Comments on NERC's draft GMD Benchmark Report

I have grave concerns about the validity of NERC's April 2014 "Benchmark Geomagnetic Disturbance Event Description" report and wish to alert you to major technical problems with its contents. Because of significant flaws in the report, the GMD Benchmark Event should not be approved in its present form. Re-investigation and revision is needed.

The text of my letter below speaks to major concerns. I have also included an attachment that provides specific comments by paragraph based on my review and methods of 'extreme event' probability expert, Dr. Charles T. C. Mo.

To begin with, the NERC report misuses available statistics on solar storm environments. The report employs an incomplete data base that uses a 20 year time window to make inferences about the probability of 100 year effects. In effect, the report assumes the sun behaves the same during all solar cycles, an assumption known to be erroneous. The report bases its conclusions on subjectively extrapolated tails of probability distributions using incomplete data sets. This methodological error effectively closes the door on preparedness for "outlier" storms such as the 1869 Carrington event or the 1921 Railroad Storm.

The NERC report contains no reference to or rationale for dismissing measured geoelectric fields and GIC data that are far in excess of what the GMD Benchmark would predict.

Statisticians often assess risk using a number called "expected loss," which is derived by multiplying the probability of an accident times the value of the loss caused by the accident. This approach is implicit in NERC's concern about reducing the probability of a major GMD event— viz. by using a 20 year interval of relatively mild solar storms, and reducing the expected loss by minimizing the expected 100 year peak electric field, and by inventing the concept of limited-area solar storm electromagnetic "hot spots." A prudent person would base decisions involving high consequence events on factors that go beyond the expected loss.

A better approach for low-likelihood, high consequence events has been developed by Professor Yacov Haimes at the University of Virginia. In his "Partitioned Multi-Objective Risk Method" or PMRM approach[1], Haimes argues that it is necessary to account for catastrophic events separately from ordinary accidents. Rare but extreme loss catastrophes may have a manageable expected loss, but that does not mean that accepting their risk is justified.[i]

As an illustrative example, a catastrophe involving a 100 year Carrington-class solar storm could conceivably shut down the U.S. economy for 1 year or more. The value of the economic loss would be one GNP or approximately 17 trillion dollars. If the probability is 1% per year (the historic probability is in this ballpark), the expected loss would be $170 billion, which is relatively small in comparison to the annual U.S. federal budget. But the PMRM approach would argue that because hundreds of millions of lives are at risk and because continuity of national governance is at risk, such a catastrophe must never be

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[1] [i] Haimes, Y. Y. et al, Multi-objective Risk-Partitioning: An Application to Dam Safety Risk Analysis, U.S. Army Institute for Water Resources, IWR Report 88-R-4.

allowed to happen. In summary, even though a Carrington Event-caused shut-down of a continental-scale portion of the North American electric power grid is unlikely in any single year, it is also totally unacceptable.

Based on Professor Haimes' arguments and other reasons, I submit that the entire North American grid should be protected against GMD if FERC and NERC are serious about safeguarding the American public. Reasons include:

1. Uncertainties in magnitude of worst-case GMD fields are at least a factor of ten. Southerly latitudes may well be exposed to much larger GMD than predicted by the NERC standard de-rating formula.
2. Protective measures are commercially available and cost-effective. Neutral current blocking devices can accommodate a factor 5-10 excursion in the field magnitude above the NERC 8 KV bogey proposed in the draft standard.
3. The entire North American grid is susceptible to exposure to the effects of a nuclear EMP E3 that outstrips the NERC 8 KV bogey by a factor of 10. Nuclear E3, unlike GMD, increases at southerly latitudes. In the event of a nuclear EMP event, portions of the grid unprotected against GMD will succumb to EMP-E3 effects. It is highly prudent and cost-effective to address EMP-E3 and GMD protection concurrently – otherwise another highly redundant and unnecessary round of costly protection assessment and implementation will be required.

In closing, we need to be very careful where the survival of millions of Americans and the breakdown of our national governance is at risk. There is reasonable certainty that GMD storms and EMP events will occur with magnitude in excess of the Benchmark GMD Event. These high-magnitude events will render moderate protection designed to a defective GMD Benchmark completely ineffective. Implementation of the current draft GMD Benchmark will leave us susceptible to continental-scale grid failures from solar GMD and EMP. I recommend that NERC incorporate Yacov Haimes' PMRM approach to protect our society. Finally, I urge you to send the current Benchmark Geomagnetic Disturbance Event Description document back to the Standard Drafting Team for revision.

