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BEFORE THE

FEDERAL ENERGY REGULATORY COMMISSION

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In the matter of : DOCKET NO: RM15-11-000

RELIABILITY STANDARD FOR :

TRANSMISSION SYSTEM PLANNED :

PERFORMANCE FOR GEOMAGNETIC :

DISTURBANCE EVENTS :

- - - - - -X

Commission Meeting Room
Federal Energy Regulatory Commission
888 First Street, Northeast
Washington, D.C. 20426
Tuesday, March 1st, 2016

The technical conference in the above-entitled
matter was convened at 9:00 a.m., pursuant to Commission
notice, before:

CHAIRMAN NORMAN BAY
COMMISSIONER CHERYL LaFLEUR
COMMISSIONER COLETTE HONORABLE

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1 PRESENTERS:

2

3 PANEL 1:

4 MARK LAUBY, Senior Vice President of Chief
5 Reliability Officer, North American Electric Reliability
6 Corporation

7 ANTTI PULKKINEN, Standard Drafting Team, NASA
8 Research Astrophysicist

9 DR. SCOTT BACKHAUS, Los Alamos National
10 Laboratory

11 DR. JEFFREY LOVE, Research Geophysicist, U.S.
12 Geological Survey

13 PROFESSOR ADAM SCHULTZ, Professor, Oregon State
14 University

15 DAVID ROODMAN, Senior Advisor at the Open
16 Philanthropy Project

17 DAVID BOTELEER, Head, Space Weather Group,
18 Natural Resources Canada

19 JOHN KAPPENMAN, Principal Consultant, Storm
20 Analysis Consultants

21

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1 PRESENTERS:

2

3 PANEL 2:

4 MARK LAUBY, Senior Vice President and Chief
5 Reliability Officer, North American Electric Reliability
6 Corporation

7 DR. LUIS MARTI, Standard Drafting Team, Director
8 of Reliability Standards and Compliance at Hydro One
9 Networks

10 MICHAEL STECKELBERG, Senior Transmission
11 Planning Engineer, Great River Energy

12 RANDY HORTON, Standard Drafting Team, Planning
13 Manager, Southern Company Services, Inc.

14 PROFESSOR THOMAS OVERBYE, Fox Family Professor,
15 University of Illinois

16 PROFESSOR TREVOR GAUNT, University of Cape Town,
17 Cape Town, South Africa

18 TERRY VOLKMANN, President, Volkmann Consulting,
19 Inc.

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1 PRESENTERS:

2

3 PANEL 3:

4 MARK LAUBY, Senior Vice President and Chief
5 Reliability Officer, North American Electric Reliability
6 Corporation

7 DAVID BOTELEER, Head, Space Weather Group,
8 Natural Resources Canada

9 DR. JEFFREY LOVE, Research Geophysicist, U.S
10 Geological Survey

11 PROFESSOR TREVOR GAUNT, University of Cape Town,
12 Cape Town, Couth Africa

13 DR. LUIS MARTI, Standard Drafting Team, Director
14 of Reliability Standards and Compliance at Hydro One
15 Networks

16 FRANK KOZA, Standard Drafting Team Chair,
17 Executive Director, PJM Interconnection, L.L.C.

18 JERRY SCHUMAN, PingThings, Inc.

19 THOMAS POPIK, Chairman, Foundation for Resilient
20 Societies

21

22

23

24

25 Court Reporter: Alexandria Kaan, Ace-Federal Reporters

1 P R O C E E D I N G S

2 (9:02 a.m.)

3 MR. BARDEE: Good morning everyone. Welcome to
4 our technical conference today. I'm Mike Bardee, I'm
5 director of the Office of Electric Reliability and I'll be
6 monitoring the conference today. I'd like to thank all of
7 you for coming today, especially some of you who have come
8 from very long distances. Let me start by saying
9 Commission Order No. 779 in 2013 directing NERC to address
10 the impact of geomagnetic disturbances on the bulk power
11 system in two stages. The first stage resulted in
12 development by NERC and approval by FERC of the new
13 reliability standard requiring entities to develop,
14 maintain, and implement an operating plan to coordinate GMD
15 operating procedures. The second stage was to include a
16 benchmark GMD event, a process for vulnerability
17 assessments, and for corrective action plans. NERC has
18 filed that second stage in May of last year; the Commission
19 issued a proposal to approve that and to direct
20 modifications to the standard and other actions. One of
21 the most significant proposed modifications was a revision
22 to the definition of the benchmark GMD event so that the
23 definition is not based solely on spatially-average data.
24 We have received comments on the proposal and today's
25 conference is intended to supplement the record so that the

1 Commission can make a final decision on this matter.

2 With that as the background, let me go over just
3 a little bit of housekeeping for today. After the opening
4 remarks are concluded, we'll turn to the first panel, which
5 will end around 11:45; we'll take a lunch break for about
6 an hour and return at 12:45; and this afternoon we'll hear
7 from the second and third panels with a 15-minute break in
8 between. Each panelist will have about five minutes for an
9 opening statement, and then we'll have questions and
10 discussion. We've set up a clock here to help the
11 panelists keep track of their time, and we'll also provide
12 reminders if it will help.

13 Finally, I want to make one other point. The
14 development of this standard has been an unusually
15 controversial and even confrontational process compared to
16 your usual FERC our NERC process. At times the comments
17 filed in recent months with the Commission have veered into
18 allegations about bad faith or similar conduct. I just
19 wanted to remind everyone that, while there is uncertainty
20 about many issues in this area, we assume that all of the
21 participants are presenting their views in good faith and
22 that the disagreements here are professional, not personal
23 or ad hominem. We expect the conversation to stay at that
24 level and we expect all of the participants to do the same.

25 With that, let me turn to the Chairman and

1 Commissioners and see if they have any opening remarks's.

2 CHAIRMAN BAY: Good morning everybody. First, I
3 want to thank staff for putting together this technical
4 conference. I also want to thank our panelists for coming
5 here today to share their views with us. This is a
6 particularly interesting issue. I very much appreciate the
7 leadership of my colleague, Cheryl LaFleur, on this issue.
8 And what we'll really trying to do today is to get our arms
9 around the risks posed by I think we would consider to be a
10 classic black swan event, that is a low-frequency,
11 high-impact event, And what the appropriate regulatory
12 response ought to be. So I very much look forward to
13 hearing your comments today as we consider this I think
14 very important issue. So thank you.

15 COMMISSIONER LaFLEUR: Thank you, Norman. I'd
16 also like to thank all of our panelists for coming in and
17 for their hard work on the subject, and staff for getting
18 ready of the tech conference. We had to spread out at the
19 table because our sets of background materials are so
20 voluminous in this case, which I think is a testament to
21 the importance of the issue.

22 This is an issue that is very important to me
23 personally; I've been closely following it for the past
24 five years. And I think we're at a critical point as we
25 try to sort through what the shape of the second standard,

1 the mitigation standard which will presumably we know a lot
2 is going on, but in itself will lead to a lot of action to
3 make sure we do the best job we possibly can. I'm going to
4 be here for as much of the day that I can, and I'm
5 particularly interested in the discussion of the benchmark
6 event, because if we're going to key so much off from this
7 standard we want to make sure we're protecting to the best
8 of our ability for the right thing. I'm also extremely
9 interested in GIC monitoring. I didn't realize until I
10 read the prep material how much monitoring there was in
11 place around the United States, and I'm quite interested in
12 how we can get the benefits of that either in the standard
13 or in the educational loop as we go forward and learn from
14 this. As always, the more concrete and specific your
15 suggestions are for what we should do, the better at these
16 things.

17 Finally, I want to underscore Mike's point, or
18 his final point was going to make, emotions have run very
19 high around this subject. Anyone with a TV knows that
20 civil discourse is sometimes a lost art in our society, but
21 around this table we still hugely do it. So thank you very
22 much.

23 COMMISSIONER HONORABLE: Good morning everyone.
24 And thank you staff for your very hard work in particularly
25 pulling together all of this information which has been

1 very helpful. I want to especially thank you, the
2 stakeholders, for your commitment to this issue and also
3 your willingness to aid us and educate us on this very
4 important topic. And also want to thank those of you who
5 took the time to come in and visit with us about your
6 particular concerns in an effort to educate us. Today's
7 technical conference represents a significant effort to
8 better understand the potential effects of geomagnetic
9 disturbance events on our transmission systems, as well as
10 next steps for protecting against these events. I, too, am
11 particularly interested in learning more about how the
12 benchmark GMD event thresholds were developed, whether
13 those need to be refined at any point; the potential
14 effects of any proposed changes and methodologies on
15 induced electric currents. I also look forward to better
16 understanding the true risk that these events pose to the
17 reliability of our bulk power system. And I, too, for a
18 number of years, even before joining the Commission, have
19 been very focused on resiliency efforts and have gotten to
20 become acquainted with a number of you who have been
21 operating in this space as well.

22 Lastly and as somewhat say most importantly, I
23 look forward to receiving your feedback. Thank you to all
24 of those you who took the time to file comments, and also I
25 look forward to the engagement today. I, too, will be in

1 and out as I have appointments and such, but I look forward
2 to popping in from time to time to hear your remarks and
3 comments. Clearly, we all understand what's at stake, and
4 I think that's demonstrated by your presence here today,
5 and I look forward to our collective working. Thank you.

6 MR. BARDEE: Thank you all.

7 So let's go ahead and get our first panel
8 started. We'll start with Mark Lauby from the North
9 American Electric Reliability Corporation.

10 MR. LAUBY: Chairman Bay, Commissioners, FERC
11 staff, and fellow panelists, my name is Mark Lauby and I'm
12 the senior vice president and chief reliability officer of
13 the North American Electric Reliability Corporation. I'm
14 delighted to be here and sincerely appreciate the
15 opportunity to participate in today's technical conference
16 on the proposed GMD standard.

17 The proposed standard is an important addition
18 to the body of reliability standard for North American
19 power grid. The standard's rigorous approach elevates
20 resilience across the North American bulk power system to
21 the potential serious consequence of GMD events, and sure
22 as mitigation is planned and coordinated effectively.
23 Through NERC's cross-disciplinary collaborative efforts,
24 much has been accomplished in just a few short years to
25 address this vital reliability concern. In developing

1 standard, NERC energized the substantial scientific,
2 engineering, and operational expertise following the
3 standards. NERC has also initiated the work of GMD task
4 force, which has been advancing the industry's
5 understanding of the GMD risk since its formation in 2011,
6 and which has developed the state-of-the-art guidelines,
7 modeling approaches, and technical research to underpin the
8 proposed standard.

9 In keeping with the Commission's directive in
10 order 779 NERC has proposed a technically-justified
11 benchmark GMD event to serve as the basis for the GMD
12 vulnerability assessments required by the proposed
13 standard. The benchmark GMD event represents the most
14 severe GMD conditions that the bulk power system has
15 effectively encountered in 100-year period. By adopting
16 the 100-year storm scenario, the Commission will ensure
17 reliable operations during events similar to the 1989
18 storm, while at the same time reasonably protecting the
19 grid from substantially stronger GMD events. NERC's
20 estimate of the magnitude of the 100-year GMD event is
21 based on a widely-used scientific data, rigorous
22 statistical methods, an understanding of the physical
23 processes involved in the production of geomagnetic-induced
24 currents in the power system. Over time, researchers have
25 developed advanced techniques to avoid local spatial bias

1 by averaging field strength data over areas to improve the
2 accuracy of geomagnetically-induced current modeling. This
3 is a key difference in the 100-year benchmark geomagnetic
4 even definition and as compared to estimates that have been
5 used in the past. As a common wide reliability standard,
6 the benchmark event incorporates what is known as different
7 as effects of geomagnetic disturbance events and how they
8 might have different effects throughout North America.

9 First, the proposed standard includes
10 latitudinal scaling factors based on documented research
11 and public geomagnetic data, the strong event since 1980,
12 including the 1989 Quebec event. The factors enables
13 entities to tailor the benchmark event to a geomagnetic
14 latitude over their systems. These factors model the
15 changes in field strength that occur geographically from
16 the northern latitudes towards the equator and it's much
17 more advanced than previous analysis.

18 Second, to account for the variations in deep
19 earth conductivity, the proposed standards and scaling
20 factors based on the document studies of geological
21 structure for each of the claimed geographical regions
22 spanning the North American electric grid. Although the
23 geology of North America is extremely complex and resulting
24 deep earth conductivity may have local variations, accurate
25 geomagnetic-induced current model can be obtained by

1 assuming the uniform geoelectric fields to the earth's
2 models that approximate the effective deep-earth
3 conductivity over the geographic area of interest.

4 The proposed standard provides flexibility for
5 entities to use areas specific to earth conductivity models
6 in place of the provided default scaling factors where they
7 exist. Nevertheless, NERC agrees with the Commission more
8 research is needed. For example, research efforts are
9 underway to incorporate granular models that will allow 3-D
10 surveys that may provide more precise geomagnetic-induced
11 current calculations, particularly in areas where they're
12 difficult to represent with uniform earth conductivity
13 models such as coastal regions. The proposed standard is
14 based on the most advanced currently evidence currently
15 available and supported by rigorous analysis by leading
16 experts in academia, organizations, and industry.
17 Therefore, NERC urges the Commission to approve the
18 proposed standard. NERC remains committed to working with
19 the Commission and industry to continue our research and
20 gather new data to inform our standards as needed. Thank
21 you, and I look forward to addressing any questions.

22 MR. BARDEE: Thank you, Mark.

23 Next we have Antti Pulkkinen from NASA.

24 MR. PULKKINEN: Good morning. My name is Antti
25 Pulkkinen. I'm a research scientist at NASA at the space

1 center. I've been working for quite some while on the GMD
2 problem. And I represent the science side, or the
3 science-consultation side team. And as assignments, I'm
4 use to talking through slides; I don't think you have that
5 here, but I think you have the five aerial in front of you
6 there, so I'll be talking through my slides here.

7 I have four key points I'll be hitting home
8 pertaining to the statistical approach that we've used. A
9 couple words about the source spatial scales, geomagnetic
10 scaling, and then I'll also say a couple words about the --
11 that I'm sure the goes forward we're going to be having
12 much more detailed discussions about that as well.

13 MR. BOTELEER: Excuse me, can I interject? Are
14 there going to be slides available?

15 MR. BARDEE: We have projectors. And I'm hoping
16 we can arrange for slides, but I'm not sure of the status
17 of that.

18 MR. AYOUB: And to follow up, they're all posted
19 on the website.

20 MR. BOTELEER: I thought we would be talking to
21 the slides. I'd get those to have the images, otherwise
22 I'm doing lots of diagrams in the area trying to explain
23 what I'm talking about.

24 MR. BARDEE: We'll see if we can get that to
25 work right now.

1 But if you could go ahead, Antti.

2 MR. PULKKINEN: I'm just talk through the
3 slides, I'll wave my hands. If I do this, it's a graph.

4 (Laughter)

5 So in the first point I want to make pertains to
6 the statistical approach we have here. We used a dual
7 approach where we used visual exploration of a graph for
8 specific peak geoelectric fields that we have computing
9 from the observations of geomagnetic variations. And
10 jointly with that we also carried out rigorous extreme
11 value analysis for the same data. And it turned out that
12 the two quite-different approaches actually aggregate quite
13 well. And I also want to be very specific that in our
14 extreme value analysis we accounted for the correlations
15 within the data, so we actually carried out analysis of
16 data maxima and we also carried out a clustering or
17 correlation of that data maxima data to ensure that that
18 sample, when it goes to the extreme value analysis, that
19 status is statistically independent. And in addition to
20 that, we also accounted for solar cycle modulation. So in
21 that sense really the statistical approach that we used to
22 represent the state-of-the-art, robust-possible approach
23 that you can have and robust visual analysis of the
24 statistics.

25 The second point pertains to the spatial scales.

1 Over the past several years when we started looking at
2 these extreme geomagnetic field enhancements during extreme
3 geomagnetic storms, we discovered that many of these
4 extreme enhancements are not only temporally but also
5 spatially localized, meaning that the peak geoelectric
6 field, computed geoelectric field, between two close-by
7 stations can be off by order of 5 to 10. Which means that
8 you cannot take single-station extreme geoelectric field
9 values and directly apply over regional values led alone
10 continental scales.

11 Can we go to the third slide? Thank you. So,
12 what it means is you cannot take the same value and then
13 apply it over a regional area. So something else has to be
14 developed. And the approach that we had here was to
15 characterize the appropriate spatial scales over regional
16 areas by using spatial averaging. And this is consistent
17 with the idea that GIC, that actually flows around the
18 transmission lines, is a function of the integral
19 geoelectric field. An integral in some sense is nothing
20 but an averaging procedure. So also that was physical
21 phenomena how GS is generating over the transmission
22 systems.

23 Next point, next slide, pertains to the
24 geomagnetic latitude scaling. We know that the rural
25 boundaries do move quite a bit during extreme storms, but

1 also what we have discovered, and many of our colleagues
2 around the world have discovered, is that there is
3 so-called saturation or stoppage for the expansion of this
4 rural boundaries during extreme storms. And this is
5 something that we see for all major storms since 1980's.
6 And it's been published in the literature by a number of
7 authors, and in the new paper coming out that, you know,
8 indicates very similar kind of behavior. And actual
9 physical behind this saturation or stoppage is a well-known
10 phenomenon in the geophysics or space sciences. There are
11 many different biospherics, rural and polarimeters for
12 which we experience and observe similar kind of saturation.
13 So this is really not such a big surprise for us, but it's
14 a matter of fact that we do observe this saturation or
15 stoppage for all these extreme storms that we have observed
16 since the 1980's.

17 And the final point, if you go to the next
18 slide, pertains to the duality. So there are a lot of
19 different approaches pertaining both to the space-physical
20 modeling and to the modeling of the geomagnetic --actually,
21 called one-dimensional approaches; two-dimensional;
22 three-dimensional approaches. The fact, again, here is
23 that while this 1-D models are always approximations, they
24 have been the workhorse of the GIC research for the past
25 several decades, and they have been very successful in

1 doing that. And also especially pertaining to the GIC's,
2 they're very appropriate, okay. That being said, of course
3 science moves forward -- and we'll be seeing today from
4 Jeff and Adam I'm sure -- there are three-dimensional
5 effects also in terms of the geomagnetic induction process,
6 so also the future of the GIC will be including those
7 three-dimensional effects. But for those hazard
8 assessments that we're going after here, I strongly believe
9 that the one-dimensional approach is a good approximation.

10 So if you go to the final slide, which is the
11 bottom line, I strongly believe that the science is mature
12 enough for us to take action now. The scientific research
13 will go on: We will have future observations, mean
14 observations, space-age observations, done for example by
15 our agency. They will be done by organizations like Oregon
16 State, USGS and so forth. And we will have an
17 understanding of the fitting of the GIC, and that will push
18 the science forward and that will allow us to do
19 refinements into the future. That's it, thank you.

20 MR. BARDEE: Thank you.

21 Next we have Dr. Scott Backhaus with the Los
22 Alamos National Lab.

23 DR. BACKHAUS: Thank you. I'm Scott Backhaus,
24 Los Alamos National Lab. I'm program manager for most of
25 Los Alamos's office for electricity programs, and I'm also

1 the team leader for our GHS team; I'm the guy that looks at
2 critical infrastructure throughout the United States.

3 We were asked by Department of Energy to look
4 into some of the uncertainties within the NERC process for
5 evaluating the threat and hazard environment for
6 geomagnetic disturbance. We weren't given a specific
7 request in terms of which parts of the NERC process to look
8 into, so we looked quite broadly across the entire
9 spectrum. In that investigation we agreed with NERC that
10 the workflow is more than adequate for looking into, for
11 investigating the impacts of GIC on the power system
12 itself. However, we found that perhaps some of the input
13 data into that process required deeper investigation. We
14 looked at three main areas of the input data: One was the
15 statistical approaches that were being used to define the
16 100-year benchmark event, geomagnetic latitudes; we also
17 looked at the scaling of that benchmark event with respect
18 to latitude for both small-scale events and large-scale
19 events; finally, we also looked at some of the
20 uncertainties with respect to earth conductivity. I will
21 only comment on the first two of these because there's
22 clearly people on the panel that have much deeper knowledge
23 of either me or my colleagues at Los Alamos with respect to
24 earth conductivity.

25 The first thing I'd like to comment on were the

1 statistical methods that were used to define the benchmark
2 event from the data itself. As Antti has pointed out,
3 there are two main methods of looking at this: One is
4 looking at the statistics of individual observations of the
5 geomagnetic field, really the time derivative of the
6 geomagnetic field; and a second approach is extreme value
7 theory. The main point with respect to looking at
8 individual observations, you have to take into account the
9 autocorrelation in geomagnetic disturbance signal. That
10 autocorrelation shows that the events that individual
11 observations are not independent, and you have to deal with
12 the statistical independence appropriately. If you do not
13 take into account that autocorrelation time, you will
14 over-count events in the midrange of geoelectric fields,
15 geomagnetic fields, and you will bias the probability
16 distribution of observations such that when you extrapolate
17 that, that probability distribution out to currently
18 unobserved geomagnetic fields, you will underestimate the
19 100-year benchmark event. However, the extreme value
20 methods that have been also used in this area do not suffer
21 from this same problem. So we believe that the extreme
22 value theory approach to analyzing the statistics is more
23 than adequate for analyzing these events.

24 If we go to the next slide. The latitude
25 scaling that has been an exponential latitude scale that

1 has been proposed within the NERC workflow for scaling the
2 benchmark event at 60 degrees north latitude to lower
3 latitudes. Obviously, this scaling is the power system at
4 a more subtle latitude, more relief from the more intense
5 geomagnetic fields. However, I think most power engineers
6 in the room will realize, that have experience with it,
7 that small events do not necessarily behave the same as
8 large events. Case in point would be a bulk evasive
9 pervasion in dynamics of power systems, if you're dinging a
10 power system with a small disturbance it responds one way;
11 you ding it a little bit harder, it responds to scales;
12 proportionally, just like one might think, if you ding it
13 hard enough it goes to a different regime and the system
14 responds in a fundamentally different way.

15 With that analogy in mind, we looked at
16 different events, different geomagnetic disturbance events,
17 and how they scale with the magnitude of the disturbance.
18 Using the disturbance storm time index as a crude measure
19 of the geomagnetic strength, we bend the data according to
20 the strength of the geomagnetic disturbance. When we did
21 that, we clearly found that small events scaled very much
22 like the proposed scaling in the NERC workflow; it was
23 relatively consistent with that. You can see that in some
24 of the graphs; it's difficult to see from here. But the
25 small events follow the NERC scaling quite well. However,

1 when we started to condition the observations based upon
2 the strength of the disturbance, primarily based on the
3 disturbance storm time index, we found that the geomagnetic
4 field showed significant enhancement at other latitudes:
5 It shows significant enhancements at southerly latitudes
6 relative to the NERC scaling. These enhancements primarily
7 occurred in the range from 50 to 55 degrees north
8 geomagnetic latitude. We believe that this enhancement for
9 large storms needs to be taken into account in future
10 revisions of this standard. However, we also feel that the
11 current scaling is sufficient to get the standard in place
12 so that, in agreement with Antti, we can let the science
13 evolve as we move forward and revise the scales as we move
14 on. Thank you.

15 MR. BARDEE: Thank you, doctor.

16 Next we have Dr. Jeffrey Love from U.S.
17 Geological Survey.

18 DR. LOVE: Thank you. I'm going to talk from my
19 slides; I have a movie. My name is Jeffrey Love. I work
20 in the geomagnetism program at the USGS and I'd like to
21 tell everybody that I'm only a scientist, and I say that
22 because I know there are issues here that are related to
23 engineering. But I will talk about the natural hazard that
24 is of relevance to this discussion. I'm also working with
25 the National Science and Technology Council in the

1 development, ongoing development, of geoelectric benchmarks
2 which are of interest to this discussion as well. And I
3 guess I would like to say there will always be progress
4 being made in science. So, yes, we have some work that has
5 been done; a lot of work has been done. But there will be
6 a lot more progress made in the future as well.

7 The next slide. This is a very qualitative
8 picture which I like to use, it's actually three diagrams
9 one on top of the other. I will just briefly talk about
10 this. I will say that the issue here that I'm interested
11 in is what kind of geoelectric fields are induced or
12 generated in the electrically-conducting earth during
13 magnetic storms. So we have to quantities there:
14 Magnetism, magnetic field variation which is caused by the
15 other's interaction with the sun; and the resulting
16 induction or cause of geoelectric fields in the solid
17 earth. That is a process that can be described in terms of
18 a filter: You have a mathematical object that acts on an
19 input signal and gives you an output signal. And in this
20 case the output signal that we're interested in is the
21 geoelectric field, the input field is the geomagnetic
22 field, the filter is the solid earth.

23 So I'll move onto the next slide. So this is a
24 movie which is a result of a synthetic calculation. What
25 we are doing is we are using magnetotelluric survey data.

1 These are measurements that are made at different locations
2 where those black dots are. And what has been done at
3 those locations is that an empirical, a measured estimate
4 of the relationship between geomagnetic field variation and
5 geoelectric field variation, has been established. That's
6 an impedance, that's that filter that we're talking about.
7 Once we have that impedance we can understand what kind of
8 geoelectric fields could be generated given a magnetic
9 field variation. So for this particular calculation, we're
10 assuming a very simple magnetic field variation, it's just
11 a synthetic calculation, it is a simple sinusoid magnetic
12 field variations. But the result, the resulting
13 geoelectric field, is shown by those black vectors which
14 are dancing back and forth. And what you see is they are
15 different in different places, they have different
16 directions in different places, and they have different
17 phase in different places. All of that is the result of
18 the solid earth, the electric-conducting earth that is
19 underneath our feet. And the fact that there is so much
20 geographic variation, even though we're assuming a
21 homogenous and perfectly uniform magnetic field variation,
22 is the result only of the earth's conductivity. So if you
23 were to take that kind of map and then add on the
24 complexity of real geomagnetic field variation, you can see
25 the kind of difficult issues that you have to face.

1 So just to -- I'll go to the next slide, then.
2 All right, so just to conclude, if we were to have an input
3 signal, which is kind of characteristic of a
4 once-per-hundred-year event, put it through that map, we
5 can estimate the geoelectric field variations that we could
6 get. And it's kind of interesting, on average they're kind
7 of like those values that's being used by NERC. But
8 there's a great variance, great dispersion, about that
9 average. And in fact that dispersion is over two orders of
10 magnitude, all right. That's a huge variation. The solid
11 earth is a first order issue for this discussion. And
12 until we have really -- until we have more those
13 measurements that are made, we are going to be talking
14 about very rough estimates for the kind of geoelectric
15 fields that can be induced during the magnetic storm.
16 Okay, I can come back and I can talk about it all day, but
17 that's where I'll leave it for now. Thank you.

18 MR. BARDEE: Thank you, Dr. Love.

19 Next we have Mr. David Roodman.

20 MR. ROODMAN: I have slides, I'm going to be
21 skipping the first half; I don't know if you got them. I
22 should begin with the disclaimer: I'm here representing
23 the Open Philanthropic Project in San Francisco for whom I
24 work. My views are attributable only to me, they're
25 not official organizational positions.

1 There's been a lot of discussion already about
2 the details of the benchmark events, and I have in my own
3 way commented on those in the record. I would like to zoom
4 out and talk about a larger question, somewhat respectfully
5 provocative, just ask a really broad question to start
6 with: Why are we here? I think a sort of subtle answer to
7 that question would be that we're here to support FERC and
8 NERC in designing a process that involves complex
9 institutions interacting in complex ways, populated by
10 fallible human beings responding to various incentives,
11 aiming at assessing and, if necessary, reducing a black
12 swan event, the risk of a black swan event,
13 low-probability/high-cost event. A more blunt way of
14 saying it is we're here to prevent disaster. And in that
15 sense, NERC and FERC are in part engineers, not traditional
16 engineers but engineers of process in these institutions.
17 And one of my concerns is that all the expertise that's
18 available here that seems to be related to the science and
19 the hard engineering, but there isn't expertise on how one
20 designs such a process to make it work well. And in my
21 slides I just talked briefly on a few different disasters
22 that we know about: 9/11; the explosion of the shuttle
23 Challenger; Fukushima; and then I also have one on the
24 collapse of a bridge that was built across the Tacoma
25 Narrows in Washington State, it was built in 1940, did not

1 last a year. Each of those examples have a story behind
2 it, and they're different stories and they offer different
3 lessons, and sometimes the lessons contradict each other.
4 But it seems to me it would be valuable for someone
5 involved in this process to be learning from those stories
6 or bringing in the expertise of people who have sought out
7 how you deal with human processes to avoid disaster as much
8 as possible. And I'm concerned that that is not happening
9 very much here. In perusing these stories, I gleaned a few
10 tentative lessons. In fact, if somebody thought about this
11 more carefully could come up with a richer and better set
12 of lessons. One is it's important to understand not just
13 the pieces of the system that we're trying to manage risk
14 in, but the whole. And I think actually that lesson is
15 pretty well reflected in the process proposed here, because
16 we're looking not just at the individual transformers but
17 also how the power system as a whole behaves. Our system
18 here is really quite complex: The power system affects
19 other systems within our society and emergency response,
20 water delivery, fuel pipelines, which in turn can affect
21 the power system; there also is GPS satellites, it is quite
22 a complex problem.

23 Another basic lesson is that the ultimate
24 failures when they've been disasters are not in the
25 equipment but the people, right. It doesn't get us very

1 far to say that the bridge was fatally flawed; we need to
2 understand why human beings made such a bridge. Another
3 lesson is that in a lot of cases there have been strong
4 institutional incentives not to worry too much. Certainly,
5 that was the case with the shuttle Challenger. The story
6 is that the night before the decision the launch the
7 Challenger in January of '86 there was a very tense meeting
8 with NASA managers and engineers and managers, refused to
9 sign off on an launch recommendation. And one of the NASA
10 managers said something like, "When are you expecting to
11 launch, next April?" And that quote sort of embodies the
12 incentives that were at work within the agency to keep the
13 launch schedule on track, which ultimately led to in
14 retrospect was a bad decision. And so the question is how
15 does FERC avoid repeating that mistake? Which is not to
16 say how does FERC prevent all disaster, but how does FERC
17 make wise judgement to preventing within reasonable
18 measures to do so?

19 Another lesson from history is that there are
20 different failure modes. If you look at the different
21 disasters, different things went wrong. In the case of the
22 bridge, the lead engineer designed that bridge in
23 Washington State, he was a very imminent engineering in his
24 field and people respected him, and he got it wrong. In
25 the case of the shuttle, the engineers got it right. So

1 there's a warning about deferring too much imminence among
2 engineers, but also worrying about the need to listen to
3 engineers, which is somewhat paradoxical. In some cases
4 there has been a failure of imagination; certainly that was
5 the case in 9/11. Maybe less so here, I think we have
6 gotten pretty good at imagining what can go wrong. And in
7 some cases there has been a failure to cultivate and fully
8 listen to descent. What implications does that have for
9 what we're trying to do here? I think the big message is
10 in the value of institutionalizing critical thinking.
11 Critical thinking is actually what made the scientific
12 method, why we're able to be here. More concretely, it
13 seems to me to be valuable to simulate far more than one or
14 two scenarios, to aim for robustness. We have chess
15 computers that can simulate a million moves a second. I
16 think if we asked Google to work at this problem, they
17 would not just simulate one scenario. If I told you,
18 "Well, the space shuttle simulated one scenario," I don't
19 think that would be very reassuring. And it seems to me we
20 can do better here.

21 I think there's also an argument for minimizing
22 reliance on companies to evaluate the safety of their own
23 products. We've seen that with Volkswagon which U.S.
24 regulatory system was given the job of evaluating the
25 emission level of its own cars. There's an argument for

1 maximizing transparency, the more data on actual current
2 flow in terms of the system now, the more data on the state
3 of our transformers, the more data on the analysis that was
4 done to define the benchmark event, the more that we can
5 marshal all the world's scientific resources to study this
6 problem in a sense for free, and we will advance the
7 conversation more quickly by doing so.

8 I would argue that there are ways to
9 institutionalize critical review within this process. The
10 Department of Defense, which has thought very hard about
11 how to anticipate in dealing with risks, may stretch their
12 own imagination, has made increasing use of something
13 called the Red Team, which is an independent unit which can
14 go in and play devil's advocate. And they've written about
15 that experience; I've submitted some write-ups of that
16 experience into the record. I think that could be very
17 useful here.

