UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Reliability Standards for	**)**	**Docket No. RM12-22-000**
Geomagnetic Disturbances	**)**	

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I am grateful to have the opportunity to submit these comments in response to Notice of Proposed Rulemaking on Reliability Standards for Geomagnetic Disturbances (GMD) in FERC Docket RM12-22-000. Storm Analysis Consultants of Duluth, Minnesota is a firm dedicated to understanding the complex and scientifically challenging threats posed by severe geomagnetic storms (or GMD) to modern day critical infrastructures.

I have been one of the principal investigators on several of the noted US government sponsored reports on the impacts of GMD on the US Electric Grid. The findings at times have been so fundamental and important that we have had to force change in long entrenched schools of thought in both the Space Weather science arenas and for the electric power grid infrastructure that can be severely impacted. The nature and extremes of impulsive geomagnetic disturbances have not been fully understood in organizations such as NOAA, NASA and USGS and many others in the Space Weather scientific community. It is now recognized by these groups that their traditional indices like K, G and Dst have been enormously misleading in understanding of the extremes of these storms and attributes of these storms that can cause harm to modern infrastructures. In some cases, the intensity of these impulsive GMD environments can be fully 10 times larger than previously known.

This poor characterization of the GMD threat potential has had the unintended consequence of lulling the designers of infrastructure that could be impacted into thinking that they have experienced the worst case scenarios and are adequately prepared. As the recent detailed examinations have been undertaken concerning the interaction of geomagnetic storm environments with power grids, the realization has developed that these infrastructures are becoming more vulnerable to disruption from geomagnetic storm interactions for a wide variety of reasons. This trend line suggests that even more severe impacts can occur in the future, anticipating reoccurrences of large storms. These trends of increasing vulnerability also remain unchecked, as no design codes have been adopted to reduce geomagnetically-induced current (GIC) flows in the power grid during a storm. This fundamental GMD threat environment change has required a significant recalculation of the threat potential and we have also had to point out problems, gaps, deficiencies and lack of rational standards on this topic area that have engulfed organizations such as NERC, EPRI, IEEE, sectors of the electric utility industry and major equipment manufacturers.

The importance of our work and findings has thrust us into many other forums where it has been reviewed. Our point of view on the importance and potential consequences of these threats to critical infrastructures has been understood and adopted and even independently verified in the ever growing science, technology, and risk management communities.

While we have been leaders in these technologies, it is clear that all the science is not fully known and new findings and discoveries are being made on a continuing basis which improves the scientific understanding of this complex threat and potentially adds to the seriousness of the threat. Indeed each major geomagnetic storm has taught us on new and unpleasant impacts that these disturbances could cause to electric power grids. Time and again it has brushed away rosy assumptions and replaced them with less pleasant realities. It is quite possible that further analysis of electric grid risks from this threat could result in additional findings that were previously unknown, making this threat more challenging in dimensions than many other threats that the US electric industry has contemplated in their more normal business.

Clearly we know that there might be new understandings that could further expand on the full dimensions of this threat, but we know enough at this time to conclude that the threats posed by severe GMD's could hold catastrophic potential for the US electric grid; both contemporary experience and analytical work adequately support these general conclusions. We also know that the likelihood of a severe storm of historic proportions, given sufficient time is a certainty. We have worked over many years to estimate the vulnerability of the US electric grid and assess the potential impacts for severe geomagnetic disturbances. We have performed rigorous as possible analysis of the risks and have undertaken extraordinary efforts to seek independent reviews and other methods to validate and test the accuracy of our results to provide the highest level of confidence possible. These efforts have gone more than the extra mile and have also lead the various government agencies and panels with which we have worked to reach the conclusion that severe GMD events have the potential to pose unimaginably severe threats to the North American electric power grid and to the nation as a whole.

While we have had to make estimates to arrive at various damage scenarios, in reality, it is not difficult

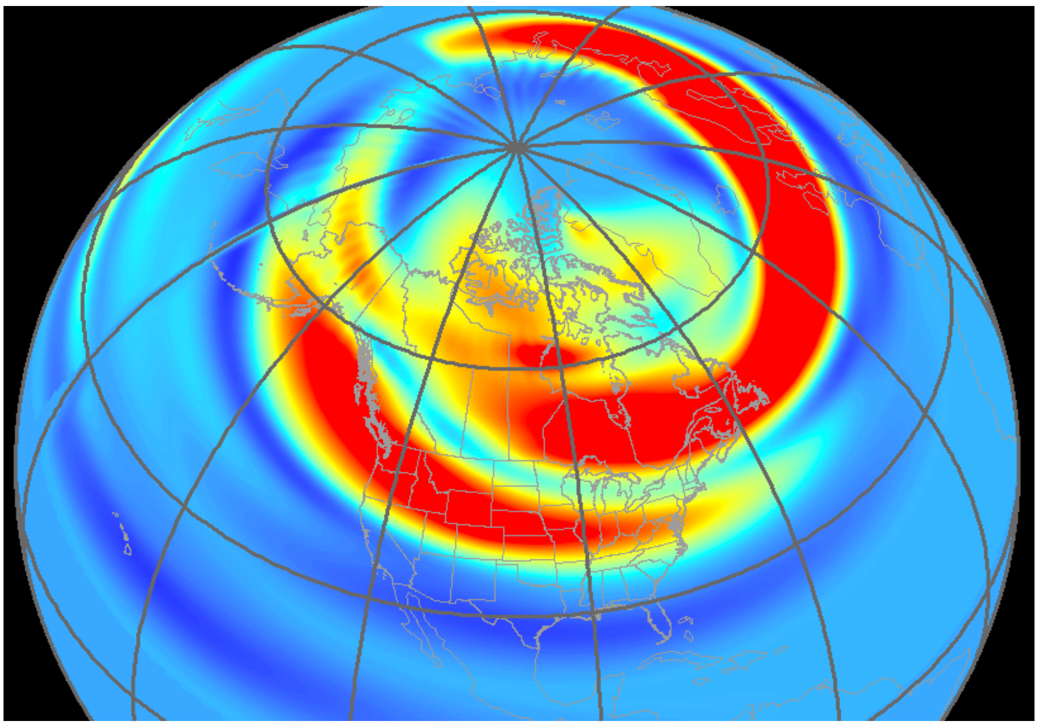

Figure 1 - The boundaries of large dB/dt impulses observed during the March 13, 1989 superstorm. The above map provides a forensic recreation at time 22:00UT March 13, 1989 of the region of large geomagnetic field impulses that occurred in Northern Hemisphere. It was at this time during that the US electric grid came uncomfortably close to a grid collapse that could have extended from the Mid-Atlantic region through the Pacific NW. .

for anyone to make these projections and arrive at the same conclusions. We actually do have an adequate information framework for making reasonable projections, even in the face of attempts to conceal that information. Anybody that did any analysis would realize that we have observed some key equipment damage beginning at storm levels as low as 60 to 100 nanoTeslas per minute (nT/min). The widespread problems triggered during the March 1989 storm generally occurred at intensities between 300 to 500 nT/min. However, we now know that historically large storms of as much as 5000 nT/min have occurred before and will occur again at 100% certainty.

These serious threats stem from the ability of the disturbances to appear simultaneously over wide geographic regions (as indicated in Figure 1) and their capability to produce significant and widespread collateral damage to key equipment in this critical infrastructure. Among the most troubling aspects of these reports is the possibility of an extremely slow pace of restoration from such a large outage and the multiplying effects that could cripple other infrastructures such as water, transportation and communications due to the prolonged loss of the electric power grid supply. This extended recovery would be due to permanent damage to key power grid components caused by the unique nature of the electromagnetic upset. The recovery could plausibly extend into months, or perhaps years, in many parts of the impacted regions and pose the threat of placing millions of lives at risk.

The nation has very recently experienced enormous strategic surprise by the level of impacts to interdependent infrastructures in the aftermath of electric power outages associated with Hurricane Sandy. Unlike a hurricane which creates its most severe damage within a few counties of landfall, the geographic footprint of a geomagnetic storm could be continent wide and encompass vast portions of the US electric grid.

The industry can rightfully point to excellent and well-rehearsed mutual assistance programs that come into play even before these types of disasters occur. For the most part they focus on distribution level damage to the power grid, not this type of disaster which would cause large substation level damage. Nor are they tested for the extraordinarily widespread footprint of this type of disaster either. In addition, the damage from this type of storm will require a large scale and untested response program, even though some considerations of spares have been made. Line truck and line men will do no good for damage to substations and substation equipment. These are far different specialties and assets and repair on such a grand scale has never been conceived or tested.

Because the damage involves large and difficult to replace assets like transformers, the ability to replace and restore (even if we have sufficient spare transformers on hand and at exactly the right locations) is measureable in weeks, not hours or days. If these spares need to be transported, the logistics of that will add additional weeks, as they cannot be flown in from across the country, as crews and line trucks were in response to Hurricane Sandy. The Salem nuclear plant transformer was replaced with an identical spare post March 1989 and that took over 40 days with a regional and national infrastructure that was fully intact. Multiply this damage by several hundred-fold and add on top of it compromised infrastructures like transportation and communications and it becomes a problem of unimaginable dimensions.

As I have worked with various groups and experts on the potential consequences of such a scenario, we know that such an outage to this critical infrastructure has a long tail to produce enormous secondary impacts. The most critical of these impacts involve loss of potable water, loss of perishable medications and foods, loss of sewage pumping and waste treatment, loss of fuel supply for transportation and back up generation that can cripple many other vital public safety services involving communications, police and fire protection and even critical safety systems such as at nuclear power plants. These impacts can occur in nearly every large populated region across the country, all at the same time. Our ability as a nation to cope with disasters is heavily predicated on the ability to supply aid from nearby unaffected regions. The large footprint of the damage posed by this scenario entirely negates that response coping base of operations. The nation could experience the equivalent of a hundred Katrina sized disasters all at the same time.

Even within the context of these limited duration outages, millions of lives are placed at risk. Across the nation, we have nearly 1 million diabetes sufferers that need daily doses of perishable medications, an even larger number of other sick and elderly that also need continuous treatments and care. It will be the weak and the vulnerable within society that will experience the first and ultimate consequences. It is conceivable that within the first few weeks of such a widespread disaster that the nation may sustain fatalities in numbers equal to all US war casualties sustained in all of the nation's wars combined (approximately 1.3 million).

More ominously, even longer regional power grid outage scenarios are plausible. Estimates of key equipment considered at risk of permanent damage and loss are so large that even existing spare equipment may fall far short of being able to affect adequate restoration and can place even larger portions of the nation's population at risk, even threatening the continuity of the nation as we know it. As Dr. William Graham, Chair of the EMP Commission described during Congressional Testimony, these are "of a small number of threats that can hold our society at risk of catastrophic consequences".

Unfortunately it is human nature to be reactive to complex and difficult to understand threats rather than to be preventive. Sad experience shows that a disaster event needs to occur before regulations are put in place and an "investment" is made. This mode of human experience and reaction has shaped most of the modern design codes that exist for other catastrophic hazards such as fire, storms, floods, earthquakes and so forth that are all smaller footprint events in the first place. Today's power grid has not yet been exposed to these large but relatively rare GMD events, nor is it desirable for society as a whole to learn firsthand how much damage could occur. As discussed, the dimensions of the GMD threat are so large in scale, that the only way to cope is to prevent it from ever being allowed to unfold in the first place. And that will require an enormous effort in leadership that runs counter to our human experience in preparation for similar disaster scenarios. A threat like this should be of exceedingly paramount importance to the nation and would put any nation on a war posture, enacting appropriate self-defense precautions, if such a threat were posed by any belligerent forces.

