

Geomagnetic Disturbance Mitigation for Nuclear Generator Main Power Transformers

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NextEra Nuclear GMD Mitigation

Agenda

- Purpose
- Background
- GMD Mitigation Procedures
- Monitoring & Validation Period
- Solar Cycle 24 Storm Reviews & Impacts
 - Lessons Learned: Adjustments
- Conclusion

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Purpose:

- **Identify NextEra Northern Nuclear sites susceptible to Severe/Extreme Solar Geomagnetic Disturbances.**
 - Geomagnetic Induced Currents (GIC) in the large power generator step-up (GSU) Transformer high side neutrals.
 - NRC Information Notice 90-42 “*Failure of Electrical Power Equipment Due to Solar Magnetic Disturbances*”
- **Develop written GMD mitigation operating procedures.**
 - Abnormal Operating Procedures (AOP)
 - For use by the Nuclear Main Control Room (24/7)
 - Entry/Exit Criteria (NOAA SWPC Notifications)
 - Monitoring actions (GSU GIC Monitors)
 - Defined GIC limits and actions

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Background:

- **NextEra Energy Resources (subsidiary of NextEra Energy) expands outside of Florida to 28 states during first decade of 2000:**
 - Includes three Northern Nuclear Generating Stations (Seabrook, Point Beach, Duane Arnold)
- **Seabrook had recorded GSU Transformer GIC during weekly switchyard rounds during this time.**
 - Acquired in 2003
 - Many instances of readings coinciding with Solar Geomagnetic Storms, confirming Seabrook susceptibility.
 - No GMD mitigation procedures prior to acquisition.
- **Point Beach:**
 - Acquired in 2007
 - Power Uprate: New generator step-up (GSU) transformers – added GIC Study/Hardening to scope of work due to GIC susceptible area
 - EPRI “*Geomagnetically Induced Current Estimation in the Wisconsin 345kV Power Grid*”, August 2008 confirms Point Beach GIC susceptibility
 - No GMD Mitigation Procedures; however, had GIC Monitor feed to Transmission Operator.

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Background (Cont'd):

- **October 29, 2003 Solar Storm:**
 - Seabrook records 80A GIC on GSU Transformer
 - Note: Seabrook was returning from outage and Holding at 30% Power for Reactor Physics
 - Point Beach Unit 1 down powers (Unit 2 in Refueling Outage)
 - K-Index 9 issued from WE PSS to Point Beach Control Room
 - Peak GIC was 48A DC (varying between 9A and 48A)
 - “Significant Growling” reported in Operations Logs
 - Transmission Company opened one of the transmission lines reducing GIC to about 4A (GSU noise reduced)
 - GIC rises again to 68A DC
 - PBNP U1 reduced power between 70% - 84% for 54 hours.
 - 10/29/2003 @ 03:13 to 10/31/2003 @ 09:00.

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Background (Cont'd):

Nuclear Solar Cycle 24 Readiness: Spring 2010

- GMD Assessments of Seabrook, Point Beach, Duane Arnold
- Seabrook historical evidence of elevated GSU neutral current readings during past storms (kept weekly records).
 - Also reported “growling” during solar storms
- Point Beach had GIC monitors on both GSU transformers
 - Only feed was to the former WEPCo Transmission Office
 - No local feed to the Point Beach Station Nuclear Control Room
 - Useful during days when Point Beach was regulated
 - Also reported “growling” during solar storms
- DAEC no historical information, was confirmed off-line during both March & Sept 1989 storms, so no Ops Logs records.

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Background (Cont'd):

- **Seabrook GSU Transformer Data:**
 - General Electric
 - Single Phase: Wye - Delta
 - Four leg core type
 - 345kV/24.5kV
 - Neutral: Solid Ground
- **Point Beach GSU Transformer Data:**
 - Mitsubishi
 - Single Phase: Wye - Delta
 - Core form
 - 225MVA
 - 345kV/18.5kV
 - Neutral: Solid Ground

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Background (Cont'd):

- Chief Executive Officer (CEO) forms Solar GMD Team for entire company in Summer of 2010.
- Company to follow Nuclear GMD proposed mitigation approach

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GMD Mitigation Procedure:

- **Establish GMD Protocol with respective Transmission Operator (TO) for NOAA K-Index Notification to the Stations.**
 - FPL Transmission & Performance Diagnostic Center (TPDC) Backup
- **Develop Nuclear Abnormal Operating Procedures (AOP) for procedure Entry (initially set at K-Index 7 WARNING) for the three Nuclear sites**
 - Install clamp-on hall effect DC ammeter w/100 foot cable and data logger
 - Manual action to turn on all transformer cooling bank fans
 - Established max GIC level/duration tables with action levels
 - Action would be to down power the Nuclear unit to a prescribed value (e.g. 78%).
Three tiered approach
 - Also monitored other available parameters (e.g., GSU winding hot spot temperatures, oil temperatures, dissolve gas analysis, etc.)
 - Record data for post storm analysis by Engineering
 - Procedure Exit: Expiry of NOAA K-Index 7 WARNING.

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Monitoring & Validation Period:

- During majority of 2011 period, installed DC Hall Effect split-ring transducer during NOAA K-Index 6 WARNINGS.
- Seabrook and Point Beach confirmed GIC “Hot Spots”
- DAEC barely registered past 3A DC during Solar Cycle 24
- Seabrook has reached greater than 40A DC multiple times
- Point Beach reached 55.8A DC during the October 24 & 25, 2011 Solar Storm:
 - Note: With one of the PBNP units in a refueling outage GIC on the remaining unit was double past GIC readings (Note: Kewaunee was on-line).
 - No down power required.
- Over time, GMD procedures were improved (Lessons Learned) and NOAA K-Index Entry temporarily moved from K-7 to K-6

