2011 INTERNATIONAL CONFERENCE OF DOBLE CLIENTS
TENTATIVE PROGRAM AS OF JANUARY 17, 2011

The review of the discussion subjects received at the October Doble Client Committee Meetings in Austin, Texas, as well as additional items raised at the meeting, led to the formulation of the following tentative program for the 2011 International Conference of Doble Clients. This program is subject to change.

Asset and Maintenance Management Committee

1. ***Power Transformer Spares Analysis***
   Mohamed Shamog; National Grid U.S.

As with other utilities, National Grid is faced with an aged infrastructure with many critical items either obsolete or with little manufacturer support. Holding the correct number of power transformer spares is vital to ensure the availability of operational systems. Yet critical spares are often expensive, have long purchasing lead-times and may only infrequently be needed. The business case for determining which items are worth holding, in what numbers, can be challenging and accomplished using different tools.

In this paper National Grid will describe how with the use of equipment experts, spreadsheets and off the shelf software it building a robust and auditable transformer spares policy that allows for continued serviceability of its core critical assets while minimizing cost and lead times.

2. ***Integration of Site Performance Data despite Access Protocols and Security Issues***
   Lee Ayers; Doble Engineering

The future must be to provide the system operator with a robust indication of the risk in operating 100% availability. But there are many hurdles and this presentation will described them. This includes access protocols to make the data from specialist condition monitoring vendors to mix seamlessly with traditional substation performance data as well as allowing access by such vendors to the data for integration into a scoring process.

3. ***Progress toward a Reliable Transformer Service Life Prediction***
   Richard Heywood, Hongzhi Ding and Simon Ryder; Doble Engineering, UK

Dealing with aged power transformer fleet has challenged the utilities for years. Like human beings, power transformer will experience its infancy, normal operation and wear-out stages. As the power transformer ages, it fails more frequently and eventually reach its end of life. The reason the utilities are concerned about the transformer service life is because of the risk caused by end-of-life failure of aged power transformer. In order to manage the risk of ageing failures of power transformers, it is imperative to develop reliable prediction of aged transformer service life and the probability of the end-of-life failure, and the mode of failure.

This technical paper aims to review existing methodologies for transformer service life prediction, describe the actions and activities prerequisite to estimate the transformer service life and discuss, with case studies, the implementation towards the development of reliable techniques for transformer service life prediction and end-of-life management.

4. *Strategic Sourcing at Bonneville Power Administration*

Mark Nadeau; Bonneville Power Administration

This paper will discuss BPA's recent adaptation of strategic sourcing methodology and the value it has brought to our purchases. Specific focus will be on:

Using a formal project framework to gain organizational leverage, goal focus and continuity of knowledge

Applying a total cost of ownership model to evaluate product delivery and performance

Identifying opportunities and gaps through effective market research and internal analysis

Discussion will reference specific findings and experiences from BPA's strategic sourcing projects.

5. *Doble Portal: Information via Internet for Doble Clients*

Arturo Oropeza; Doble Engineering

As we all have come to accept but not completely understand electronic data is part of our daily lives. From e-banking and e-commerce to endless "net-surfing" sessions to find information on whatever subject we are interested in, relevant or irrelevant to our lives, the Internet is a source for all kinds of information and misinformation.

Not too long ago (late 1990's), Internet access was limited and perhaps not attainable to all but with the advent of new technology, faster and more powerful networking servers and personal computers, many around the world now enjoy access to the "Information Superhighway" of today.

Accessibility of information in today's Internet world may be overwhelming and plagued with unseen detours, as aptly portrayed by a recent TV ad campaign for a search engine. Not knowing how to avoid these "forks in the road" or take the correct path at that fork in the road may be the difference between a one day project and a one week project.

Acknowledging these circumstances and also considering the fact that Doble Engineering Company is recognized as a premier world leader in knowledge for the electric power industry, Internet use is a natural fit as means to disseminate information; having the right vehicle to access the more than 80 years of accumulated knowledge relevant to the Power Industry is of utmost importance. For that reason Doble created a Client "Portal", which in today's Information Technology world is considered as the gateway for users to access desired information.

This paper will describe this Doble Client "Portal" and the way to use this tool for the benefit of its users and how to take advantage of the applications included.

6. *Control Building HVAC and Battery Ventilation*

Phillip Prout; National Grid U.S.

National Grid, Substation Engineering Services presently has a working committee studying the heating and air conditioning requirements of system substation control houses. We will be informing the utility community how we have been dealing with the following questions and concerns:

1 Equipment operating temperature – Do we need to heat and cool buildings to maintain the temperature for equipment operations? If yes, to what temperatures?
2 As control houses are designed as unmanned facilities is there a need to heat and cool for O&M or other personnel? If there is, what temperatures are desired? (upper and lower temperatures).
3 Is heat and cooling needed to control other functions such as humidity?
4 If there is a need or want for HVAC, is redundancy needed? If yes, why?
5 We would also be interested in hearing any other discussion points others have considered when addressing these concerns.

7. Second Generation Computerized Maintenance Management Systems

John Stead; KEMA

A Computerized Maintenance Management System (CMMS) is a data base containing all the necessary information required for an organization to maintain their assets, sometimes know as Enterprise Asset Management. The function of this data base is to help maintenance workers do their job more effectively and allow management to make informed decisions concerning maintenance budgets. In the utility industry another key function, which has become extremely important is verifying regulatory compliance. First generation CMMS were typically initiated in the manufacturing industry and simulated into the utility industry. These systems had several shortcomings since the utility industry has certain characteristics in contrast to the manufacturing process. Unlike manufacturing facilities the core assets of a utility are spread over a large territory, difficult to access, exposed to varied and demanding environmental conditions, and pose various safety and environmental hazards. In addition to these differences the first generation systems were focused on preventative maintenance and not condition based maintenance, which most utilities are now focusing on. One of the main drivers for the need to more to condition based is the large number of aging assets utilities own. Prioritization of maintenance based on the health of the asset and the consequence of failure of that asset is critical in extending the life of and preventing the failure of critical assets. The second generation CMMS must become a more complete Asset Management tool, where prioritization is key and options such as refurbish and replace are integrated into the maintenance plan. This is a shift from the original concept of maintenance as a standalone function.

