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2009 INTERNATIONAL CONFERENCE OF DOBLE CLIENTS

March 29 – April 3, 2009

Westin Hotel Copley Place, Boston, Mass., USA

LIST OF TECHNICAL PRESENTATIONS

ARRESTORS, CAPACITORS, CABLES AND ACCESSORIES

Thursday, April 2nd, 4:45 pm – 6:00 pm

America South Ballroom

ACCA-1 On-line Partial Discharge Monitoring and Diagnosis at Power Cables

M. Boltze - LDIC GmbH, S. M. Markalous - LDIC GmbH, A. Bolliger - LDIC AG, J. Chiu - Chan-Ching Electric Technique Consulting Co., LTD, O. Ciprietti - Brugg Cable LTD

Most defects observed in today's EHV cable systems cause partial discharges (PD) under AC stress in the accessories. Combining AC testing and sensitive PD measurements results in best test efficiency. The condition-based maintenance of power cables requires reliable significant diagnosis methods for the integrity of operation of power cable systems.

This paper describes actual field experiences with Partial Discharge measurements during installation tests of high voltage XLPE insulated single core underground cable systems that were tested with AC series resonant voltages. Considering the importance of installations in power stations permanent PD monitoring have been performed at GIS and outdoor cable terminations after commissioning. Non-conventional partial discharge methods have been established for condition assessment of power cable insulations. A new system applying UHF sensors and acquisition was developed, suitable for any kinds of HV XLPE cable terminations like transformer sealing ends, cable terminations for metal-clad substations and outdoor sealing ends based on past experiences during investigations on site. This paper reports on successful efforts of PD measurements and monitoring in the accessories after connection to EHV-XLPE cable systems. The new UHF- PD measurement method with its benefits is also described.

ACCA-2 High Voltage Substation Surveillance using Radio Frequency Interference Measurement

A.Nesbitt, B.G. Stewart, S.G. McMeekin, S. Conner, J.C. Gamio
School of Engineering and Computing, Glasgow Caledonian University, Glasgow, UK
L. Hall, C. Capel, Doble PowerTest Ltd., Guildford, UK
K. Liebech-Lien, H.O. Kristiansen, S. Kråkenes, Doble TransiNor, Trondheim, Norway

The deployment of radio frequency interference (RFI) measurement is gaining increasing acceptance as a front line non-invasive technique to assess the condition of individual high voltage (HV) electrical equipment items as part of a substation surveillance program. Existing portable spectrum/RFI analyzers can be placed in a mode to detect discharge events that typically accompany electrical deterioration. However, the low repetition rate and nature of the discharge events are not readily identified using current commercial instruments without an expert knowledge of the nature and characteristics of electrical deterioration mechanisms. This paper presents a number of case studies that demonstrate a novel technique that is responsive to the low repetition rate and characteristics of discharges and is effective with a wide range of HV equipment. The technique does not require expert knowledge for a practicing Engineer to confidently characterize and trace electrical deterioration with a high degree of confidence. The results will show RFI traces from various HV plant items and the change in the frequency spectrum induced by discharge events.

ACCA-3 De-Rating and Field Testing Techniques for Fuseless Capacitor Banks

Lawrence P. Hayes, First Energy

This paper describes an enhanced approach for both de-rating and field testing fuseless capacitor banks in substations. This new approach was developed as the result of the de-rating and subsequent failure of a 230 kV, 142 MVAR capacitor bank at the West Wharton Substation of the Jersey Central Power & Light Company in June 2008. The failure created a five week delay in restoring the capacitor bank because the diagnostic techniques employed were mainly focused on identifying element failures of the individual capacitor units. Over the course of the five weeks, the bank was examined and tested in almost every conceivable way in an effort to identify the problem but most of these tests proved ineffectual. In addition, all the failed capacitors that were removed from the bank were later individually tested in an effort to determine which diagnostic testing techniques were most effective in identifying specific types of problems. As a result of this incident, FirstEnergy has redefined its approach for both de-rating fuseless capacitor banks and for the diagnostic techniques used to troubleshoot them.

ASSET AND MAINTENANCE MANAGEMENT

Tuesday, March 31st, 1:30 pm – 5:30 pm
America Center & South Ballroom

NERC Panel Discussion for the AMM Committee

Utilities are facing more and more scrutiny regarding maintenance practices as well as other standards within their organizations. The era of NERC audits and enforcement has begun and it will be necessary for utilities to be prepared for these audits by having an effective compliance system.

The panel discussion will include many of the major topics in understanding the audit process. The topics of discussion will cover the eight methods of the Compliance Monitoring Process which includes compliance audits, spot checks, periodic data submittal, exception reporting, investigations, self-reporting, complaints and remedial action directives. In addition, CIP (Critical Infrastructure Protection to include CIP-002 to CIP-009) and PRC (Protection and Control) standards will be discussed.. All recent compliance changes from the 2009 Implementation Plan will be covered as well.

National Grid U.S. and Y-W Electric Association, will give their perspectives on how they prepared for an audit and the outcomes and lessons learned. This will allow for both a large and small company view of the audit process.

Panel Speakers:

Sal Buffamante
Compliance Audit Manager
Northeast Power Coordinating Council (NPCC)

Sal Buffamante has thirty (30) years experience in the utility industry. His career has included functions of increasing responsibility that have included key positions in System Operations, Substation construction and maintenance, Underground Transmission systems, Project Management and Sequencing, and Engineering. He has managed departments of up to 116 union employees and 38 management employees. His professional growth has come through titles such as Associate Engineer, Senior Engineer, Superintendent, Senior System Operator, Manager, and Section Manager. Sal received a Bachelor of Engineering degree in Electrical Engineering from NY Polytech and an MBA from NYU.

He worked for Consolidated Edison Company of NY until 2001 when he went to Orange and Rockland Utilities. In 2006 he moved to the NYISO as a senior engineer in the Market Monitoring and Auditing department. He has been at NPCC since May, 2007 as the Compliance Audit Manager for NPCC's Compliance Audit Program.

Bryan J Gwyn
Director Protection Engineering
National Grid U.S.

