Agenda is subject to change.

**LEGEND**

TP: Transformer Professional Program (M-TH)
TP-A: Transformer Professional Program - Advanced Training (W-TH)
TM: Transformer Maintenance Program (W, TH, F)
RP: Transformer Relay Protection Program (M-TH)
LS: Laboratory Seminar (F)

**Note:** There is no need to pre-register for particular sessions. Simply choose the session that’s right for you.

Sunday, February 10, 2019

4:00 PM – 7:00 PM Registration & Information Desk Open

Monday, February 11, 2019

6:30 AM – 6:00 PM Registration & Information Desk Open

6:30 AM – 8:00 AM Attendee Breakfast

TP & RP 8:00 AM – 8:15 AM Welcome & Introduction
Bryan Sayler, President
Doble Engineering Company

**Bryan Sayler** brings 28 years of experience developing and implementing highly engineered test solutions for wireless, EMC and microwave applications in the electronics, automotive and aerospace industries. Prior to joining Doble, Mr. Sayler was Sr. Vice President Solutions Development at ETS-Lindgren where he led global project management, hardware, software and strategic solutions development through active participation in global standards bodies including IEEE, CTIA, 3GPP and the WiFi Alliance.

TP & RP 8:15 AM – 8:45 AM Opening Keynote

TP & RP 8:45 AM – 9:15 AM Primer on Large Power Transformers
Jeff Short, Manager, Client Service Engineering
Doble Engineering Company

As we move forward into the 21st Century, the use of electricity by mankind has evolved into a necessary staple of everyday life. But it wasn’t always this way. The advent of power transformers in today’s world is a function of necessity, a product of ingenuity, and a marvel of technology. Power transformers are the key element in the present system of electrical power distribution, and this system could not function without transformers. Let’s take a look at why and how they were developed.

9:15 AM – 9:30 AM           Break

TP & RP 9:30 AM – 10:30 AM  Transformer Specification & Vendor Prequalification
Bill Griesacker, Principal Engineer  
Doble Engineering Company

An effective procurement system utilizes the preapproval process to identify suitable power transformer vendors and a design review to establish an agreed upon design and procurement process. This preapproval approval process should include factory qualification audits which are essential to confirm a manufacturer’s ability to meet a purchaser’s requirements and expectations. The design review is performed to establish an agreed upon design and to facilitate the procurement process. That the supplier is capable of meeting the purchaser’s procurement specifications is confirmed during this process and the procurement process is expedited by bringing the purchaser and supplier together on the technical details of the purchased transformer.

Bill Griesacker is a member of Doble Engineering Company as a transformer engineer working on projects that include factory inspections, condition assessment, design reviews, failure analysis and general consulting. He previously worked for Pennsylvania Transformer Technology Inc., where he held various positions including Engineering Manager. His work included high voltage insulation design, transient voltage modeling of power transformer windings and various LTC and DETC switch development projects. Prior to this, he was employed by the Westinghouse Electric Company, working on synchronous generator projects as a member of the Generator Engineering Department. Mr. Griesacker started his career with Cooper Power Systems in large power transformers and later worked in the Kyle Switchgear, Vacuum Interrupter Department. He has earned a MS in electric power engineering from the Rensselaer Polytechnic Institute and a BS in electrical engineering from Gannon University. Mr. Griesacker is an active member of the IEEE, PES Transformers Committee where he holds positions in several working groups and subcommittees.

TP & RP 10:30 – 12:00 PM  Transformer Design & Manufacturing
Dharam Vir, Vice President of Engineering  
Troy Kabrich, Vice President & General Manager – Services Division  
SPX Transformer Solutions, Inc.
Transformers are tailor made products. The design process begins with understanding customer requirements. Using optimization programs, a quote design is provided with the lowest total owning cost meeting customer requirements. During final design detailed dielectric, short circuit and thermal calculations are performed to ensure the transformer meets performance and customer requirements. The mechanical design of the tank, stiffeners, lifting and clamping structures enables the unit to withstand vacuum, pressure, short-circuit, seismic and shipping conditions. After completion of the design, production and fabrication drawings, designs are released for manufacturing. The presentation will review major operations in the manufacturing process including visual aids that show construction, testing, and shipping activities.

Dharam Vir joined SPX Waukesha in 2004 with over 25 years of service to the transformer industry in EHV design, testing, production and plant operations. Prior to his current position, he held the positions of Engineering Manager for the Waukesha plant and director of our EHV program, leading the team responsible for the Waukesha facility expansion. Mr. Vir is an active member of the IEEE Transformers Committee and holds a BSEE from University of Delhi India, a MS in Electrical Engineering from NIT Bhopal India and an MBA in Finance and Marketing from Bhopal University India.

Troy Kabrich is currently the Vice President & General Manager for the Goldsboro, NC Manufacturing Plant and the Service and Components Division of SPX Transformer Solutions, Inc. During his twenty-five years of industry experience, Mr. Kabrich has held positions as a Plant Manager, Director of Field Services, Repair Operations Manager, Field Service Engineer, and Sales Engineer. He has published articles for T&D World and Utility Automation and Engineering magazines, was author of Installation and Maintenance Chapter of Third Revision of the Electric Power Transformer Engineering Handbook, and is a frequent contributor to industry training programs. Troy has a Bachelor of Science degree in electrical engineering from Rose-Hulman Institute of Technology.

12:00 PM – 1:00 PM Lunch

TP & RP 1:00 PM – 1:45 PM Keynote

Understanding Factory Testing Data
Mark Lachman, Director of Diagnostic Analyses
Doble Engineering Company

This presentation briefly describes significance of various electrical production tests including typical test plan covering all final factory tests as per IEEE C57.12.00-2015 and C57.12.90-2015. For each test the discussion includes physics behind the measurement, setup and test methodology and acceptance criteria.
Mark F. Lachman, Ph.D., P.E., has been with the power industry for over 30 years. In 2005, he joined Delta Star in San Carlos, CA, where, as Test Manager, he was responsible for the test department operation. In 2011, he returned to Doble Engineering Company as Director of Diagnostic Analyses.

3:30 PM – 3:45 PM  Break

TP &  
RP 3:45 PM – 4:30 PM  Shell-Form Design & Construction
Pablo Pacheo, Shell Transformer Global Product Manager  
ABB Inc.