Clearly taking such important stands and telling our colleagues in the power industry news they might not want to hear has not been easy at any time; but something that was necessary for the public good. This simple guideline of working towards the public good, in the face of such a serious threat, should bring an amazing level of clarity to our mission and every decision each of us and ultimately the nation must make.

The nation has experienced multiple decades of migration of risk transfer into the power grid infrastructure to the point where it constitutes an *Unrecognized Systemic Risk to the Nation*. A threat from grid design evolutions that have unknowingly and greatly escalated GMD risks and potential impacts which have been unchecked by a rational Design Code that takes this threat into consideration.

FERC's NOPR in this regard should be viewed as one of the most important and pivotal rulings in the history of this nation. Acting in the public interest, the Commission would change the dangerous trend lines of growing vulnerability of this infrastructure. Standards for protection and an associated action plan would remove, or at least substantially prevent and otherwise to mitigate this risk to an electricity-dependent society.

At times it is extraordinarily troubling to hear and experience some of the response that has occurred from a few of the organizations within the power industry that should have the public interest as the main focus of their function. I will have to also bring forward in my comments observations and experience that call into question some of these behaviors which at times have been unserious and inappropriate. I am also not alone in expressing these concerns, rather they merely add to other observers and participants that have also reported these concerns to the NERC Board of Trustees, the FERC Commission and other public comments that they have made. While I take no pleasure in having to supply this information, it is necessary that the FERC Commissioners and public knows. I would fear that without this additional information being made available to the Commission that it may not guide in developing sufficiently adequate policy measures to prevent future abuses, and to protect the public interests before an irreversible calamity affects our nation.

NERC – Long Term Reluctance to Engage in Review of GMD Threat to the US Electric Grid

In the NERC Final Comments Docket Filing for the FERC April 30 Technical Conference (AD-12-13-000), the NERC CEO Mr. Cauley et.al. make note of the following in regards to the nature of various US Government sponsored reports.

> *"A number of previously completed government-sponsored studies have reached a conclusion that an extreme geomagnetic disturbance would result in irrecoverable damage to large amounts of bulk power system equipment. However, these prior studies did not engage the industry subject matter experts in long-term planning, equipment design and manufacture, solar storm characteristics, or real-time operations. Furthermore, the results documented in these prior studies, which predicted wide-spread equipment failures, were the product of the same principal authors."*

For clarity in the public record it is necessary to examine the veracity of these NERC assertions and to more objectively examine how NERC has responded to repeated efforts to engage them in this important topic discussion. In particular the Cauley statement from above of "*these prior studies did not engage the industry subject matter experts"* can be examined over the past decade. Initial work on the severe GMD threat to the US Electric Grid was initiated in late 2001 by the Congressional EMP Commission. From the outset, the Commission wisely recognized that intentional EMP attacks and geomagnetic storms are two faces of a threat that have the potential to impact common vulnerabilities in the critical infrastructures. As a result, extensive efforts were also undertaken to examine plausible impacts due to severe geomagnetic storms on the US electric power infrastructure. At all stages along this investigation the industry (via NERC no less) was fully vetted and fully invited to participate. In fact a NERC HEMP Task Force was created and Dr. James Swift from the EMP Commission staff attended a number of NERC meetings to brief on the Commission's efforts. The roster of membership from this NERC Task Force is provided in Table 1. In July of 2003 I participated in a special two day formal briefing with the NERC Task Force and a number of others from Industry (including EPRI) that were invited. This briefing included extensive discussion on GMD threats to the US grid and the critical risks that they posed. In spite of these efforts very early on, no mention was offered by NERC of problems with the analysis and no NERC or industry actions appear to have been taken at that time or in the several years after this encounter.

At Congress's direction, the EMP Commission filed additional reports in 2008. As part of the follow-on of these Commission reports and activities, a multi US Government agency working group was established under the National Communications Systems office called the "Communications Dependency on Electric Power Working Group". This group was especially focused on impacts to the nation's communications infrastructure posed by "Long Term Outages of Electric Power". I was asked to be a keynote speaker and participant in a key workshop event. This workshop was held in Washington, DC area on April 8-9, 2008 (Agenda is attached). The workshop involved all stakeholders, particularly NSTAC but also including Mr. Stan Johnson who was the formal NERC Critical Infrastructure representative to this working group. He was particularly disruptive to the information that I attempted to provide to this Committee and workshop. Prior to my talk, no others in the workshop (including NERC) had formally presented any information of a threat, which could plausibly cause a Long-Term Outage (LTO). The NCS staff had asked me to specifically discuss scenarios that could lead to a potential LTO. I primarily discussed a severe geomagnetic storm scenario. Mr. Johnson from NERC was not present for my presentation, and he only joined the meeting as I was answering a few questions related to power industry awareness and procedures for geomagnetic storms and whether NERC members would view this threat as a priority. I did express the concern that at present severe geomagnetic storm scenarios, uncovered in recent EMP Commission investigations, could produce threat environments a factor of ten times higher than the March 1989 storm and were not well understood by the power industry. I also expressed concern that existing procedures (largely developed from the March 1989 experience) may not be adequate to prevent transformer damage and prevent the development of an LTO.

Mr. Johnson from NERC was scheduled to formally present following my talk, and as he took the podium, he noted that he missed my presentation and while not intending to take anything out-of-context, he proceeded to strongly rebuke the conclusions that an LTO from solar flares (his term) was possible. He specifically said this discussion was "over the top and that we needed to climb down" from this position. He again emphasized that procedures exist in the power industry for alert notifications from NOAA for storms and conservative operation measures in reaction to and for the prevention of widespread problems during storms. I reported these events back to the EMP Commission members via summary memorandums.

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Table 1 – NERC HEMP Task Force, July 2003

To my knowledge NERC did not begin to seriously engage in this topic until late 2009, after reports from the National Academy of Sciences had been made public on the serious nature of the GMD threat to the nations power grid and Congressional investigations of NERC and industry preparedness for cyber, GMD and EMP threats had taken place.

It is also somewhat interesting to note that NERC is now calling into question their own NERC HILF Report of early 2010, even though I was only a co-author and NERC and their members reviewed and extensively edited much of my contributions to this report and ultimately this report had to receive top levels of NERC approval to be released. The main change at NERC since this HILF report was released was major changes in NERC CEO and other key top management. These NERC management changes may have brought with it new approaches on these threats. This posture seems to suggest a tactic to shift focus away from the problem, a strategy on the part of NERC and its members of *"If you can't win on the facts, call your opponent names."*

At any time it should be noted that NERC or anyone in the industry could have engaged with Metatech (the contractor I worked for on this project) for engineering services related to the GMD threat analysis, which is still true today. Yet I am not aware of any NERC effort to do that. I also provided very limited services via my firm to NERC in 2011, but that information was not made available broadly to the GMD Task Force, especially its observers, so no efforts that I know of have been made to do any formal expert evaluations by NERC of the prior models. Therefore this level of independent assessment or engagement has not been pursued by NERC.

Because of both the critical nature and potential consequences of this threat to the US electric grid and to the nation and the still emerging state of the science; I would fully agree and would also be the very first to advise that FERC, NERC and the nation should consider seeking out multiple and independent assessments of their vulnerability. Much more importantly these assessments should also be backed-up with appropriate and ongoing system monitoring and observations and continual testing of the analysis. Further the findings should be open to public scrutiny so that independent experts can determine if there are errors or omissions, rather than just industry self-assessments that provide only vague and non-specific assurances that there is no problem. That has been the model used in all prior reports that NERC has raised concerns about. Indeed in a report (Storm-R-111) that I provided to the NERC GMD Task Force in early 2011, I illustrated a number of these sort of self-checks of the model results in various government reports. I was asked to provide summaries of Peak GIC flows in the US for severe GMD threats as these were very high levels. But I also showed using publicly known GIC levels from any storm, that reasonably good peak estimates from this empirical data could be derived for the very severe GMD scenarios as well. I demonstrated using multiple and simple analysis techniques how one could arrive at the same high levels of GIC exposure in the US electric grid for the most severe storm cases using just simple empirical extrapolations. Over the last year, others such as PowerWorld Corp have developed models using information contained in the reports I authored and are also now estimating similar high GIC flows. Unfortunately as an adverse result of the empirical self-checks that I provided to the NERC GMD Task Force, the industry and EPRI has prevented any release of additional GIC measurements that could be used to further independently evaluate the risk to the US Grid. Ignorance of the law is not an excuse, perhaps it equally needs to be recognized that organizations such as NERC have a responsibility when chartered with public fiduciary duties to be responsive in addressing new threat issues that are brought to them. NERC's statements regarding engaging more subject matter experts are not at all consistent with their actions. In large part, NERC's and the industry's lack of engagement has been self-inflicted as the above record demonstrates. Therefore NERC's statements should not be given any weight by FERC or consideration of additional delays that NERC may seek in reducing the risks posed to the public by GMDs. The best way forward is for FERC to continue to promote the broadest possible interest and independent investigations, not limiting any of these investigations to just industry self-assessments as has been the usual practice over many years and which failed to recognize the enormous growth of risk from this threat that has occurred in the electric industry.

Basic Flaws in NERC Review of Transformer Over-Excitation

In the same NERC Final Comments Docket Filing for the FERC April 30 Technical Conference (AD-12-13-000), the NERC CEO Mr. Cauley et.al. make note of the following in regards to the applicability of existing transformer over-excitation standards for transformers:

> *Finally, from a technical perspective, NERC notes the inappropriateness of using the incremental excitation current necessary for transformer core saturation as a way to suggest vulnerability of transformers to geomagnetic induced currents.*

NERC then provides an Attachment D, which is an apparently anonymous briefing on transformer over-excitation, which draws some clearly misleading and wrong conclusions on this topic. The unknown author of Attachment D references some work by "Walling" which is very limited on this topic and attempts to expand upon that limited work. However no tangible facts such as actual transformer data, testing to validate new claims or any other data on transformers or related information that can actually substantiate these remarkable claims are provided.

One of the most troubling claims by this author is that they seem to suggest that over-excitation can only occur with elevated voltage levels in transformers and further state that GIC-caused over-excitation cannot "stress the dielectric strength of the insulation". This clearly is not true nor the intent of the existing standards which I substantiated in my Storm-R-112 Report to the NERC GMD Task Force. This same report also illustrated how other manufacturers have chosen to account for GIC-caused over-excitation. Certainly over-excitation can be caused by over voltage but unlike the claims made in NERC's Attachment D, over-excitation can also be caused by under frequency at the normal or even reduced voltage, which is also clearly the intent of the over-excitation standards. Further, heating damage brought on by GIC-caused over-excitation can cause insulation damage leading to dielectric failure; one only needs to look at a picture of the Salem transformer windings to make that conclusion.

These submittals are likely an effort at damage control and changing the narrative from testimony and comments that I and others submitted in Docket AD-12-13-000 in calling into question findings in the NERC Report of Feb 2012, which essentially advocated the concept of NERC and its members ignoring existing standards for over-excitation which would be applicable to the bulk of existing transformers in the US bulk electric system. Adhering to these standards would require substantial limits on GIC exposure for transformers. The fact that the NERC report ignored these standards as a design basis is perhaps an embarrassing and difficult to defend oversight that they do not want on the public record. Therefore they and arguably some in the transformer community (note IEEE Transformer Committee) are put into the awkward position of having to claim that valid transformer design standards which have existed for many years are not valid. The logic of their arguments are being undone by their own lack of self-consistency and it appears that they may not like traceability in design standards that leads them to an outcome they may not want in regards to hardening the grid, and therefore instead act to oppose an outcome that would be better for the public interests.