Sincerely,

George H. Baker
Professor Emeritus and Former Director, Institute for Infrastructure and Information Assurance,
James Madison University
Congressional EMP Commission

Attachment: Detailed comments on Project 2013-03 Benchmark Geomagnetic Disturbance Event Description

Attachment 1
NERC Project 2013-03 Benchmark Geomagnetic Disturbance Event Description

Detailed Comments
George H. Baker and Charles T.C. Mo

- Page 6, paragraph 4. Do you include *<u>all</u>* data in the 100 year time span? If not, another layer of statistical inference is needed based on a model that includes the sampling nature of the known data vs. the actual occurrences. The analysis must based on all available data and objectively and truthfully exclude any subjective data truncation.
- Page 6, formula (1). An added factor is needed to account for shoreline enhancement. Many generator stations and associated transformers are located along edge of water bodies.
- Page 7, paragraph 1, sentence 1. Should include data going back as far as possible even if 100 year span is not available. Look for and include data from outlier events.
- Page 7, paragraph 2.
    - The latitude scaling was not explained in the earlier formula (1) discussion. Is this just a cosine law or empirical? Show the relation curve and error range.
    - The 8kv/m level is lower than historically measured peak GMD field values.
    - You need to add the approximate low frequency formula that maps $d\mathbf{B}/dt$ to $\mathbf{E}\|$ including its dependence on earth conductivity and effective ground depth.
- Page 9, Statistical Considerations, paragraph 1.
    - You dismiss the Carrington event from the data base since there is inadequate information to relate $d\mathbf{B}/dt$ to $\mathbf{E}$ field. You made no mention of the 1921 Railroad Storm where $d\mathbf{B}/dt$ levels. Data from this storm will be very important to include since it was a high-side outlier.
- Page 9, Statistical Considerations, paragraph 2.
    - Explain why you see a correlated relationship between DST and storm strength.
    - Again, why have you not referenced the 1921 Railroad Storm?
    - Per your statement, "These translate to occurrence rates of approximately 1 in 30-100 years," please include the confidence level or Bayesian coverage if a subjective Bayesian formulation is used. Also, you need to explain the "translate" model, e.g. do these events have Poisson independent arrival times of constant rate, or what? In any case, extrapolating from a 20 year data base to 600 years assumed a strong stationarity of the event occurrences. Proper statistical inference from such events needs be accompanied by a reduced confidence since the extrapolated time span is significantly longer than the data time window.
- Page 10, Figure I-1. Please provide a reference for this figure. Where in the refereed professional journals have you seen the "hot spot" concept developed?

- Page 11, paragraph 1 and figure I-2. You need to convince the reader/user. How do these four 10.0 to 18.9 year coverage curves infer complete 100 year behavior?
- Page 11, Figure I-2. Behavior of the tails of these distributions is not shown. Extreme values of the low end of probabilities are subject to large uncertainties.
- Page 12, Paragraph 1. The fundamental flaw of following the 20 year model fit regression type statistical analysis (and thus claim to infer from one cycle the sunspot behavior of many other cycles and accordingly infer solar behavior over a much longer time span) is that your approach assumes that the model parameters are actually the same set of constants in all cycles. As a result, your estimates and inferences from data in just one solar cycle, or in two cycles is equivalent to expanding them to represent one much larger data set, i.e., you are assuming parameters computed based on one cycle immediately valid for any other cycle. But if these parameters are themselves random sample realizations from cycle to cycle, then the analysis is totally invalid. As an extreme example: if within one 11 year cycle you have a very large sample set, then you can estimate these parameters with near certainty in a almost point value estimate. But then you have ***no*** information of their value in another cycle. Realistically, you must physically model these parameters as random variables themselves, such that each cycle contains a parameter set of their realization. Then use these sets to develop your estimates. The proper approach is mathematically more complicated but a physically more realistic two layer statistical inference problem.

- Page 12, Figure I-3. The sample time window is too narrow to infer 100 year behavior.

- Page 16, paragraph 1. Not clear how the intensification factor of 2.5 was derived. Please explain and provide reference.

- Page 16, Figure I-6. It is important to take into account where the locus of transformers within the grid. If the transformers are positioned at choke points, the loss of small number can be significant.