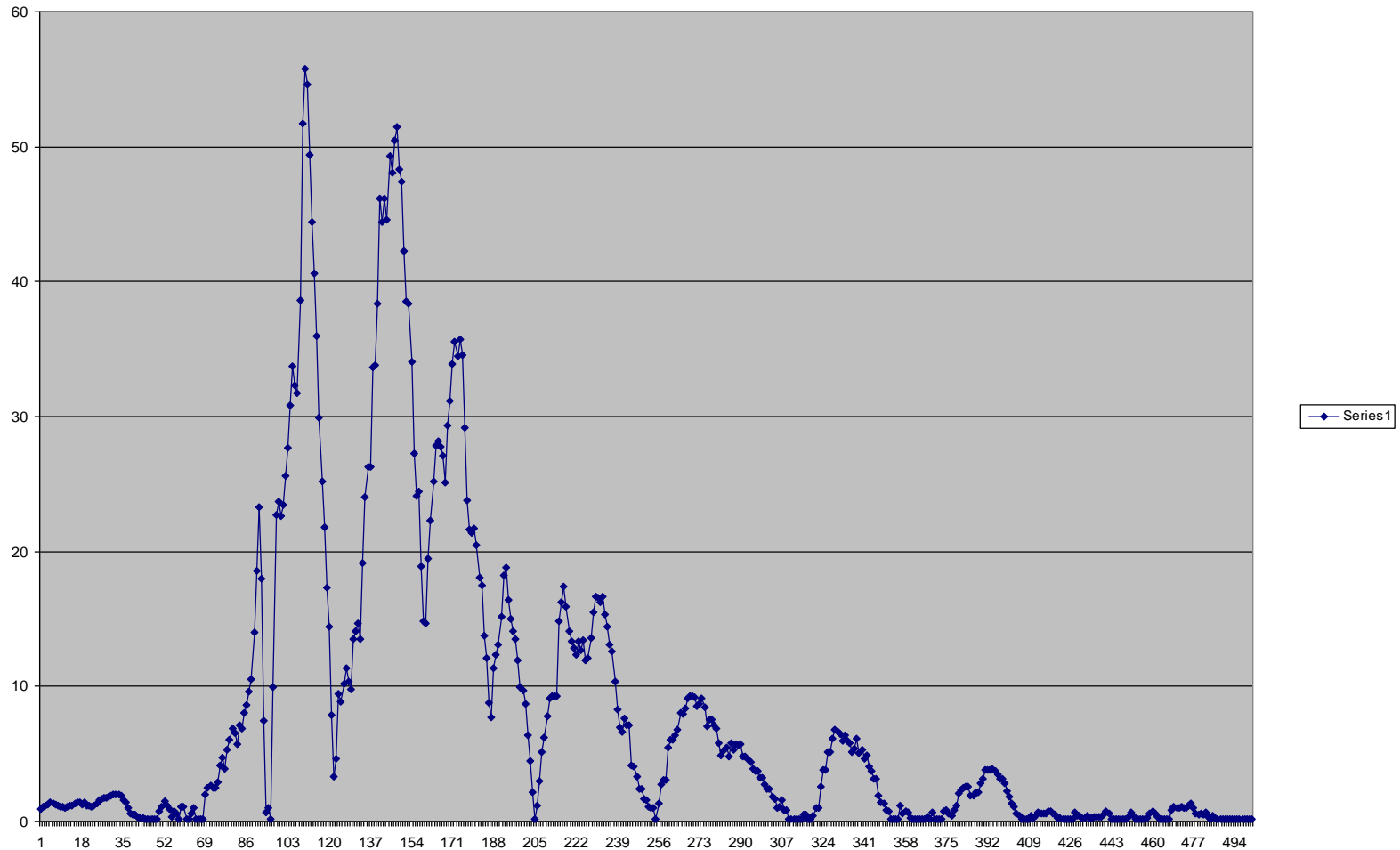
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Solar Storm of October 24 & 25, 2011:

- **Highest NOAA ALERT: K-Index of 6**
- **Point Beach:**
 - Point Beach Unit 2 GIC data peaked at 55.8A on October 24, 2011 at 8:27 PM (Central)
 - Point Beach Unit 1 was off-line for refueling outage
 - Kewaunee (5 miles north) was on-line
- **Significant GIC event duration was approximately 22 minutes (short duration)**
- **Seabrook:**
 - No GIC data available as Seabrook was off-line in an outage

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Point Beach U1: October 24/25, 2011



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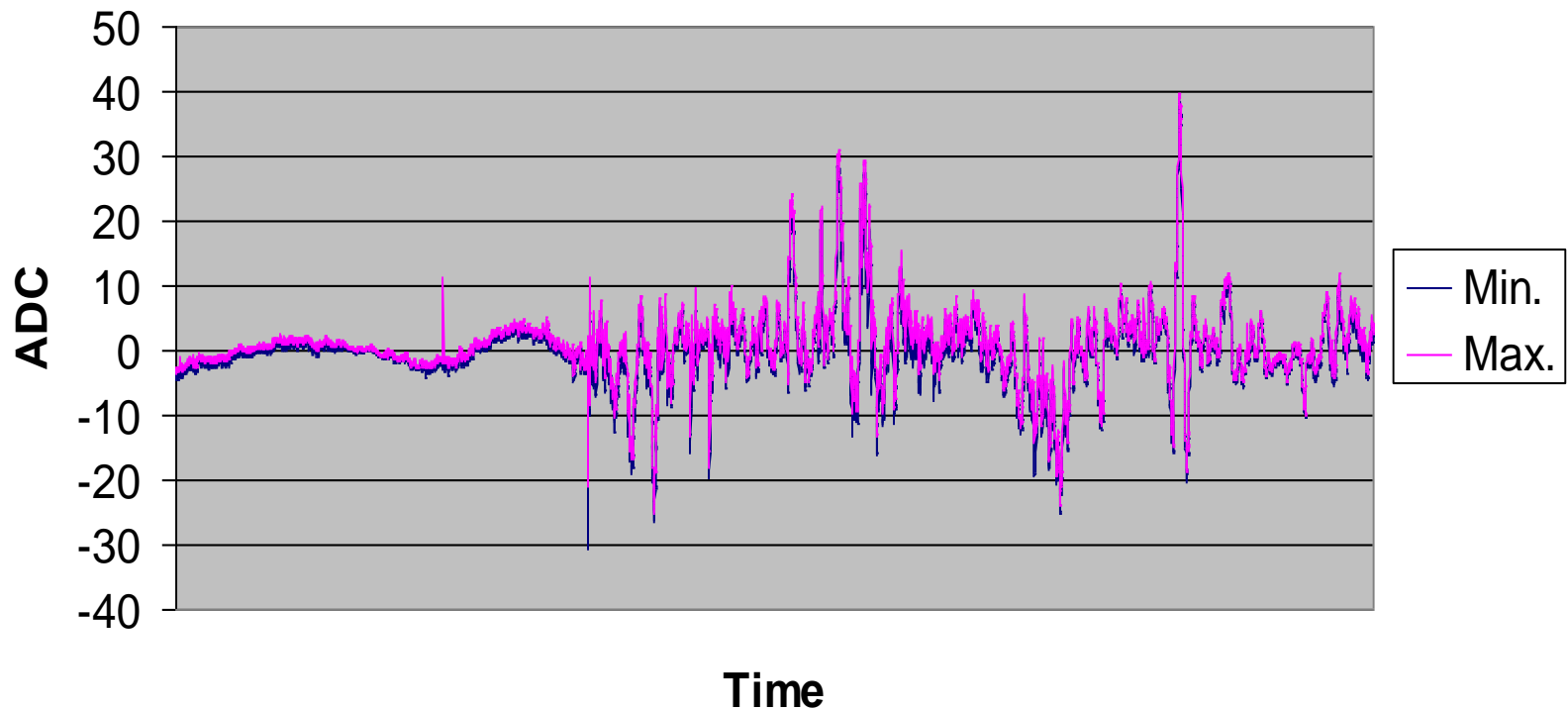
Solar Storm of July 15, 2012:

- **Highest NOAA ALERT: K-Index of 6**
- **Seabrook:**
 - Highest GIC peak: 40A DC
 - Three GIC peaks of 30A DC
 - First Down power from 85%* to 78%
 - Second Down power from 78% to 63%
 - Duration: 40 hours (long elevated GIC event)
 - 7/14/2012 at 14:10 (EDT) to 7/16/2012 at 06:46 (EDT)
- **Point Beach:**
 - GIC not as significant in Wisconsin; however, storm registered
 - Both Units peaked approximately 3.5A DC

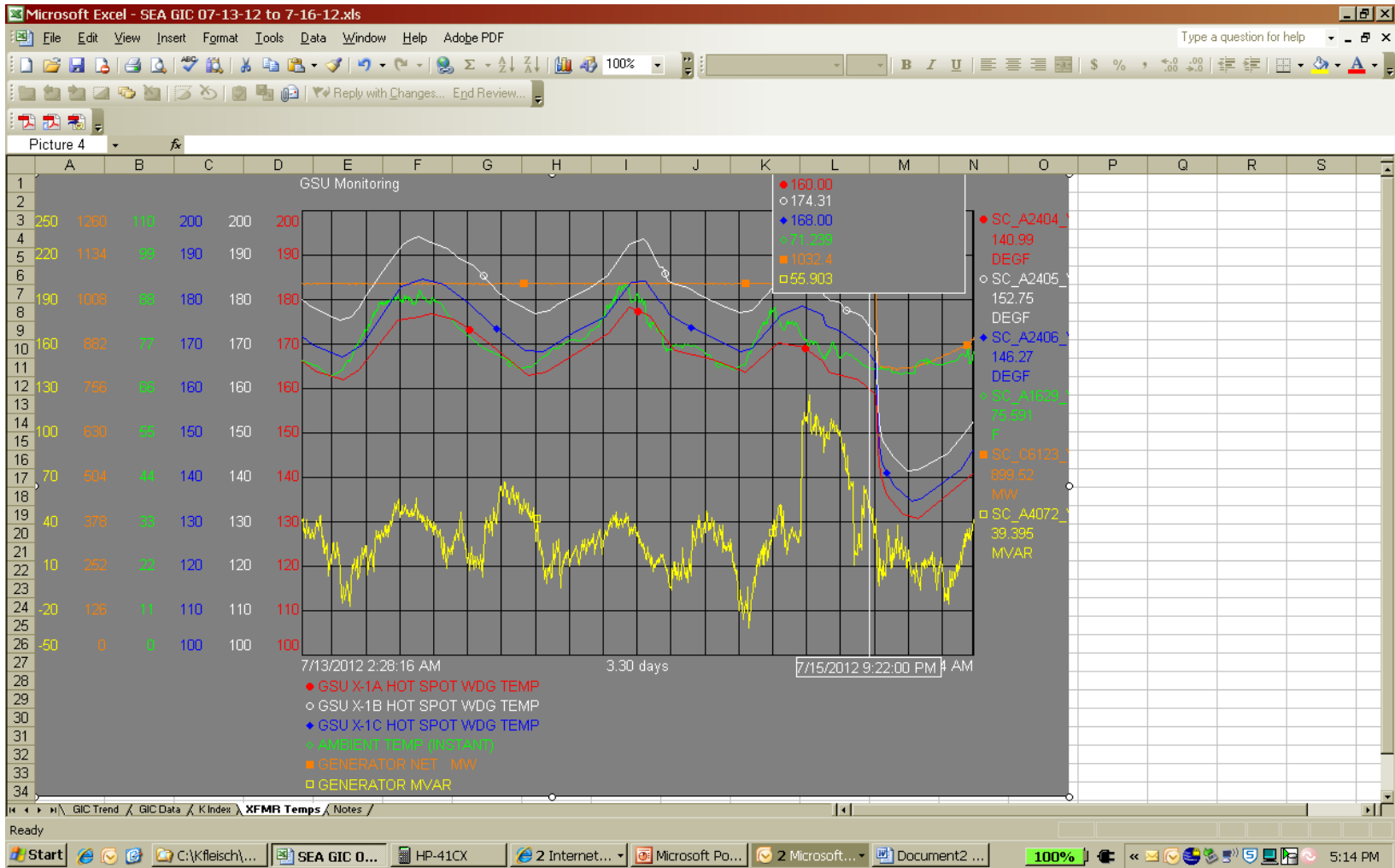
*Seabrook was derated to 85% power due to an unrelated issue with the main generator.