One of the most important concerns that have been raised in regard to the NERC GMD Task Force process is the complete lack of equipment data and information made available by the industry in order to do reasonable forensic investigations or to conduct the needed investigations of pathology of GIC-caused deleterious impacts to equipment. It is clear that factors such as the transformer specific information such as E/I or saturation curves are needed, also needed but not provided are the exact details on the knee points of the saturation curves, data on air core reactance etc. to determine when these transformers would be driven into saturation by GIC. Observations of GIC and transformers being over-excited by GIC were also noted as being held by EPRI, but not being made available for examinations by any of the GMD Task Force participants. Again in this NERC docket, they have failed to provide any additional real design or experience data, just vague and unsubstantiated claims much like contained in the prior NERC Report and in this NERC Docket. Any transformer designer would ultimately have to admit that for the bulk of transformers in the network, once you experience operation above the core saturation threshold, the transformer flux management systems in the design for normal operation are no longer valid for this over-excitation mode of operation and deleterious impacts can then occur.

I carried out the industry's very first tests for GIC on large 500kV and 230kV transformers which pointed out a number of wrong assumptions that had prevailed in the transformer design community on this topic. The industry has experienced a number of important and unpleasant surprises in regard to transformer behaviors and potential for damage during a number of storms. These events were not at all predicted by transformer designers as no real efforts had been undertaken to develop much expertise in this topic as it was thought to be of low importance, due to underestimates of storm extremes and lack of assessments of network vulnerability. Further we have been presented only vague and non-specific reassurances by the industry and transformer manufacturers that nothing is at risk, but as I noted in my Storm-R-112 report and other reports to the NERC GMD Task Force, little substantiation is provided and many important unanswered and open questions remain. The industry has made decisions to actively withhold important data sets on GIC exposure and failures that could further aid in such forensic and pathology investigations on these topics. In any process of risk management, the burden of proof on equipment safety and performance limitations lies with the equipment manufacturers and owner/operators, not the public who may be put at-risk by defects in this equipment or the manner in which it is allowed to operate beyond safe performance envelops. Ultimately the public interests will require that we carefully and fully investigate these issues to shape the best public policy for risk management. Transformer designers have not demonstrated simulation models that are capable of predicting the safety of transformers for this unique hazard. Further there are no tests or testing ability to demonstrate the ability of transformers to be exposed to high GIC levels. Further manufacturers are presently selling transformers with GIC withstand levels that have not actually been tested or certified in any way to withstand those GIC levels. Lacking all of these basic public protections, it is better to have access to actual transformer operational data. Transformer heating problems leave clear and traceable signs that something is going wrong inside the transformer and when it can be related to specific GIC exposures, this provides the best source of guidance on the nature of these impacts. Only one US electric utility publicly reported this type of data after the March 1989 geomagnetic storm and this data noted impacts to ~36% of their transformers. No other reports have been allowed to surface from the entirety of the US electric utility industry for this storm or any storm since.

Failure and test data that has been made available indicate failures of transformer types and processes that models have not been able to replicate, such as indications of discharging or heating in unexpected places, or on shorter time intervals than models would predict, heating that is occurring in locations other than predicted as GIC levels change. Prediction models of heating have not yet been demonstrated that can be benchmarked to observations even for low GIC levels. As GIC levels increase to much higher levels it remains uncertain whether models can predict even thermal behaviors and no ability exists to predict some of the other behaviors of such as discharge, etc. that we know very little about.

Electric industry comments may argue that some levels of transformer overload with controlled and limited loss of life is an accepted practice for the grid. Overloads of this type will cause increased transformer operating temperatures. These procedures are sometimes used in a very small number of transformers for limited extents for overload operations during summer heat waves or other emergencies that could develop within the grid. These practices have been backed up by nearly a century of design and operating experience and the development and continual updating of design and operating guidelines and standards that have spanned nearly a century. Operating for overloads of this type are also more predictable as the heating that is of concern for transformer loss of life is more uniformly distributed and will have much slower onsets and be imposed over larger surface areas of the transformer. This makes the job of temperature control and cooling easier to engineer in transformer designs as well. Installations of transformers across the grid are also provided with continuous real-time monitoring of loading and other environment conditions that play a role in determining transformer stress that will result. Further autonomous and near-instantaneous relay and protection systems are in place for all major transformers in the network to further protect them from damaging conditions that could arise during normal operations.

None of these experience bases or protections has been provided for the public in the case of GIC-caused transformer heating and transformer damage. Rather it has been a very uncontrolled and unpredictable situation and with geographically wide spread concern brought on by the sudden development and large geographic footprint of these disturbance environments. Transformer heating and damage knowledge from overloads does not translate very well towards understanding the risks posed by over-excitation which causes much different modes and placements of heating in a transformer. Little to no monitoring of environment conditions such as GIC is even in place for the most part in the grid. Very poor understanding presently exists on what will happen as far as internal heating for GIC in a transformer and where and how much damage would occur in a particular transformer design. The nature of GIC-caused over-excitation can cause stray fluxes to concentrate and impinge in small but critically important windings and structures inside a transformer. Monitoring for elevated internal temperatures for this condition is enormously more difficult than the overheating posed by simple overload, as spot heating can be very small in affected area but can generate enormous temperatures that can rapidly burn through insulation systems or even large current carrying conductors and temperature probes to monitor these conditions will not be in thee right locations to provide a useful warning. This behavior makes predicting transformer performance much more difficult compared to normal overloading. Further the wide variations in design of transformers add to the difficulty of the prediction problem as it may be unique for each design rather than something that can be more broadly generalized. For controlling temperature increases, there is no guarantee that sufficient cooling systems will be available to the exact overheated spots under this mode of operation to prevent damage. Further, this could be occurring not in just a small subset of transformers but in large numbers of transformers all at the same time.

I am sure that we will hear from a number of transformer manufacturers and even owners and operators of transformers will provide comments noting broad reassurances that transformer cannot or will not be damaged. There will even be claims that transformers have been warranted for various levels of “GIC Withstand”, some to remarkably high levels. But there is no agreed upon and verifiable certification process for arriving at these conclusions. In some cases, transformers are being sold with “high GIC Withstand” levels, even though that manufacturer is unable to perform physical tests of this stress on the transformer. The same limitation is true for most other manufacturers as well as they work to introduce “high GIC Withstand” transformer designs.

There are several things that we do know about GIC and the potential for damage in transformers; it starts with the fact that every test that has been done results in increased heating in unusual and hard to predict locations in that exposed transformer. The other is that we are not great at predicting how transformers will behave in terms of permanent damage mechanisms that can be activated by GIC. We do not even have models for some behaviors that have been observed. Therefore we have no legal or technical basis to assume that this mode of operation is safe and prudent to be allowed. We have no agreed upon test protocols, test facilities, or even numerical simulation models to certify in any way that transformers or other power grid equipment or systems will be safe to high levels of GIC. We have no industry standards that allow GIC exposures above levels and limits based upon existing over-excitation standards. We can also expect that as a transformer ages and the condition of its insulation degrades; that whatever GIC withstand that existed when new has eroded over time. Making the problem of continuity of GIC withstand difficult to maintain and assure unless GIC reduction technologies are deployed. We also know that the demographics of the US EHV transformer population places a large segment of that population in the last quartile of their life and that failure rates are about 5 times higher for these transformers.

We have been subjected to a number of meetings with transformer experts that fail to substantiate their vague assurances that transformers are not at-risk, even though this same group develops and continually ratifies standards on over-excitation which would draw entirely different conclusions. One of the most familiar refrains we have heard from them is “We are the experts”, while we have to tell them that actually “the transformers themselves are the experts” on whether GIC is harming them and we are prevented from examining the information these transformers are attempting to tell us.

We also know that protective relay systems and schemes that protect transformers for other stresses will not work for the GIC-caused over-excitation stress. Present over-excitation protection is usually provided by a Volt/Hertz relay that is set to detect the conditions of either an overvoltage or an under frequency which would lead to over-excitation of the transformer. This important protection scheme does not work for GIC-caused over-excitation as this mode of over-excitation occurs without the presence of an overvoltage or under frequency, a serious design gap. Transformer differential protection is also inadequate because harmonics produced by GIC-caused over-excitation are used in this protection scheme to restrain or prevent operation of the protection system, another critical design gap. We know that large generators are also at risk, though very little work has actually been performed to examine this more fully and that important data and analysis here is also not available for independent analysis. Hence, this has unknown potential for HILF concerns as well. We know that large and difficult to replace EHV circuit breakers may be called upon during collapse to interrupt sizable DC currents, which they are not at all rated to handle this duty and no work at all has been done by the industry to understand the consequences of this scenario either. NERC's recent report featured their favorite narrative of a grid collapse as the likely outcome of a severe storm. Yet NERC assumed it would be benign in its potential for damage only by ignoring the danger posed to circuit breakers brought on by this type of scenario. This very well could pose nearly the same restoration difficulty issues, only circuit breakers instead of transformers that have been the core of current discussion.

There are clearly a long list of "known-knowns" on power grid impacts, but also a long list of "known-unknowns" that are even more troubling. We also have anecdotal data on harmonic impacts to sensitive systems that we have yet to even begin exploring, these have the potential to not only impact grid-wide control systems, but also impact the ever more critical and sophisticated end-users of electricity in vital sectors like IT, data centers, and other vital highly automated public services, etc. We have generally experienced new and unpleasant surprises from every significant storm that has occurred since March 1989(unknown-unknowns). There is no reason to expect that are no more new ***unpleasant surprises*** awaiting society for this threat. We also know that stopping the flow of GIC into the network in the first place will arrest all of these long-tail impacts to the grid and society. These accumulated deficiencies create uncontrolled risks for the bulk electric system which have gone unchecked for decades and must be addressed with appropriate remedial design actions by the industry.

I am sure that the industry will comment that there will be costs to implement these remedial measures and that part is true. But in all the analysis that I and others have performed, it is not at all a major cost and well within the means of the nation and probably would constitute no more than round-off error in the financial ledgers of sunken investments already in place in this infrastructure. Others are even noting the possibility of offsetting operational benefits for taking such measures in enhancing the performance of the grid during storms. It should be recognized that if we had the benefit of hindsight, the industry would have been alerted to make different choices in how to develop the grid over the past

50-60 years while taking this threat into proper consideration. They would have spent these costs and likely much more in design modifications that would have engineered a safe and secure grid to this threat starting over a half century ago. There are perhaps some advantages that may have inadvertently accrued for the industry by their deferring these prudent design requirements. Clearly, there are better technologies available today for how to affect these remedial measures and at lower overall costs than would have been achievable previously. Hence this needs to be looked at more appropriately in the context of history.

I am sure that a number of comments from industry will come in describing the fix of blocking GIC as being a "whack a mole" type problem, where if you block GIC inflow at one location is shows up in another location. In a sense this is correct and I have labored in various reports to the nation in looking at mitigation strategies. This behavior however is amplified or set into place by the historically poor choices that have been made in the past on grid design. It is common practice to employ autotransformers ubiquitously throughout the bulk electric system, which not only increase GIC flow levels, but also exacerbate the abilities of GIC to readily seek alternate ground paths. In spite of this tendency to displace GIC flows, in all cases adding blocking devices produces significant improvements in reducing overall GIC flows and their potential for impacts to the grid. It is also appropriate to note that this is a common concern for other codes in society such as the fire code, which compels all buildings and domiciles to design for uniform requirements to limit the potential for spreading wild fires. GIC mitigation therefore needs to be understood in this sort of "preventing wildfire" context.