18 In sum, I just want to say I think we are all
19 engineers here and we're building a process involving human
20 beings, and I hope that expertise on that kind of
21 engineering will be added to the process. Thank you.

22 MR. BARDEE: Thank you, Mr. Roodman.

23 Next we have Professor Adam Schultz from Oregon
24 State University.

25 PROFESSOR SCHULTZ: Thank you very much. I'm

1 not going to go through the slides; I'll just talk and be
2 very straight-forward. I think this follows very nicely
3 from the previous presentation, what we have to contend
4 with is a doctrine of a standard at a time when scientific
5 knowledge is advancing. And in this case, when the
6 standards were first proposed there was very little
7 information about the three-dimensional variations of
8 electrical conductivity in the crust and mantle of North
9 America. And that has changed during the time that this
10 has been deliberated and the standards have been
11 considered. I think these are actually good standards,
12 they're an advance on previous standards. But our
13 knowledge has changed.

14 Now, one of the points -- a point to make is
15 very technical, that is the intensity of the electric field
16 at ground surface along the transmission line path depends
17 on the electrical conductivity of the ground below that
18 path. It depends on the conductivity at various depths,
19 actually to considerable depth below the earth's surface.
20 The current practice in industry is to couple that power
21 line system into the earth, assuming that the electrical
22 conductivity varies only with depth. And in fact we know
23 from industry practice that the United States have been
24 divided into a series of regions, each region is assumed to
25 have the same conductivity of depth profile within it.

1 What has happened in the intervening years is our
2 understanding that in fact that we have been systematically
3 mapping the electrical conductivity of the crust and
4 mantle, it is far from that situation. Let me skip ahead
5 rather quickly. Using this method known as the
6 magnetotelluric method, we measured the electric fields and
7 the magnetic field through a series of locations. Some of
8 these are permanent, some of these are temporary. I've
9 been responsible for systematically mapping the
10 conductivity of the United States on a grid of stations
11 every 70 kilometers.

12 Now, there have been some very well-known
13 examples, I think from some of the panelists here, where
14 the application of a one-dimensional sort of model of the
15 electrical conductivity to the problem of predicting the
16 GIC in a power grid hasn't worked so well. In other cases
17 there have been examples where it has. The technical
18 question is: As a general rule, can one average out the
19 different variations in the electric field at ground
20 surface over the length of a transmission line so that one
21 can adopt an equivalent one-dimensional model for that
22 power line's electrical conductivity structure? And the
23 answer is we don't know as a general rule. There are
24 certainly places where that seems to work well but there
25 seem to be places where that doesn't work well.

1 You may have seen this already; this is just a
2 series of stations that we have already occupied in our
3 systematic mapping effort. By the end of this particular
4 activity, which is funded by the National Science
5 Foundation, in 2018 we will cover approximately half of the
6 territory of the continental U.S. During that process we
7 have discovered that the electrical conductivity variations
8 are extraordinarily large. At every different depth within
9 the earth's crust and mantle we find that perhaps three or
10 more orders of magnitude variation with position laterally
11 at any given depth range, which is a great deviation from
12 the one-dimensional view of the earth.

13 Now, this is true not only in places that you
14 might expect would be very complicated, such as the very
15 geologically-active Western U.S., but even in the Midwest.
16 We see huge variations in conductivity. Equivalent to
17 those we see in the geologically-active West, even in the
18 midsection of the country. So we're finding, as we've now
19 swept to the Atlantic in this past year, the same situation
20 of huge variations in conductivity structure. So what does
21 this mean in practical terms? It means that at ground
22 level, one-dimensional earth -- and I provided some
23 animations of real data to illustrate this -- as the
24 magnetic field varies from place to place and with time in
25 a one-dimensional earth, the electric field is always at a

1 right angle to that. And the magnetic field changes
2 intensity, the electric field changes its intensity
3 proportionally. The three-dimensional earth is entirely
4 different: You can have even a small directional change in
5 the earth's magnetic field at ground surface and you can
6 add that to a dramatic change in the orientation of the
7 electric field and a nonlinear change in the intensity of
8 the electric field. So the three-dimensional earth, the
9 old relationships that one may assume fall away. In
10 practical terms the question, then, is: As one goes along
11 the link of the power line, can one assume that all of
12 these dramatic variations of electric field intensity and
13 direction given any particular magnetic field that
14 generates this, can they average out in some way to
15 approximate the conductivity as one-dimensional? And as I
16 say, the answer is: It is not settled that you can do this
17 as a general rule at all; there are places where it appears
18 this will not work. And, again, I've offered a variety of
19 animations of actual data, not model data but actual data
20 if you play through them.

21 Skipping to the end, I'd like to make
22 recommendations that -- I'm skipping through my various
23 animations here . I'd like to make recommendations that
24 where three-dimensional data exists that we apply that
25 three-dimensional data to estimating the electric field

1 background surface. There had attached previously been
2 technical limitations in applying nonuniform electric
3 fields along ground surface to geomagnetically-induced,
4 coupled predictions, GIC, Geomagnetically-Induced Current
5 predictions power lines, those technical limitations appear
6 to have largely gone away now. So we can make use of
7 nonuniform electric fields. To summarize, where we do not
8 yet have the actual data from the field of the electrical
9 conductivity structure, it's a small and rather easy matter
10 to obtain it. So my recommendation is that this be done
11 and that the widespread use of three-dimensional
12 information in the GIC be adopted by the industry. Thank
13 you.

14 MR. BARDEE: Thank you, Professor Schultz.

15 Next we have David Boteler from National
16 Resources Canada.

17 MR. BOTELER: While we're bringing up the
18 slides, yes, my name is David Boteler. I'm with the
19 Geomagnetism Group of National Resources of Canada. Our
20 group runs the magnetic observatories across the country.
21 So we've got observatories spanning a wide range of
22 latitudes. The plot on the right shows the observatories
23 are ordered in terms of magnetic latitude. And it's a
24 typical situation where we got a lot of activity in the
25 rural zone and less up in the polar cap and then in the

1 South. And of course that's the region where we are
2 worried about, and we live without all the time. And then
3 as you've heard, when things get disturbed that rural
4 region expands and brings it down to the Southern and our
5 utilities get enacted, and then on occasions brings it down
6 into the U.S. So hang on a minute. This is the talk for
7 this afternoon.

8 (Laughter)

9 I was wondering about duplications last night.

10 MS. NIMIS: We apologize.

11 MR. BOTELER: Now, this makes this slide work
12 even better because now you've seen where all the
13 observatories are, this is a listing of where they started
14 and what dates are available. And one of the questions,
15 we'll come back to this, when we're talking we think we got
16 a lot of data but when we're looking in the one-in-100-year
17 event, how much data do we really have? Our first
18 observatory started in 1840, they brought analogue records,
19 they were trying to digitize and couldn't quite figure it
20 out. But in terms of digital data, it wasn't until the
21 1970's we started. So at one-month sampling it shows we've
22 got digital data now for the last 40 years. So it's still
23 not 100 years, which we'd like to do a 100-year study, but
24 at least we're getting there. Faster sample data not until
25 the 1990's, so we've got about 25 years of data now for

1 that.

2 So what we've done, we've done extreme value
3 analysis. And the issue that's been brought up by a number
4 of speakers is independence of the data going in. And this
5 was an issue flagged to us by Andrew Richards with the
6 National Grid Company. And so because of his warnings
7 about this, it's all really bent over backwards in this
8 study to make sure the data was independent. So we start
9 off with the geomagnetic ranges and we determined that the
10 maximum value for each five-day log, so five days to make
11 sure we span the whole, one big value for a magnetic storm.
12 And then we go to the extreme value distribution. And then
13 as part of the testing of the process, we actually
14 restricted our data set; we got four years worth of data
15 but we did an analysis of 16 years worth of data, and that
16 allowed us to estimate what the 40-year return peak would
17 be. Because we got 40 years worth of data compared to that
18 what the peak was, and that's the comparison there and it
19 is a pretty good test. So then we've done this for
20 geomagnetics going out to estimate the 100-year, 50-year
21 examples, and we've got an approximate term period there.
22 We worked with the geoelectric field and calculated the
23 models as described. And this is a station close to the
24 Aurora zone. Interestingly, it's not the same extreme
25 value distribution that fits all of the data; it's

1 different ones from different times. So we've got that,
2 and that's giving us an estimate. Spread across -- you
3 start to get down to the Aurora area of the new interests
4 of a single drop-off there.

5 One other issue to flag with this I think is
6 important is, that's been done with one-minute data because
7 that's what we had available for the longest period, the
8 other studies have been done with 10-second data. As you
9 go to faster sampling you're going to get higher peaks.
10 The question is I think comes back to geophysics community
11 as to what are these fast variations that we should worry
12 about, is what we want an answer from the power industry is
13 as you go to faster and faster sampling, say we get to 60
14 hertz you're obviously getting into all of the inductions
15 of the power system and you're going to limit what the GIC
16 are. At what point do we have to take into account the
17 impudence of the network, not just the resistance of the
18 network? When we were doing one-minute sampling or so in
19 the past -- I'm sure that was fine -- transformers getting
20 bigger, larger inductors on the system, that's a question
21 we don't know, that's a question we're looking to the
22 industry to answer.

23 So this is just an example. We got into this in
24 the week of the March '89 storm when we did the peak
25 geomagnetic assessment in the early '90's for the Canadian

1 Electricity Association. As part of that, we developed
2 earth models for the main geologic zones that are shown
3 there, and they've shown as development, but we've
4 recognized, along with others, that that's not good enough.
5 So we've had a lot of work underway and we've refined the
6 models. We now have four models for the country, we've got
7 70 to 80. And, for example, we've broken down each
8 province into different zones based on the geology, and
9 then from the available empty data we developed this.
10 We've done that for all of the provinces now.

11 To conclude, we feel the multiple earth models
12 is the first approximation for the geoelectric structure,
13 recognizing it ignores the boundary effects between the
14 different models, and the strongest way to get the boundary
15 effect is of course at the Coast. And there's work
16 underway, there's IEEE task force of GIC analysis, there's
17 a working group on the Coast effect looking at this. But
18 this is another of these areas that is a work in progress.
19 And basically the modeling techniques, whatever electric
20 field information we can get, we got the techniques in the
21 GIC modeling to handle that.

22 MR. BARDEE: Thank you.

23 And finally we have John Kappenman from Storm
24 Analysis Consultants.

25 MR. KAPPENMAN: Thank you. I'll also speak from

1 my slides here, if you could bring those up. Being the
2 last presenter this morning, I guess that gives me the
3 opportunity to reflect on the previous presentations, react
4 to it a bit, and act as a segue into the follow-up
5 questions that you might pose to us.

6 Let me reflect on what has been presented, what
7 I see as the two main problems with the NERC standard.
8 First one is the threat level for the proposed
9 one-in-100-year sort of event. This blue line here shows
10 you what NERC has indicated is what they would propose
11 based on their modeling and statistical analysis methods.
12 So these were largely based on very small regions on the
13 earth, and actually there was no observatory in the entire
14 Conus region included in that statistical analysis. When
15 we start looking at actual observatory data, what we see is
16 a large number of observations that greatly exceed this
17 100-year threshold. And these have occurred within
18 approximately the last 30 years. So this truly indicates
19 to us that we don't even meet a one-in-30-year sort of
20 standard in regards to this approach.

21 Let's talk about the issues of ground modeling,
22 both Dr. Love and Dr. Schultz talked about 3-D modeling,
23 Dr. Pulkkinen talked about the 1-D modeling approaches, as
24 well as Dr. Boteler. You know, if you're looking at how to
25 model this, the emphasis has usually been on ground

1 conductivity in these models. That's a very difficult
2 thing to establish because we don't have direct
3 measurements that go to these enormous depths that are
4 being talked about; they're only inferred. What we are
5 truly interested in is the geoelectric field response to
6 that deep earth, and it's that response that's producing
7 the GIC and the threat to the power grid. And we actually
8 have ways of measuring this directly, as I'll talk about.
9 But let's talk a bit more about the modeling here. If you
10 are looking at both 1-D and 3-D models, there's going to be
11 enormous amounts of uncertainty. For example, in the 3-D
12 methods, their measurements are confined to 100-meter
13 square areas within a 70-kilometer region. There's a half
14 a million other equal-sized locations that they have not
15 directly measured anything on. So there can be enormous
16 uncertainties in that sort of approach; it's very indirect,
17 very imprecise, and the accuracy will suffer from
18 inadequate regional sampling that occurs. On the other
19 hand, GIC data is actually directly measuring the response
20 of the power grid and the earth in total. It avoids
21 unnecessary, inaccurate, and inexpensive steps of
22 conductivity modeling. Further, since the GIC is measured
23 over mesoscale distances of the power grid assets
24 themselves, it fully integrates and averages the 3-D
25 complexities of the region.

1 In short, GIC is an actual measurement of the
2 GMD impact on this power grid asset that the public is
3 concerned about, rather than measuring some uncertain proxy
4 that will go into a model. If we look at the known GIC
5 measurements sites across the U.S., all these red circles
6 here indicate GIC locations that have existed, that have
7 been reported to have been existed, there are probably a
8 number of other unreported sites that can add into that.
9 These already-existing GIC measurements can be used to
10 develop and validate the ground models for the most
11 important parts of the U.S. grid. And some of these
12 locations have actually existed for more than 20 years.
13 Further, you can see there's a lot of overlap between the
14 sensor regions that the GIC covers. So there's multiple
15 redundant data sets available there that can confirm or
16 shed light on further issues that need to be discussed.

17 So in summing up, let me just emphasize that GIC
18 monitoring can tell us a lot about storms and responses of
19 the power network in the apparatus that may be harmed. The
20 GIC measurements do the mesoscale coupling of the storm to
21 the critical infrastructure. We have precise information
22 on grid asset locations and resistances, much better
23 information than we do on any deep-earth ground
24 characteristics. And therefore that GIC monitoring fills
25 that important knowledge gap. Further, this will be a

1 simpler, faster-to-implement, less-expensive, more-accurate
2 approach to modeling these problems in the required
3 standard. It is easy to continuously forensically audit
4 and update as network additions occur as well.

5 In short, I think Mr. Roodman best summarized
6 it: We've got a human problem as well as an observation
7 problem. Models are going to be dependent upon human
8 interpretation and lack of full understanding of the
9 physics that go into these very complex models. I have
10 never seen a GIC measurements get statistics wrong,
11 however. I have never seen a GIC measurement that gets the
12 physics wrong, however. I have never seen a geomagnetic
13 observatory measurement that gets the physics wrong. And
14 if you stick to that sort of approach, I think we'll
15 achieve the best outcome for this standard. Thank you.

16 MR. BARDEE: Thank you Mr. Kappenman.

17 Let me turn to our Chairman and Commissioners
18 for any questions they may have.

19 CHAIRMAN BAY: I'm going to start with this
20 question: One of my favorite books that I've read recently
21 is Daniel Collins, you may have read this book, where he
22 talks about the cognitives biases that we all have. One of
23 the biases he identifies is something he calls planning
24 fallacy, where we think we have the right answer, we kind
25 of march ahead as lemmings, as it were. One of the

1 anecdotes to planning fallacies where you engage in a
2 thought exercise where he says okay, so you're trying to do
3 a certain thing and you plan for it, and it turns out our
4 plans were wrong. So it's a year later after we start
5 these plans -- and this kind of goes to what Mr. Roodman
6 was saying -- we have these plans; we thought we had
7 prepared; and something went wrong. In this case, let's
8 say geomagnetic disturbance, and there are widespread
9 outages across the United States. And so the thought
10 exercise he proposes is to ask this question: Ask the
11 people at the table to tell you what they think went wrong.
12 So let me pose that question to each of the experts at the
13 panel today sure.

14 MR. KAPPENMAN: Well, since I was last maybe
15 I'll going first this time.

16 I think what perhaps went wrong with the way the
17 standard was constituted is there simply was not enough
18 data brought into the initial analysis. In fact, there was
19 a lot of effort to exclude most of the relevant data. We
20 see observatory data that was confined to Finland and one
21 observatory in Japan that went into developing the NERC
22 100-year threat profile. Well, there's actually no
23 observatory in that data set that matches this same
24 latitude as the continental U.S. And I showed in one of my
25 slides there how many times we've had storms at various

1 locations around the world and in the U.S. that greatly
2 exceeded what was in the NERC standard. I asked it many
3 times during the NERC standard development process, why are
4 we not collecting a GIC data? And I got no really good
5 answers for that. So we set out to exclude almost all of
6 the relevant data from what went into developing this
7 standard at the outset, and that's why we have serious
8 concerns about the adequacy about this standard right now.
9 Thank you.

10 MR. BOTELER: I can perhaps provide a rather
11 historic example of exactly what you're talking about,
12 because we lived through that in March 1989. March the
13 13th 1989 hydro was blacked out and the question is what
14 did we do wrong? And at that time it was a matter of
15 denial, and it was a wake-up call for the industry. I
16 worked along with John; we go back far enough, we were
17 working in this field prior to that. I don't know what
18 your experience is. Mine certainly was -- but on the
19 strict understanding that this was just an academic
20 curiosity and was going to have no effects on the passing,
21 and that was the attitude that I think the whole industry
22 had back on March the 13th, 1989. So we've learned from
23 that, that was a transformative event in this field, and so
24 I don't think that scenario is happening now, as an example
25 of what you're talking about.

1 MR. ROODMAN: I think it's a fantastic question.
2 I just wanted to mention briefly: I think you asked the
3 narrow question of whether the proposed benchmark event is
4 conservative enough, conservative in a lot of the
5 historical data that we have, that the answer is mostly
6 yes. And I've written up why I think that's that might
7 not. But I think we must be thinking much more broadly.
8 So if there were a disaster, I think the answer, the
9 explanation, would be something like: Everybody involved
10 with the best of intentions kind of moved along established
11 institutional paths. I think by law FERC must delegate to
12 NERC primary responsibility for designing this standard;
13 NERC designs it in a way that makes most sense to it in
14 light of all the constraints and incentives it faces; and
15 it seems adequate at the time because that's how we've
16 always done things. And only in retrospect, if something
17 goes wrong will we recognize that we weren't hard enough on
18 ourselves.

19 PROFESSOR SCHULTZ: I'll echo some previous
20 comments. I think there is a risk of treating academic
21 work as an academic exercise in the pejorative sense. And
22 my view is the standard is based on information available
23 but hasn't used all information available, especially
24 information that has come online since the process. My
25 view is one based on nearly a thousand actual measurements

1 of the relationship between the electric and magnetic
2 fields all over the continental U.S. Has that really come
3 into the planning process? Not yet. It's still largely
4 viewed as an academic exercise. So I would argue for
5 breaking down those institutional stovepipes so the latest
6 research can affect standards in a far more rapid way than
7 currently is possible.

8 DR. LOVE: Mr. Chairman, just to respond to your
9 question: If we had widespread outage of electricity, from
10 my perspective what could have been the problem. I could
11 imagine there could have been lots of problems. But I will
12 comment on a possible set of problems that could be related
13 to the natural sciences. Mr. Kappenman was highlighting
14 the utility of making direct GIC measurements in the grid,
15 and I'm all in favor of more data, as every scientist is.
16 The challenge with those data assessments in context is
17 they've been collected over a finite duration of time,
18 relatively short, whereas we're talking about what happens
19 once every hundred years. Furthermore, they are data that
20 pertain to the electric power grid as it is configured and
21 operated at the time the measurements were made. So the
22 natural science of measuring geomagnetic field variation,
23 which we've done for 40 years at one-minute stages which
24 we've done for over 100 years at one-hour cadence, those
25 provide useful insights as to what possibly could happen in

1 the future in terms of magnetic activity. Making
2 perfectly-valid measurements, magnetotelluric measurements,
3 and making perfectly-valid inferences of what the impedance
4 relationship is between geomagnetic field variation and
5 geoelectric field variation, tells us what kind of natural
6 event we could expect in the future, and with that
7 knowledge we are able to make plans as to what kind of
8 magnetic storms might occur. And with that understanding,
9 we can better understand how to mitigate against their
10 causes, how to possibly reconfigure power grids so they are
11 less vulnerable. That is the utility of the natural
12 science and that is the aspect that I'm familiar with and
13 it is the aspect that I think needs to be promoted in
14 addition to the engineering issues.

15 DR. BACKHAUS: So I guess I get through life
16 primarily by being a good observer of the obvious. And I
17 would say is the obvious answer to the Chairman's question
18 is: If there's large-scale blackouts, we either didn't
19 understand hazard, we didn't understand the system
20 response, or both. So I come at this from an experimental
21 physics background even though I primarily manage a bunch
22 of people who do modeling and simulations. In the
23 experimental physics, what I didn't understand what my
24 experiment was doing, I had the pleasure of going back in
25 my lab and kicking it and seeing what happened. So I would

1 kick it in different ways and observe it and try to
2 understand the relationship between the stimulus and the
3 response. I think what you've been hearing up and down the
4 panel has been components of that process, both from
5 observing the GIC and also trying to understand the system
6 response, open natural system response, which is what Dr.
7 Schultz looks at, and also the power system engineering
8 response which I'm sure we'll hear more about from others
9 on the panels later today. I think what I would say is:
10 To understand that response and to understand the input, if
11 that did happen at the appropriate scales and at the
12 appropriate intensities of disturbance, then perhaps we
13 wouldn't have the scenario that the Chairman postulates.

14 MR PULKKINEN: I would maybe the same way as Dr.
15 Boteler's comment on the March 1989 events. I think what
16 could go wrong is that we would have another event because
17 we were not prepared. As I said in my opening remarks, I
18 think we have -- I strongly believe we have enough
19 information to take action now. Space weather, geologic,
20 all these complexities complete a very difficult physics
21 problem. We're looking at the chain of interacting
22 nonlinear processes extending from the solar atmosphere
23 through the heliosphere, through the magnetosphere,
24 ionosphere, upper atmosphere, ground structures, all the
25 way to the transmission grids. And all of these processes

1 are also significantly imperfect from the science. And it
2 will not always be so. But over the past several decades
3 we have established this, that allowed us to shrink certain
4 dates associated with these extreme events analysis and in
5 the whole analysis that will now allow us to take action.

6 MR. LAUBY: Thank you, Mr. Chairman, for your
7 question. I think we need to reflect also how well
8 industry has done in its planning of systems. And although
9 there have been bumps along the way, be it the blackout of
10 1968 I believe, and 2003, we continue to learn and get
11 better. One reason why NERC, for example, was to develop
12 standards to add central core for uncontrolled cascading of
13 the bulk power system because the widespread potential
14 impacts -- again, a learned opportunity in working with
15 these industry -- a good sort of standards and continue to
16 develop them.

17 Remember that NERC has an extensive toolkit.
18 Recently we worked with FERC staff on research for trees
19 that might grow into the transmission system. Once we got
20 new information data, we first of all put the standard in
21 place, and as we got more information we then allowed NERC
22 staff to work with the NERC alert to saying, "Hey, there's
23 going to be a change as a result of the research." And
24 then we baked it into a standard -- which we'll be bringing
25 here -- so industries were then starting to take action

1 through the alert, and then of course we were able to bring
2 a standard to move forward for FERC consideration. So we
3 have an extensive toolkit. We can take advantage of new
4 research results as they become available. What we need
5 now, I urge, is the standard to be approved by FERC so that
6 we can start moving forward and building and improving a
7 standard. Thank you.

8 CHAIRMAN BAY: Thank you.

9 One more quick follow-up question. And I
10 appreciate the responses I've gotten. And some of you I
11 think have answered this question somewhat, my second
12 question, and that is: Given the nature of the problems
13 that you've identified, and kind of speculating with me on
14 this thought experiment that I pose, what would be your top
15 two or three pieces of advice for FERC, for regulators, on
16 what we can do to avoid the very issue, the explanation for
17 the problem that you've provided to us?

18 MR. KAPPENMAN: Well, let me suggest that
19 ultimately the models and so forth need to be validated.
20 No effort has been undertaken by NERC to validate any of
21 these models against the actual-observed GIC that occurred
22 during storms. I undertook an enormous effort to
23 independently do that assessment since I had available to
24 me a complex nationwide electric grid model that could be
25 used for that. And what we found in numerous instances

1 that we included in all of the docket filings is that the
2 NERC model underestimates the GIC by anywhere from a factor
3 of 2 to a factor of 8, 8 being too low. So I would
4 certainly recommend that a rigorous validation effort be
5 done by anybody who is starting out in doing assessments of
6 this, that somehow this validation include some
7 availability and transparency to the GIC data that we know
8 exist for a number of storms.

9 In many cases, utilities have made this publicly
10 available, but in many more cases it's actually being very
11 closely held from the public, from the scientific
12 community, from the engineering community at large that
13 could do a lot of useful things in advancing the accuracy
14 and state of the models if it were available. So thank
15 you.

16 MR. BOTELER: As a general thing, I think we've
17 come a long way in this. If you go back quite a few years,
18 we were making assumptions that the magnetic disturbance
19 was uniform across the whole power grid. So as we've heard
20 from a number of people, there's a lot more detail in
21 there. When we use those assumptions originally, it wasn't
22 because we believed them, it was because it was the only
23 data that was available. So now things are being refined;
24 I think, if anything, it's just showing we need to go
25 another step forward. We need the density of magnetic

1 observatories we're trying to bring data into this greater
2 sampling there of the magnetic disturbance of the special
3 characteristics there; we're hearing that the modeling 3-D
4 structure of conductivity is important, which we knew but
5 we just didn't have the data before, Now projects are
6 providing that. Professor Schultz said by 2018 half the
7 U.S. is going to be covered. That's great, that's a big
8 step forward, but what about the other half? We're relying
9 on a similar project in Canada, the Mithapur Project, we're
10 relying on the data for that. But often we've got a survey
11 through one part of the geologic region and we have to
12 extrapolate the information for that over the rest of that
13 zone; so, again, more data.

14 Now, so we measure the natural phenomena of
15 magnetics, and then the earth's conductivity. More actual
16 recordings of the electric grids on the ground, I don't
17 want to mention planning -- talk about that this afternoon,
18 planning to put in long electric field measurements as a
19 public recording system. The other thing I think tends to
20 get forgotten in all of this is the structure of the GIC
21 and the underground substations because it's the easiest
22 measurement to make. But I've seen a number of studies in
23 the past where they've done some modeling and they compared
24 with the observations and it's not been very good, and the
25 authors have really beaten themselves in the pages, saying

1 "It didn't work, it didn't work." But they were in the
2 middle of a network, and really what I think was happening
3 when I looked at the results was GIC was flowing along the
4 transmission lines, and what you get going to ground is the
5 difference of what's coming in on one line and going out on
6 the other. And slight differences in the ratio between
7 loads completely reversed direction from geo-activity going
8 to ground. And I think the missing link in a lot of this
9 is to know that GIC is transmission lines, I think it would
10 really help us to understand the sequence of processes
11 throughout. And some people tried to develop sensors for
12 that a long time ago and they had a lot of temperature
13 issues, I think it would be a worthwhile investment to
14 reexamine that issue.

15 MR. ROODMAN: If I understand the proposed
16 process -- and I hope the gentlemen will correct me if I'm
17 wrong -- there's supposed to be assessments of both a
18 response of power system, each component of the power
19 system, and then also the usual pieces of equipment,
20 notably transformers. And I am not aware of any
21 requirement that be publicly disclosed, that analysis. So
22 I think I would tend to echo John, it seems the single
23 thing that would make the biggest difference would be to
24 institute a default of transparency. If I understand it,
25 the situation right now is the investor-owned, for-profit

1 entities involved in this process have to meet a higher
2 standard when disclosing their financial conditions when
3 disclosing information relevant to this Homeland Security
4 threat. And that doesn't seem right to me. We can post
5 the data on the observations on GIC's that have occurred
6 and on the state of the transformer fleet and other
7 relevant information, as well as the specific analyses
8 performed under this proposed rule, that would be a great
9 step forward.

10 PROFESSOR SCHULTZ: A comment made by David
11 Boteler, by the end of the efforts program we will have
12 complete half of the continental U.S. on this 70-kilometer
13 grid. There has never been, to my knowledge, a utility
14 industry effort to systematically map the three-dimensional
15 conductivity structure in the United States beneath the
16 grid. To me, there is a glaring deficiency because we will
17 have holes in the Northeastern United States, along the
18 Gulf Coast, Southern California, and here will be
19 completely uncovered. There is where we anticipate we will
20 meet a tremendous complexity and intensification of the
21 electricity along the power lines.

22 I'd like to point out one comment: Our
23 measurements create a quantity called the electromagnetic
24 impedance. Impedance you can view as a filter. You pipe
25 in the magnetic field and the earth's surface will get an

1 electric field for any magnetic field of any frequency
2 content within the band that you measure, which is quite
3 wide. That doesn't depend on constructing a
4 three-dimensional conductivity model, it's a simple linear
5 filter. So to say that there are inaccuracies in any
6 activity model is secondary to the fact that, regardless of
7 how the conductivity may vary, this filter tells you one
8 relationship between the electric field. So with the
9 knowledge of the impedance everywhere along that power
10 line, you can from magnetic observatory measurements -- and
11 there are not enough of them, I agree, in terms of spatial
12 coverage -- you can transform that into electric fields.
13 That's terribly important because during the course of a
14 geomagnetic disturbance you're energizing different volumes
15 of the subsurface in different orientations of magnetic
16 field, and if you do not accommodate that fully-developed
17 impedance you will not be able to predict what the electric
18 field is with any accuracy, I think. So that's a key
19 point.

20 I think, as John Kappenman said, validation is
21 terribly important. I think this will be an ongoing
22 process; after you adopt a standard, you're going to
23 continue to want to validate that standard and improve it.
24 So my two recommendations are: Let's include our knowledge
25 of the impedance everywhere in the continental U.S., for

1 purposes of this, and then let's continuously validate to
2 improve our process.

3 DR. LOVE: Mr. Chairman, to address your
4 question what needs to be done to avoid this widespread
5 loss of electricity that you're hypothesizing, and in
6 particular in the context that I answered, I highlighted
7 the need for improved understanding of the natural hazards
8 that lead to these problems. And in order to improve that
9 understanding we need three things: We need to complete
10 the national magnetotelluric survey, this is fundamentally
11 important; we need improved geomagnetic monitoring; and we
12 need some continuous geoelectric monitoring. This
13 monitoring data, geomagnetic and geoelectric data, allow us
14 to validate the models that are produced by the
15 magnetotelluric data. So there is some modeling involved:
16 It can be modeling in order to estimate impedances; there
17 needs to be some validating in making causal predictions in
18 geoelectric fields. But these three things: The MT
19 survey, improved geomagnetic monitoring, and some
20 geoelectric monitoring, would be exceedingly useful in this
21 context.

22 And then finally I will also just say that
23 sciences, yes, would like to better understand the response
24 of the power grid itself. So this GIC data that is
25 available, open availability of this would be extremely

1 useful for a scientist. And I say that because scientists
2 oftentimes look at data sets to get a context to understand
3 the effects of the work that they are working on. So if
4 you're a natural scientist you might be curious about the
5 effects on the power grid which is motivating your
6 research. And sometimes that work is undertaken
7 opportunistically. You just say, "Well, what does the data
8 look like?" So you don't know what you say until you've
9 kind of browsed through the data, so this issue of open
10 access.

11 So there you go, some geophysics needs to be
12 done and some open availability of engineering data would
13 be great as well.

14 DR. BACKHAUS: I think fundamentally the problem
15 that we face is extrapolating from current observations
16 from things that we have not seen yet. And I think we need
17 to be humble when we do that because there are
18 non-linearities that we may not currently know about. But
19 I think that extrapolation, in any way that it's done, has
20 to recognize the possibility for different non-linearities.
21 I've heard two different things with respect to the earth
22 conductivity models or the magnetotelluric data: I've
23 heard linear program, I've heard nonlinear process. I'm
24 trying to sort that in my head right now, that
25 contradiction to me and I don't understand that we're going

1 to -- but we'll talk.

2 (Laughter)

3 Any analysis that has been done has to recognize
4 the presence of non-linearities to the possible presence of
5 non-linearities. I think we also have to admit that we
6 won't know everything and that there will always be
7 uncertainty. And there has to be provisions for power
8 system operator imports, is that when something is observed
9 to be going on that operator has to be able to import on
10 the system to correct it. And I think that's probably a
11 year process for this panel to discuss those issues. But
12 there will always be uncertainty and we need to have
13 appropriate operational mitigation in place to deal with
14 uncertainty.