NextEra Nuclear GMD Mitigation Seabrook: 7/15/2012 Solar Storm

7/13 to 7/16/12 Seabrook GIC Data

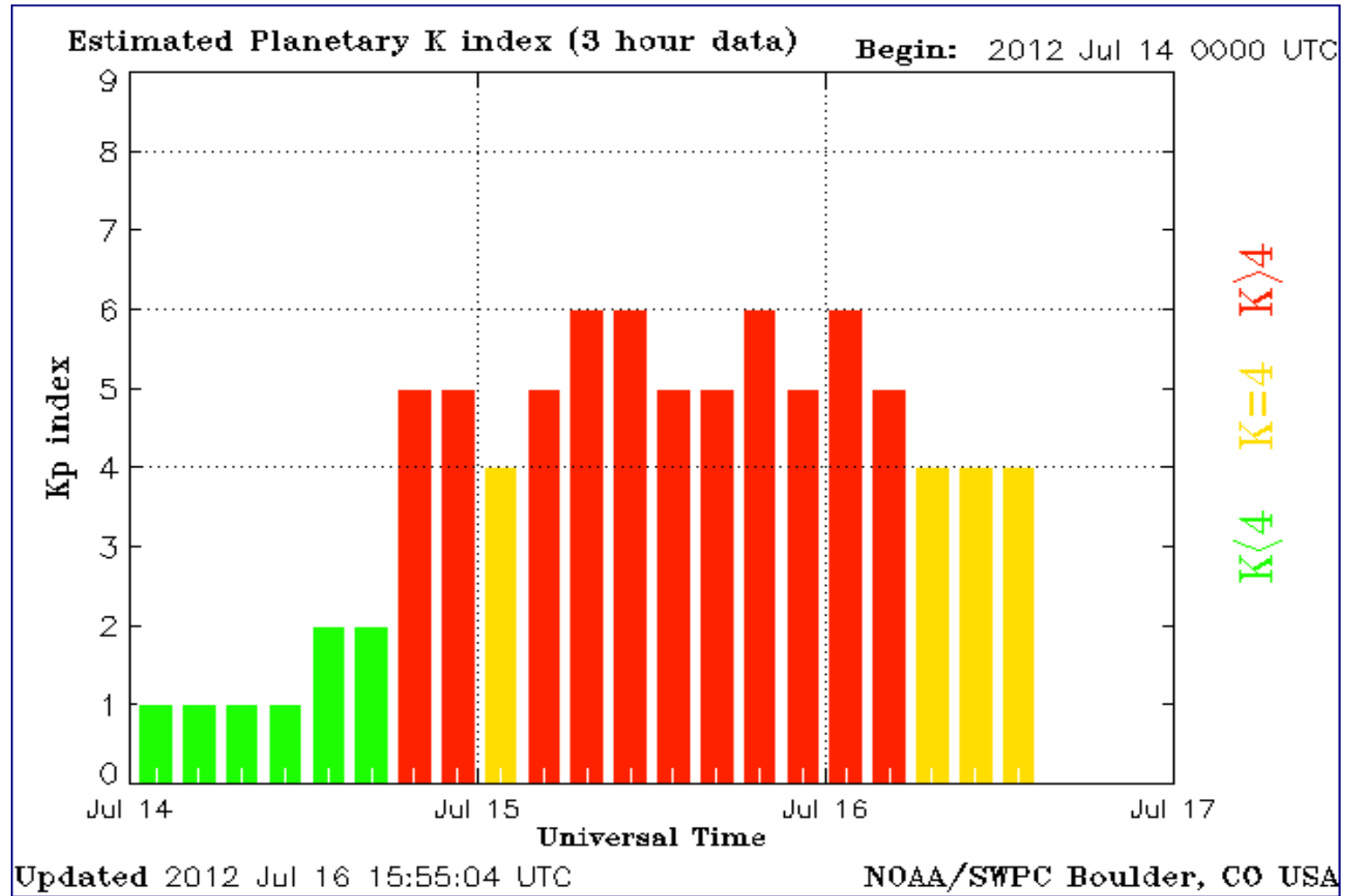


NextEra Nuclear GMD Mitigation Seabrook: 7/15/2012 Solar Storm



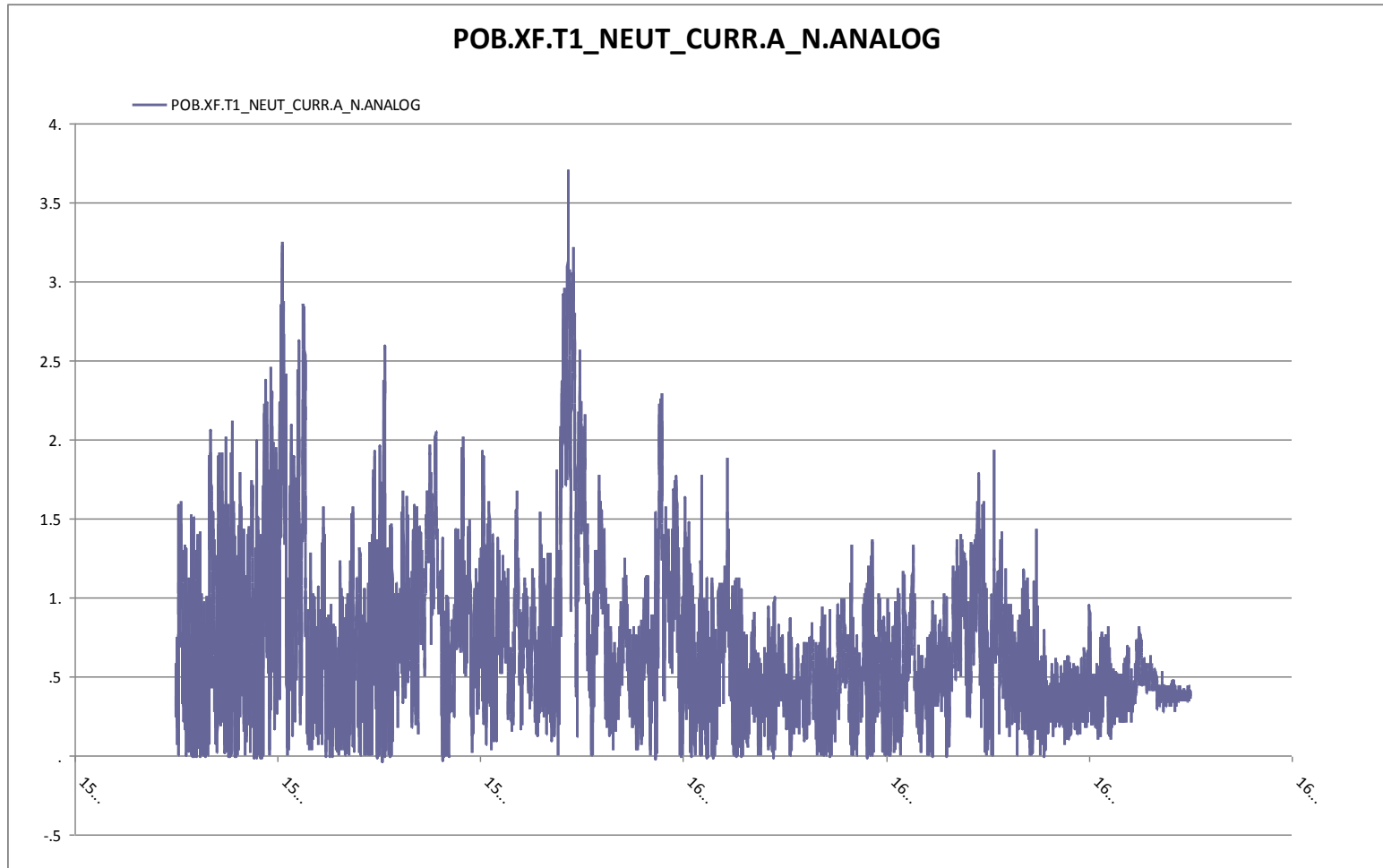
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7/15/2012 Solar Storm