Therefore the FERC Commissioners should give little weight to comments on unnecessary costs from the industry and it is time for industry to recognize that historically this has been an inadvertent design code omission and safety concern of the broadest possible nature. We have all enjoyed the free lunch of these deferred costs, while having the good fortune of not learning about this potential for disaster to the public the hard way. However, luck is not a strategy that will work in the long run and the bill for this free lunch needs to be paid. We should all recognize the need for recovery of investment costs that will be needed to make the grid secure and robust against this threat and we should invite all to help bring forward the technology options to consider in these tasks. Work and designs that I have been involved in have already been placed in the public domain and are not subject to any patent protections on my part. Indeed I am already aware of organizations which are actively manufacturing such methods and I hope others will add their own ingenuity to this enterprise.

The Role of EPRI in GMD/GIC Research and Impacts to the Public Interest

The Electric Power Research Institute (EPRI) is an industry-funded scientific research organization. According to various EPRI documents, EPRI has been determined by the Internal Revenue Service to be a tax-exempt 501(c)(3) organization created specifically to serve the public interest through electric power and other energy-related research.

I did several research projects with EPRI starting as early as 1977 on geomagnetic disturbance (GMD) and geomagnetically-induced currents (GIC) while I was employed at Minnesota Power which was also an EPRI member and funding contributor. In fact, my work was the very first EPRI work on this topic. These projects have spanned basic science of the phenomena, to monitoring and vulnerability assessments of the electric grid, to actual development, and to deployment and testing of GIC blocking devices and strategies. This work was made up of several small projects on which I served as the Principal Investigator and sponsor. All of my work with EPRI formally ended in 1996.

While the initial stages of work on GMD/GIC were an interesting topic area, we were not expecting it to have wide interest in the power industry. At the time the work was initiated, GMD was considered to be a nuisance level problem, not the national security threat now being considered. I did co-author and publish a paper in 1980 that made the following prediction:

> **"There is a non-zero probability that GIC could cause a wide-area blackout for a severe geomagnetic storm" - V. D.** Albertson, J. G. Kappenman, et.al. IEEE PAS February 1981

This statement received some healthy skepticism but ultimately was proven to be true during the March 13, 1989 storm that caused the Quebec blackout and a large number of significant operating anomalies across substantial portions of the U.S. grid. The March 1989 storm also caused a large extra high voltage (EHV) transformer to fail at the Salem, New Jersey nuclear power plant.

As a result of the Quebec blackout and transformer failure, some acceleration of activity and research was undertaken by EPRI; this included work they asked me to do in development and testing of transformer neutral devices for blocking the flow of geomagnetic induced currents (GIC). While I had done work in pioneering measurements of GIC and geo-electric fields prior to the March 1989 storm, EPRI also began efforts to create a collaborative monitoring network called SUNBURST. My company was a charter member and participant in SUNBURST; we installed several monitoring locations and undertook other activities to support the science.

As I preceded with these EPRI activities, staff from the Nuclear Regulatory Commission (NRC) sought me out and shared with me information on a rash of Generator Step Up (GSU) transformer failures that took place at U.S. nuclear power plants in the several months after the March 1989 storm. I undertook a statistical analysis showing a significantly elevated rate of failure (4 to 6 times higher failure rate than normal) and reported these findings in various forums in the mid 1990's.

After my statistical analysis of GSU transformer failures at nuclear plants, I received a personal phone call from an EPRI Senior VP (an unusual occurrence) in which he suggested that I should no longer have any contact with the NRC staff or pursue that line of investigation. Because EPRI had a large nuclear power research division, it was apparent that pressures were being applied to limit research related to nuclear power plant vulnerabilities to geomagnetic disturbances.

While EPRI was doing significant research on nuclear power, I was also not aware of any research in that division on GIC risks to these plants. Therefore I was concerned about the inherent conflict of interests that this funding interest posed. While EPRI can do collaborative research with industry funds on nuclear power issues, it does raise legitimate concerns about the overlaps which can act to block avenues of research or compromise science in the public interest versus EPRI member interests.

The public should not be naive in these inherent conflicts of interest, as EPRI members do want their R&D funds to go to efforts that reflect not only their research priorities but also their very human biases and economic interests. Therefore, FERC must be vigilant of this potential then as well as now and in the future.

It was also about this time, in the mid-1990s, that my funding for work on GMD projects ran out and overall interest on the part of EPRI on this topic rapidly declined. I submitted my final report on the GIC Blocking Device testing in late 1996 (Attachment 5). This report was structured like other EPRI reports that were published on my work. It summarized engineering analysis of GIC blocking devices as well as the success of their deployment for both staged and long term field tests at Minnesota Power. For reasons never explained to me, EPRI failed to publish this report, even though the materials contained in the report are of exceedingly relevant and of high interest in discussions of this NOPR.[1]

In parallel investigations on the related topic of electromagnetic pulse (EMP) and the threat posed to the electric grid, EPRI also again played an unfortunate and pivotal role. In 1986 a paper written by an EPRI scientist on EMP and power grids was presented and subsequently published in 1987. The following is the topic and author of the paper:

> "Effect of Fast Nuclear Electromagnetic Pulse on the Electric Power Grid Nationwide: A Different View" by Mario Rabinowitz, Electric Power Research Institute, IEEE Transactions on Power Delivery, Vol. PWRD-2, No. 4, October 1987.

We now know, in retrospect, that this paper presented inaccurate information on the EMP threat environments. The seemingly benign conclusions of the Rabinowitz paper, published just two years before the contra-indications of the Quebec blackout that affected both Canadian and U.S. electric utilities, served in large part to stall electric power industry understanding of the EMP threat until the Congressional EMP Commission was established and presented their reports in 2004-2008.

Unfortunately, as EPRI has stalled and hindered the understanding of the EMP threat to the nation's electric grid infrastructure, it is also poised to do similar harm to efforts to improve our understanding of the threat posed by solar GMD.

EPRI has been in possession of extensive data (going back to 1990) on GIC flows in various locations across the US power grid. In addition to this data, EPRI possesses various reports of the analysis of this data and its impacts to transformers, generators, and relay systems. But EPRI has chosen not to release either the full time series of GIC data or the relevant EPRI analytic reports, despite repeated requests by researchers and public interest organizations. In preparation for discussions at the NERC GMD Task Force meetings in 2011 on the possibility of damage to transformers caused by GIC, a Google search turned up a June 2004 article from Transmission & Distribution World Magazine that contained the following information about an EPRI-sponsored research project:

[1] See, however, the research paper was accepted and published by the IEEE: J. G. Kappenman, "Geomagnetic storms and their impact on power systems," IEEE, Power Engineering Review, v. 16, no. 5, May 1996, pp. 5-8. This paper is cited in at least 78 subsequent research papers or proceedings.

- *Case 5. A continuous monitoring of a single-phase, shell-form, GSU transformer was performed during a solar storm.* Along with the AE sensors, the current on the ground terminal was monitored to detect geomagnetically induced ground currents (GIC) and correlate this parameter with any AE detected.

  A sudden increase was detected in the ground current (Fig. 10) at the same time acoustic activity was detected, as well as a few events located in the area where the core-ground connection exits. Twelve hours later, the on-line gas monitoring system indicated increases on ethane and methane gases in the unit.
  http://tdworld.com/mag/power_locating_assessing_faults/#ixzz2FGejyGGJ

This article establishes high quality real-time measurements were available that show definitive proof that GIC was causing internal heating damage to this transformer at an unspecified location. EPRI has failed to release this and almost all other vital data on the impacts of GIC on the electric grid. No explanation has been given by EPRI as to why the data will not be made available after many months of delays, with EPRI staff indicating that they were working with their members to make this information available. This data is important evidence and its public release is clearly in the public interest, but it also is apparent that release of this data conflicts with the interest of EPRI clients. EPRI engaged in publicizing this tidbit of information in order to market its research services to the industry. But is EPRI failing to live up to its charter of working in the public interest by not fully releasing this vital information? This behavior cannot be defended, especially when EPRI qualifies for tax exemptions for its special public interest status.[2]

Because of these mixed priorities of public interest versus client interest, the FERC Commissioners and Staff should take appropriate precautions to avoid dependence on EPRI in the drafting of rules for GMD threats to the US grid and for standards and for implementations of any action plan specifics that come from NERC and the industry in response to these rules.

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[2] EPRI is incorporated as a non-profit organization in the District of Columbia. EPRI's Articles of Incorporation, as amended, provide in Article 3(b) for sponsorship of "electricity research and development for the public benefit;" EPRI's Article of Incorporation, Article 3(i) provides "for the exchange of information for <u>all</u> organizations and persons, public or private, concerned with electric power scientific research and development;" (underlining added).

GIC data and reports of transformer failures need to be comprehensively available, and considered as vital evidence that is subject to necessary protections and force-of-law regulations. The nation cannot again be put into a situation where evidence vital to protection of public health and welfare, and to the reliability of the bulk power system, is withheld indefinitely. No organization, whether it is EPRI, NERC, or NERC-member utilities that are subject to FERC jurisdiction, should be permitted to take willful acts to obstruct lawful investigations essential to protect the national security and the viability of the nation's critical infrastructure. EPRI has acted to deprive the nation of more than twenty years' knowledge of GIC; they have acted to impede the nation's understanding of naturally occurring geomagnetic disturbances, and man-made EMP phenomena and their potential impacts, and the cost-effectiveness of alternative grid-protective investments.[3] The nation should suffer no further injury from EPRI's failure to act in the public interest.

NERC in their first formal actions in developing the GMD Task Force turned to EPRI as the prime contractor to carry out all research and investigations on this topic, the very organization which has acted to impede public knowledge and corrective action in the public interest.

These types of close interrelationships of NERC and EPRI and also various interlocking confidentiality agreements between EPRI and electric utilities, which mislabel data essential to protect grid reliability as "proprietary information," must be reconsidered and circumscribed. Federal laws and regulations do not permit operators of commercial airliners, or cruise ships, or manufacturers of automobiles to conceal information on accidents as "proprietary information." Without standards that require essential public disclosure and data sharing for research purposes, electric utility industry data confidentiality agreements, whether through EPRI, NERC, or IEEE, may foreseeably encourage withholding of evidence, collusion, and other actions harmful to the public interest.

FERC's Final Order in Docket RM12-22-000, and implementing regulations must prevent collusions in standard-setting that exclude "public observers" from access, at key stages, to relevant safety and

[3] Some academic researchers, e.g. K. F. Forbes and O. C. St. Cyr, project significant financial benefits from reductions of GICs within electric grids, but they increasingly rely upon regional observatories for GIC measurements because GIC data from public utilities is only selectively available and because the EPRI SUNBURST database is still unavailable for academic research. Release of EPRI data from the entire SUNBURST database would provide opportunities to improve estimates of payback periods for grid protective equipment, and to independently review research findings that, at present, lack systematic access to the SUNBURST datasets.

accident data, and to relevant solar weather data and analyses. NERC and EPRI have obvious advantages of market power to control the nature of the research and to control the narratives that come out of that research. Without independent review and oversight, these tax-exempt institutions and their industry sponsors can act to withhold business and otherwise retaliate against independent consultants that do not produce biased GIC assessment and mitigation plans using fallacious assumptions and rosy scenarios, and otherwise assist electric utilities in evading reliability standards. FERC should consider the need for checks and balances on data entitlements.

FERC should also act to preserve independent research, diversity of views, and institutional knowledge that cannot be guaranteed as experts on EMP, from the era before cessation of nuclear testing in 1992, die or retire. Similarly, independent expertise on risks from solar geomagnetic disturbances is at risk as industry sponsored organizations that have resisted reliability standards for more than two decades withhold funding.