Dom Corsi, Senior Transformer Consulting Engineer  
Doble Engineering Company

Transformers are categorized as per their role in a power system and they are also classified according to their construction or technology type: shell-form or core-form. Shell transformers were developed by Westinghouse Electric Corporation in US, and licensed to a number of manufacturers world-wide. This seminar will cover history and development of shell transformers in industry, as well as a brief comparison between typical shell and core transformers construction features and performance characteristics.

Shell transformers are well known to present a compact construction that enables robust behavior under short circuit solicitations, reduced dimensions for transportations and replacements, laid down configuration for single phase units and multi=voltage capabilities among others. New applications like mobile HV shell transformers benefits and ester oil advantages will be also explained.

Pablo Pacheo joined ABB in 2010 at the Large Power transformer manufacturing facility in Córdoba, Spain. During six years Pablo worked as shell form transformer electrical designer mainly focused in US market. During that period, he worked on the first Polystarnsformer for US as well as first Mobile Hybrid unit design at 420 kV voltage level among others. After that, he became global shell form product manager in ABB Power Transformers, he is now focused on managing the product line in terms of Marketing and Sales, R&D and Operations perspective. Pablo holds an Engineering Degree from Seville University in Spain as well as two Engineering MSc at Cranfield University (UK) and Seville University regarding Machines Design and Power System respectively.

Dom Corsi has 27 years of experience in the manufacturing and electrical design of large power transformers. This experience includes both core and shell form designs. Mr. Corsi joined Doble in 2004 as a Transformer Consulting Engineer for Doble Global Power Services. In the last 12 years, he has concentrated on electrical power apparatus testing, condition assessment, and forensics. Additionally, he has designed transformers up to 400 kV and 570 MVA and reviewed or supervised transformer designs to 525 kV and 1100 MVA. His main interests are in the fields of power transformer design, and power transformer applications. A frequent presenter, Dom Corsi trains participants on many transformer related topics including Transformer Repair, Remanufacturing and Replacement, Transformer Design Review, Transformer Factory Inspections.
This session offers an overview of power transformer insulation with a focus on cellulose based insulation materials. Both raw materials and the conversion of cellulose to transformer board will be discussed including environmental considerations. The main function of cellulose insulation in a power transformer will be covered and the electrical, mechanical, and aging properties of pressboard, pressboard laminate and laminated wood will be discussed.

Lars E. Schmidt is the Product Line Technology Manager for Transformer Insulation at ABB and located in Bad Honnef, Germany. He is responsible for the development of new insulation materials and manufacturing processes since 2011. ABB produces transformer insulation in different factories including Sweden, India, and Germany. Lars joined ABB Corporate Research in 2006 and worked in the field of polymer based medium and high voltage insulation. He has a background in Material’s Science and holds a PhD from the Swiss Federal Institute of Technology, Lausanne.

Transformer attendees, exhibitors and their guests are invited to attend. This event includes dinner, drinks and good conversation with colleagues at the Red Rock Resort and Casino’s Crimson Nightclub.

Tuesday, February 12, 2019

6:30 AM – 6:00 PM Registration & Information Desk Open
6:30 AM – 8:00 AM Attendee Breakfast

TP 8:00 AM - 9:30 AM Transformer Type Designs

**Autotransformers**

**Phase Shifters:** Waldemar Ziomek, PTI Manitoba

**Mobile Transformers:** Marion Jaroszewski, Delta Star

**Generator Step-up Transformers:** Kiran Vedante, Mitsubishi

**Autotransformers:** When the primary and secondary voltages are obtained from the same winding, or from two windings which are galvanically connected, such a transformer is called an autotransformer. The autotransformer requires less turns than a two-winding transformer and this leads to a more economical design. The presentation will focus on fundamentals,
design and applications of autotransformers. It will start with basic concept and typical winding arrangements. Next, the voltage variation will be addressed through presentation of different tap winding arrangement in the unit. Magnetic field distributions and resulting impedance at different tap positions will be shown. The selected problems of insulating system will be discussed (e.g. end fed vs center fed HV lead bring out, stresses in the end insulation). Examples of the lightning impulse voltage distributions for different winding arrangements will be shown.

Phase Shifters

Dr. Waldemar Ziomek works as a senior expert - power transformers and high voltage insulation, for PTI Manitoba Inc, Canadian manufacturer of power transformers. In 2013-2015 he worked for CG Power Systems, an international T&D equipment company, as a global senior expert. Till 2013 he was employed by CG Power Systems Canada Inc. (formerly Pauwels Canada Inc) as Manager of Engineering. He started with Pauwels in 1997 as an electrical designer, then in 1999 as an electrical engineering manager, and since 2003 as manager of engineering. Since 2001 he is also an adjunct professor at The University of Manitoba.

Mobile Substations: Types and applications of mobile substations are presented. A mobile versus power transformer is discussed with emphasis on the temperature ratings and associated with it hybrid insulating system, short circuit and dielectric strength, oil preservation and cooling system design. The mobile transformer and substation testing is discussed. The essentials of specifications, protection and trailer components are also addressed. Examples of the mobile substations 10 MVA to 100 MVA with HV ranging from 25 kV to 230 kV class are also provided.

Marion Jaroszewski's expertise is in applications and design of transportable high temperature transformers and substations as well as core type power, generator step up, auxiliary and grounding transformers, autotransformers and voltage regulators. Mr. Jaroszewski graduated from Technical University of Lodz Poland with specialization in Transformers, Electric Motors and Generators. He worked as an Electrical Engineer in ELTA in Lodz Poland, Transformer Engineer in Alamo Transformers in Houston, TX and since 1985 in Delta Star, Inc. (formerly HK Porter). He was promoted to following positions: Senior Design Engineer in 1987, Manager of Engineering in 1995, Corporate Technical Officer in 2004 and General Manager of San Carlos facility the same year and to Vice President of the company in 2005.

Mr. Jaroszewski retired at the end of 2009 and currently works part time as a consultant and technical advisor for Delta Star, Inc. He is Life Member of IEEE and active participant in Transformer Committee working groups.

Generator Step-Up Transformers: Generator Step-up Transformers (GSU’s) are a specific application that can present unique challenges to both the user and the manufacturer. The purpose of this presentation is to demonstrate how the unique parameters of this application can impact the design and construction of the transformer.