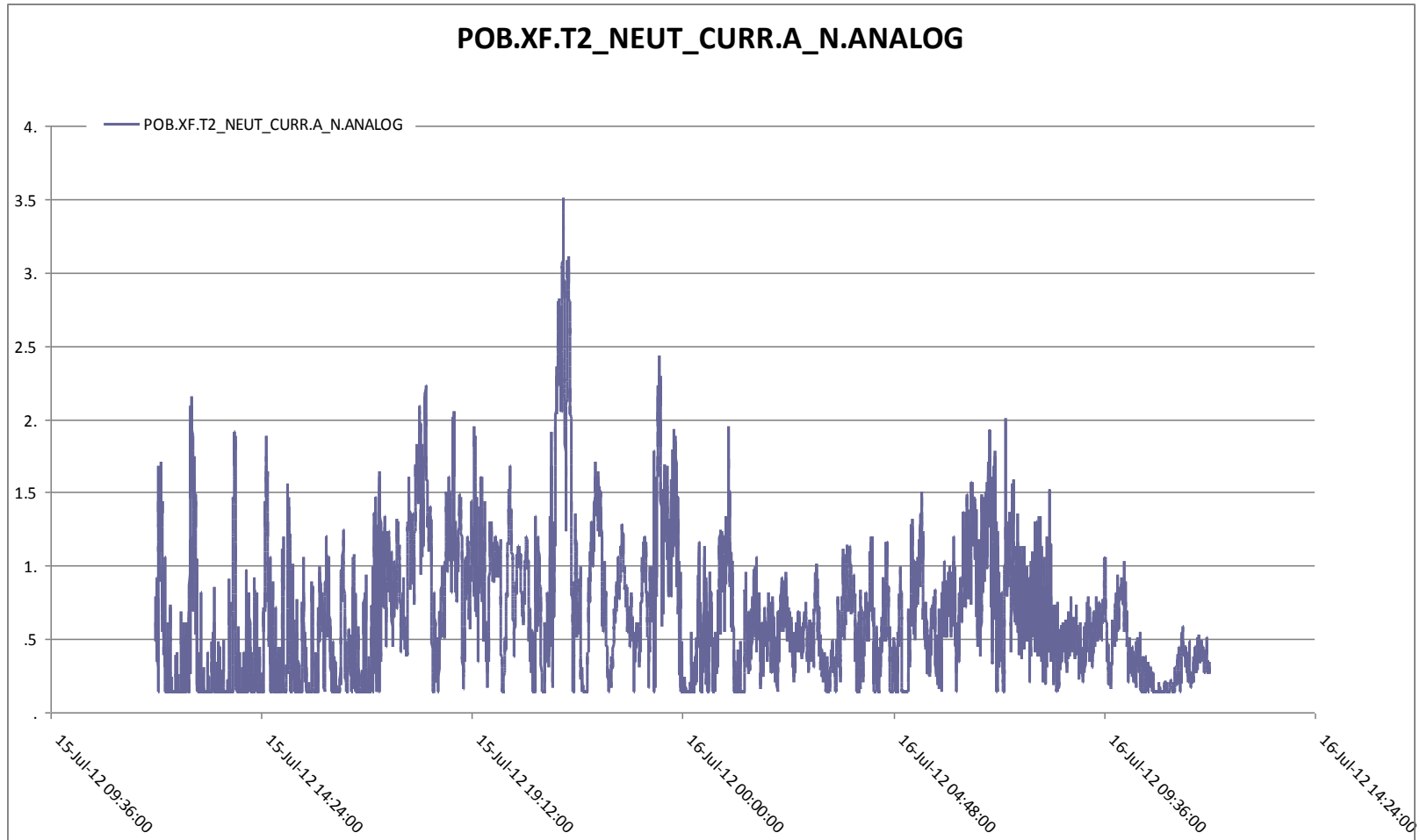
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Point Beach U1: 7/15/2012 Solar Storm



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Point Beach U2: 7/15/2012 Solar Storm



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Lessons Learned: Review of Seabrook GSU GIC Rating:

- No formal engineered GIC rating was available
- Up to this point: followed Solar Cycle 23 Salem GIC rating of 10A as a conservative starting point
- Solar Cycle 24 storm monitoring and data analysis indicated that Seabrook is GIC “Hot Spot”
 - Single site, 345kV transmission lines, igneous rock.
 - GIC consistently greater than Salem/Creek (3 unit site)
 - GSU trends were always stable and never increased during all Cycle 24 solar storms; confirming 10A was conservative.
- Commissioned Vendor to perform GIC studies/rating of Seabrook Transformer
 - New GIC rating: Orders of magnitude higher
 - New GIC rating would have prevented 7/15/2012 down power

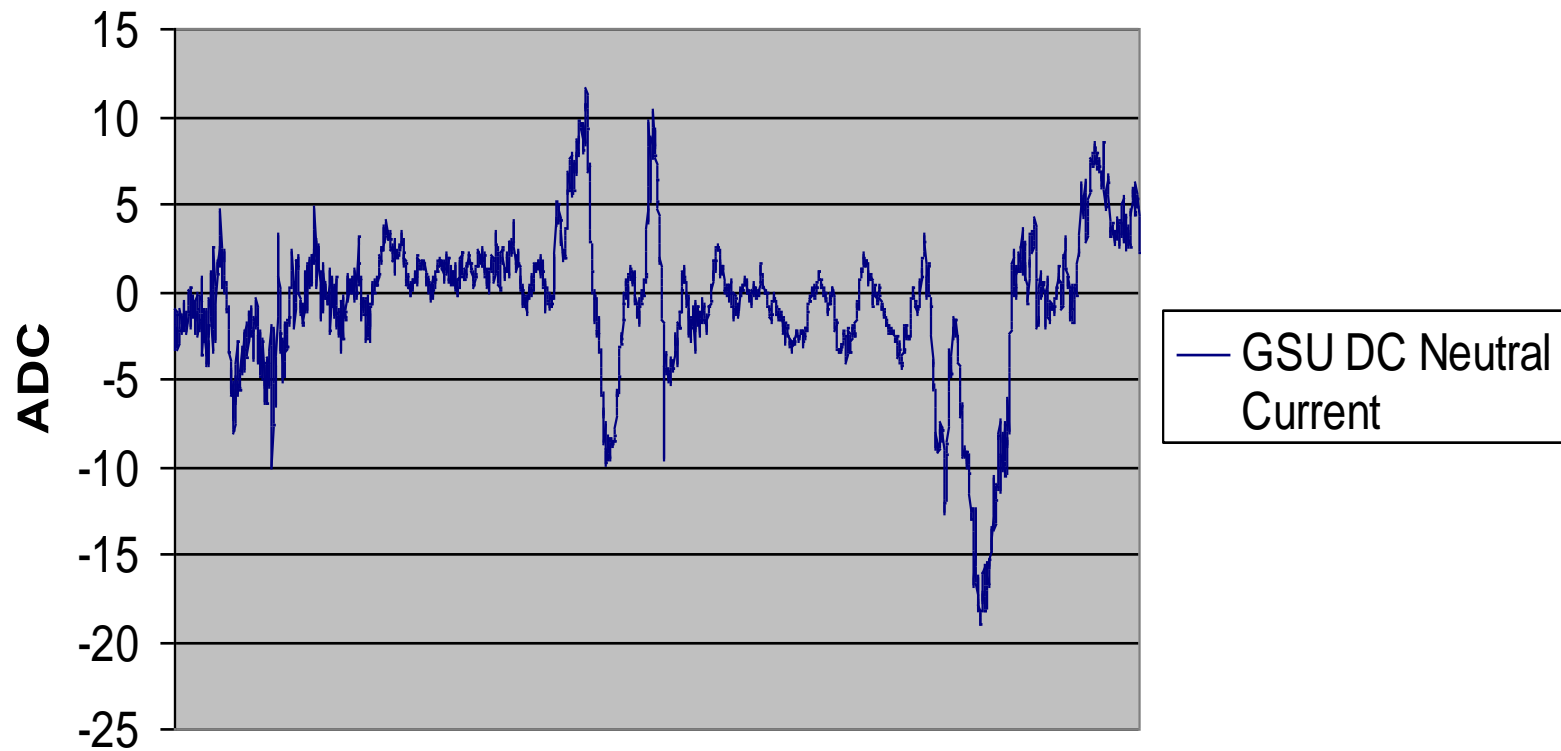
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Review of Three Other Past Solar Storms