After all, it was not EPRI and their vaunted research programs that uncovered the full dimensions of the GMD threat to the U.S. Electric Grid, nor was it NERC and their actions to supposedly ensure electric grid reliability. Rather the GMD threat was uncovered by small independent research efforts that prevailed in spite of efforts to sidetrack this work by these two organizations. The general public and public officials responsible for policy development and standards enforcement need to recognize with honesty that NERC and EPRI have not lived up to their public duties. The industry has deployed extra high voltage transmission systems that provide more efficient antennae connecting to grid equipment and for over a period of decades have been inattentive to the accumulated risks of GMD to these systems. These research and standard-recommending entities have even acted, at times, in unhelpful ways that hinder and obstruct full discovery, investigation, and remedial actions to this day.

The nation should not depend on EPRI and NERC to be the primary stewards of correcting hazards which have expanded and festered on their watch. It is reasonable for the FERC Commissioners to conclude that entitling EPRI and NERC to further information “gate keeping” and discretion in standard-setting makes absolutely no sense and would not be in the public interest.

IEEE Transformer Standards – Tainting the Standards Process?

In NERC CEO Mr. Cauley's supplemental filing under FERC Docket AD-12-13-000, that organization stated the following regarding the issue of developing equipment standards:

> *NERC will continue working with organizations such as the IEEE and IEC to improve equipment standards and specifications where the results of assessments and analysis signify requirements.*

In Mr. Cauley's pre-filed testimony (April 2012) for this docket, he also offered other statements regarding NERC interactions with the IEEE Transformer Committee:

> *Transformer Specifications:*
> *Resulting from NERC's recently released report, the IEEE Transformers committee has begun development on a guide on transformer and step response specifications to meet the service conditions related to a geomagnetic disturbance as well as the magnitude and stress cycle due to geomagnetically induced current transformers should be designed to withstand. This project was initiated at the spring 2012 meeting of the IEEE Transformers Committee in Nashville, Tennessee. We will continue to monitor the progress of this effort, and provide technical expertise as warranted to its conclusion.*

In reviewing the minutes of this particular IEEE Transformer Committee meeting held in March of this year, we can get a sense of what the agenda, objectives, and priorities were for the ongoing processes that are being developed there. Attachment 3 is the minutes of one of the important subcommittees which succinctly describe their highest priority near-term actions which are:

> *The meeting was called and chaired by Ramsis Girgis. After welcoming the attendees, the chair gave a brief context of the purpose of the meeting; namely:*
> *1. Writing a position paper, on behalf of the IEEE Transformer Committee, in response to the IEEE Spectrum article written by John Kappenman; "A Perfect Storm of Planetary Proportions" that appeared in the February 2012 issue.*
> *2. Forming a Task Force to produce a proposal for an IEEE GIC Guide and identifying the purpose, applications, and scope of this Guide.*

Note that responding to my IEEE Spectrum was actually their top priority. This group further justified this priority action with the following stated rationale:

The <u>*Spectrum*</u> *article had mainly three claims that are not accurate:*

1. GIC would fail a very large number of Power Transformers due to damaging overheating

2. Power Utilities have not done much since the 1989 GMD storm to be prepared for the next storm

3. A GIC Blocking device is the only solution to avoid the harmful impact of GIC

All in the room were in agreement that the IEEE Spectrum article went too far and exaggerated the impacts of GMD on power transformers and the power grid. Moreover, The GIC issue is more a Power systems issue rather than a transformer overheating failure issue as the Spectrum article claims.

A question was raised in whether any of the attendees was requested to review and provide comments prior to the article being published. Emanuel (Bernabeu from NERC GMD Task Force) *stated that a representative of Dominion was requested to review the draft article, but was not given sufficient time. The reviewer gave feedback that the article should not be published and that a lot more work needed to be done before such an article would be published, but the feedback was ignored.*

By early April this discussion and activity of the Transformer Committee had been elevated and widely coordinated across the entire IEEE Power and Energy Society (PES). On April 12 the Chair of the IEEE PES Technical Council (which coordinates all IEEE PES technical committees) sent out an email (Attachment 4) which coordinated efforts as noted below:

As our goal is to have a comprehensive response focusing on all aspects of GMD to best counteract the Spectrum paper

Note the emphasis was to counteract, not seek information, and was based upon the information communicated via the Transformer Committee.

These statements are remarkable in that this Committee has apparently already decided the outcome before they have even started and provide no pretense of due process, due deliberation of the information which is a requirement in a standards setting organization. Several of these members (including the Chair) were also participants and members of the NERC GMD Task Force. This raises legitimate concerns that their purpose may be to circumvent the intent of FERC via the IEEE Standards process. Further the NERC GMD Task Force holds considerable information on these issues where considerable debate has already taken place on transformer vulnerability. Much of this debate centered on lack of reliability of the technical arguments put forward by the Chair of this subcommittee that is now developing new IEEE Standards. Because NERC restricts distribution of the reports and comments that have taken place, this information has not been made available for consideration by the rest of the subcommittee for their due diligence. Effectively making it easier to produce an outcome to that aligns with their self-interests.[4]

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[4] Development of NERC standards via a substantially overlapping committee (the Transformer Committee) of the IEEE, to review and to selectively share historical data on transformer performance, GIC histories, and transformer vulnerabilities with IEEE Committee members who are also key participants in NERC 's Geomagnetic Disturbance Task Force , while excluding public observers from access to meetings, GIC data, and other information relevant to standard-setting, has the effect of circumventing the due process and right of public participation in NERC standards development for transformers or other critical equipment affected by geomagnetic disturbances. Excluding the NERC GMD Task Force public observers from meeting notices, exchanges of information, GIC data histories, etc. effectively defeats the procedural safeguards in NERC's own Bylaws for development of reliability standards.

In particular, the NERC Bylaws adopted in August 2009, and in effect since October 14, 2009, provide:

NERC Bylaw Article IX, Section 2: "**Procedures for Development of Reliability Standards**: The Corporation shall develop reliability standards pursuant to procedures and processes that shall be specified in the Rules of Procedure of the Corporation. The Rules of Procedure shall provide for the development of reliability standards through an open, transparent, and public process that provides for reasonable notice and opportunity for public comment, due process, and balancing of interests and is designed to result in reliability standards that are technically sound. Participation in the process for development of reliability standards shall not be limited to members of the Corporation but rather shall be open to all persons and entities with an interest in the reliable operation of the bulk power system."

Moreover, the Transformer Committee of the IEEE also requires due process that appears to be inconsistent with the actual practices of that Committee. IEEE Transformer Committee "Operating Procedures" effective since July 2009, purport to require: "the orderly transaction of activities of the Transformers committee. For the development of standards, openness and due process must apply, which means that any individual with a direct and material interest who meets the requirements of these Operating Procedures has a right to participate by a) Expressing a position and its basis, b) Having that position considered, and c) Appealing if adversely affected. Due process allows for equity and fair play. In addition, due process requires openness and balance (i.e., the standards development process should strive to have a balance of interests and not to be dominated by any single interest category). However, for the IEEE Standards Sponsor ballot, there shall be a balance of interests without dominance by any single interest category."

While the most important aspects of this lack of appropriate institutional behavior are the enormous public interest and concerns to protect critical infrastructure, it is necessary to address both the underlying accusations made against me, and the public interest issues at stake.

There are several diverting accusations that have been leveled, and which need to be addressed in FERC Docket RM12-22 so the Commissioners are better informed when they issue a Final Order.

1. "the recent Spectrum article on Geo-Magnetic Disturbances (GMD) is an example of the sensationalistic journalism"

My response: All of the information in the Spectrum article is - derived from publicly available information that existed prior to the article as well, including the ORNL Reports; these are not new findings. Rather they have received rigorous professional reviews, just not by these particular members of the Transformer Committee. Even the mention of Nuclear Plant vulnerabilities is taken from active rule-making related filings publicly available via the US Nuclear Regulatory Commission. All of these concerns have been in the public debate for some time and are important underpinnings of the pending FERC Notice of Proposed Rulemaking on Geomagnetic Disturbances.

2. "review and comments by experts were ignored (as commented by the chair of Transformers Committee, Bill Chiu)."

My Response: In regards to the IEEE Spectrum Article, I received no negative feedbacks on the article during the Spectrum editorial process. During the course of developing this article for the IEEE Spectrum Magazine, the only people I interacted with were the editors Glen Zorpette and Jean Kumagai. No review process or concerns of a review process were raised with me. If a review was done as alleged by Mr. Bernabeu, I was not aware of it and he should produce physical evidence that some violation of the review process did occur. At any rate, if I had received such a review I would have been more than glad to provide the extensive rebuttal information I had already filed with the NERC GMD Task Force on transformer damage issues (for example, the Storm-R-112 Report) and would have also noted how NERC, EPRI, and NERC members have refused to collect and turn over for independent analyses known additional evidentiary materials concerning geomagnetic induced current (GIC) data and transformer failures, so that they could also be reviewed.

There clearly are major disagreements with members of the Transformer Committee on the potential assets at-risk due to severe geomagnetic storms. I have not ignored their comments but have actually filed extensive reports with NERC and FERC pointing out major problems with the statements put forward by members of this Committee. These reports also note vulnerabilities that may extend to other power grid apparatus from these threats including:

- large generators,
- circuit breakers,
- SCADA equipment, etc.

Simply stated, there are no standards that define "GIC-Withstand" of transformers; the only standards that do exist are in regards to Over-Excitation (which GIC certainly causes) and these standards clearly define limited levels and time durations of Over-Excitation that can be tolerated in transformers. These levels will be greatly exceeded in a number of transformers for severe storm scenarios. These are the standards, by the way, that the Transformer Committee itself has defined.

As noted by my response, these are all accusations of which any reasonable person should be appalled and deeply troubled, both by the tone and by the purpose of such a widely distributed email on this subject. While issuing this call for action, they have made a number of unsubstantiated claims that are simply without factual or logical basis.

The need for prompt, science-based reliability standards to mitigate risks to the bulk electric system is paramount. The Commissioners should not be diverted by efforts to disparage independent expertise, or to seek endless "study" of the robustness of transformers, instead of requiring industry wide standards to protect our critical infrastructures. It is understandable how the Transformer Committee has not liked much of the information that has been brought forward on this topic area. They have not historically taken any specific actions in mitigating this threat and potentially have, in a number of ways, but inadvertently, made the potential consequences of the threat far greater. For example, leaving transformers without GIC-related standards while the bulk transmission system has over recent decades adopted higher operating voltages has inadvertently increased the vulnerability of equipment essential for grid functionality. The Committee and IEEE PES as a whole have never put forward a single guideline or standard in regards to risks posed by geomagnetically induced currents (GICs) or Geomagnetic Disturbances..

This FERC-initiated rule-making may ultimately act to bring to light issues of misjudgments and negligence on the part of individuals, manufacturers, consultants and owners and operators of transformers or other power system equipment. But the more important goal must be to accelerate understanding of the problems that uncontrolled exposure to GIC may pose to society; and to identify risks requiring remediation, and cost-effective solutions.

The continued operation of these Committees, without appropriate representation by independent experts, and without review and accountability to stakeholders who represent the needs for greater reliability throughout the bulk power system, is troubling. Section 215 of Federal Power Act, created via the Energy Policy Act of 2005, requires openness, a transparency, and a balancing of interests. The work of the Committees, as illustrated in my comments, shows a primary concern for "self-interest" with no offsetting balance to protect public interests in a more reliable electric grid. This lack of balance of interest ultimately also brings into question whether recommendation of this and other committees will comply with ANSI or other standards accreditation certifications that require openness, transparency, and balance of interests as being of paramount importance to assure acts and standards that are in the public interest.