15 MR. PULKKINEN: So two recommendations for
16 FERC. Maybe I'm in danger of repeating myself. I think
17 that we understand the science, take action. I don't think
18 we can afford not to take action right now. Again, I think
19 this communication and discussion and research needs to go
20 on, I think it is called out by all of our panelists here.
21 I think in my personal experience one of the big
22 breakthroughs in understanding this problem came through in
23 the NERC proposals. In my experience this was the first
24 time when a large number of engineers and scientists got
25 together around the same table talking about the same

1 issue. In the science and engineering, the physical
2 equations that we use to solve many of the problems are the
3 same, but the language in many occasions is completely
4 different. So there's the barrier of communications and
5 drying to understand each other, and passing meaningful
6 information through that barrier so that people can utilize
7 and take action based on that information. And I think
8 what we have established in the GMD passthroughs over the
9 years is that we have pushed through this barrier. So now
10 we have a common interface where science and engineering
11 can exchange information, actionable information. We can
12 pass scientific information that will allow engineering
13 analysis of hazards, and then again we can get request from
14 the engineering side of things about the science. And
15 that's an increased refinements, provide further
16 clarification on these things so we can do our engineering
17 job better. So establishing that communication path I
18 think has been very critical for making this field move
19 forward over the past several years. So I would strongly
20 encourage a culmination of such discussions.

21 And as the science moves on and these
22 discussions go on and new science will be pushed through
23 the engineering side and the engineers will come back to
24 the scientists having these new requests about the
25 understanding of geoelectric fields, extreme storms, and

1 all of that stuff, we look into to reduce those
2 uncertainties that are associated with some of these
3 extreme assessments right now. And hopefully work will
4 have the flexibility to review that new level of
5 understanding over time and also have flexibility to have
6 realignments to these standards so that we always have the
7 latest, greatest science as part of the standards.

8 MR. LAUBY: Thank you also for the follow-up
9 question, Mr. Chairman. It begs the question of what NERC
10 envisions going forward and what work we will continue to
11 support once the standard is approved and moves forward. I
12 think it's important, as my colleagues have indicated, that
13 we do move forward so that we can start doing the kind of
14 vulnerability analysis that we need to do which will
15 further our knowledge and awareness of the actual models
16 themselves. We will support FERC's implication of the
17 standard, as that will certainly be one area that we focus
18 our energy on to ensure the industry understanding is
19 complete when we're talking about here when it comes to
20 geomagnetic and transparency of magnetic disturbances. And
21 we'll review the results from the vulnerability assessments
22 because that will inform improvements in the standards
23 itself. We do have allocated models; so we need more and
24 more information and make sure we got different types of
25 transformers, locations, and directionalities of different

1 types of storms.

2 Then of course the ground model research must
3 continue. When we started this work in 2011, there was
4 very little to work with. And it's moved forward in a
5 positive way, and we will continue to support that. We
6 will also review the spatial scales that we have when we
7 look at perhaps averaging, we'll take a look at perhaps
8 the smaller grid size of a sample. Some studies have
9 already been done in that, and we haven't seen any
10 significant differences. Throughout the implementation, we
11 will gather information, look for improvement, continue to
12 support the research, and then of course improve
13 transformer models and look at harmonic impacts, some other
14 outcome of saturated transformers, and potentially even
15 some of the protection system and the worries there, make
16 sure that we get those set right. So this is work that
17 needs to continue.

18 We brought people to the table for the very
19 reason that Antti talked about: We brought together the
20 scientists from NASA; we brought together the DOE's; we
21 brought together vendors and manufacturers; we brought
22 together industry and academia; we brought together folks
23 that write software and made software models available free
24 to everybody. Because that's one thing I learned a long
25 time ago: If you don't plan for something, you're never

1 going to be ready for it. So making sure that the models
2 are available, that any vendor can take and put into their
3 software packages, and that's happened. We need to
4 continue to move forward, get the standard approved, and
5 start advancing this continuing advanced science and
6 improve the standard as we move forward. Thank you.

7 CHAIRMAN BAY: One last comment. I appreciate
8 the work of everyone on the panel by working on this
9 difficult issue. I'm hearing everyone on the panel say
10 that we understand the science well enough to take action,
11 but that the science is evolving and that we are learning
12 more each year about the potential impact of GMD. And this
13 is probably where things are a little bit difficult for
14 FERC, or at least for us as regulators, in the sense that
15 it is said that regulation is part science but also part
16 art. And while you can't have all of the data and all of
17 the answers, you still have to craft a policy that makes
18 sense so that you don't under-react but also you don't
19 overreact, because there's that balance between ensuring
20 adequate reliability of the grid while taking into account
21 the best process of any standard that's involved. But I
22 certainly appreciate all the very thoughtful remarks of
23 everyone on the panel this morning. So thank you.

24 COMMISSIONER LaFLEUR: Thank you very much,
25 Norman. And thank you to everyone on the panel for sharing

1 your work with us. I think it was Dr. Backhaus who said
2 "be humble". That's not hard when you're listening to this
3 material and trying to make decisions on it. I'm not an
4 electrical engineer; I'm not a physicist at any level, I
5 didn't even take physics in high school. Although I am the
6 mother of a physicist, which doesn't have nothing to do
7 with anything but I like to say it.

8 (Laughter)

9 So what I'm trying to do is understand the
10 science and engineering and the industry expertise that's
11 been assembled as the experience of our neighbors in Canada
12 and elsewhere on these storms, and try to simplify it into
13 a decision. So I assume everyone on the panel is familiar
14 with the standard that the standards drafting team put
15 forward in this case, trying to come up with a
16 one-in-100-year benchmark based on one made data spatially
17 averaged in certain areas, and try to come up with some
18 sort of benchmark against which we would then order people
19 to take specific actions, be it the equipment or
20 operational, but more than just operational certain
21 equipment modifications or installation of equipment, to
22 protect against that benchmark. So I guess based on the
23 incomplete set of what we know -- I'm going to ask perhaps
24 an unfair question: As far as the future, we can approve
25 the standard that's before us; potentially direct some kind

1 of updating process, build that in in some way on some kind
2 of timeline; we can direct changes to the standard; we
3 usually get farther with ones we can articulate pretty
4 clearly and say "do this instead or come back"; or we can
5 direct some sort of process to set up changes like "base it
6 on this or come back"; or we can send the team back to the
7 drawing board, say "you did it wrong, do it this other way,
8 and come back"; or we can decide we don't have a standard.
9 I have an extremely-strong bias against the fourth and a
10 fairly-strong bias against the third. But I'm hoping to --
11 I'm just trying to figure out how best to take us forward.
12 I'm sure a standard of any sort -- I'm not sure, but --
13 it's likely that it's better than nothing, but we have an
14 opportunity to potentially get it better than better than
15 nothing. So I guess I welcome advice about, at this
16 juncture based on what we know -- because we only are going
17 to know what we know now, we want tell us in 2025 of what
18 we might know after 10 more years of modeling -- do you
19 think we should approve it in direct updating or make some
20 changes or build in some different process? I welcome
21 advice from anyone who cares to offer it.

22 DR. LOVE: Commissioner, I'll just try to
23 respond to this question, essentially what should we do
24 given what we know? And, again, I am just a scientist, so
25 I'm going to just talk about the science. And I would say

1 there has been a lot of great science done that's gone into
2 this. I think there is a lot of great science being done
3 and that is going to maybe inform future decisions. I
4 don't know what the process is within FERC, and I maybe
5 don't even want to comment on it, but I'm just curious as
6 to what about having a standard and then having a new
7 standard in the future? And I say that because I know that
8 science always progresses.

9 And then I guess the other thing I would just
10 like to throw in here, and it's confirming Mr. Backhaus'
11 assertion that we should be modest. And I would say that
12 the new data that we have is showing us that there is
13 significant uncertainty in the science that has been done,
14 but that it amounts to essentially a variance about a mean
15 which is reasonably like the NERC standard. So that sounds
16 kind of technical and wiggly, but that's the reality. The
17 solid earth is presenting us with a very significant
18 challenge and it results in very diverse, spatial variance
19 in terms of the geoelectric field that's induced. But the
20 average of that is not dissimilar, let's just say that from
21 what has already been produced by the NERC standard, how
22 that's handled, that's not the job of a scientist, that's
23 somebody else, so that's not my job.

24 MR. KAPPENMAN: In trying to look at minimal
25 changes into what has been put forward as to how to go

1 forward, I would recommend that we look at a threat
2 profile, 100-year storm threat profile, that at least meets
3 the 30-year extremes that I posted in one of my slides.
4 And perhaps we need to understand that a true 100-year
5 threat goes well beyond that in reality.

6 In addition, quite a bit of work has already
7 been filed in the comments, in the docket comments, on
8 analysis that I've conducted on the accuracy of the ground
9 models that NERC has been using. In many cases I'm seeing
10 that they're factor of two, maybe as much as a factor of
11 eight, too low, those ground models could be easily adopted
12 to agree with actual GIC observations that have been
13 captured during those storms. And in fact if more GIC data
14 is made available -- remember, we have lots of GIC data
15 that is not publicly available -- that work could be done
16 very quickly to recalibrate the ground models and get the
17 responses that are more in agreement with the actual
18 observations.

19 Now, I don't know if -- I don't honestly believe
20 that there's truly critical infrastructure reasons for
21 keeping this GIC from being publicly available. BPA TVA
22 have been very open with sharing their data; others sent
23 published data from time to time which we've captured in
24 public engineering documents, and so forth. But for the
25 most part, that data is not being made available.

1 Oftentimes it's being given the excuse that it is critical
2 infrastructure information. And I honestly don't want to
3 get into that debate. Perhaps there is some mechanism that
4 would allowed qualified experts, subject matter experts, to
5 have that sort of access on a more-secure basis, if need
6 be.

7 COMMISSIONER LaFLEUR: Thank you panelists for
8 that data, the industry people on it. So I'm quite sure
9 we're going to have a lengthy discussion.

10 Yes?

11 MR. ROODMAN: I think I share your bias towards
12 doing something. And I think I share the need to learn
13 more of the process; steps are complicated and I'm sure
14 some are more realistic than others. I'm sorry, I don't
15 have a full understanding of the constraints in which you
16 work. But you would hope some of them don't require two
17 years of consultations with engineers to make a decision on
18 it; I'm certain they would require some consultation.

19 I have thought about this question whether I'm
20 going too far in saying things are complicated. Because if
21 I asked you what would happen if a real big asteroid the
22 size of the moon hit the earth? You could say that's a
23 really complicated question, we don't know exactly which
24 piece, where it would go. But there's a point where you
25 the events are so traumatic you don't need actually need

1 the -- I think a more concrete example would be like
2 engineering a car to withstand an accident that occurs once
3 every million miles. And the truth is there's
4 uncertainties in that modeling. So one way that you might
5 handle those uncertainties is we'll actually model for two
6 million miles. In other words, it may make sense -- if we
7 believe that a 100-year benchmark is to right benchmark to
8 think about from a point of view, then we recognize there
9 are areas with uncertainties, maybe we ought to be
10 instituting a 200-year benchmark. Not because we believe
11 we need to be see designs that are robust for 200 years,
12 but that is a relatively simple way for engineering
13 compensation for all the uncertainties that we're hearing
14 about. But mostly I think it would be great to act, but
15 plan to learn and iterate.

16 PROFESSOR SCHULTZ: I concur with the sense of
17 the panel that I think it is time to act. From my
18 perspective, the proposed standard is physical framework.
19 Even if one were to require use of three-dimensional
20 information, either in the form of the impedances or the
21 conductivity models were available, that's actually a very
22 small change of the standard. To me, it's a very small
23 change in the technical implementation. So I don't think
24 one should hold up the entire process on that basis,
25 whether from the FERC perspective that means an amendment

1 to the standard downstream or some other approach is
2 outside my area. I'd like to comment that as one validates
3 against actual GIC measurements in this 3-D world, it's not
4 a simple matter of multiplying something, you don't just
5 get a simple scaler relationship that I will fit the
6 measured GIC's better by observing a bunch of GIC's and
7 then multiplying the magnetic field by an approximate. As
8 a storm, geomagnetic disturbance, happens it's actually
9 energizing varying volumes of the ground beneath the power
10 line to different depths, and that changes with time. So
11 that means the three-dimensional effects are a bit more
12 complicated than that. But again, this is all within a
13 framework I think the standard can handle, so I don't see
14 any reason not to go forward promptly.

15 DR. BACKHAUS: So let me try to give and
16 perspective from another system that we now have to resort
17 to strictly modeling and the relation to guaranteed
18 reliability of. I don't speak in any way for Los Alamos
19 National Lab here. But nuclear weapons now are a complex
20 device governed by very complex physics and very finely
21 engineered systems that we have to certify the reliability
22 of once a year. The certification is not held back by the
23 fact that we don't have all of the best available science
24 because we probably never will because of the extreme
25 environments that those devices operate in. However, that

1 also does not stop the DOE from initiating science
2 campaigns which look at the long poles in the tent in our
3 lack of understanding of how to guarantee reliability. At
4 some point each of those scientific campaigns is no longer
5 the long pole in the tent and money is directed elsewhere
6 to address those. At some point perhaps GMD will no longer
7 be a long pole in the tent with respect to power system
8 reliability. And I would say that there be some space for
9 a process by which we assess, NERC assesses whether or not
10 this is a continuing uncertainty if it's the most important
11 one so that the resource materials should be focused
12 elsewhere.

13

14 MR. PULKKINEN: Again, I may be repeating myself
15 here. I believe your option one or two, I think again the
16 science is mature enough for us to take action now, and I
17 think, you know, the panel seems to be echoing that quite
18 well. But I also think, reflecting my personal thinking
19 here, that it makes sense to implement some kind of
20 procedure that will allow inclusion of related science and
21 engineering over time through communications with the
22 science/engineering world, with FERC, NERC, everybody, and
23 maybe having some kind of inclusion of that latest
24 knowledge into the standard.

25 MR. LAUBY: Thank you, Commissioner LaFleur. As

1 I mentioned before, my advice of course it to get the
2 standard up and running and get it approved and the
3 industry will start moving forward. Right now there's a
4 lot of uncertainty as to what the next step is, and it's
5 been some time since we met the directive to bring the
6 standard forward to the Commission.

7 I think once the industry starts moving forward
8 and starts doing the vulnerability analysis that they're
9 going to be needing to do in this four- or five-year
10 implementation, that they'll be putting up more monitors to
11 get more information, validate further, improve the models;
12 we'll continue to support of course the conductivity model
13 developments; and as we turn new credible information and
14 industry of course understands it, we do have mechanisms
15 available to us. Obviously keep the Commission informed
16 formally, as well as we do the FERC staff informally all
17 the time. But then we can certainly issue alerts if needed
18 to make people aware, as well as start advising
19 enhancements to standards so that could go in parallel.
20 There's a periodic review built into the standard process
21 built into a ten-year clip, again, just this is an
22 implementation of over five years, so we can take a look at
23 some thoughts there to take another review of it as well if
24 needed. But the main thing is to get it moving forward so
25 we can really start gathering the information, assessing

1 the vulnerability of individual transformers, continuing to
2 support some of the scientists we have here, continue the
3 dialogue with industry through the GMD task force, I think
4 are all mechanisms to bring the right people to the table
5 so that there's understanding, improvements, and continued
6 support by the Department of Energy certainly, but
7 certainly NERC, and the USGS certainly, and of course
8 Canada. Thank you.

9 COMMISSIONER LaFLEUR: Thank you. I think
10 that's a good point. In addition to the standard, and I do
11 have a strong bias for action there, we have the authority
12 to direct assessments, to direct data production, to
13 protect increasing protection given us by Congress and
14 CEII. So there are other things we can do.

15 Just to comment: Beyond whatever we do on GMD,
16 the whole thing I think is illustrating something about the
17 standard's process. Through the standard's process
18 increasingly over the last few years we've been applying to
19 it evolving and emerging challenges as opposed to
20 well-understood challenges. With all due respect to the
21 botanists, I think tree-trimming and how fast they grow in
22 different weather cycles and how you have to trim them is
23 fairly well understood, so you can debate about it. But
24 when you start talking about cyber security or GMD, there's
25 people who want us to look at EMP, which is a whole other

1 can of worms. We're looking at stresses that are changing
2 all the time.

3 And standards process is so slow: If we order
4 something then the team starts; then they file it; then we
5 do a NOPR; we ask for comments; then we write it again;
6 then we send it back; then we re-mandate it. If you look
7 at cyber security, we have three sets of standards
8 overlapping each other while we're reviewing one, because
9 the world is changing so fast. And I wonder whether we
10 need to start thinking about self-correcting standards that
11 have -- I know there are laws that have values in them that
12 you look every so many years and then we figure another
13 process, we're going to set this now, and not a full
14 process and then set is going forward, or something to
15 avoid the full standards process every time a threat
16 changes. Because threats are changing too fast for the
17 process we have. I don't want to make this one -- I don't
18 want to hold up this one while we design a new process, but
19 it's illustrating something that goes beyond GMD I think.

20 Thank you.

21 COMMISSIONER HONORABLE: Thank you for
22 enlightening us and offering your perspectives. Mr.
23 Roodman, to your reference of using the word "complicated".
24 I hail from Arkansas has a state regulator and we would
25 have to go before the General Assembly and explain why we

1 needed to -- or why we needed to pay some very, very
2 expensive consultant. We use the term "complex" often.
3 It's very complex work. One woman who was an outspoken
4 educator said look "I'm not a physicist, I'm not a
5 scientist, I'm not even a lawyer. I get it, it's
6 complicated. Move on."

7 (Laughter)

8 So to your presentations today, the fact that
9 it's complicated I think is an understatement. You all
10 have done a very good job of giving us just enough. I
11 agree, one of the panelists said we can talk about this all
12 day. And I feel much more enlightened about the task ahead
13 and honestly maybe a pathway forward. I heard a number of
14 you mention -- I'm from the South -- speak to you, saying
15 that we often use: "Let's not let perfect be the enemy of
16 good". And maybe we should get started on this path with
17 the thinking I think that it is Dr. Love mentioned that the
18 science is evolving, it will evolve, it will improve, let's
19 get on the journey. And also Mr. -- is it Kappenman? --
20 really I think strongly supports using the GIC data to
21 begin with. For me, the foundation will be key because
22 this work can evolve. But if we don't get it right
23 initially, even the work that we use to build upon that
24 could be flawed. And I recognize from hearing from you all
25 challenges with regard to getting complete data, that there

1 may be a lack of transparency. I do want to understand
2 throughout the day or another setting how we can move past
3 that.

4 But first I want to ask, I think Dr. Love spoke
5 in supportive maybe of the new GIC data, but I wanted to
6 ask the other panelists is anyone concerned about using
7 this data?

8 PROFESSOR SCHULTZ: I feel that there has been
9 an open accessibility of GIC data, and that's sort of the
10 ground-truth information that someone like me would find
11 very valuable. Keeping in mind in terms of concerns, well,
12 the power grid is a dynamic beast that's always changing
13 its characteristics, so it calibrates a GIC measurement
14 from one of these devices against a particular GMD at that
15 time, while the grid may change three weeks later or even
16 mere dynamically than that. So you do have that problem.
17 So, to me, it's a system where you're measuring this
18 ground-truthing, where you can, the data's available
19 openly, measure our impedances as we do, that data is
20 available openly, that's in the public domain, and I think
21 the openness issue is really the big question here.

22 MR. PULKKINEN: Maybe just a quick comment on
23 this, and I'm sure many of the other panelists today will
24 touch on this topic. The GIC is a real complex information
25 about the GMD process. What I do caution people is that

1 the GIC is a product of a number of different things: It's
2 a product of the geophysical content, the geomagnetic
3 induction process, the space-physical processes; and also
4 the basic characteristics of a transmission system itself.
5 And for you to be able to become more information from this
6 data, you need to have information about all these
7 different components of the problem.

8 Over the years my team and our group, we've been
9 doing a lot of collaboration with various entities, and we
10 have been working with the GIC data in close collaboration
11 with the utilities themselves, which ensures that we have
12 information available about the grid so we can extract this
13 information about the GIC. So my only comment is that:
14 Word of caution -- and I'm sure other panelists will go
15 into much more detail about this -- that this type of work
16 is utterly compacting very close collaboration between
17 scientists that have availability to the geophysical
18 observations and the utilities that have information
19 available about the transfer system itself.

20 MR. KAPPENMAN: Let me also discuss the utility
21 of GIC measurements. I'm going to disagree in part with
22 some of the comments of Dr. Pulkkinen in that, yes, it is a
23 deconvolution problem. There are multiple things that
24 enter into the physics of that actual GIC flow that occurs
25 on the power grid. That can be simplified quite a bit by

1 being very selective about the types of storming rifts that
2 we want to analyze. For example, we know that the sudden
3 commencement events produces a very broad uniform
4 geomagnetic field disturbance across wide areas. They can
5 be continental lay-downs. So we've removed the uncertainty
6 of variation in the geomagnetic field attached to that GIC
7 measurement. Then removing the complexity of the power
8 grid is a very simple process. Power engineers are very
9 good at that: We absolutely know the resistance of
10 transmission lines, transformers; we know physically where
11 the substations have been installed; and so forth. So
12 there's no question about the integrity of that
13 information. We know how the power system is configured at
14 any state in time so that, again, allows us to use Owen's
15 Law to resolve the geoelectric field, and so forth.

16 In regards to the complexity of the 3-D response
17 of the earth and so forth, I agree it's going to be very
18 complex. I'm not sure how many decades it will be before
19 we understand all that complexity. But in a simple sense,
20 we don't need to understand that because the power grid
21 does actually get the physics right on the GIC
22 measurements. It takes all of that complexity and figured
23 it out in the process and tells us in very simple terms how
24 to model that for purposes of power grid threat estimation.
25 If we look at the examples from the arrays, the

1 70-kilometer arrays and so forth, we're seeking factors of
2 100 uncertainty from one measuring location to another.
3 But the problem is that you've got a half million
4 unmeasured locations in between those two points that could
5 be, again, entirely different. So you get no averaging by
6 those 3-D complexity by these very small regional
7 measurements as they're being conducted. And that's why
8 GIC has much more relevant accuracy and utility to the
9 problem that we need to solve. And that's why it becomes a
10 very simple problem to solve if we start at that point.

11 PROFESSOR SCHULTZ: I feel the need to respond
12 to that. I think the last couple of statements lack the
13 physics in the magnetotelluric method. I don't understand
14 where this figure of a factor of 100 uncertainty from one
15 measure to another. There's variability from one location
16 to another because it's 3-D. You see strong changes in
17 conductivity, that doesn't speak to uncertainty in the
18 measurements. Actually, our measurements are quite precise
19 and we don't accept data from a site unless it meets
20 certain objective standards of confidence.

21 Furthermore, the physical process of relating
22 the electric and magnetic fields is an averaging process
23 over large volumes of the earth; it's not sensitive to the
24 conductivity just at that point. As a geomagnetic
25 disturbance carries on, it energizes the earth beneath it

1 with a spectrum of frequencies. Low frequencies energize
2 deeper and wider volumes of earth than high frequencies.
3 So as we collect the spectrum of measurements we're
4 actually seeing an integrating effect over the area between
5 the different measurement locations. So I just felt the
6 need to respond to that.

7 COMMISSIONER HONORABLE: Let me just ask that
8 you respond to my question, if you don't mind. But I
9 appreciate, you know far more about this than I do. And
10 you've pointed out there's a different point of view on
11 that point.

12 Dr. Love?

13 DR. LOVE: Yes, Commissioner. My short answer
14 to your question, is there anything bad about using GIC's?
15 I would say that I don't personally know of anything from
16 the standpoint of pursuing the natural sciences. There
17 might be some issues that are relevant for the power grid
18 industry, but I don't speak to those. So I don't see any
19 disadvantage to using GIC data. I just don't think that
20 they on their own are sufficient to address the issues that
21 we're taking on.

22 MR. ROODMAN: There was a good point to your
23 question. Antti made a good point saying that the data are
24 in effect analyzed in cooperation with the people that
25 produce it. Good point. But that in and of itself -- and

1 I don't think he meant to say this, I'm presuming -- that
2 doesn't mean that it would be harmful to make the data more
3 accessible. People that are not cooperative still bring
4 value to the science.

5 COMMISSIONER HONORABLE: Thank you.

6 Yes?

7 DR. BACKHAUS: So just to follow up on that, I
8 think people look at this, the GIC data by itself is not
9 necessarily all that useful. You need to have the
10 underlying model of the power system that the GIC goes on
11 and the current operational state under which those GIC's
12 were measured. So analysis of the GIC by itself could
13 potentially be very misleading without that other
14 information. And it may be that it's some of the utilities
15 that are saying that this is critical infrastructure
16 information, maybe realizing that this is in fact their
17 point of view, but to give up or transfer that GIC data
18 would then require transfer of operational states of the
19 power system.

20 COMMISSIONER HONORABLE: Dr. Love?

21 DR. LOVE: I don't disagree but I would say that
22 we have all information about the grid and its operational
23 state at the time the GIC data was collected. That kind of
24 additional metadata, or whatever you want to call it, is
25 also useful, especially if you want to make a very detailed

1 analysis of specific features in the data. But I would
2 also say that just having some broad GIC data easily
3 available, a catalogue of what's available out there so
4 that scientists can explore the data is also useful
5 because, perhaps this just represents the level of lack of
6 transparency, sometimes you just want to know if there's a
7 signal in the data. And we would like to know, for
8 example, when there's a magnetic disturbance and during
9 periods of magnetic disturbance is there a period of
10 disturbance in the GIC data? Can you analyze that
11 statistically? And that kind of general issue also has
12 merit. It wouldn't necessarily rely on all of the
13 specifics that we're talking about, but there is merit to
14 even this simple raw data.

15 COMMISSIONER HONORABLE: Thank you.

16 Yes?

17 MR. BOTELER: If I can chip in, I'd just like to
18 echo some of the comments that having access to GIC data
19 would be very valuable. And it's unknown exactly how
20 scientists would find ways of using it, so we need to give
21 them that opportunity. But generally the problem we're
22 looking at, I much rather handle it -- we got the magnetic
23 disturbances; then the earth conductivity; the power grid
24 model to get the GIC. I'd much rather view that forward
25 problem and get all of the information about that and then

1 use the GIC measurements as validations of those models.
2 When we can do that, because ultimately that forward
3 problem which we need -- because we don't have GIC
4 recorders from 100 years forward, we're trying to estimate
5 what's going to happen. So we're going to rely on our
6 estimates of the 100-year event and then all this modeling
7 steps. So I'm much more comfortable using GIC as
8 validation rather than doing the inverse problem with that.

9 COMMISSIONER HONORABLE: I'm glad you jumped in
10 with that fact, and I saw a couple of heads nodding in
11 agreement. Thank you.

12 MR. BARDEE: Thank you. Let me turn next to any
13 of the staff. Starting with this side of the table, if
14 they have any questions?

15 MS. POINTER: I just have one question. I hear
16 a lot about the uncertainty -- let me back up. I'm looking
17 at it as an engineer, not as a physicist or anything. And
18 sometimes we kind of get too bogged down in getting the
19 number just right, the same way Commissioner Honorable said
20 "don't wait for perfect". But just thinking about it, just
21 say from a logical perspective, say if I have all these
22 variables and I know the answer is around about say 20, I
23 always add in a little buffer. I'm speaking to the
24 gentleman, Mr. Roodman, I call it the fudge factor. Would
25 that be something reasonable that -- there's been a lot of

1 work already done, and say not to discount that, but just
2 as an engineer looking at it, if I have all these moving
3 targets variables, we talk about conductivity differing
4 from the -- is there, and I'll just call it a "fudge
5 factor", that would be appropriate or reasonable? Again,
6 that's adding some other uncertainties, I think that would
7 give some people some comfort in addition to allowing the
8 additional research to continue.

9 DR. LOVE: Is it okay if I respond?

10 MS. POINTER: Sure.

11 DR. LOVE: It's a very interesting and important
12 question. This comes back to the question about being
13 modest about what we know. I guess the fudge factor kind
14 of depends on how the models and the numbers are going to
15 be used. If one is integrating over geographic regions,
16 then detailing knowledge -- or detailing factors, let's put
17 it that way -- of what conductivity we have in that county
18 versus another county is going to be integrated over. But
19 to do the integration, one must know the function over
20 which one's integrating; that's Calculus 1. So there is
21 definitely uncertainty involved in just assuming from the
22 get-go that we're going to use these 1-D models.

23 I will just say, though, that when we look at
24 the 3-D work now with the new magnetotelluric data that we
25 have now from our scope that is terrifically powerful, it

1 tells us there is this spread, that's that geographic
2 difference. And that geographic place-to-place difference
3 is substantial. So generally speaking, say if we're
4 talking about magnetic variations -- and I'm going to get a
5 little bit technical here -- at 100 seconds, you can expect
6 geographic differences in conductivity varies from one
7 place to another by about four orders of magnitude, that's
8 a factor of 10,000, all right. The geoelectric field that
9 would be corresponding to that factor of 10,000 difference
10 in electrical conductivity is about a factor of 100, it
11 guess knocked down by the square root. A factor of 100
12 uncertainty in geoelectric field from one place to another
13 is substantial, but if you integrate over it it can go
14 away. And that, again, comes back to that issue of how the
15 data are used, how the models are used. I'm sorry, I can
16 only tell you from the natural science perspective that
17 that is the sobering kind of uncertainty that's involved.

18 MS. POINTER: Thank you.

19 MR. PULKKINEN: Just a quit comment on the fudge
20 factor. A little bit more technical term in our field
21 would be "quantification of uncertainty associated with the
22 problem". And I think this pertains also to Jeff's
23 comment. In the statistical work that went into this from
24 the standard of: We spent a lot of time, even as a part of
25 the GMD task force when I personally spent a lot of time

1 here at FERC trying to communicate to the engineering
2 community that we do have to come up with the number. The
3 level of knowledge, it's not selfish for us to give you a
4 single number. All of the numbers that we're going to be
5 giving you are going to be associated with range of
6 uncertainty. And one way this can be implemented is when
7 we review these tests of establishment and extreme analysis
8 is that you can take the upper bounds of these uncertainty
9 factors. This is actually is the approach we took in the
10 standard, we implemented the higher upper bounds of 95
11 percent confident unit to come up with the data in the
12 100-year. So from the physics standpoint and the occlusion
13 of the fudge factors can be implemented by looking at the
14 quantifications of uncertainty associated with the problem
15 you're viewing.

16 PROFESSOR SCHULTZ: I think uncertainty is the
17 moving target or upgraded uncertainty is where you have no
18 data. Now, we have data, as Dr. Love has mentioned, over
19 half the country. And at those points we know to a good
20 degree of precision what the relationship is between any
21 given magnetic field and the electric field that is
22 adduced. So that could be quantified, regardless of
23 whatever variations in the underlying conductivity. Where
24 we don't have any information we really have a problem in
25 trying to establish an engineering safety factor based on a

1 standard that assumes a known conductivity. And it's
2 challenging, as Antti has said there have been efforts made
3 in the standard to deal with that. I think this ultimately
4 boils down to an engineering question, the uncertainty as
5 I've mentioned varies geographically. There are going to
6 be places where, keeping in mind if you start putting in
7 large fudge factors, you're driving up the cost of the
8 industry to comply with this, so you have to be very
9 judicious in using those. So my way of thinking is you
10 eliminate uncertainty to the greatest success possible by
11 acquiring the data necessary to tie it down.

12 MS. POINTER: Thank you.

13 MR. LAUBY: May I add just a little bit more?
14 Because there's a lot of fudge going on here.

15 (Laughter)

16 But at least now we have it defined. We also
17 have some conservatives, I'll call it, in the amperage
18 itself, 75 amps on the peak, which this is kind of an
19 instantaneous peak if we actually look at it much more
20 broadly. If you look at the standard of what's being
21 active for long-term, over-30-minutes sustained amperage,
22 and we usually don't see that in these kind of events. And
23 I think also the idea that the field itself moves quite a
24 bit, and again our amperage of the 37 amps is conservative.
25 And then of course you heard about the voltage of the

1 medium of 6.5 volts but with the 95 percent uncertainty you
2 get the 8 volts. So we've had quite a bit of conservatism
3 built into the reaction, especially the thermal impacts of
4 the transformer, as well as of course the actual curve
5 itself or the benchmark itself. So I think that all helps
6 a bit. I understand your concern, and we want to make sure
7 we err as conservative as possible while still taking into
8 account the cost of the implementation.