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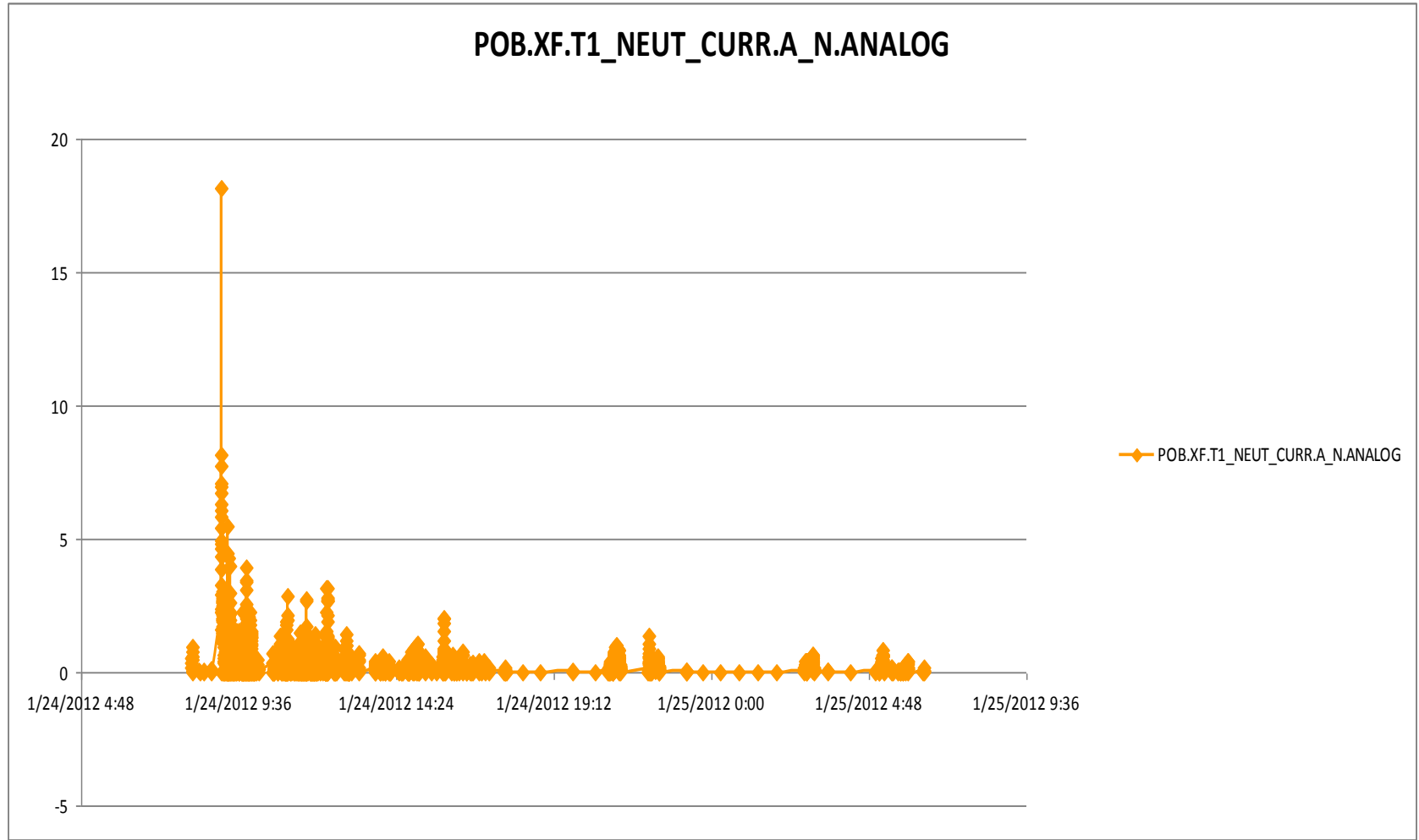
Jan 24, 2012 K-Index 6 WARNING Solar Storm

1/24/12 Seabrook GIC Trend



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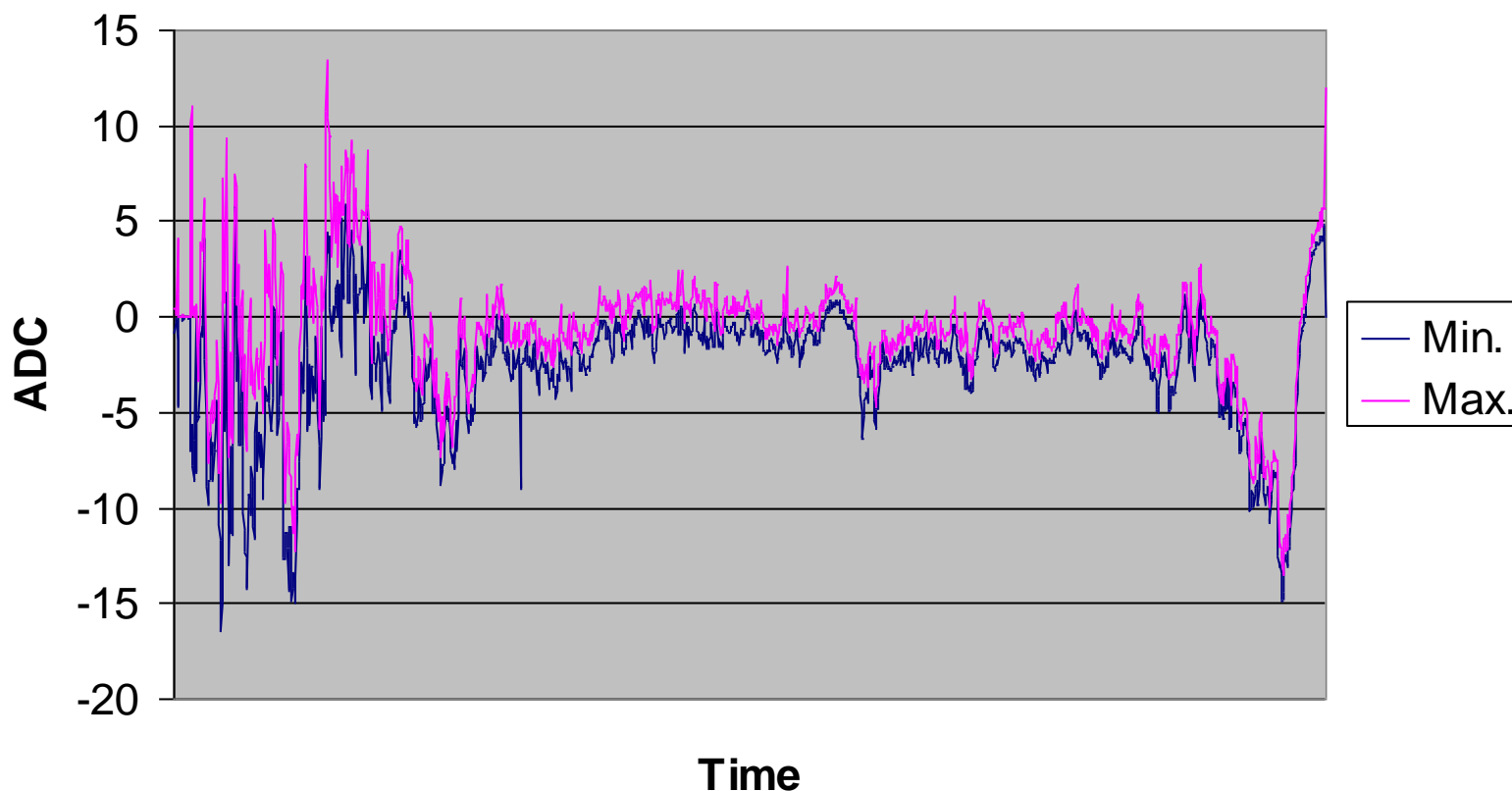
Jan 24, 2012 K-Index 6 WARNING Solar Storm



