2008 INTERNATIONAL CONFERENCE OF DOBLE CLIENTS

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LIST OF TECHNICAL PRESENTATIONS

ASSET AND MAINTENANCE MANAGEMENT COMMITTEE

AMM-1 Reliability-Centered Maintenance of Oil Immersed Transformers: A Work Group Approach from Several Companies

Iony Patriota de Siqueira, CHESF

Study Committee B3 of CIGRE Brazil created, in 2005, a task force to study the application of Reliability-Centered Maintenance to substation equipment. As a pilot project, the committee has selected power transformers as the initial objective, as a way to test and consolidate a methodology to be used for all substation equipment. Two deliverables were required from the group: a Guide on the Application of RCM to Power Transformers, and a database recording all major data used in the Guide. Since its creation, the task force has counted with contributions from major transformer manufacturers (Siemens, ABB, MR, etc), all large generation, transmission and distribution utilities from Brazil, and Cepel (The Brazilian Electric Energy Research Center). The task force is now finishing an FMEA study of all major internal system of power transformers, prior to definition of maintenance activities. A paper relating the current status of this project is proposed for the next Doble Conference.

AMM-2 Risk Management Associated with Power Transformers

Mark Theyerl, Substation Maintenance Consulting LLC

Managing the risk of a power transformer failure is becoming increasingly more critical and difficult. However paying attention to details from an established Predictive Maintenance program can reap major cost benefits and a substantial increase in reliability. As budgets are cut, the maintenance programs are the first to be eliminated. This is because there is no immediate consequences to deal with. This type of analysis is flawed. The predictive maintenance takes on a more vital role as regularly performed maintenance is shunned to save costs. Doble testing of transformers, transient analysis of LTC's, vibration analysis, and dissolved gas analysis become the only windows to conditions assessment.

AMM-3 Asset Management Begins with the Assets

D. Angell, J. Gavin, T. McGrail, National Grid U.S.

Asset management has developed from a good theory to a publicly available specification: PAS55. In the specification there are elements relating to strategy, risk, planning, work delivery and a host of other things. The key to the application of PAS55 is an understanding of what the assets are and what they are meant to do. Without this knowledge and understanding it is impossible to provide a closed loop control between the assets, work planned and asset performance.

AMM-4 Manhole Security: Protecting America's Critical Underground Infrastructure

Paul Joyal, National Strategies Inc.

Over the past five years, a series of terrorist attacks around the globe created new imperatives to protect civilian populations. High among these priorities is maintaining the integrity of a nation's critical infrastructure. Most citizens take for granted the vast utility network that lies underground in nearly all major urban areas. Lying just a few feet beneath the pavement is a complicated web of pipes, wires, cables, and other conduit that transport electricity, natural gas, telecommunications, potable water, waste, and steam. In addition to the utility networks, particularly in urban areas, much rail transportation and some road traffic is underground. The entirety of this network is accessible through one common avenue – manholes. Manholes are simply the street side access point to underground infrastructure including public utilities and telecommunications. They are mostly found in urban areas, where a substantial portion of critical infrastructure is housed underground. However, the overwhelming majority of manholes in the United States are not secured. The lack of manhole security provides terrorists and other individuals intent on doing harm and damage with considerable opportunity to easily disrupt and damage business and commerce, and generate significant loss of life and injury. It is therefore imperative that high-risk manholes be secured.

AMM-5 Component Reliability and Damage Costs in Distribution Systems-Athens Metro Case Study

V. Papada, E. N. Dialynas, National Technical University of Athens-School of Electrical and Computer Engineering, Athens Metro Operational Company S.A.

The main objective of transport companies is to maintain a high level of services, where infrastructure elements play a vital role. The introduction of high speed networks and increased traffic levels require new technologies in railway infrastructure and trains, which must go through a rigorous control of quality service and maintenance processes during their operative lives. Traction substations are probably one of the most important infrastructure elements of the railway system because of their effect on the system safety, reliability and quality of the service.

Asset management methods consider all relevant life cycle cost related to network equipment and provide strategies for reinvestment, maintenance and fault elimination. However, the methods require information about the components reliability of the installed equipment. Further, the component reliability depends on component age, maintenance history and operational stresses.

The objective of this paper is to assess the failure rate of the main elements that the traction substations consist of, with reference to their total operational period. Data of historical damage events is collected in a special damage statistic to provide more detailed results. Medium voltage circuit breakers and high speed DC circuit breakers are assessed regarding the occasion of damage information and the damage effect on the regular operation of the system. The damage analysis includes data for the years 2000 up to 2006, which are the years that the Athens Metro operates in Greece.

AMM-6 An Update on the Cigré World Wide Reliability Survey

John Skog, Maintenance and Test Engineering LLC

This paper will discuss the reliability of GIS (Gas-Insulated Switchgear), Single Pressure SF6 Circuit Breakers Disconnectors and Instrument Transformers. The presentation would focus on two key areas:

a. Early findings from the 4 year World Wide Survey

b. Final request to ask for North American utilities to get involved. It is not too late for them to provide year 2007 data. The response from this continent has been extremely poor.

AMM-7 Making Sense Out of the "Alphabet Soup" of Maintenance Strategies

John Skog, Maintenance and Test Engineering LLC

This paper is an overview of the dominant maintenance strategies used by utilities today. It covers RCM (Reliability Centered Maintenance), PFM (Performance Focused Maintenance), CBM (Condition Based Maintenance), RBM (Risk Based Maintenance), etc. and explains the genesis and differences of each approach. For new Doble members, this will provide some historical background and help make sense out of these often used and misused acronyms. For all members, this venue will provide for reflection on their current approach, challenge their current strategy and provide some thoughts on how they might further refine their asset management strategy.

<u>**ARRESTERS, CAPACITORS, CABLES AND ACCESSORIES COMMITTEE**</u>

ARRESTERS

ACCA-1 Manitoba Hydro's Arrester Acceptance Test Program

Mr. Reg Gamblin, Manitoba Hydro

Manitoba Hydro purchases (on average) several hundred surge arresters per year which are mainly distribution and station class but also includes specialty units for installation at our generation and converter stations. Manitoba's arrester test program requires that arresters be acceptance tested prior to the supplier being paid. The acceptance test includes Doble watts-loss tests as well as a test for partial discharge and a characterization of the V-I response of each unit. Maintenance tests are limited to the Doble watts-loss test and when practical, the V-I characterization. Personnel reviewing test results apply the limits as specified in standards IEC60099 and IEEEC62. The methodology for qualification of test results includes that results for similar models as well as sister units should be comparable.

The maintenance program for preventing in-service arrester failures has specified frequencies for performing said electrical tests (every 8 to 10 years depending on make/model) as well as annual infra-red scanning for temperature variations. We feel that this approach has been very successful for Manitoba Hydro.

SUBSTATION ASSETS

ACCA-2 Best Practices for using Infrared Thermography for Condition Monitoring of Utility Substation Assets

Mr. John Snell, Snell Infrared

Infrared thermography is being used more and more often as a tool to monitor the condition of utility substation assets including surge arresters, capacitors, power cables and their terminations among others. When conditions are conducive and the thermographer is qualified, the results provided by thermography are remarkable: the proper operating condition of the system can be verified; when anomalous conditions exist, they can be located long before the assets fail. This enables system owners to manage the process of further diagnostic testing or repairs in a timely, cost-effective manner. This paper discusses the current best practices for using thermography for condition monitoring of utility assets, guidelines for success and an overview of mistakes that are commonly made.