RP 8:00 AM – 12:00 PM Slippery Slopes---Journey through Differential Protection---
Ed Khan, Director of Protection Testing
Doble Engineering Company

Ed Khan is with Doble Engineering Company. Mr. Khan has been with Doble for 10 years working in various capacities including Product Manager for protection tested related instruments. Currently, he is the Director of
Protection R&D and Training at Doble. Prior to Doble, Mr. Khan has worked for GE, ABB, SEL, KEMA and others in various capacities. He has 36 years of experience in system studies, protection applications, relay design, power plant design, teaching and product management. He has a thorough knowledge about product development, protection, harmonic analysis, harmonic filter design, stability studies, real time digital simulations, generator protection and more. He has presented courses on behalf of GE and Doble in US, Southeast Asia, Middle East, Mexico, India and China. He also taught GE Protection course on few occasions. Mr. Khan is a member of CIGRE and is currently a member of the CIGRE Working Group B5.56 (Optimization of Protection, Automation and Controls). He has written and presented papers and articles on protection and testing related topics.

TP 9:30 AM – 10:00 AM  
Transportation and Rigging  
Andy Burns, Sales Manager  
Edwards Moving & Rigging

The transportation of large, heavy, and oversize transformers has always been fascinating and mysterious for those who have witnessed a large loaded trailer pass by, seen a crane lift at a port or just been amazed by the sheer size of the units. Some think it must be incredibly difficult while others say it is simple. This presentation is designed to provide Logistic Solutions and to better understand the challenges of moving transformers at all levels. Edwards Moving and Rigging moves over 300 large transformers annually. This presentation will provide real life examples and case studies to illustrate all modes of transport and rigging used in the transformer industry as well as provide logistical considerations and applications for moves, whether an internal movement of a spare within a utility or receiving a new transformer from factory to pad.

Andy Burns is Director of Regional Sales Edwards Moving & Rigging. He has worked in the transportation and rigging industry for over 13 years. In that time, he has served as sales/project manager, business growth developer, estimator, sales trainer and industry speaker. He has been a noted speaker at numerous industry conferences/conventions (Doble, RICA, IEEE, Break Bulk, and other Power & Electric Utility Training Programs) on the subjects of Logistics, Heavy Haul and Rigging. His current position with Edwards Moving and Rigging is Director of Regional Sales. In this capacity, he oversees the daily activities of Salesmen and Project Managers located in the following Regions: Ohio River Valley, TVA-Tennessee Valley, Midwest, Northeast and Southeastern United States. Andy and his Regional teams provide heavy haul transportation and rigging solutions for a variety of industries, such as Power Generation, Utility Transmission and Distribution, Manufacturing, Road & Bridge Construction, Steel Mills, and Refineries. These industries involve the movement and installation of large components with examples being transformers, generators, turbines, presses, reactors, vessels, bridges, duct work, and furnaces.

10:00 AM – 10:15 AM  
Break

TP 10:15 AM – 11:00 AM  
Insulating Fluid Materials – Part I  
Nikola Lukenda, Technical Services Advisor  
Petro-Canada Lubricants

Insulating Fluid Materials – Part II
This bushing fundamentals session will cover bushing theory, design, function, terminology, standards, and different insulation technologies. Advantages, disadvantages, and differences in the types of oil-impregnated paper (OIP) bushings and dry & composite-type bushings available on the market today will be discussed. Attendees will have a clear understanding of installation, maintenance, and testing procedures, and the challenges that may be encountered when working with OIP and dry & composite-type bushings. A thorough understanding of the details needed when planning a bushing replacement project will be presented.

**David Geibel** started out at General Electric Co. in Pittsfield MA over four decades ago and became a transformer components engineer. GE sold him to Westinghouse and Westinghouse sold him to ABB. Mr. Geibel has been the Engineering Manager for the ABB Alamo transformer components plant for about the past decade and have recently transitioned over to Technical Director. He graduated Magna Cum Laude from the University of Pittsburgh with a BSEE and holds several transformer components patents.

With temperature control being crucial in newer transformers, heat dissipation becomes very important. However, cooling system performance, with or without moving mechanical equipment, deteriorates with age. Even systems without oil-pumps or fans can fail due to weathering, rusting and fouling. How do we evaluate the health of the cooling system? Technology has improved with time, so what optimized solutions are available?

**Craig Stiegemeier** is the Director of Technology and Business Development for ABB’s North American Transformer Remanufacturing and Engineering Services (TRES) organization. He is responsible for developing effective processes supporting condition evaluation, assessment tools and life extension solutions for utility and
industrial users of power transformers. Mr. Stiegemeier began his career 36 years ago as a development and design engineer for large shell-form transformers for Westinghouse in Muncie, Indiana. He also has project management experience for the US Navy as well as technical and commercial management for ABB’s transformer components business. He led the ABB TrafoStar winding production improvement processes and was commercial operations manager for the St. Louis power transformer operations before moving into transformer services in 2004.

**RP 1:30 PM – 2:30 PM**  
**Sudden Pressure Relays—Concept, Construction, Application & Testing**

Learn the theory behind the deployment of the sudden pressure relays in preventing further catastrophic events within a transformer in the case of a rapid pressure rise. Realize the methodology behind placement and application of both mechanical and electronic models, including two out three logic and adjustable sensitivity. View construction methods and understand the distinct advantages between mechanical and electronic models. Proper installation tips will be discussed to ensure units are operating in the manner in which they are intended on both new and retrofit installations. Principles behind field testing will be demonstrated as well as the importance of maintaining unit health in the field to avoid potential false trips.

**TP 2:30 PM – 3:15 PM**  
**Transformer Overloading & Its Impact on Transformer Aging**
Hugo Campelo, Principal Technology Expert  
Efacec

**RP 2:30 PM – 3:15 PM**  
**Buchholz Relays – Concept, Construction, Application & Testing**

This presentation will talk about the the concept, construction, application and testing of Buchholz relays. These relays, which are applied on liquid filled transformers and reactors with oil conservators, act as a central protection system. Installed in the pipeline between tank and oil conservator, it reacts to faults which occur inside the transformer. Damages which are not visible can be detected early by the Buchholz relay. Gases moving in the direction of the oil conservator or shock waves created by the rapid gas development trigger the signaling system of the Buchholz relay. The Buchholz relay also takes over the function of an oil level indicator when there is not enough oil in the conservator or when there is an oil leak.

**3:15 PM – 3:30 PM**  
**Break**

**TP 3:30 PM – 5:00 PM**  
**Load Tap Changer Fundamentals**
David Geibel, Engineering Manager  
ABB Inc.

Bernhard Kurth, General Manager  
Reinhausen Manufacturing, Inc.