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March 9, 2012 K-Index 7 ALERT Solar Storm

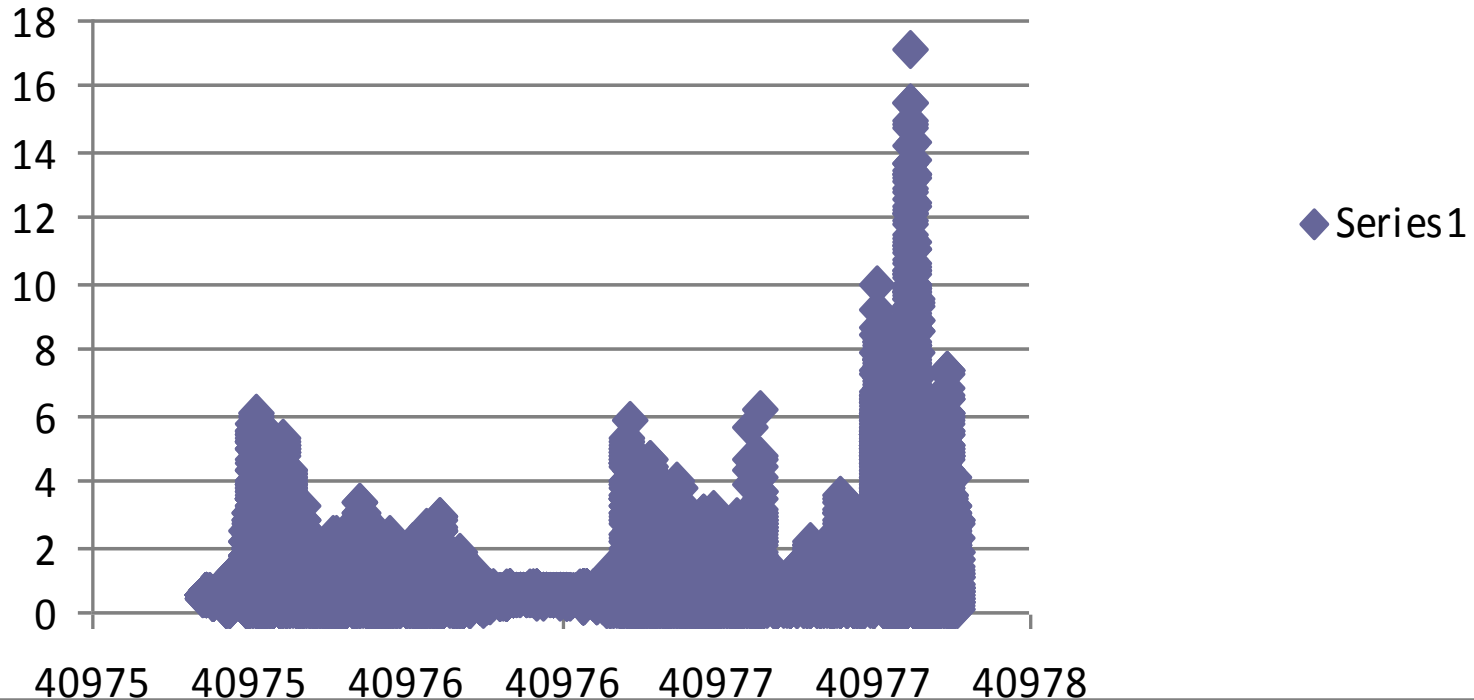
3/9/12 0749-2036 Seabrook GIC Data



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March 9, 2012 K-Index 7 ALERT Solar Storm