It has been recognized our North American power system is reaching it's expect end of life and recent widespread outages have raised a concern regarding the maintenance programs and the downsizing of organizations coupled with the retirement of the baby boomer work force. Maintenance organizations once flush with knowledgeable experience workers; reliable equipment and easy access to perform maintenance on redundant equipment are now faced with quite different circumstances. Critical equipment is now extremely difficult to remove from service to maintain, while the expertise utilized in the past to perform maintenance is retiring and the probability of human error during maintenance has increased. The practice of removing equipment from service to maintain based on a time schedule because "there is a chance there is a problem" is no longer acceptable. Limited resources and outage times now dictate that maintenance organizations expend these resources only when necessary and that equipment condition be more fully understood. Justification for an outage to a major industrial customer must be shown in the form of a risk assessment with preferably quantitative data or subjective data backed with experienced judgment in order to be accepted.

This paper will describe the functionality of the new breed of CMMS systems and how they contribute to a successful maintenance program in conjunction with conditional test data from test instruments such as power factor, partial discharge, SFRA etc. and real time operational stress experienced by high voltage equipment.

8. A Utility Perspective of Substation Battery Maintenance and NERC PRC-00

Paul Gogan; WE Energies

9. Seismic Mitigation Program at Bonneville Power Administration

Leon Kempner; Bonneville Power Administration

The Bonneville Power Administration's (BPA) has the potential to experience one of Mother Nature's largest seismic events, a subduction zone earthquake. BPA has an active seismic mitigation program to prepare for a subduction zone earthquake. For new facilities, BPA uses current industry standards such as the IEEE 693 and the International Building Code. For older facilities, BPA has conducted vulnerability studies. Based on worldwide transmission line faculties earthquake performance, and BPA's vulnerability studies and research and development activities, a seismic mitigation program has been implemented. This paper will summarize the components of BPA's seismic mitigation program.

10. EMI Evaluation of Plant Assets

James Timperley; Doble Engineering

Please note: this program is subject to change.

This paper will have examples of how EMI diagnostics can be used to prioritize the maintenance activities for transformers, power cables, bus, switchgear, potential transformers, breakers and other plant assets.

11. Employee Engagement and Employee Productivity

Charles Rogel; DecisionWise

The concept of employee engagement is a real challenge in today's multi-generational workforce. It becomes even more difficult if companies don't consider the changing demographics and whether current human resources strategies will continue to drive engagement for the new mix of employees. Especially since the more engaged employees are, the more productive they will be.

Each of the four generations has a differing identity, and approach to life and work. As employers, it is important to understand how these differences impact the workplace and your workforce. The tactics that may engage one generation will not necessarily engage the others. It is critical to define your organization's future generational mix, understand the key needs of this mix, and respond by defining and implementing a proper response in order to maintain employee engagement across the new workforce.

Arresters, Capacitors, Cables and Accessories Committee

1. North Battleford Termination Failure
Jay Beattie; SaskPower Technical Services and Research

A 500 MCM Nexans cable punctured on the secondary of a 72/25 kV 10/13.3 MVA transformer (707T1) on a temporary installation in the North Battleford substation. The cable was installed in November 2008 and failed shortly thereafter. The close-in fault failed the transformer. The cable puncture was inside the cable terminator. Although the 3M terminator had no model identification on it, it appeared to be a Quick Term II 5654 with datecode "08" (SaskPower Stores Code 83529). All three terminations with cable stubs were removed from the installation. After failure analyses in the field, they were brought to the SaskPower High Voltage Laboratory for further review in April 2010. This report presents the results of that latter study.

2. Acquiring, Installing, Testing and Managing Cable Systems at eThekwini
Daren Papayya, Raj Dhrochand; Durban, South Africa

Please note: this program is subject to change.

Bushings, Insulators and Instrument Transformers Committee

1. Update on Failure of COTA Bushings and the Possible Cause
Trench Limited

This paper will provide an update of the failures of Trench type COTA bushings. Several utilities have suffered violent failures of Trench type COTA bushings, mostly at 230 kV. Progress Energy has lost six of these bushings. Others that have lost this type of bushing: XCEL Energy, Georgia Power, Alabama Power, Salt River Project, Duke Power, and PG&E.

2. Failure of Trench Type COTA Bushings
Andre Lux, Sue Oxford; Progress Energy

A discussion of the failed COTA bushings and comments on the paper listed above.

3. Findings after Teardown of Two O+C Bushings, One Found With High C1 Power Factor, the Other With Blackened Oil In Sight Glass
Doug Hollands; SaskPower

Recently, some cases of ABB type O+C bushings have been found with blackened oil in the sight glass. Upon investigation, high amounts of gases were found. This paper will describe the circumstances of the investigation. In addition, a case of high power factor in the same type of bushing (not related to the blackened oil) is discussed.

4. Understanding Resin Impregnated Paper Type Bushings and the Application of Non-Porcelain Materials as Insulators
Rolf Segeschneider; HSP Bushings

Use of Resin Impregnated paper type bushings with silicone rubber shed insulators is more widespread in Europe than in the USA, as are bushings with silicone rubber weathersheds on transformers. This paper is designed to familiarize the reader with these types of bushings.

5. Testing Bushings with Two Taps
Reynaldo Galera; Doble Engineering, Brazil

This paper will describe how to test bushings with both a test tap and a potential tap.

6. Partial Discharge Measurement for In-Service Current Transformers and Correlation with other Condition Assessment
S. Victor P. Selvakumar, P. N. Dixit, Sanjeev Singh, R. N. Nayak;
Power Grid Corporation of India Limited, Gurgaon

Please note: this program is subject to change.

Circuit Breakers Committee

1. *Oil Circuit Breaker Field Experiences – Testing, Diagnostic and Reconditioning*

Mathieu Lalonde; Hydro Quebec – TransEnergie
Long Pong; Doble Engineering

For long time, Hydro Quebec has routinely tested Oil Circuit Breakers (OCB) using Doble standard test and analysis method for condition assessment. There are over 1500 OCBs in the Hydro Quebec network, 40 to 60 years old and most of them are KSO type, made by GE and rated from 120kV and below; however the most problematic detected by power factor test was on OCB rated 25kV and lower. The problem ranged from component deterioration, such as gaskets, bushings and interrupters, to spare part replacement. This paper will compile the field experiences such as the field testing, findings, test method improvement, repairs, reconditioning techniques and how Hydro Quebec solved the problem of spare part unavailability. It will include the field test procedures, data tabulation, description of internal inspection, dismantling, dissecting, cleaning and drying the OCB components.

2. *SF6 Moisture and Purity Limits at Bonneville Power Administration*

Steve Lowder; Bonneville Power Administration

In 2010, Bonneville Power Administration (BPA) finalized SF6 moisture & purity limits for new and in-service equipment. BPA determined these limits after: performing a utility survey, reviewing equipment manufacturer's requirements, and reviewing moisture/purity limits for new and reclaimed SF6.