CAPACITORS

ACCA-3 Testing Fuse-less Capacitor Bank with Serial Unit String Using the M4000 Test Instrument – Update of the CapBank Test Procedure

Lisa Vo Van, Hydro-Quebec
Long Pong, Doble Engineering

This paper describes the field test experience of the fuseless capacitor bank with serial unit string and the capacitor bank with both ends grounded using the Doble M4000 test instrument to troubleshoot multiple capacitor failure alarms. The test method is the variance of the Doble CapBank technique which does not require disconnecting the capacitor unit during testing.

BUSHINGS INSULATORS AND INSTRUMENT TRANSFORMERS COMMITTEE

BIIT-1 C1 and C2 Testing Sensitivity on a Current Transformer

Jiten Jesing, CLP Power India, GPEC Paguthan CCPP

This paper will highlight the importance of power factor and capacitance testing on current transformers and the sensitivity of C2 tests in identifying the potential problem with the current transformers. The current transformers involved in the study were 245 kV, oil filled. This paper will provide details on the power factor and capacitance testing, dissolved gas analysis DGA, water PPM, and some experimental testing on the current transformers in order to pinpoint the problem areas.

BIIT-2 Factory Verses Field Testing of C2 for HSP Bushings

Jerry Cotter, PG&E
Matt Kennedy, Doble Engineering Co.

This paper will review the factory C2 test results verses the field test results to provide information on difference that can occur due to ground planes and test setups.

BIIT-3 Analysis and Comparison of Failure Modes of OIP and RIP Bushings

Marcos Caddah Melo, Furnas BRAZIL

This paper describes and compares the internal evolution of failures of RIP verses OIP bushings. It will show the different steps taken in the investigation of equivalent 550 kV bushings of each type, as well as the pros and cons, and the disadvantages and risks associated with each technology.

BIIT-4 Failure of Two Balteau 115 KV Potential Transformers Type UXT -115

Chad Bowman, Chelan Public Utility District
Bill Fernihough, Doble Engineering Co.

Chelan Public Utility District recently experienced two catastrophic failures of Balteau, 115 kV potential transformers (PTs) Type UXT-115, manufactured in 1991. The PTs provided hot-line indication and sync potential and were located on opposite ends of the yard, the second PT failed within three minutes of the first. There is no evidence of lightning in the area, nor does it seem a line fault preceded the failures. The discussion will include details on the failure and the investigation that took place. The utility is also interested in other company's experience with this type of potential transformer.

CIRCUIT BREAKERS COMMITTEE

CIRCUIT BREAKER ASSESSMENT

CB-1 ABB Type 15-VHK-500 Vacuum Breakers Manufactured Between 1989 and 1997
Robert Jensen, Salt River Project

Mr. Jensen reported mechanism problems with this circuit breaker model. In particular, "The problem with the breaker, as we understand it, was that a mechanism from their 600 volt breakers was adapted to the 15kV VHK breaker. The low voltage mechanism then wore out after anywhere from 200 to 1000 operations and would machine gun operate until it failed or we could get a person to the site to turn it off."

The second issue applies to all the VHK breakers on the system. The VHK breaker has a complicated mechanism with long control rods. In their heat and dust, the grease turns into something resembling concrete, and gums up the long rods to a point the breaker won't trip when called on to do so. During maintenance the gummy grease has to be cleaned off, and sparing amounts of different grease applied only where needed. It is also a reliability issue in that a stuck breaker typically results in the entire switchgear lineup (5 feeders) being taken off line by backup relaying.

CB-2 In-Service Assessment and Teardown of an ABB PME362-50-30 SF6 Filled Dead Tank Circuit Breaker
Jay Garnett, National Grid
Chuck Sweetser, Doble Engineering Company

National Grid and Doble Engineering participated in a collective study of SF6 filled dead tank circuit breaker diagnostics using the Acoustic Emission (AE) diagnostic technique. The AE diagnostic technique is a non-intrusive in-service test used for monitoring acoustic signals produced by partial discharge and loose components.

THE ENVIRONMENT, SF6 GAS CONCERNS

CB-3 Tracking Down the "Greenhouse Gas" SF6 with Infrared Thermography
Matt Knights, FLIR Systems

Sulfur Hexafluoride (SF6), used as an insulator in high-voltage utility equipment, has been targeted for emissions reduction by the EPA. Together, the EPA and many major utility companies are working to better control emissions because SF6 contributes more to the greenhouse effect than any other gas. This session will explore how a recent technological advancement in infrared thermography can now detect SF6, which has a projected atmospheric life of 3,200 years, in real-time. Highlighted will be some of the benefits of using this technology, including decreasing SF6 emissions, helping to preserve the environment, and detecting 20+ other fugitive gases.

CB-4 SF6 Gas Management
Kenji Hibi, Tokyo Electric Power Company

This paper presents SF6 (Sulfur hexafluoride) gas management activities in Tokyo Electric Power Company (TEPCO) and the successful results for emission reduction. Based on Kyoto Protocol, the SF6 gas is to be reduced to the nation target. This approach is taken as government and industry-wide activities. TEPCO uses many of SF6 gas insulated apparatuses; GCB (Gas-insulated Circuit Breaker), GIS (Gas Insulated Switchgear), and GIT (Gas Insulated Transformer), etc., and actively manage and reduce the SF6 gas emission as a large user.

FAILURES

CB-5 Oil Circuit Breaker (WE 2300-GW-20000) Failure Due To High Moisture Content
Andre Lux, Progress Energy

In December 2006, Progress Energy experienced a failure of a Westinghouse 2300-GW-20000 (1475 gallons of oil/tank, 230kV, 2000A, 20GVA, mech. AA-14-130) circuit breaker. On C phase, the breaker flashed inside to the wall of the tank. It should be noted that the day prior to the event it was 48 degrees F and during the night prior to the event it dropped to 17 degrees F. The actual event occurred the following morning at 10:25am.

The paper will describe the failure and lessons learned. It should include a discussion of Tank Loss Index (TLI) and how it is used for detecting contamination problems in oil circuit breakers. In addition, a historical review of breaker failures occurring during freeze and thaw cycles will be covered.

TESTING

CB-6 Revision of the Doble Test Procedure for SF6 Dead Tank and Vacuum Breakers
Joe Brown, Doble Engineering Company

There has been a discussion within Doble to change the current test procedure for tests 1-6 on SF6 dead tank and vacuum circuit breakers. The current procedure is to energize one pole of the breaker and float the other side of the same phase. The breaker is in the open position for these tests. The test mode is GST ground.

The proposed change is to guard the opposite pole associated with the phase being energized. The current method tests the pole energized to ground and also the series combination of the capacitance from the interrupter and the capacitance of the grounded insulation on the opposite side of the breaker (bushings, stand-offs, and operating rods). If the opposite pole is guarded then only the grounded insulation on the energized side of the breaker will be tested. The interrupter insulation is tested when performing the UST tests (tests 7-9).

Some benefits of the proposed method are that it better isolates a smaller part of the insulation system when the test is performed which will better indicate problems in the breaker and may help identify where the problems exist. Another benefit is while the low voltage lead is on the opposite side of the phase both the GST and UST tests (for example, tests 1 and 7) can be performed without changing test connections.

Mr. Brown will provide a discussion of the theory with some electrical models and also provide some actual data with tests performed using both methods. He does not expect there to be a large difference in vacuum and single break SF6 breakers due to the small capacitance of the interrupter assembly. In multiple break breakers where grading capacitors exist there may be more influence when not guarding the opposite pole.

