INTEGRATING MONITORING AND DIAGNOSTIC EQUIPMENT ON AGING TRANSFORMERS - PART II

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III. CASE STUDIES

Case Study #1

Overall System Requirements

1. To gain remote control & monitoring of two Substations

• By reducing outage times
• By reducing operating costs
• By reducing trips to the field
• By catching problems before failures occur
• By maintaining a healthy system.

2. To improve monitoring and load management

• By balancing single phase loads
• By monitoring underground for potential overload conditions
• By managing the transformer loading and
• By monitoring and controlling the voltage levels

3. To accommodate future SCADA System growth and to be expandable throughout the entire electrical system

• Including the remaining substations
• Including other distribution breakers and capacitors

The overall system installed is shown in the architecture drawing in Figure #1. The two dispatch centers communicate with the SCADA system via DNP 3.0 over IP on the SCADA System. Data Concentrators/RTUs were installed in the substations, which communicated with several Intelligent Electrical Devices (IE's). Additionally, communications equipment was installed to support the initial system. The new communications equipment utilized available channel space on the company digital microwave system.

New Dispatch Centers

The SCADA software was configured nearly identically at the two masters. The only other difference with the two dispatch center systems is the master stations have different IP and DNP addresses. This allowed the two systems to be operated independently. System analog and status changes and control signals are communicated to both masters over the same communication line. This is possible because the system operates over Ethernet communications. This also provided the ability to dispatch for the entire system from either master, providing additional coverage during busy times or a secondary master station if a problem occurs. The similarity of the two

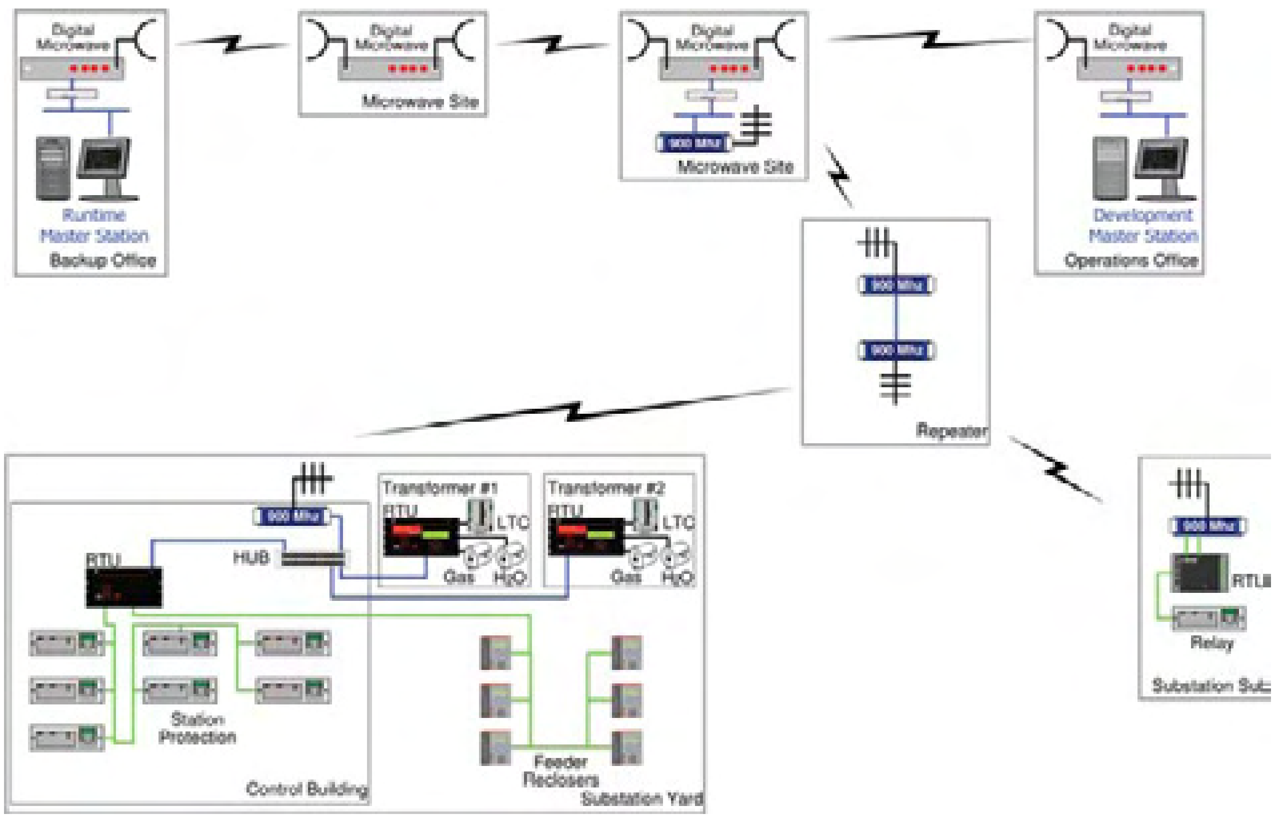

Figure #12: Case #1, System Architecture

Master Stations simplified software configuration of the masters and the RTUs.