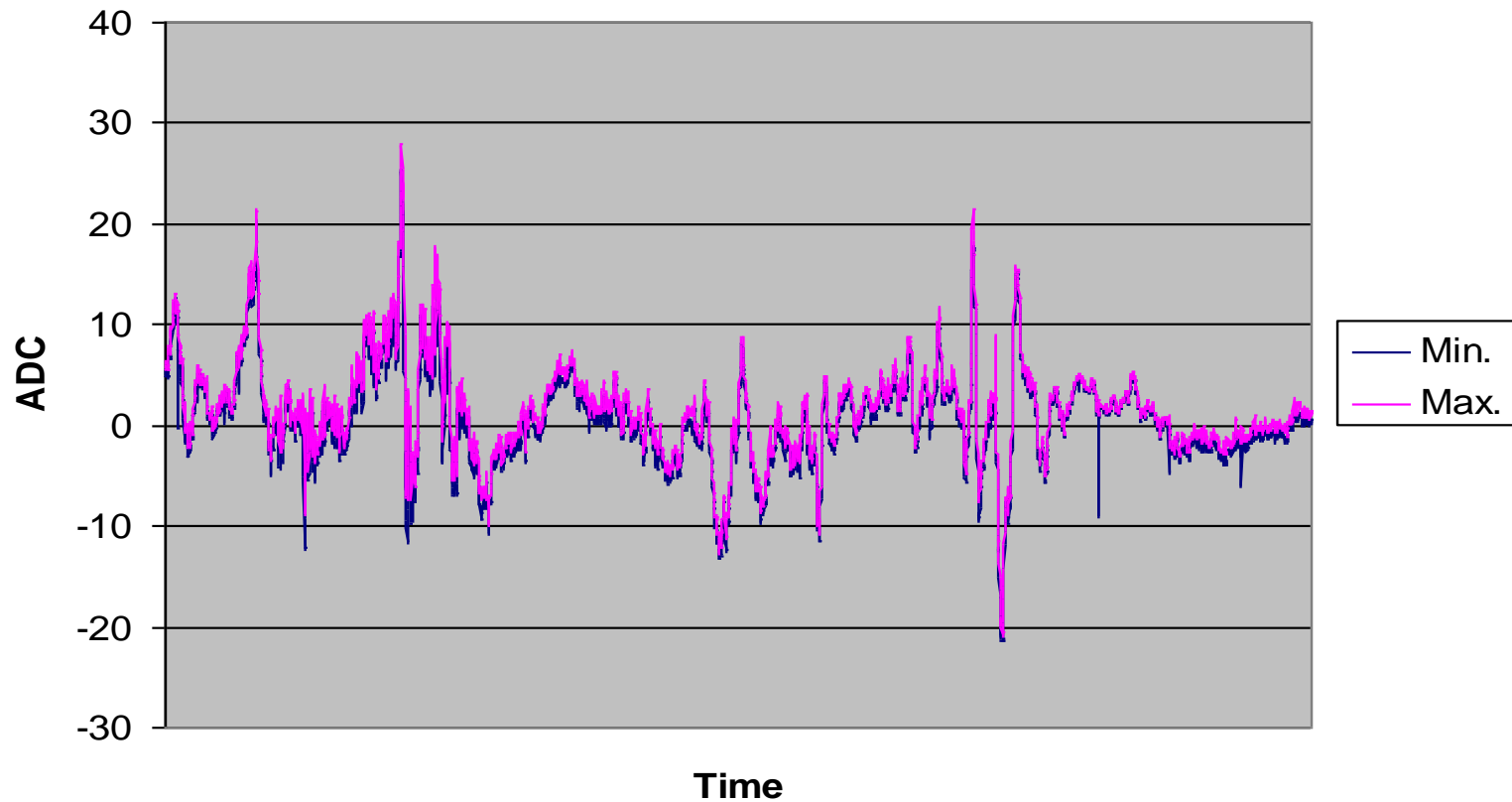
POB 2 Neutral Current



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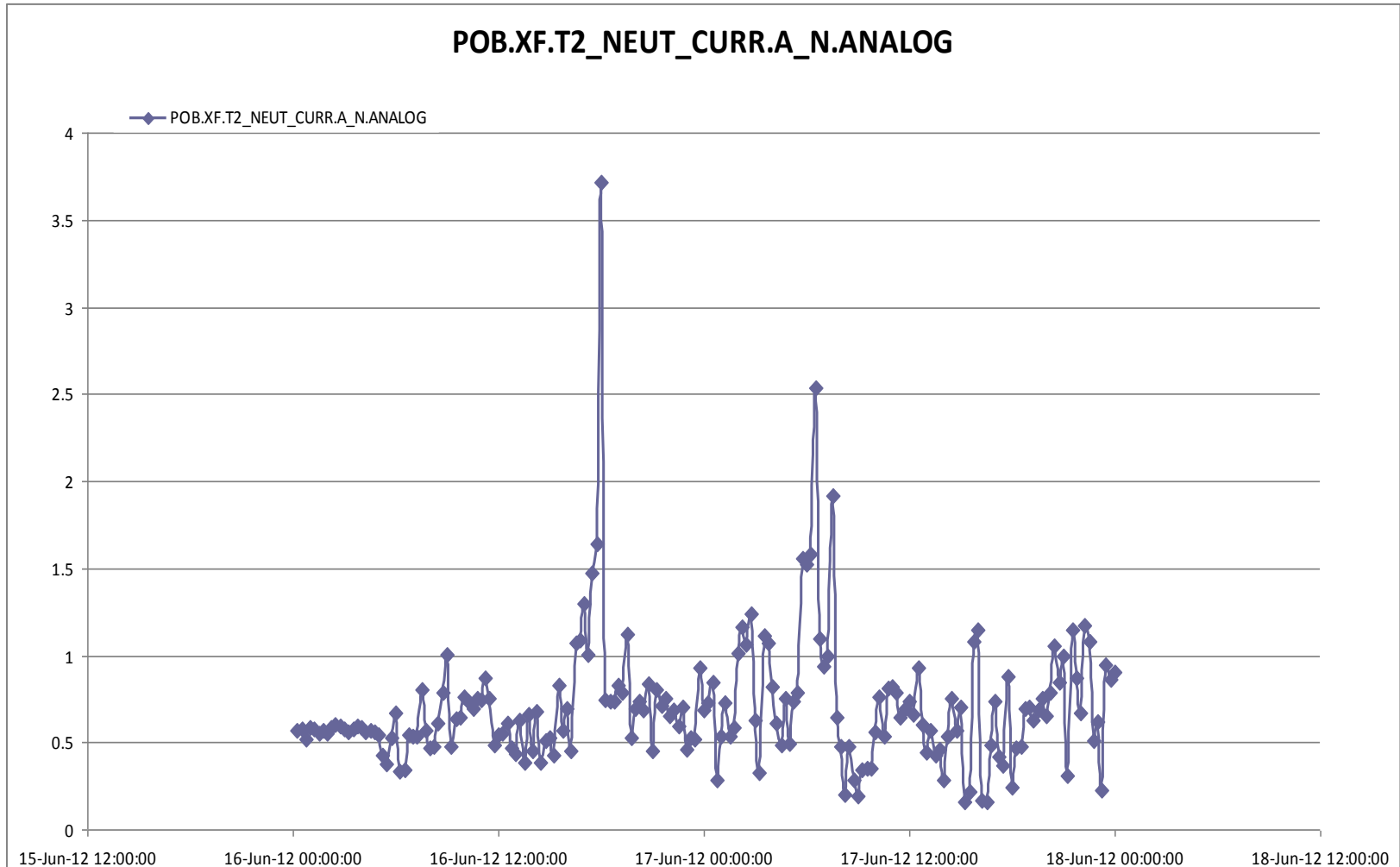
June 16 & 17, 2012 K-Index 6 ALERT Solar Storm

6/16 to 6/18/12 Seabrook GIC Data



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June 16 & 17, 2012 K-Index 6 ALERT Solar Storm



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Conclusion:

- **NextEra Energy Resources Nuclear Power Plants are Solar Cycle 24 Ready:**
 - **NextEra Energy Resources Nuclear Power Plant GSU Transformers are protected from damage during Severe/Extreme GMDs:**
 - GSU Transformer GIC Ratings established
 - Formal written procedures exist for GMD Mitigation
 - NOAA SWPC Notifications for Procedure Entry/Exit
 - Temporary unit down power is ultimate mitigation action to protect GSU transformers
 - **Protocol with Transmission Operators (TO) to mutually manage severe/extreme GMD events:**
 - Formal communication of NOAA SWPC Notifications.
 - FPL Transmission: Back up NOAA SWPC Notifications.
 - Sharing of Nuclear Station GMD Mitigation w/TO