9 MS. POINTER: Thank you.

10 MR. ROODMAN: Just several people have made the
11 point that the ideal answer to your question involves
12 thinking about cost, because there is a balancing act here.
13 And so if it turns out that meeting these standards
14 proposes are horrendously expensive, that might be an
15 argument for taking an even more conservative, and in fact
16 maybe even loosening it. On the other side, it turns out
17 that complying with this proposed standard it costs very
18 little, that would be an argument from an economist's point
19 of view. So it seems that dataflow would be useful going
20 forward.

21 MS. POINTER: Thank you.

22 MR. AYOUB: I have a couple of questions, I'll
23 make them quick. My first question is on the
24 spatially-averaged kilometers. So, if you look at the
25 NOPR, the proposal was to maybe look at both. So my first

1 question is: How do you foresee changes to TPL 007 to
2 incorporate maybe looking at not just spatially-averaged
3 but looking maybe at both spatially and non-spatially
4 averaged, and maybe the pros and cons for using that?

5 MR. PULKKINEN: I'll respond on the science side
6 of this, and I'll let Mark deal with the TPL. I think one
7 of the big I would say discoveries over the past several
8 years when we started looking at this, thanks to that
9 enhanced communication with the engineering community we
10 discovered that a lot of these extreme geographic field
11 enhancements due to the source structure are spatially
12 localized. A lot of the earlier analysts over the years
13 have been building statistics of looking at extremes of
14 using that from a viewing station. And what we realized at
15 that point was that it would be very wrong to apply those
16 single station statistics to uncover reasonable data; from
17 a physical perspective, that would be wrong. So that's
18 when we started looking for a means to characterize the
19 extremes and extreme geomagnetic fields as appropriate, and
20 that's where the spatial averaging came into the picture.
21 So from the scientific standpoint, there's a very solid and
22 sound scientific reason for starting to look at this,
23 again, because it would not be appropriate to apply single
24 station extremes over original or wide areas.

25 MR. KAPPENMAN: Could I add some discussion to

1 that? In fact, there is data that shows for extreme events
2 there can be a much broader lay-down than what to Dr.
3 Pulkkinen has asserted in various publications that he has
4 done. For example, I looked at one of his publications
5 where he was looking at a small array of magnetometers in
6 Finland and making the argument that the lay-down of that
7 extreme event only extended about 500 kilometers. When I
8 started adding in observatories on outside of that little
9 single array that he used, I found that it actually
10 correlated across nearly 7,000 kilometers. It wasn't just
11 limited to that very small footprint.

12 In addition, we have GIC observations that call
13 into question this idea that these are small footprint
14 events. For example, AEP published data in the July 15,
15 2000, storm that showed simultaneous GIC's in Indiana, West
16 Virginia, and Virginia, all peaking at the same time.
17 Again, access to this sort of data will guide us best as to
18 what the nature of the extreme events are. But we also
19 know that, looking back at extreme events like the May 19,
20 '21 storm, we saw the Auroral expansion going all the way
21 down to the Puerto Rico, Tuscan area, spanning all the way
22 from Canada to those regions. And, again, that calls into
23 question some of the observations that Pulkkinen says about
24 ionospheric saturation and so forth for big storms. So,
25 again, I think a better analysis and more complete analysis

1 of data sets that he does not consider needs to be done in
2 order to get to the true answer of this.

3 MR. PULKKINEN: Okay, maybe I'll respond to
4 that. I don't know if it's lack of understanding of the
5 physical problem or what the problem here is. I think John
6 misunderstood in this is that there is a very two-faceted
7 nature associated with GMD. In one sense you can't have
8 global activity during geomagnetic storms. But we think
9 that single storms you will have localized elevations in
10 that activity. The NLJ used for a more public speaking
11 kind of presentations is the analogy within the
12 thunderstorms. You will have thunderstorms coming in and
13 you will have a stormy period within your area of interest.
14 But these localized extremes associated with these storms
15 are almost like lightning strikes: They tend to be not
16 only temporary but also spatially localized. The
17 differences of a measure or reflection of the very
18 turbulent character of the near space, we know that the
19 ionosphere qualities operating in the duration occurring
20 during the storm times are very turbulent. And this is
21 nothing more about the reflection of that turbulent nature.
22 So you will have overall elevation of activities over very
23 large areas in the Northern and Southern hemisphere, but
24 within that elevation you will have these hot pockets, the
25 high spirals within the turbulation, if you wish. So there

1 are these two facets associated with this problem, and from
2 the physics side what exactly is the key physical process
3 that creates this localized enhancements, that's still TBD.
4 We observe these things; we see those in data; we seem in
5 the magnetotelluric rate that are dense enough for us to
6 detect them. But the physical process actually really
7 behind these are still TBD, and this will actually be one
8 of the more interesting scientific problems that we're
9 going to be attacking over the years. But this is an
10 observed fact.

11 MR. AYOUB: Thank you.

12 Yes?

13 PROFESSOR SCHULTZ: I'd like to bring up that in
14 your packets in the digital form there are various
15 animations showing real data collecting. There is such an
16 example that Antti refers to, we've actually completed a
17 measurement episode in the anterior of Alaska of a large
18 array of magnetotelluric stations. What was special about
19 this place was there was also an ionospheric imaging
20 system, an infra-scattering system, an optical imaging
21 system. For the first time a large synchronously operating
22 magnetotelluric array was operated under the footprint of
23 such an imaging system. And we captured some modest scale
24 GMD's, and you see exactly the effect that Antti's talking
25 about. Yes, you see a wide area affected by this GMD, but

1 in addition you see local intensifications of the magnetic
2 field, as well as the resulting electric field. So this is
3 sort of an established fact and not just model conjecture.

4 MR. BARDEE: If I could ask a follow-up on that.
5 Accepting the entire description you just provided, which
6 is sort of intuitive, you would think it's like that. I
7 think one of the concerns or problems we have with the
8 record is: We don't have a whole lot of information on
9 this stuff besides what's the scale? What's the distance
10 that you would average that would be appropriate? Whether
11 it's a large scale, a very small scale. And one of the
12 ideas that came in through comments here was: Well, to try
13 to deal with that lack of data, take a hotspot model and
14 run it a few times over different pieces of equipment on
15 your system, over this part of your system, over this part
16 of your system, and if you're assuming there's a hotspot
17 that's maybe 50 kilometers-100 kilometers, what does it do
18 your system when you place it in different places? Would
19 that be a good way to deal with that lack of uncertainty at
20 this point?

21 MR. KAPPENMAN: In regards to the size of the
22 hotspot, again, physics tells us that this is derived from
23 an overhead current system in the ionosphere; that's
24 approximately 100 kilometers overhead. In order for that
25 current to radiate a field down, it radiates at $1 \text{ over } R$,

1 assuming it's a line current. So that really eliminates
2 the idea that the hotspots are going to be as small as 100
3 kilometers just because of the physics of that. You have
4 to have a current that connects through. When you get into
5 extreme storms, you're not going to have as many of these
6 little twists and turns that you see in the more-frequently
7 observed small storms. It kind of becomes a difference
8 between widely-standard showers and a hurricane. And
9 obviously within a hurricane there will be intensifications
10 that occur. But, again, I would say we would be really
11 going down a wrong track in regards to the physics to
12 speculate that these are going to be small regional
13 hotspots. They are going to be generally much more
14 pronounced within -- especially as you get into the extreme
15 storm events.

16 DR. LOVE: I'll just respond to this issue about
17 hotspots. It's not terminology that I normally use, but
18 that's all right. In terms of kind of localized
19 realizations of geoelectric fields, there are two factors
20 that effect that: It's the localization of magnetic
21 activity; and it's the localization of earth conductivity.
22 So we could talk all day about space-weather, but if you're
23 not also talking about the complexity of the solid earth
24 than it's just not realistic. So there can be very
25 localized realizations of intense geoelectric fields.

1 I am going to stay out of the issue of how that
2 information is used, but that is a fact, but it's useful to
3 know that. Having said that, again, the dispersion of
4 these kinds of results geographically kind of look like the
5 average that is being used at NERC, so.

6 DR. BACKHAUS: So I think what we're all talking
7 about here are fluctuations in geomagnetic fields and
8 geoelectric fields. And I think Dr. Schultz has pointed
9 out quite well is that the geomagnetic field gets filtered
10 through some properties of the earth to produce a
11 geoelectric field. And I think what you're getting at is:
12 What is the appropriate filter to apply then to geoelectric
13 fields spatially varied, temporally varying, and turn it
14 into the voltage sources, the long-dominant voltage sources
15 that are used within power models to estimate GIC effects?
16 The relevant light scales there cannot be predefined within
17 the standard; they have to be associated with the system
18 that is doing the filtering. And that system is the
19 transmission system that is doing the filtering. That's
20 what will define the appropriate spatial scale for setting
21 those filtering parameters, if you want to call it that.
22 So I'm not sure that you can set that a priori; it needs to
23 be associated with the system on which the geoelectric
24 fields are being applied.

25 MR. AYOUB: Meaning that if you have a system

1 that is typified by short lines, you would look at it
2 differently than a system that has very long lines?

3 DR. BACKHAUS: Yes, that's intuitively what I
4 would think. But short lines between the appropriate
5 points within the system in which GIC's cannot return.

6 PROFESSOR SCHULTZ: And it's not only the length
7 of the transmission line, as particular topology, but
8 what's sitting on top in terms of geologic structure.

9 The other point I'd like to make is, while you
10 aspire to integrate in some longer distance and finding an
11 averaging-out of some of these more local effects, in fact
12 it might not be necessary to do that from a technical
13 perspective. Where you do know impedances along the line,
14 then the integration distances are actually quite small
15 because it's just the spaces between your measuring
16 stations. At that point it's a question of really
17 software, whether the software used by a particular utility
18 can handle those nonuniform electric fields, and as I
19 understand that's no longer such an issue.

20 DR. LOVE: It's such an interesting question.
21 So this issue about localized hotspots and all: I also
22 would like to point out it depends on the frequency of
23 variation that's of interest, all right. If you're talking
24 really high frequencies -- I had a question before about
25 EMP's, not something I do -- really high frequencies are

1 going to have really localized effects. But as you go to
2 longer and longer periods, the geography of averaging
3 increases. So we have this EarthScope data; it's been
4 collected at 70 kilometers; it shows good coherence from
5 one station to another at periods of 100 seconds and
6 longer, okay. I believe -- and I'm happy to be
7 corrected -- that 100 seconds and longer is kind of an
8 interesting set of periods for the electric power grid
9 industry. Maybe really high frequencies are less
10 important, I don't know. But in terms of natural
11 geomagnetic field variation, there's an awful lot of
12 natural variation at 100 seconds and longer. And so that
13 means that 70 kilometers -- the light scale is not going to
14 get shorter than 70 kilometers really, except in some
15 really special places like Northern Minnesota where there's
16 some really complicated earth conductivity, but that's an
17 exception. Most of the survey data shows good coherence
18 from one station to another, and that is very reassuring in
19 terms of the quality of the data and the inferences we're
20 making from it.

21 MR. LAUBY: I think, Mike, you postulate a
22 classic engineering approach, which is: What am I
23 designing to? And, then, also I take it to the next step,
24 I push it harder, and see how robust is this, how close am
25 I to voltage instability, for example. And so if I do the

1 8 volts, for example, and I come across an okay, maybe I
2 have an action plan I got to put in place, now let's go to
3 10, see what happens. Maybe I go to voltage instability,
4 what's my backup plan, then? So now I'm into like what's
5 my plan after? We look at the transfer capabilities, we do
6 that with transfer stability all the time, we look at the
7 bulk loads, we look at capacity of lines. So these are
8 kind of like extreme events, right, beyond the design
9 basis. There's something to that. But right now the
10 science is not exactly what that number should be for that
11 next kind of extreme event. But I think it's something we
12 need to continue.

13 MR. AYOUB: Just a follow-up on the 3-D
14 modeling, I understand by 2018 we will have half of the
15 United States. But what you have right now I noticed you
16 mentioned that -- even that you mentioned the data you've
17 looked at what NERC's model was -- and I believe you said
18 something along the lines -- there wasn't much difference
19 between the 3-D maybe that you have, or have you validated
20 the NERC model using the 3-D?

21 PROFESSOR SCHULTZ: The NERC model is based on
22 regional 1V. What we've seen is that the conductivity
23 structures that we actually obtained are actually quite
24 different -- within any given region are quite different
25 from the NERC model with the variations, as Dr. Love has

1 said, perhaps four orders of magnitude in conductivity
2 within a given depth of that model. So when we then
3 compare that to our actual measurements of electric and
4 magnetic fields, you see how strongly that underlying
5 conductivity structure maps to a very different
6 relationship between the electric and magnetic fields.
7 It's complicated: A small variation in a magnetic field
8 can actually lead to a very large variation in electric
9 field direction; a small change in magnetic field amplitude
10 can lead to a very large change. So the question really
11 going back to the hotspots and tying it all together is:
12 Could you integrate over enough of these so that in some
13 sense it averages out and maps more closely to a NERC
14 model? To me, the answer is probably there are places --
15 and there's some demonstrations of this -- where it's a
16 pretty good approximation and it seems to be working fine,
17 but there are going to be other places where I would assert
18 that that doesn't hold. And at this point we don't really
19 have a firm foundation for saying definitively we can do it
20 one way or the other.

21 MR. AYOUB: Thank you.

22 MR. BOTELER: If I could interject a couple of
23 comments: (1) In comparing these load models with the new
24 data that's becoming available, where does this model come
25 from? Well, just from my review of the literature of the

1 varying studying that EarthScope is doing, I think this is
2 a perfect example of just have more data that becomes
3 available, we get better information, things are going to
4 change. And perhaps in terms that needs to be
5 accommodated.

6 The other point I'd like to make is just to pick
7 up on the comment made about the tie-in between the geology
8 or hotspot, the natural phenomena and the system. When we
9 got perhaps not a hotspot but an area where we know there's
10 going to be a localized strong electric field, that is the
11 Coast and the kind of initial studies that we've done of
12 the Coast effect shows that you got a spike at the Coast,
13 it falls off as you go inland. Now, that fall-off changes
14 the amplitude, changes the frequency, the spatial scales
15 that fall off changes the frequency, so very much what
16 you'll get on the pacific power line when you start to put
17 that into the logical grid and you integrate say your first
18 line from the substation right on the Coast to the next one
19 inland is 50 kilometers, what you need is the voltage for
20 that 50 kilometers, your integrating for that. Now, at
21 some frequencies the scale length is about some-15
22 kilometers along the frequency, so it changes the whole
23 thing. Then if you got a different substation in there,
24 it's going to be 20-kilometer difference. So it's all very
25 much tied in: How the effect it has is going to be very

1 much tied in with this combinations of the natural
2 phenomena and the network. The model capability is getting
3 to the point where we can handle all that, it's just a
4 matter of running the models for each situation into that
5 grid.

6 MR. AYOUB: And do the model stations take into
7 account the boundary effects across the lines currently?

8 MR BOTELER: They don't have the model
9 development currently.

10 PROFESSOR SCHULTZ: The three-dimensional models
11 that we've been producing most certainly do. The Coast
12 effect is just an extreme example of three-dimensional
13 conductivity dimensions. EarthScope carries out the
14 70-kilometer grid work, but it also does more fine-scale
15 work. And we recently completed an amphibious
16 magnetotelluric project where we had 160 stations
17 half-straddling the coastline of Oregon and Southwest
18 Washington going all the way inland, as the other half
19 going offshore. So we have, if you wish, the definitive
20 test of the Coast effect. And as David Boteler has
21 explained, it does depend on frequency. But we can see the
22 Coast effects hundreds of kilometers inshore in some
23 circumstances, so there's no hard-and-fast rule, but
24 certainly the models do accommodate.

25 MR. BARDEE: We've got just a little time left.

1 MR. WAGGEL: I had several questions here but I
2 see we're coming up on lunchtime here so maybe I'll save
3 them for the next panel. Maybe this panel, some of the
4 physicists can clarify a few things. One is: When we talk
5 about wide-area and localized events, what type of areas as
6 far as geographical areas are we speaking when we're
7 talking about localized events? How much of an impact?
8 Would that be 100 kilometers or would it be less than that
9 or more than that?

10 MR. PULKKINEN: One of the pieces of information
11 is the separation between the stations you're using to
12 detect the enhancements. And that was the primary reason
13 why we had to use the image network to investigate this.
14 At the densest portion of the network, the separation of
15 the stations is an order of 100 kilometers or so. And
16 there are instances where we see the enhancements from one
17 station to another to change by a factor of 5 to 10. So we
18 do see a significant falloff of these perturbations over a
19 distance of 100 kilometers. I think if we use the
20 scientific terms, we would have to deploy a much denser
21 array of magnetic field measurements and maybe full-empty
22 stations and wait for these storms to really start gauging
23 the details of the spatial scales associated with this.
24 Now we see available information to us, which is dictated
25 by the spacing and reduced even over the 100 kilometers or

1 so.

2 MR. WAGGEL: I guess my concern here is the way
3 that wide area was defined; but it seems to be defined on a
4 geographic basis. And that was defined roughly I think
5 it's 96,000 square miles, it's where they looked at 105
6 kilometers. But if you look at a more localized aspect,
7 say for instance New York City which is 300 square miles,
8 it's not technically defined as a wide area but it has a
9 lot of people there and it has a real big impact to those
10 people themselves. So whenever you average these fields
11 over a large area and then apply it to a place like New
12 York City which may see the actual localized impacts, so
13 localized fields, do you feel that's a correct method for
14 evaluating the impact of Washington D.C. or New York City
15 or any place like that?

16 MR. PULKKINEN: I think that's more of an
17 engineering question, maybe Mark may have some comments on
18 the engineering side. But, again, I repeat from the
19 science end and purely physics standpoint, we do have these
20 two sides to this phenomena. You do have these localized
21 enhancements that take place during extreme storms. And it
22 is not appropriate to use those localized enhancements to
23 the field over wide areas.

24 MR. WAGGEL: Just one more, and you may be able
25 to answer it. It deals with the way the dynamics of the

1 storm itself, if you compared it to the thunderstorm before
2 and how it would come through and move through an area,
3 when I look at a lot of these animations of let's say, for
4 instance, vectors of electric fields, and as you go through
5 them it's a different process for a large area. Now, my
6 concern here is: If that's the way a storm acts, is it
7 possible that you could have it pop up in one area, have a
8 localized impact for instance take out a station
9 transformer, and then actually have it move on and take out
10 another localized area? And what I'm getting here is:
11 Maybe they're localized impacts that eventually would add
12 up into sort of an cascading outage here.

13 MR. PULKKINEN: That's the reason why I used the
14 analogy. Because right now there's been the exception
15 about these things moving around let's say a tornado
16 fashion over large distances. The storms that we have
17 observed since the 1980's, we do not see this kind of
18 tornado moving around type of thing. These enhancements
19 are localized both in space and in time, which means that
20 they appear at certain stations, we detect them, and then
21 they go around, but they do move around across areas. That
22 is what we have observed for all the storms over the years.

23 DR. BACKHAUS: If I could make one last comment
24 on that. And that the question is, this is not just a
25 spatial question but it's a temporal question, it's

1 associated with what power system in effect you're trying
2 to analyze. And I believe the averaging scales, if that's
3 what you want to talk about, are dependent upon what impact
4 you're looking at. I believe the situation you were
5 primarily getting at was perhaps operation and protection
6 because of harmonic generation. That's going to be a
7 localized -- the spatial scales for that and the time
8 scales for that are much smaller and shorter for that
9 particular process than they are for something like voltage
10 collapse. And certainly they're shorter and smaller scales
11 than for transformer heating. So I think if you want to
12 address averaging scales both in time and space, they need
13 to be aware of the power system effects that you're
14 concerned with.

15 MR. WAGGEL: All right.

16 MR. BARDEE: Well, let me end this panel. Let
17 me thank all of our panelists for being here today and
18 offering such an interesting discussion. Unfortunately,
19 today still has two more panels because I'm sure we could
20 continue this discussion much longer. But thank you all.
21 And some of you will be seen this afternoon.

22 Let's take our lunch break. We'll be back at 10
23 of 1:00.

24 (Whereupon a recess is taken.)

25 MR. BARDEE: Welcome back everyone. If everyone

1 will take their seats, we'll get started with our second
2 panel for the day. We answered all the hard questions this
3 morning; we'll going to turn to the easy stuff now.

4 (Laughter)

5 Actually, before we get to the substance of the
6 second panel, just a housekeeping. Staff found something
7 right outside the room here on the floor, if you lost
8 something please check with Mary Agnes at the break. And
9 if you can identify it, you can claim it.

10 So let's turn to our second panel. And, again,
11 the issue is vulnerability assessments, a very complex
12 area. We'll start again with Mark Lauby from NERC.

13 MR. LAUBY: Thank you. And I want to thank the
14 FERC staff and my fellow panelists. My name is Mark
15 Lauby, I'm chief reliability officer at NERC. I appreciate
16 the opportunity to chat a little bit about the
17 vulnerability assessments and mitigation work within the
18 NERC standard.

19 The GMD vulnerability assessments required by
20 the proposed standard provides the framework for owners and
21 operators to evaluate the potential impacts of the
22 benchmark GMD event on their equipment and the bulk power
23 system as a whole. The process outlines in the proposed
24 standard coordinates the planning, modeling, and analysis
25 activities of entities into an integrated assessment of

1 risk. Recognizing that industry's understanding of GMD
2 impacts will continue to evolve, as we've heard this
3 morning panel, the proposed standard provides entities with
4 the flexibility to incorporate new models, tools, and other
5 capabilities in the vulnerability assessments as they
6 become available. The GMD vulnerability assessment process
7 identifies an entity's susceptibility to two primary risks
8 of GMD events on the bulk power system: First, the
9 reactive power support, which can lead to voltage collapse;
10 And second, the possible damage the powered transmission
11 transformers.

12 Using system models to calculate the adduced
13 current flows for the benchmark GMD event, these models
14 represent the direct current characteristics in the
15 transmission system, including applicable power
16 transformers, transmission lines, and reduced current
17 reduction or blocking devices. In order to realistically
18 assess the voltage impacts of the severe GMD event, the
19 models must consider the potential equipment impact that
20 relate to the harmonics had on transmission models,
21 including protection systems and reactive power
22 compensation devices. The geomagnetic data-induced current
23 flow information at each applicable power transformer is
24 used with electric models to determine the maximum reactive
25 power losses. These reactive power losses are applied to

1 power flow analysis to determine if the system is at risk;
2 this can occur in a matter of seconds rather than minutes,
3 and these models have been validated. You'll hear more
4 about that from my colleagues here on the panel.

5 To determine the additional transformer heating
6 that could be caused by a benchmark GMD event, entities
7 would use thermal models and geomagnetically-induced
8 current flow information of a benchmark GMD event to
9 conduct transformer thermal impact assessments. The
10 proposed standard does not require detailed thermal
11 simulation for a transformer that experiences
12 geomagnetic-induced currents with an instantaneous peaks.
13 And those peaks lasting less than ten seconds of less than
14 75 amps per base, that will lead into discussion. NERC
15 analysis which used validated transformer models indicated
16 that worst-case heating of an otherwise-healthy transformer
17 would not exceed the IEEE industry equipment standard
18 C57.91.

19 In the next step of the GMD vulnerability
20 assessment process, entities would evaluate the results of
21 the power flow analysis and transformer thermal impact
22 assessment according to the proposed standard assessment
23 criteria. Where necessary, an entity would develop a
24 corrective action plan to mitigate the vulnerabilities and
25 meet the standard's performance requirements. Throughout

1 the process, entities would share the analysis information
2 with other organizations, thus supporting a wider area
3 view.

4 The modeling and analysis techniques forming the
5 technical basis for a proposed standard are leading edge,
6 evolving through collaborative partnership among industry
7 experts, researchers, software application vendors, and
8 equipment manufacturers. In recent years a number of
9 vendors have introduced software tools that enable entities
10 to gain experience in analyzing GMD impacts. These tools,
11 along with the development of the GMD task force technical
12 guidelines and the GMD reliability standards, establish a
13 consistent, engineering-based approach for addressing the
14 risks that severe GMD events could pose to the bulk power
15 system. To further advance the tools and techniques for
16 assessing and mitigating GMD impacts, NERC maintains an
17 active research effort through the GMD task force and other
18 partners. For example, NERC completed a technical report
19 recently containing considerations for specifying and
20 evaluating current reduction devices.

21 NERC is committed to work with industry and
22 other partners during the proposed 48-month implementation
23 period to improve the available simulation model validated
24 by measured field data to support the thermal impact
25 acceptance. Therefore, NERC urges the Commission to

1 approve the proposed standard. As mentioned above, NERC
2 remains committed in working with the Commission and the
3 industry to continue our research and gather new data to
4 inform our standards. Thank you and I look forward to
5 addressing your questions.

6 MR. BARDEE: Thank you, Mark.

7 Next we have Dr. Luis Marti from Hydro One.

8 DR. MARTI: As you said, my name is Luis Marti.

9 I hold a position with director reliability studies
10 standards and compliance. It's a long title that means I'm
11 mostly responsible for the folks that do special studies,
12 which is what ties into this. I have, according to my
13 notes, 30 years of experience in the modeling assimilation
14 of transience. Okay, that's a long time to do those
15 things. And I got my PhD and master's degree from the
16 University of British Columbia in British Columbia, Canada.
17 I have served as a professor in four universities:
18 Ontario, Toronto, and two others, Lake Myers and Western.

19 So, what I would like to do here today, and
20 based on what I saw this morning with the panel, I will
21 give a very brief outline of the questions that we were
22 asked to address. And I fully expect that there will be
23 lots of questions, perfect. So the questions that I'm
24 going to -- the questions that I'm trying or I thought I
25 would address is the question of: Well, what is the state

1 of the knowledge of transformer thermal model? And after
2 that the question that I heard mentioned this morning, and
3 I will hear it again in the pursuit, which is: How did you
4 arrive, how does a SAT team arrive at a threshold of
5 certain -- and lastly why would you choose 1989 waveshape?
6 So I will address those very quickly, and I fully expect to
7 get an opportunity to answer questions afterwards.

8 So the next slide we can skip because it was
9 designed for ten minutes, not five. So right now the state
10 of the art for thermal modeling, there's about three ways
11 to do it: One of them is using finite elements; the other
12 way -- the problem with finite elements or one of the
13 things with finite elements is we have to have very precise
14 knowledge of the structure of where the last volt is. It
15 is very time consuming, I am told, and it appears to be
16 limited to just DC steps of current DC current. There's
17 another bit of thought that uses a proprietary empirical
18 formula that manufacturers have used and accumulated over
19 time and used in those designs. And they use those to
20 create -- one of the things they use is what they call
21 capability curves. So basically it says, in the next page
22 of course, it says -- what does it say? -- it says
23 something for like two minutes you can withstand 200 amps
24 per phase, 300 percent milliliter. So that kind of
25 information. That kind of information is off, you have to

1 somehow fit a square box into the performance of a
2 transformer.

3 So if you move it to the next page. That is the
4 next page? Yes, it is. So that's the state-of-art
5 technology in terms of modeling, in other words you have
6 this structure of the transformers, you have the model, and
7 you get the behavior. And the other way to do it is by
8 measurement. When you have a unit, you have the thermal
9 and you're going to suspect you're going to have heating,
10 you run it and see what happens.

11 Another way to do it was the realization that,
12 according to classical control theory and systems theory,
13 if you have the step response of function of a black box
14 and you know what those step responses are to a number of
15 stimuli, you can actually create a transformer function
16 that allows you to see what the results are. This has an
17 advantage that it allows you to not be restricted to just a
18 step of the step down, you can actually put an arbitrary
19 waveshape. So on the left, for instance, you see in the
20 red the ultimate value GIC from the benchmark event, and in
21 blue the temperature calculated for one of the
22 transformers. Is this accurate? Well, I think so. It's a
23 fairly straight-forward mathematical construct, again,
24 based on classics theory. So if you look at the right the
25 little staircase with the GIC steps that were used in

1 FINGRID tests in the '90's. And blue and red, and the blue
2 is the simulation, red is the measurement showing the
3 comparison obtained from those measurements themselves.
4 And the reason I know that blue is the simulation is
5 because they start measured sooner than we simulated in the
6 cool-down period.

7 So I'll try to go very fast with this. The 75
8 amp threshold, first of all it's instantaneous value, okay.
9 It represents an increase in hotspot heating of about 100,
10 over maximum operating temperature. And it does not take
11 into account the fact that according to IEEE 57.91 those
12 suggested limits over which you do not have a measurable or
13 meaningful degradation of the transformer for the lifetime,
14 will just be turned and not even take advantage of the fact
15 that you can last about 30 minutes at that temperature.

16 So the other thing that was to select the
17 threshold was that we have a number of models both based on
18 measurement, the information that the GMD task force gave
19 us, theoretical and whatnot. We use those: We put every
20 single simulation, every possible combination of current,
21 presenting any possible combination of transformer into the
22 system; we ran through those simulations, and this gets us
23 to what is shown as the green one and the red one, and
24 looked at the maximum. And the data that's interesting to
25 look at is that for the same 75 amps or 100 phase, you

1 could have different heating depending on where the
2 transformer is in the system. And that's something that
3 sometimes is missed, and I can talk to that a little bit
4 later.

5 And finally, why the benchmark waveshape? Well,
6 we looked at a number of events; we looked at even
7 different observatories, same event; we ran the thermal
8 simulations; and lo and behold it turned out that the
9 combinations are the waveshapes that we had available
10 because the one that ended up was with the highest heating.
11 And I will not go through the remarks because (1) I will
12 run out of time and (2) they said what I just said. Thank
13 you.

14 MR. BARDEE: Thank you, Dr. Marti.

15 Next we have Michael Steckelberg from Great
16 River Energy.

17 MR. STECKELBERG: Good afternoon. My name is
18 Mike Steckelberg and I'm senior transmission planning
19 engineer at Great River Energy. Great River Energy is an
20 Electric GMD cooperative with facilities located in
21 Minnesota and North Dakota. We are the largest electric
22 power supplier in the State of Minnesota. We supply the
23 majority of electrical needs for 28 GRE members,
24 distribution cooperatives in Minnesota. We own
25 approximately 668 miles of transmission line and 37

1 transformers that will be operated above 200 kV, which will
2 therefore require a characteristic review to comply with
3 the requirements included in the NERC TPL 0071 in the GMD
4 standard. In addition, the area has approximately 3,500
5 miles of transmission line operated at less than 200 kV
6 that are connected to the low side of autotransformers that
7 may contribute to the GIC current caused by the GMD events.
8 GRE is also a partner the 2020 project, which has recently
9 added additional 800 miles of 230 kV and 345 kV
10 transmission lines located mostly in Minnesota. GRV owns
11 and operates a 1,200-megawatt base load generating station
12 in North Dakota that supplies power over a 436-mile-long
13 HDVC transmission line. Located at both our converter and
14 inverter stations and the generator plants are large power
15 transformers, which are loaded at nearly full capacity
16 almost one hundred percent of the time.

17 Because GMD are real events -- we realize
18 this -- these events will continue to occur with some
19 degree of impact to the bulk electric system in certain
20 regions such as Minnesota, GRE supports the efforts to
21 develop a standard that starts the process to assess these
22 effects to the electric system. As a proactive effort, GRE
23 has installed ground current monitors in the large power
24 transformers such as HDVC terminals, correlating data for
25 the monitors that GRE gets. During a recent K6 event in

1 December of 2013, there were no significant changes to the
2 monitored GIC levels and these events caused no system
3 impacts, nor were any changes to the GRE systems
4 configurations needed during the event.

5 The reliability analysis of the electric system
6 is an ongoing challenge. New issues have come about
7 through the changing use of the system through the addition
8 of non-synchronous generation and new transmission
9 technologies, SDC's DFAX devices, longer transmission
10 lines, and market access. These issues have brought about
11 challenges such as increased harmonics and voltage collapse
12 due to the transfer of power over long distances. High
13 voltage caused by the addition of longer transmission lines
14 during light-load periods is also becoming an increased
15 planning and real-time operations challenge. These
16 challenges can be addressed through modeling, corrective
17 action plans, and feedback from transmission operators
18 about the effect on this solution. Effective devices such
19 as relays and remedial action schemes can be used to
20 protect the BPS by automatically adjusting the system to
21 avoid damage.