Energized Load Tap Changers (LTCs), De-Energized (DETC), Transmission Class, Distribution Class, Resistive, Reactive, and so very much more. This is by far one of the most impressive presentations of the week, and it is
jam-packed with information about history, usage, various designs, operations, maintenance, gas analysis, repairs, failures and components. Representatives of ABB and Reinhausen will be on hand to make presentations and then open the floor for discussion, and most importantly, to field your questions. This extremely practical presentation will allow the attendees to ask about all types of subjects related to the everyday operations, loading, and maintenance of transformer tap changers.

**David Geibel** started out at General Electric Co. in Pittsfield MA over four decades ago and became a transformer components engineer. GE sold him to Westinghouse and Westinghouse sold him to ABB. Mr. Geibel has been the Engineering Manager for the ABB Alamo transformer components plant for about the past decade and have recently transitioned over to Technical Director. He graduated Magna Cum Laude from the University of Pittsburgh with a BSEE and holds several transformer components patents.

**Bernhard Kurth** was born in Quito, Ecuador on June 29, 1960. He received a M.S. degree in Electrical Engineering from Rhineland Westphalia Technical University at Aachen, Germany in 1987. Mr. Kurth has been around On-Load and Off-Circuit Tap Changers for his entire career. He has been President of Reinhauen Manufacturing in Humboldt, TN since its foundation in 1991. Before joining Reinhauen Manufacturing, Bernhard worked as Area Sales Manager at Maschinenfabrik Reinhauen GmbH in Regensburg, Germany, being then transferred as President of Reinhauen Canada Ltd. to Toronto, Canada in 1990.

**RP 3:30 PM – 4:15 PM**  
Integration of Protection Data & Transformer Gas Analysis for Full Asset Monitoring

Transformer differential is one of the most often mis-operated protection systems within the power system. When the differential operates, it is often difficult to determine cause because a fault may be buried deep within the transformer. Dissolved Gas Analysis(DGA) can help the trouble-shooter make statements about thermal faults and arcs and faults and help to identify the presence of a legitimate transformer fault. DGA can also help the transformer asset management team make long term statements about the health of the transformer over-time. An on-line DGA system can be added to the transformed to give reliable continuous data about the health of the transformer. Additionally, the on-line DGA can help to trouble-shoot after a transformer fault by giving dissolved gas analysis of the transformer oil. This paper examines a novel technique which uses the electrical fault data from a transformer and the DGA data and incorporates them into a single report to facilitate faster decision making after a transformer fault.

**RP 4:15 PM – 5:00 PM**  
Modeling of Transformers in Real Time  
Dean Ouellette  
RTDS

**5:00 PM – 5:30 PM**  
Ask the Experts Panel

**5:30 PM – 7:00 PM**  
Industry Expo Opening & Reception  
ABB and Delta Star will have heavy equipment on display during Industry Expo.

**7:00 PM – 10:00 PM**  
Social Event at the Red Rock Resort & Casino
Wednesday, February 13, 2019

6:30 AM – 6:00 PM  Registration & Information Desk Open

6:30 AM – 8:00 AM  Attendee Breakfast

TP & TM  8:00 AM – 9:30 AM  Transformer Assembly, Oil Processing & Commissioning

Troy Kabrich, Vice President & General Manager – Services Division
SPX Transformer Solutions, Inc.

This presentation will highlight recommendations for the proper receipt, inspection, field assembly, oil processing, and acceptance testing of large liquid immersed power transformers. Transformer field installation processes and standards will be reviewed to include impact recorders, equipment requirements, assembly operations, field dry out techniques, determination of insulation moisture concentration, provisions for cold ambient temperature processing, vacuum filling processes, and acceptance testing.

Troy Kabrich is currently the Vice President & General Manager for the Goldsboro, NC Manufacturing Plant and the Service and Components Division of SPX Transformer Solutions, Inc. During his twenty-five years of industry experience, Mr. Kabrich has held positions as a Plant Manager, Director of Field Services, Repair Operations Manager, Field Service Engineer, and Sales Engineer. He has published articles for T&D World and Utility Automation and Engineering magazines, was author of Installation and Maintenance Chapter of Third Revision of the Electric Power Transformer Engineering Handbook, and is a frequent contributor to industry training programs. Troy has a Bachelor of Science degree in electrical engineering from Rose-Hulman Institute of Technology.
An effective procurement system utilizes the preapproval process to identify suitable power transformer vendors and a design review to establish an agreed upon design and procurement process. This preapproval approval process should include factory qualification audits which are essential to confirm a manufacturer’s ability to meet a purchaser’s requirements and expectations. The design review is performed to establish an agreed upon design and to facilitate the procurement process. That the supplier is capable of meeting the purchaser’s procurement specifications is confirmed during this process and the procurement process is expedited by bringing the purchaser and supplier together on the technical details of the purchased transformer.

**Bill Griesacker** is a member of Doble Engineering Company as a transformer engineer working on projects that include factory inspections, condition assessment, design reviews, failure analysis and general consulting. He previously worked for Pennsylvania Transformer Technology Inc., where he held various positions including Engineering Manager. His work included high voltage insulation design, transient voltage modeling of power transformer windings and various LTC and DETC switch development projects. Prior to this, he was employed by the Westinghouse Electric Company, working on synchronous generator projects as a member of the Generator Engineering Department. Mr. Griesacker started his career with Cooper Power Systems in large power transformers and later worked in the Kyle Switchgear, Vacuum Interrupter Department. He has earned a MS in electric power engineering from the Rensselaer Polytechnic Institute and a BS in electrical engineering from Gannon University. Mr. Griesacker is an active member of the IEEE, PES Transformers Committee where he holds positions in several working groups and subcommittees.

**RP 8:00 AM – 9:00 AM**

**Differential Protection including Sensitive Negative Sequence Element for Turn to Turn Faults**

Bill Griesacker, Principal Engineer

Schweitzer Engineering Laboratories

In this session, we will discuss traditional transformer differential protection, and some of the challenges and solutions associated with protection security and dependability. One challenge is that during heavy load conditions, the resulting increase in restraint current renders traditional phase differential element less sensitive, particularly from detecting transformer winding interturn faults. Since negative-sequence currents are unaffected by load for balanced conditions, a negative-sequence differential element can provide more sensitive protection.