Bryan is currently Director of Protection Engineering in the Network Strategy Group of National Grid. Activities of the department include protection engineering and design, development of company wide protection standards, asset health, replacement strategies, disturbance analysis and operations & maintenance policies.

Bryan came over from National Grid in the United Kingdom in 2001 on assignment and decided to stay on a permanent basis. He represents National Grid and NPCC on several International Industry Committees including:-

- NERC, System Protection & Control Subcommittee
- Northeast Power Coordinating Council (NPCC), Task Force on System Protection
- CIGRE Working Group B5.31 on the Management of Relay Settings
- IEEE Power & Energy Society - Power System Relay Committee Working Groups; Protection Redundancy and Functional Testing of Protection Systems

Bryan has held several positions in the protection field, developing technical specifications and carrying out disturbance analysis on Transmission and Distribution networks, both in the US and UK. Other activities include Business Planning and R&D management

Bryan Graduated from City University, London. His first degree is a Bachelor of Engineering Degree in Electrical and Electronic Engineering and his second degree is a PhD in Electrical Engineering, specializing in Power System Fault Analysis. Bryan is a Chartered Engineer and a member of the Institution of Engineering and Technology, and also a member of IEEE Power and Energy Society.

James Ziebarth
System Engineer
Y-W Electric Association

James A. Ziebarth, P.E., graduated from South Dakota State University in 2002 with a BS in Electrical Engineering. In the same year, he joined Highline Electric Association in Holyoke, CO where the bulk of his engineering duties are performed for Y-W Electric Association in Akron, CO through a shared engineering resources arrangement. He is a member of IEEE and a licensed Professional Engineer in Colorado and Nebraska.

AMM-1 Asset Management: Getting Started

Edward Rider, New York Power Authority

This paper would include discussion on the following areas:

1. Defining your assets and determining the criticality of those assets.
2. Maintenance Programs including what are the advantages and disadvantages of time-based and condition driven maintenance programs?
3. Spare parts inventory (O&M, Emergency, etc.)
4. How can a CMMS system aid you?
5. Futurist view including dynamic process, age of equipment, operating conditions and regulatory issues.

AMM-2 Asset Management: Feedback from KPI's to Assets

Tony McGrail, National Grid U.S.

A 2007 Doble Conference paper noted that "Asset Management Starts with the Assets"; this is a follow-up paper which looks at asset function and performance metrics.

A fundamental requirement of an asset management system is knowledge of what the assets are supposed to do and what constraints, if any, are put on their performance. Electric utilities are often set performance targets in terms of CAIDI/SAIDI/SAIFI via local regulation. In times of very limited capital budget, and reductions in operations dollars, it behooves us to identify the assets which provide most risk to us achieving performance targets and then identifying strategies to mitigate those risks. Closing the loop in terms of cost and benefit allows for rational decision making and helps justify inspection, maintenance and replacement programs.

AMM-3 An Update to the NFPA 70E Guidelines for Electrical Safety

Jim White, Shermco

The NFPA 70E has become the primary reference for electrical safety in the industry. The 70E has been recognized by OSHA as "a guide for meeting the OSHA electrical regulations" and by Federal courts as "standard industry practice". A new edition of the 70E has been released and many changes have been made. There were a total of 580 proposals considered during this cycle and more than 800 comments made concerning those proposals. This paper will cover the changes made to the 70E and also why the changes were considered and adopted by Jim White, NETA representative to the 70E committee. Jim was on the Word and Phrase task group and the Tables task group and can offer insights as to what the considerations were during the committee meetings.

BUSHINGS, INSULATORS, AND INSTRUMENT TRANSFORMERS

Tuesday, March 31st, 7:30 am – 12:00 pm
America Center & South Ballroom

BIIT-1 Investigation of High Power Factors on Two ABB 23kV, 12000Amp Bushings

Daniel Falla, National Grid

The paper reports on the investigation that took place on two 23kV, 12000 Ampere bushings that were replaced on a transformer due the high C1 power factor measurements. The bushings were sent to Electrocomposites for further investigation and to have the bushings rebuilt. The high power factors appear to be caused by corrosive sulfur. National Grid will discuss the teardown investigation and the plans to rebuild the two bushings.

BIIT-2 Effects of Contamination on Bushing Power Factor Test Results

David Stelmach, Doble Engineering Company
Norbert Gilbert, Doble Engineering Company

External influences such as high humidity and contamination can create a challenge to testers when power factor testing bushings. This paper will examine the issues related to abnormal measurements observed while performing C1 and C2 tests and will include guidance on methods to remove the external influences during testing. This paper will discuss case studies in which bushing surface leakage was reduced which allowed representative test results to be obtained.

BIIT-3 Chronicling the Degradation of a 345 kV General Electric Type U Bushing

Steve Molter, ITC Holdings Company
Robert Brusetti, Doble Engineering Company

This paper will discuss a sudden rise in C1 power factor measurement on a General Electric Type U bushing detected by an on-line monitoring system. The bushing was rated at 230 kV, 800 Amps. The bushing was removed from service. A teardown investigation followed at PCore Company to determine tha cause for the rise in the C1 power factor measurements. This paper will detail the electrical, and oil testing that was performed, and the details of the investigation. The paper will also review how the increase in C1 power factor was detected by the bushing on-line monitoring system.

BIIT-4 Understanding Power Factor Testing Results Relative to Modern Instrument Transformers

Nick Powers, Kuhlman Electric
Rolando Gomez, Arteche

Power factor testing of insulation systems is a well understood concept, but equating it to instrument transformers of all types and sizes is a mystery that is not necessarily intuitive. This paper will provide insight into the different instrument transformer insulation structures, and how best to apply the power factor concept to truly measure the dielectric integrity. Designs to be detailed are:

Inductive Voltage Transformers
Station Service Voltage Transformers
Capacitive Coupled Voltage transformers
Current Transformers
Single Phase Combination Current/Voltage Transformers
Three Phase Combination Current/Voltage Transformers

The author's intent is to provide the necessary understanding of instrument transformer designs relative to power factor measurement, so as to aid in the proper evaluation of the IT dielectric systems. Standard power factor tests defined by Doble will be examined in relation to what is physically in the measurement circuit.