This document will outline the finalized SF6 moisture & purity limits for new and in-service equipment, why the levels were chosen, why BPA has stricter requirements for reclaimed SF6, and the QA process BPA uses to ensure quality of the SF6 in warehouse stock.

This document will refer to equipment and services purchased by BPA as part of its SF6 purchasing and quality assurance program. These references should not be viewed as an endorsement of such equipment/services nor an exclusion of any other equipment/services.

3. *Substation Metalclad Assessment using Handheld Ultrasonic and Transient Earth Voltage Testing Devices*

Jay M. Garnett, John E. Gavin, Anthony J. McGrail, Timothy J. Miles; National Grid USA

National Grid has experienced some failures of metalclad switchgear, and breakers in the switchgear, and has been looking for ways to find incipient problems before a failure occurs. National Grid has been trying different manufacturers of ultrasonic, acoustic emissions, and transient earth voltage (TEV) testing devices to see how these devices can help in detection of problems in the breakers and switchgear.

This study involved analyzing the effectiveness of these hand held devices when surveying known metalclad switchgear that either had a history of problems or was suspected of having problems. Three regional divisions in New York State of National Grid where selected to test these units on selected metalclad switchgear. There was a crossover in the central region near Syracuse, NY to see if one manufacturer would detect problems that the other manufacturer might not detect.

The bulk of this report is based on one of those manufacturers unit, and their report, that performed the best from this particular study. Other parts of this paper cover other types of analysis and how they can differ in application and results. This report shows that by using ultrasonic and Transient Earth Voltages (TEV) many problems can be detected, with reasonable confidence, of finding a serious problem that is in the process of becoming a future equipment failure.

4. *Determination of Transient Recovery Voltage of a High Voltage Circuit Breaker*

John Kweku Amoo-Otoo; Exelon Nuclear

A Transient Recovery Voltage (TRV) is the voltage that appears across the contacts of a circuit breaker when the current is interrupted or it can be defined as the voltage that occurs across switching devices. The voltage achieved is based on the power system configuration. Most often than not this voltage can be disintegrated into two voltages within successive time intervals with the first part of the voltage being the transient voltage and the second part of the voltage is only power frequency voltages. During the interruption process as the instantaneous current tends to approach zero, the arc begins to lose conductivity which is a phenomenon called current chopping. The power system then has to respond to the lost of the arc conductivity and the changes in current interruption and that is what generates the Transient recovery voltage. Transient Recovery Voltage can also be defined as the difference in the power system capability of response to voltage levels between the source side of the circuit breaker and the load side of the circuit breaker. The magnitude of the transient Recovery Voltage (TRV) is also dependent on the design of the circuit tied to the power system. The design could be resistive, capacitive, inductive, and sometimes it could be the combination of the resistive, inductive and capacitive circuits (R-C, R-L, and R-C-L). Based on the analysis of the circuit, a driving voltage develops which is the Voltage that is developed at the incept of interruption or across the circuit elements before interruption.

For Circuit Breakers, transient voltages after the current interruptions are of great concern with the ability to interrupt the current relating to insulation recoveries and also transient voltage across the contacts.

Capability of a Circuit Breaker is mostly determined by the Transient Recovery Voltage of the Circuit Breaker and the interruption process for a circuit breaker can be successful based on the breaker being able to withstand the transient recovery voltage (TRV). There are different shapes that the TRV voltage can assume to include triangular, oscillatory and exponential and sometimes it could be a combination of these shapes.

The contents of this paper are a brief introduction of the phenomenon of TRV, the different types of high voltage circuit breakers and the various wave shapes from TRV that is achieved based on the type of grounding scheme for the neutral, type of the power system (Capacitive and inductive), the type of fault level and magnitude and lastly the type of loading connected to the circuit breakers. Lastly is a typical example to determine the TRV of a circuit breaker using a IEEE standard table with parameters and multiplying factors. The TRV can also be calculated from first principles but that is out of scope of this paper.

5. *Motion Measurement and use of Transducers for Detection of Circuit Breaker Characteristics*

Jozef Levi; Doble Engineering

The aim of this paper is to introduce motion testing on circuit breakers using test instruments. For every measurement there is a need for transducers which will transfer one physical value to another for example an electrical signal. For proper measurement characteristics and position of the transducer have to be known. Different positions will give different results.

Examples of test results dependence of motion transducer position are presented. Special attention is given to detecting shock absorber reaction using velocity. Case studies are presented and commented.

6. *Doble Testing of SF6 Circuit Breakers (A Progress Report)*

Linda Nowak & Leah Simmons; Doble Engineering

The object of this paper is to review and update Doble Engineering test techniques which have been developed for SF6 gas circuit breakers. The previous report by Doble Engineering Company covering this same topic was presented at the 1989 Client Conference.

Included in this report are test procedures, an updated tabulation of data and some case studies. This information along with some general comments and observations are intended to assist the tester in proper testing and analysis of the equipment.

7. SF6 Gas Leak Repair for Circuit Breakers

Jim Hackett; Colt Atlantic Services Inc.
Tony Picagli; United Illuminating

United Illuminating (UI) has recently adopted a policy to strive for zero SF_6emissions. In accordance to UI's policy "The practice of releasing even the smallest amount of SF_6 during commissioning, maintenance and testing has become unacceptable."

While this may seem to be quite ambitious, the policy has led us to develop both preventive and corrective maintenance techniques. Corrective techniques are well documented throughout the industry and are generally based upon the equipment manufacturer's recommendations or repairs made by companies specializing in gas and oil leak sealing. These repairs can be both costly and time consuming. With the inability to easily remove equipment for service, or leave equipment out of service for prolonged periods, preventive, rather than corrective, maintenance methodologies need to be examined, tested and, where practical, employed. This paper will discuss a few techniques and concepts being developed to prevent leaks for gas filled circuit breakers (GCBs) and gas insulated substation (GIS) installations.

8. A Case of a 362kV GIS Bus Flash-Over

Howon Hwang; Korea Electric Power Corporation (KEPCO)

Korea Electric Power Corporation (KEPCO) is practically the only electric power company in Korea and they have adopted Gas Insulated Switchgear (GIS) system since early 1980s. Recently 87% of substations are of the GIS type in over 700 substations in KEPCO. With a lot of construction and operation with GIS, KEPCO has accumulated a broad variety of experience in GIS operation.

Basically one of the GIS design concepts is maintenance-free, though it doesn't mean failure free. Between 2005 and 2008, KEPCO has experienced several GIS bus flash-overs in a certain substation. This paper discusses the analysis and findings of one flash-over case.