The communications system will be discussed in further detail in a subsequent section.

Integrated Transformer Monitoring

Two monitoring systems were installed on the two 120 MVA transformers and integrate into the system using DNP 3.0 protocol over IP. The monitoring and diagnostic (M&D) systems contain smart RTUs, which form the foundation for the diagnostic system.

These RTUs integrate data from several sensors and the transformer monitoring IEDs and perform the diagnostic models. These IEDs consist of a LTC monitor, and sensors which monitor combustible gases and moisture of the oil in the main tank. The M&D RTUs then analyze the data using several of the diagnostic models. It is important to operations and maintenance personnel that the transformer monitoring system reduce the amount of raw data provided. All the intelligent models described in the previous section were implanted which provided information regarding the health of the transformers. These models focused on three main areas; the main tank, the cooling system, and the Load Tap Changer (LTC).

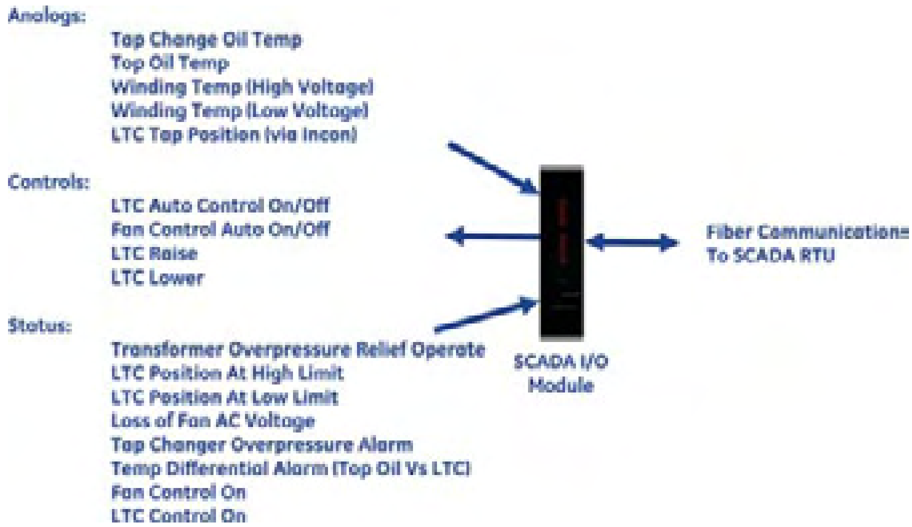

Figure #13: Case #2, System Architecture

Case Study #2

This system utilizes on-line monitoring with no on-line diagnostics. It provides an inexpensive method to capture data from the transformer and assist in off-line diagnosis of transformer problems.

Distributed I/O

This system is based on distributed SCADA I/O modules communicating back to an RTU in the control building. The I/O modules have on-board digital status, analog and control allowing the transformer monitoring system to be integrated into the SCADA system.

Analogs – the following values are used to detect problems with the LTC or the main tank. Indication of the LTC position is also provided, which can be used to determine operation of the LTC and potential problems such as LTC hunting or subsequent tracking of the number of operations of each tap between maintenance intervals. These values include:

Tap Change Oil Temperature – to detect problems with the LTC

Top Oil Temperature – can detect problems with the tank or cooling system

Winding Temp (High Voltage)
Winding Temp (Low Voltage)
LTC Tap Position

Controls – provides on/off control of the LTC and Fan automatic systems. In addition, remote control of the LTC is also provided. The points included are:

LTC Auto Control On/Off
Fan Control Auto On/Off
LTC Raise
LTC Lower

Status – The status points monitored include indication of the control points and on other transformer alarm points. The Top Oil vs. LTC temperature alarm is a primary alarm indication of LTC problems whenever the LTC tank temperature exceeds the top oil tank temperature. The status points include:

Transformer Overpressure Relief Operate
LTC Position at High Limit
LTC Position at Low Limit
Loss of Fan AC Voltage
Tap Changer Overpressure Alarm
Temp Differential Alarm (Top Oil Vs LTC)
Fan Control On
LTC Control On

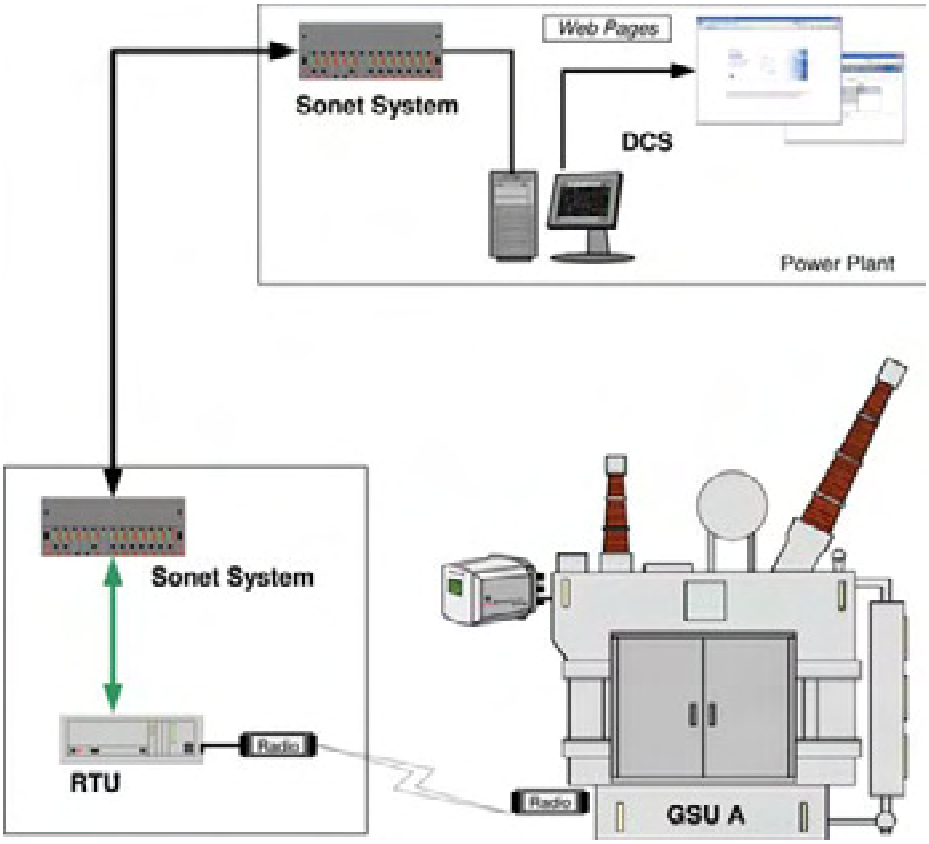

Figure #14: Case #3, System Architecture

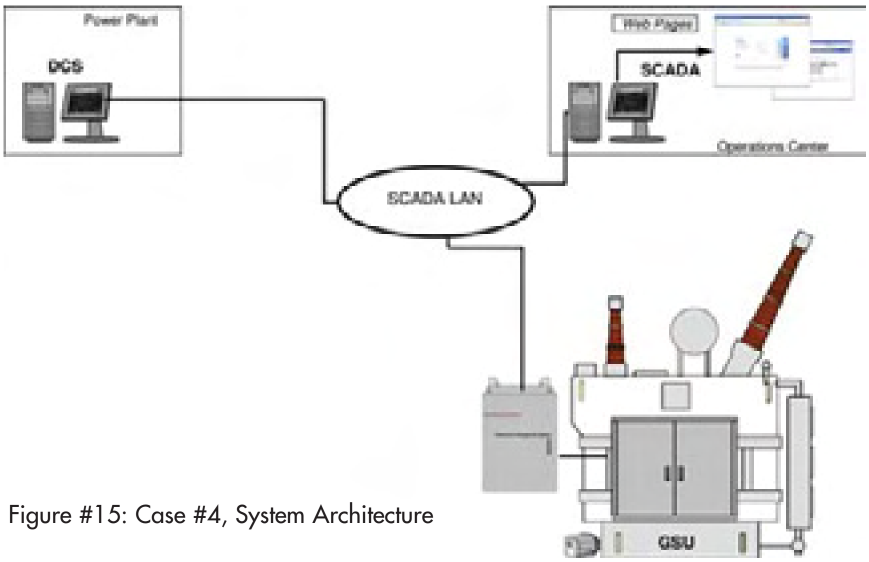

Figure #15: Case #4, System Architecture

Case Study #3

This system is installed on a power plant Generator Step Up (GSU) transformer. From manual oil samples collected from the transformer, it was found that this GSU was gassing above normal operational parameters. The transformer was taken off line in mid-October of

2006 for maintenance. On-Line monitoring is critical for this transformer, as failure could result in a loss of revenue exceeding $100K per day.