BIIT-5 Field Experience with 800 kV Gas Insulated Free Standing Voltage Transformers

Viorika Aresteanua, Hydro Quebec
Hermann Dietz, Trench Germany

This paper will summarize Hydro Quebec's field experience of a 800 kV gas insulated voltage transformer.

Hydro Quebec installed thirty three 800 kV gas-insulated free-standing voltage transformers since 1995. Each unit features two silicone section insulators and provides an extended accuracy for 765 kV Shunt Reactors Controls Switching. In addition to all the tests required by IEC 186 and IEC 61462 TR, a low temperature tightness test, an internal arc tests and a line discharge test have been performed. During the internal arc at 50 kA (rms), 130 kA peak (fully asymmetrical), with an arc duration of 200 ms, the pressure relief operated after 500 ms.

After seven years in service, one unit failed on 2002-10-25 in a Hydro Quebec substation. The peak current value of the short-circuit current was 29 kA and the fault duration 43 ms. The voltage transformer withstood the internal arc. The repair cost was approximately 40% of the initial price of the unit.

BIIT-6 Failures of 800 kV Areva Ritz Type OSKF Oil Filled Current Transformers

Viorika Aresteanau, Hydro Quebec

This paper will discuss the failures of 800 kV oil filled current transformers that Hydro Quebec has experienced. It will also provide details of the investigation/teardown of the subject units.

CIRCUIT BREAKERS

Thursday, April 2nd, 7:30 am – 11:00 am
America Center & South Ballroom

CB-1 NAS Battery Load Leveling & Islanding Applications

John Mandeville, American Electric Power (AEP)

Sodium sulfur (NAS) battery technology is a new battery technology which has been developed for energy storage by NGK - Japan. During 2008, AEP has installed (3) 2 megawatt (MW) installations which were designed to provide dynamic load leveling and islanding capabilities. This paper will summarize AEP's experience of NAS battery technology used in islanding and load leveling applications.

CB-2 New Method to Prepare Current Transformers for Micro-ohm Testing

Rick Asche, Portland General Electric (PGE)

PGE has been short circuiting breaker Current Transformers (CT) prior to testing with 100amp micro-ohm meters. We do use filtered units, but still feel it is necessary to take precautions. However the shorting practice has lead to false trips of 2 stations due to upsetting of differential circuits. We have now devised an alternate plan which actually lifts the wires on relaying CTs.

CB-3 Trip Coil Signature Case Studies

Linda Nowak, Doble Engineering Company

This paper will be a collaboration of material from the Trip Coil Signature Subcommittee. It will include several case studies which show problems detected by analysing trip coil signature traces.

CB-4 230 kV Circuit Breaker Failure in a GIS Substation

Alberto Quintero Nieves, CFE Mexico

This proposed paper will describe in detail the events that lead to a failure of a 230 KV SF6 breaker in a GIS substation. It will review all the historical information since installation until failure and manufacturer involvement, it will include all tests performed by CFE and manufacturer. The event and failure will be analyzed in detail and it will describe the independent investigation and analysis completed by CFE, which did not agree with the manufacturer analysis and conclusions.

CB-5 115 kV Circuit Switcher Failure

Rene Tuballa, NStar Electric & Gas

A 115kV circuit switcher in one of the NSTAR substations flashed over and catastrophically failed during the opening operation of a 115kV shunt reactor resulting in a disconnect switch, located further upstream, to disintegrate and also cause abnormal voltage conditions that were seen all over the system. The flash over of the circuit switcher was cleared by a circuit breaker that is electrically located between the circuit switcher and the disconnect switch. Post event inspections revealed that all damages were all on phase A of the circuit switcher and the disconnect switch. This paper discusses the transients generated during the switching operation and the possible causes of the failure of the switching equipment. A simplified ATP model of the 115kV system in proximity to the Shunt reactor was modeled to simulate the transient recovery voltage (TRV) generated during the switching operation.

Following the incident the gang operated breaker was replaced by a breaker with a mechanically staggered opening and closing operating mechanism that is controlled by a synchronous switching relay. This paper discusses the methodology used in the selection of the replacement breaker and the details of its operating mechanism.

CB-6 A Predictive Maintenance Strategy for Oil Circuit Breakers

Alex Salinas, Edison International Southern California Edison

The purpose of this paper is to provide insight to Southern California Edison's program, Oil Circuit Breaker Analysis (OCBA). This program encompasses the use of a Predicative Maintenance (PM) strategy to systematically optimize Circuit Breaker performance at all substations in SCE's 50,000 square mile service territory. This paper will present the various aspects of SCE's circuit breaker maintenance ideology and approach. Items covered will be the description of a Predictive Maintenance Program, discussion of the Maintenance Paradigm postulating the current state of the electric industry. Moreover, an in-depth review of SCE's OCBA Program that includes process and functional and business impacts, detailed descriptions of the "Closed Loop" process and the criteria for performance measurement will be presented. There will also be performance statistics available and case studies for review.

INSULATING MATERIALS

Wednesday, April 1st, 7:30 am – 12:00 pm
America Center & South Ballroom

IM-1 Dual-Temperature Model Aging of Insulation Systems for Liquid-Immersed Transformers

Roger C Wicks, Dupont USA
Lisa C Bates, Dupont USA
Richard P. Marek – DuPont USA
Thomas A. Prevost – Weidmann Diagnostic Solutions, Inc.

Insulation systems for liquid-immersed transformers have been essentially unchanged for the last 100 years, using combinations of mineral oil and cellulosic based papers and boards. Test methods developed for evaluating the thermal life of these materials worked well, in part because the thermal capability of the solids and fluids are similar. With the introduction of new materials with a wide range of thermal capability, both solid and liquid, for use in transformer applications, a new method that could separately control fluid and solid insulation temperature was required to help develop life curves for new combinations of materials.

This paper outlines work nearing completion to validate a dual-temperature model test for this evaluation. The paper will focus on the validation tests designed using both non-upgraded and upgraded cellulosic paper in conjunction with mineral oil. The paper will show how this test method compares to historical test methods. Much of the paper will address work conducted to improve the accuracy and repeatability of the test. Finally, the paper will focus on how this method can predict the effect of moisture on the insulation system including both non-upgraded and upgraded cellulosic papers.