CB-7 Detection of SF6 Circuit Breaker Problems Using the Doble Test Set
William J. Fernihough, Doble Engineering Company

Occasionally the validity of power factor testing of SF6 circuit breakers is questioned. There is very little solid insulation in a SF6 circuit breakers, the majority of the insulation is gas. This results in a very low current and watts readings. The results can be largely influenced if exterior bus work is left connected and many testers do not want to take the time to disconnect the leads or sometimes the use of solid bus causes difficultly disconnecting. This paper will document cases where testers found problems using the power factor test set, review test procedures and provide an updated tabulation.

BREAKER MONITORING

CB-8 Vacuum Bottle Monitoring

Jennings Technology
Alex Salinas, Southern California Edison

This paper shall discuss the case studies of the typical vacuum loss incidents which have occurred at Southern California Edison for the past eight to ten years. The case studies shall cover potential root causes, failure modes, and consequences of the vacuum loss failures. A technical evaluation of recent advances in vacuum loss detection shall be included. In addition, to be presented are data and perspectives on vacuum loss in medium voltage vacuum circuit breakers based on a Newton-Evans/Jennings Technology survey of 57 domestic and international major electric utilities, 59% of the utilities reported an average of four vacuum interrupter failures a year on their vacuum circuit breakers.

NEW TECHNOLOGY

CB-9 New Battery Technology

John Mandeville, American Electric Power

An article in the USA Today referred to NaS (sodium sulfur) batteries used as a backup energy source for transmission systems. Supposedly, this battery technology is compact, long lasting and efficient. With power demand always growing these batteries may help defer construction of new power plants, transmission lines and substations. The stored energy would be a reliable source to use in high demand situations and even backup power during outages.

John Mandeville, American Electric Power (AEP), commented that AEP has one of these batteries (2MW, 10 hour) installed in Charleston. They may be installing another battery in the next couple of years. Mr. Mandeville will describe the technology in his paper.

CB-10 Remote Breaker Racking

Brian Anderson, Colorado Springs Utilities

Mr. Anderson explained that this paper will cover changes in their 15kV metalclad switchgear design. Currently the new switchgear is all arc resistant. They were faced with the question, what should they do with the existing switchgear? The most dangerous work item with the existing switchgear was manual racking the breakers in and out of the cubicles. They partnered with a manufacturer to design a remote racking design so manual racking would not be necessary. This paper will cover the new design and show some examples of switchgear that has been upgraded.

CB-11 Switching 138kV Breakers with Capacitors Using Gang Operated Switches Causing Arcing

Timothy True, National Grid

When a 138kV breaker is opened with has TRV capacitors that are connected to ground and a switch is used to then disconnect the breaker/capacitor from the energized system, an arc can occur on the switch which can cause damage to PT's and control and protection devices. The paper explains why the arc occurs when opening the switch. The problem is not ferroresonance and will not be stopped by putting resistors in the PT secondary.

INSULATING MATERIALS COMMITTEE

IM-1 Technical Presentation on the Insulating Materials Technical Questionnaire
Matthew Kennedy, Doble Engineering Company

In 2005, the IM committee submitted a technical questionnaire on sample frequency, apparatus sampled, types of tests performed and types of oil related work performed on the apparatus. The results of the questionnaire will be published and presented.

IM-2 Field Assessment Of Sulfur Hexafluoride Gas
Ian Wylie and Nick Dominelli, Powertech Labs Inc.
Canada and Luke van der Zel, EPRI, USA

Detailed analysis of SF6 for contaminants and decomposition products can be used to determine the condition of in-service equipment and detect incipient faults in gas-insulated substations. Yet, despite its potential benefits it has not matured into a routine diagnostic technique similar to dissolved gas-in-oil analysis. Ideally, SF6 analysis should be done quickly and on-site in order to minimize depletion of decomposition products and contamination during sampling, storage and shipping. This paper discusses the challenges and obstacles to developing equipment and diagnostic techniques for on-site field assessment of SF6 gas. Laboratory and field tests are presented showing that a customized micro gas chromatograph can measure contaminants and decomposition products at the levels recommended by CIGRE for SF6 in in-service equipment. For the detection of low ppm levels of SF6 decomposition products, a decomposition products detector (DPD) was developed and field-tested at several utilities. This instrument is portable and designed for quick and accurate measurement of the predominant SF6 decomposition products in the field.

IM-3 Investigation of the Dielectric Design Criteria for Pressboard/Natural Ester Interfacial Stress
Thomas Prevost, Weidmann-ACTI
Michael Franchek, Weidmann Electrical Technologies
Kevin Rapp, Cooper Power Systems

Considerable knowledge exists on the transformer insulation system design based on the use of cellulose insulation used in conjunction with mineral oil. This knowledge is based on over 100 years of transformer design and manufacture. The insulation system designer must determine the stress in the fluid, in the solid insulation and along the interface. With knowledge of the insulation configuration, applied electrical stress and the insulation material properties the designer can calculate the dielectric stress in the fluid, in the solid insulation and along the interface. Design curves have been established for mineral oil which give limits to the allowable stress for each of these criteria. The purpose of this investigation was to establish design criteria for the interfacial stress (creep stress) of cellulose pressboard in natural ester fluid. The dielectric properties of the mineral oil and natural ester as well as pressboard and Kraft paper impregnated with each fluid were determined. These properties were used to design a test arrangement which stressed the fluid/pressboard interface while minimizing extraneous factors from the electrodes and test vessel. Several creep distances were tested with over twenty breakdown tests for each distance to give statistical validity to the results. The applied stress was varied in order to include those test criteria specified for power transformers. These included; 60 Hertz, Impulse and Switching Surge. All of these tests were done in natural ester fluid and mineral oil for a direct comparison.

IM-4 Update on Corrosive Sulfur Issues in Transformers
Paul Griffin, Doble Engineering Company USA

Research on corrosive sulfur continues to occur at a quick pace within the Doble laboratories and other laboratories around the world. Work continues on detection, testing both on oils and electrical apparatus, and mitigation techniques. This paper will review the latest information in this field and provide information on future research.

IM-5 Stop Corrosive Sulfur: A Successful, Multi-Directional Approach
Dr. David Sundin, DSI Ventures, Inc., Brazil & USA

Corrosive Sulfur in transformer oil has been the cause of high profile transformer failures in recent years. Oil treatments consisting of copper passivators have been only partially effective. A new sulfur inhibitor package been proven to change oils with corrosive sulfur into non-corrosive status, as well as significantly slowing oxidation and aging of insulating oil and paper. This paper discusses its performance in both laboratory tests and field application.

IM-6 Destruction of Dibenzyl Disulfide in Transformer Oil
Scott Reed, Power Substation Services, USA
Lance Lewand, Doble Engineering Company USA

Dibenzyl Disulfide (DBDS) is one of several sulfur compounds known to cause sulfur corrosion in transformers under certain circumstances. Remedial processes such as adsorbents, absorbents, and oil changeout have been known to reduce the concentration of DBDS in the oil but not totally remove it when the technique cannot treat all the oil in the transformer. Passivators are being used to protect the copper against corrosive sulfur attack but does not remove any corrosive sulfur species or those sulfur compounds that can become corrosive. The paper will discuss a process in which the destruction of DBDS is complete to below 1 ppm, can be performed at the transformer, and the oil reused in the same unit.