The customer flushed and filtered the oil and inspected the transformer for any potential problems. A continuous on-line gas PPM monitoring was installed to provide the Power Plant operations indication of combustible gases in the oil

System Description

This system uses an on-line gas monitor integrated into station RTU which feeds data to the DCS system using Modbus over IP. The on-line gas monitor reports the following data:

- PPM value of composite combustible gas measurement
- Short term and long term rate of change of PPM value of composite combustible gas measurement
- Relative saturation (humidity) of moisture dissolved in oil (%RH)
- Hourly average of %RH and PPM of water in oil
- Computes the PPM water content in oil
- Computes the water in oil condensation temperature

Monitoring these parameters at the plant will help reduce the potential of an unexpected outage due to failure of the transformer.

Case Study #4

This system is installed at another utility on a series of power plant Generator Step Up (GSU) transformers. This utility had similar concerns about the potential revenue lost from unexpected GSU failure. Much of their fleet of GSU transformers is over 30 years old. This utility was also looking for a method of reducing maintenance costs and loading on limited maintenance resources by moving to a condition-based maintenance system. On-Line diagnostics was installed to provide real-time information to the plant control operators on their DCS systems and to their SCADA system.

System Description

This system uses an on-line diagnostic system integrated into station DCS using Modbus over IP. All the diagnostic models described in Section II were installed and integrated into the DCS critical data was also provided to the SCADA system via web pages from the DCS system. The on-line diagnostics system was installed because the models reduced the amount of raw data being handled by the operators and the value of calculated output data which then generates an alarm when the model detects a problem. Over 150 gas monitors and 40 diagnostic systems have been installed to date. The utility plans to install an additional 40 units over the next three years.

Figure #16: Case #5, Transformer Photos

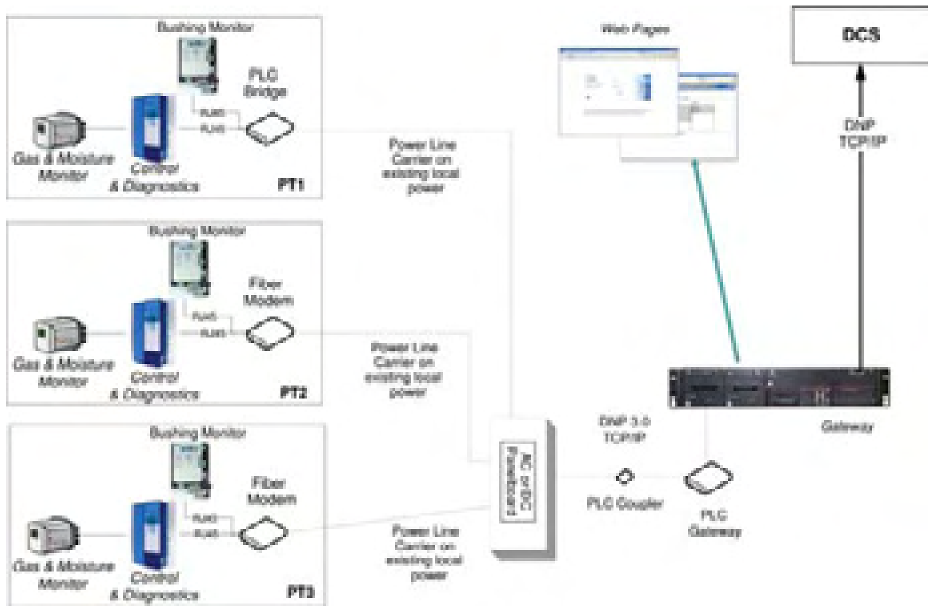

Figure #17: Case #6, System Architecture

Case Study #5

This case study describes a system installed on two large 400MVA station transformers.

The utility decided to install a diagnostic system because of the critical nature of these transformers and the costs of an unexpected failure. The diagnostics systems for these transformers, shown in these photos, were installed late in 2002.