Other combinations of materials are also under evaluation using this dual-temperature aging method and will be presented in future papers.

IM-2 Paper Ageing and Its Indication from Real Transformers

Richard Heywood, Doble PowerTest, UK
Hongzhi Ding, Doble PowerTest, UK

As the in-service age of the power transformer population continues to increase it is becoming crucial important to have a better understanding of the real condition of each aged power transformer and be able to accurately estimate the remaining life of a power transformer. The oil/paper insulation system of high voltage power transformer has been suffering electrical, thermal, mechanical and environmental stresses during normal and transient loading conditions. Under these stresses dielectric capability of paper insulation is gradually degraded, permanently and irreversibly, resulting in reduction of both the mechanical and dielectric withstand strength and therefore ageing of the power transformer. When the dielectric strength of the paper insulation decreases under ageing process and becomes lower than the stressing field, transformer will fail. It is generally believed today that the condition of the transformer paper insulation rather than years of in-service determines the remaining life of a transformer. The ageing of paper insulation has been well documented in literature which is primarily governed by operating temperature and the presence of water and oxygen. When paper degrades by-products are produced which are soluble in the transformer oil. Measurement and analysis of the oil for the concentration of paper degradation by-products such as furans can be used as chemical indicator to determine the degree of paper ageing, but Doble PowerTest (DPT) experience from real transformers suggests that there are considerable doubts about the reliability of applying the laboratory derived correlations between furan concentrations and estimated DP for real transformers. Not only there are still considerable uncertainties in assessing the real condition of paper ageing in real transformers, but also reality is that failures of transformers have occurred much earlier from causes other than paper ageing. This has been evidenced by forensic tear down investigations that have been undertaken by DPT in the UK. New approach is therefore required to take into account all known ageing indicators in assessing the ageing condition of older power transformers.

IM-3 Chemical Markers for the Determination of Power Transformer Insulation Life, State-of-Art at Hydro-Quebec

J. Jalbert, Institut de recherche d'Hydro-Québec (IREQ)
Y. Denos, Électricité de France (EDF-R&D)
R. Gilbert, Institut de recherche d'Hydro-Québec (IREQ)
P. Tétreault, Institut de recherche d'Hydro-Québec (IREQ)
S. Duchesne, Institut de recherche d'Hydro-Québec (IREQ)
P. Gervais, Hydro-Québec Trans Énergie (HQ-TE)

A linear relationship between one of the oil-soluble degradation by-products, i.e. methanol, and the number of ruptured 1,4-β-glycosidic bonds of cellulose, regardless of the type of paper (Kraft or thermally upgraded Kraft (TU)) was established. Aging at 130°C of model compounds of the Kraft paper constituents (α-cellulose, hemicellulose and lignin) and two cellulosic breakdown byproducts (D-(+)-glucose and 1,6 anhydro-β-D-glucose pyranose) confirmed that the α-cellulose degradation was mostly responsible for the presence of this molecule in the system. Additional experiments have shown that at least one molecule of methanol is formed for each rupture of the 1,4-β-glycosidic bond of the molecular chain. Stability tests showed that the aging indicator is stable under the oxygen and temperature conditions of open-breathing transformers. The presence of methanol was detected in 94% of oil samples collected from over 900 in-service pieces of equipment, confirming the potential for the application. Results are presented and discussed in comparison with 2-furfuraldehyde, which is the current reference in the domain.

IM-4 The Duval Triangle for Load Tap Changers, Alternate Fluids and Other Applications

Michel Duval, Institut de recherche d'Hydro-Quebec (IREQ), Canada

The Duval Triangle is widely used to identify faults in equipment such as transformers, reactors, bushings and cables filled with mineral oils. New versions of the Triangle are proposed for other types of equipment, fluids or applications: the Duval Triangle 2 for load tap changers (LTCs) of the oil-type, where normal operation involves arcing in oil; the Duval Triangle 3 for equipment filled with non-mineral oils (e.g., natural and synthetic esters and silicones); the Duval Triangles 4 and 5 for low-temperature faults in mineral oils, where "stray gassing" of the oil may interfere with diagnosis; and the Duval Triangles 6 and 7 for low-temperature faults and stray gassing of natural esters in service.

IM-4A Stray Gassing of FR3 Oils in Transformers In Service

Michel Duval, Institut de recherche d'Hydro-Quebec (IREQ)
Ramona Baldyga, Alliant Energy

Gassing data from transformers retrofilled with FR3 oils since 2001 are reported. A significant difference with gassing in mineral oil prior to retrofilling is the formation of ethane and hydrogen in FR3. This gas formation can be attributed to the stray gassing of FR3, which is the unexpected gas formation from some oils at relatively low temperatures in the 80 to 250 °C range. These are not considered a fault or a concern with the transformer. Methods to identify this stray gassing and distinguish it from more serious thermal faults in the transformer are proposed. Observations suggest that some batches of FR3 may be more susceptible to stray gassing than others.

IM-5 Gassing Tendency of Electrical Insulating Oils and the Effects of Additives

Paul Griffin, Doble Engineering Company
Lance Lewand, Doble Engineering Company

The gassing tendency of transformer oils under partial discharge conditions can be an important property under some conditions. The gassing tendency is influenced by the amount of unsaturates. Typically in electrical insulating mineral oils these are aromatic compounds. This paper reviews documented information on this special

property and provides information about correlation with other oil properties. Research results are given on some possible types of additives to improve gassing tendency.