22 The analysis of impacts to the electric system
23 due to GMD events is another engineering challenge that can
24 be addressed through proper modeling or proper data.
25 However, due to the unpredictability of GMD events, even

1 the best modeling, the best data, will not entirely
2 eliminate the risk. Today, GRE has not experienced
3 equipment damage because of a GMD event. Using protective
4 devices using existing or new technologies will likely be
5 required as a backup to directive action plans developed by
6 transmission planners.

7 As a transmission owner and planning member of
8 MISO, GRE will develop ensuring processes to gather the
9 data necessary for the GMD assessments to meet the
10 requirements of the standard. Due to the fact that the
11 data required will be pseudo DC calculations, the data may
12 or may not be readily available, particularly for
13 transformers since they are quite old many of them. GRE
14 has begun the internal process of assessing the reliability
15 of the necessary data, and some of the data such as
16 transformer DC resistance, core form, shell form, number of
17 legs, et cetera is not really available on the standardized
18 computerized database record. Other information such as DC
19 drowing, resistance of substations, a line normally
20 operated at 60 hertz, locating the substations will also be
21 needed. A manual review of paper or digitally-scanned
22 records will likely be required to gather this data and
23 could take some time for a relatively small utility such as
24 GRE.

25 GRE supports the effort to develop a standard

1 that starts a process to assess the impacts of GMD events
2 on electric system. GMD are real events that will continue
3 to occur, and planning for these events reduce the risk of
4 emission assets is particularly important. It is important
5 that the GMD event assessment process move forward,
6 starting with the gathering of data necessary to develop
7 the models. GRE is confident that sufficient time will be
8 allowed for the responsible entities such as GRE to comply
9 with the requirements in the standards, which is why GRE
10 supports the approval TPL007-1, as filed with FERC to allow
11 this process to begin amendments. As a transmission owner
12 and planner, our staff are looking forward to working with
13 MISO, the GRE planning coordinators, to comply with the
14 standard. Thank you.

15 MR. BARDEE: Thank you, Mr. Steckelberg.

16 Next we have Randy Horton from Southern Company
17 Services.

18 MR. HORTON: FERC staff, fellow panelists, good
19 afternoon. My name is Randy Horton and I'm the manager of
20 transmission planning stability at Southern Company
21 Services located in Birmingham, Alabama. I have a PhD
22 degree in electrical engineering with a specialization in
23 electric power system, and I have over 17 years of
24 experience modeling and simulating power systems,
25 transients, and power quality phenomenon. I'm a senior

1 member of IEEE and have also served on various working
2 groups, including being secretary of that IEEE standard
3 519, which is the harmonic standard. I appreciate the
4 opportunity to be here with you today.

5 Over the past several years NERC and electric
6 utility industry have made significant progress in
7 understanding and addressing the reliability risks that GMD
8 events pose to the bulk power system. The proposed TPL7
9 standard is an important addition to the body of
10 reliability standards for the North American electric grid.
11 This standard is based on the most advanced information
12 available and is supported by rigorous scientific and
13 technical analysis. The standard is key in that it focuses
14 on protection against widespread bulk electric system
15 concerns, such as voltage collapse, cascading, and
16 uncontrolled algorithms, thereby adding to the overall
17 resiliency of the grid. We agree that Southern Company is
18 has encouraged the Commission to approve the TPL7 standard
19 as submitted. So, the focus of my remarks today are going
20 to be on harmonics and vibrational effects of the benchmark
21 GMD event. And I'll quickly go through the slide
22 presentation that I provided to you.

23 So, starting with sort of what the state of
24 knowledge and modeling capability is with regards to
25 harmonics and vibrational effects. The modeling capability

1 in the industry with regards to assessing the harmonic
2 impacts of what I would refer to as a typical nonlinear
3 drive in electricity, things of this sort, is very
4 immature. And the capability to perform those kinds of
5 studies have been around for decades. However, when you
6 take that same modeling capability and sort of fit it to
7 looking at harmonic impacts of benchmark GMD events,
8 there's a number of challenges that need to be overcome
9 before in order to do that on a large scale that's required
10 for benchmark GMD events. I've got a number of challenges
11 there, but I would kind of focus your attention to the
12 first one and the last one. The first one being in order
13 to do that in a TPL7-type setting, there has to be a
14 significant modification so the Commission and commercial
15 utility can have that be available to us.

16 And then lastly the harmonic impacts in a lot of
17 cases are very short-duration harmonics. The IEEE
18 standards -- I don't really have a whole lot to say about
19 short duration, but there's additional performance criteria
20 that needs to be assembled with regards to that. On
21 vibrational effects, when a transformer is in half-cycle
22 saturation they do create vibration, they create a
23 considerable amount of noise. But with regards to
24 reliability impacts, the technical community at large is
25 unaware of any transfer failures or reliability issues that

1 can be directly attributable to GIC-induced vibration.
2 From an assessment standpoint, we have really no
3 commercially-available models, tools, or performance
4 criteria to perform those types of studies.

5 Moving on to impacts of harmonics of protection
6 equipment, I'll move real quickly through this. Basically,
7 the potential impacts of harmonics on the protection
8 equipment -- which kind of leads into the next slide, which
9 is the impacts to reactive power sources -- are basically
10 dependent upon what type of protection: What kind of
11 relays you have employed; what type of element it is; and
12 what type of protection equipment is used to protect that
13 element; and then also the frequency response of the
14 instrument, which is frequently left out of discussion.
15 Now, in certain cases where the harmonics, protection
16 scheme may be employed, and what kind of element it is and
17 so on, if the harmonics is such that the protection scheme
18 can trip that element offline, you sort of have an issue
19 going on where you at the very time you need that reactive
20 power resource it's coming offline. So that's sort of the
21 negative impact of protection impacts on the reactive power
22 resources.

23 There's also questions that come up like, Okay,
24 we actually have harmonics, reliability impacts to that
25 capacity banker? There can be additional heating with

1 operational protection systems, as I mentioned before. But
2 from the additional heating and reliability or performance
3 of the actual element there's really not good assessment
4 criteria right now to determine that.

5 Impacts on generators: Harmonic current flow in
6 generator warnings does create additional heating in
7 generator routers. There's IEEE standards that limit the
8 amount of negative sequence current that a generator can
9 withstand, and also those standards have been updated to
10 include harmonics. Typically, the relays that are employed
11 today all have worked at 60 hertz quality, so they're kind
12 of desensitized to what the harmonic impacts of one
13 potential modification moving forward, if the applicable
14 entity determined this was a need you can install relays,
15 you can sense harmonics as well to kind of see the effect
16 of the negative sequence measurement. The key thing with
17 generators -- I kind of hit it on the first slide -- is in
18 order to do an accurate assessment of that, you really have
19 to do these full-blown harmonic studies on a large scale
20 that is necessary for a benchmark GMD event. And of course
21 all the modeling challenges that I mentioned previously
22 apply there.

23 System impacts related to reactor power demand:
24 This is kind of central to what the issue here is, the
25 saturation, they absorb a significant amount of 60 hertz

1 current that looks like a large reactive load to the
2 system. In the course of that, if it's significant enough,
3 you can have a voltage depression.

4 In summary, just kind of the key points:
5 Southern Company encourages the Commission to approve the
6 standard as submitted. Some key points for future worked
7 would be to develop commercial available tools that can be
8 used to assess harmonic impacts of benchmark GMD events.
9 Transformer vibration and audible noise that's a result of
10 half-cycle saturation do not appear to be damaging to power
11 transformers, and thus shouldn't be considered in the
12 standard. And announce that the potential system is a very
13 important aspect assessing the harmonic impact of benchmark
14 GMD events. However, there's a number of challenges that
15 I've pointed to, including development of new computer
16 modeling tools and also an increase in expertise. Thank
17 you.

18 MR. BARDEE: Thank you, Mr. Horton.

19 Next we have Professor Thomas Overbye from the
20 University of Illinois.

21 PROFESSOR OVERBYE: Thank you. I've got a slide
22 set, if you can bring that up. I have three main points to
23 talk about today, and I think they're actually three very
24 positive points. First, as Mark mentioned and some of the
25 other people have mentioned, we as an industry have made

1 tremendous progress over the last five years in modeling
2 the impacts of GMD's on the power system. If you look at
3 where the tools were five years ago and where they are
4 today, it's like night-and-day difference. It's a very
5 positive story. My passion in this area is to get tools
6 out to the engineers at the utility level who are going to
7 be the ones who have to deal with the GMD storm. And
8 regardless of what we set the standard at, the actual storm
9 they see is not going to be what is in the standard. And
10 they're going to have to have the flexibility to deal with
11 that and make the right decisions, so I want to help with
12 the rest of the industry get them the tools to be flexible
13 enough to deal with that. Here's an example of a
14 visualization where we took the NERC GMD storm and I was
15 playing around with adding hotspots, I think Randy said,
16 Hey, can you put hotspots in the software? So we put in a
17 hotspot. That big red spot there is a hotspot over
18 Michigan. And regardless of whether it's 100 kilometers or
19 200 kilometers, we can deal with them in software now. So
20 dealing with nonuniform electric fields is routine. And if
21 you look at the color shading there, that's the assumed
22 electric field as it implements at exponentially function,
23 so going from the North which is up by Lake Superior down
24 to the South, you can see the assumed fields in the
25 drop-off in the GMD's. By the time you get down to

1 Southern it's attenuated.

2 Things like visualization: This is a
3 visualization of where the GIC's would come out of the
4 ground, those are the red ovals, and go into the ground,
5 that's the transformer impact from a nonlinear storm, those
6 are all straight-forward to calculate now. These tools are
7 available. If the Commission changes something, I think as
8 someone who makes these tools, they can get implemented
9 very quickly. So I don't think you have to be concerned
10 about getting it out quickly.

11 We've talked about what's the worst case,
12 because the direction of the field has an impact. Now, if
13 it's a uniform direction but a nonuniform magnitude field,
14 you can automatically in the software calculate the worse
15 direction. So this is all automatic and it's available in
16 commercial tools now.

17 That's another type of visualization.

18 The second point I want to make today is, as has
19 been made earlier, GIC analysis is a work in progress, we
20 made a lot of progress over the last five years and that's
21 going to continue. It requires very interdisciplinary
22 collaboration between electric power engineers and people
23 that we usually don't talk to a lot, those who study the
24 earth and those who study the sky. Here in the U.S. that
25 work is funded to the large extent by the National Science

1 Foundation, and here my point would be very positive in
2 that that process is working. Our academics team up with
3 our friends in different systems to write proposals, and in
4 this case we got a very large project funded by NSL to
5 study the impact of GMD's on the power grid. We very much
6 want to work with the utility industry on this; we've had
7 very good prosperity, people like Randy have been very
8 helpful, throughout the industry. But we want to keep
9 doing that and moving forward and doing these studies,
10 working with advancing the science.

11 Because the science needs to advance. For
12 example, as part of this project we have four magnetometers
13 that we're going to install at various locations, and these
14 include the electric field measurements that have been
15 talked about. There's a picture of one there. We hope to
16 find two additional locations: One's going to be at Texas;
17 one's going in the University of Illinois. And we hope
18 somebody will come forward and say we have additional
19 locations to put these in. Because we really need the
20 partnership between the research community and the industry
21 moving forward on this.

22 There's a map of some of the work that's going
23 on on the electric field estimates. We're very coupled in
24 this research with the NSF Earth Scape, so it's very
25 complimentary to that. You need to take that data and

1 couple it with the knowledge that us power engineers have
2 about the grid and advance the science. That's not going
3 to help you make a decision today, but it's going to help
4 us as an industry continue to move forward.

5 And then the last point I wanted to highlight
6 was the need to get access to the GIC data. That's been
7 mentioned -- I have been trying to get access to GIC data
8 for many years and I very much appreciate the utilities
9 that have provided us data, we've done that under NDA's and
10 we're very appreciative of that. But it is a very
11 time-consuming process. So the more this data could be
12 made public or made more easily available to researchers,
13 that would very much help us with the validation that we
14 need to do. And a good chunk of this NSF project is
15 validation of the results, it is very coupled because you
16 have to deal with the storm that's overhead, you have to
17 deal with models of the earth, and you have to deal with
18 the power system. You do need to know operational
19 information about the power system in terms of what lines
20 are in service. We're working with Bonneville Power
21 Administration on a project and we need to know which
22 series capacitors are in service and which are not in
23 service. So we do need operational data; we don't expect
24 that to be public. But the more GIC data we can get, my
25 plea would be that the more data that can be made public or

1 made available without us having to go to each individual
2 utility for an MDA, the better.

3 The last point is that this is more work that's
4 funded by Department of Energy, is we need better GIC GMD
5 test cases. Randy was a leader in this effort: He came up
6 with a very nice test case. We're working actually with
7 somebody that Randy knows very well to develop synthetic
8 cases that we can get out to the tool manufacturers and
9 utilities to do benchmark studies that could be public, so
10 to do that we need public models. Thankfully our
11 government is funding that work and we're moving forward,
12 so my story is very positive.

13 MR. BARDEE: Thank you, professor.

14 Next we have Professor Trevor Gaunt from the
15 University of Cape Town, South Africa.

16 PROFESSOR GAUNT: Good afternoon. This is where
17 I work in a mountain far away. I come to this meeting
18 because I expect the Commission will assess utilities and
19 regulators from countries outside North America, and
20 because I've had very privileged experience of GIC's from
21 which I can contribute. I will address the three topics
22 put by the Commission to the panel, you have them in the
23 agenda. And the first is harmonics, distortion, and it's
24 effect on power. I apologize for the size of the font.

25 Often referred to as quasi-DC's, GIC's are not

1 constant like DC's. They generate varying levels of
2 harmonics in balance and since in 1989 caused some voltage
3 in reactive power systems could prevent system collapse.
4 Before the enactment of power, changes with GIC magnitude
5 and direction have been stripped. 1415 is the conventional
6 definition of nonactive power, but it does not accommodate
7 an imbalance, an alternative general power theory does. We
8 can think of the general power theory as building on the
9 usual power triangle of an RP and reactive power cube A,
10 that can be compensated by energy storage devices. Taken
11 to a Q little A, nonactive power can be compensated by
12 energy transfer between wires. Little right angle symbols
13 in the diagram show orthogonality. The whole approach is
14 rigorously mathematical in derivation in secondary linear
15 autograph and very simple in its entirely arithmetic
16 measurement algorithm.

17 In correct power plants by controlling the phase
18 shift between voltage V and current I , the harmonic
19 imbalance of GIC distortion could cause extra heating in
20 the capacity. Relays normally initiate particular
21 tripping, as some utilities have harmonic relays. During
22 the Quebec geomagnetic disturbance, coincidence of a sharp
23 increase in the geoelectric E field, SVC protection relays
24 initiated tripping. A relatively lightly-loaded system,
25 seven SVC's tripped in less than one minute, voltage levels

1 dropped, and the system separated. Equipment was damaged
2 at several stations. The Quebec power system collapsed,
3 gave its name to the geomagnetic disturbance.

4 As shown in Quebec, these required external
5 impacts to be delivered from generators, lowering delivery
6 efficiency and causing voltage drop. The distortion
7 reduces delivery efficiency too. Long-active power in
8 power vector, which is simply an index of delivery
9 efficiency, are inadequately defined in IEEE 1459. With
10 the result of voltage being distorted by GIC's, system
11 collapses more likely than expected from conventional load
12 close studies.

13 The second topic for this panel is the
14 suitability of the 75 M threshold proposed in TPL7. When
15 the magnetic transformers distorted by GIC, leakage flux
16 outside the core causes entire winding conductors and the
17 tank. Many construction details affect the heating
18 intensity and location. TPL7, a number of prior
19 simulations of heating in any transformers expected to
20 carry GIC, exceeding the benchmark disturbance.

21 Let's characterize four levels of disturbance:
22 The first is a short-duration disturbance that can lead to
23 a cascade failure as in a Quebec; Second, sustained high
24 GMD's cause the near transfer load and overheating, leading
25 to failure for days as in Salem; Third, localized peaking

1 by moderate GMD's can shed degradation that continues even
2 after the GIC ends, causing a transformer to fail in weeks
3 to months as we saw in South Africa in 2003; Finally, high
4 streams can occur in halls and cause multiple GMD's that
5 can contribute to cumulative low energy degradation. Thus,
6 we can define two regions: (1) to impinge short GIC in the
7 system collapse. The blackouts earlier in a storm will
8 protect transformers from further damage. In the second
9 region, overlapping the first, transformers are exposed to
10 early on high and moderate GIC's.

11 We saw multiple transformers failures in South
12 Africa after the Halloween Storm. I've been told that the
13 failures must have been due to other causes since the GIC's
14 did not exceed 15 M's per phase in any of the transformers.
15 The challenge later developed a low-energy degradation
16 triangle, which has shown a strong correlation between GMD
17 events and degradation in the transformers. But the issue
18 is: What GIC's temperature lead to failure? This shows
19 the 5 amps phase cause temperature rise of about 15 degrees
20 centigrade. Increasing the GIC to 16.7 M's per phase for
21 just one minute caused rapid heating that could take
22 temperatures to volumes within 15 minutes. However, GIC is
23 not GMD. Experience of the damage by Rio's GIC's and Salem
24 and South Africa transformers and the tests by Seaman's
25 show no proposed 75 amps per phase could lead many

1 vulnerable transformers undetected. I recommend a
2 threshold of 15 amps per phase, appreciating that not all
3 of the transformers will be vulnerable, appreciating that
4 not all of the transformers will be vulnerable. And a
5 compromise of, say, 40 amps per phase would be appropriate
6 for this phase of studies. My recommendation is based on
7 the consent of public benefit.

8 Independent of GIC's, we can define a cost of
9 failure for equipment and systems. GIC's simply add to
10 that cost. We can identify a public utility phase, begin
11 to assist mitigation options. Valued risk is not defined
12 by the risk of system collapse, but by all processes
13 affecting reliability. Valued risk can replace contingency
14 and invest planning and operation. With or without GIC's,
15 planning and operating decisions are in blue, based in
16 measurements in yellow, failure probability is in system
17 shape in white, and derived values in green. This process
18 illustrates the public benefit approach to reliability.
19 The third issue for this panel is the nonuniform E field --
20 I'll be brief -- equipment system, now GIC's in nonuniform
21 fields to be calculated. Instead, next uniform benchmark
22 oversimplifies reality. Rio GIC's, upgraded and
23 statistical dispersion over the uniform field model,
24 changing the influence of nonactive power on system
25 collapse. Nonuniformity of E fields requires appropriate

1 power system techniques.

2 MR. BARDEE: Thank you, professor.

3 And finally we have Terry Volkmann from Volkmann
4 Consulting.

5 MR. VOLKMANN: Thank you, I appreciate this
6 opportunity. I run my own consulting company that
7 specializes in NERC compliance consulting. I have a lot of
8 clients that I help out meeting all the NERC standards, so
9 I'm very familiar with the NERC standard process and
10 evidence. But I've also participated in GMD voltage class
11 studies in the State of Wisconsin and Maine, and that's why
12 I'm here talking about some of the things that we've
13 discovered in those studies. I also come here with over 30
14 years of transmission operations experience.

15 I have a couple comments. This morning we spent
16 a lot of time talking about electric fields, hotspots, et
17 cetera. The system operator in me tells me when I have a
18 measured data that doesn't agree with the model, I have to
19 think about the modeling part of it and why does my data
20 not agree. If you look at geomagnetic scaling, India at 10
21 degrees had documented magnetic during the Carrington
22 event, also in 1986 event that they published; China, 12
23 degrees in their 2005 minor event recorded through GIC's
24 and calculated the E field had an E field that was
25 equivalent to what would be calculated in Northern Florida

1 at 40 degrees. The Chinese concluded that the GIC impacts
2 are not only restricted to high latitudes, middle and the
3 low latitudes have GIC impacts also. So I think with the
4 scaling factor I think it underestimates the field strength
5 in the lower part of the United States from that
6 standpoint.

7 Second issue, as we discussed this morning on
8 the field of whether it's 500 kilometers or 100-kilometer
9 hotspots, that same India data from recorded magnetic
10 fields they had equivalent very similar fields over 2,800
11 kilometers in distance between their recording. So I think
12 it's important for vulnerability studies that we get this
13 peak magnitude and duration nailed down right in order to
14 do these studies to protect the grid.

15 We talked a lot about the magnitude of the
16 storms and the benchmark but we have never talked about the
17 length. The benchmark waveform is 32 hours. And in that
18 32 hours there's at least 20 peaks of 70 percent of the
19 maximum in that 32 hours, extrapolate out Carrington.
20 Carrington was a 12-day event with five days of very severe
21 activity, that would be 180 peaks. So if this peak is
22 occurring over several days and moving around and if it's
23 much bigger than 100 kilometers, you're going to have a
24 majority of the U.S. under a peak condition that sometime
25 may be vulnerable peaks before it's all over with. So I

1 think it's important to get this correct and go forward.
2 And I know in the NOPR there's a suggestion of looking at
3 peak fields as a norm, I think that provides a necessary
4 safety standard. I don't think spatial averaging will
5 provide enough of a safety factor with all of the
6 uncertainty.

7 So if you look at that 75 percent magnitude that
8 I talked about there, that would equate in the hotspot of
9 12 to maybe 16 to 20 volts per kilometer. When we did the
10 Wisconsin and Maine studies, that was the voltage collapse
11 point that we saw, was in that range. So it's very
12 important. We've done some preliminary and other parts of
13 the system, and we're seeing a common thread. So it's
14 really important to get the peak right because that's going
15 to -- what we're seeing is that's the level where voltage
16 collapse can occur.

17 Another issue with the TPL7, it's a planning
18 standard. And as Mark Lauby mentioned earlier about
19 looking at reactive support during an event leading to
20 voltage collapse, I even questioned whether the shot
21 capacitors that are connected up should be used at all in
22 consideration of it for this reason. When we studied
23 Wisconsin and Maine, we could arrest the first voltage
24 collapse with capacitors, we could keep the voltage up.
25 But if you look at the waveform, there's tens of hundreds

1 transitions through zero. When you go through zero, you
2 don't have any mega-bar loss from the transformer and
3 voltage goes high. We saw voltages in the emergency range,
4 all those capacitors are going to switch out, now you're
5 going to go into the negative peak and you're going to need
6 them again. In most capacitors the standard is a
7 five-minute wait period for draft charge. So if that field
8 comes back within five minutes, those capacitors are not
9 going to be available to the rest of the second peak, and
10 if you plan on having 70 of 80 of these transitions during
11 your timeframe you're really going to tax the use of
12 capacitors to the use of your voltage.

13 The final area is in harmonic study. Harmonic
14 system analysis is very difficult to perform, not ready for
15 standard. But I think looking at it as a single source
16 type of thing, there's plenty of data that suggests what
17 transformers produce harmonics based on GIC. Idaho
18 National Labs show that transformers of a little less than
19 10 amps in the neutral can exceed the IEEE 519 standard.
20 Also, generation interconnection agreements: One of the
21 key causes there is the generators of the transmission
22 owner shall distort the voltage that exceeds 519, and if as
23 little as 10 amps can do that then most of the
24 interconnection agreements will be violated.

25 And finally there was an independent insurance

1 study looking at industrial equipment damage. And when
2 they subtracted out all of the known events from known
3 causes, they looked at the ones they couldn't correlate,
4 they correlated with GMD events a during ten-year period
5 where there wasn't much activity and to a tune of, what,
6 two billion dollars or more a year. So I think looking at
7 harmonics and figuring out how to stop them at the source
8 is very important. So I will conclude my comments. I look
9 forward to your questions.

10 MR. BARDEE: Thank you, Mr. Volkmann.

11 Let me turn to staff, see if there are any
12 questions.

13

14 MR. AYOUB: Thank you very much. I have a
15 question, and Professor Gaunt mentioned it as well, and
16 it's in your slides, it's about the 75 amps per threshold.
17 So I wanted to ask -- I know we have some IEEE senior
18 members on the panel -- and IEEE just came out with a
19 standard last September, IEEE 67.163. And in that standard
20 they do state that -- it's worth looking at -- there's
21 susceptibility between 15 amps and 75 amps as well when
22 they did that study. There's a high susceptibility of
23 obviously 75 and above. But I wanted to see what are your
24 thoughts on what Professor Gaunt said, as well as with IEEE
25 standards, there's some concern with below 75 as well. So

1 I'll open it up maybe to the IEEE members.

2 Dr. Marti, if you want to go ahead.

3 DR. MARTI: It would be a good idea to put what
4 the GMD application guide, done by the standards committee
5 but it's an application guide, what it says and suggests.
6 They are basing those numbers for stability, they're
7 looking at transformers which have the same phases, more
8 lower equipment, five types. And they also define a
9 standard curve which they liken to the type of curve that
10 you use for installation coordination IEL or BIL tests. So
11 we have -- I don't have it with me unfortunately, but there
12 is studies 60 minutes of what they call base level,
13 followed by one pulse, two minutes, which is about I
14 believe it's four times higher than the value, before
15 eight. I need to check my notes. Four times. And then
16 followed by a negative pulse, again, two minutes along four
17 times, followed by a rest period of 20 minutes at the base
18 GIC level. So when you compare that type of test waive
19 with the say 1989 waveshape, with the same peak scaling,
20 the difference is like night and day. The 57.163, the peak
21 temperature reaches about 200 Celsius, whereas the --
22 they're using the same model, so I'm comparing apples to
23 apples. All I'm doing is trying to figure out the
24 difference between using a recording entity and a waveshape
25 and a synthetic one to see how well it represents a real

1 thing -- whereas a difference of about 50 degrees Celsius
2 between the two. So if you use the synthetic one you would
3 hit the 5791 limit, 35 you'd have 60 degrees leeway. So
4 when we say 75 as far as that standard, it's not the same
5 75 as far as the FPS7 is concerned. So it's like comparing
6 apples with apples.

7 MR. HORTON: One thing to add or maybe another
8 way to look at this is: As they've described what's in the
9 standard sort of the assessment process that was performed
10 is different than what we have in the TPL7 standard. And
11 we feel what's in the TPL7 standard is kind of the latest
12 and greatest from a technological standpoint. So when you
13 compare the results from what we're using in the standard,
14 and compare it -- standard TPL standard, the NERC standard
15 -- and compare it to the IEEE standard in that context is
16 overly conservative.

17 MR. AYOUB: I was to follow up, Mr. Volkmann, I
18 think for the same subject, for the testimony, for the data
19 you had transformers that showed damages at levels below 15
20 amps. Was that consistent with the IEEE findings?

21 MR. VOLKMANN: I don't recall that correlation
22 there. That was what the original standard came up with.
23 The original standard came out with 15 and then it was
24 changed to 75, so we were questioning the data as far as
25 when it justified change to 75 amps per phase.

1 MR. AYOUB: Yes.

2 DR. MARTI: Can I comment as to why that
3 happened? The 15 number, and I believe FERC staff were
4 present in some of those discussions, the 15 was a number
5 that came up steady-state, continues, forever benchmark,
6 whereas 75 continued value no duration. Mark said 10
7 seconds because he wanted to have a duration; nothing is
8 instantaneous, so we said 10 seconds just because of the
9 sampling rate for the GMD event. So that's where that
10 number came from. Then in sequence in discussions, it
11 become apparent that we're going to ask the folks to do a
12 thermal assessment with default tools that we're giving to
13 them and they're not going to do any different than what we
14 could do if we run a few thousand simulations. Which if
15 you look at some of the slides that I presented is what
16 those nice technicolor slides. So why undue burden on
17 utilities that are starting to create this kind of stuff
18 and we provide the values to them? So that why the
19 difference between 15 and 75.

20 MR. AYOUB: One more question. Maybe Mark, from
21 this morning's panel, this afternoon's I've heard several
22 times we'd like access to GIC data. So from your
23 experience, is that something that is easily accessible?
24 What is the burden of trying to take out for that concern
25 access to get that data?

1 MR. LAUBY: I was not on the last panel. But
2 right now NERC is trying to collect geomagnetically-induced
3 current data. We haven't had a need for it yet. And as
4 you understand, there's a limited number of these devices
5 now out in the system. Although we are learning, you'll be
6 able to hear in the next panel, there may be other sources
7 of information. So from an insurance perspective, it may
8 be of interest of people down the road to have it, but
9 right now we're not gathering. We could use Section 1600,
10 et cetera.

11 MR. VOLKMANN: I would like to respond to that.
12 Dealing with NERC standards, as part of my consulting,
13 there are standards out there that the reliability
14 coordinators can establish specifications to provide this
15 data, especially for reliability purposes. And I'm seeing
16 some reliability coordinators are not progressed to the
17 point of adding that as a standard to their data
18 specification. That may be one area they can improve
19 because they've got that compliance authority right in the
20 standards of getting what data that they need for
21 reliability.

22 MR. LAUBY: I would say that when it comes to
23 data collection, NERC is shying away from standards to
24 gather data rather than using Section 1600 data collection.
25 And one thing I was remiss in mentioning is that of course

1 GIC data is useful to us unless we have good models for the
2 system itself. So overlaying the two together is where you
3 have the value, again, that could be something from an
4 insurance perspective we want to look at the vulnerability
5 assessments down the road it might be useful.

6 MR. AYOUB: Thank you.

7 MR. BINDER: I'd like to ask Dr. Horton, in your
8 prepared comments you talked about instrument transformers
9 becoming inaccurate during a GMD event, which makes sense,
10 they're transformers. But can you talk a little bit about
11 how significant of an issue that is and would it be more
12 significant for utilities in Minnesota and Canada as
13 opposed to...

14 MR. HORTON: I'll try, anyway. I think probably
15 -- all right. Basically, we have two types of instrument
16 transformers in the broad sense: You got voltage
17 transformers, which they be wound PT's, it could be 60 PT
18 storm; and you've got current transformers. The current
19 transformers is the frequency response as the lower order
20 harmonics we're interested in from the GMD standpoint are
21 fairly accurate. I think where you kind of cross over to
22 the inaccuracy is going to be in particular with a CCPT
23 where you might get into the third, fourth, fifth harmonics
24 and the CCPT is unable to replicate what's going on in the
25 actual power system. So if you couple, what really matters

1 is what is at the other end of the instrument transformer.
2 If I've got a microprocessor advanced relay that filters
3 out advanced harmonics, it's really not an issue. If I
4 have a solid state relay, for example, that uses a peak
5 detection-type technology to determine whether or not it
6 needs to take an action, the frequency response is going to
7 have a much broader impact. Because as I say, for example,
8 I had different voltage, the voltage wave form may be higher
9 than it normally would be, and as you take that through the
10 CCPT it may be even amplified beyond what's actually in the
11 system. So it's sort of -- I think it was mentioned on the
12 earlier panel, you almost have to look at all of this stuff
13 in the systems contract. And I think the frequency
14 response to the instrument transformer would be strongest
15 in that. As far as where the effect would be greater, it's
16 essentially going to be greater wherever the harmonics in
17 the system are greater, and that can be where that happens
18 to be.

19 MR. BINDER: Would there be more harmonics of
20 the peaks of the GIC and the geomagnetic fields and the
21 geoelectric fields were sharper?

22 MR. HORTON: Conceivably. I mean, it starts to
23 get a little more complicated in a real power system
24 because as the same time we have all these harmonic current
25 injections, we also have faster banks and we're using that

1 to prop the voltage up. So you have numerous resonance
2 going on, which can actually not only increase the voltage,
3 it can actually decrease the voltage depending on where you
4 are in the system. So it's very complicated. Now, if you
5 were to ask me in general would I expect the harmonic level
6 to be higher up North as opposed to down South, and I would
7 say yes, but it's going to be very system dependent.

8 MR. BINDER: All right.

9 Professor Overbye, could you give us a feel, if
10 you're comfortable, about how prepared is industry to
11 provide -- to have the data needed to do a GIC study on a
12 wide-regional basis all over the country? And since I
13 don't want to sandbag you, second part is: How more
14 difficult would that be? How much more preparation would
15 it be to do nonuniform geoelectric fields?

16 PROFESSOR OVERBYE: Well, I don't think I would
17 be the best one to answer for industry given that we've got
18 such good industry representatives here. We have done a
19 number of studies -- "we" being the University of
20 Illinois -- where we go out to various companies and ask
21 them for the data that we need. One key parameter is the
22 substation grounding resistance. Some utilities are able
23 to provide that fairly easily and some aren't. So it will
24 be a standardization across the industry to gather the
25 data, something that NERC might do. I was talking to one

1 of my friends from a smaller utility, he said when you're
2 at that FERC meeting be sure to mention that these GIC's do
3 travel across utility boundaries. So if you're a small
4 utility, you'll need data from your neighbors. So there
5 needs to be a data sharing mechanism to take place. On the
6 nonuniform field issue, the software is there to deal with
7 the nonuniform fields right now. So I'm coding in the NERC
8 event as already done, if we needed to code in 100
9 geographic regions versus 11, that it's fine, that's just
10 data input, that's not that hard to do.

