APPENDIX A
STATEMENT OF WORK

Study of the Impact of Geomagnetic Disturbance (GMD) Events on the Entergy System Associated with NERC TPL-007.1

Introduction

The purpose of this project is to perform a study looking at the impact of geomagnetic disturbance (GMD) events on the Entergy footprint to assist Entergy in meeting the requirements of NERC TPL-007.1 (the Standard). This study will be performed by personnel at Texas A&M University (TAMU) using PowerWorld Simulator, with the PowerWorld Simulator add-on that includes an integrated GMD Impact calculation. This project will consist of the following tasks.

Statement of Work

1. Setting Up the Power Flow Modes for Geomagnetic Disturbance (GMD) assessment:

Entergy will supply at least two power flow cases that represent the conditions noted by 4.1 of the Standard. That is, a System On-Peak case and a System Off-Peak case for the desired planning time frame. The project team has CEII clearance from FERC to access these cases. These power flow cases do not usually include GMD specific input fields, such as geographic locations of buses, substation grounding resistances, transformer winding resistances, etc. Therefore TAMU and Entergy will work together to provide this data.

TAMU will provide the mapping of power flow buses to substations, and then substations to geographic locations, using information supplied by PowerWorld Corporation. Prior to doing any study Entergy will review these values, providing updated substation mappings and geographic coordinates as appropriate.

Entergy will provide TAMU with the following data for as much of their system as possible in templates supplied by TAMU

- Substation grounding resistance
- Transformer grounding configuration
- Transformer coil resistance, ohms/phase ("From" side and "To" side. Series and Common Winding resistances for autotransformers.)
- Transformer core type (single phase, 3-phase shell, 3-legged 3-phase, 5-legged 3-phase)
- Transformer grounding configuration
- Whether a transformer is an auto-transformer (yes/no)
- Whether a transformer is a three-winding transformer (yes/no)
- Optionally, a linear scaling factor, K, that relates the total transformer reactive power losses at unity per unit voltage to the effective GICs in the transformer
- Generator step-up transformer parameters
- Provide transformer thermal model parameters for each transformer for which a GIC thermal impact study is desired.
- Coil resistances for an HV/EHV shunt reactors that Entergy would like included in the study.

TAMU will map and load this data into the power flow cases, and use estimated/default values for all other substations and transformers, such as those outside of the Energy footprint.

2. Perform a Power Flow Based GMD Study on Each Case Using the NERC GMD Benchmark Event Described in the Standard Attachment 1.

TAMU will perform power flow studies on the cases from part 1 using the GMD Benchmark Event from Attachment 1 of the Standard. Hence this study will be performed with an assumed maximum electric field of 8 V/km, modified by the product of the geomagnetic latitude scaling values α and the geographic scaling values β. The assumed electric field will have non-uniform magnitudes, but will be assumed to be uniform direction. Results will be provided for all variety of different directions, such as using 10 degree increments. In addition, analytic techniques will be used to determine the worst case direction. TAMU will work with Entergy planners to assess compliance of the results of these studies with Table 1 of TPL-007.1.

In this study TAMU will work with Entergy to simulate scenarios that include the loss of reactive devices and other transmission facilities that can trip due to operation or misoperation of relays due to harmonics induced by the GIC event. However, this project will not involve actual harmonics studies.

TAMU will also provide Entergy with the effective GIC time series, GIC(t), for Entergy's high voltage transformers in response to the Attachment 1 time-varying benchmark event from the Standard.

3. Perform a Basic Thermal Assessment for Transformers with More than 75A of GIC

Using the effective GIC time series from part 2 for transformers with more than a maximum of 75A per phase of effective GIC, TAMU will work with Entergy to perform the thermal analysis required in R6 of the standard. The particular approach will be jointly determined between TAMU and Entergy. One promising approach is to use the approximate heating functions described in [1].

[1] Marti, L., Rezaei-Zare, A., Narang, A. "Simulation of Transformer Hotspot Heating due to Geomagnetically Induced Currents." IEEE Transactions on Power Delivery, vol.28, no.1. pp 320-327. January 2013.

4. Develop a Corrective Action Plan

If the results of the previous parts indicate that Entergy does not meet the performance requirements from Table 1 of the Standard, TAMU will work with Entergy to develop a Corrective Action Plan as noted in R7 of the Standard. Even if the results do meet performance requirements, we can work with Entergy to determine mitigation measures that could be used in actual GMD events, which would surely differ from what is considered in the standard. Potential mitigation measures could include interruption of firm transmission service, load shedding, generator re-dispatch, transformer tap changes, inclusion of transformer neutral blocking device, or transmission series capacitors.

5. Knowledge Transfer

Apart from briefing on the study results, there will be knowledge transfer session(s) wherein the study methodology, and the tool itself will be introduced to key Entergy engineers. It may involve a visit to one of the Entergy locations.

6. Report and Briefing

A report summarizing the findings of this work will be provided to Entergy. Also, the PowerWorld Simulator cases developed for this project will be provided to Entergy. In addition the key TAMU personnel involved in the project will have at least one visit to Entergy to provide a debriefing of study results.