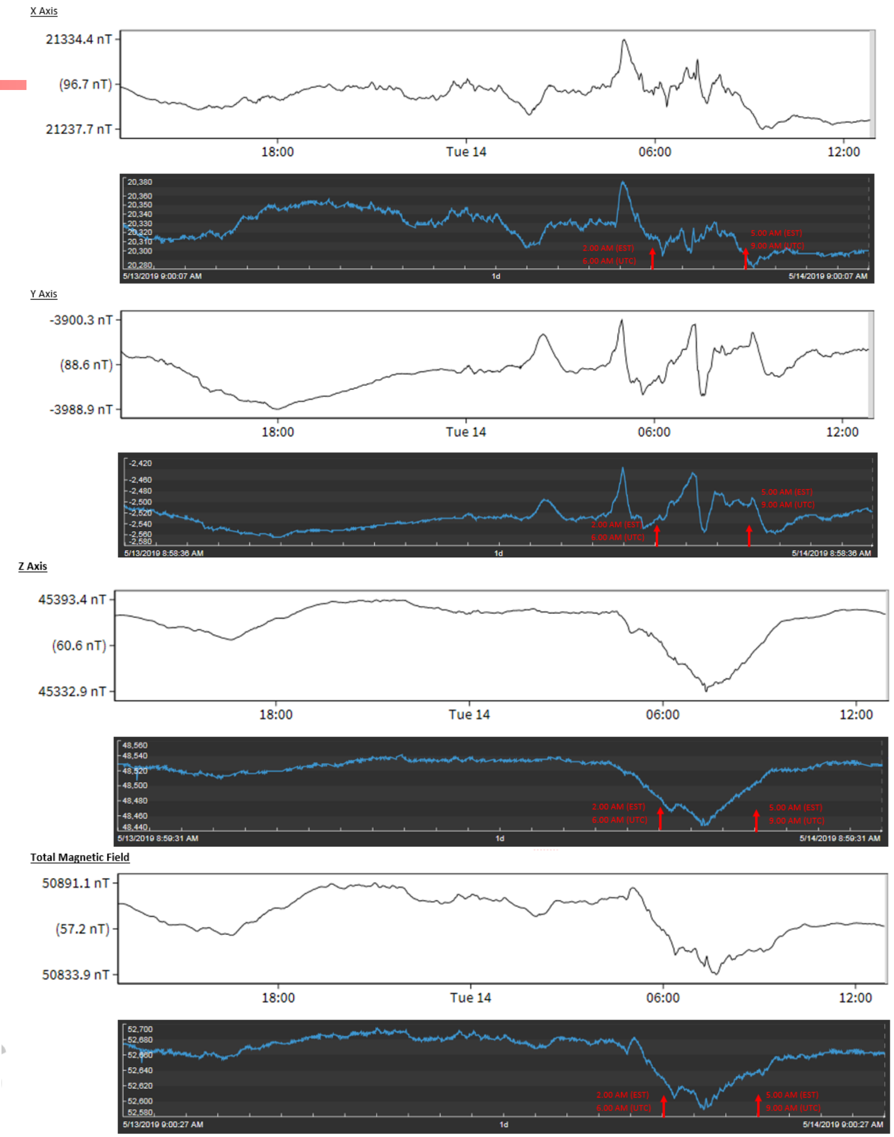
# Data Validation Case #2

## Geomagnetic Event on 5/14/2019 at 8.59 AM (UTC)

- Space weather prediction center (SWPC) issued an alert for a geomagnetic storm with a k-index of 7
- Data profiles were consistent with magnetic field data for the same event from USGS (Fredericksburg, VA observatory)



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# Concluding Remarks

- AEP successfully designed and commissioned a magnetometer measurement system to measure the earth's magnetic field variations
- AEP will use this data along with transformer GIC 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

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Questions?