IM-6 Verification of Non-Corrosive Sulfur in Transformer Oils used in Japan

Tsuyoshi Amimoto, Mitsubishi Electric Corporation, Japan
Fukutaro Kato, Mitsubishi Electric Corporation, Japan
Junji Tanimura, Mitsubishi Electric Corporation, Japan
Satoru Toyama, Mitsubishi Electric Corporation, Japan
Noboru Hosokawa, Mitsubishi Electric Corporation, Japan
Eiichi Nagao, Mitsubishi Electric Corporation, Japan

Corrosive sulfur tests such as ASTM D1275, Modified ASTM D1275 and IEC 62535 are conducted in three transformer oils used in Japan and the possibility of the deposition of copper-sulfide on insulating paper is found to be significantly low. These three transformer oils have been mainly used in power transformers in Japan. Dibenzyl disulfide (DBDS) in transformer oil is known as one of the main compounds causing the deposition of copper-sulfide, which decreases the dielectric strength of coil insulation, which may lead to fatal failures in the worst case. A highly sensitive analysis method of detecting DBDS is developed by Mitsubishi Electric Corporation. The detection limit has been remarkably improved to be less than 1 ppm by using solid phase extraction (SPE) followed by gas chromatography equipped with mass spectroscopy (GC-MS). The concentrations of DBDS in the three transformer oils described are confirmed to be significantly low by using this technique.

1, 2, 3-benzotriazole (BTA) has been widely used as a passivator of transformer oils for more than 20 years in Japan for the purpose of suppressing the static electrification due to oil flow. The addition of BTA was also found very effective for suppressing the deposition of copper-sulfide on insulating paper. This suppressing effect reflects the formation of complex layers on a copper surface that are created by the reaction between BTA and copper.

IM-7 Identification of Compounds Leading to Copper Sulfide Formation on Insulating Paper in Transformers and the Degradation of Suppressing Effect of 1, 2, 3-benzotriazole and Irgamet® 39 in Insulating Oil

Kota Mizuno, Mitsubishi Electric Corporation, Japan
Satoru Toyama, Mitsubishi Electric Corporation, Japan
H. Kawarai, Mitsubishi Electric Corporation, Japan
Junji Tanimura, Mitsubishi Electric Corporation, Japan
Y. Fujita, Mitsubishi Electric Corporation, Japan
Fukutaro Kato, Mitsubishi Electric Corporation, Japan
Tsuyoshi Amimoto, Mitsubishi Electric Corporation, Japan
Noboru Hosokawa, Mitsubishi Electric Corporation, Japan
Eiichi Nagao, Mitsubishi Electric Corporation, Japan

Identification of compounds causing copper sulfide formation is necessary for preventing transformers from failures due to copper sulfide formation. The rate of copper sulfide formation was investigated by using typical sulfur compounds contained in mineral insulating oils. The typical sulfur compounds such as dihexyl sulfide, dihexyl disulfide, dibenzyl sulfide, dibenzyl disulfide (DBDS) and dibenzyl sulfoxide were chosen. The rate of copper sulfide formation of DBDS is found to be about five times higher than those of the other sulfur compounds.

Duration of the effectiveness of inhibitors such as 1, 2, 3-benzotriazole (BTA) and Irgamet39 was evaluated by heating test of oil under the atmospheres of air and nitrogen. It was clarified that the concentration of these inhibitors decreased due to the thermal degradation as well as oxidation degradation. Decrease of these inhibitors was accelerated by the existence of oxygen. The decreasing rates of BTA and Irgamet39 are equal in both the atmospheres of air and nitrogen.

PROTECTION AUTOMATION CONTROLS & COMMUNICATIONS

Wednesday, April 1st, 1:30 pm – 5:00 pm
America Center & South Ballroom

PACC-1 Testing and Commissioning Protection and Control Systems Based on IEC 61850 Process Bus

David McGinn, Vijay Muthukrishnan, and Ilia Voloh-GE Multilin

This paper defines testing as verification and re-verification of a complete protection and control system after it has been deployed - initial commissioning, repair, periodically or after a major work such as protection system expansion, firmware upgrade or component replacement. The concept of IEC 61850-9-2 process bus is presented at a high level and one particular architecture is briefly described. Challenges related to the testing and maintenance of highly distributed communication-based protection and control systems are explained. Finally a procedure for the presented system is proposed that allows verification of a single zone of protection without affecting adjacent and/or associated equipment, consistent with commonly-accepted practice for testing of protection and control systems.

PACC-2 Factors in Determining Generator Differential Settings

Jane Heineman, US Army Corp of Engineers

Will your relay settings work? Most of our generator relay settings were developed 30-50 years ago by engineers that understood the generator and how the system components work together. Over the years we have replaced exciters, switchgear, current transformers, relays, many times without completely understanding how these components interact with the system. Excitation power is pulled directly from the generator bus versus station service power. Electromechanical relays have been replaced with microprocessor relays. The operating conditions for generators have changed. We are expected to do black starts, energize transformers with the generators, do grid restoration and help stabilize the grid. To develop proper settings, engineers need to understand the operating characteristics of all of the system components and how operating conditions change setting requirements.

PACC-3 Testing Imbedded Current Transformers in Delta Tertiary Windings

Robert Boisvert and Kevin Drozynski, National Grid

This paper describes a method of testing the ratio of current transformers that are embedded in the delta winding of a three winding transformer. When using conventional ratio testing technique, the ratio error was fluctuating between 5% and 20%. This paper describes the reasons for the fluctuations and it also provides a procedure for testing the ratio of CTs applied under conditions described above.

PACC-4 Protection System Coordination, Testing, and Maintenance to Comply with NERC Requirements

Nathan Myers and James DeHaan, USBR

This paper presents a detailed description of NERC requirements as it relates to relay maintenance at generating plants. The US Bureau of Reclamation has 58 hydro plants and this paper details the contents of various internal documents that have been generated by the Bureau to keep their maintenance practices in line with NERC guidelines. This paper presents a very detailed description of how the tests are supposed to be conducted at each of the 58 hydro plants. The maintenance interval for each class of equipment is outlined. The maintenance of battery systems which is an integral part of protection has also been dealt with in this paper.

PACC-5 IEC 61850 Basics

Ed Khan, Doble Engineering Company

This presentation deals with the basic concept, ideas and implementation of IEC 61850 communications standard. The material presented will also address the testing of relays that comply with this standard. The aim of this standard is to help system automation and integration in a very seamless manner. This standard is gaining

popularity in The US and several utilities are embarking on pilot projects involving this standard. Hence, we believe this is timely presentation that will help the audience get good practical information related to IEC 61850 at a very basic level.