9. Failure Analysis and Emergency Repairs for a GIS 400kV Blade Type Breaker

Alberto Quintero Nieves; CFE Mexico

Insulating Materials Committee

1. *Development of New Hybrid Insulation System using Natural Ester Fluids*

Roberto Asano, Luiz Cheim, Don Cherry, Clair Claiborne; ABB Inc.
Lisa Bates, Jean-Claude Duart, and Eric Key; DuPont

Hybrid insulation systems were developed many years ago with high temperature aramid materials (e.g. NOMEX®) and mineral oil. Recent developments have led to the combination of hybrid insulation systems in natural ester fluids (e.g. BIOTEMP®). Although the wire insulation, spacers and sticks in these hybrid insulations systems are high temperature materials, there are other insulation components such as cylinders and angle rings which are made out of cellulose board. Such material now becomes the thermally limiting component. The thermal capability of cellulose paper has been studied in the past but there are few published studies on thermal capability of cellulose board like structures. In order to optimize the use of hybrid insulation systems, thermal capability of such cellulose boards should be understood. This paper will present thermal evaluation of a cellulose board in a natural ester fluid. The test results suggest the thermal behavior of low density board may be better in natural ester fluid than in mineral oil and leads towards the establishment of accepted procedures for determining the thermal capability of solid insulation in different liquids.

2. *Consideration for Thermal Performance Calculations with Various Cooling Liquids for Power Transformers – Natural Ester versus a Range of Mineral Oils*

Jin Sim; Waukesha Electric Systems

Natural esters are environmentally friendly coolants made from edible seed oils. They are biodegradable, non-toxic and have low flammability. They are finding increasing use in transformers where these issues are of concern. Thermal parameters of natural ester, such as its temperature dependent viscosity, thermal conductivity, specific heat, and density, are used in a cooling program for transformers which models the fluid flow in the ducts of the windings, the tank, and the radiators. This calculation is compared with a similar calculation using the thermal parameters of standard mineral based transformer oils with a range of characteristics. These calculations are also compared with test data.

The main thermal difference between natural ester and mineral oil is the higher viscosity of natural ester. The higher viscosity results in a slower moving liquid compared with mineral oil. For the same transformer and radiator configuration, the natural ester temperatures are higher than those of mineral oil in the normal temperature range of operation. We performed calculations and tests for transformers rated from about 10 to 100 MVA. The natural ester average oil and winding temperatures were about 2 to 4°C higher than those of mineral oil. The natural ester top oil and hottest-spot winding temperatures were about 5 to 10°C higher than those of mineral oil. For an existing unit retrofitted with natural ester, these higher temperatures can generally be counteracted with more radiators and/or fans to maintain the temperature rise limits or accept higher temperatures based on slower thermal aging of cellulose insulation impregnated with natural ester.

3. *An Advanced Technique to Diagnose Internal Faulty Parts of the Oil-Filled Transformers Based on the Condensing Analysis for Trace Components Decomposed from Insulating Materials*

Yasuhiko Hanamaki, Tokyo Electric Power Co.

Dissolved in insulating oil gas analysis (DGA) has been adopted throughout the world as the most effective diagnostic technique for fluid filled transformers. It is difficult to identify damaged materials because carbon monoxide (CO) and carbon dioxide (CO_2) are also produced by normal aging in service of transformers.

An advanced technique has been developed to aid in identification of damaged materials, and thus the location of faulty parts. It is based on the quantity of trace components in the insulating oil determined by the purge and trap analysis (hereafter abbreviated as P/T analysis). The P/T technique was employed due to the normal properties of the components of the solid insulating materials. For example, compounds from solid insulation materials have a

higher boiling point and lower vapor pressure than components decomposed from insulating oil. The P/T technique was also used because it is difficult to extract and analyze trace components decomposed from insulating materials dissolved in insulating oil using conventional analysis methods such as vacuuming and bubbling methods.

This paper will discuss the implementation of the technique especially the concentration and extraction of trace components from the oil that will enable determination of solid material degradation and location within the transformer.

4. Progress Energy's Experience with On-line Drying

Kate Brady; Progress Energy - Carolinas

On-line drying is a useful tool to reduce the water content in a transformer insulation system if the transformer itself cannot hold vacuum, the unit cannot come out of service in the immediate future or for a long time or that repairs need to be made but are on a delayed schedule. This paper with discuss the decision process that made this remedial activity cost effect at Progress Energy, the selection of the transformers that will undergo this process, which on-line drying process that was employed on a given unit, case studies and pros and cons of the process itself.

5. On-line Drying Using a Filtration Process

Ben Taylor; Velcon, Inc.

This type of on-line drying process has been in place for almost 20 years and many utilities have adopted it. This paper will discuss the technical aspect of the process itself about how it actually works, how it is monitored, safety provisions that are provided for unattended operation and techniques to determine if the process was successful at removing moisture.

6. On-line Drying Using a Filtration Process

TBD

Vacuum drying of transformers and oil has been use for many decades. Within the last 20 years though, it has been incorporated in to an on-line technique for drying of the insulating fluid and subsequently some of the solid insulation. This paper will discuss the technical aspect of the process itself about how it actually works, how it is monitored, safety provisions that are provided for unattended operation and techniques to determine if the process was successful at removing moisture.

7. On-line Transformer Drying, on Filter Method

Doble Client

8. Case Studies Involving Dibenzyl Disulfide

Doble Engineering

The recent failures (within the past 10 years) due to buildup of copper or silver sulfide on the conductor and the paper insulation, has mostly been attributed to dibenzyl disulfide (DBDS). Research has shown that the initial concentration of DBDS appear to be around 150 to 200 ppm. It is known that as the DBDS degrades it starts to react with the copper or silver to form copper/silver sulfide through various mechanisms.

It is not known at which point in the degradation process of DBDS that the criticality of copper/silver sulfide deposition is caused that will ultimately cause the transformer to fail. Doble will review concentrations of DBDS in its database and provide case studies in which DBDS has been involved to help elucidate the DBDS degradation process and formation of sulfide films. In addition, an analytical method for the detection of DBDS will be provided.