IM-7 Study of a Failure of a 161 kV, 50 MVA Trifasic Transformer by Deposition of Corrosive Sulfur in Mexico
Emmanuel Blanco, Engineer, Industrias IEM S.A. de C.V., Mexico

The problem of corrosive sulfur in transformers has been studied these last year by the initiative of manufacturers and users of electrical equipment world-wide, due to the increased failure of equipment that had only be in operation a short time. The difficulty to identify the deposition mechanisms of corrosive sulfur and to predict precisely a failure have intensified the research. The magnitude of the problem and its economical impact need concrete solutions and allow the life extension of contaminated transformers in operation. The objective of the proposed article is to document the failure case of a three-phase transformer of 161 kV and 50 MVA that occurred in Mexico and the subsequent investigations. The first part mentions the failure situation registered in the world that was provoked by the presence of corrosive sulfur in power transformers and reactors. In the second part, the corrosive sulfur deposit mechanisms formations are explained as a source of the failure and the test methods for the detection of corrosive sulfur and potentially corrosive sulfur are presented. A case is then presented in which using laboratory tests it is possible to identify the origin of the failure and to identify the presence of risky conditions due to the presence of corrosive sulfur in transformers in operation with the same design characteristics. Presented also are recommended techniques to mitigate the problem thus allowing the extension of the life of a contamination unit. In this manner is achieved the identification the corrosive sulfur deposits in insulating paper as the determining factor in the failure occurrence and to recommend some practices to prolong the useful life of the contaminated transformers while the advance of definitive solutions continues.

IM-8 Identification of Contributing Factors for Copper Sulfide Generation on Insulating Paper
Mr. Tsuyoshi Amimoto, Assistant Manager, Transformer Insulation Technology Sec., Mitsubishi Electric Corporation, Japan

The mechanism of copper sulfide generation on insulating paper has been intensely studied around the world. It was revealed over the past several years that almost all of the malignant oil contained dibenzyl disulfide (DBDS). However, the details of the mechanism have not been clearly solved yet. This paper reports the results of the heating test, which aims to identify the contributing factors of the phenomenon and to study the mechanism. The effects of temperature, oil brand and atmosphere were investigated.

Several commercially available mineral oils were used. Sample oil, paper-wrapped and bare copper plates were put together in a glass vessel. The sample oil was bubbled with nitrogen or air in advance to investigate the atmosphere condition. The heating temperature was kept constant during the single test and the temperature was changed from 120°C to 160°C. The heating time was changed from 72 hours to 432 hours. After the test, generated copper and sulfur on the paper and copper plates were analyzed by X-ray micro analyzer (XMA).

Metallic luster was observed on some of the paper. Both copper and sulfur were detected at the area and a remarkable decrease of the surface electrical resistance was also observed. Therefore copper sulfide can be generated on insulating paper by using the above procedure. There was a clear distinction obtained in the oil brand whether copper sulfide was generated or not. DBDS was found from the oil brand where copper sulfide generation had occurred. There was also an incubation period observed as copper sulfide generation on insulating paper did not occur immediately after the beginning of the test. The conditions of the incubation period are discussed more fully in the paper. Copper sulfide generation was found to be accelerated by temperature. The generation speed became twice when the heating temperature was increased by approximately 10°C. However, there was a critical temperature observed around 150°C in which copper sulfide generation was suddenly halted. There was no difference observed at 140°C whether the heating was done in the air or in nitrogen. But ti was found that copper sulfide generation in the air started earlier than that in nitrogen at 120°C.

IM-9 Non-destructive and In-Situ Analysis of Cellulose Insulating Materials in Power Transformers

Gary, Stevens, Henryk Herman and Patrick Baird, GnoSys UK, UK

Rapid in-situ analysis of the aging condition of power transformer winding insulation Kraft paper is essential when determining condition of the winding. This paper will discuss the use of recently developed portable fiber-optic and broad-band spectroscopy with multivariate statistical analysis to provide a non-destructive means of measuring the condition of the paper and its water content in power transformers. The technique allows spatial mapping of paper condition along and around windings in detanked transformers as well as for on site local forensic studies. Tests have shown the technique to provide highly reliable DP measurements that are within „b ƒ£0 DP units, as verified by conventional viscometry and water contents as low as 0.1% by weight. The same technique can also be used to determine the oil content of the paper insulation and to carry out a local as well as global oil analysis.

IM-10 Improving the Assessment of Transformer Condition by Enhancing Laboratory Accuracy Using Dissolved Gas in Oil Standards

Peter Lazarski, National Grid USA
Marc Cyr, Morgan Schaffer Inc., Canada

Laboratory analysis of transformer oils to measure dissolved fault gases is the single most important test available to transformer owners for assessing the condition of their equipment. As critical asset management decisions are made based on these analyses, the laboratory must insure proper control of its analytical processes. This paper outlines how dissolved gas in oil standards can be used demonstrate process precision and accuracy, and help in solving analysis problems that would not be noticed otherwise. It also discusses how dissolved gas in oil standards can be used to evaluate the uncertainty of laboratory measurements and what laboratory quality control data should be available to asset managers to help them understand the scope of validity of their laboratory data.

IM-11 Use of High Temperature Insulation with Alternative Fluids

Jean-Claude Duart, Dupont Switzerland, and Lisa Bates, Dupont USA

Traditional design of liquid filled transformers has been based for many years on the combination of cellulose solid insulation and mineral oil. As a result, average temperature rise for windings is normally limited to 65 K, and top oil rise to 60 K, as given in IEC 60076-2. Sometimes, high ambient temperatures, space or weight limitations force designers to look for new solutions. Then, designs with higher temperature rises can be proposed, using high temperature materials. Aramid paper thermal class of 220°C is much higher than Kraft cellulose paper, which allows operating of the equipment at higher temperature rise for windings without any negative impact on the insulation life.

Aramid solid insulation can be combined with both mineral oil or with alternative fluids, like silicones or esters. Silicones and esters fluids are also materials with higher temperature class than mineral oil, so combining them with aramid solid insulation gives a chance of not only operating windings at higher temperature but entire insulation systems to be more effective in terms of thermal properties. Using high temperature insulation materials allows for significant reduction of cooling system. Allowing higher temperatures within windings results in the possibility of applying higher current densities in winding conductors. This leads straight to significant savings in raw materials. Smaller cooling system, less conductor, and use of natural ester fluids could mean less environmental footprint of the equipment built.

Transformers based on high temperature design may be about 30% lighter than conventional transformers of the same power rating, or may have about 30% more power when comparing to the conventional unit of the same size. Fire safety resulting from high temperature class of the materials used is another very important factor in favor of high temperature design and will be favored in suburban areas or in underground substation. This is already a reality in small and medium power transformers as it will be detailed in the paper.

Additional advantages are observed when transformers need to be overloaded in certain periods of time. Due to limitation from the liquid side on the temperature of the design, normally, the aramid insulation does not operate at its full capacity of 220°C. Hence, in case of emergency overload, unexpected temperature rise does not have a critical impact on insulation life, as the allowed temperature is hard to be exceeded. This means that aramid based designs can be considered more reliable and are especially recommended when periodical overloads are expected like during hot summer peak demand or cold winter peak demand.

The recent IEC publication (IEC 60076-14) describes several high temperature insulation systems and provides general guidelines for temperature rises which can be used in such designs. For example, the average winding rise in a hybrid insulation system could be up to 95K while maintaining the conventional hot-spot temperature at maximum ambient at 118°C. Semi-hybrid insulation systems could have an average winding rise of 75K while maintaining the same conventional hot spot temperature at maximum ambient of 118°C.

This paper will highlight a few transformers which have been designed with aramid solid insulation and alternative fluids, including discussion of why the particular design was selected. We will also present technical results showing the aging characteristics of aramid insulation combined with alternative fluids such as silicone oil, synthetic ester, or natural ester fluids.

PROTECTION, AUTOMATION, CONTROLS AND COMMUNICATIONS

PACC-1 Making Arc Flash Protection Work

Michael F. Schacker, Burlington Electrical Testing Company
Mike Wactor, Powell Industries, Inc.