11 MR. BINDER: Aren't some of the data unique to
12 the nonuniform fields? Like, for example, if you're
13 dealing with uniform field all you really need to know is
14 where a line originates and terminates, whereas if you're
15 going to have nonuniform fields you need more detail?

16 PROFESSOR OVERBYE: Strictly speaking, with a
17 nonuniform field you would need to know the right-of-way
18 for the transmission line, I mean where it actually goes.
19 But having done these studies, there's very little error
20 introduced between point to point. When we talk about
21 nonuniform fields, they're not that nonuniform over the
22 length of a particular line. So you're right, if it's
23 uniform you just need the end points; if it's nonuniform,
24 you need to know the path the line takes. But there's not
25 a lot of error introduced in dealing with that.

1 In doing these studies, there's a lot of
2 unknowns in the study. As Luis likes to point out,
3 transmission line resistance varies with temperature, it
4 varies by .4 percent per degree C. So the resistance we're
5 assuming for a transmission line, usually we ignore this in
6 a power flow because the reactants tends to dominate on the
7 flows. But we've got parameters that are varying by 10,
8 20, 30 percent. And then you couple that all together and
9 then you start talking about what the most significant
10 source of error? There's going to be error here, we know
11 that. It's just: What's the most significance source of
12 error? It's a very challenging problem, but as I said we
13 have made good progress. I would not say we need to know
14 the right-of-way lengths and all the lines. Point to point
15 is pretty good.

16 DR. MARTI: You mentioned you wanted to see
17 utility's perspective on the fields for a number of years.
18 And I want to use precise language. There's nonuniform
19 geomagnetic fields caused by the fact that the earth models
20 are different in different geographical parts. That is one
21 thing, and that's perhaps what Tom's referring to. Those
22 are relatively straight-forward. We model the interior
23 system with seven different zones, each one with its own
24 geographic region earth model. Our experience is similar
25 to that in some cases, a lot of them are different. But we

1 can talk about that in the next panel session, but I will
2 bring it up. The part that is challenging is: What do you
3 do with the geomagnetic field? You assume that it's
4 uniform, you assume that it has a drop-off, whatnot. And I
5 believe that the jury is still out there as to what is the
6 best way to do it. There's ways to verify that, it's not
7 impossible if it needs to be done, which is you compare
8 what I call the steady-state drop-off, which is the
9 latitude scaling, you have to compare it with multiple
10 events and see where that goes.

11 MR. AYOUB: Thank you.

12 Just a quick follow-up. Professor Overbye, in
13 your presentation on the strongly-designed utility
14 participation, it sounded like you have magnetometers ready
15 to be deployed and you're looking for a -- is there a
16 burden on the utilities to actually place the magnetometers
17 and store them? Can you elaborate more on that process?

18 PROFESSOR OVERBYE: Right. It's the board on
19 one of my slides. One of the projects that I mentioned is
20 the 2.65 million dollar three-year project. In the first
21 year of the project we're going to deploy magnetometers at
22 two locations, so they're already selected. One is in
23 Texas and one is in Illinois. The next two that are funded
24 through this project will be deployed somewhere, that's
25 what we're looking for. So it will be a year out. We

1 don't know where to put those. If we have ideas, but
2 ultimately we need partner sites to locate them at. That
3 could be university, that could be utility. I will say
4 from a utility's perspective, we can't have electrical
5 lines nearby because they interfere with it. So you got to
6 have land that's kind of remote to put these in. But as I
7 understand it -- this is not my part of the project, it's
8 done by Jennifer Ganon -- there's not much upkeep once you
9 put them in. There's power devices so they don't need
10 infrastructure, probably come communication costs
11 associated with them but they're rather minimal.

12 DR. MARTI: Again, this is part of the next
13 panel, but I find it prudent to bring up as it comes up
14 because the panel itself has questions, but anyway. We
15 have a project to increase the number of geomagnetic
16 magnetometers in the area from one, which is the what was
17 geomagnetic magnetometer to add six more. And there's one
18 heavy advantage, that we had a truckload of -- and if one I
19 want to chat about: What's the best way to do it? I'm
20 happy to do that. Because we did go through the exercise
21 and we actually got help from the what was laboratory to
22 tell us the things to do and what was the best way to do
23 it. The first one will be in service in the month or two,
24 the last one will be in service before the end of the year.

25 MR. AYOUB: Thank you.

1 PROFESSOR GAUNT: I will give the math in the
2 next panel, which shows the increasing number of
3 magnetometers and magnetotellurometers, which we're
4 installing and you'll see within is much greater than what
5 has been spoken about here.

6 MR. BARDEE: Professor Overbye, we can go back
7 to the project that you just described with the four
8 magnetometers. Are you going to have GIC monitors either
9 right there or nearby?

10 PROFESSOR OVERBYE: No, these devices may
11 measure magnetic and electric fields, okay. So the GIC
12 measurements are on transmission neutrals and the devices,
13 they have to be located in locations where there's no
14 electrical equipment.

15 MR. BARDEE: But they'll measure both fields,
16 magnetic and electrical?

17 PROFESSOR OVERBYE: Right.

18 MR. BARDEE: Okay.

19 Other than the considerations you mentioned
20 about not being near electrical wires, what kind of things
21 are you going to place a unit like that?

22 PROFESSOR OVERBYE: I'm not the expert on
23 placing these units, so. They did tell us they want places
24 that are kind of remote. So you can't have other equipment
25 nearby, that's for all sorts of types. Like we were trying

1 to put one at University of Illinois, which we are but
2 we're going to have to put it in a very remote location
3 where we don't have any other equipment because other
4 equipment will interfere with the measurements. But once
5 this data is out there, it's public. So we're going to
6 make sure this data gets out publicly, just like the other
7 locations.

8 DR. MARTI: Can I comment on my experience?
9 Based on our own experience, we actually put magnetometers
10 next to a station that is measuring GIC because part of our
11 intent is to monitor the models. So to be able to
12 ascertain that we were in good shape with the help of the
13 Ottawa observatory, we actually put them at different
14 distances such as the station to the distribution line in
15 parking lots and determined that we could actually track
16 the daily variations in magnetic field, not geomagnetic
17 disturbances but the variation of a distance of 75 to 100
18 meters from the station. So to give you a sense of this
19 stuff. If it is observatory quality, maybe it needs to be
20 somewhere very far away. But as far as we're concerned,
21 the measurements, 75-100 meters is a decent distance.

22 MR. WAGGEL: NERC selected the particular
23 thermal model that they did. Unfortunately, we don't have
24 any transformer manufacturers here, so maybe somebody else
25 can answer this. If the NERC thermal models was netted

1 with transformer manufacturers, and if so are they in
2 agreement that that's the model that should be used to
3 assist their transformers in the field?

4 DR. MARTI: I assume the question was directed
5 to me on the basis of eye contact.

6 MR. WAGGEL: I figured you'd be best to answer
7 it.

8 DR. MARTI: The transformer manufacturers, let's
9 -- I would like to be precise as to what you called as the
10 transformer NERC model. And same as we're talking about
11 NERC models, in reality it's not NERC model, it's storm
12 models that NERC has considered to be the best available.
13 What I was referring to when I showed the transformer
14 function in step response, that is just a mathematical tool
15 to use any response on a transformer model. So the model
16 itself comes from the manufacturer or from measurements;
17 there's no such thing as a NERC transformer model. So what
18 you saw in the combined pictures uses three different
19 models: We use critical knowledge, one based partially in
20 measurement causing extrapolation of the behavior because
21 the measurements are picking up very low current. That
22 extrapolated model has been criticized by concerned
23 manufacturers as being too onerous. And I agree with them,
24 because at high GIC currents extra elements would saturate
25 as well as the core does. So using a linear extrapolation

1 with long-term GIC is extremely conservative. So
2 notwithstanding the criticism, the drafting team felt that
3 was an excellent margin to add to their assessment.

4 MR. WAGGEL: Then the 75-amp limit, what is that
5 based on then? We had discussed that, but is it based on
6 the modeling and the thermal results that were obtained,
7 that you obtained? Or how is that obtained?

8 DR. MARTI: Can I have my presentation on the
9 screen? It's a lot easier to point at something. Models
10 were shown through that particular slide, through what
11 didn't really have to be shown because it was much longer
12 than the other one. So one is actually based on
13 measurement, transformers are put in the grid, GSE and
14 measured response. Can we go forward a bit? So you see
15 something similar here to three cones. And the blue cone
16 is the same grid test; the red cone is a combination of
17 magnetic and synthetic, the one that some complain saying
18 is crazy conservative; and the green one is, if you see the
19 synthetic behavior, as GIC goes up it does taper off. And
20 again that's to be expected, and it's reasonable.

21 MR. HORTON: I think the one thing I would add,
22 and I think I would agree with Luis you question was would
23 the manufacturers use that assessment of transformer
24 deployment? We worked with them in taking the measurement
25 data. And essentially it may be helpful to kind of

1 visualize the mathematical construct that Lui's talking
2 about as almost like a black box model. So we injected the
3 transformer with DC, actually measured the hotspot
4 temperature until it was steady-state. We can take those
5 curves and you no longer really need to know exactly what
6 the actual thermal model of the device is.

7 So they agree that it matches the measurement
8 results. Now, they, as a manufacturer, have access to all
9 of the design data; they have their own custom models. I
10 suspect they would use those models to assess the
11 transformer, but they would agree that the model that Luis
12 developed does replicate thermal behavior of the
13 transformer.

14 MR. WAGGEL: I guess that's part of the
15 question, part of the problem here, is it may very well
16 work for one or two transformers, whatever transformers,
17 but the manufacturers would look at it a little bit
18 differently because there are over 600 different designs of
19 transformers out there, different core designs, different
20 construction models, that whenever you saturate a
21 transformer it is going to affect different parts of that
22 transformer differently. And really only they would know
23 the design of that particular transformer to see whether
24 the particular core is going to be at a location that may
25 be impacted or whether the bindings are going to have

1 problems. And that's why -- I'm not saying this is a wrong
2 model, I'm just saying I think they would look at it a
3 little bit differently.

4 MR. HORTON: You hit a key point. So part of
5 the whole process here -- and this kind of leads into the
6 future work that we need to be doing in this area -- is the
7 whole idea is that you can take the transformer and have it
8 treated, whether it's in the fact or on the field, field's
9 better. As long as you can actually model, even if you --
10 and actually we're really careful you make sure you're
11 modeling the actual generator source that's at the factory,
12 and so on. But if you're able to model all that, then
13 that's the measurement. Then you can feel good about the
14 thermal modeling the manufacturer has. Now, once we've
15 been able to do that a few times -- and we've done it a few
16 times, we probably still need to do more -- but once you're
17 comfortable with the models, then you have the
18 manufacturers go out and basically just create, essentially
19 simulate what the models are for all these transformers
20 which can then be fed into the tool we're using. So good
21 point, and that's something we've identified. But moving
22 forward, we'd like to have available responses, a lot more
23 transformers.

24 DR. MARTI: Let me add to what Randy said, is
25 that so many manufacturers also have been wishing for those

1 responses for a number of years. So those are their
2 theoretical responses. Then we have models where those are
3 invariably a lot more resilient than anything we have
4 tested.

5 MR. BARDEE: I have a couple of questions. One
6 for you, Dr. Marti. Some of the written comments in our
7 docket, with they criticize the 75-amp-per-phase threshold,
8 cited a paper you and a colleague wrote about generator
9 thermal stress, not transformers but generators. And the
10 paper concludes that the simulation results conclude that
11 the generator capability limit tends to be CS modeling GIC
12 levels 50 amp per phase and rotor damages likely during a
13 severe GMD event. Can you address the concerns they've
14 raised with your paper and it's reference to --

15 DR. MARTI: That's continuous GIC.

16 MR. BARDEE: As opposed to a peak of a --

17 DR. MARTI: As opposed to a realistic waveshape.

18 MR. BARDEE: Okay.

19 DR. MARTI: The other thing that the paper
20 includes, if I recall properly, is the message of the paper
21 is at the end of the day that the standards that make
22 recommendations for the settings for a negative sequence
23 relays ought to take into consideration even harmonics.

24 MR. BARDEE: How long was it continuous for? Do
25 you mean just indefinitely? And do you know from your work

1 on this paper if the same effects would have shown up as
2 some shorter duration, some finite duration?

3 DR. MARTI: Probably, but not long-term. And
4 the standard that sets the overheating limits is
5 continuous. That's one of the things, for instance I heard
6 said that limits on 519 should be met in the case of a GIC
7 event -- correct me if I'm wrong -- that 519 limits are
8 intended for continuous harmonics. Because you have
9 capsize and others in the system, so I thought you should
10 have a continuous stream of harmonics. I don't believe
11 there is a standard that takes harmonics and duration into
12 account. For instance, 5791 takes into account temperature
13 but over two minutes, two hours, two days.

14 MR. BARDEE: If I have a question for you,
15 Mr. Horton. It's on the vibrational effects. You
16 indicated on your statement, and stated again here today,
17 there are no documented cases of vibrational damage from
18 GMD's and there's no model to assess that impact, anyway.

19 MR. HORTON: Correct. First, I have been unable
20 to find any documented cases that states there's been
21 damage due to GIC-induced vibrations. As for as the
22 assessment criteria and models, there again to my
23 knowledge, there aren't any commercially-available tools or
24 performance criteria to do those assessments.

25 MR. BARDEE: To the extent there's an issue

1 there, and as a layman I just assume there's an issue when
2 you have a big piece of equipment that's vibrating, how
3 could we go about finding out what might be appropriate
4 criteria or limits? Or when do you start worrying about
5 that?

6 MR. HORTON: That's an excellent question, and
7 I'm not sure I have a good answer for you. I think that
8 question is when you really want to bring the transformer
9 manufacturers in. Without guessing, I hate to give you a
10 solid answer on that. Now, that being said, I have
11 witnessed the transformer test at Seaman's, for example,
12 and I can assure you when you set in 30 amps of DC current
13 into an autotransformer it makes lots of lots of noise.
14 And associated with that noise is vibration, that frequency
15 vibration. We can take a transformer that has not had any
16 issues associated with it. So from an experience
17 standpoint, that's all I can speak to.

18 DR. MARTI: If I can add a little bit to what
19 Michael Horton said. Two things: Noise and transformer
20 audible noise has had a lot of work done on it by
21 transformer manufacturers because customers do not want
22 transformer that violates the noise limits in their
23 neighborhood or their complex. But that is for very small
24 numbers for either citation or DC bias. So the state of
25 tools for the general engineer that don't exist, the

1 manufacturer probably has their own. There's dozens of
2 papers being written on noise. But again, it is really not
3 germane in a very small way. One of the sources we had
4 measured is we measured GIC-measured noise. And my
5 reasoning was maybe I could use noise for a proxy for GIC
6 measurements themselves. Unfortunately, the probe detached
7 itself halfway through the exercise, we had incomplete
8 data.

9 MR. HORTON: If I could add just one thing,
10 because he reminded me of something. There's a lot of
11 application in the power system today where we would expose
12 a transformer to vibration, For example, an art (phonetic)
13 furnace transformer where it's continually taking in the
14 harmonics created by an art furnace. So I'm sure there's a
15 design criteria in those cases that I think would have to
16 be careful by taking that same design criteria and applying
17 it in this case because it would be in one case for, like
18 the art furnace transformer, that's sort of a continuous
19 type of application, whereas the GMD we have experiences is
20 very rare and doesn't happen that often. So I think
21 there's a lot of technical difficulties going down that
22 road as well.

23 MR. KELLY: This question is probably more
24 toward the measurements. But can you describe how a system
25 planner could take into account the impacts of harmonics

1 with increased requirements caused by a GMD events with the
2 vulnerability assessment?

3 PROFESSOR OVERBYE: We're anxious to get the
4 studies underway so we can determine what -- we haven't
5 done a GMD GIC study for a long time. Now, I understand
6 there are utilities in Minnesota that have already done
7 one; that was several years back. But the whole issue of
8 GMD's and GIC impacts have really come to the forefront, so
9 we're scrambling, we're looking at papers that are 20 years
10 old, 30 years old, transformer assessments for thermal
11 impacts for the GIC, some of those are pretty old papers
12 but they're still valid. So we're trying to gather that
13 information. We would probably -- our demand on the
14 transformer would be part of what goes in that planning
15 model based on its DC loading. And so we'll have to
16 determine based on the contingency in the area whether
17 there's a large supply of voltage stable. And that's the
18 way we would do the assessment.

19 MR. HORTON: I think right now there's probably
20 some very rudimentary things you could do. I am sure Luis
21 is going to talk about one, a standard. But another one
22 would be we could assume that any capacitor you have, let's
23 say it's ground-wide and it's protected with electrical
24 mechanical relay or solid state relay, you could assume
25 it's going to trip offline. So you take that off during

1 your planning studies. The problem with that is, assuming
2 every single one of them trip off, you're getting a very
3 conservative answer. But the issue is we really don't have
4 the utilities necessary to sharpen a pencil at this point.
5 I'll let Luis describe the other one, but if he doesn't
6 I'll follow up.

7 DR. MARTI: I think that first, the GIC
8 assessment we did in 2012, 2011, so believe it or not the
9 ones that we do today are significantly different than the
10 one we did in 2011. A lot has happened; we have learned a
11 lot. And what I would like to do is de-couple the reactive
12 power absorption and power utility from harmonics. As
13 Randy Horton mentioned, it's really a different analogue.
14 And to do it properly, one of my very strong people in my
15 view of the determination of the NCP -- created a new tool
16 from scratch. It doesn't give you one answer, it gives you
17 a range of answers. But that's good enough from an
18 engineering point of view. From a station point of view,
19 one of the concepts that we use is reliant reactive power
20 margins in certain regions. So, because if there is a
21 contingency, you want to be able to supply that rate; if
22 not, you have to control the condition and a single
23 contingency you would have to start shedding both. So I'm
24 not sure that answers the question, or if it answers in
25 more than one different way.

1 PROFESSOR OVERBYE: Let me just make a comment,
2 since I helped develop some of these tools, particularly
3 for reactive power. They're out and they're used in
4 practice, and we've done a lot of studies with them. As
5 long as you don't say the word "harmonics". As Randy
6 mentioned, harmonics is much trickier to deal with. The
7 standard reactive power voltage stability studies, we do
8 that for standard GIC events; we also do it under M minus 1
9 conditions. That's all standard for uniform or nonuniform
10 fields, so those tools are available. Dealing with
11 harmonics is trickier. Where Randy talked about you assume
12 some of the capacitors trip, that's kind of the state of it
13 right now.

14 MR. BINDER: Can I ask a follow-up question to
15 anybody, anybody that can answer? I was just thinking
16 about the tripping through the harmonics. I assume that's
17 influenced by the level of GIC in the area.

18 MR. HORTON: Yes and no. Obviously, you got to
19 have GIC to have the half-cycle saturation harmonics.
20 Depending on which capacitor banks you have on and where
21 they are, you can have harmonic resonances that can kind of
22 attribute to the issue. So I wouldn't say it's necessarily
23 just GIC alone.

24 DR. MARTI: And the don't depend on the systems
25 that you have. There's lots of relays that you have, it is

1 messy exercise.

2 MR. HORTON: And the thing that really makes the
3 harmonics assessment even more complicated, and I kind of
4 highlighted some of that stuff in my written comments where
5 you get into it, the nonlinear creation of the harmonics
6 based on the GIC. But that alone, just the normal
7 harmonics assessment, is the response of no matter how much
8 damage you have in the system. Because you put these
9 capacitor banks on your nodes to create resonance, it's
10 much more frequent. It depends on where the nodes are,
11 what are the amps. It gets very complicated very quickly.

12 MR. VOLKMANN: May I follow up on that? In
13 addition to harmonics, you also got to consider those
14 transition's through zero. Because when you put the fields
15 through zero you're going to have zero followup in the
16 transformer. Both the Wisconsin and Maine studies the
17 voltages don't even, outside of the emergency voltage,
18 limits on the transmission system. So you also got to
19 consider that in. Because many times those capacitors, if
20 they don't have zero crossing breakers, they're out for
21 five minutes and they're not available for the next peak
22 that comes through if it comes through within five minutes.

23 COMMISSIONER LaFLEUR: Thank you, Michael. I
24 have Mike's question partly related to this panel while we
25 have all these experts here. Looking at the resiliency of

1 the high-voltage transformers when we track the
2 vulnerabilities, can any of you shed any light on efforts
3 that might be going on with transformer manufacturers to
4 give them more specifications to make the transformers more
5 resilient? I know that some companies are spending certain
6 things, but in my dreamworld there'd be some kind of
7 consistent spec we could agree on that somehow tied to what
8 we thought a transformer should be able to absorb, but I
9 don't know if it's being company by company. So that would
10 be a good chance to know something. Thank you.

11 DR. MARTI: I don't believe that there is a
12 specification standard for transformer resilience to GIC.
13 The recent transformer guide for GIC resiliency capability
14 is basically how to do an assessment after the fact. I can
15 only speak for my own company. In the last five years we
16 have had some specifications for GIC. It is completely
17 unclear to me if those specifications were used to transfer
18 more quickly, differently or simply to set the DC relay, I
19 don't know.

20 MR. LAUBY: I would add that I think approving
21 the standard as submitted to FERC will start us down that
22 road. The vulnerability assessments will turn up the need
23 for potentially giving the specification of transformers.
24 So that of course goes hand-in-glove with approving the
25 standard and continuing to do the research work, gather the

1 information, and then get it in front of IEEE or NERC
2 standard, that's what we need to do.

3 MR. HORTON: I agree with that, and also mention
4 there are a number of utilities that are including GIC in
5 their transformer specifications.

6 PROFESSOR GAUNT: I know of two transformer
7 manufacturers who are currently running tests to ascertain
8 basic physical response so that they can improve their
9 models and improve their designs.

10 COMMISSIONER LaFLEUR: Thank you, that's very
11 helpful.

12 COMMISSIONER HONORABLE: I can follow up. Thank
13 you for the question, Cheryl. I'm pleased to hear that
14 there is some effort providing some consistency, even for
15 the sake of operability and the ability to work well
16 together going forward, it really would be helpful to know
17 whether going forward there would be some commitment to do
18 that, particularly if we're going to go down this road and
19 do it seriously. So thank you for those waiting and thank
20 you for the question.

21 COMMISSIONER LaFLEUR: It's just that when you
22 look at the companies that are governed by the NERC
23 standards, that's a pretty big universe of the consumers of
24 high-voltage transformers that you think could impact the
25 market once we get there. Thank you.

1 MR. AYOUB: I know we've talked about
2 benchmarks, we've talked about assessments. Maybe just
3 corrective action plans just as an example. I know
4 there's some actions that entities take, and once you do
5 the assessments I find there's a vulnerability.

6 And, Mr. Volkmann, you mentioned for example
7 series capacitor. That was an example of a series
8 capacitor, and I think Dr. Marti in one of his workshops,
9 those actually would be an impediment as opposed to a
10 solution. Maybe a minute or two, what is an example of a
11 corrective action plan besides what's just in the standard?
12 Because that's coming down the pipeline. What's something
13 an entity would put together?

14 MR. VOLKMANN: I'd like to respond to that.
15 Even if you, on the transformers, get a higher
16 specification for GIC, there's still going to produce fire
17 losses, also going to produce harmonics. So the only way
18 you can get those two things involved is to stop the GIC
19 flow and the transformers and the capacitors stop that flow
20 either the capacitor is neutral or the capacitor on the
21 high end. And those two would stop the flow, and that is
22 part of the transformer. Now, an autotransformer has its
23 own unique problem where you can block the neutral but
24 there's still a pathway for GIC's flow as part of the
25 transformer just by their nature. But capacitors would

1 block the quasi-DC from flowing.

2 DR. MARTI: Okay. Let's put the question inside
3 a box, which would be: What is it that we are currently
4 planning to do in our shop? So in our shop we carried out
5 countless studies, both thermal and load flow studies, to
6 look at the bio-absorption voltage issues, lack of
7 compensation, whatnot. And on the basis of that we came
8 out with, Well, if this transformer sees this much, thou
9 shalt redirect GIC. And GIC, like you mentioned one of
10 things that seemed to be truly counterintuitive is that the
11 amount of capacitor compensating banks, series capacitor
12 compensation banks, one of the mitigating measures is
13 actually to take the series camp bank out of service. In
14 so doing it, the next GIC waiting meets the burden of the
15 station we're seeing a lot of GIC. So when you talk about
16 series compensation, you have to think in terms of
17 redirection. In terms of neutral blocking, that does flow.
18 Remind you, you send it to your neighbor and your neighbor
19 needs it. Those are the things that we have done today.
20 Are we ruling out completely the application of neutral
21 reduction device? No, but we would have to have strong
22 reason to do so and it would have to be coupled with
23 extensive studies, generally would be this study to be sure
24 that we have no unintended consequences.

25 PROFESSOR OVERBYE: Let me just follow up on

1 that. The idea is to get tools out to the engineers and
2 the utilities because they're the ones that are going to
3 make the plans, something that they've already done with
4 Luis' shop to do this, and it would probably involve a
5 combination of real-time GIC monitoring devices so that you
6 make up plans for the operators so that if the flow goes
7 over 50 amps, do this, 100 amps, do that, 200 amps, all the
8 way up, regardless of what the standard says. Because if
9 there is a big storm, it's not going to be as we planned
10 and the operators are the ones that are going to have to
11 respond dynamically right then. And what I'd like to say
12 is waiting until the storm is on its way to prepare is not
13 a good idea. So getting these operating procedures, which
14 requires engineers know how to use the tools to at least
15 think through what should we do, what advice do we give our
16 operators?

17 DR. MARTI: Can I add a little bit past that? I
18 know you're smiling; I'm talking too much. One of the
19 things I wanted to say -- and I'll speak more to that more
20 on the next panel -- is when you get a bunch of engineers
21 in the same group they inevitably start drifting towards
22 what problems are going on, other things could go wrong,
23 what else could we know make things go boom? And stepping
24 back and seeing the state of the task force four years ago,
25 where those folk were then, where we are now,

1 notwithstanding all the troubles and all the little things
2 that we find and are there and we're wrong and they're
3 overestimating or underestimating, just getting the
4 industry as a whole to pay attention to this, start working
5 and took studies on any level is a tremendous improvement.
6 So much for my...

7 MR. HORTON: I'd like to tell it like it is. I
8 think as people start to do the assessment, you'll see the
9 corrective has sort of been very varied. At the end of the
10 day, you're either going to try to do something to mitigate
11 the effects of potential stability issue or try to mitigate
12 or block the flow of GIC, or somehow mitigate that.
13 Because that's something that's causing that issue. So
14 joining with them, you can see a myriad of things in a
15 corrective action plan. Some of those would be similar to
16 what you see in a normal TPL-type thing.

17 MR. BARDEE: With that, we'll end our second
18 panel. We'll come back in 15 minutes. Let me thank all of
19 the panelists here, and some of you we'll see in 15
20 minutes.

21 (Whereupon a short recess is taken.)

22 MR. BARDEE: Okay, and we're ready for panel
23 No. 3, if everyone will resume their seats we'll go ahead
24 and get started. All right. So panel No. 3 is on
25 monitoring and future work. As we have the prior two

1 panels, we'll start this panel with Mark Lauby from NERC.

2 MR. LAUBY: Thank you, FERC staff. I appreciate
3 being invited to this third panel, as the other two. I've
4 really enjoyed the conversation. NERC used to divide
5 activities into two categories with different objectives,
6 responsibilities, and information elements in each. The
7 first category concerns monitoring activities that support
8 the basic understanding of space-weather, the geomagnetic
9 environment, and the geoelectric fields that are in the
10 American bulk power system and other infrastructures. In
11 the research-focused area, NERC believes it is important to
12 continue to collaborate with research partners to increase
13 the density of the magnetometer network in North America,
14 use monitoring of other means such as measurements to
15 refine conductivity model, and undertake other activities
16 to improve the understanding of the geomagnetic
17 environment. NERC intends to continue its collaborative
18 efforts through NASA, USGS, Natural Resources Canada, and
19 others that oversee these research to possess the necessary
20 expertise and to leverage NERC's position to engage in
21 these efforts. This monitoring should add to the
22 understanding of geoelectric fields throughout North
23 America that are used during the GMD event. Ongoing
24 collaborative research is important to continue to meet
25 NERC's standards and the benchmark GMD events with

1 up-to-date information.

2 The second category of monitoring activities
3 focused on entities' information needs for reliable
4 operation and filing of their system and equipment for GMD
5 resilience. And in these operating plans may call for
6 operator awareness of near real-time
7 geomagnetically-induced current models so that
8 predetermined steps can be taken to maintain reliable
9 operations. And that it may also need additional
10 geomagnetically-induced data allowing system information
11 and data of a geomagnetic environment to improve its system
12 models by comparing actual-induced current levels with
13 predicted levels. These, and other GMD monitoring
14 activities, are complex and relatively new to many in the
15 industry. When these are gaining and sharing valuable
16 experience related to siting, installation, and the use of
17 geomagnetic-induced current monitors and magnetometers. As
18 NERC has emphasized in its comments on the NOPR, an
19 entity's GMD vulnerability assessment is the foundational
20 element for the rationally-related application monitoring.

21 In addition, the best placement and the number
22 of monitors depends on both the underlying geology and
23 specific network configurations. Further, these monitoring
24 networks must be periodically calibrated by the operating
25 entity to ensure it provides the right consistency and

1 accuracy in the measurement of induced currents.

2 Until all the relevant needs and factors are
3 better understood, NERC believes that the mandatory
4 reliability standards requiring entities to install
5 monitors will be a bit premature. However, NERC knows that
6 many entities are already installing monitors, absent a
7 mandatory requirement to do so. A number of entities have
8 installed monitors either through the collaborative
9 Sunburst Program. For example, the Sunburst Network
10 currently operates over 40 monitoring nodes, providing the
11 real-time geomagnetic-induced currents participating
12 members. There are also a number of entities that have
13 installed monitors independently to address their
14 operational need for data. One example of that is PJM's
15 use of monitoring the trigger operating procedures which
16 was noted by the Commission in the NOPR; another is the
17 advanced monitoring network and operation procedures at
18 Hydro One in Ontario.

19 NERC anticipates that the continent-wide
20 implication of the proposed would further promote
21 entity-initiated modeling systems and data acquisition as
22 applicable entities address system and equipment impacts
23 identified through the GMD vulnerability assessment
24 process. The growth trend in monitors resulting from the
25 implementation of the proposed standard would support the

1 timely and affective development for standing information
2 for operational needs. However, much remains to be learned
3 before an affective mandatory standard could be developed.

4 To move forward on the improvements I envision
5 or we discuss, NERC urges the Commission to approve the
6 proposed standard. NERC is committed to work with the
7 Commission and industry to continue the research and gather
8 new data for the standards, as needed. Thank you for the
9 opportunity to present at all these panels today. I look
10 forward to answering any questions.

11 MR. BARDEE: Thank you, Mark.

12 And once again we have Dr. Marti.

13 DR. MARTI: Can I have the presentation on the
14 screen? So, as a followup on Mark's comment on how we use
15 the GIC monitoring, I am going to be talking about what we
16 call extreme space-weather managing. And that is a
17 real-time application that is in the control room, and it
18 uses magnetic field measurements as input to estimate
19 practically everything in the system of real-time. So I
20 set estimates of GIC flows in every part of the network,
21 real-time. It actually takes into account the real-time
22 configuration of the network, so if a breaker opens that
23 informs the solver. It takes -- it has 800 kV circuits,
24 and about 232 kV. It estimates the VAR absorption of a
25 transformer; it estimates a hotspot temperature in every

1 transformer; it estimates how current capacity impact.