9. Issues with Transportation and Contamination of New Oil

A utility in Africa is currently receiving a lot of new transformers and hence new oil. They have been experiencing very bad problems with delivery and processing of oil on site. It is understood that the refiner can only be responsible for loading the oil in the tanker but before the oil enters the transformer the utility is checking for particles and has learned a lot from this. Some contractors will do anything to make their money as fast as possible and if it is not checked you won't know what is in the oil. Maybe else where in the world utilities do not have similar problems - but in AFRICA they need to be alert for everything. The tankers used are in most cases not dedicated tankers - and yes they can show you their clean certificates - it may be visually clean, but not to the extent it is required. This utility prefers in-line particulate analyzers (they don't promote the blockage technology) - sampling for lab analysis is quite an art and believe me very challenging. It is amazing how many people think if you change the filters the oil should be very clean - there is some serious increase in particulates following a filter change.

This utility has a whole list of items that are checked when new oil arrives. This is especially important if the oil was previously stored. They have had problems where there was solvent contamination and only the IFT showed a problem – they performed a tan delta, that passed, but the flash point also showed a problem. They have had another case in which the IFT dropped from just above their specification to just below the spec and also saw an additional peak on the FTIR following this - unfortunately they could not identify the contamination.

Silicone oil was also detected as a problem. In this example, oil was stored on-site in newly made holding bags. Unfortunately, the bags had traces of silicone oil from the rubber processing, which contaminated 100,000 liters of new oil to a level of 7 ppm - it foamed like crazy.

This utility has had some bad experiences and very costly delays due to incorrect handling of the oil after it leaves the supplier. They have changed their specification in an attempt to rectify some of these adverse conditions but they are getting a lot of resistance from their European oil suppliers.

10. Possible Passivator Interactions with Oil

Mt. Kato; Mitsubishi Electric

Protection, Automation, Controls & Communications (PACC)

1. ***NERC Update***
   Phil Winston; Southern Company

2. **TBD**
   Alex Salinas; Southern California Edison

3. ***PG&E Processes and Initiatives to become NERC Compliant***
   Jerry Timiraos; Pacific Gas and Electric

4. ***Understanding the Lessons Learned from Recent Blackouts***
   Chuck Mozina; Beckwith Electric Company

5. ***NERC/CIPS Requirement as Viewed by National Grid***
   William Breault; National Grid

6. ***Single Point Vulnerabilities of Large Power Transformer Failures and Maintenance***
   John Amoo-Otto; Exelon Nuclear

Please note: this program is subject to change.

Rotating Machinery Committee

1. Optimizing Isolated Phase Bus Maintenance with EMI Diagnostics

Peter Longo & James Timperley; Doble Engineering

EMI (electromagnetic inference) is an on-line real time technique that provides information on the condition of insulation, conductors and associated components in an isolated phase bus. Examples of several defects found with this technique are presented.

2. Understanding Typical Large Main Generator Inspections

John Amoo-Otoo; Exelon Nuclear

To assess the condition of a main generator either during a major outage or a minor outage can prove to be challenging. One should also be aware that though there are scheduled inspections for the main generator, there are other areas that have limited access and very difficult to inspect even using the state of the art tooling and inspection kit. Also when electrical test are performed on the main generator and exciter it poses a heavy challenge sometimes where you have to make a careful decision not to overstress the insulation to create weak areas of the main generator. The different methods to assess the condition of a turbine generator are continuous on line, periodic on line, minor outages and major outages. That means an established good inspection programs in addition to scheduled electrical testing using an in-house PM program and manufacturer's recommended frequency of testing can itself provide an excellent condition or integrity of the main generator components. Proper established maintenance practices combined with a good analysis of the electrical testing results and scheduled recommended repairs from OEM'S will help maintain the reliability of the main generator and rotating exciter. This paper will provide a detailed description of the various components of the main generator and the exciter (rotating exciter) that is inspected during a major inspection when the rotor is out, appropriate inspection frequencies, and also during a minor inspection when the rotor is intact using a typical check list. For the rotor the components that have to be inspected are the vent holes, rotor forgings, retaining rings, collector rings, brush holder, windings, and fans. For the rotating exciter inspection of the stator, rotor, collector ring, seal system and bearing components are the ideal inspection performed.

3. Insulation Degradation in Generator Stator Bars due to Spark Erosion and Partial Discharge Damage

William G. Moore & Aleksandr Khazanov; National Electric Coil

This paper will present recent findings of insulation damage in large, air-cooled generators. The primary damage mechanism is due to spark erosion, sometimes called vibration sparking, but evidence of partial discharge deterioration is also presented. Borescope inspection of the windings provides an indication of the degree of damage. Bars removed from these generators were closely examined for insulation damage and correlated with the borescope inspections. The deterioration mechanisms will be described through visual observation, high magnification photography, dissection and evaluation. Insulation damage can be correlated with the amount of service hours of the unit. Multiple inspections have enabled a regression curve to be formulated indicating a time line of failure. Of these large, air-cooled generators, the majority are failing or are having to be rewound prior to failure within their first ten years of service life. Typical generator stator winding insulation systems last an average of thirty years or more. These modern, epoxy mica based insulation systems are failing prematurely due to spark erosion and partial discharge. Root causes of the insulation degradation are presented, along with readily available solutions that can be implemented to present this problem as part of a rewind.

4. Advances in Motor and Generator Rotor Health

John M. Reschovsky; Accumetrics Associates, Inc.

Until recently, power plant operators have had very limited options for on-line monitoring of the health of motor and generator rotors, particularly those with brushless excitation systems. Degradation of field winding insulation can lead to ground faults or shorted turns, with little or no warning. Moreover, the capability to monitor local hot spot

temperatures on rotor windings in service has not been available even though monitoring of stator windings with resistance temperature detectors (RTDs) has always been commonplace.

In the past decade, digital rotor telemetry technology has come of age, offering new options for rotor condition monitoring on motors and generators. This technology involves placing electronic modules on rotors that perform direct measurements of electrical signals and sensor inputs, digitizing the information, and using wireless technology to pass the data off the rotor. This allows continuous monitoring and long term trending of field voltage and current, insulation resistance to ground, average winding temperatures and hot spot temperatures. On brushless machines, it detects ground faults, issuing an immediate alarm when a ground occurs.

This paper discusses application of this new class of rotor condition monitoring options using digital rotor telemetry technology to continuously monitor the health of rotor insulation systems in large motors and generators.

5. Return to Service of a 173 MVA Hydrogenerator with Five Coil Bypasses and One Removed Inoperative Parallel Circuit - Load Limit Testing and Results

Eric P. Eastment; U.S. Bureau of Reclamation

Emergency repair of stator windings after a failure often includes bypassing coils or entire parallel circuits, rarely does it involve both.