**RP 9:00 AM – 10:00 AM**

**Software Tools to Verify Transformer Relay Performance for Commissioning & Field Events**

Bill Griesacker, Principal Engineer

Schweitzer Engineering Laboratories

Transformer differential protection can be successfully applied and commissioned if we follow some simple rules...
using nameplate data, ct connections, phase-to-bushing connections, and polarity. Still, mistakes can occur. Sound testing and commissioning using event reports and software tools to view and validate measured currents and voltages can greatly improve reliability and reduce errors. In this session, we demonstrate some practical commissioning, testing and troubleshooting principals that lead to successful transformer differential deployment and performance.

**TP & TM** 9:30 AM – 10:15 AM  
Insulating Fluid Basics & How to Take a Proper Oil Sample  
David Koehler, Technical Manager  
Doble Insulating Materials Laboratories

This presentation will provide information on insulating fluids, focusing on various characteristics and the most common analytical tests performed on insulating fluids to assess the condition of the insulating fluid and health of the transformer. Important aspects of the sampling process for insulating fluids will be covered to help ensure that a representative sample of the bulk insulating fluid is obtained.

**David Koehler** received his Bachelor’s Degree in Chemistry from Indiana University and obtained his M.B.A. He is the New Business Development and Technical Manager for the Doble Engineering Company Insulating Materials Laboratories. He has 19 years of experience in the testing of insulating liquids and management of analytical laboratories. Mr. Koehler has provided numerous technical presentations and published technical articles within the power industry. He is a member of the ASTM D-27 Technical Committee on Electrical Insulating Liquids and Gases. In 2011, he was an Executive Committee Member of the Indiana American Chemical Society. In 2016, David was elected by the IEEE Region 4 voting members to the position of Region 4 Director-Elect. In 2017-2019 David serves as the Region 4 Director-Elect, chairing the IEEE Region 4 Strategic Planning Committee. In 2019-2020 Mr. Koehler will serve as the IEEE Region 4 Director, while also serving on the Board of Directors for IEEE.

**TP-A** 9:30 AM – 10:15 AM  
LTC Maintenance Requirements and Steps for In-Tank LTC  
Bernhard Kurth, General Manager  
Reinhausen Manufacturing Inc.

**Bernhard Kurth** was born in Quito, Ecuador on June 29, 1960. He received a M.S. degree in Electrical Engineering from Rhineland Westphalia Technical University at Aachen, Germany in 1987 and has been around On-Load and Off-Circuit Tap Changers for his entire career. He has been President of Reinhausen Manufacturing in Humboldt, TN since its foundation in 1991. Before joining Reinhausen Manufacturing, Mr. Kurth worked as Area Sales Manager at Maschinenfabrik Reinhausen GmbH in Regensburg, Germany, being then transferred as President of Reinhausen Canada Ltd. to Toronto, Canada in 1990.

10:00 AM – 10:30 AM  
Break

**TP** 10:15 AM – 11:00 AM  
Intelligent Transformer Condition Monitoring  
Tony McGrail, Solutions Director, Asset Management & Monitoring Technology
In this presentation we will look at aspects of transformer condition monitoring - from the need to set goals and defining relevant monitoring parameters through to communicating of data/information and the need to have a predefined and agreed action plan. Intelligent condition monitoring can yield great benefits and we will discuss and present ways and means to achieve those benefits. Dissolved gas analysis, bushing, partial discharge and other condition monitoring solutions will be discussed.

Tony McGrail is Doble Engineering Company’s Solutions Director for Asset Management & Monitoring Technology, providing condition, criticality and risk analysis for utility companies. Previously Dr. McGrail has spent over 10 years with National Grid in the UK and the US; he has been both a substation equipment specialist, with a focus on power transformers, circuit breakers and integrated condition monitoring, and has also taken on the role of substation asset manager and distribution asset manager, identifying risks and opportunities for investment in an ageing infrastructure. Dr. McGrail is a Fellow of the IET, Chairman of the IET Council, a member of the IEEE, ASTM, CIGRE and the IAM, is currently on the executive committee of the Doble Client Committee on Asset and Maintenance Management, and a contributor to SFRA and other standards. His initial degree was in Physics, supplemented by an MS and a PhD in EE and an MBA. Dr. McGrail has a commitment to lifelong learning and is an Adjunct Professor at Worcester Polytechnic Institute, MA, leading courses in power systems analysis and distribution fundamentals.

ALL 11:00 AM – 12:00 PM Transformer Field Testing
Robert Brusetti, Director, Client Service Engineering
Doble Engineering Company

Financial implications and complex of the asset are the primary reasons power transformers are viewed as the most critical component in the electric power system. Field-testing provides the engineer with a group of tools to assess the condition of the transformer and to identify problems and the level of criticality. Each test provides data to support decisions about transformer. The early detection of problems can minimize the repairs involved and mitigate catastrophic failures. The scope of this presentation is to consolidate all the current techniques for field testing transformers and identify each test’s true capability.

Robert Brusetti received his BS in Electrical Engineer degree from the University of Vermont in 1984 and a MBA from Boston College in 1988. He has been employed at Doble Engineering Company for twenty years and currently serves as Director of Client Service Engineering. Prior to his present responsibility he has held positions as Product Manager and Field Engineer. Mr. Brusetti is a licensed Professional Engineer in the state of Massachusetts.

12:00 PM – 1:30 PM Industry Expo & Lunch
ABB and Delta Star will have heavy equipment on display during Industry Expo.

ALL 1:30 PM – 2:30 PM Transformer Field Testing - continued
Robert Brusetti, Director, Client Service Engineering
Doble Engineering Company
Transformer life depends mainly on the condition of the liquid & solid insulation. The liquid insulation can be maintained and restored with purification & reclamation. The solid insulation however is difficult to maintain directly. Various technologies and techniques are available to maintain the insulation (both directly & indirectly). Appropriate selection and application of transformer dry-out technologies and techniques can extend transformer life, reduce downtime and save money. These technologies and their field applications will be discussed during this presentation.

**Greg Steeves** is the Chief Technical Officer and principle engineer of Baron USA, LLC. Baron is the premier provider of transformer dry-out and dielectric fluid processing systems for OEM’s, utilities and field service organizations worldwide. Greg joined Baron USA as Engineering Manager in 1987. He is currently responsible for managing the daily operations and overseeing the application, engineering design and manufacturing of oil purification equipment, vacuum chambers, vapor phase processing and transformer dry-out equipment. He earned his degree in Mechanical Engineering from Tennessee Technological University and is licensed in the state of Tennessee.

