

Transformer Bushing & HV CT Monitoring

L'Dee Curtis - Deseret Power
Jeff Benach – On-Line Monitoring Inc.

Introduction

The paper discusses the use of the *SOS Tand* system for on-line monitoring of transformer bushings at Deseret Power's Bonanza Power Plant.

Background

Deseret Power is a generation and transmission cooperative serving six rural distribution co-ops, and with long-term power sales to several Utah municipalities, two municipal agencies, as well as, other power systems and marketers. Deseret's Power's primary power resource is the Bonanza Unit 1, near Vernal, Utah. This 460 Mw, coal-fired plant began commercial production in 1985, and in 2001 was cited as the top power plant in the U.S. based on its capacity factor of 97.66% or close to 100% of maximum output.

While the staff at Deseret takes a great deal of pride in Bonanza's performance, it's the dollars and cents that make any plant a success. Any forced outages are costly to both customers and the bottom line. For that reason Deseret Power implemented an in-depth risk management program in 2001. The program's goal is to minimize unscheduled downtime by addressing potential equipment failures that could lead to outages of significant durations. The program includes, but is not limited to, stocking parts and equipment that have long lead times involved for ordering replacements.



As part of this proactive risk reduction program, Deseret recognizes the critical role of its Bonanza substation high voltage "HV" equipment. A failure anywhere in this primary distribution node could cripple operations for months and significantly impact revenues, not to mention having a negative affect on the company's reputation among key customers.



An assessment of HV equipment risks identified the following key findings: First, many of the HV bushings currently in service at the Bonanza power plant have documented history of failures. Second, it was evident that transformer bushings were aging and thus possibly vulnerable to failure. Third, bushing failures not only force outages, but many times result in collateral damage to other substation equipment as well. Fourth, these bushings are operating at record high capacity factors that preclude the typical outages required for offline testing leaving a blind spot in terms of preventative detection.

These findings triggered the attention of Deseret's risk mitigation program. Deseret Power investigated alternatives to reduce the failure risk of these bushings. Given the economic mandate for continued operations, it became obvious that only online testing and measurement could provide the necessary information to prevent a possible failure. Online monitoring also came with the significant additional benefits of reduced staff time for conducting tests and improved safety for Deseret personnel.

After research and discussions with manufacturer representatives and other user utilities, Deseret selected the On-Line Monitoring Incorporated (OMI) SOS *Tan d* System for the bushing monitoring project.

The SOS *Tan d* System – Overview

The OMI SOS *Tan d* System estimates deterioration in insulation of the on-line equipment by measuring the relative *Tan d* value of the monitoring equipment. It calculates the *Tan d* of a unit as a relative value compared with a reference voltage from another unit that it is grouped with. Since the system uses relative measurements, there is a minimum requirement that at least three (3) units be grouped for each phase of an evaluation. *Tan d* is a measure of the dielectric losses, which are caused by capacitive leakage current in the dielectric material used to make a bushing core and are generated within the paper insulation of the core. One of the symptoms of insulation deterioration is its increased sensitivity to changes in temperature and voltage, which manifests itself in the form of relative increased dielectric loss.

Tan d and capacitance are properties of the bushing design and the dielectric material used in the design. Monitoring and measurement of the *Tan d* gives an indication of the quality of the insulation and its sensitivity to temperature and voltage changes.

The monitoring system installed at Deseret Powers' Bonanza Power Plant monitors 345 kV, 220 kV, 138 kV, 69 kV, 34.5 kV, 25 kV, & 11.5 kV bushings across twelve (12) transformers switch yard and generator step up units from the power plant. The system collects, evaluates, and displays information from a total of 69 monitoring points. The system is intended to provide an early warning of bushing insulation breakdown. It provides real time information on the operational condition locally through alarm contacts, and remotely through Deseret Power's WAN.

The system consists of the following components:

- I) The Bushing Tap Coupler (BTC). One for each monitoring HV device.
- II) The Capacitor Divider Unit (CDU). Also one for each monitoring device.
- III) A Junction Box where cabling from the CDU's are terminated
- III) A "Rendezvous cabinet", inside the control house, that houses the monitoring system electronics and where signals from the various monitoring points is terminated through underground cabling.



220KV bushing with a Bushing Tap Coupler (BTC) installed.