However, in some instances, this may be necessary due to lack of spare coils or other unforeseen situations. Predicted de-rating calculations for cases involving multiple coil bypasses and a parallel circuit removal are not available. This presentation/paper will detail the return to service of a 173 MVA hydrogenerator with 5 bypassed coils and one parallel circuit removed (inoperative). It will briefly discuss the winding design, locations of the coil bypasses and removed parallel circuit, and focus on the calculated vs. actual measured de-rating and lessons learned.

Additionally it will discuss the load limiting factor along with direct monitoring of the damper winding temperature.

6. Comparison of Large Main Generator Inspection and Electrical Testing in Nuclear and Fossil Plants

John Amoo-Otoo; Exelon Nuclear

To assess the condition of a main generator either during a major outage or a minor outage can prove to be challenging. One should also be aware that though there are scheduled inspections for the main generator, there are other areas that have limited access and very difficult to inspect even using the state of the art tooling and inspection kit. Also when electrical test are performed on the main generator, exciter it poses a heavy challenge sometimes where you have to make a careful decision not to overstress the insulation to create weak areas of the main generator. The different methods to assess the condition of a turbine generator are continuous on line, Periodic on line, Minor outages and Major outages. That means an established good inspection programs in addition to scheduled electrical testing using an in-house PM program and manufacturer's recommended frequency of testing can itself provide an excellent condition or integrity of the main generator components. Proper established maintenance practices combined with a good analysis of the electrical testing results and scheduled recommended repairs from OEM'S will help maintain the reliability of the main generator and rotating exciter. This paper will provide a detailed description of the various components of the main generator and the exciter (rotating exciter) that is inspected during a major inspection when the rotor is out, appropriate inspection frequencies, and also during a minor inspection when the rotor is intact using a typical check list. This paper will further address the type of electrical testing that can be performed to establish the integrity of the stator core, stator windings, rotor windings and exciter components and the scheduled frequencies for these electrical testing. The inspection components of the main generator includes the core area, slot portion and end-winding and the coolers, main lead box for the high voltage bushing, brush holder rigging, instrumentation wiring. For the rotor the components that have to be inspected are the vent holes, rotor forgings, retaining rings, collector rings, brush holder, windings and the fans. For the rotating exciter inspection of the stator, rotor, collector ring, seal system and bearing components must be accomplished. Most of the test voltages used for the testing of the main generator stator and rotor are marginal and not destructive except the hipot testing voltage.

7. *A Brief History of Turbine-Generator Electrical Insulation and Support Systems*

Clyde V. Maughan, P.E.; Maughan Generator Consultants

This paper is based on the author's recollections from a 60-year career in turbine-generator design, manufacturing and service – 36 years with General Electric and 24 years as an independent consultant. Having joined GE in 1950, and having worked closely with the "old timers" of that day, the direct knowledge base goes back into the teen years of the 1900s – a span of almost a century. No guarantee is offered that all the information is exactly correct, but the essence should be acceptably close to give a general understanding of the difficult evolution to the present designs of turbine-generators.

Because the major OEMs of the day kept pretty close (informal) watch on each other, we were pretty well informed on the designs, and troubles, of each other. Thus the information on non-GE OEMs should be fairly accurate.

There has been considerable commonality of materials and designs between OEMs throughout this history. An important example: all forgings for all OEMs come from the same steel mills. But there have been major and important differences in design details. An OEM fortunate enough to have a truly genius engineer in their organization was likely to have solved difficult problems with an elegant, simple design. Whereas an OEM with truly excellent engineers (but not genius) may have solved the problem with a complicated, almost Rube Goldberg, design. Examples include field ventilation, stator winding support systems, stator bar strand transition, compensation for non-symmetry of 2-pole circumferential stiffness, isolation of stator core vibration. Over time, as OEMs have studied competitor generators, there has been convergence on many issues, but there remain to this day, major and fundamental differences.

In writing this "brief history" the focus has been on materials and structural configurations. Little detail is provided as to why specific materials were selected or why the configurations were needed. In the last 15 years, the writer has produced a number of technical papers and a 210-page text addressing some of these issues. The interested reader can find these texts at web site: www.generatortechnicalforum.org. On the discussion topic, Inner Water-Cooled Stator Windings, click on any thread, click on the Documents tab at the top, and find downloadable 20 papers and a 210-page text on generator maintenance.

8. *Rotating Machine Partial Discharge Measurements via 80-pF Line Couplers in Terms of Picocolumb (pC)*

H. Elze, S. Kornhube, M. Boltze; Doble-Lemke

At partial discharge sources in rotating machines we distinguish between external end winding discharges and the more dangerous internal slot discharges. Due to the low pass behaviour of the signal path inside the slot those internal PD are attenuated.

Only the lower frequency contents remain at the measuring point in contrast to the higher frequency contents of the end winding discharges.

Rotating machines equipped with 80-pF line couplers are accessible for repetitive PD measurements. With the 50-Ω load of the PD detector this forms a high pass of approx. 40 MHz. Usually the mV-quantified PD measurements are done in the frequency range of several tens of MHz. Hence internal slot discharges are measured with poor sensitivity, whereas the PD pattern is dominated by the end winding discharges.

More promising in that respect is the PD charge measurement in picocolomb acc. IEC 60270. The reading for the PD activity is less depending on the pulse shape. That provides more sensitivity for internal slot discharges leading to a better reliable assessment of the entire insulation state.

The paper resolves the apparent contradiction to the 80-pF line coupler high pass behaviour. By signal conditioning it is possible to maintain the signal integration, necessary for charge measurement. Additionally the test voltage signal can be derived for synchronization the phase resolved PD-Pattern. Comparative measurements at a generator stator with larger coupling capacitors illustrate the feasibility of charge measurements via 80-pF line couplers. Further ideas of characterisation the integration behaviour are presented and calibration questions are discussed.

Transformers Committee

OPERATING USE

1. Induced Transformer Testing in the Field

Tony Bustamante; Edison Company; Los Angeles

The Edison Company in Los Angeles performs induced testing in the field for transformers that are rated 230 kV and above. These induced tests are for acceptance during commissioning. This is NOT a common practice for utilities! The Edison Company has adopted this policy because they are minimizing their visits to the factories to witness the production and testing activity. They participate in the design review but depend of the induced testing in the field for acceptance. They have had this policy for about two years and have found a few problems. The paper will include how their testing program is structured, their plans for the future testing and some issues with transformers that they have found.