There are numerous strategies currently employed to mitigate the effects of an internal arcing fault in metal-enclosed switchgear. As we learn more about the behavior of the arcing fault and how the switchgear and installation affect the severity of the fault, it is recognized that many of the techniques may be combined to improve performance. A review of the internal arcing fault and mitigation techniques is provided with discussion on how these techniques may be combined to produce positive results. Specifically, when the mitigation technique has a response time that is longer than the rise time of the internal overpressure phenomenon associated with arcing faults, a need for structurally enhanced switchgear exists. A brief review of the test guide for measuring the structural enhancements to the switchgear is offered and strategies for coordination of arc resistant construction with mitigation techniques are discussed.

PACC-2 Commissioning and Maintenance Testing of Multifunction Digital Relays

Charles J. Mozina, Beckwith Electric Co., Inc.

A Working Group of the IEEE IAS wrote this paper. The paper was published in the IAS Magazine and won the award in 2005 as the best IAS magazine article. The paper discusses the challenges that users face in testing and commissioning digital multifunction relays. It also explores the impact on maintenance testing by self-diagnostics—the digital relay's internal capability to check itself for failures.

Commissioning multifunction digital relays offers some unique challenges to the user. Multifunction relays have protective functions that interact with each other, making testing more complicated. These relays can also be programmed to do control logic, which must be verified. In addition, digital relays can have multiple setting groups, which may be switched to address varying system conditions. This flexibility increases the commissioning complexity. This paper presents method and techniques to address the above cited challenges. Digital relays also have significant input monitoring capability that can greatly assist the user in determining whether these relays are properly connected to their CT and VT inputs, helping to verify that the relay is functioning properly. This paper outlines many helpful test techniques to help the test engineer utilize these features, which are available within all digital relays.

PACC-3 Evolution of SCADA Systems to Today

Dr. Jay Park, BCI Technologies

This paper will provide what changes SCADA providers have developed over the past 10 years toward making all-in-one SCADA system. The discussion will cover, "What does it takes, how is it done, and what customers need to look for in a new multi-faceted SCADA system."

As systems have developed over the years, customers have had various requests for additional features. Some of the features are, but limited to, improved troubleshooting and problem analysis, faster response time from the company to the customer, improved ability to analysis real-time data, managing load data, simulation of what will happens when a fault occurs and isolation of the fault through switching that takes place, preventative maintenance, and health checking with alerts of the devices like transformers, bushings, IED units, and breakers {Hoske, 2006 #316}{Katzel, 2003 #244}.

All other these new features are discussed for a good representation of software and hardware product selection for various vendors in the market place.

PACC-4 High Impedance Fault Detection in Feeders

Mark Adamiak General Electric
Iliah Voloh, General Electric
Yakov Knobel, Doble Engineering
Jun Verzosa, Doble Engineering

Downed conductors, tree limbs touching conductors and insulation degradation often result in high-impedance faults in distribution feeders. The fault currents due to these faults are very low for traditional ground fault detection techniques to reliably detect. This paper presents a Hi-Z function implemented in a feeder protection system that accomplishes high-impedance fault detection using a variety of algorithms, all coordinated by an expert system. At the heart of the high-impedance fault-detection function is the identification of arcing on a feeder. Distinction between an arcing intact conductor and an arcing downed conductor is determined by looking at patterns in the load current at the beginning of the fault. The detection of a downed conductor or arcing condition is accomplished through the execution of the following algorithms: energy algorithm, randomness algorithm, expert arc detector algorithm, load event detector algorithm, load analysis algorithm, load extraction algorithm, arc burst pattern analysis algorithm, spectral analysis algorithm, arcing-suspected identifier algorithm, even harmonic restraint algorithm, and voltage supervision algorithm. The paper describes the overall high-impedance detection function and these algorithms. Methods of testing the high-impedance fault detection function and testing results are also presented.

PACC-5 Upgrading Power Transformer Protection From Power Fuses To Circuit Switchers at Substations Which Do Not Have a Control House

David Childress SSIPower LLC

Many smaller substations have no control house and do not need one since the power transformer is protected by power fuses; eliminating the need for relays, a battery bank and charger, and communications equipment. Typically these small substations have been located in remote rural areas which have very light loads; however, rural isn't quite as rural as it once was, and these substations are now being loaded at much higher levels. With these increased loads due to the increased number of customers served by the substations, the utility may find it desirable and/or necessary to upgrade the power transformer's protection from a set of power fuses to a circuit switcher. The utility would understandably like to accomplish this upgrade at the lowest possible cost without sacrificing reliability, and if it was not necessary to add a control house to the substation a significant cost savings would be realized. This paper provides full information on a circuit switcher solution which can provide current sensing, fault interruption, an uninterruptible power supply, a capacitor trip device, a digital protection relay, and an RTU--all integrated into a single product package to produce full functionality at a fraction of the cost of adding a substation control house. This solution, its full capabilities, and the advantages (financial, functional, and otherwise) will be covered in this paper.

PACC-6 Undervoltage Load Shedding

Charles Mozina, Consultant, Beckwith Electric Co., Inc.

This paper discusses why voltage as well as frequency load shedding may be necessary to prevent major system blackouts. Investigations of recent blackouts [1,3,7] indicate that the root cause of almost all of these major power system disturbances is voltage collapse rather than the underfrequency conditions prevalent in the blackouts of the 1960 and ‘70s. This paper explores the nature of recent power system blackouts (2003 east coast, 1996 California and others) and explains why voltage collapse is the leading edge indicator of impending power system problems. It also discusses the design and security issues that need to be addressed in the design of an undervoltage load shedding (UVLS) scheme and why relying on underfrequency load shedding (UFLS) may be “too little, too late.” The paper addresses the current level of UVLS on utility systems as well as current NERC (North American Electric Reliability Council) pronouncements on the subject.

ROTATING MACHINERY COMMITTEE

DESIGN

RM-1 New Generation of a Class 180°C (H) Electrical Insulation System for High Voltage Machines

Thomas Hillmer and Heinz Brandes, Von Roll Switzerland Ltd.
Nancy Frost, Von Roll USA, Inc.

Two decades ago a first generation of a Class H electrical insulation system was introduced in the high voltage market. Since then, an entire family of products have been developed for traction, wind power, low and high voltage applications, as a response to the market demand. These drivers developed with the increasing use of inverter driven machines and the usage of permanent magnets, the designs of which both generate additional heat. As a result of these developments, approximately 400 tons of this type of resin is sold per annum. In addition, designs of electrical machines with improved output and compact dimensions are being developed and have increased the market demands for insulation that utilized thermal class H systems. Based on customer requirements for improved dissipation factor characteristics and bond strength to the stator core, a second generation of the well-known system has been developed and recently introduced to the market. Results of the first and second generation of the Class 180°C (H) electrical insulation system will be presented and compared to a standard Class 155°C (F) system.

MAINTENANCE

RM-2 Inspection, Test and Operating Issues with Collector Rings

Clyde V. Maughan, Maughan Engineering

Carbon-brush collectors have historically been an operations/maintenance concern on turbine-generators. This is understandable in that this relatively small component is one of the most frequent causes of generator forced outages. The root cause of collector service problems is lack of performing the required on-going inspection and maintenance. While this inspection/maintenance effort is relatively minor, it is sometimes overlooked or done inadequately.

This paper will discuss collector performance and root causes of collector forced outages, and will provide guidance on identifying and correcting collector operating conditions before serious problems develop. In addition, information is included on retrofit of fixed brush holders with removable brush holders. Performing of the items in the maintenance checklist at the end of the paper, Table 1, should greatly reduce or eliminate exposure to carbon-brush collector service problems.

