5.13 Smart Sensor Development for Power Transmission and Distribution (T-20)

| Summary | On-line monitoring systems require an intelligent system to analyze and interpret large amounts of data into meaningful conclusions. This research integrates advances in power electronics, intelligent control and new sensory systems to automatically (and without major efforts of maintenance personnel) provide real-time health assessment of the T&D infrastructure. This study concentrates on the development of an intelligent optical sensor monitoring for on-line health assessment of HV oil based transformers and oil based breakers. |
| Research Need | Research and development is required to improve monitoring and state assessment of power transmission and distribution systems. Smart sensor systems capable of prediction, communication and intelligent interaction with environment will leverage new fault management of devices and control for distributed resources. During the first phase, this project will contribute to the development of predictive maintenance technique of transformers by on-line monitoring of the degradation of the oil with an optical sensor system that detects changes in the refractive index. |
| Research Stem | T&D Technologies |
| Academic Team Members | Marcelo Simoes (Colorado School of Mines-lead: msimoes@mines.edu) Rahmat Shoureshi (Colorado School of Mines) and Mladen Kezunovic (Texas A&M) |
| Industry Team Members | Art Mander (Tri-State) and Paulette Kaptain (Western Area Power Administration) |
| Funding Period | June 1, 2002 to June 30, 2004 |
| Budget | Simoes: $20,000; Shoureshi: $25,000; Kezunovic: $10,000. Total $ 55,000 per year for two years (2002-2003). |

Project Description: The health of power transmission and distribution systems depend on transformers that step up and down transmission voltages, running on wires, buses that split the distribution power off in multiple directions, circuit breakers, switches to connect substations to the transmission grid. Maintenance is expensive, requires trained personnel and costly power interruptions. On-line monitoring and assessment of the T&D systems, and more specifically breakers, transformers, conductors and support towers is vital for the assurance of power reliability and quality.

Research and development is required to improve monitoring and health assessment of power transmission and distribution systems. Smart sensor systems capable of prediction, interpretation, communication and intelligent interaction with the environment will leverage new fault management of devices and control for distributed resources. Fundamental research has already been carried out to develop smart sensors to monitor and control robotics, mobile vehicles, cooperative autonomous systems, mechatronics and bio-engineering systems. Such smart information technology manifests the potential for myriad of applications, including monitoring environmental conditions, such as powerflow congestion, air pollution or magnetic fields. In this project, it is envisioned that concepts of smart sensors and information technology can be transferred and applied to the power delivery system.

Intelligent control is a proven methodology for diagnostic and increased reliability and can be applied to generation, transmission, distribution, and utilization aspects of the power system. In the last few years expert systems, neural networks and fuzzy logic have been showing promises for power system analyses, load forecasting and fault management. However, very little of such powerful technologies has been integrated directly to sensors required in transmission and distribution infrastructure.
Potential Industry Benefits: Online monitoring system requires an intelligent system to analyze and interpret large amounts of data into meaningful conclusions. The research will integrate advances in power electronics, intelligent control and new sensory systems to automatically and without major efforts of maintenance personnel provide real-time health assessment of the T&D infrastructure.

Important areas to invest new devices and control concepts are smart sensor for breakers and transformers. For each component of the T&D infrastructure a system capable of embedding analytical models, interface with instrumentation and data acquisition, communication links between the equipment and remote control centers, or among the sensors and monitor themselves need to be developed.

Since an encompassing and full research program is required to achieve the above goals, a major project in collaboration with academia and industry is planned and proposed. This study will concentrate on the development of an intelligent optical sensor monitoring for on-line health assessment of HV oil based transformers and oil based breakers. The following benefits are expected:

- Reduced 0&M expenses
- Reduced equipment downtime
- Increased reliability and economic life of equipment
- Provide useful information and data to the substation service crew
- Low cost monitoring system for TF & breakers