2. Wind Farm Transformers

Chuck Kelly; S D Myers

Trending in several pad-mounted transformer show elevated levels of hydrogen, carbon monoxide in some units, acetylene in others and hot gases (methane, ethane and ethylene) in others. Units have not been in service for extended time, i.e. couple years. Are others seeing this trend in combustible gases indicating partial discharge, high energy discharge and overheating? Peak temperatures recorded do not indicate units are overloaded. Could this be due to design issues, manufacturing processes, mechanical issues such as off load tap changer, circulating currents?

Oil quality appears like new oil - no dielectric, moisture or other physical or chemical irregularity being noted. Just the DGAs are abnormal for such a new transformer population.

3. Wind Farm Design Considerations

Mike Dickinson; Pacific Crest Transformers

CONDITION ASSESSMENT

4. Transformer Condition Assessment in Practice

Bill Griesacker & Orlando Pena; Doble Engineering

When a transformer experiences an event that calls into question its condition and suitability for service, experience shows that careful consideration should be taken to verify its condition before making the decision to energize. Two recent experiences will be presented and discussed showing the steps taken, the outcome and the lessons learned from the efforts to determine the condition of the transformers. The first case is a transformer that experienced a shipping event that was questionable. The second case is a transformer that sustained a close-in through fault. The diagnostic tests conducted, inspections performed and evaluation of relevant details surrounding the events will be presented for each case.

Please note: this program is subject to change.

5. Comprehensive Condition Evaluation of Service Aged Power Transformers

C. Sumereder; Graz University of Technology
G. Valtin; University of Applied Sciences
T. Friedrich; ENSO Energie Sachsen Ost AG
S. Kornuber, M. Boltze; Doble Lemke GmbH

Service aged power equipment were the most critical part in the electric energy production and transmission chain. In this contribution the focus is laid on oil immersed power transformers which were operated more than 25 years. The aim of this investigation is to determine the condition in a comprehensive way. Beside the results of different diagnostic measurements the historical operational dates as well as a visual inspection should lead to a more expressiveness statement about the technical condition.

In this project the historical oil analysis data and operational loads were collected in a standardized data schema. This data set was the basis for a statistical analysis. For the investigation in the liquid insulation system the mineral oil was evaluated according to the standards of IEC and IEEE as well as other assessment methods. The most common were the dissolved gas analysis (DGA) and the chemical physical parameters.

At several service aged power transformers an extensive diagnostic program was performed: The solid insulation was tested by winding resistance, winding insulation, polarization and depolarization current (PDC), frequency domain spectroscopy (FDS), frequency response analysis (FRA), the tap changer was tested as well as the bushings and the tank by visual inspection. At some transformers actual oil samples were taken and analyzed by chemical parameters, DGA and furan analysis. All the test results were evaluated under the aspect to determine the condition of the whole transformer system and to detect weak components of the investigated transformer. At one transformer an end of live inspection was done in the manufacturer site. The results of the diagnostic measurement onsite and the results of the inspection after opening the transformer corresponded excellent.

Finally an algorithm was developed to collect the results of the measurements for the evaluation process for a whole transformer fleet in a utility. By the method of benchmarking a health index is calculated for each transformer. The aim of this algorithm is to get the benchmarks of each transformer, to create a health index and finally to optimize the maintenance strategy.

This algorithm was programmed in a standard calculation program and its aim was to guide the user with commends and recommendations for maintenance measures. It consists of different modules, the oil module with the focus on the evaluation of the mineral oil condition, the visual inspection module, the insulation resistance module, the module for risk assessment and finally the benchmark module where the transformer fleet is observed.

LIFE CYCLE MANAGEMENT

6. Improvement of a Maintenance Strategy of Aged Transformers with a Computerized Maintenance Management System

Hiroyuki Nakajima; Tokyo Electric Power Company

Replacing aged transformers based solely on its age does not always guarantee companies of economical advantage and blackout risk reduction, although most transformers on service were originally designed and produced to operate for thirty years without any major troubles. This report discusses an expected life of conventional transformers based on a research on aged transformer samples done by Tokyo Electric Power Company (TEPCO) and then discusses the shortened expected life of certain transformer types, in which we have identified some defects in its designs and productions. Correspondingly, some diagnostic methods for known transformer defects are introduced.

Also, the necessity of a computerized maintenance management system to monitor individual machines condition and to develop the optimum maintenance program is discussed.

FAILURES AND TROUBLES

7. 500 kV GSU Failure Due to Air Bubble Formation

Craig Swinderman; Mitsubishi Electric Power Products
Michael Lamb; Dominion
Paul Griffin; Doble Engineering

The high voltage failure of a 500 kV, 400MVA ODAF cooled Generator Step Up (GSU) transformer at Dominion's North Anna Nuclear Power Station on October 29, 2008 led to an extensive root cause investigation by the OEM, Dominion, and other industry experts. The failure occurred a few minutes after the GSU bank was returned to service following a routine refueling outage, and the findings of the investigation suggested that negative pressure existed within the main tank which resulted in air bubble formation. It was determined that the most likely cause of the negative pressure was an inadequate conservator tank breather system and an extended cooling pump operating time, which allowed air bubbles to form and collect in the HV bushing turret resulting in voltage breakdown between the 500 kV bushing shield and the bushing turret. Furthermore, there is strong correlation with this transformer failure and those of other catastrophic 500 kV shell form ODAF cooled transformer failures that Dominion experienced in the 1980's, which were thought to be caused by static electrification but no obvious signs were discovered due to the extent of the damage.

8. Unintentional Transformer Core Ground – Diagnostic and Mitigation

Martin Gamache; Rio Tinto-Alcan
Long Pong; Doble Engineering Company

Rio Tinto-Alcan has many old transformers of vintage 1950s and wants to maximize the use of these assets to meet the corporation objectives: Production increase and high reliability. So we undertake many reconditioning and monitoring projects on the critical transformers and have identified two chronicle gassing transformers due to unintentional core ground. This paper will describe the troubleshooting method and mitigation of the unintentional core ground, and why the unintentional core ground becomes the obstacle to the corporation objective. The trouble transformers are English Electric 20MVA, 161/13.8 kV Single Phase GSU, vintage 1951, identified as T0309 and Westinghouse Voltage Regulating Transformer rated 40MVA, 13.8kV, vintage 1956, identified as T1117. It will also include the monitoring and field test data before and after mitigation, and the procedure of the visual inspection, core ground resistor engineering and installation, fiber optic installation, repair and testing.