TESTING AND DIAGNOSTICS

RM-3 Electrical Testing and Tabulation of High Voltage Motors

Eddie Brynjebo, ElecktroSandberg Kraft

Fingerprinting and benchmarking of electrical apparatus is highly valuable for knowing the status of the assets. Adequate application and the use of diagnostic measurement technologies allows the owner to keep track of ongoing degradation to avoid unplanned outages and failures. This paper will discuss how ElektroSandberg, as a service provider, performs tests, tabulates results and tries to predict the future for high voltage motors. The paper will also provide examples as case studies.

RM-4 Condition Assessment of RM Field Poles Using M4000 Test Set

Hugo Simard, Alcan Power Operations
Vernon Ryman, PPL Electric Utilities
Long Pong and Keith Hill, Doble Engineering

This paper describes the condition assessment of field poles on rotating machinery (RM) using the Doble M4000 test instrument. The technique's basic theory, the test procedure, and three case studies will be provided. This test method is suitable for salient pole and cylindrical rotors, as well as the field poles of synchronous motors. The electrical condition of a field pole is mostly dependent upon the turn-to-turn insulation in the poles and their interconnection. The challenge in the condition assessment of this system is that the evaluation task can be done only in the static condition, which is different from the in-service condition (constant rotation). The utility compensates for this difference by applying AC voltage to the entire pole circuit and manually measures the voltage drop across each pole. Using the M4100 in conjunction with the M4110 makes testing rotor poles easier due to better control and protection over the test, and the test data will be obtained in an electronic format. The test involves very little investment for present M4000 users, and provides vital information on the rotor condition.

RM-5 High Voltage Equipment Condition Assessment with EMI Diagnostics

James Timperley, Doble Engineering

EMI (electromagnetic interference) is an on-line condition assessment tool that can provide useful information for maintenance planning. This paper provides examples of the electrical and mechanical conditions found with large motors rated 4kV and higher. Case studies of problems detected with air cooled and hydrogen cooled turbine generators as well as the associated isolated phase bus will be presented.

RM-6 Continuous Partial Discharge Monitoring on Motors

Igor Blokhintsev and Cal Patterson, Eaton Electric

Nowadays industries strive for extending life of main process equipment without sacrificing personal and environmental safety. Advances in technology are allowing new approaches to maintenance. These include reliability-centered maintenance, predictive maintenance, condition monitoring and expert systems. Proactive maintenance programs are widely promoted by trend setting organizations. This paper is centered around several case studies on how pre-emptive actions on several 13.8 kV motors affect stator insulation condition as assessed by continuous partial discharge monitoring. The impact of swapping line and neutral leads on an old winding in an attempt to extend the winding lifetime can be clearly seen with much accelerated upward trends in partial discharge activity. CO2 or other cleaning methods of stator windings can bring PD activity down in some parts of the winding, while not affecting PD activity in the rest of the stator. Continuous PD monitoring when used in conjunction with other parameters such as temperature, moisture and load can also assist in explaining widely varying PD levels thus relieving anxiety associated with periodic PD tests. Often intermittent high magnitude partial discharges as seen from line side couplers can be identified and eliminated by re-positioning high voltage cables, away from ground and or away from each other.

RM-7 Generator Neutral Point Partial Discharge Monitoring Case Studies

Thomas Laird, Alstrom Power Inc., USA
Ruediger T. Stein, Alstrom Power Ltd., Switzerland
Chris Watters, Alstrom Power Ltd., Switzerland

Today Partial Discharge (PD) measuring technology is one of the most useful monitoring tools for high voltage machines in power plants. Since many service providers have applied PD monitoring for more than 20 years as part of generator diagnostics, a wide range of experience in PD data analysis and interpretation is available. Several techniques have been used to accurately capture the PD activity within the stator winding system. Depending on the acquisition equipment and the monitoring frequency, PD sensors are commonly placed near the high voltage area of the winding. On some installations where low frequency PD monitoring is used, an additional sensor has been placed at the neutral point of the stator winding beside the three of more sensors at the high voltage output of the generator of bus.

RM-8 Endwinding Vibration in Large Rotating Machines

Andrew Tesla and Andre Tetreault, VibroSystM

In the past 10 years, risk of failure due to endwinding vibration has been clearly acknowledged by both end users and OEMs. As one industry expert puts it, “You have to monitor the level of endwinding vibration if you want to have any real idea on the health of your machine". Though it may be a relatively simple concept, measuring endwinding vibration is by no means a simple strategy. Innumerable factors are in play. Among the many decisions to be made; How many sensors? Where should they be placed? Is the data reliable? How much is noise? What levels are important? Whether a plant should even invest in the technology is really what is at stake. This paper has been written to help plant managers assess whether or not an investment in an Endwinding Vibration Monitoring Program should be made. It will review some history on the subject, decision making considerations, cost (time and money) considerations, practical data interpretation and recourse. This paper is practical guide for those who will be taking a closer look at the health of their machine – Monitoring Endwinding Vibration.

FAILURES, TROUBLES AND NONCONFORMANCES

RM-9 Flatiron G1 Stator Winding Insulation Failure – Coil Dissection Analysis and Dielectric Test Data Correlation

Eric Eastment and Jill Smith, U. S. Bureau of Reclamation

On September 11, 2006 Flatiron G1 tripped off-line via differential relay (87G) action followed by a stator ground (64G) and CO_2 discharge resulting in lockout. The initial investigation of this 47.8 MVA, 13.8 kV generator was performed by plant personnel and revealed copper and steel slag in the air housing which was apparently ejected through the #6 cooler. Following the initial investigation Hydroelectric Research and Technical Services personnel were called in to assist with the diagnosis, testing, and repairs. This unit was commissioned in the 1950's and rewound/up-rated in 1982.

The paper will discuss the investigations, electrical testing which includes Insulation Resistance, DC Ramp, Power Factor and Corona Probe. The paper will also discuss the coil dissection analysis of both failed and non-failed coils, cause of failure, coil cut-out diagrams and testing of a sister unit. In addition, the paper will detail the core damage and repair. The calculations used to de-rate the generator versus the actual measured de-rating via the parallel circuit current measurements will be presented. Lastly, the core repair process and core testing during repairs will also be discussed.

RM-10 Motoring of a 350 MW, 20 kV, Hydrogen Cooled Electrical Generating Unit

Ing. Alberto Quintero Nieves and Ing. Sergio Arroyo Ramos
Comision Federal de Electricidad, MEXICO

On October 26, 2006, at 14:23 Hours, while generating 90 MWs and increasing its load, the Unit 3 was tripped off line by operation of the boiler's MFT, sending trip signals to the generator's excitation as well as the unit circuit breakers (CB's) A2080 and A1030. In this last CB only phases B and C open, while phase A remained closed, maintaining two phases energized to the generator due to the delta connection at the main step up transformer, causing a generator motoring condition.

The unbalance created by pole A of CB A1030 remaining closed caused:

Trip operation of the Unit 3 and 4 Start Up transformers back up ground over current relay (51NT).
Trip operation of the Unit 5 and 6 Start Up transformers back up ground over current relay (51NT).

Under these conditions Unit 3 remained energized by Bus 1 of the Lazaro Cardenas Potencia 400 kV substation for 17 minutes, operating as an unbalanced induction motor until the 14:40 Hours. At that time the Local Control Center carried out operating maneuvers in the substation, opening the CB's connected to Bus 1, de-energizing Unit 3.

The Unit 3 protective relays which operated were:

32G, 40G, 46G and 86G. However, the CB did not open one of its poles.

The phase A of CB A1030 did not open due to the failure (burning) of two resistors in series with the CB trip coils. The resistors were burnt because the CB trip coils remained energized and their moving contacts got stuck due to a CB manufacturing defect.