Technical Approach: The need for on-line condition monitoring is driven primarily by a desire to redirect interval-based-preventive maintenance to predictive or condition-driven maintenance. With on-line monitoring systems, the faults or trend of faults in the equipment can be detected in real time. Therefore, severe damage can possibly be avoided, the reliability of the system will be greatly increased. In addition, less personnel input is necessary and cost in daily maintenance can be reduced. Power transformers are a vital link in the transmission and distribution of electrical power. To keep their size acceptable, modern high-voltage transformers are built with relatively tight insulation tolerances compared to older equipment and are consequently subjected to increasingly high stresses in service. They are also quite expensive; the cost of a large 765kV unit easily exceeding $2 million. It is therefore very important to closely monitor their conditions to avoid catastrophic failures, costly outages and losses of production. Because all of the energized and high temperature components of a transformer are immersed in the transformer oil, the condition of the transformer oil reflects the health condition of the transformer. Among the characteristics of the transformer oil, several of them have been monitored on line in the thrust of the on-line monitoring system development. They are Temperature, partial discharge, dissolved gas analysis (DGA), water content and oil conductivity have been monitored. The optical sensor will provide on-line monitoring system based on the UV absorbance characteristics of the transformer oil, depending on the degradation and contamination of the quartz oil, the absorbance of and transmittance of a light signal through optical light guide will indicate changes in the transformer health in intervals of ten to twenty minutes. The principles are based on the ray of light in a medium of refractive index (the ratio of speed of light in the air to the medium) which strikes the interface with another medium of refractive index, depending on the relationship of rays transmitted and reflected, the refractive index can be monitored for changes. Therefore, monitoring the degradation of the transformer oil is the most efficient way of predicting the health of the transformer. Although there have been many optical measurement technologies and optical sensors on the market, only a few of them have been utilized in the monitoring of the health of power transformer, even fewer in the monitoring of the transformer oil.
Work Plan:
Task #1: Review the existing optical monitoring systems and the existing transformer monitoring technologies. Advantages and limitations of these technologies and systems will be accessed.
Task #2: Experimental investigation for a suitable optical technology in the monitoring of power transformer oil, UV absorption and analytical chemistry validation with spectrometry measurements.
Task #3: Development, design and construction of the prototype system based on the previous experimental results.
Task #4: Design of electronic hardware, signal processing unit, interface with the optical system.
Task #5: Evaluation of transformer conditions. Laboratory tests
Task #6: Field tests
Task #7: Implementation of industrial prototype.

Related Work: There is a rich literature on control robotics, mobile vehicles, cooperative autonomous systems, mechatronics and bio-engineering. Very few works on T&D have been identified.


How this Work Differs from Related Work: The related work proposes intelligent sensory systems for monitoring and detect control loop failures in an interconnected power system. No efforts were identified to bring computing capabilities to the hardware of T&D. This work will develop a smart optical sensor for transformers and breakers that would be integrated with results from the PSERC Intelligent Substation project. There has been no effort in using single optical monitor that can detect and identify multiple failures in a transformer. This new sensor will have unique characteristics that will significantly enhance the quality of transformer monitoring and health assessment.

5.13.1 Project Status

Status as Reported for the May 2002 IAB Meeting

Work progress since the report for the December 2001 IAB meeting
This is a new PSERC project. Work is just beginning. A review on literature and state of art in the area has been conducted. The system has been conceptually planned with required experiments to measure the frequency response of UV absorption and analytical chemistry validation with spectrometry measurements.
Description of work activities and anticipated project outcomes/deliverables by each project team member during next reporting period
The following tasks are expected to be completed towards the end of 2002:

Task #1: Review the existing optical monitoring systems and the existing transformer monitoring technologies. Advantages and limitations of these technologies and systems will be accessed.

Task #2: Experimental investigation for a suitable optical technology in the monitoring of power transformer oil, UV absorption and analytical chemistry validation with spectrometry measurements.

A conceptual design for the sensor and related sub-systems will be ready for next reporting period.

Description of and reasons for any revisions to the workplan that was reported for the December 2001 IAB Meeting
No revisions.

Students working on the project during the next reporting period
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5.13.2 Project-Related Documents
No documents yet. Work on this project is just beginning

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