ROTATING MACHINERY

Wednesday, April 1st, 7:30 am – 12:00 pm and 1:30 pm – 4:15 pm
America North Ballroom

RM-1 Generator Rotor Pole Crossover Replacement

William Moore, National Electric Coil

Generator rotor pole crossovers are an essential part of the field winding circuit, allowing transfer of current from the winding of one pole of the rotor to the other. Pole crossovers require specialized design to accommodate relative displacement of the windings of each pole, as the unit comes up to speed and also due to thermal changes. Most designs incorporate some type of flexibility, allowing bending and displacement of this copper component, in an effort to minimize stresses and extend its ability to accommodate many start / stop cycles.

In the last ten years, however, new designs have emerged that have problems. Many are on the influx of large air-cooled generators. Problems are compounded by the high number of start / stop cycles with these machines. Some designs do not incorporate enough flexibility, while others included weaker brazed joints within highly stressed areas. One of the OEM's has issued a bulletin about potential problems with pole crossovers on certain style units.

NEC has been involved in the analysis, redesign, testing and replacement of these failing pole crossovers on the newer air-cooled generators. We have replaced the pole crossovers on over ten generator rotors that are susceptible to failures in this area in the past two years. Some replacements were done in the factory and some in the field, with the rotor still in the stator, despite limited accessibility.

This paper will report on the development of the technology to redesign, test and replace these pole crossovers. Considerable development was necessary to perform a successful replacement in-situ. Of course, this provides a considerable savings to the owner, not having to remove the rotor, and at the same time eliminating a serious failure mode.

RM-2 Stator Winding Change Due to Stator Coil Design and Manufacturing Error

Ing. Alberto Quintero Nieves, CFE
Ing. Aristarco Martinez Romero, CFE

RM-3 Stator Winding Diagnostic Test Comparison – PDA vs. Ramp DC vs. Power Factor vs. Corona Probe

Eric Eastment, U.S. Bureau of Reclamation

This paper will provide historical data from PDA, DC Ramp, power factor and corona probe test methods from 1999 to the present on large hydroelectric generators. This paper will also include an investigation of diagnostic tests on a failed 165 MVA hydro electric generator and three sister generators. The paper could also include information regarding the theorized value of making dielectric power factor measurements at multiple voltages and plotting the results.

RM-4 Testing of Interlaminar Insulation of Hydrogenerator Stator Cores Using ELCID

Mladen Sasic, Iris Power

The reliability of large generators is of major importance to maintain the integrity of power supply plant. Continual monitoring or frequent inspection is therefore desirable to be able to remedy growing defects before a catastrophic failure or more major work becomes necessary. Recent test information may also permit more effective use of routine or unscheduled outages by means of additional preparation and provisioning.

The stator core is a major component of a generator to which this applies in particular, as failure and associated repair or replacement necessitates major disassembly of other parts of the machine. Information on condition of the core structure is therefore significant, but is increasingly difficult to obtain at frequent intervals. Low power core

testing can be performed more quickly and easily than using traditional full flux methods and may need to be considered an indispensable tool to increase or maintain essential monitoring levels.

A traditional method of detecting faults is the High Flux Ring Test, often referred to as a Thermal Loop Test. The rotor is removed from the machine and the stator core magnetically energized by a high voltage high current excitation winding. The principal disadvantages of the Thermal Loop Test are those associated with the safety (high current and voltage), time and risk of further core damage.

Another test method, EL CID, was devised in late 1970's to sense fault currents by electronic means and to separate them from other magnetic fields present due to the excitation winding. EL CID testing has subsequently been adopted as routine by many utilities on hydrogenerators. Despite a number of spurious effects not present in turbogenerators, due mainly to method of construction, the ability to carry out tests on hydrogenerators with the rotor in situ, particularly if a pole is removed to improve access, is a major attraction. This paper will present some aspects of application of EL CID on hydrogenerator stator core testing.

RM-4A Discussion of Paper: Testing of Interlaminar Insulation of Hydrogenerator Stator Cores Using EL CID

Reg Gamblin, Manitoba Hydro, Canada

Mr. Gamblin will provide a discussion on Manitoba Hydro's experience with performing EL CID tests on hydro electric generators.

RM-5 30 Years of Ramp DC Testing Hydrogenerator Stator Windings Test Results and Interpretations

Eric Eastment, U.S. Bureau of Reclamation
Bert Milano, U.S. Bureau of Reclamation

This paper will discuss an overview of 30 years of Ramp DC testing performed by the Bureau of Reclamation. Reclamation owns and operates approximately 240 units which include medium to large synchronous generators and motors; each is ramp tested every three to five years. The paper will present diagnostic data that can be obtained by performing ramp dc testing. In addition, details regarding data interpretation and case studies for stator windings from new to aged and some at end-of-life will be presented.

RM-5A Discussion of Paper: 30 Years of Ramp DC Testing Hydrogenerator Stator Windings Test Results and Interpretations

Reg Gamblin, Manitoba Hydro, Canada

Mr. Gamblin will discuss Manitoba Hydro's experience with DC ramp testing, which will also include PI and one or two case studies.

RM-6 AC and DC High Voltage Testing

Ing. Nicolas Leon Rivera, LAPEM

Stator windings today are designed to have a useful life of between 30 and 40 years. The length of this time will depend upon the design, manufacturing, operation, and maintenance of the unit. One of the tools available for evaluating the condition of units in service is high voltage testing. Despite the possibility of causing damage to the unit under test, as they are high risk methods, when properly applied AC/DC HV tests are a valuable tool to locate faults with relatively low impact in the remaining useful life of the unit.

Based on IEEE 930, the calculated deterioration from HV testing (1 minute at 1.5E voltage) is similar to 235 hours or 10 days of operation. This loss of useful life by HV testing when compared to the expected useful life of the unit (30–40 years) is minute, and the benefits are worth this risk.

This paper will present the case for AC and DC HV testing by outlining their benefits and the failure modes that each method is capable of identifying.

RM-7 Extending the Life and Efficiency of Your Iso-Phase Bus – The Hidden Truth

Eric F. Netter, Electrical Builders Inc.
Jessica D. Netter, Electrical Builders Inc.