The 400 kV SF6 GIS substation is of the 8DQ1 type with a closed ring CB scheme with 5 CBs for 2 generating units and 2 transmission lines.

The event analysis using Finite Element is presented as well as work carried out in the generating unit, the power CB and the changes made to the protective relaying, specifically in the 50BFI scheme which did not operate during the fault.

RM-11 Electrical Failure Mechanisms on Large Generator Stator Windings

G. C. Stone, Iris Power Engineering
Clyde V. Maughan, Maughan Engineering

In the late 1980s and again in the past few years, some turbine generator stator windings have apparently failed due to a mechanism variously referred to as spark erosion, vibration sparking, contact sparking or Type 1 slot discharge. The mechanism can produce relatively intense sparking between the surface of the stator bar and the core. The intensity of the sparking is such that it may erode the groundwall insulation much more quickly than partial discharges (slot discharges). Unlike the normal loose coil/slot discharge failure process, spark erosion can happen anywhere in the winding, and not just in stator bars that are operating at high voltage. For this mechanism to occur (a) the partly conductive slot coating must be much more conductive than normal; and (b) the bar must be loose in the slot and vibrating under the magnetic forces. This paper will explain the physics of the failure mechanism; show that it is the result of poor quality control by the machine manufacturer, and comment on detection of the problem while in service.

RM-12 In-Situ Collector Connection Repair

Mike Bresney, AGT Services, Inc.

A generator field suffered an in-service ground caused by the failure of a collector to bore copper bolted connection. The mechanical connection between the collector connection strap and the bore copper lug had degraded over time to the point where arcing / burning occurred – ultimately opening the field circuit and coincidentally causing a field ground condition. Due to the design of the field winding components, removing the bore copper for repair would require removing the field from the stator, removing the retaining rings and rewinding both number one coils. AGT Services designed and implemented a high quality repair method that was performed with the field in place, which minimized the length of the forced outage and cost of the repair scope. This paper will discuss the failure, but most importantly the repair.

TRANSFORMERS COMMITTEE

OPERATING USE

T-1 Investigation of Transformer Hydrogen Gassing
Don Platts, PPL Electric Utilities

PPL Electric Utilities began a comprehensive forensic investigation of a transformer after removing it due to high levels of hydrogen and a gassing generation rate that appeared to be accelerating toward an exponential trend. Three others of the 11 duplicate units on this order were also showing a similar gassing trend. An internal inspection did not reveal any indication of a source of hydrogen, but it did allow us to find a lead with severe discoloration. A subsequent inspection of a second unit found similar conditions. It was returned to service, but analysis of these observations did serve to confirm suspicions of a generic problem with the design, materials, or manufacturing. We began a project to investigate the gassing; identify the source; and develop an appropriate mitigation plan to apply to the remaining units.

The transformer was shipped to a repair shop for testing and repair. Since our primary objective was to find the source of the problem we began by performing induced voltage, extended over excitation, and extended heat run tests. None of the tests produced any significant hydrogen gas trends or generation rates. We had expected to find partial discharge and or gassing that could help to identify the problem. These test results were disappointing and did not lend any insight to the problem. During the teardown we removed all of the windings individually. We found no tracking or other signs of partial discharge. There was no indication of any dielectric problems. We did find unusual deposits and discoloration on the core coating, the wooden dowels in the core steps, on the pressboard insulation from core to ground, and on the same lead. We also found some charring of the wooden spacers. We could not associate any of the unusual observations with production of the hydrogen. The suspicious materials were removed and sent to Doble labs for material analysis. The material test results are presented in the paper and then analyzed for relevance to the production of the hydrogen gassing.

T-2 Innovative Power Flow Regulating Tap Changer Control Installed on Multiple Phase Shifting Transformers
Hank Miller and John Burger, American Electric Power
Michael Thompson, Schweitzer Engineering Laboratories, Inc.

This paper describes the development and installation of a power flow regulating tap changer control that has been installed on multiple phase shifting transformers (PST's) on the AEP system. These transformers are also known as phase angle regulating (PAR) transformers because they control the phase angle across a networked transmission system branch circuit to regulate the real power flow in that branch of the transmission grid. PST's regulate the phase angle by inserting a quadrature voltage into each phase by action of a tap changer mechanism. AEP installed the PST's to optimize power flow on existing transmission assets until planned transmission system upgrades can be completed. Historically, most PST installations have been manually controlled because the regulated quantity, power flow, is only indirectly controlled by the position of the tap changer. The actual delta-P for each tap step is a function of system conditions so it is easily possible that an automatic control will hunt (control action overshoots the regulation dead band which causes the tap position to continually change). AEP desired a control that would provide automatic regulation to an operator set point. This requirement led to the development of a control with an adaptive bandwidth feature that learns system conditions to prevent the possibility of hunting. In addition to local and remote, automatic and manual control, the control includes automatic features such as one-button "take off bypass and put in service" and "put on bypass and remove from service" automatic switching sequences to ensure proper switching sequences and operator safety. The first of five units was energized in the summer of 2006 and the most recent was energized in the summer of 2007. All installations are operating satisfactorily.

T-3 Effects of Stray Leakage Flux on the Tank of a 420 MVA, 20/230 kV Generator Step-Up Transformer

Ing. Alberto Quintero Nieves and Ing. Salvador Lopez Chavez
Comision Federal de Electricidad, MEXICO

The analyzed power transformer was placed in service in January 1998 in order to replace the original transformer. At that time, all the start up tests were within acceptable parameters.

In September 2002 a hot spot was found in the joint between the transformer cover and the tank on the low side of the transformer. The highest temperature detected was 164 °C. In 2004, the temperature at this point was 125 °C.

In July 2005 there was a fault on the 230 kV GIS substation. Two potential devices exploded sending fragments in the direction of the Unit 1 GSU transformer, damaging a number of its cooler's radiators. After repairs, the GSU was re-energized in August of the same year.

Afterwards there were detected areas of high temperature in the GSU unit, in the joint between the cover and the transformer tank, with evidence of high temperature: paint completely burnt. These hot spots had not been detected previously since the hot spots had moved toward the phase A, low side bushing area showing temperatures of 387°C. From that moment on a very detailed temperature monitoring was put in place at this spot.

In the paper the studies and analysis which were made are presented. Similarly, the work made to control this temperature is described until the point in time in 2007, when the temperature was stabilized. Members of CFE's and Doble's Transformer Committee as well as specialist of the transformer manufacture participated in these analyses.

Following were the suggested recommendations:

- Periodic thermal infrared monitoring as well as measurement of the circulating and ground currents.
- Changing the original magnetic stainless-steel-316 bolts holding the cover to the tank for non-magnetic monel steel bolts with Belleville washers.
- Improvements to the transformer grounding connection, including a ground current recorder as well as using welding for the connections.
- Measurement of each bolt's magnetic field.
- Finite element analysis to calculate the magnetic field intensity present at each bolt as well as the magnetic field lines of force existent when there is good contact and when it becomes loose.
- Installation of copper braided bridges, proposed by the manufacturer, to provide better contact between the 49 bolts holding the transformer cover and the tank.
- With the above, the temperature was held to about 100°C with the generating unit at full load (350 MW) during its normal operation.

The generating unit remained synchronized to the system, generating power at full capacity during all these analyses and work. Only during the generating unit scheduled outages work was done on the GSU transformer.