Personal attacks will not dissuade me in the near term, but there is reason to be concerned that it may act to dissuade others from also expressing their true opinions, when the Chair starts from the outset to publicly enforce an outcome to denounce honest efforts at debate. It is counterproductive to the openness requirements of a creditable standards development process and ultimately harmful to assuring the public interests.

Just as was asked in prior discussion on the roles of NERC and EPRI, perhaps the same set of observations and questions of proper public interest policy can be framed in this case for IEEE as well.

Since the organization has been complicit via benign inattention to this problem and since their actions now raise questions on their conduct and intent; is it not also reasonable for the FERC Commissioners to conclude that entitling IEEE to further discretion in standard-setting makes absolutely no sense and would not be in the public interest. Certainly it will be important for FERC to closely follow this group and to ensure actions coming from them conform to the public interest.

Policy Framework for Mitigation of Severe Geomagnetic Storms

While the FERC has put forward proposed rules that are comprehensive to address the underlying GMD threat for the nation, I feel it is again appropriate here in this public record to discuss the underlying need for this historic policy framework and decision on their part and why the public should fully ratify these decisions as well. Prior publicly available reports provided to FERC have given considerable insights into the potential for catastrophic failures that the electric power grid infrastructure could face due to severe geomagnetic storms and EMP threat scenarios. As defined by Perrow [Normal Accidents] in the context of geomagnetic storms and EMP, power grids are at High Risk for the infrastructure operators, their customers, innocent bystanders, and for future generations of the country. Clearly the long term outages to the power grid fits within Perrow's definitions as he applies it to "*enterprises [that] have catastrophic potential, the ability to take the lives of hundreds of people in one blow, or to shorten or cripple the lives of thousands or millions more*." The US National Infrastructure Plan defines "risk" as a function of threat, vulnerability and consequence {i.e. R=f(T,V,C)}. In the analysis provided of the electric power grid infrastructure the threat, vulnerability and consequences are exceedingly high, making Risk as a function of these three characteristics are also exceedingly high as well.

Various reports have discussed in detail the threat environments and have provided new understandings (that were not known to both the scientific community and to the power industry) of these severe threats. For example in the case of geomagnetic storms, it was previously understood that the March 13-14, 1989 storm was representative of the worst case scenario. It is now known that these estimates were wrong. Historically large storms that have impulsive disturbances 4 to 10 times larger than those that occurred over North America in the March 1989 storm have occurred before and given sufficient time are certain to occur again. EMP events have not occurred over mainland portions of North America and as a result are even more difficult to comprehend as a threat environment. In regards to vulnerability, the power grid infrastructure has been experiencing a "Design Creep" over many decades that has unknowingly escalated the risks and consequences of severe geomagnetic storms and EMP (i.e. an Unrecognized Systemic Risk from GIC and EMP). In regards to consequences, it needs to be understood that Critical infrastructures have been also undergoing “Dependency-Creep” which has created interdependencies that can self-reinforce failure modes if one infrastructure such as power grids experience collapse. Loss of electric power means that almost immediately or within short periods of time that other critical infrastructures will fail. These are important for providing essential services such as potable water, perishable foods and medications, transportation of people, foods, fuels and communication to just name a few. Therefore the Risk of a power grid collapse can impact many other economic and technical systems in modern society as these combined critical infrastructure and technology systems are an essential scaffolding of modern society. As a result, these High Impact, but Low Frequency of occurrence events (HILF) can have significant social impacts. But because they are low frequency of occurrence events, they do not occur often enough to allow society to fully understand their full consequences and to subsequently develop plans to mitigate or cope with the event.

To avoid such consequences to society, risk management of the critical power industry infrastructure becomes the pressing need. In the US, the power grid infrastructure is predominantly owned and operated in the private sector, though there are portions which have both federal and state ownership and management. However, even these publicly owned power grid infrastructures are typically set up to operate autonomously and in close coordination and cooperation with other power industry private enterprises. In regards to risk management, most private sector infrastructure operators do not have the management and budgetary systems that can readily focus on HILF threats. Power grids are 24 hour continuous operation entities and operate under mandates for constant and reliable service with economic performance being perceived as highly important for their success while being reliable against the familiar challenges to network operations. Many of the state regulators, that these entities are accountable to, also reinforce this focus. Therefore, the very infrequent and extreme HILF events are poorly understood in this economic sector. Further, sustaining preparedness and planning for HILF events is difficult as it distracts significantly from the 24 hour operation focus of the organization. In the private entities organizational focus, trade-offs in the budgetary process is always one of deciding whether to expend limited budget monies on improvements in “Efficiency” versus reducing “Vulnerability”. In this organizational budgetary trade off – “rare and uncommon events” are viewed as ripe for elimination of “unneeded” costs in the budget. Although the private entity “Bottom Line” is immediately improved, this outcome accumulates over multiple entities making all of society vulnerable to HILF's. Hence, risk from GMD events are not managed or controlled, but rather it is silently transferred to the public via this decision on the part of the corporate entity. It is via this process that the HILF event and more specifically the GMD threat have become a broad Social Problem. Therefore, the risk management solution needs to be addressed via institutional approaches that circumvent the budgetary processes of private entities that have limited grasp of the consequences of accumulated lack of action. Unfortunately NERC and associated industry self-assessment has failed as an institutional approach to address this adequately.

Complex modeling of power grids for threat environments and mitigation (such as those performed for the ORNL studies) are necessary to allow decision makers within society to understand what was previously conceived as "incomprehensible" and frames the issues in terms of the basic threat, vulnerability, and consequence concerns. This begins the process of allowing managers and organizations to learn how to understand and begin to deal with severe HILF events without having to directly experience them on their critical infrastructures and within society as a whole. The outcome of this analysis begins to help determine the elements necessary to arrive at solutions by fostering the support of political leadership, support from business, and knowledge in the public.

How to promote the solutions to HILF threats can perhaps be best illustrated by examining both "Encouraging" as well as "Discouraging Examples". One of the most relevant "Encouraging Examples" was the power industry preparedness that was exhibited in the preparation for the Y2K event. It was technically recognized that modern digital control systems would not degrade gracefully if they were not prepared for the Y2K rollover event. Strong federal leadership was exerted to force evaluation, testing and compliance throughout the power industry for this rare event. In essence the policy and regulatory frameworks to manage extreme events was the job of public authorities, a good example of success for anticipatory governance. Clearly one major advantage that was present in the preparation for this event is that the day of the event was well known and allowed maximum focus of the organizations involved. Unfortunately that is not entirely possible for GMD threats.

I am sure the argument will be made that self-policing by the industry could be equally effective, if allowed to occur. Unfortunately there are recent "Discouraging Examples" which undercut the premise of these arguments. The August 2003 Blackout in Midwestern and Northeastern US was the largest event on record and yet largely stemmed from inadequate tree trimming along several important transmission line corridors. Similar large scale western US blackouts occurred in 1996 due to an identical root-cause. While line right of way maintenance is recognized as important, the exact proscriptions for these tasks had never been formally instituted as a mandate and had been left to company discretion on when, where and how-much to expend in this effort. In all of these cases, society was fortunate in that wide-spread catastrophic damage to the system did not occur for these events and restoration of power was achieved within a few days or less in all locations. It is clear from the analysis of the GMD threat, that risks of widespread catastrophic damage to the infrastructure will be the most important concern. Therefore the risk to society is even more a matter of urgency for these threats than compared to the right of way maintenance issues which failed to protect society in these discouraging examples. Further as discussed in the forgoing, at every opportunity in prior years NERC had been briefed, vetted and was in a position to act, yet never did do so.

Industry self-policing can be particularly indicted in the case of geomagnetic storms, in that the vulnerability of the infrastructure to this threat has steadily grown over decades to the proportions where it can now be legitimately called an “Unrecognized Systemic Risk”. This is a Risk which has remained unchecked, as there has never been a design code by the power industry to take into consideration this threat. Therefore power grid infrastructure operators, power system operators and planners have simply not appreciated the extent to which risk has migrated through their technical systems from this specific threat. This suggests a framework for solutions that must be focused on mandatory requirements; such as codes of design and, where needed, remedial corrections of the infrastructure with appropriate “force of law” oversight. Again numerous examples already exist on how these practices have been routinely adopted in areas where the interests of society need to be protected, such as fire codes, codes of construction for private and public buildings (and associated occupancy permits for these facilities), environmental emission laws and standards, etc.

In further assessing ways to make the power grid infrastructure more resilient to the unique threats posed by severe geomagnetic storms, it is necessary to appropriately understand and weigh the solution options. The prior reports provide areas to guide in this screening as well. The broad conceptual approaches to making the infrastructure more resilient can be described as follows with a brief overview of the advantages and disadvantages of each for these specific threats.

- *Detect* – This is a process of identifying potential threats/attacks for purposes of validation and to communicate the information. Improved scientific understanding and improved situational awareness in particular for geomagnetic storms can be beneficial. Therefore a widespread and comprehensive effort must be considered for GIC and GMD storm impact monitoring. All storms of all sizes contribute valuable information which will advance understanding of this threat and needs to be done at all latitudes of the US as well.

- *Mitigate* – It is clear that this will be the most important and primary methodology that will be used to frame the recommendations. This approach is to lessen the impacts of an attack or natural disaster. While some mitigation approaches involve system redundancy, in the case of this threat all redundant systems are equally At-Risk, so hardening of the infrastructure by reducing threats to acceptable levels is the approach that will be further described.
- *Respond* – While difficult to perform, improved situational awareness and operating procedures should be explored in attempting to prevent damage or collapse during the rapidly evolving nature of both the natural and intentional causes of these threats. Sound recommendations need to be advanced that improve our monitoring of smaller incidents (lower intensity geomagnetic storms in particular) that can educate us about the consequences and risk vectors of larger scale threats. In the US, the National Transportation Safety Board reviews not only crashes but near-misses in order to prevent failures before they happen. What is particularly important is that these are not industry self-assessments which have been the norm for the electric power sector. Rather these are independent expert s specifically set up and selected for this event review. This is an institutional approach for the power industry that needs to be adopted and put forward by FERC.
- *Recover* – Because electric power is the “keystone” infrastructure that allows continued operation of all other infrastructures, it is necessary to ensure that efforts begin immediately. At minimum, a skeletal network that must be hardened sufficiently to allow vital public services, businesses, and government operations to continue, while hardening of all other portions of the infrastructure are also brought up to needed standards.

As these comments illustrate for both reasons of national interests and because of inadequacy of present processes, it is time to move beyond industry self-assessment, much as society mandates for other critical industries. One can point to the airline industry as a model for what is needed for the electric power industry. That industry provides a useful outline of an effective public policy framework that allows for a management of these complex risks.

Flying aircraft is very complex, designing aircraft is very complex. But certainly no less complex than operating a power grid, so lack of meaningful safety regulations within the power sector is inconsistent with what has already developed in sectors such as airlines. For example, airlines have a set of regulations that require certification of the aircraft. It requires defining the performance envelope of the aircraft, blackbox recorder (monitoring) devices and examination by independent expert teams. This equivalent is not present however for electric power grids or their key equipment certification for GMD threats, even though the consequences to the nation are far larger for a grid crash. Electric Power Industry self-certifications have not been effective in the important role of assuring the public interests and such self-certifications would not be allowed in operation of aircraft, neither should it be solely allowed for the critical lifeline services provided to the public for ensuring electric power supply.