Since 1980 electromagnetic interference (EMI) Diagnostics has provided information on the electrical and mechanical condition of several thousand mission critical assets in power plants, heavy industry, petrochemical and marine locations. This on-line technique has been applied to many sizes and designs of generators, motors, transformers, switchgear, power cables and bus. This session provides case studies of electrical and mechanical deterioration identified with EMI Diagnostics. Several methods for data analysis are offered.

**James E. Timperley** is currently a Sr. Principal Engineer with Doble Engineering. He has 45 years’ experience in the power industry with an emphasis on diagnostic testing, large electrical rotating machinery and isolated phase bus. Jim has authored more than 80 technical papers in the areas of applied research, advanced insulation systems, diagnostic testing, failure investigation, inspecting, maintaining and specifying rotating machinery for IEEE, Doble, ASME, CIGRE, EPRI, DEIS, PCIC and the American Power Conference. His work has involved root cause analysis of equipment failures, insulation deterioration mechanisms and developing repair procedures for use at petrochemical and industrial sites as well as in fossil, nuclear and hydroelectric power plants.

**Life of a Transformer™ Seminar**
**Get Empowered with Doble**
**February 11-15, 2019 | Summerlin, Nevada USA**
Ed Khan is with Doble Engineering Company. Mr. Khan has been with Doble for 10 years working in various capacities including Product Manager for protection tested related instruments. Currently, he is the Director of Protection R&D and Training at Doble. Prior to Doble, Mr. Khan has worked for GE, ABB, SEL, KEMA and others in various capacities. He has 36 years of experience in system studies, protection applications, relay design, power plant design, teaching and product management. He has a thorough knowledge about product development, protection, harmonic analysis, harmonic filter design, stability studies, real time digital simulations, generator protection and more. He has presented courses on behalf of GE and Doble in US, Southeast Asia, Middle East, Mexico, India and China. He also taught GE Protection course on few occasions. Mr. Khan is a member of CIGRE and is currently a member of the CIGRE Working Group B5.56 (Optimization of Protection, Automation and Controls). He has written and presented papers and articles on protection and testing related topics.

3:15 PM – 3:30 PM Break

TP & TM 3:30 PM – 4:15 PM Measuring and Locating Partial Discharge in Transformer in Service
Falk Werner, Principal Engineer
Doble Engineering Company

Subject of the presentation is a transformer fleet PD assessment performed in the Caribbean in 2015. Measurement approaches and findings are laid out covering HFCT, RFI and acoustic PD testing. As a result of the assessment a transformer with defective cable L-bows was identified. In order to prevent failure of the equipment, those L-bows were inspected and significant deterioration was found within the connection.

Falk Werner studied Electronics and Information Technology with a focus on Telecommunication and Signal Processing at the University of Stuttgart in Germany. His final thesis was Location of Partial Discharges by Means of Sensor Arrays. Mr. Werner has in-depth knowledge of partial discharge (PD) diagnostics and measurement methods on high voltage insulation systems. At Doble Lemke in Germany he co-developed the PD solutions range. Mr. Werner has several publications to his credit and is currently a Doble Power Services Engineer at Doble Engineering Company focusing on partial discharge, diagnostics and solution development.

TP–A 3:30 PM – 4:15 PM System Critical Non-Segregated Phase Bus Inspection & Maintenance Best Practices

This presentation will review best practices for analysis, inspection, cleaning and maintenance of the bus duct systems of the power generation facility. Many plant operations and maintenance managers ignore the bus duct system, forgetting it is a system critical component in the power plant that does not have redundancy AND is connected to expensive plant assets on both ends. The presentation will review numerous case studies from more than forty years of field.

TP & TM 4:15 PM – 5:00 PM Industry Strategies for Improved US Electric Grid Resiliency
Power transformer withstand testing is one of the most sophisticated processes undertaken to assess a transformer before it can be placed into operation. The full range of tests to be performed are very complex and the test systems must fulfill challenging demands. Ongoing technical progress in power electronics now gives transformer manufacturers and end-users access to static frequency converter (SFC) based power sources in the factory and field. These systems can provide a stable and virtually harmonic-free test voltage for a transformer test system. Because the output frequency can be freely adjusted, a wide range of AC transformer tests are possible. The main principles and applications of test systems for transformers with SFC-based power sources will be presented and explained.

**Thursday, February 14, 2019**

6:30 AM – 5:30 PM  
Registration & Information Desk Open

6:30 AM – 8:00 AM  
Attendee Breakfast

**TP & TM**  
8:00 AM – 9:45 AM  
Transformer Life Extension & Maintenance Solutions  
**Transformer Leak Repair:** Jim Hackett, Colt Group  
**Robotic Internal Transformer Inspections while Oil Filled:** Craig Stiegemeier, ABB, Inc.

**Bushing Replacement Considerations – Case Study:** Bill Esposito, NV Energy  
**Bushing Replacement Considerations – Case Study:** Sebastien Riopel, Electro Composites  
**Cooling System Upgrade – Case Study:** Kevin Riley, Trantech Radiator  
**On-Site Major Core Rewinds/Repairs**

**RP**  
8:00 AM – 8:45 AM  
Testing and Troubleshooting Tools used with Transformer Protection Relays  
Drew Welton, Director of Sales  
Beckwith Electric
Various types of digital relays designed for transformer protection offer software that can assist test engineers and technicians during the testing process. Since mechanical calibration is no longer a concern, our testing focus is associated with the proper setting and configuration of the protective elements. In this session, we will:

1. Review of the protective elements associated transformer protection
2. Assure proper validation of the transformer configuration
3. Use the relay software to visualize and validate proper CT secondary wiring
4. Test the 87 elements
5. Test the harmonic restraint
6. Discuss the importance of, and test over excitation protection with the V/Hz element

We will use a Beckwith relay model M-3311A and related software to assist throughout the testing process, which can also be associated with other types of transformer protective relays.

**Drew Welton**, Director of Sales for Beckwith Electric Company, provides strategic sales leadership and further develops and executes Beckwith’s market development and business plans. Mr. Welton was previously the North American Regional Manager for OMICRON, starting with the company in 1997. Prior to his career with OMICRON, he was a Regional Sales Manager with Beckwith Electric. He also served as National Sales Director for Substation Automation with AREVA T&D.