2 The input, as I said, was the magnetic field
3 data from the what was observatory and it has a one segment
4 sampling rate and we received that in packets of one minute
5 because otherwise we'd crash their server. So the
6 calculation time, including data on average, 115 seconds.
7 A transfer of data to and fro on that system is 18
8 milliseconds, and not on this laptop. So that's quite
9 remarkable. Having said that, and probably I'm jumping to
10 one of the questions that was asked by this panel whether
11 what kind of sampling rate is good enough, in our
12 experience if we look at the one-second sampling rate the
13 calculations look fuzzy but they're so fast they have very
14 little -- they have zero influence on heating and very
15 minor, if any, influence whatsoever, in VAR absorption.
16 Because it takes time for the flats to build into the core.
17 And that's usually in the 1- to 10-/12-second range. A
18 little bit more about going into a sampling rate below 10
19 seconds seems to be a little bit of a dip. I'll speak a
20 little bit more about if we have an offline simulation, we
21 look at VAR flows, we look at transformers that overheat.
22 I think somebody mentioned it when we did it we did it
23 within the standards which at the time had not existed.
24 And we did it throughout the electric fields and see what
25 it is. And so I frankly don't remember to what values we

1 ended up, but that's what we did: We recorded the
2 operational measures and in accordance to the alarms that
3 extreme space-weather appears, the operators would take
4 certain actions or not.

5 So some of things that we do -- I see you can't
6 -- is it models seven regions, which means seven earth
7 models. We have measurements of high-voltage harmonics
8 through P60IED's, measures that can actually measure
9 harmonics. We also have a number of units with online
10 analysis where we have the capability to receive the tool.
11 We also have something that's really cool -- it was never
12 intended for this application, but we have it, it's a unit,
13 which we might as well use it -- which is the gradient
14 which is based on loading, the oil temperature which you
15 add to the hotspot increases. So you also get power-flow
16 information from the measurements. And that is the latest
17 and coolest toy that we have, which is our magnetometers.
18 So the magnetometers are the red cylinders, the red
19 cylinders is the Ottawa observatory, and the green spots
20 are the 18- or 19-GIC monitoring stations. So as you can
21 see, the magnetometers were in place one next to a
22 combination, one next to a GIC monitoring station that
23 measures a significant amount of GIC. Also, it was spread
24 on a latitude basis and a longitude basis, trying to cover
25 all of the bases. One thing I have to point our is that

1 the system, as you look at it, it covers of almost 10
2 degrees of latitude from the topmost to the south-most, and
3 the topmost being the 60-degree level. That's what it
4 looks like to the upgrader, and this is an example where we
5 are putting back an event for upgrader training.

6 So, to finally answer the actual question: Why
7 do we have monitoring equipment? For two reasons: (1) To
8 provide situational awareness for the real-time operation.
9 Right now the operators are not allowed to take action if
10 there's no agreement between calculated and measured. And
11 to do that we devise what we call canary stations, which
12 means stations that seem to be sensitive to these north,
13 west, south, and different parts of the system just to
14 increase the reliability and operational awareness. And
15 lastly for earth model validation. And for that, we
16 believe you really ought to have GIC's collocated or
17 collocated as possible, and you have to have exquisite and
18 complete information about the system. And that's what
19 we're going to be doing.

20 And one of the things that I will say in 15
21 seconds is that: This is strictly has to be done with
22 care. It has to be done minding the sampling rates of your
23 magnetic field; your sampling rates of your electric field;
24 you have to make sure your that your tying steps are
25 actually accurate, otherwise you have to guess, shift; you

1 have to pay attention to the entire frequency range from
2 going to one to one hertz or at least 200 millihertz at the
3 worst. Other criteria for placing GIC monitors in areas
4 where the GIC is very high, areas where you feel a certain
5 piece of equipment seeing GIC is an issue or a delicate
6 thing. And as we found out ten years after we started, we
7 have to stay away from public transportation systems
8 because being near a subway was giving us measurements that
9 were spurious but were actual measurements of the DC risks.
10 And I think that's probably DOT's.

11 MR. BARDEE: Thank you, doctor.

12 And, again, we have David Boteler.

13 MR. BOTELEER: Okay, bring up my slide, please.
14 So I'm going to show you some of the Canadian recordings
15 and also thought it'd be interested to look at this in an
16 international context. So this is a slide you've seen of
17 the geomagnetic observatory network, the magnetic
18 conservatory that Luis just mentioned the one in the lower
19 right. But as well as the observatory network that we
20 operate, there's a couple of university networks. This is
21 the Charisma Network down from Mulatona (phonetic) where we
22 mainly have source of data there for some of these studies
23 of more localized events. And there's a new network, the
24 automatic network in Alaska, that is down through Quebec,
25 and that's the new data set that we're looking for now.

1 And as you've already heard, there's other magnetometers
2 being installed by power utilities such as Hydro One.

3 We're also -- the question came up of a
4 validating the electric fields that we calculate using the
5 earth models and the electric field data. The individual
6 -- well, the earth models or the response functions we may
7 have spoken about are derived measurements of the magnetic
8 field and the electric fields. So those are electric
9 fields we go into that electric field measurements. So
10 you'd expect to get back to there. But the local in the
11 magnetotelluric analysis, there's a lot of data forwarding,
12 a lot of processing to remove local effects. We felt that
13 what was needed was more of a measure of the electric field
14 on the scale side, power lines, so we're looking
15 measurement as a 20-kilometer lengths, and those show one
16 kilometer north-south and one running east-west. And the
17 first client installation is in Osuwa (phonetic), and if
18 that all goes well we're looking to do this at several
19 other geomagnetic observatories.

20 In the umbrella association for the geomagnetic
21 tree operating around the world, and in particular a couple
22 of things I wanted to mention, the standard for magnetic
23 observatories have the one-minute sampling rate, a new
24 standard now for one-second data. So all of the
25 observatories around the world are moving to one-second

1 data. A lot of -- such as ourselves at the USGS are
2 already there, but it's the same in terms of timing.

3 Another feature I wanted to bring in is an
4 Intermagnet collects all of the magnetic activity around
5 the world and there's a geomagnetic activity map available
6 through the Intermagnet web pages. And this is an example
7 of the worldwide picture. There's activity, you can go
8 back and look through historic events, it's got a
9 movie-style view that you can see how the activity changes
10 and where it goes. And there's particular zoomed-in
11 features to zoom in for North America just to let people
12 know that's available.

13 Another issue is not just a matter of
14 integrating, but GIC data, where do you get it all from?
15 We're facing all the data is available from FTP cites,
16 that's not necessarily the most usable form nowadays with
17 computer software wanting to run simulations. So we found
18 out with our own simulation we wanted to be able to
19 automatically access the data, so we set up a web service
20 now for that. So Intermagnet, there's being discussions of
21 Intermagnet to standardize that. All of the geomagnetic
22 data will be working through the same format, so if you've
23 got software that want to access geomagnetic data you can
24 do that and you'll have access to all of the data from the
25 different operators from around the world.

1 And one thing I'd like to suggest is: I know
2 every magnetometer, the questions that has been asked what
3 the format that have been used? What's the best way to get
4 the data out? Well, the formats is standard data, I'd
5 recommend that. And then we're going to make -- this is
6 all going to be open-source standards to be shared with
7 everybody, this could be a common format for everyone to
8 make the data available.

9 And this is just an example of GIC simulator
10 that we're using here, software -- recall significantly
11 over the last five years, they can incorporate the spatial
12 variability data, they can input multiple magnetometers,
13 and multiple earth models to get the spatial data into the
14 U.S. structure. It's just a matter of putting all these
15 in. So the software capability, the modeling theory is
16 there and the software capability is being built up. Okay,
17 thank you.

18 MR. BARDEE: Thank you.

19 And again Dr. Love.

20 DR. LOVE: I have a presentation as well. All
21 right, so I'd like to talk to you today about three things:
22 Monitoring, surveys, and modeling. And I'm just going to
23 slide through this. I already showed this slide, but again
24 the issue I want to emphasize is the relationship between
25 geomagnetic activity and geoelectric activity, it's

1 electric fields actually in the earth and the two are
2 related to each other through the electrical conductivity
3 of the earth, and that is the process that can be described
4 in terms of an impedance or a filtering process. I work
5 for the USGS geomagnetism program, we are a tiny little
6 part of the USGS but I think we do some really important
7 work. We've been collecting data at our magnetic
8 observatories, which are shown there and they're kind of
9 spatial distribution from Guam in the Western Pacific to
10 Puerto Rico to the North of Alaska. Some of the stations
11 have been in continuous operation for over 100 years. I
12 think we can fairly say we are an expert in collecting
13 magnetometer data, so. This is an example of kind of data
14 that I think we need to have more of in the United States.

15 On the top I'm showing magnetometer data, so we
16 already have that. This is magnetometer data recording
17 three days worth of magnetic variation at Takaoka, Japan
18 Japan during the so-called Halloween Storm. So, again,
19 that is the kind of data that we have. But the data that
20 we don't have is the data at the bottom, that is
21 geoelectric data. This is, in principle at least, very
22 simple data to require. You essentially stick a giant volt
23 meter into the ground and measure the voltage difference.
24 Now, there's issues about doing this reliably and
25 continuously in time, and when you have lightening storms,

1 et cetera. But it is a very useful set of data. The two
2 together are what you would call magnetotelluric data, and
3 when you have the two you have the input and the output of
4 the filter and that allows you to make an inference for
5 what the filter is, that is in this case the electrical
6 conductivity structure of the earth. These data are also
7 useful for testing algorithms and validating your models.
8 And that's why, even though I'm going to advocate
9 completing the magnetotelluric surveys, I also advocate for
10 having some level of monitoring of geoelectric data in
11 combination with geomagnetic data.

12 All right, so this is a map showing where there
13 has been recent surveys accomplished and being accomplished
14 by the EarthScope program. It's a National Science
15 Foundation program managed by Adam Schultz, who's been here
16 today, and funded by the National Science Foundation. So
17 the red dots are where the measurements were made up until
18 recently, although the work is all ongoing. Green dots are
19 ongoing, are very recently required. And that will be then
20 the end of the funding for that program. This is where we
21 need to be. So these white dots are all the places where
22 right now EarthScope has no plans to install
23 magnetotelluric measurements. And I'm just going back and
24 forth, there's a big difference. In particular, the
25 Northeast United States. If we want to make accurate

1 estimates of geoelectric fields and then use those to
2 estimate GIC's, we need to complete the survey and do some
3 modeling for solid earth electrical conductivity. This is
4 just an example of a model constructed up in the Northwest
5 United States. We can faintly see the maps there, there's
6 Oregon and Idaho, and Montana, etcetera. But this is a
7 three-dimensional model of the electrical conductivity of
8 the earth. And it gives you an idea of the spatial
9 complexity that there is. It shows you tentatively how
10 these data are used by scientists. But if you had then
11 magnetotelluric data, you estimate the impedance and you
12 use those to make these sort of models, if you have these
13 sorts of models then you can, if you want to, estimate the
14 impedance anywhere where that model is pertaining, even
15 between the stations where you acquired the magnetotelluric
16 data.

17 So I'll just conclude right here with the three
18 things that I would like to emphasize as being important:
19 Completing the magnetotelluric survey, we need to do that,
20 we need to have improved geomagnetic and some geoelectric
21 monitoring; we need to construct models in order to better
22 estimate the impedance over the geographic United States;
23 and just a little bit of a promotion here for some of the
24 work that we're doing here at the USGS future products, we
25 plan to develop gridded maps of geomagnetic activity. So

1 these would be time-dependent maps showing you ho
2 geomagnetic activity varies as a function of location; we
3 would provide gridded estimates of impedance based upon
4 three-dimensional models; and we would provide an algorithm
5 which allows you to calculate the geoelectric field from
6 geomagnetic activity and impedance.

7 And then finally I just want to, I guess, close
8 with a question. We've had some discussion in the first
9 panel about geomagnetic monitoring, geoelectric monitoring;
10 we had some discussion about that in the second panel. I
11 did find it interesting in that the discussion for
12 installing magnetometers was discussion with the electric
13 power grid industry. And I guess I'm just wondering why
14 we're asking the electric power grid industry to collect
15 what is geophysical data? We have geophysical institutes
16 that are experts at collecting that. And I would just
17 suggest that those institutes, be they through the National
18 Science Foundation or USGS or others, that they need a
19 modest amount of support to continue doing the job they're
20 already doing very well and they could do it very well for
21 this industry. Thank you.

22 MR. BARDEE: Thank you, Dr. Love.

23 Next we have Frank Koza from PJM.

24 MR. KOZA: Thank you. Good afternoon. I'm
25 Frank Koza, executive director of infrastructure and

1 planning at PJM Interconnection. I'm also the chair of the
2 NERC PMD standards drafting team.

3 In my remarks I talk about the experiences PJM
4 has had with both measurement and implementing operational
5 procedures related to GMD. I'm really not going to go
6 through that given the time. I'd like to focus on a couple
7 of points: First, industry is not standing still in
8 addressing this issue. When I think back to the beginning
9 of our implementation of GMD proceeding at PJM, I think we
10 had about five or six GIC detectors. We're now up to 50
11 GIC detectors. We now have companies beginning
12 installation of magnetometers on the system as well. So in
13 terms of measurement and getting data in, we've made
14 tremendous strides in that regard. On the analytical side,
15 we have member companies in PJM who have done the
16 vulnerability assessments that are contemplated in the
17 standard already, we've done a preliminary basis. And PJM
18 has lead the development of a vulnerability assessment of
19 the entire PJM system. So a lot of work is being done,
20 there's progress being made on the industry. To me, it
21 kind of supports: In the morning you kind of heard the
22 scientific community is making tremendous strides in
23 advancing the scientific knowledge on this topic. And what
24 I would offer to you is the industry side or the
25 engineering side, similar progress is being made as well.

1 Now, when I think about future progress, though,
2 the concern that I hear from member companies, at least at
3 PJM, is they're reluctant to take additional steps and
4 they're basically waiting for the development or the
5 approval of the standard. Right now we're in somewhat of a
6 suspended animation state in that people are awaiting for
7 the standard to be approved so they'll know what the next
8 steps are going to be. What we hear is I shouldn't be
9 undertaking any kind of work right now if I don't know what
10 the requirements are about to be. So what I would mention
11 to you, and we would recommend the approval of the standard
12 as is as a significant step toward getting the ball and
13 continuing the progress on attacking this issue.

14 If I can take one step back and talk about
15 data-sharing for a minute. I mention that we have about 50
16 GIC detectors, all of the information is tele-metered into
17 PJM. We use that for the implementation of our operating
18 procedure. We do in fact feed that information to every
19 support there, research programs. But I think what needs
20 to be said is, rightly or wrongly, that data is considered
21 confidential and in some cases CEII so that if any kind of
22 further dissemination of that information is to take place,
23 we have procedures, at least in PJM and I know a lot of our
24 peers have procedures for the dissemination of confidential
25 information. And any kind of party or individual who wants

1 access to that information will have to go through that
2 fairly-significant procedure to get organizations like ours
3 to release that information. So it can be done, however
4 it's a pretty onerous process to be able to understand how
5 it's going to be used and for what purposes. So, to me,
6 that's one thing that can be done but it's certainly
7 something that will take some significant work from
8 individuals or groups that want to have access to the GIC
9 information as well.

10 So in conclusion I'd just like to say that we
11 think that the next real step to push the ball forward here
12 is the approval of the standard as is. It's been my
13 privilege to work with the standard drafting team members,
14 members from whom you've heard from today. I would mention
15 that in the audience there are a number of people who are
16 not standard drafting team members who are been working
17 with us on the NERC GMD task force over the course of years
18 here who have provided input to us as well. So we think we
19 have the best information; the standard we had drafted we
20 think is an excellent starting point; and certainly there
21 will be more science progress to be made, more progress on
22 the engineering community as well. But we think that the
23 appropriate next step here is to prove the standard as is
24 and start moving forward. Thank you.

25 MR. BARDEE: Thank you, Mr. Koza.

1 And, again, we have Professor Gaunt.

2 PROFESSOR GAUNT: I will describe some
3 experience we have gained when entering GIC's and
4 particularly their effect. In this work we've collaborated
5 continuously known as SANSa Space Science. I also
6 acknowledge intimate collaboration with ESKOM and recently
7 the AM power which is electricity.

8 The first topic given to this panel is present
9 monitoring, and again you have the details in the agenda.
10 My introduction to GIC's was an introduction from ESKOM in
11 1998 to participate in the Sunburst Project. In comparison
12 of measurements and calculations shown here, the agreement
13 was good but not perfect. And this started a search for
14 the differences. We found the nonuniformity of assumed
15 uniform fields made a difference to the calculation.
16 SENSa's implementing measurements through data models which
17 fields nonuniform in direction and magnitude. As an
18 indication of scale, the distance between the Intermagnetic
19 observatories in the North and in the South is about 1,000
20 miles.

21 We are also measuring GIC's in terminal
22 substation by direct measurements in the neutral, and using
23 different magnetometer measurements shown on the right of
24 the GIC and single-circuit overhead line. Additionally,
25 ESKOM measured the approximate GIC's in about 20

1 transformers. I say "approximate" because there's a fairly
2 high error. The analysis of the GDA records of over 200
3 large transformers used led to the load degradation
4 triangle I mentioned earlier. Healthy transformers located
5 in the corners, degradation progresses upwards and right.
6 Jumps in the degradation should correlate very well with
7 GIC events, as well as with other factors.

8 The second topic is the potential for more
9 monitoring. The characteristic of extreme GMD events is
10 the correlation between magnitude and duration. It appears
11 that severe events are associated with bulk flow CME's.
12 The well-known Carrington event was not the result of a
13 single CME. By comparison, a much smaller event in 2004
14 lasted only three days. An analysis of this event by the
15 U.K., at least five shocks of the measurements happened
16 during the event. Such relationships in extreme GMD events
17 lead to modeling. The analysis also illustrates the
18 potential benefit of having allocated simultaneous data
19 such as solar wind and earth surface fields, and GIC's and
20 field measurements. Better understanding of system
21 response requires nonactive power, power, voltage and
22 current measurements including GIC. We have found good
23 reasons for field and electrical parameter measurements to
24 be made at ten-second cadence. And transformer degradation
25 require access to dissolve gas analysis and failure

1 records. Assessing the impact of GIC events require the
2 context of normal system fault. As described earlier,
3 public benefit and mitigation depend on the value at risk.
4 The collection of characteristic failure and cost of
5 introduction data is essential to assist public benefit.

6 Research does not require real-time data. Data
7 collection for operations imposes additional requirements
8 very well understood already by utilities. Deterministic
9 system modeling is extremely limiting. Probabilistic data
10 models and analysis of real dispersion are needed, from the
11 GMD to the cost of interruptions. Balancing public benefit
12 requires more than simply finding deterministic cost of
13 impact and avoidance.

14 Finally, the topic of the availability of data.
15 Our analysis of large transformer failures at ESKOM shows a
16 strong increase after period of large geomagnetic
17 disturbances. A similar response is apparent in the best
18 survey of GSU failures in the U.S.A. between 1980 and 1994.
19 Additionally, surveys provide failure rates but not time
20 profiles. In the failure on the right, the grade showed
21 every failure rate of 1 percent for large transformers, my
22 experience is that most utilities will not allow access to
23 GIC or GDA data, claiming it too sensitive. Utilities
24 collect some relevant data but most do not analyze it, nor
25 allow others to see it. And most suggestions of ideas from

1 outside could have much value. As a result, I believe
2 space-weather research appears to be much more advanced
3 than GIC and public benefit research. Thank you.

4 MR. BARDEE: Thank you, professor.

5 Next we have Tom Popik from the Foundation for
6 Resilient Societies.

7 MR. POPIK: Thank you very much. Again, my name
8 is Thomas Popik, I'm chairman for the Foundation of
9 Resilient Societies. We're a nonprofit group that
10 advocates for greater critical infrastructure protection.
11 Since 2011 we have been part of the geomagnetic disturbance
12 task force process at the North American Electric
13 Reliability Corporation. We have extended thousands of
14 hours of professional staff time in analyzing
15 vulnerabilities to GMD and in commenting on the FERC docket
16 process, as well as participates in NERC standard settings.
17 So there's quite a bit of a basis for what I'm going to be
18 saying today. I've sat here all day -- let me also say I
19 very much appreciate the opportunity to testify here today.
20 I think it speaks well for the Commission and for the
21 individual Commissioners that we've been given this
22 opportunity. Previously, Mr. Roodman talked about the need
23 to cultivate descent. And I won't say that FERC has
24 cultivated descent, but potentially they're allowing
25 descent by giving me this opportunity. So again, I really

1 appreciate it.

2 But I find it very notable that we've gone
3 almost the whole day and we haven't talked about the really
4 graver consequences of a severe solar storm. We haven't
5 talked about long-term blackout. We haven't talked about
6 the consequences of which the Oak Ridge Laboratory brought
7 forth in their 2010 report, they talked about an outage
8 that could last years for 130 million Americans. This is a
9 very dire consequence. Let's make this even a little bit
10 more personal: My wife and I have children, and I know
11 other people in the room have children and some don't. And
12 for the people that don't, I think they can recognize the
13 future of our society does depend on children. So what's
14 the chance that there's going to be an extreme solar storm
15 and that hundreds or thousands or millions of today's
16 children will perish? I'm going to go ahead and assert:
17 It's the position of Resilient Societies that the chance is
18 about one in two. And we get these probabilities in
19 several ways, but one is from the Oak Ridge National
20 Laboratory report, and there are other published sources
21 that estimate the chance of a severe solar storm of about
22 one percent per year or about 10 percent per decade. So
23 then you get to the next step in the probability chain, if
24 there is a severe solar storm then what's the chance that
25 there's really a catastrophic blackout or will the system

1 be able to ride through with operating procedures or some
2 kind of protection for the grid? There's a lot of dire
3 things that could happen during severe solar storms: The
4 transformer's catching fire and exploding being one of
5 them. I'm not going to take a lot of time to go through
6 everything that can happen.

7 So, then, what's the cost to protect? And Oak
8 Ridge National Laboratory estimates about 20 cents per
9 ratepayer per year. Our estimate -- which we actually show
10 the numbers behind -- is about 58 cents per ratepayer per
11 year. Will the current standard require any significant
12 degree of protection? And I think the answer to that is
13 no. And so what I'd like to do is show two slides, and
14 it's very fortunate that Frank Koza from PJM is on the
15 panel so that during the ample time for questioning I hope
16 that Mr. Koza could be asked about some of things that
17 we're going to be talking about. So I'm going to go to the
18 second slide, if I could get this thing to progress. So
19 Mr. Lauby from NERC has been talking for a good part of the
20 day about how the industry is going to do some
21 vulnerability assessments. We have the fortunate
22 circumstance two major utilities have already done their
23 own vulnerability assessments. The one that I have up here
24 on the screen is from Central Main Power. They had 14
25 transformers in their assessment. They did their

1 assessment under the metrics of the draft NERC standard at
2 that point, and they came up with only one of those 14
3 transformers might need protection, not would need
4 protection but might.

5 So then I'll move on to a presentation of slides
6 that was given out by Frank Koza at Idaho National Lab.
7 And I really appreciate that Frank gave this slide, and I
8 appreciate that PJM was proactive to do this kind of
9 analysis. It's small print here, but it's a ranked list of
10 the transformers in the PJM network of which there's over
11 500 by the model GIC. And what it shows is there's only
12 two transformers in their network which have over 75 amps
13 of projected GIC under the metrics in the NERC benchmark
14 GMD event. And so it turns out that those two transformers
15 that the vulnerability studies says are at risk don't
16 include two transformers that have already failed during
17 solar storms at the Salem 1 and Salem 2 plant. So, again,
18 with empirical data we know that there's something really,
19 very wrong with this NERC standard, it just doesn't seem to
20 comport with real impacts.

21 And I would also point out John Kappenman talked
22 about if you look at the benchmark event it doesn't comport
23 with real measured data. So this particular standard, I'm
24 going to be very frank, I think the best thing I can say
25 about this standard is it needs dramatic improvement. And

1 in my written testimony we call it a weak standard. So the
2 question from a policy standpoint is: Should this weak
3 standard be passed by the Commission with potential
4 improvement later on? And it's our position that is really
5 no. Because there are really grave harms to the public
6 that are done when the Commission approves a weak standard,
7 even with the very best of intentions.

8 And I'm just going to read these off with the
9 remaining 30 seconds that I have. A weak standard provides
10 the public a false assurance of safety; it prevents cost
11 recovery for utilities that want to protect above that
12 minimum level; it undermines engineers within the utilities
13 that might advocate for better protection; significantly,
14 it harms vendors who invest in private capital in
15 protective devices that may never be sold; it could cause
16 damage to a customer's equipment; it could give false
17 signals to the equity markets on the true risk and the real
18 value of industrial utilities; and finally it obscures the
19 need for other remedies, including reform legislation by
20 congress. So I've come to the end of my time. But I
21 really would encourage questions, and maybe even as I said
22 some of the other panelists can respond to what I've said.
23 Thank you very much.

24 MR. BARDEE: Thank you, Tom.

25 And next we have Jerry Schuman from PingThings.

1 MR. SCHUMAN: Thanks. I'd like to first thank
2 the Commission, Commissioners for the opportunity to speak.
3 I have a slide deck. So PingThings is a software company
4 that literally is about two years old now, and we have
5 literally been looking at the GIC problem for our entire
6 two years. And what we do differently is we're bringing
7 pretty much advanced data science machine learning to this
8 problem set and we're basically doing it by building an
9 Internet-scale real-time stream analysis engine that can
10 take in high-frequency sensor data to help us get a better
11 handle on what's truly happening as a system holistically
12 when GIC flows are present. It's a significantly different
13 way of looking at what does transpire when a GMD is
14 currently going on. You'll notice that most everyone, for
15 most of the day, the instruments that we have been talking
16 about have been magnetometers, magnetometer readings coming
17 from either Canada or the USGS. Which is great, we take in
18 that data from the USGS and actually do take data in from
19 what was. You heard about GIC monitors and that case it
20 happens to be a transducer that's attached as a neutral of
21 a transformer, and it's actually getting GIC flows as they
22 happen.

23 So what we do a bit differently -- and I'll just
24 jump ahead a couple slides -- is we're actually going to
25 take advantage of the 348 million dollar investment by the

1 Department of Energy in the distribution of PMU's,
2 synchrophasers, to basically take and analyze that data to
3 see if we can in fact find GIC flows through that PMU data.
4 The first question we get all the time when we talk to
5 engineers is, Hold on, PMU's can't see DC current flowing
6 through a transformer, or quasi-DC which is really what is
7 going on. And that's true, we can't. But what we can see
8 are the manifestations. We've all talked about the
9 manifestations today: Vibration, noise, thermal, and
10 probably the one that is most disconcerting in some ways is
11 basically VAR consumption, you're basically reactive power
12 support drops, we got basically voltage collapse problems.
13 So we actually got wind of this problem vis-a-vi -- and she
14 actually is the one that threw the gauntlet down to say
15 could you guys actually see GMD? Could you guys actually
16 see GIC flows? And we said, Interesting, we love big data,
17 PMU's kind of do that by generating an inordinate amount of
18 data. We're now PMU's that are deployed are about
19 2,400-plus in the United States; that number is probably
20 inaccurate, it's probably a lot higher. They are in fact
21 present and you'll hear a lot of talks in the relays today
22 in the protection side of things. They are present in a
23 lot of relays that are currently being deployed, they might
24 not be turned on but they're out there. And basically that
25 data now currently sampling is about two PMU samples in

1 most configurations, but it can go high. There's an
2 example of a vendor here on the East Coast that's currently
3 producing a PMU that does 240 samples per second, which
4 gets those facts of harmonics which we haven't had access
5 to. So I think there's another way to monitor for GIC and
6 that is kind of what we want to talk about and bring to the
7 marketplace, that there are alternatives to in fact
8 magnetometers, which are great and we use them, or Halifax
9 transducers which we also use because we use it for ground
10 truth to see if what we we're seeing inside the PMU's are
11 in fact what shows up in those transducers.

12 One of the things we want to talk about, too, is
13 also some of the assumptions that we've been hearing about
14 GIC's. Now, we've been looking at data from a number of
15 different places. We're actively engaged at Central Main
16 Power where they basically outfitted a substation with an
17 inordinate number of sensors: Halifax transducers; we
18 actually have audio being captured; we have a lot of
19 different things happening. We can take that data and then
20 analyze it for its ground truth and how it applies to
21 PMU's. Something that was talked about on the assumptions
22 side is that the impacts are only limited to high-voltage
23 equipment, which we know that that's not true, the
24 insurance study is a great example of that, that work is
25 that the potential to cross boundaries to get past the

1 demarkation point that is in fact transmission or
2 distribution. That only affects higher magnetic latitudes,
3 we also know that that's probably fairly inaccurate; in
4 fact we heard testimony hear today that that's the case.
5 The other thing that: GMD's don't just happen during
6 storms, it's not active storms that are generating GIC's as
7 an example. GIC's, one thing we hear all of the time is
8 that it's talked about as an event. We've seen in the data
9 itself is GIC flows are actually happening all the time:
10 They're in the system, they're present at all times,
11 they're just at very low magnitudes but they are present.

12 And that the other point, the assumption I think
13 is made, and this one's a little bit troubling and actually
14 this is based on Dr. Gaunt's paper which he cites which is
15 really that some of these effects are actually months down
16 the road when a transformer finally -- because here's the
17 problem that happens: If you're looking at a GIC flow for
18 a Halifax transducer, what are you seeing? You're seeing
19 it as it happens. The data's captured, or if it is
20 captured it shoveled back off to a historian, never to be
21 seen again. Three months later a transformer fails, nobody
22 knows, that GIC three months ago, because that data is not
23 being looked at, it's not forensically checked against what
24 happened. So there's an entire set of assumptions that we
25 think are kind of flawed when you start assessing GIC's.

1 This was the insurance study; I won't go back.
2 But we're talking about GIC's but we should actually
3 seriously talk about the exponential threat factors that
4 are currently on the grid itself right now. Geomagnetic's
5 one thing, we got distributed generation causing all kinds
6 of data specifically because you didn't plan on power flows
7 coming back in. Mother nature is great, she likes to cause
8 a lot of problems. And then ultimately nobody wants to
9 talk about the issues with cyber security. And each one of
10 these instances, it's still holistic views of the world
11 that we really ought to know. How is the system going to
12 respond to any one of these events? Holistically, as a
13 whole. And right now when you start talking about Halifax
14 transducers, you're talking about discreet sensors:
15 They're on a transformer, on a neutral bus. We heard the
16 fact that you got to worry about series capacitors, and how
17 are they doing? Are they contributing to it or are they
18 not contributing to it? There are a lot of things. Again,
19 this is into the system itself, not from external sensors
20 like a magnetometer, not from an external sensor that's
21 discreet like a Halifax transducer.

22 So we believe -- and unfortunately this
23 animation is just a standard -- it's a PDF -- we believe in
24 real-time observation. And this also goes down to the fact
25 of -- and there was mention by Dr. Gaunt earlier -- to a

1 deterministic system to a probablistic [sic] system that
2 takes in all of the variables that are floating around out
3 there that need to be analyzed in real-time. Thank you.
4 This is actually just a chart of an actual Halifax
5 transducer against PMU data, and you'll see that those
6 curves are almost exact matches.

7 MR. BARDEE: Thank you, Mr. Schuman.

8 Commissioner LaFleur, do you have any questions?

9 COMMISSIONER LaFLEUR: Yes, I do, if I may?

10 Okay, that's a lot of information.

11 (Laughter)

12 I want to start with monitoring, because it
13 seems to me unimpeachable that knowing more about the
14 subject would help us make better choices; it would help
15 with what we heard about in the first panel this morning;
16 it would help us learn from the progress of whatever
17 standard we put in place. I have been following this for
18 some time, I'm very impressed with how much our neighbors
19 to the North have done. It's hard not to think that was
20 partly because they encountered an event, and I like to
21 think that we can get there without having to have a 1989
22 storm to make us do more monitoring. So, like everything
23 in this business, the more I know the more I know I don't
24 know. But if I understand it, there's geomagnetic,
25 geoelectric, magnetotelluric, these are big area-wide

1 monitoring that -- I'm blanking out -- the gentleman from
2 the government said that government institutes should do
3 something that expects an individual company to do. And
4 then there's GIC sensors and PMU's can potentially be
5 applied that are more down at a company level. I guess my
6 question is: What can FERC do besides approve the standard
7 -- which we heard from Mr. Koza and Mr. Lauby -- but what
8 can we do on monitoring to help the science move forward?
9 Is there anything we can do as regulators that would get us
10 closer to where we need to be?

11 Yes.

12 DR. LOVE: So just to respond to the fellow from
13 the government quote, I was suggesting the geophysical
14 institutes collect geophysical data.