MAINTENANCE PRACTICE

T-4 Low Frequency Heating Field Dry-Out of a 750MVA 500kV Autotransformer

Elisa Figueroa - Hydro One
Ed teNyenhuis – ABB

The dry-out of 30 year old EHV 750 MVA 500kV GE autotransfomer using the Low Frequency Heating (LFH) process is reported. It is generally difficult in the field to achieve acceptable dryness for wet EHV transformers using the traditional hot oil cycling method. The LFH process applies near DC current to the windings allowing uniform winding temperatures progressively and safely up to 110C. The LFH drying process was completed in 2 weeks with significant water removal and the moisture in cellulose brought down to below 1%. This is one of the largest field applications of the LFH drying process. This transformer had been removed from service due to significant tank wall overheating caused by improper shield isolation. The transformer had the tank wall shielding repaired and other upgrades were completed as per a detailed engineering design study. The LFH drying process was an integral part of the field repair and will allow a transformer to be successfully returned to useful service for the utility.

MOBILE TRANSFORMER SYMPOSIUM

The interest in the issues regarding mobile transformer use, specifying and procuring became evident in discussions in the Transformers Committee Meeting in September 2007. This symposium was created in response to this interest. The following representatives shall describe their experiences regarding mobile transformers. Questions from the audience are encouraged after the presentations are completed.

T-5 John Stead, AltaLink
T-6 Harry Ruggles, American Electric Power
T-7 Doug Hollands, SaskPower
T-8 Progress Energy

LIFE CYCLE MANAGEMENT

T-9 Assessment of Insulation Dryness Using Dew Point Measurements of Transformers Below Freezing

Phil Prout, National Grid
Rich Simonelli, Waukesha Electric Systems, Inc.

The dew point measurement is the most widely used and accepted test to measure the moisture content of a transformer which has been shipped or stored without oil primarily because the test may be done without having to open the transformer. We propose to deliver a paper researching the concerns with application of the dew point for temperatures below freezing. We shall follow and collect data on a sample of 6-12 new transformers and track the units through production to installation. Utilize moisture test blocks to confirm the field measurements. Research methods that can minimize error producing variables. Support industry-wide R&D to develop ways to measure moisture contents of working transformer accurately and reliably.

FAILURES AND TROUBLES

T-10 Transformer Failure and Teardown Report

Terry Troop, FirstEnergy

The failure and teardown of the East Windsor Substation Bank 1 transformer will be presented and discussed. The reason for the failure was determined which may help in future design considerations. The importance of a section in the specification requiring the manufacturer to report to the purchaser the quantities and types of salvage materials for each transformer is noted. The method for conducting the teardown is explained.

T-11 Failure and Condition Assessment Tests of 60 Cast-Resin Transformers for a Windmill Power Plant in Quebec, Canada

Jean-Yves Cote, Gemitech
Sébastien Courcy, Gemitech
Long Pong, Doble Engineering Company

(This Paper will be Published but NOT Presented)

This paper describes the failure and condition assessment tests of 33 cast-resin transformers manufactured by Siemens and SGB in 2004, rated 34.5/0.69kV, 1.45MVA. With less than two years in service the transformers experienced a failure due to the electrical arcing, tracking and partial discharge on the surfaces of the HV windings. The test campaign has two objectives: evaluate the insulation condition and establish the test data baseline. Also, the result of the failure investigation, analysis and tabulation of Doble test data, including power factor tip-up, for this type of transformer are included in this paper.

THE ENVIRONMENT

T-12 Transformer Damage Caused by an Earthquake

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

On July 16, 2007, an earthquake, rated 6.8 on the Richter scale with its epicenter 17 km underground, hit the Chuetsu area in Japan. Kashiwazaki-Kariwa nuclear power station, 8.2GW/7 units, in Tokyo Electric Power Company, was affected by the maximum seismic acceleration of 680 Gal (cm/sec2) compared to the design value of 273 Gal (cm/sec2) at bedrock. Even in this situation, the nuclear reactors were safety shut-down, and the fundamental safety functions operated and secured correctly. However, the in-house transformers were damaged by the huge earthquake. This paper reports the investigation of the transformers' damages caused by the excessive seismic acceleration.

DIAGNOSTIC METHODS

T-13 SFRA - AEP's Prospective

John Mandeville, AEP

AEP has begun to use SFRA as a diagnostic tool. Since 2004, AEP has been building a database of base line data which will be used in the future to help identify transformer problems. In the past 2 years, SFRA has been used in three cases to help identify suspected transformer problems.

At our Smith Mountain plant, the substation took a direct lightning strike which tripped off 5 units. So what was the condition of these GSU's? A comparison of outside phases SFRA response did not show anything significant and the units were returned to service.

While testing a mobile transformer, SFRA indicated that there was a problem with the center phase high voltage winding. Upon further investigation, it was determined that a bonding jumper was missing from the center phase bushing.

During a normal inspection, a GSU was found to have a bulged side at our Knox Lee plant. SFRA testing was performed on the suspect transformer, (serial #K546615) and a sister unit (serial #K546616) did not identify anything that was significantly abnormal. It was later determined that this transformer was recently serviced and that the conservator valve was closed. The bulged transformer tank expansion was caused by excess oil pressure. Since there was not internal damage, the unit was returned to service.

T-14 Field Experiences with SFRA

Matt Kennedy, Doble Engineering Company

(This Paper will be Published but NOT Presented)

This paper describes recent transformer problems that have been detected by using Swept Frequency Response Analysis (SFRA).

T-15 Frequency Response Analysis for Fault Detection in Power Transformers

Servando Sánchez, CFE-DCO MEXICO
Carlos Pérez, Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) MEXICO
Alberto Avalos, UMSNH MEXICO

This work, shows our experiences in diagnostic of power transformers through the Sweep Frequency Response Analysis (SFRA) test, through a three year period. We show some important factors analyzed which affect the test such as bad connections, core magnetization due to electrical tests such as insulation resistance, excitation current, etc. Results of SFRA tests of a new transformer obtained at different moments: in plant, in site (substation) and after eliminating core magnetization. Some incipient faults were detected in a power transformer showing the SFRA response with the fault and after it was eliminated. Additional tests are shown including TTR at 10 KV, leakage reactance, etc.

T-16 High Voltage Transformer Tests Uncover Manufacturing Defect Not Detected in the Factory

Robert Stephens - Exxon Mobile
Keith Hill, Doble Engineering Company
David Stelmach, Doble Engineering Company

Investigated a new transformer that had excitation currents of 300, 120, and 1240 mA. Power Factor, TTR, and winding resistance were acceptable. De-magnetizing procedures did not change the current patterns. The TTR capacitor indicated a problem as the test voltage had to be lowered to 2 kV for a TTR test to be performed. The low voltage TTR did not reveal a problem. SFRA tests verified a problem. Transformer was to be shipped to a repair facility for investigation/repair.

T-17 Difficult Transformer Problems Diagnosed by Effective Testing

John Lapworth, Doble PowerTest
Richard Heywood, Doble PowerTest

Some transformer faults are straightforward to diagnose, with protection indications and oil analysis results pointing to the type of problem, and it may only require excitation currents to be measured to diagnose shorted turns, a typical end of life failure mode for service aged transformers. However, in many other cases it is difficult to diagnose what type of transformer fault is involved and even harder to determine the cause. In some cases the transformer may be damaged but this may not be obvious from normal monitoring.

This paper describes three unusual transformer faults: one dielectric, one thermal and one mechanical fault, which were different to diagnose for various reasons, and describes how these problems were solved by a combination of tests implemented in the most effective way and using sophisticated interpretation techniques.

T-18 Influence of Preventative Autotransformer Crossed Connection on Single-Phase Exciting Current and Loss Measurement

Mark F. Lachman, Delta Star Inc.
James Ziebarth, Highline Electric Association

(This Paper will be Published but NOT Presented)

This paper will describe the influence of crossed connections in preventative autotransformer on the measured single phase exciting current and loss results.