IEEE PES Transformers Committee
Fall 2019 Meeting
Columbus, Ohio USA

Tutorial on Embedded Optical Sensing Systems for Distribution Transformer Monitoring

— Technical Presentation —
Thursday, October 31, 2019

By Bradley Kittrell, Ajay Raghavan and Malcolm Smith

1. Abstract

Traditional utility monitoring systems do not provide real-time visibility into the condition of transformers or accurate performance measurements. This has resulted in the use of lagging indicators, such as oil sample analysis, typically requiring expensive field visits, grid outages and laboratory sample testing. This tutorial reviews the use of optical sensing systems for managing transformers and improving grid resiliency and safety. These sensing systems allow direct internal monitoring of critical transformer components. Versatility covering different monitoring parameters of interest in embedded configurations for new transformers and a retrofittable configuration for older transformers is achieved by applying "hair thin," multiplexed fiber optic and other low profile optical sensors in combination with a high resolution optical readout and advanced analytics. This technology could enable utility professionals to gain information they can use to better plan for maintenance/management and improve grid performance, which would, in turn, accommodate DERs and other evolving grid market dynamics

Under an initiative funded by the Department of Energy Office of Electricity, PARC, GE and Con Edison built, tested and qualified commercial network transformers with embedded optical sensing systems. The parameters monitored were validated across a range of scenarios with lab instruments typically used for qualification testing. An ongoing field trial to demonstrate the robustness of the technology for remote monitoring through the industrial internet under demanding grid deployment conditions in New York City is showing promise toward scale-up of the technology.

This tutorial will provide an overview of the typical pain points in managing transformers and parameters for monitoring. We will also cover requirements for highly constrained installations that require a larger capacity and flexible rating while fitting into a tight space. The unique capabilities of optical sensing systems and a low-cost approach to interpreting the sensor signals in transformers for predictive maintenance will be covered. The presenters will discuss the sensors' compatibility in the transformer environment, validation testing per IEEE standards that enabled the solution to be implemented in field-deployable commercial transformers, initial results from the field deployment and the technology's potential to provide systematic alerts for unsafe/unexpected events.

2. Learning Objectives

This tutorial provides the following learning opportunities:

- Review the pain points for transformer management and traditional approaches to monitoring

- Understand how optical sensing can enable innovative, non-invasive monitoring capabilities, enabling proactive maintenance in a cost-effective and reliable manner
- Review examples of detection capabilities and validation in laboratory tests and field-deployed network transformers
- Learn how advanced analytics and the industrial internet can be leveraged for remote monitoring and predictive maintenance

3. Learning Outcomes

By attending this tutorial, attendees will gain an understanding of the following:

- Capabilities of optical sensing systems and their potential for field-deployable internal transformer monitoring
- Application of advanced analytics to enable predictive maintenance from embedded sensors
- Options for monitoring transformer and grid asset fleets that can enable proactive maintenance and improve long-term planning

4. Presenters' Biographies

Bradley Kittrell is an engineering supervisor in the Distribution Engineering Equipment Group for Consolidated Edison of New York. He manages the application of analytics to the operation of Consolidated Edison's fleet of network transformers and provides guidance on its application of network transformer operation and maintenance. Bradley has an MBA from the University of Carolina at Chapel Hill and a BS in Electrical Engineering from the University at Buffalo. He has worked for Consolidated Edison for the past five years.

Dr. Ajay Raghavan is the strategic execution director and manages the Analytics for Condition Evaluation of Systems (ACES) area within the System Sciences Lab at the Palo Alto Research Center (PARC, a Xerox Company). The ACES team focuses on developing cutting-edge analytics and sensing technologies for reliable, safe and optimal life cycle management of critical systems in the energy, transportation, aerospace, defense and manufacturing sectors in partnership with major industry clients. Ajay has served as a principal investigator on major cross-disciplinary projects between PARC and industry partners, such as Con Edison, GE, LG Chem, GM, VicTrack and VicRoads to develop and transition fiber optic sensing-based health monitoring systems for distribution transformers, electric vehicle batteries and bridge structures. He has 16 pending patents granted and 30+ pending patents and published two book chapters and 40+ papers in leading journals and conferences that have garnered 2000+ citations. He received NSF Fellowship and "Best Paper" awards at IEEE International Conference on Prognostics and Health Management and the Prognostics and Health Management Society conference. Dr. Raghavan obtained his MS and PhD degrees in Aerospace Engineering at the University of Michigan-Ann Arbor. He has a bachelor's degree in mechanical engineering from the Indian Institute of Technology Bombay.

Malcolm Smith is a senior engineer–network transformers and voltage regulators at General Electric's transformer manufacturing/testing facility in Shreveport, Louisiana, and is an established leader on transformer design and testing and sensor validation procedures. He previously served as an engineering manager and product leader in the network transformers business over a 17-year career at GE Renewable Energy. Malcolm holds a BS in Mechanical Engineering from Northrup Institute of Technology and is currently a licensed, registered professional mechanical engineer in the states of Washington and California.