15 COMMISSIONER LaFLEUR: Not the government?

16 DR. LOVE: It can be. It can be universities,
17 that's also a typical entity. But it sounds obvious to me.
18 Geophysical institutes that already collect geophysical
19 data should be supported in collecting it. And we make it
20 available to the power grid industry and lots of other
21 users as well, it helps the entire community of science.

22 COMMISSIONER LaFLEUR: Besides my checked
23 Princeton, which is probably not enough magnetometers, is
24 there something we can bully pulpit to advocate it?

25 DR. LOVE: Bully pulpit, that's what I would

1 advocate. We have different initiatives, including the
2 President's budget for example, to improve monitoring in
3 accordance with for example the National Space Weather
4 Program's strategic and action. Those plans lay out.

5 COMMISSIONER LaFLEUR: Representatives around
6 the table?

7 DR. LOVE: Exactly. Those plans lay out
8 expectations that different agencies with the government at
9 least will do certain specific things to address, for
10 example, risk for the electric power grid industry. That
11 includes monitoring, and I want to make a distinction that
12 it also includes surveys. So monitoring is where we
13 operate a station at one particular place for a long time
14 and see how things change, and a survey is where we sweep
15 over a geographic area to see how things are at the moment.
16 So it's about difference in time scale relative to the kind
17 of measurement that's made. Those two kind of things need
18 to be made, and the strategic plan issued by the Office of
19 Science and Technology Policy, a White House office, is
20 laying out some of the expectations. But there does need
21 to be some funding.

22 And I'll just say in some cases very modest
23 amounts of money can do an awful lot of positive things for
24 this nation. To complete the magnetotelluric survey, to
25 complete it for the entire nation, four or five million

1 dollars. So to add a few observatories, we're talking
2 hundreds of thousands of dollars. It is not a lot of
3 money. But it doesn't come from nowhere, it needs to come
4 from somewhere and there needs to be some coordination.
5 That's enough from me to say on that.

6 COMMISSIONER LaFLEUR: Trying the GIC
7 monitoring, which is something we can encourage through
8 standards or our direct work, I'm encouraged that there's a
9 lot more GIC monitors than I realized but discouraged that
10 there seems to be so little sharing of information. As one
11 of the agencies with responsibility for the critical
12 infrastructure regs, I'm pretty sure the CEII was not
13 intended to prevent scientific research or efforts to
14 protect the grid. And in fact we just recently got a FOIA
15 exception from CEII in the new legislation, something
16 that's been needed for a long time. I'm interested in
17 hearing from anyone why this information, why companies are
18 concerned, if they are, about sharing it? And is there
19 something in the standard like requiring standard updates
20 or something we can do? I'm sure I can think of something.
21 But rather than something you might not want I welcome
22 ideas that might be more palatable for how we can get that
23 information played into the process.

24 PROFESSOR GAUNT: I'm happy to contribute
25 presenting trying to get information. And I think one of

1 the reasons people are afraid of providing information is
2 that it could put them in a position of negligence. And I
3 think that what happens is --

4 COMMISSIONER LaFLEUR: Position of what?

5 PROFESSOR GAUNT: Of having been negligent.

6 So, for example, I've been looking for PJM's
7 transformers. And the technique we have allows us -- and
8 it was experimental until a few years ago -- allows us to
9 give warning of a transformer very early and on one
10 occasion like six years before it actually blew up
11 explosively and caught fire. And a utility that puts that
12 data in the public domain but doesn't act on it would
13 obviously be negligent for having failed to act. And I
14 think that is one of the things driving the secrecy of
15 data.

16 COMMISSIONER LaFLEUR: But just whether they
17 give it to FERC or not, if they were negligent -- and I'm
18 certainly not accusing anyone was if they were anyway, it's
19 just a question of having that be no -- in other words, can
20 we collectively make more of the data if we have it? I'll
21 just throw that out there.

22 Frank?

23 MR. KOZA: As I mentioned earlier, any kind of
24 this data of this nature becomes sensitive operational
25 data. And none of us in the operating community are going

1 to feel comfortable giving that kind of information out
2 without some pronouncement we're going to be -- okay, for
3 example, FERC could say GIC measurement data is not
4 confidential and that would provide at least some cover for
5 the operating entity who released it.

6 DR. MARTI: I agree to some extent with what
7 Frank and Trevor have said, but there's two aspects of it.
8 We have shared GIC data for scientific purposes for a very
9 specific reason, and we have done that within our camp.
10 Putting the data out there for whatever reasons is
11 something that's very high risk for a number of reasons:
12 One of them is misuse of the data. Because again, from a
13 physical point of view, if you have GIC data but you do not
14 have magnetometer data that's fairly close nearby but it's
15 not synchronized, more importantly you do not know assess
16 it as measured, that data is likely to be misused, cannot
17 be used properly let's put it that way. There's a reason
18 why we're putting our magnetometers close to obtain
19 measurements, this is why we're doing the things that we
20 are doing. And from experience from having done it, it is
21 not trivial. There are many things that can trip you off,
22 there are many things, apparently little details, that can
23 end up stakes.

24 COMMISSIONER LaFLEUR: Thank you, that's very
25 helpful. It's clear that whatever use is made of this,

1 whether it's something we require a company to do as part
2 of their vulnerability assessment, a physical standard, or
3 something else, it has to be protected, I do understand
4 that.

5 Tom?

6 MR. POPIK: If I could just say my group has
7 been very successful in getting GIC data released. So we
8 got Central Main Power to release some of their data, which
9 was very helpful. Also, we did Freedom of Information Act
10 request to Bonneville Power and to TVA. GIC data educates
11 the risk of particular transformer locations. It
12 essentially is public safety data. So we really need to
13 think very carefully about the public policy implications
14 of concealing to any degree public safety data and what the
15 public would say if there were a severe storm and a
16 blackout and that data had been concealed. Think for a
17 moment if a hurricane we considered CEII, right, does that
18 make sense? So, again, we're in kind of a little bit of a
19 cloistered atmosphere here, but I'm trying to bring in a
20 little bit more of a public perspective on this.

21 COMMISSIONER LaFLEUR: I want to limit myself to
22 one more question with all this expert staff here. I want
23 to pick up on something you said earlier, Tom. I do
24 understand if you kind of pair back what you said, one
25 thing is a disagreement with the vulnerability assessment

1 of the benchmark, what we were talking through this
2 morning, which is something we're going to have to sort
3 through. But I wanted to take a second on the statement
4 which I've heard so many times the last six years, that it
5 would be very, very cheap to the do this and we could put
6 on this whoppers and they're virtually available and
7 they're easy. Because it seems like I've been in this yin
8 and this yang of people saying that and then I talk to
9 other people and they say it's not that simple at all, it's
10 way more complicated, et cetera, and that could have
11 implications. So I just want to throw it open to the rest
12 of the panel because we have you here to comment.

13 DR. MARTI: I'm going to repeat what I said a
14 little bit earlier is one the potential number of tools in
15 the arsenal. But it is a complex solution as far as it's
16 known today with many -- I will use the analogy of moving
17 parts -- and each one has its own reliability risk, as I
18 view it as a whole. And implementation requires extensive
19 study, it's not true. Again, after we put together a
20 report on this not very long ago, I don't know exactly if
21 it has been published or not, it's the extensive lots of
22 studies. So the last -- and again we have been looking at
23 this for a number of years, we have contemplated it, and we
24 are not ruling it out, but it's not just plug it in, one in
25 every garage or in every home, it's not that solution.

1 COMMISSIONER LaFLEUR: So it's not like a plug
2 it in, if you put one in one place it could have
3 implications on -- it was the interrelationship. Is that
4 correct?

5 DR. MARTI: There's one of the simplest, the
6 other ones are resonances, the other ones are protection
7 and control. There's a number of those. And the more
8 value that you put in, the more complex it becomes. And,
9 again, they are not an insignificant investment.

10 MR. LAUBY: If you don't mind, from the standard
11 perspective of course, as you know we're technology
12 neutral, we look for performance. And if an organization
13 is looking at particular transformers, comes up with an
14 action plan which would include the addition of equipment
15 like a block as far as standards is concerned is fine. So
16 we we're neutral on the solutions, we just want to get
17 solutions that meet the criteria.

18 COMMISSIONER LaFLEUR: Thank you. We're going
19 to be working very hard to try to balance all of these
20 considerations, but with a function toward affective action
21 we can figure out what that is.

22 Turning back to Mike.

23 MR. BARDEE: Thanks.

24 I'd like to go back to the question the
25 Commissioner raised on the availability of data to make

1 sure I understand a little more precisely the nature of the
2 concern. Professor Gaunt, you had mentioned the issue
3 about negligence, and I can certainly understand why that
4 would be a concern of the owners of the data. But that's
5 not a reason I think this Commission would allow
6 confidentiality. I think for Mr. Koza, you mentioned
7 concerns about releasing the operational data, and I'm not
8 sure maybe you meant that in real-time that could have
9 commercial implications, is that not your point?

10 MR. KOZA: No, not necessarily. Any kind of
11 operational data is not necessarily marked as sensitive.
12 I'm talking about just the release of operational data in
13 general is considered sensitive enough that, you know -- at
14 PJM you would have to go through a significant process to
15 get the permission of the owners of the data. By the way,
16 the GIC detectors are owned by transmission owners members.
17 So you've got to go to them for the approval for us to
18 release the data, that's the process. And again, it can be
19 done, it's a somewhat onerous process but it can be done.

20 MR. BARDEE: Is there a security issue about
21 this? Help me.

22 MR. KOZA: It's operational data. I hate to
23 cast that wide of a net, but any kind of operational data
24 is considered sensitive enough not to just automatically
25 release it. And as was mentioned earlier that reliability

1 coordinators can request it, and that's absolutely true.
2 And PJM has requested it. But that does not give us the
3 authority to release it outside of the four walls of PJM
4 for general use.

5 MR. BARDEE: Professor Marti, you mentioned
6 about the potential misuse, and again I might have
7 misunderstood, though I thought the way you were describing
8 it was that people might use it in ways that had analytical
9 errors. Whether purposely or inadvertently, they didn't
10 understand the data, they missed some pieces of data, and
11 they put this all together in a way whether to purposely
12 portray an inaccurate picture?

13 MR. MARTI: I do not suggest that. But I have
14 seen instances where that has happened.

15 MR. BARDEE: But what your were describing is
16 not a security issue, it's a misperception of the people
17 who ended up getting the analyzed data?

18 PROFESSOR MARTI: Security from the point of
19 view. How do you use the term "security"? In terms of
20 system security or in terms of cyber security?

21 MR. BARDEE: In terms of not the former but the
22 risk of someone with an intent to harm the grid might be
23 able to use this data.

24 DR. MARTI: It is possible and the regulatory
25 environment is different face to face. In our case the

1 decision to -- again, it depends on a number of things.
2 Would it be susceptible to something if you released GIC
3 data completely way out there without any restriction, any
4 purpose whatsoever? I can probably dream up a few cases
5 where something like that could be used. The other things
6 that needs to be considered is data is considered property
7 and the company has to make the decision whether or not to
8 release intellectual property.

9 I want to highlight that there's a large
10 difference between sharing information with an entity for a
11 purchase to leaving information out there for whatever
12 unintended purposes or circumstances might happen.

13 MR. BARDEE: So let's assume for the moment that
14 the Commission agrees that there's some reason to limit
15 access to the data but at the same time grants access to
16 the appropriate circumstances some sort of nondisclosure
17 agreement, would you have any concerns with that assuming
18 it was your decision? Mr. Koza?

19 MR. KOZA: No, I think that's the route you'd
20 have to go, some kind of MDA arrangement. And like I said,
21 at PJM you'd still have to get stakeholder approval, if you
22 will.

23 MR. POPIK: From our perspective as a public
24 interest group, if public safety data is concealed then we
25 would object very strongly to this. I think that the

1 panelists are really struggling to come up with good
2 reasons as to why this data should be concealed from the
3 public, but let's be clear: If a small storm shows 100
4 amps of GIC at a particular location, there's a basic
5 physical principle, Faraday's Law, and it's linear and you
6 can figure out what the GIC would be at that particular
7 location with a more extreme storm. There's not a lot of
8 calculations required and it has pretty dramatic
9 implications for the surety of the power supply in that
10 particular location. And a lot of these transformers do
11 support critical facilities, whether they're military
12 bases, hospitals, and that kind of thing. So we would have
13 very strong exception to, again, public safety data being
14 concealed from the public.

15 MR. BARDEE: I'm not an expert on our CEII regs,
16 at least not any time recently, but at least the way we've
17 treated it in the past if I understand it and remember it
18 is we confirm the legitimacy of the requester. And it was
19 not confined to a specific category of requester. It
20 wasn't as if you had to work in a national lab to get CEII
21 from this agency. So let's assume for the moment that the
22 Commission were to decide that some sort of MDA process is
23 a reasonable approach to this, would to be appropriate for
24 us to require a standardized process instead of the
25 difficulties that some of the speakers earlier today have

1 described as we go through each utility and negotiate one
2 by one to get data?

3 MR. SCHUMAN: I can speak to this from a private
4 company standpoint. It's been very difficult to get data,
5 in fact probably been the biggest obstacle for -- it's been
6 the biggest obstacle for lots of us. We had just gone
7 through this process, we're actually currently working with
8 two reliability coordinators: We're working with MISO New
9 England, and we have a data-sharing agreement with them;
10 and before them we had worked over nine months to work
11 something out with Peak RC. So we now have that but it was
12 an extremely difficult path to take. And we did have to
13 jump through multiple hoops, including cyber security
14 assessments that actually weren't standardized, and we got
15 two different sets of standards to walk off of to prove
16 that we were able to access and have this data. We're
17 talking about PMU data, I'm not talking about GIC data.
18 But GIC data is just as difficult to get. So it is an
19 arduous process that we had to go through, and there was no
20 guarantee that we were going to get through it either. But
21 in the case, we had to go in front of the board multiple
22 times, and it was out for comments I can't even tell you
23 how many times before we finally got the opportunity.

24 COMMISSIONER LaFLEUR: Just to pick up: My
25 understanding of the CEII regs is they're intended to

1 protect if information was in the public domain and it got
2 in the wrong hands, that it could be used to cause harm,
3 that they started after 9/11 I believe. So for example to
4 Tom's point that if the public knew that there was a weak
5 transformer right near a hospital or whatever, somebody
6 else that had the vantage could knock the foundation could
7 know that too. So I think there's a difference between
8 putting it in the newspaper and anyone can get it or on the
9 Internet, and allowing it for standard and planning and
10 research and so forth.

11 MR. POPIK: If I could just interject? If that
12 data was released, it will have absolutely no effect on the
13 probability of a solar storm actually occurring. You can't
14 order up a solar storm because the data --

15 COMMISSIONER LaFLEUR: It's not protecting
16 against the sun, it's other individual actors.

17 DR. LOVE: This is Jeff Love. I'm just speaking
18 out as a research scientist. A few things: Most research
19 scientists want to publish things, they want to make things
20 public because there's a whole issue of reproducibility,
21 which is the cornerstone of the scientific method. And
22 obviously data that are restricted or metadata is taken off
23 of time series or we don't know where it came from, those
24 kinds of things, makes it a lot less useful for research.
25 So I guess I'm wondering maybe there's another way to do

1 this. And perhaps one way is to have a time window where
2 data are not available but then after 10 years or something
3 they could be analyzed by scientists. Lots of scientists
4 would love to just know what data are, what GIC were
5 available for the Halloween Storm in 2003, all right, 13
6 years ago. And to have that information in terms of time
7 series from different geographic locations there would be
8 very interesting research done that would be beneficial to
9 everybody. And maybe, I don't know, maybe a window of time
10 like 10 years or something would be acceptable, I'm just
11 putting that out as an idea.

12 MR. LAUBY: As I mentioned in my remarks, I
13 think where the real challenge is right now is we're now
14 going forward with presumably getting a standard in place
15 which will call for vulnerability analysis of transformers.
16 This will then result in the addition of monitoring devices
17 or some sort or another event, big data analysis for
18 community data is an interesting perspective from
19 reliability, and physics and other things you can look
20 there, too. Modeling systems and failures and transformers
21 and breakers, et cetera. So something of interest. But
22 once we understand where is the right place to put
23 monitors, and of course on the geology and the network
24 configurations we're dealing with, once we understand all
25 those aspects we can start thinking about what kind of data

1 sharing makes sense, who should be gathering the data, how
2 long they're going to store it and where they're going to
3 store it. And the implications of all of that I think
4 become more important.

5 Right now I think we have data that's being
6 created and being used for operational applications, some
7 of the dates back many years, I don't know PJM how many
8 years of data you have and how far back it goes. Because
9 this stuff takes a lot of room: I know the PMU data would
10 fill gigaflops and gigaflops, I don't even know enough
11 about the IT industry, it's a lot of data. So once we
12 understand really what's the right place to put monitors;
13 how extensive the network should be; how do we gather the
14 data? How we should be sharing the information? I think
15 that's where we should start looking at where should we
16 locate the information. How do we share it with
17 researchers? And as far as up to this point in time what
18 data is available I don't really have a significant
19 comment, I don't know the status of that data, how well
20 it's calibrated. Because you have calibration where you
21 end up with all sorts of different voltages which are not
22 really accurate because they haven't been calibrated. And
23 then the RPE's private networks which we know as well, so.
24 So that's collaboration work that needs to be done in order
25 to understand what is the right place to locate the GIC's

1 monitors and how to gather and how to analyze it, the
2 logistics of the monitors and how to gather it and how to
3 analyze it to get the right kinds of useful information.

4 MR. BOTELER: It would be just having the data
5 available, is that as part of making the data available to
6 a group to work with an important aspect of that is the
7 dialogue between the people who have done the original
8 measurements would get lost along the way. As a scientist,
9 I always want easy access to data all around the world, but
10 working with a group that is a data supplier and made
11 available, but sometimes we cringe when we see how it's
12 being used. And there's the danger if you've got a list of
13 things on the Internet people are going to grab it and
14 start to make wild connections. One study I saw years ago
15 someone tried to correlate protection events on a system
16 with sunspot numbers, and you just think there's so many
17 steps in between it would be remiss to really -- some of
18 those aren't actually harmful, they're just a waste of
19 time. But the other ones that can be misleading, a few
20 years ago someone put out a list of disturbances on
21 electric power systems in North America due to geomagnetic
22 storms. So we looked through this list with interest and
23 we were a bit surprised, but we had just done a similar
24 study and we thought we had a pretty good handle on it. So
25 we looked through, and most of them were the ones that we

1 knew about. And we saw one that we hadn't heard about at
2 all, we were so interested we jumped on that. So we
3 actually went to the extent of tracking down through our
4 connections the company where this had happened. And we
5 heard about it. What had happened was there had been a
6 transformer failure on a certain day and there had been a
7 magnetic storm on the same day, so someone saw had seen a
8 list of magnetometers and put the two together. What we
9 found was far more interesting, the transformer failure had
10 happened about 6 o'clock in the morning and the magnetic
11 storm happened about 6 o'clock in the evening. So the
12 prediction capability for magnetic storm, this is going to
13 be wonderful.

14 (Laughter)

15 But what they explained was a transformer was
16 being energized and they fried it, and that I have been
17 told from power engineers that's the kind of thing that can
18 happen on the power network. Just an example, when you've
19 got data with people with incomplete knowledge they are
20 going to make spurious connections.

21 DR. LOVE: Okay, fine. That kind of data is
22 what I would call anecdotal. And that's a limited utility.
23 When we're talking GIC data I hope we're talking continuing
24 time series where quantitative measures of multiple
25 occurrences which have some statistical significance can be

1 established as opposed to a one-off oddity in the data, so.

2 PROFESSOR GAUNT: I'd like to comment on what I
3 said about keeping data confidential for a period. And I
4 think that we need to understand the comments that we've
5 heard about scientific knowledge continuing to progress and
6 that if we are going to project ourselves forward in four
7 or five years' time when this whole assessment process
8 starts for a second time, if the data has not been
9 available we're not going to be able to give guidance about
10 where the sensors should be located or what sort of data to
11 take into account to assess reliability. So I think we
12 need to balance off a present and a past situation against
13 where we're going to be in four or five years from now.

14 MR. BARDEE: Mr. Koza, for the monitors that
15 have been on the PJM system for any length of time, has
16 that data been recorded or is it just monitored in
17 real-time?

18 MR. KOZA: It's certainly monitored in real-time
19 because it's in our operational procedure. But it is
20 archived in the database for I guess we have at most
21 probably several years' worth.

22 MR. BARDEE: Dr. Love, in terms of your concern
23 about publication of the results and others being able to
24 look at it and reproduce it, let's assume the Commission
25 were to decide that the proper treatment for this data is

1 to make it available but only under a nondisclosure
2 agreement, are there ways that scientists could use the
3 data, publish their results, keep the data as necessary if
4 others come to them to say How'd you get that? And at the
5 same time publish results that doesn't disclose whatever
6 the Commission might have decided was, Oh, we don't want
7 this out there?

8 DR. LOVE: That's a very interesting question.
9 And there's kind of a collage of different ways to get
10 results out. But they're also changing. So, for example,
11 AGU, American Geophysical Union, is really clamping down on
12 publishing papers that have confidential data. You're
13 supposed to make the data available for the publication.
14 And that agency is doing that because they want to promote
15 reproducibility. Having said that, I have seen papers I've
16 seen GIC papers published by AGU, I don't know if that's
17 going to continue in the future. You know, there's been
18 other issues, though, in my own research which are in a
19 different subject but the issue is relevant here -- there
20 are agencies and sometimes private companies that right now
21 claim that they can predict earthquakes. And they have
22 published such claims of successful identification of
23 signals which might be indicators of impending earthquakes.
24 I have seen these papers published. I have requested the
25 data because frankly I'm skeptical, and I have so far from

1 these companies been denied access because in those cases
2 they were -- well, I don't know the reason why. But I
3 can't check their results. These are private companies who
4 in some cases are hoping to make money some day, but I
5 don't know that their methods are valid. It's further
6 murky because in some cases some of the censors were paid
7 for by the U.S. Government through some collaboration
8 between the company and the government, and presumably
9 since part of it was government data the data would be
10 accessible, but in this case the company would say, Well,
11 actually we don't know, the money just went into a pot and
12 we had some private money added to it as well so it's not
13 government money anymore, it just goes around in circles.
14 But my experience is that many, maybe most, research
15 scientists won't even deal with it. And they won't deal
16 with it because it's hassle, they will move on to analyze
17 other data for a different project because they can get
18 something done more easily there. So it does dissuade
19 research.

20 And like I have also said before, open access
21 for data means that a scientist can explore it and see what
22 is in it and from that make discoveries that might be
23 interesting, that may be unexpected. And in that sense he
24 may not have known what data to request before he took the
25 exploration. So I understand there's multiple reasons here

1 and companies needing to be careful with their operations
2 and their profit and there's issues with security, and I
3 don't know the answer to these things, I'm only expressing
4 to you the opinion that I have as essentially an academic
5 research scientist, so.

6 MR. AYOUB: Just a couple of questions. First,
7 Luis Marti, you mentioned in one of your slides you have
8 two models: One was theoretical and one of the models
9 match the actions and one they don't, because when they
10 don't agree obviously they don't. Do you have a sense of
11 how often that happens, what's the success rate of match
12 versus non-match?

13 DR. MARTI: Surprisingly good, meaning close.
14 Considering the current limitations in the models that we
15 have today in service, I am very pleasantly surprised by
16 the fact that they are in the same way. So it has been
17 used.

18 MR. AYOUB: Okay.

19 And just quickly, Dr. Love, the Halloween Storm,
20 you had a slide, let me see if I can get it.

21 DR. LOVE: I know which slide you're talking
22 about.

23 MR. AYOUB: I'm just going off from memory, the
24 top one was actual and the bottom one was trying to
25 replicate --

1 DR. LOVE: So the top one was magnetic data and
2 the bottom one was geoelectric data. Those data were
3 acquired from Japan. Japanese have a very healthy support
4 for geophysical monitoring. It's not GIC, this is just in
5 the earth. And so, yeah, that data is from Japan, they
6 have three stations that do this terrific monitoring of the
7 geoelectric field in combination with the geomagnetic
8 field. And the chain together allows a scientist like
9 myself to better understand how geoelectric fields are
10 induced during magnetic storms. Since it's long-term
11 monitoring, they record the big ones as opposed to just
12 kind of temporary deployment. It's long-term, dedicated
13 monitoring, so.

14 MR. AYOUB: If you had access to that voltage
15 data that you had referenced, had you tried that with other
16 events and was there a match as well?

17 DR. LOVE: So what you'll see in that data is
18 there is a not-simple relationship between the blue and the
19 green time series on top, which is the magnetic time series
20 and the black and the red time series on the bottom.
21 There's not a simple relationship. And that is due to the
22 electrical conductivity of the earth. So then there would
23 be probably a relatively simple relationship between those
24 geoelectric data and GIC data, but I don't know. But
25 that's the cause and effect. The cause and effect:

1 Magnetic fields causes electric fields; electric fields
2 derive GIC's in the system. So that's the geophysics side
3 of it.

4 PROFESSOR GAUNT: And the pure electric fields
5 drive potentials in the system which are filtered by the
6 resonances of capacity banks and the inductions of the
7 transformers and the dumping of the loads which give rise
8 to the practical GIC periods.

9 MR. POPIK: And to follow the chain to its
10 logical conclusion, the GIC then impacts transformers and
11 causes transformer failures. And that's another type of
12 data that is not publicly available or we could even say
13 might be concealed. So why is this transformer impact data
14 so important? Well, for the nuclear power industry it's a
15 safety issue, because if you have a GSU transformer fail
16 then you have load rejection and it causes a reactor scram,
17 and that's a safety incident. So, again, it's a whole
18 chain of data that is not publicly available. I think the
19 magnetometer data, because it's collected by governments,
20 that's available. The geoelectric field data is
21 infrequently measure but could be publicly available; the
22 GIC data, not publicly available; and then the end of the
23 chain is the transformer impact data.

24 MR. AYOUB: Thank you. And last question, I was
25 going to mention: I recalled there was an example from

1 693, I'm not sure how applicable it is to the GIC data.
2 But at some point through a standard Section 1600 there was
3 a standard neutral plants with restoration times
4 collectively to NERC, and NERC would file quarterly reports
5 with the Commission, and that went on for awhile. But I'm
6 not sure that is something NERC had considered is the same
7 where the gentleman mentioned there is -- Section 1600,
8 also there is an IRO 10 where ROC has full authority to
9 request specification, any kind of data and so forth. But
10 I think all that would feed through NERC potentially, like
11 I said we used to have something similar with the nuclear
12 restoration times where CEII and so forth came into play.

13 MR. LAUBY: Again, the tools are there to
14 request data on a mandatory basis. And assuming we make
15 justification rule of why we're asking for that data and
16 that data comes to us, we request under 1600, it's covered
17 confidentially through 1500, then FERC request the data,
18 too, or if they can justify. But to be clear here, I need
19 to understand -- I think we all need to understand -- is if
20 you have a GIC monitor, I want your data, then nobody's
21 going to put them out. So we have to understand exactly
22 where is the right place to put monitors, or let's get you
23 out of this information and use it for reliability
24 applications via vulnerability analysis, I'm sure obviously
25 some people use different operating procedures, but also

1 using it to validate their models. So as we go through the
2 vulnerability assessments, the monitors will go in place
3 I'm certain, or they may use other pseudo-monitors for
4 their protection systems or PMU data and make their
5 calculations. So we can start looking at the right time
6 once we determine where they're located, which ones are the
7 right ones that are put in place, and of course would be
8 used for insurance purposes. Right now it's spurious, some
9 places they have them, some places they don't.

10 DR. MARTI: I'm aware of two good reasons to
11 have GIC data: One for situational awareness and
12 real-time; one for model validation if you have magnetic
13 field data and system information integration and whatnot;
14 I heard the third one, which is to further knowledge in an
15 undefined way. What else is there? I don't know. The
16 first two are a matter of self interest. I would be happy,
17 but it's not happening. So the part that is giving me
18 pause because of duration is putting GIC data out there
19 that could have unintended consequences other than those of
20 improve my system for the knowledge, I am concerned about
21 those. And I have seen examples such as the ones that
22 David has mentioned, and I have seen examples where
23 somebody used magnetometer data that wasn't inside a
24 station to prove a point. Well, that is not the wisest
25 idea because it interferes with the magnetic field that I

1 just mentioned. So that is suspect. If the things are not
2 properly timestamped, and I'm probably going to go into the
3 details, but we'd have to deal with a day-to-day basis --
4 if they are not, they get the stamp of the time they get in
5 the system folded. That could be easy two or three seconds
6 apart. When you're using magnetic field data that you use
7 to calculate the time derivative, you multiply the
8 potential errors by a number I'm not going to try to
9 qualify, just say that it's big. So I'm just trying to
10 explain why the reluctance to release data for which I
11 don't know what it's going to be used for. We have
12 released our data for clearly articulated scientific
13 purposes. We were told we are going to do a statistical
14 analysis, over time, open places, we're not going to
15 identify specific stations, and all that kind of stuff.
16 And we shared that information, nothing else because we
17 wanted to go as far as we could without their help.
18 Releasing the data as part of the reliability standard,
19 that would probably be a problem for many utilities.

20 COMMISSIONER LaFLEUR: If I could just answer
21 that? There's only one valid reason as far as I'm
22 concerned for this Commission to want the data, and that's
23 to inform us in our responsibility to try to help propound
24 standards that are going to protect the public from this
25 serious risk, like all the other risks that we have. I

1 personally, Cheryl LaFleur, do not need the data for
2 situational awareness because I don't run the grid. I used
3 to have a role in running a little part of it a long time
4 ago, but that's not what we do in this building. Data I
5 need is to understand the standards that we are making to
6 the extent it helps. When I first started -- this has been
7 one of my top priorities for five and a half years, maybe I
8 have that wrong but whatever, five-something years -- when
9 I first started I was told there wasn't enough data to go
10 on, it would take years to study, it would take seven
11 years-eight years before we could even think about a
12 standard because we had to study, study, study. And as I
13 started peeling the onion it looks like there's more data
14 than I realized. And I've heard anecdotally from people I
15 know in the industry that on a day when something happened
16 they saw something in the substation. And, to me, that's
17 really interesting because the more we can get our arms
18 around that the more we can make whatever our intelligence
19 standards are, or require somebody else to make
20 intelligence standards, or somehow harness this data to
21 make sure what we require people to do is the sensible
22 thing. To me, that's the only real -- I know that some
23 people want it for public safety, but I'm not a public
24 safety officer propounding warnings. I just want to make
25 sure whatever we do is smart and worth the money and the

1 time that people put into it and is going to offer more
2 protection. And the more informed we are with information
3 in making those standards, the more likely we are to get it
4 right. And knowing that there's a lot of monitors out
5 there that people don't want to have known is troubling,
6 just because it suggests that maybe there's a bigger
7 problem that we know. And maybe there's not, but it just
8 -- I see Mike and I both kind of grappling on why can't we
9 know? What is this? So that's my intent to answer.

10 DR. MARTI: Not that I'm questioning you, it's
11 probably the other way around. But I would say what you're
12 saying absolutely the reason why you want to have the
13 monitors and the magnetometers is to be able to improve
14 your models. That's the first priority.

15 DR. LOVE: Sorry, I don't know what you're
16 talking about. Why would you use that to produce earth
17 models?

18 DR. MARTI: Qualitate earth models, that's the
19 simplest thing you can do.

20 DR. LOVE: GIC data?

21 DR. MARTI: Yes.

22 DR. LOVE: No, that's not what I would do.

23 DR. MARTI: Well, seeing that, the best thing
24 for magnetometers we have, that is what I would -- and for
25 that, I would absolutely give to you, give to USGS,

1 whatever, so I could have a good model that I could use in
2 my system. I applaud that, and that is in the spirit of
3 what you're saying.

4 COMMISSIONER LaFLEUR: Thank you. I have
5 already said more than I planned to by quite a bit. But I
6 again want to thank everyone who put their time into this.
7 It took a lot of time for the people to write all these
8 studies and for staff to gather them and work on this for
9 all this time. So I really appreciate it, thank you.

10 MR. BARDEE: So with that, we'll end our day.
11 It's been a very interesting day. And Commission has some
12 hard decisions to make at this point, but we very much
13 appreciate all the input you all have provided and look
14 forward to issuing a final rule. Thank you.

15 (Whereupon the FERC technical conference scheduled for 9:00
16 a.m. on March 1st, 2016, is concluded at 4:35 p.m.)

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