In situations where various incident information about GMD event impacts and externalities are being withheld, these can lead to harmful effects on public health and safety. There have been similar issues of externalities that are well-known in environmental law and regulation. In these cases, mandatory ongoing monitoring and reporting to a regulatory entity becomes essential to minimize or at least manage risks to the public interest.

Professional organizations are ideally supposed to represent the public interest, but may be failing to do their proper functions in this case. As we have noted, there is clearly a potential for concerns over the shared financial interests of "professionals" which can lead to conflicts of interest. In a situation as discussed here, there is a clear case of essentially a single interest which dominates how standards are being developed and set, those in that specialty may tend to favor regulatory policies and practices that protect that industry at the expense of overall benefits to the larger society. Therefore in this situation, mandatory information sharing with the government is essential when "social costs" of private transactions are significant.

As a result, it may not be prudent to rely on professional organizations to set standards without parallel governmental oversight. Otherwise, the experts in an industry may devise rights and standards that produce outcomes that may not align with the public interest. Or at least to balance and protect against standard-setters who protect their self-interest.

Therefore these proposed FERC rules will take the needed first steps to ensure the core requirement that the public regulatory or licensing entities have authority to mandate public reporting of information essential to protect public health or public safety, or both. If there is a continuously updated body of knowledge that supports public regulatory decision-making, abuses within professional standard-setting organizations will be minimized, contained, or at least publicly identified.

What should be done to accelerate protection of public health and safety impacts of the electric utility industry? The first need is to require public reporting for all activities or events that have actual or potential for unacceptable harm to public health or public safety, or both. Data in these databases needs to be accessible, at a minimum under the Freedom of Information Act with constraints on exceptions for "proprietary data" or other "confidentiality" abuses. This allows independent third parties to test the validity or inadequacy of regulatory standards.

Ideally proposed standards coming back to FERC from NERC should meet various tests:
Several databases need to be mandatorily reported to a public regulatory organization to ensure a higher level of reliability for the bulk power system, because society has become and will in the future become even more dependent upon reliable electric service than in the past.

- accidents that risk loss of service or loss of service reliability to significant numbers of customers;
- equipment designs or operational practices that endanger public health or public safety;
- geomagnetically induced currents at sites of critical infrastructure equipment, and the duty to require installation of additional network monitoring and sampling equipment throughout a network upon which the public relies for essential services, to identify unsafe operating practices, to support cost-recovery mechanisms to protect public safety, etc.

There should also be a mandate towards the establishment of a nationwide network to monitor and to support independent safety and reliability assessments for all FERC-jurisdictional utilities. This should then support rapid progress in these important areas:

- to model the management of geomagnetic disturbances to the bulk power system cost-effectively and prudentially.
- to accelerate investments in grid-protective equipment and practices;

- to protect the public interest using an "all hazards" approach to protect against geomagnetic disturbance hazards.

If there were mandatory reporting, and mandatory "black box" installations, and mandatory public access to these databases, controlled by FERC and not controlled by NERC or EPRI or any other conflicted organization, these other organizations would reform their practices that have exacerbated risks to public health and safety. EPRI and IEEE, etc. would have to work in the sunshine of public data access and independent expert knowledge. The antiseptic benefits of openness and transparency need no defense. Integrity within professional standard setting bodies call for openness, transparency, and a balance of interests. These standards are not self-implementing, but need to have active assurances. Control over pertinent information affecting public health and safety can undermine compliance with even the best-written professional organization charters.

If FERC mandated a database managed by FERC, not by NERC, many of the concerns that have been documented would be in a far better posture for allowing self-correction at an accelerated pace. The cure is better information and better public access to that information through public regulatory entities such as FERC and the NRC (Nuclear Regulatory Commission).

These regulations if properly composed along this model would have enormous and important public interest protections. The public should also know that these proposed regulations are also consistent with regulations for public safety that exist in many other sectors, airline safety, general transportation safety, railroad and even pipeline safety which have been developed over the years, yet which have not been allowed to develop in the electric industry until the Energy Policy Act of 2005. These proposed FERC Regulations would be a vital step in bringing into existence a safer and more secure grid for this important threat.

In September of this year, we observed the 50 Year Anniversary of the publication of Rachel Carson's book "Silent Spring", a pivotal book in America's history that ultimately brought forward important environmental regulations. The book was the product of four years' worth of labor, Carson's Silent Spring carefully and coherently detailed the threats pesticides pose to public health and the environment. More importantly, she translated the work of scientists and made the impacts of pesticides personal. The prospect of chemicals like DDT leading us to a spring without songbirds was a chilling warning of the dangers we faced. In retrospect, even the industries that voiced significant opposition at that time have now come to embrace the underlying ethics of this movement. These industries have also done so while bringing forward advances in chemical and agricultural productivity and innovations that continue to propel society forward. Viewed in the prism of history, virtually no one disagrees with the importance of a change that was necessary for society.

We are at a similar and potentially even more important turning point in the history of the development of the electric power grid. None of these dangers that we now face have happened due to malice on anyone's part, rather it was unknowingly spawned due to the complexity in visualizing the face of the threat. I would like to emphasize that in comparison, the importance of electric energy is even more critical to the viability and support of modern society. It is a critical lifeline for the nation's population. Fifty years after Silent Spring, a very similar set of arguments and tactics has transpired in this important discussion as well. We have a similar cloud of misinformation, inattention and even attempts on the part of some to stop any action, claim that the problem is overblown, uncritically accept industry assurances that no problem exists, or that the problem does not apply to them and even take steps to conceal any information that exists on the full nature of the threat. We must not fail to heed the warnings of history in this endeavor as well. Indeed, if we fail to take the needed action and thereby allow some of these worst case scenarios to unfold, we could threaten our nation's existence and we would rightfully deserve history's condemnation. I would rather think that my colleagues in the electric power industry will respond like the nation did post-Silent Spring and ultimately embrace new and important regulations and then act to fully meet these challenges and make the country stronger for it. We owe that to the American people, we owe that to our future.

I thank the Federal Energy Regulatory Commission for the opportunity to present my views and for the work of the Commission and its Staff in developing requirements for reliability standards in this and other Dockets.

Respectfully submitted,

John G. Kappenman
STORM ANALYSIS CONSULTANTS
301 West 1st Street
Duluth, MN 55802

National Communications System, Committee of Principals, Communications Dependency on Electric Power Working Group
Long Term Outage Workshop

Agenda

Tuesday, April 8, 2008

7:30 - 8:30	**Registration, Coffee and Danish**
8:30 - 9:00	**Welcome and Orientation** Mr. Dan Hurley, National Telecommunications and Information Administration (NTIA) and Communications Dependency on Electric Power Working Group (CDEP WG) Chair
9:00 - 9:20	**Keynote Address** **The President's National Security Telecommunications Advisory Committee's *Report to the President on Telecommunications and Electric Power Interdependencies* - Findings and Recommendations** Dr. Jack Edwards, Nortel
9:20 - 10:00	**Overview of Workshop Objectives** Mr. Hurley and Topic Discussion Leaders
10:00 - 10:30	**Coffee Break**
10:30 - 11:00	**Topic A: Understanding an LTO** Ms. Susan Moore, United States Department of Agriculture and Mr. Paul Marrangoni, Federal Communications Commission
11:00 - 11:30	**Topic B: Electric Industry Engagement in LTO Prevention and Recovery** Mr. Stan Johnson, North American Electric Reliability Corporation (NERC)
11:30 - 12:00	**Topic C: Alternative Power Supply Technology** Mr. Jeffrey Mazer, Department of Energy
12:00 - 1:00	**Lunch**
1:00 - 4:00	**Topic Area Break-Out Sessions for Topics A, B, and C**

4:00 - 4:15	**Coffee Break**
4:15 - 4:35	**Topic A Briefing to Workshop Participants** Ms. Moore, Mr. Marrangoni
4:35 - 4:55	**Topic B Briefing to Workshop Participants** Mr. Johnson
4:55 - 5:15	**Topic C Briefing to Workshop Participants** Mr. Mazer

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Wednesday, April 9, 2008

7:30 - 8:20	**Coffee and Danish**
8:20 - 8:40	**Review of Workshop Progress and Day Two Objectives** Mr. Hurley
8:40 - 9:00	**Keynote Address** **LTOs and the Electric Power Industry - Scene Setter** John Kappenman - Metatech
9:00 - 9:30	**Topic D: Situational Awareness, Information Sharing, and Cooperation** Mr. Johnson, NERC
9:30 - 10:00	**Topic E: Potential Injection of LTOs into National Exercises** Mr. Chris Algiere, NTIA
10:00 - 10:30	**Coffee Break**
10:30 - 12:00	**Topic Area Break-Out Sessions for Topics D and E**
12:00 - 1:00	**Lunch**
1:00 - 2:30	**Topic Area Break-Out Sessions for Topics D and E, continued**
2:30 - 3:00	**Coffee Break**
3:00 - 3:20	**Topic D Briefing to Workshop Participants** Mr. Johnson
3:20 - 3:40	**Topic E Briefing to Workshop Participants** Mr. Algiere
3:40 - 4:00	**Concluding Remarks and Adjournment** Mr. Hurley

minnesota power / 30 west superior street / duluth, minnesota 55802 / telephone 218-722-2641

December 19, 1996

Ben Damsky
EPRI
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA. 94303

Re: Final Report Draft - RP3211-02

Dear Ben:

Please find enclosed a draft of the final report for RP3211-02, both an electronic set of files as well as a paper copy are included with this submittal letter. As we had previously discussed, we would like to receive the accumulated retainage for this project at this point within our 1996 budget year. An invoice will be separately sent for that purpose as a follow-up to this submittal. We have not yet received the instruction package on report format that you were to send and once we have received that will begin revisions as appropriate to this final report draft. As you might expect we will attempt to complete as soon as possible in 1997. Thanks again for your assistance and we await any further recommendations you may have regarding the report.

Sincerely

John G. Kappenman

John G. Kappenman

10.13.8 Insulation Life – B. Forsyth Report: Yes, Four new topics – moisture TF, high temperature insulation, wdg temp indictors, heat run Hot Topic: Yes

10.13.9 Performance Characteristics – E. teNyenhuis Report: No Hot Topic: No

10.13.10 Power Transformers – T. Lundquist Report: Yes, New WG's – C57.93 and C57.135 PST. Hot Topic: No

10.13.11 Underground Transformers & Network Protector – C. Niemann Report: No Hot Topic: No

10.14 Old Business

None

10. 15 Minutes of Special Task Force on GIC (Geomagnetic Induced Currents)

This was an impromptu meeting, not on the Agenda but was put together at the last minute.

Planning meeting on Effect of GIC on Power Transformers and Power Systems
Bluegrass Conference Room, Nashville Renaissance Hotel

March 13, 2012 9:30 AM - 10:30 AM

Attendees

Bill Chiu, SCE
Brian R Penny, American Transmission Company
Donald Chu, ConED
Donald W Platts, PPL
Emanuel Bernabeu, Dominion
Gary R Hoffman, Advanced Diagnostic
J. Edward Smith, H-J Enterprise
James McIver, Siemens
Kiran Vedante, ABB
Loren Wagenaar, WagenTrans Consulting
Mohamed Diaby, EFACEC
Ramsis S Girgis, ABB
Stephen Antosz, Antosz & Associates
Thomas G Lundquist, PTC
William H. Bartley, Hartford Steam Boiler

Minutes of Meeting

The meeting was called and chaired by Ramsis Girgis. After welcoming the attendees, The chair gave a brief context of the purpose of the meeting; namely:

1. Writing a position paper, on behalf of the IEEE Transformer Committee, in response to the IEEE Spectrum article written by John Kappenman; "A Perfect Storm of Planetary Proportions" that appeared in the February 2012 issue.
2. Forming a TF to produce a proposal for an IEEE GIC Guide and identifying the purpose, applications, and scope of this Guide

The Chair then requested, around the table, introductions. Each attendee stated his affiliation and gave a brief statement of his perspective on the issue of GMD and the IEEE Spectrum article.