Mr. Welton is the author of numerous articles on substation maintenance testing, and has conducted training sessions for substation technicians and engineers at utilities and universities across North America. He has a bachelor’s degree in Business Administration from Fort Lewis College, Durango, Colorado. He is a 20-year Senior Member of IEEE-PES, has been a contributor on a number of PSRC working groups, and presented at many industry conferences specific to power system protection and control.

**RP 8:45 AM – 9:45 AM**

**Concepts & Enhancements of Transformer Protection**

Roy Moxley, Principle Power Systems Protection Consultant

Siemens

Fault energy is the key component to causing transformer damage from through fault current, and increasing damage from internal transformer faults. This discussion will focus on avoiding transformer damage by implementing faster fault clearing on close in faults and reducing transformer damage by faster tripping on internal faults. Relay operating principles, security, and testing limitations and practices will be presented.

**Roy Moxley** has worked in relaying and T&D application engineering for more than 36 years. He joined Siemens Smart Grid as Principle Power Systems Protection Consultant in 2012, following 23 years at GE and 13 years at SEL. Mr. Moxley holds a BSEE from the University of Colorado at Boulder. He is a member of IEEE, a PE in Pennsylvania and a seasoned presenter with more than 20 papers on protective relay to his credit.

**9:45 AM – 10:00 AM**

**Break**
**Ed Khan** is with Doble Engineering Company. Mr. Khan has been with Doble for 10 years working in various capacities including Product Manager for protection tested related instruments. Currently, he is the Director of Protection R&D and Training at Doble. Prior to Doble, Mr. Khan has worked for GE, ABB, SEL, KEMA and others in various capacities. He has 36 years of experience in system studies, protection applications, relay design, power plant design, teaching and product management. He has a thorough knowledge about product development, protection, harmonic analysis, harmonic filter design, stability studies, real time digital simulations, generator protection and more. He has presented courses on behalf of GE and Doble in US, Southeast Asia, Middle East, Mexico, India and China. He also taught GE Protection course on few occasions. Mr. Khan is a member of CIGRE and is currently a member of the CIGRE Working Group B5.56 (Optimization of Protection, Automation and Controls). He has written and presented papers and articles on protection and testing related topics.

**TP & TM** 10:45 AM – 12:00 PM  
**Transformer Asset Health Indexing & Fleet Management**  
Paul Griffin, Vice President Global Professional Services

In today’s modern utility, capital investments in transmission and distribution assets can be on the order of billions of dollars. With all that spending, there is enormous pressure to ensure that we are making the right decisions with regard to managing risk and ensuring the reliability of our system. With the ever increasing amount of real-time asset health information that is available to the asset manager, as well as all the traditional database type condition information obtained from preventative maintenance, the sheer amount of data can be challenging. Without a viable solution for turning that data into information that can drive repair replace decisions, the job of the asset will be difficult. This presentation will discuss PHI’s approach to fleet asset health indexing and our partnership with Doble on the dobleARMS project.

The final portion of the presentation pertains to the health analysis of Dominion Energy’s Large Power transformer fleet. This analysis drives a risk-based approach to maintenance plans, life cycle management, and proactive replacement. Transformers included into this plan are oil filled power transformers with a minimum rating of 7 MVA, and include primary winding voltages of 13.2kV to 500kV

**Paul Griffin** is Doble Engineering Company’s Vice President of Global Professional Services. Mr. Griffin has been with Doble since 1979 and prior to his current role has held various positions including Laboratory Manager and Vice President of Laboratory Services. Since joining Doble, Mr. Griffin has published over 50 technical papers pertaining to testing of electrical insulating materials and electric apparatus diagnostics. He is a Fellow of ASTM and a member of Committee D-27 on Electrical Insulating Liquids and Gases. He was formerly ASTM Subcommittee Chairman on Physical Test, ASTM Section Chairman on Gases in Oil, and the
Technical Advisor to the U.S. National Committee for participation in the International Electrotechnical Commission, Technical Committee 10, and Fluids for Electrotechnical Applications. Mr. Griffin is a member of the IEEE Insulating Fluids Subcommittee of the Transformer Committee.

12:00 PM – 1:00 PM Lunch

TP & TM 1:00 PM – 1:45 PM Calculating Probability of Failure (POF) for Transmission Assets: Challenges & Methods
G. Matthew Kennedy, Solutions Director, Enterprise & Data Technology
Doble Engineering Company

G. Matthew Kennedy is Doble Engineering Company’s Solutions Director: Enterprise and Data Technology, overseeing the complete software and cloud product vision of the company. During his time at Doble, Mr. Kennedy has had leading roles in the innovation and development of products such as the M-Series (M4, M5, M7), DTA, dobleARMS™ and dobleDATABASE™. With a keen interest in diagnostic technology, Mr. Kennedy has authored diagnostic analysis sections for international standards in addition to numerous papers, journal and magazine articles for the power industry. He holds a BS in Electrical Engineering from the University of California, Santa Barbara where he studied signal and digital signal processing. His post graduate studies continued with the US Navy: Nuclear Power School, University of Idaho in Electrical Power Engineering and Cornell University in Product Design and Development. He is a member of IEEE, IEC, USNC, and ISO.

RP 1:00 PM – 1:45 PM Demonstration of Testing Transformer Protection Relay SEL 487E
Ed Khan, Director of Protection Testing
Doble Engineering

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TP & TM 1:45 PM – 3:00 PM Forensic Analysis

Root Causes of Failures: Bill Griesacker, Doble Engineering Company
Forensic Decommissioning: Anne Bailey, A-Line
Case Studies
**Root Causes of Failure:** Forensic examinations are conducted for a number of reasons; however, the end goal is typically to determine the root cause of the failure. Often this examination involves the review of historical operating conditions prior to the failure and the disassembly of the failed transformer in search of supporting evidence. Case studies will be presented.

**Bill Griesacker** is a member of Doble Engineering Company as a transformer engineer working on projects that include factory inspections, condition assessment, design reviews, failure analysis and general consulting. Mr. Griesacker holds an MS in electric power engineering from the Rensselaer Polytechnic Institute and a BS in electrical engineering from Gannon University. He is an active member of the IEEE, PES Transformers Committee where he holds positions in several working groups and subcommittees.

**Forensic Decommissioning:** Each transformer recycling project is unique based on the transformer design, location and circumstances for removal. This presentation will provide project examples to showcase on-site removal options and expectations as well as showcase the specialized equipment available to aide in the detailed assessment of power transformers. Project examples will include premature transformer failure assessment as well as procedures for obtaining samples during routine transformer replacement projects to aide in condition assessment initiatives.