As an inert component within a power plant, often, the isolated phase bus (IPB) system is ignored until it becomes an emergency issue. The intent of our presentation is to educate the audience on the issues and problems that can occur with the IPB when a predictive/preventative maintenance program is not implemented and enforced. Once the potential deterioration issues and problems are explained, we will educate the audience on solutions that can be implemented to help remedy the situation and avoid emergency repairs.

This paper will discuss business challenges, common IPB trouble areas, solutions, using cases studies. The presentation is a photo intense and drawn from real life experiences.

RM-7A Discussion of Paper: Extending the Life and Efficiency of Your Iso Phase Bus – The Hidden Truth

James E. Timperley, Doble Engineering Company

Mr. Timperley will discuss his experience with detecting problems in isolated phase bus including one or two case studies.

RM-8 Identification of Vibration Sparking with EMI Diagnostics

J. E. Timperley, Doble Engineering Company

This paper will discuss EMI testing on several turbine generators known to have partial discharge/vibration sparking problems. The paper will describe the test(s) performed, interpretation of results and recommendations.

RM-8A Discussion of Paper: Vibration Sparking Assessment using EMI Diagnostics

Clyde Maughan, Maughan Engineering

Clyde Maughan will discuss his experiences with vibration sparking. Mr. Maughan has over 30 years of industry experience. The phenomena of vibration sparking will also be discussed.

RM-9 Condition Assessment of 170 MVA Air Cooled Turbine Generator

Ian W. Simmonds, Doble PowerTest Ltd., UK

The operators of a 170MVA air-cooled turbo generator contacted DPT to undertake various electrical tests and inspection on their machine after becoming concerned with higher than expected operating temperatures and visual signs of insulation deterioration. From 1999 to 2005 the generator was operated between 0.85PF and 1.0PF, lagging. From 2005 onward it had been operating at 0.81PF, lagging. Winding temperatures increased until one of the RTD's indicated an operating temp of 122°C, which is above the IEC standard for Class F insulation with a Class B temp rise. Visual inspections carried out by station personnel highlighted overheating of the exciter and stator insulation, and severe end-winding discharges between phases.

The presentation will cover the condition assessment of a 170MVA air-cooled turbo generator carried out by DPT during 2005 and will include details of the equipment used, the measurements recorded, a look at some of the design characteristics and the recommendations for refurbishments or further condition monitoring.

RM-10 Stator Winding Life Prediction – The Difficulties of Predicting Insulation Life and Value of Diagnostic Testing

James DeHaan, U.S. Bureau of Reclamation

In the past decade the electric power industry has undergone major changes associated with deregulation, ancillary services, and extensive penetration of renewable energy sources. Hydropower plants are now being called upon more and more to provide power system regulation and load balancing and, as a result, the stressors placed on hydro units is changing and increasing. In this new environment hydro generators are being load cycled and started and stopped much more frequently than in the past. These new stressors have increased the difficultly of predicting the stator insulation life and increased the need for and value of diagnostic testing for condition assessment. This paper will outline the difficulties of predicting insulation life and emphasize the value of diagnostic testing.

RM-11 Life Extension and Modernization

Edward Rider, New York Power Authority

The Life Extension and Modernization (LEM) project is a comprehensive look of the complete generating facility with the expectation of taking advantage of historical operating data and technological advancements, knowing some of the plant equipment will be nearing "End-of-Life". The review looked at means to increase plant efficiency and reliability, and taking advantage of revenue opportunities in providing regulation and load following. The paper will outline the steps taken to preserve the facilities infrastructure, getting the tools in place to perform the work, strategies applied for cost efficiencies, and problems encountered.

RM-12 Insulation Condition Assessment of Generators Based on On-line and Off-line Monitoring

M. Boltze, LDIC GmbH, Germany
S. M. Markalous, LDIC GmbH, Germany
A. Bolliger, LDIC AG, Switzerland

Failures of generators can have a large impact on the operation integrity of power supply and can cause costly damages in the electrical power network. Part of the liability of the electrical power supply is the condition-based maintenance of generators based on on-line and off-line monitoring.

This paper describes experiences with Partial Discharge measurements during commissioning of generators. Based on the importance of the generators in power plants permanent PD monitoring has been performed after installation as part of diagnosis strategy and insulation condition assessment to avoid unplanned outages.

The design of the insulation system, the monitoring concept, the characteristic of the measuring system as well as the noise conditions are of high importance and critical regarding the diagnosis and interpretation evidence.

This paper reports on successful efforts of PD measurements and PD monitoring of the electrical insulation of rotating machines and describes the monitoring concept as well as the instrumentation.

TRANSFORMER

Friday, April 3rd, 7:30 am – 12:00 pm
America Center & South Ballroom

LIFE CYCLE MANAGEMENT

T-1 Shipping Damage of Transformer during Ocean Shipment

Mirek Bizior, Eskom, South Africa
Luwendran Moodley, Doble Engineering Africa, South Africa
Simon Ryder, DoblePower Test, UK

This paper will describe the damage inflicted on a core of two transformers during an ocean shipment. The movement recorders identified no excessive high impacts that took place during the trip. There were reports of high (9 meter) seas during the trip that did stress the apparatus.

T-2 Transformer Moisture Content / Cold Weather Dew Point Measurement

Phil Prout, National Grid
Brian Anderson, Colorado Springs Utilities
Rich Simonelli, Waukesha Electric Systems, Inc.

Data has been collected on one transformer relating to cold weather dew point measurement. It has been proposed from the sample data that the dew point measurements obtained in cold weather may NOT correlate to the moisture content of the insulation. The current charts and practices do not have the ability to correlate frost point to the moisture content of the insulation. Although equilibrium can be achieved even in freezing conditions, the physical environment is required to remain stable for a longer period of time to allow for this to occur. It appears that in cold environments the variables are changing at a rate at which equilibrium is not achieved. This finding may affect instructions that are included in IEEE C.57.93.1995.

NEW CONCEPTS

T-3 Transformer Design and Sulphur Corrosion: The Missing Link?