Paper response to the IEEE Spectrum Article

The Spectrum article had mainly three claims that are not accurate:

1. GIC would fail a very large number of Power Transformers due to damaging overheating
2. Power Utilities have not done much since the 1989 GMD storm to be prepared for the next storm
3. A GIC Blocking device is the only solution to avoid the harmful impact of GIC

All in the room were in agreement that the IEEE Spectrum article went too far and exaggerated the impacts of GMD on power transformers and the power grid. Moreover, The GIC issue is more a Power systems issue rather than a transformer overheating failure issue as the Spectrum article claims. Also, the article stated that utilities were not taking any steps to mitigate effects of GIC on power systems; which is not true. Almost every major utility in North America have taken steps in this direction.

A question was raised in whether any of the attendees was requested to review and provide comments prior to the article being published. Emanuel stated that a representative of Dominion was requested to review the draft article, but was not given sufficient time. The reviewer gave feedback that the article should not be published and that a lot more work needed to be done before such an article would be published, but the feedback was ignored.

The Chair also indicated that the NERC TF on GMD just recently published its report. One of the recommendations of this TF is for the Transformers Committee to develop an industry standard / Guide on GMD and transformers. It was agreed to do that. However, the standard development effort will take much longer to accomplish and that the industry, in the meantime, will need something much faster.

There was also a suggestion that the Transformers Committee considers issuing a "press release" to IEEE and the greater technical community that the Transformers Committee is reviewing the IEEE Spectrum article and plan to present a more balanced view point on this issue. After some discussion, the group decided that the best thing to do is to develop a, say; 4 – IEEE type (2 – column) pages, position paper on GMD and power transformers. The intent of the paper is to provide a balanced view point from the perspective of experts of the transformer subject matter.

It was also agreed that the Transformer Committee Chair will contact IEEE Spectrum to determine the appropriate forum for this position paper. It was also agreed that the proposed position paper should be written for a general audience of the greater public.

A preliminary outline of the paper was developed at the meeting, together with assigned volunteers for the respective sections; as follows:

- Effects on Power Transformers – ***Ramsis***
- Effects on the Power System – ***Emmanuel***
- What transformer manufacturers did and are doing regarding the GMD phenomenon and its effects on Transformers – ***Mohamed and Jim***
- GIC Blocking devices and what some of the issues are – ***Emanuel***
- What Utilities did after the 1989 event.– ***Bill Bartley***
- What Utilities are doing now – ***Bill Chiu***
- What government & regulatory agency are doing – ***Frank Koza***

The Chair will contact the contributors to the paper for more details.

The following action Items were agreed upon:

1. The assigned members are to complete the drafts of their sections of the proposed paper by the end of April.
2. Bill Chiu to reach out to IEEE/PES Tech Council to see if there are other technical committee interested in such an activity, and if no other interests could TC act on its own.
3. Bill Chiu to reach out to IEEE Spectrum to determine the best course of action for publishing an editorial review.
4. The team to continue meeting to complete the position paper and also work on developing a proposal for a Standard / Guide for transformers as relates to GMD.

It was also suggested that the Transformers Committee should reach out to the Power System Relaying Committee to coordinate possible actions by that committee. The Transformers Committee Chair stated that it would be appropriate to reach out to the IEEE/PES Tech Council to determine the level of interest by other parties.

Subsequent to this meeting, Bill Chiu contacted IEEE/PES Tech Council, and with the assistance of Al Rotz, connected with the Editorial staff of the Spectrum that the recommended course of action is as follows:

1. Immediately prepare a one page description of the article IEEE TC would like to publish; including the content, the criticality of timing on the subject, the expertise of the authors, and the need to present readers with a balanced view on the subject.
2. Solicit from PES Technical Council (with the representative leadership of the technical committees) in support of the need for this follow–up article would be desirable. The current PES Tech Council Chair or PES President will consider to provide that in concert with our submission.

3. The editorial staff will review and provide a decision on a go/no go, as well as timing for the article.
4. The Transformer Committee would prepare and forward the final article for review.

Proposed GIC Standard / Guide

The group discussed the possible scope of the proposed GIC Guide. The chair stated the following items as some of the items needed to be developed / agreed upon in such a document:

1. Maximum winding and structural parts hot spot temperatures recommended for high – peak short – duration GIC pulses and base long duration GIC.
2. Standard signature of GIC base and high peak short duration pulses to be used for winding and structural parts temperature calculation when the transformer is subjected to GIC
3. Process of evaluating the risk of power transformers to GIC

It was suggested that:

- A Guide would be a more suitable type of document for such information
- This Guide should include sufficient background of the GMD phenomenon, the GIC issues involved; including its effects on power systems. It may also include effect of GIC on CT (s) and PT (s).
- C57.12.00 would refer to the GIC phenomenon as an unusual operating condition for the transformer.
- The TF to develop this Guide may belong to the Power Transformer SC. However, it was agreed that a scope of this Guide will need to be developed first then a decision can be made as to which SC the TF will belong to.

Written by:

Bill Chiu and Ramsis Girgis

Email from IEEE PES Technical Council Chair and Members

Date: Thu, 12 Apr 2012 07:14:36 -0700
From: wrcassel@YAHOO.COM
Subject: Re: IEEE Public Visibility Initiative: GMD
To: DNovosel@QUANTA-TECHNOLOGY.COM; PES-tech@IEEE.ORG
CC: mani.venkata@ALSTOM.COM; alrotz48@PTD.NET; noels@K-STATE.EDU; miroslav@ECE.GATECH.EDU; p.ryan@IEEE.ORG; thomas.prevost@omicronusa.com; jhnelson@tva.gov; kozaf@pjm.com; chenh@pjm.com

Bill Chiu,
Power System Operations Committee will be happy to support this effort. Frank Koza (kozaf@pjm.com) and Hong Chen (chenh@pjm.com), both from PJM, will represent PSOC.
Bill Cassel

From: "Novosel, Damir" <DNovosel@QUANTA-TECHNOLOGY.COM>
To: PES TC List <PES-tech@IEEE.ORG>
Cc: "mani.venkata@alstom.com" <mani.venkata@ALSTOM.COM>; Alan Rotz <alrotz48@PTD.NET>; Noel Schulz <noels@K-STATE.EDU>; Miroslav M Begovic <miroslav@ECE.GATECH.EDU>; Pat Ryan <p.ryan@IEEE.ORG>; 'Tom Prevost' <thomas.prevost@omicronusa.com>; Jeffrey H Nelson <jhnelson@tva.gov>
Sent: Saturday, March 24, 2012 2:04 PM
Subject: FW: IEEE Public Visibility Initiative: GMD

Dear Technical Committee chairs,

The IEEE PES leadership has a common opinion that the recent Spectrum article on Geo-Magnetic Disturbances (GMD) is an example of the sensationalistic journalism of the Spectrum magazine as review and comments by experts were ignored (as commented by the chair of Transformers Committee, Bill Chiu).

The PES approach is to publish a more balanced article in Spectrum and, potentially, another more technical article in the Power and Energy magazine. Each paper would be tailored to the diverse audience of Spectrum and P&E. Al Rotz has taken the initiative to support Bill with the Spectrum magazine.

As you could see from Bill's e-mail, the Transformer committee has taken major initiatives in this area, including a position paper on GMD.

As our goal is to It is good to have a comprehensive response focusing on all aspects of GMD to best counteract the Spectrum paper, we would like to involve interested committees to participate.
As the time is of essence, we need to make the process simple. If interested, we suggest that you please nominate your representative to work with Bill Chiu on contributing or providing comments to the Transformers Committee paper. For example, as PSRC has done work in the past on this topic, a PSRC representative could incorporate the work done with some updates as needed.

Please send name of your representative to Bill that is leading this effort.

Thank you and let us know if you have any additional comments or suggestions,

Damir Novosel
IEEE PES, Technical Council Chair

From: Bill.Chiu@sce.com [mailto:Bill.Chiu@sce.com]
Sent: Wednesday, March 21, 2012 2:02 PM
To: Novosel, Damir
Cc: 'alrotz'; Alan Rotz; 'Bill Chiu'; 'Noel Schulz'; 'P Ryan'; 'Thomas A. Prevost'
Subject: RE: IEEE Public Visibility Initiative: GMD

Damir,

Here are few things the Transformers Committee are doing or have done on the subject of Geo-Magnetic Disturbance.

1. Position Paper - Our thought is that since the original article that created these negative attention was from the Spectrum magazine, we go back to the Spectrum magazine to present our point of view, so the paper will not have a lot of the bells and whistles as far as technical content, but rather geared for a "Scientific America" type of readership. Ramsis Girgis has been assigned the role of the Taskforce Chair to compile this paper. I am also one of the contributing members.

2. Industry guide - There are interests among our membership to consider developing a industry guide on the design considerations of large power transformers to make them more robust against GIC. Obviously the standards development part will take longer, so the position paper will serve as a stop gap measure. The development of the industry guide is also consistent with the recommendation by the NERC Taskforce on GMD.

3. Tutorials - The Transformers Committee had a fantastic tutorial last week on this subject with a pretty comprehensive coverage that provided technical insights that ranged from the causes of the GMD/GIC, its impact on power transformers and the power grid, the analytical/modeling approach to assess the GIC impacts, the types of measurement system and alerts are in place, and what can utilities do to get ready for GMD/GIC. Because of the breadth and depth of the coverage we had, we devoted two of our tutorial sessions (2.5 hours total) to this topic. It was a great success with lots of very positive feedback from the attendees.

3. Industry Papers - One of the upcoming papers sponsored by Transformers Committee at the T&D Conf & Expo is also focused specifically on the GIC and its effects to power transformers. In the same session, there is also another paper that will cover design considerations for neutral grounding devices for the purpose of blocking DC current.

On a slightly different topic - there was a suggestion earlier this year from Nicholas Abi-Samra, the San Diego GM TPC, to have a panel session on this topic. If the planning committee decide to move forward with this, we can definitely roundup an expert or two to participate on the panel.

What I'm specifically looking for are:
a. Whether there is interest at the PES level (through the Technical Council, as suggested by Noel recently) to gather additional support for the position paper in development by the Transformers Committee. I agree with Al's good counsel that time is of the essence and the more people we get involved, the longer it will take to get this done. PSRC already has a transaction paper published back in 1996 that addressed some of the protective relaying considerations in dealing the GIC. Perhaps a quick way to include their contribution is just to incorporate the work they have done with some updates as needed. I will also reach out to Bob Pettigrew for his thoughts.

b. Is there any policy restriction that prohibits Transformers Committee, as an entity, from reaching out to Spectrum magazine to present our points of view as collective body of industry experts? Hopefully not, but if so, could we do so at the PES Tech Council level or from the PES level?

At the moment, we do not have plans to publish an in-depth technical paper for IEEE Power & Energy Magazine, but that is not out of the realm of possibility - it all depends on the availability of our core group of experts and the priority of their commitments.

It would be great if you could provide some guidance on a & b above. In the meanwhile, we're moving ahead with our position paper and will make the final draft available for review/comments by interested parties from the Tech Council. Let me know if you see a problem with the path we're taking.

Thank you for reading this long winded note and for your interest in this topic.

Best Regards,
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Bill Chiu, Chair
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