**Anne Bailey** has been with A-Line E.D.S. managing transformer recycling projects for the past 10 years. She has experience contracting, evaluating and managing on-site transformer dismantling projects to provide turnkey services including the safe and environmentally sound disposal of power transformers including specialty services for forensic decomposition.

**RP 1:45 PM – 2:30 PM Transformer Withstand Capability & Protection during External Faults**

The life of the power transformer depends on the life of the insulating paper, whose deterioration is affected by temperature, moisture, and gas content. The effects of moisture and gases can be controlled to a minimum level, leaving temperature as the primary culprit in paper insulation deterioration. The no load and load losses will generate heat which will in turn cause the transformer temperature to rise, and if not controlled, can cause damage to the paper insulation. In particular, as the temperature distribution inside the power transformer is not uniform, the paper insulation closest to the transformer hot spot will suffer the greatest degradation. Therefore, standards define transformer life as a function of the hot spot temperature.

Overcurrent elements generally need be set so high they cannot detect overload conditions in power transformers. Using standard guidelines, engineers can create continuous, long term emergency and short term emergency transformer ratings, and operators can use these ratings. However, there is a chance the transformer can reach critical hot spot temperatures during the overload condition.

Transformer manufacturers guarantee the longevity of their product as long as it is operated under the temperature specifications given in the IEEE, and or IEC standards. These standards help us in calculating the effect of aging insulation and its exposure to high temperatures. The dynamic ratings for power transformers can be developed by calculating the loss of life and the winding hottest spot temperature. Such ratings can be used by
system operators during contingency conditions, which will allow them to overload power transformers for a predetermined time. These transformer dynamic ratings can also be used to create settings criteria for thermal functions. New numerical relays are capable of replicating the thermal models outlined in the Guides. The relay engineer can set thermal limits based on the dynamic ratings established by loss of life and winding hot spot calculations.

**RP 2:30 PM – 3:15 PM**

*Modelling Withstand & Protection of Transformers under Fault Conditions—Software demonstration*

When fault occurs in the vicinity of a transformer, high current could flow through the transformer. For out-of-zone fault, the transformer instantaneous protection should keep intact to allow the fault to be cleared by the corresponding zone relays and breakers. However, if the fault could not be cleared in time, which might be due to relay failure or breaker failure, the transformer could be damaged by thermal or mechanical stress produced by through fault current. Therefore, the transformer backup protection must be engaged to protect the transformer from sustained through fault current. The time delayed overcurrent protection is typically used for such purpose. For smaller transformers, the overcurrent relay might also be the only means for transformer protection. In the past, to make proper overcurrent pickup and time dial settings was not a trivial task. On one hand, the overcurrent relays must coordinate with all the adjacent line/feeder relays such that it will allow those relays to clear the fault in the first place. The overcurrent pickup setting should also allow the transformer to be temporarily overloaded to a certain degree. On the other hand, the overcurrent relay must trip if the through fault current lasts for too long. A relay engineer needs to balance the security and sensitivity under all the conditions. The modern software has made the relay settings much easier now. In this presentation, the definition of four transformer damage curves per IEEE standard will be explained and modeled on ASPEN Oneliner software. The process of making transformer overcurrent protection settings will also be demonstrated by using APSEN Oneliner software and a demo network. Various faults and protection response will be simulated to check the coordination. Through this demo, it is hoped that audience could have a good understanding of transformer withstand capability and the protection of transformers under through fault conditions.

**3:00 PM – 3:30 PM**

*Break*

**TP & TM 3:15 PM - 4:15 PM**

*Developing Diagnostic Strategies through Understanding Field Test Results - Case Studies*

Mark Lachman, Director of Diagnostic Analyses
Robert Brusetti, Director, Client Service Engineering
Doble Engineering Company

*Mark F. Lachman, Ph.D., P.E., has been with the power industry for over 30 years. In 2005, he joined Delta Star in San Carlos, CA, where, as Test Manager, he was responsible for the test department operation. In 2011, he returned to Doble Engineering Company as Director of Diagnostic Analyses.*
Robert Brusetti received his BS in Electrical Engineer degree from the University of Vermont in 1984 and a MBA from Boston College in 1988. He has been employed at Doble Engineering Company for twenty years and currently serves as Director of Client Service Engineering. Prior to his present responsibility he has held positions as Product Manager and Field Engineer. Mr. Brusetti is a licensed Professional Engineer in the state of Massachusetts.

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This one-day session provides students with a thorough understanding of how to assess the condition of electrical insulating materials and transformers.
Dissolved gas-in-oil analysis – This is the single most important diagnostic test for transformers. This presentation reviews how the test is performed, how to distinguish between normal gassing behavior and problems, and how to evaluate trends. Practical case studies and examples are used to illustrate theoretical concepts. Seminar participants will be quizzed (with class participation) on their understanding in diagnosing 12 cases.

Water in Transformer Oil – Assessing how dry a transformer requires more than a water in oil test. Learn how to assess the wetness of the transformer insulation system and why you need to know the operating temperature at the time of sampling. This session discusses water migration in transformers and how water affects the ability to overload them. Examples are provided.

Condition assessment of cellulosic insulation – The analysis of the condition of the paper insulation has changed quite a bit in the past 10 years. Learn how the solid insulation ages and how to assess the condition of the paper and pressboard insulation and its remaining life. Case studies are given to illustrate the distribution of paper aging in transformers and how operation and maintenance can influence it.

Metals in oil – This presentation provides an understanding of the importance of metal-in-oil tests as a diagnostic. To be able to use the information, the correct test must be specified – learn the difference between dissolved and particulate metals and when to choose each test. Case studies are given.

Quality of new and service aged oils – Background information is provided on the properties of transformer oil. The presentation includes how to specify and evaluate new oils, what tests to perform and how to evaluate in-service oils.

Aging characteristics of insulating materials - Aging is discussed in sections on oil and paper which provides information on how to increase the life of transformers. There are a number of factors that accelerate the aging of the insulation system that can be controlled. This session provides information on when to reclaim or replace oil and gives specifications for reclaimed oil.

Load tap changer and oil circuit breaker diagnostics – This presentation gives the latest information on diagnostics for load tap changers (LTCs) and bulk oil breakers. Case studies are provided.

Sampling – The presentation discusses how to save money on your sampling program through proper training and what common pitfalls to avoid. Proper sampling preparation, practices, and equipment are given.