Simon Ryder, Doble PowerTest

In recent years sulphur corrosion has been a cause of major concern to the power industry. According to some expects more than one hundred transformers have failed worldwide owing to sulphur corrosion. Large, heavily loaded transformers have been particularly badly affected.

Laboratory-based research has shown that many oils contain potentially corrosive sulphur compounds. These can form copper (I) sulphide deposits on conductors within transformers. Formation of these deposits is catalyzed by high temperatures and low levels of dissolved oxygen.

Conditions which favor sulphur corrosion can be created in transformers by errors in construction or design. This paper examines in detail three case studies where this has occurred.

T-4 Impact of Series Unit On Transformer Winding DC Resistance Measurement During Heatrun

Mark F. Lachman, Vadim Fomichev, Vadim Rashkovski and AbdulMajid Shaikh, Delta Star, Inc.
Alfonso A. Jo, Naval Facilities Engineering Command

The paper would discuss the subject of winding direct current resistance measurement. Specifically, on transformers with the series unit the presence of the later may have a significant impact on the dc resistance of the LV winding measured during the heat run shutdown. This may result in an erroneous LV winding average temperature produced

by the heat run. The paper would discuss the physics of the transient process during the measurement and present heat run results with and without the impact of the series unit.

OPERATING USE

T-5 Upgrading OFAF (FOA) Transformer Cooling System Design

Jesse Duffy and Rick Asche, Portland General Electric

As result of major Transformer fire and ensuing failure analysis, PGE found a scenario that was not detectable by the present alarm and control system and allowed a forced oil/ forced air transformer to continue in service without cooling. Changes are being applied to all transformers of similar designs.

The paper will detail the path to failure, a discussion of the corrective actions and the changes that are being made to transformer alarm packages.

T-6 Study of Static Electrification in Aged Transformers

Atsushi Eto, Tokyo Electric Power Company
Dr. Takayuki Kobayashi, Tokyo Electric Power Company

It has been observed that there is an increase of static electrification activity for aged transformers of both shell and core-form at TEPCo. The assessment of the static electrification by simple the ECT measurement has been insufficient to detect the activity. It has been confirmed by potential (accumulated charge) measurements that aged pressboard has a higher tendency for static electrification. The cause and mechanism of deterioration of aged pressboard is under study.

DIAGNOSTIC METHODS

T-7 On-line Partial Discharge Diagnosis of Power Transformers

S. M. Markalous, LDIC GmbH
M. Boltze, LDIC GmbH
A. Bolliger, LDIC AG

The service security, the supply reliability and the quality assurance of the power utility assets is an increasingly important factor to enhance the competitiveness of the power supply and energy service companies. Advanced diagnostic methods of power transformers complement the conventional, established inspection-practice and improve the capability of condition assessment significantly. With the results of these diagnostic methods and the consideration of the network operation and management a condition based predictive maintenance and replacement planning is feasible.

The application of on-line / on-site Partial Discharge (PD) Monitoring of power transformers in-service is a powerful tool to detect and localize defects in the coil insulation. PD measurement technologies and diagnostic methods, such as electrical, acoustic and electromagnetic UHF (Ultra-High-Frequency), as well as the application and their practical experiences in case studies will be presented. The following benefits of the UHF and acoustic site survey method will be highlighted:

- identify strong PD impulses/noises clearly (external/internal)
- verify hydrogen measurements or electric PD results
- full in-service UHF PD sensor application, performance check and measurement
- easy PD coupling (e.g. for bushings without capacitive tap)
- factory fingerprint measurement for later reference and comparisons
- location of PD (with additional acoustic measurements)

T-8 Experience of Complex Diagnostic Inspections of Transformers in Electrical Power Engineering of Russia

Vladimir Smekalov, Federal Grid Company of Unified Energy System, RUSSIA
Anisim Dolin, Federal Grid Company of Unified Energy System, RUSSIA
Sergey Otmorskiy, Scientific and Production Enterprise "Technoservise-Electro", RUSSIA
Nina Pershina, Scientific and Production Enterprise "Technoservise-Electro", RUSSIA
Sergey Smekalov, Scientific and Production Enterprise "Technoservise-Electro", RUSSIA

Complex diagnostic inspection of transformers, autotransformers and shunt reactors allows impartial assessment of their condition; diagnose defects of all systems and units of these electric machines as well as to develop recommendations for defect elimination, execution of repair works and subsequent operation of transformers.

SPA Technoservice-Electro has accumulated considerable experience of such works execution. At present about 70-80 transformers are inspected annually. Total number of transformers inspected is about 400. The results reliability has been confirmed during opening (repair) of several tens of transformers as well as by normal trouble-free operation of other transformers. Mainly, 110-500 kV as well as 10-35 kV transformers (of auxiliary block electric power stations and for industrial enterprises power supply) with capacity 5.6-1,000 MVA have been inspected. Period of the transformers service was from 0.5 to 62 years. Service time of about 75% of the transformers was 25 years and more. All the transformers had been manufactured in Russia, Ukraine as well as in Sweden, Belgium and the Czech Republic. Inspections have been carried out at electric power stations and substations in approximately 35 regions (subjects) of the Russian Federation as well as in Belarus, Latvia and Serbia.

T-9 Field Experiences with SFRA

Mario Locarno, Doble Engineering Company

As experience grows with SFRA it is useful to present and discuss results from practical application where SFRA has been used for decision support. This paper presents data from several applications in the field, along with discussion of results and lessons learned.

T-10 Versatility of using the M4000 Insulation Analyzer for Testing Power Apparatuses

Long Pong, Doble Engineering Company

This paper summarizes multiple diagnostic test techniques using M4000 series test instruments on the following apparatuses in the substation and the power plant:

- Transformer: Impedance modeling
- Rotating machinery: ground fault locating on stator and condition assessment of rotor pole
- Circuit breaker: Field testing for TRV determination
- Power Line or feeder : ground fault locating and system impedance measurement
- Capacitor Bank: Condition assessment of individual capacitor unit
- Instrument transformer: Excitation current, saturation, turn ratio, and polarity tests

For each test technique, a case study, the test procedure and the test data analysis will be provided in this report.