DIAGNOSTIC METHOD: SWEPT FREQUENCY RESPONSE ANALYSIS

9. SFRA Identifies Problems Prior to Shipment

Tony McGrail; National Grid US

"GE Prolec takes great care to make SFRA measurements on new transformers at the factory in operational configuration, and then take a final set of measurements immediately prior to shipping with the transformer in 'shipping configuration'. In this instance a transformer had a good set of SFRA results during factory testing, but when configured for shipping mode some anomalies appeared. It was not believed that there was any structural damage to the transformer in any way, but the SFRA results are a very important baseline test for the owners to check on delivery of the unit to site. It was thus decided to defer shipment of the unit until an explanation for the anomalies could be found. As it happens there were two causes for variation – neither of which was obvious during the testing before shipment – one was an inadvertent ground caused by the securing of a winding lead to prevent movement during shipment, and the other was remnant magnetism which left the core in a state which interfered with the low frequency results. However, a number of standard and less standard SFRA tests were performed in an effort to identify the causes of anomaly and it is those results which will be discussed in the paper. The anomalies were removed and the transformer tested successfully before shipment."

10. Swept Frequency Response Analysis, Realistic Expectations

Mike Bocovich; Xcel Energy

Xcel Energy is dedicating resources to swept frequency response analysis (SFRA) testing on transformers. The expectation is the SFRA will be able to detect movement of windings. We have new transformers tested at the factory in the "as shipped" condition. If movement is expected we can test the transformer on site in the "as shipped" condition and compare results to detect movement and damage. Tests were performed at Maple Grove on a transformer to verify if the expectations are realistic.

11. SFRA & Leakage Reactance Prevents Customer Outage - Viaduct Substation 115-34 kV 41.7 MVA Auto Transformer

Benjamin N. Lynch, PE; Ameren Missouri

Since 1980, Ameren Corporation has experienced a total number of 200 transformer failures. These transformer failures can be directly correlated with internal failures caused by through-fault, windings, water ingress, and LTC to name a few. Unfortunately, all of these failures resulted in some sort of unplanned event or outage to our customers. Ameren Engineering has had a 15 year history of removing transformers based on dissolved gas analysis (DGA) history; however, before the Viaduct transformer 1 had not removed a transformer based solely on testing results indicating physical movement.

The 115000 GRD Y – 34500 GRD Y 46.7 MVA transformer had experienced multiple through-fault events over its life due to various breaker failures, bus faults, and animal outages. After one such snake caused through-fault in 2009, Ameren Engineering began utilizing the Doble Leakage Reactance and sweep frequency response analysis (SFRA) test sets to perform additional diagnostic testing. The results of these tests revealed the field measured impedance had experienced a 4.6% change from the nameplate impedance. Furthermore, the SFRA data revealed a ten decibel (dB) difference in magnitude indicating a change in the geometric shape of the center windings. This prompted an internal inspection that revealed insulation debris and radial movement.

These field results along with the internal inspections prompted a planned transformer replacement. After the transformer was removed from service, Ameren completed a controlled teardown of the unit. The visual inspection revealed the center phase low voltage common winding had experienced hoop buckling. This hoop buckling was dangerously close to affecting the regulating and high voltage series windings. The inspection confirmed the testing results along with revealing enough cumulative damage was present that a future through-fault event would have caused a transformer failure.

12. SFRA a Tool to Ensure Transformer Coil Manufacturing Quality

Yargole, Arun; Doble Engineering, India

Manufacturers of medium & large capacity transformers when under time / cost pressure tend to make some manufacturing / design variations. The variances are generally seen after the tests are conducted after complete manufacturing and only when compared to sister units. Recently for a couple of cases, I noticed deviations in three sister single phase units having identical technical data. This change was seen only after comparing SFRA results. We are aware that SFRA can be used as an effective tool by manufacturing to improve quality. But can we have a variant (hardware / software) that can check the 'wound coils' during manufacturing stage itself? The idea is to allow the manufacturer to arrest the problem before the complete assembly.

13. Frequency Response Analysis of Transformers: Visualizing Physics behind the Trace

Mark F. Lachman, Vadim Fomichev, Vadim Rashkovski & AbdulMajid Shaikh; Delta Star Inc

Most field diagnostic tests allow for an easy visualization of the physical process unfolding during the test. For example, we can visualize how current during the exciting current and loss measurement creates the magnetic flux, which induces voltage in all windings magnetically coupled to the excited winding; if there is a closed loop – intentional or un-intentional – a "load" current is created thus affecting the measured values. Understanding of this simple physics helps to envision the potential scenarios that can create the abnormal "load" component in the current.

These descriptions can be created for the dielectric loss and capacitance (aka, power factor), leakage reactance and loss, winding dc resistance, and turns ratio measurements. The frequency response analysis, however, is a challenge due to a sweep of test frequencies engaging the multiple segments of the transformer.

The proposed paper attempts to provide a simple description of physical processes engaged in key frequency ranges thus helping to visualize the transformer components affecting each of these ranges.

DIAGNOSTIC METHOD: PARTIAL DISCHARGE

14. Onsite Experiences with IEC60270, UHF and Acoustic PD Measurements

Sebastian Coenen & Stefan Tenbohlen; University of Stuttgart
Matthias Boltze; Doble Lemke

The paper presents three case studies for partial discharge (PD) measurements using different measuring methods to improve interpretation and localization of PD sources. The conclusions and following actions after the PD surveys are given. Finally the different measuring techniques are evaluated for their workability under different conditions as onsite, offline and online.

15. PowerGrid Experience in Partial Discharge Measurement of Transformers and Reactors

Sanjeev Singh, P.N.Dixit S Victor , V.K. Bhaskar, Gunjan Agrawal
Power Grid Corporation of India Ltd., Gurgaon, INDIA

Transformers & Shunt reactors are expensive and critical components, therefore state of the art electrical and chemical techniques have been adopted for condition monitoring and diagnostic testing. Several techniques such as measurement of insulation resistance, dielectric dissipation factor, oil quality, moisture content in cellulose/paper and DGA have been in use for many years. New techniques like frequency response analysis, partial discharge measurement etc. are being introduced to keep pace with development worldwide. All these techniques help to assess the condition of equipment under reference and give indication to take timely action to save the transformer from catastrophic failure. In this paper, a case study has been presented to show the usefulness of on-site partial discharge in identifying the faults and remedial measures taken to mitigate the problem.

DIAGNOSTIC METHOD: TEST RESULT TABULATIONS

16. Tabulations of the Overall Tests for Transformers filled with Ester Fluids (Natural and Synthetic)

Michelle Ward, Jim McDonald & Bob Sarni; Doble Engineering

This paper will study the measured power factors for the overall insulation systems in transformer that are filled with Ester fluids. From the study it is anticipated that power factor levels shall be obtained to evaluate the condition of the insulation systems.