System Description

This system includes the diagnostics capabilities similar to the previous example but also integrated bushing monitoring. The following listing contains the values being monitored in this case study.

Functions:

- Monitor all critical parameters
- Top Oil Temp
- Ambient Temp
- Bottom Oil Temp

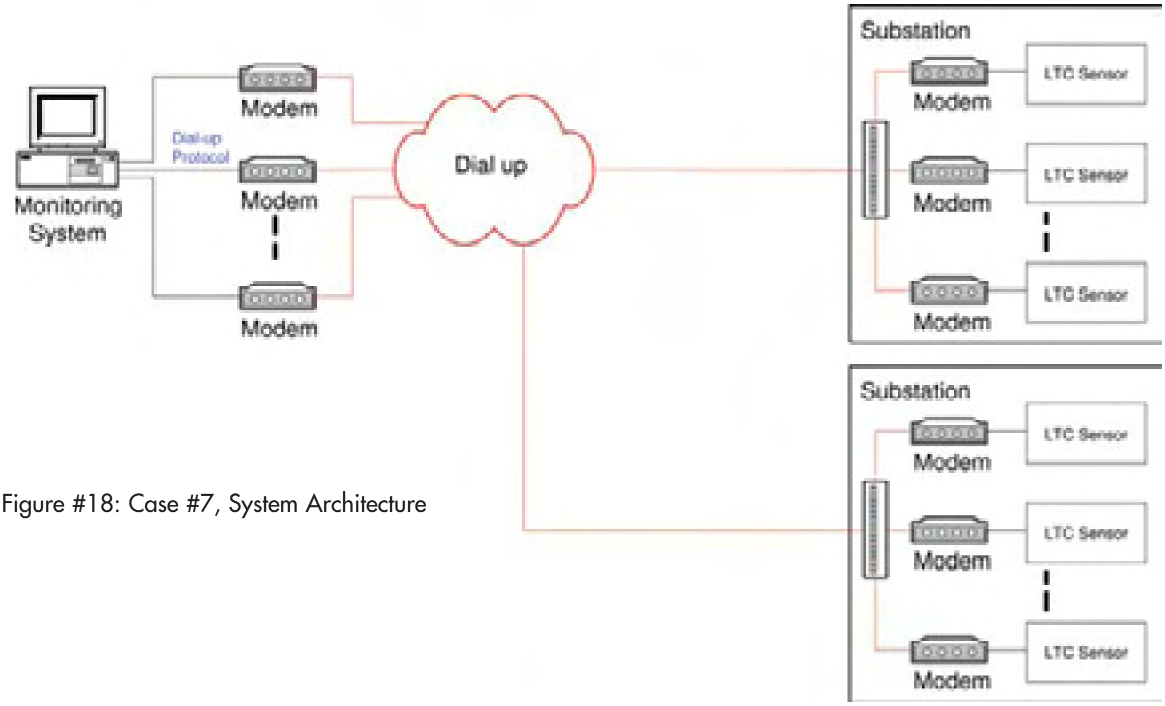

Figure #18: Case #7, System Architecture

- Dissolved gas in oil
- Moisture in oil
- Load current
- Voltage
- OLTC position
- OLTC remote control
- HV & LV Bushings

The Bushing monitor sensors are installed on the high- and low-voltage bushing on each phase. This allows the system to monitor the leakage current on each bushing and detect potential problems.

This system communicates directly with the SCADA system via DNP 3.0.

Case Study #6

This system highlights a few additional communications and functional capabilities.

First this system provides the diagnostic and monitoring of previous systems, including bushing monitoring.

The communication system between the transformers and the control building consists of a DNP IP communications over the local power line carrier system. It utilizes a secure PLC (Power Line Carrier) system that allows low-voltage wiring into an intelligent highspeed broadband networking platform. This system is useful when there is no economical method of adding communications between the transformer and the control building. This system also includes a smart gateway which has a DNP connection to a DCS and Https web-based server access by authorized users.

Figure #19: Case #7, LTC Sensor Installation

Case Study #7

The following system consists of a LTC monitoring system which communicates via dial-up modems. This system provides monitoring on the transformer and the LTC's condition including monitoring the LTC tap operations, tap operation counts, LTC tap wear factors, the temperature difference between the transformer tank and the LTC compartment, the operational characteristics while operating through the various tap positions (LTC Controls), and monitoring the drive motor current and motor index. The utility using this system now performs condition-based maintenance on their LTCs.

They also have credited this system with averting over 30 failures.