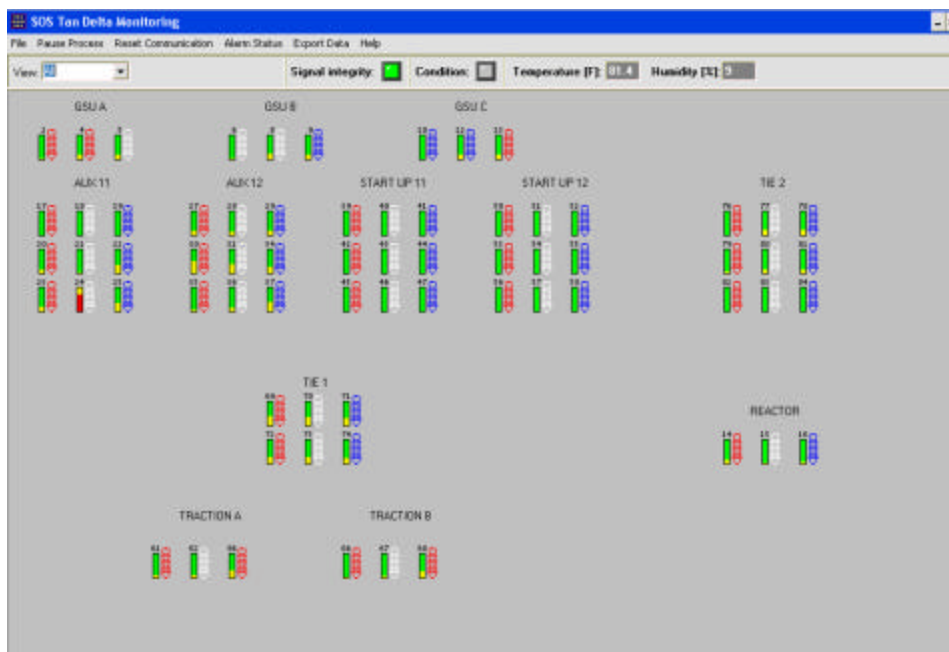
System Software

The system is based on the principle of a conventional Schering bridge under software control to measure the *Tand* of the insulation. The system has been optimized using software with minimal hardware. The deterioration of insulation is gauged on its

sensitivity to changes in the on-line operating conditions. The versatility of the system installed at substations has allowed for continuous accumulation of data. The *SOS Tan d* software optimizes the performance of measuring parameters with existing hardware. Data extracted from measurements are manipulated in matrix operations to present normalized condition values for each unit being monitored.

The signals are sampled and the data processed under software control to calculate the capacitance and dissipation factor changes. Since a second unit of equipment is used as a reference standard instead of a standard capacitor, the values are relative to that unit. This principle is extended to several units within the substation.

With specific configurations, relative measurements eliminate common mode effects, such as ambient temperature, operating voltages and load conditions, and accentuate the differences, such as design and sensitivity to changes in insulation.



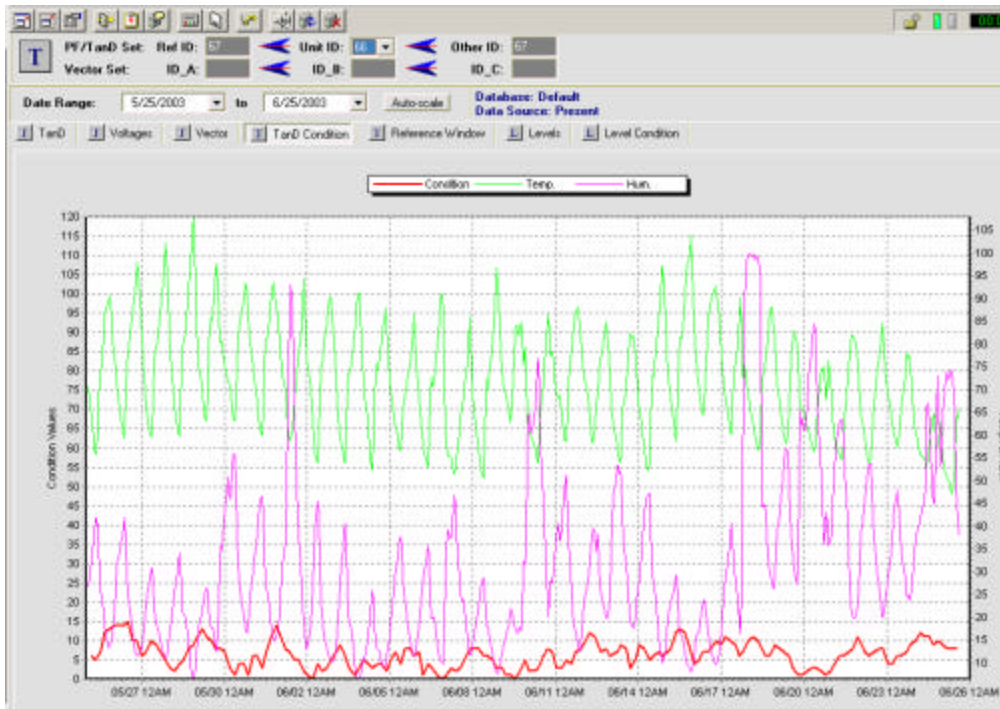
For this reason, the system requires a minimum of three monitoring points that must be on-line. A maximum of 256 hardwired points and/or 256 wireless points can be monitored in the same substation.

