

T&D General Systems Subcommittee
Practical Aspects of Ferroresonance WG
St. Francis Hotel, San Francisco, Essex
Tuesday, June 14, 2005, 10:00-12:00

Meeting Minutes

Participants:

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Bruce Mork	bamork@mtu.edu
Michel Rioual	michel.rioual@edf.fr
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Working Group Officers:

Bruce Mork, Michigan Tech Univ. is the chair of the WG. David Jacobson is co-chair and secretary. Reigh Walling is a backup (although our meeting time conflicts with Reigh's WG Distributed Generation Integration).

Discussion:

- The minutes from the 2004 WG meeting in Denver were reviewed. Bruce will ask for final comments via e-mail and will post the minutes on the WG website.
- Bruce went over the charge to the WG and outline of the WG document for new participants in the meeting. The documents can be downloaded from: http://www.ece.mtu.edu/faculty/bamork/FR_WG/
- **Technical Presentations**
- Gary Korbet presented results from a 1999 Georgia Tech relay conference paper:
 - An oil filled 8.4 kV PT was replaced with a molded case 7.2 kV pt, which resulted in ferroresonance following energization. The situation was an example of installing a grounded pt in an ungrounded system. Several mitigation measures were tried:
 - connecting grounding bank – worked
 - add 30% loading to pt – ANSI metering accuracy exceeded
 - energize high side transformer and pt – doesn't work
 - add 50 kvar shunt capacitors – worked
 - change primary grounded-wye connection to delta – worked

- three phase switching instead of single phase – doesn't work
 - Decision made to change the transformer connection as it was the lowest cost option. Ben Sperling mentioned they have used a four-legged arrester for mitigating ferroresonance situations. If transformer reconnection doesn't work this is another option.
- Fransisco de la Rosa presented Ferroresonance in a Cable Fed transformer:
 - Fransisco presented EMTP simulation results for the case of a small 6 pulse drive fed through a radial 15-kV underground cable and delta-wye three-legged transformer. Single phase opening of the cable circuit resulted in ferroresonance, which translated to a high dc link voltage in the drive circuit.
 - It was suggested to examine the harmonic spectrum of the waveform for dc offset and subharmonic content. The transformer model could be examined in more detail. A five legged core model might help. It was noted that parameter estimation for more complicated transformers has not been reported on.
- Bruce Mork presented on Ferroresonance of pts in an ungrounded system:
 - Bruce has an example where a single event damaged more than 50 grounded-wye open-corner delta pts. A post mortem analysis showed a wide variety of excitation characteristics. The recommendation was to specify a reasonably high kneepoint to avoid ferroresonance.
- Advanced methods
 - Michel Rioul discussed the merits of using the AUTO program for ferroresonance analysis. EDF uses this program for studies.
 - Bruce discussed bifurcation analysis. He showed an example of plotting the bifurcation behaviour when capacitance is varied. Bruce mentioned that tracking the energy in the capacitor may be interesting.
 - David Jacobson has created two-dimensional bifurcation diagrams (e.g. voltage and capacitance variable) for displaying ferroresonance behaviour.
 - The intent is to form a WG to report on advanced analysis methods once this WG's task is complete.
- Other contributions
 - Albert Keri offered to provide an example of ferroresonance that occurred when one circuit of a double-circuit line opened.
 - Tom Grebe mentioned that Roger Dugan may have an example of 1 phase fuse operation causing ferroresonance in England. Tom will follow-up with Roger.

- Gene Lindholm has 8 cases of ferroresonance. Some information has been posted on the web site. Bruce will ask Gene to provide the remaining documentation.
- Atef Morched has promised to contribute to the WG document but his e-mail address is out of date. Tom Grebe will send Bruce updated contact information.
- Web site
 - An IEEE General Systems web site has been created on the IEEE server. Bruce will talk to Brian Johnson in order to add a link to our website.
- Work plan
 - All contributions for the WG document are to be sent to David Jacobson and Bruce Mork by the end of November 2005. Bruce and David will select a group of 5 presenters in December to participate in a panel session at the 2006 IEEE meeting in Montreal. Panel papers will be required in January 2006. (post meeting note – deadline was missed and panel session will need to be deferred)
 - A complete draft of the WG document will be prepared and circulated for comments in early 2006. Final editing discussion will take place in Montreal.
 - The plan is to have the ~200 page WG document published in late 2006 for a tutorial in 2007. Ben Sperling will determine the necessary lead time requirements for publishing the document.

WG Special Publication assignments

- Foreward/Executive Summary – Bruce Mork
- Introduction
 - What is Ferroresonance and how does it impact us?-Bruce Mork
 - Transformer Core Structure & Equivalent Circuit Models-??
 - Typical Waveforms and Overvoltages-??
 - Nonlinear Behaviour, bifurcations-??
- Detailed Summary/Literature Search
 - Historical Background & Major Milestones -David Jacobson
 - Basic Circuit Types Susceptible to Ferroresonance-David Jacobson
 - Basic Mitigation Techniques-David Jacobson
- Catalog of Ferroresonance Scenarios and Mitigation
 - Distribution Systems
 - Examples of Ferroresonance-Roger Dugan
 - Ferroresonance in Low-Loss Distribution transformers-Reigh Walling
 - Ferroresonance in a Cable Fed transformer- Francisco De La Rosa

- Cost of Mitigation Options- Mort Knodaie
 - Ungrounded delta tertiary – Gary Kobet
 - Case Studies – Gene Lindholm
 - Subtransmission Systems
 - Open-Delta PT-David Jacobson
 - Transmission Systems
 - 230 kV Transformer/grading capacitor-David Jacobson
 - 345 kV VT/grading capacitor-Todd Sarkinen
 - Transformer Terminated Double-Circuit Line-David Jacobson
 - Capacitor Voltage Transformer-David Jacobson
 - Special Cases
 - Manifestation of Ferroresonance on Customer Side of Meter-??
 - Special Cases involving Instrument transformers, industrial Applications-??
 - Engineering Forensics, Identifying Ferroresonance, Symptoms, Damage-Atef Morched?
- Things that are NOT Ferroresonance
 - TOV Summary-Bruce Mork/David Jacobson
Refer to types described in IEEE TOV task force report, 1990 Cigre paper 33-210
 - EDF TOV Example-Michel Riouale
 - Voltage Magnification (cap bank switching)-??
 - Sustained Harmonic Inrush-Bruce Mork/Roger Dugen
 - Shunt reactor resonance-David Jacobson
 - Switch Restriking-David Jacobson
 - Misinformation in the literature-Bruce Mork
- Introduction to Modeling, Simulation, Parameters
(Goal of Chapter – provide the basics, make the engineer knowledgeable enough to continue on to more advanced techniques or to know when to seek help. Refer to TP-133-0 Modelling & Simulation of System Transients)
 - Basic Orientation and Introduction for the novice-Bruce Mork/Juan Martinez
 - Simulation Tools-Bruce Mork
 - Modeling Parameters required -??
 - Introduction to Advanced Modeling (optional)
 - Duality based modeling-Juan Martinez
 - Iron-core loss modeling-Noel Janssens
- Conclusions
Should include general recommendations on preferred connections, operating strategies, how to avoid ferroresonance in the design stage or mitigate. The cost of mitigation could be included.
- Appendices
 - Ferroresonance Literature Review-David Jacobson