An SOS monitor screen is shown on the left. The monitor screen is displayed on the

host PC located in the substation, and gives visual indication of the status of the units being monitored.

The graph shown below is a relative *Tan d* condition graph from a monitored bushing. The *Tan d* and relative capacitance values are displayed in the center of the graph, with the scale on the left y-axis. Temperature and humidity are also displayed on this graph, and use the scale on the right y-axis. Temperature is displayed at the top of the graph, and humidity is at the bottom.

Reporting



Shown to the left is a report sent via EMAIL to individuals responsible for monitoring the system. This report can also be sent via FAX. The system can also send a message to a numeric phone pager as well. The reporting and alarm levels are configurable by the user, and provide status on all devices

being monitored. Monitoring and reporting services may also be sub-contracted as well.

ail Report on: Bonanza Substation

Summary:

Free Space: 85%

signals from some units are down (signal integrity problem).

condition of all monitored units is GREEN.

signals of the following units are currently down:

| TYPE | PHASE | FEEDER | REASON |
|---------|-------|--------|--------|
| BUSHING | A | H1 | DOWN |
| BUSHING | B | H2 | DOWN |
| BUSHING | C | H3 | DOWN |
| BUSHING | A | X1 | DOWN |
| BUSHING | B | X2 | DOWN |
| BUSHING | C | X3 | DOWN |

Information on all the units being monitored:

| TYPE | PHASE | FEEDER | CONDITION | SIGNAL |
|---------|-------|--------|-----------|----------|
| BUSHING | A | H1 | Green 6 | OK |
| BUSHING | A | X1 | Green 41 | OK |
| BUSHING | B | X2 | Green 12 | OK |
| BUSHING | B | H1 | Green 10 | OK |
| BUSHING | B | X1 | Green 10 | OK |
| BUSHING | C | X2 | Green 30 | OK |
| BUSHING | C | H1 | Green 4 | OK |
| BUSHING | C | X1 | Green 22 | OK |
| BUSHING | A | X2 | Green 38 | OK |
| BUSHING | A | H1 | Green 23 | OK |
| BUSHING | B | H1 | Green 16 | OK |
| BUSHING | C | H1 | Green 7 | OK |
| BUSHING | A | H1 | Green 0 | REF DOWN |
| BUSHING | B | H2 | Green 0 | REF DOWN |
| BUSHING | C | H3 | Green 0 | REF DOWN |
| BUSHING | A | X1 | Green 5 | OK |
| BUSHING | B | X2 | Green 3 | OK |
| BUSHING | C | X3 | Green 4 | OK |
| BUSHING | A | Y1 | Green 14 | OK |
| BUSHING | B | Y2 | Green 45 | OK |
| BUSHING | C | Y3 | Green 18 | OK |
| BUSHING | A | H1 | Green 7 | OK |
| BUSHING | B | H2 | Green 1 | OK |
| BUSHING | C | H3 | Green 17 | OK |
| BUSHING | A | X1 | Green 9 | OK |
| BUSHING | B | X2 | Green 30 | OK |
| BUSHING | C | X3 | Green 15 | OK |
| BUSHING | A | Y1 | Green 0 | OK |
| BUSHING | B | Y2 | Green 18 | OK |
| BUSHING | C | Y3 | Green 1 | OK |
| BUSHING | A | H1 | Green 0 | DOWN |
| BUSHING | B | H2 | Green 0 | DOWN |
| BUSHING | C | H3 | Green 0 | DOWN |
| BUSHING | A | X1 | Green 0 | DOWN |
| BUSHING | B | X2 | Green 0 | DOWN |
| BUSHING | C | X3 | Green 0 | DOWN |
| BUSHING | A | Y1 | Green 0 | DOWN |
| BUSHING | B | Y2 | Green 0 | DOWN |
| BUSHING | C | Y2 | Green 0 | DOWN |
| BUSHING | A | H1 | Green 0 | DOWN |
| BUSHING | B | H2 | Green 0 | DOWN |
| BUSHING | C | H3 | Green 0 | DOWN |
| BUSHING | A | X1 | Green 0 | DOWN |
| BUSHING | B | X2 | Green 0 | DOWN |
| BUSHING | C | X3 | Green 0 | DOWN |
| BUSHING | A | Y1 | Green 0 | DOWN |
| BUSHING | B | Y2 | Green 0 | DOWN |
| BUSHING | C | Y3 | Green 0 | DOWN |
| BUSHING | A | H1 | Green 6 | OK |
| BUSHING | B | H2 | Green 6 | OK |
| BUSHING | A | H1 | Green 1 | OK |
| BUSHING | B | H2 | Green 1 | OK |
| BUSHING | A | X1 | Green 27 | OK |
| BUSHING | A | H1 | Green 54 | OK |
| BUSHING | B | H2 | Green 63 | OK |
| BUSHING | C | H3 | Green 37 | OK |
| BUSHING | A | X1 | Green 54 | OK |
| BUSHING | B | X2 | Green 63 | OK |
| BUSHING | C | X3 | Green 37 | OK |
| BUSHING | A | H1 | Green 34 | OK |
| BUSHING | B | H2 | Green 35 | OK |
| BUSHING | C | H3 | Green 34 | OK |
| BUSHING | A | X1 | Green 34 | OK |
| BUSHING | B | X2 | Green 35 | OK |
| BUSHING | C | X3 | Green 34 | OK |
| BUSHING | A | Y1 | Green 7 | OK |
| BUSHING | B | Y2 | Green 10 | OK |
| BUSHING | C | Y3 | Green 3 | OK |
| BUSHING | A | | Green 27 | OK |

System Cost Considerations

The true benefit of data trending occurs with an “intelligent system” more closely emulating human reasoning with automated crisis-response capabilities.

Any cost/benefit model attempting to establish the true value of any on-line monitoring system would need to track and follow these unfolding developments to accurately capture the benefits that their adoption can bring to the Maintenance Operations. Given the difficulty of accurately building such a long-term model, however, it would be argued here that present justification for such expenditures need to be based on pure merit of gains in maintenance cost and operational efficiency. The issue of safety being so profound can be debated all by itself as a sole justification criterion when appropriate.

The On-Line Monitoring system is viewed as an important cost driver holding the promise for equipment maintenance cost reduction, improvement of substation equipment performance and enhancement of safety.

Epilogue

With more than four months of operating experience, Deseret Power has experienced good results with the operation and performance of the SOS Tan δ system. With the system now on Deseret's LAN/WAN, analysis reports are delivered via Email. Initially, the system was sent daily reports. Gradually Deseret Power decreased the frequency of the reporting period to every week. The system software has a designed capability of providing reports on a “need to know basis.” In other words, if there is a detection of drastic movement of the reading on any one of the 69 bushings that are being monitored, the system could provide an alarm or a warning report.

At the present time, Deseret is working on plans to add other devices to these transformers, to monitor other aspects of the power apparatus within the same substation. The SOS *Tan δ* platform's capability of integrating other devices will reduce the costs of adding other devices, provide a one-stop monitoring for all devices and save Deseret Power time, money and resources in the future. Deseret also purchased the smaller PFLive Plus system for a smaller application that will give large substation monitoring capability in a cost effective package for smaller remote substations.

This on-line monitoring of the SOS Tan δ System gives Deseret a new pair of eyes enabling extended periods without off-line testing. For more information visit www.on-lineinc.com.