The Importance of Power System Event Analysis

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Abstract

This paper discusses the importance of and the need for good analysis of all protective system operations. The paper discusses how good diagnostic information is being left on the table after "normal" operations and opportunities for improvement to protective relay settings or signatures of equipment anomalies are missed. Examples are given of valuable information that can be gleaned with a small time investment by analysis engineers.

Introduction

There are basically two levels of analysis being performed at utilities.

1. Minimal
2. Good

At the minimal level the reviewers look at easily obtained information and make a determination as to whether or not the operation was proper. For example, a lightning strike causes a phase-ground fault on a 230kV transmission line. SCADA reports that both end breakers tripped and reclosed successfully. Both ends have zone 1 ground instantaneous targets. Case closed. The huge problem with this approach is that there are frequently incipient problems that can be identified by simply taking the time to review data that is readily available.

It is this authors opinion that every operation on the bulk transmission system (100kV and above) should be reviewed in greater detail than the scenario outlined above. Any relay engineer worth his salt knows the importance of good analysis on all operations, not just post-mortem on obvious system failures. Many incipient problems can be diagnosed and nipped in the bud.

If DFR or microprocessor event data is available for an operation it should be reviewed. For a normal operation an analysis engineer can quickly review oscillography data to check the health of the protection system.

Events

The following recent events underscore the importance of analysis and what is being left on the table by neglecting to do this analysis except on obvious misoperations.

CASE 1: Coil-to-coil short on 1400MVA Cross-compound fossil generator.

January 11, 2005 - two days after one of the compound machines experienced a rotor fault and was repaired and returned to service. A TVA System Engineer was reviewing DFR shots and noticed an unusual 1/4 cycle phase-phase event on the generator currents. No protective relays had operated and the unit remained online. Subsequent analysis (to be detailed in a later paper by Kobet et. al.) identified a coil-coil short in the 2B machine on A-phase. The machine was taken offline and the A-phase coil-coil short was repaired. The likely result of not doing this analysis would have been a fault and significant machine damage and extended unavailability of the generator.

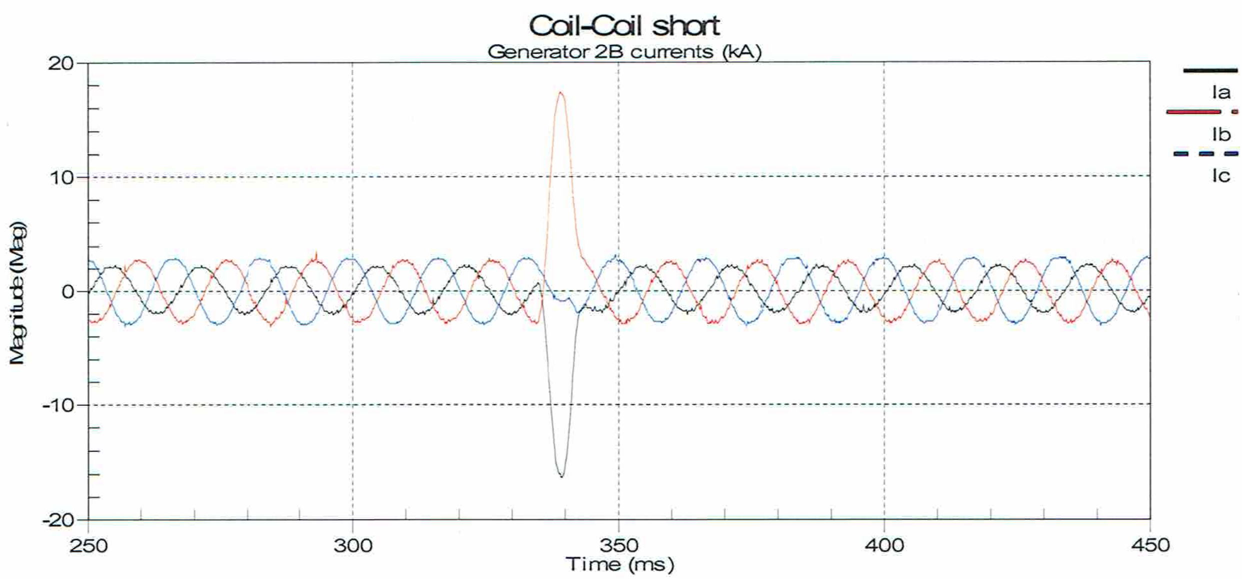

Figure 1. Coil-Coil short in A-phase of generator (machine currents).

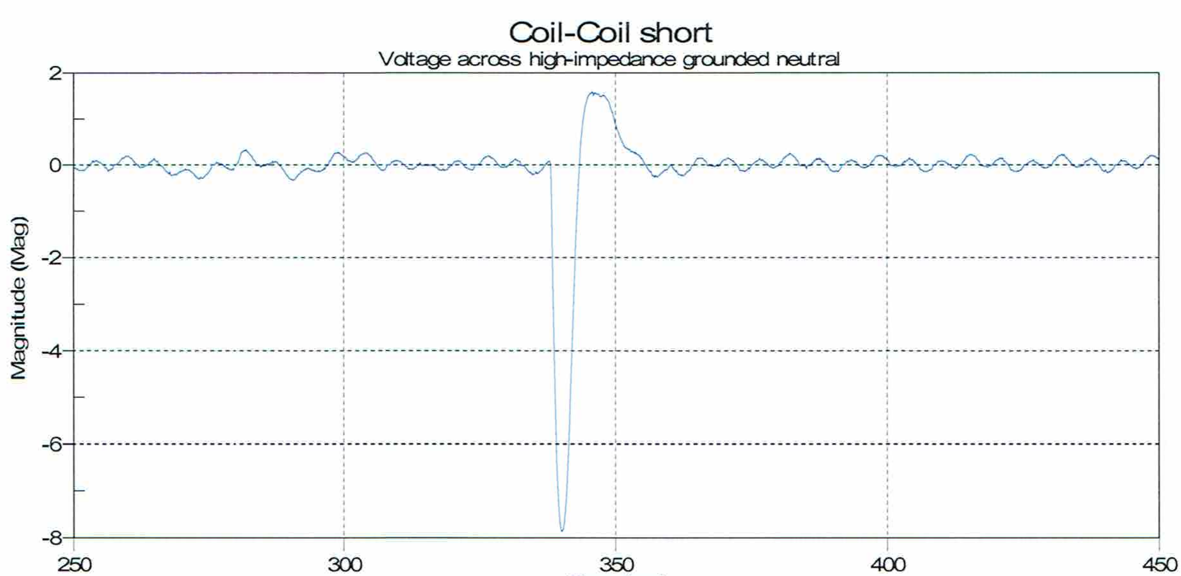

Figure 2. Coil-Coil short in A-phase of generator (neutral voltage).

CASE 2: Restrike on 161kV breaker - successful fault clearing.

October 20, 2004 - System Protection & Analysis engineers reviewed the DFR shot for a "routine" line operation with apparently "normal" clearing and relay targets at both ends. It was quickly apparent that a breaker restrike had occurred on C-phase. The recommendation was made to bypass the breaker for maintenance. The likely result of not doing this analysis would have been catastrophic failure of the breaker.

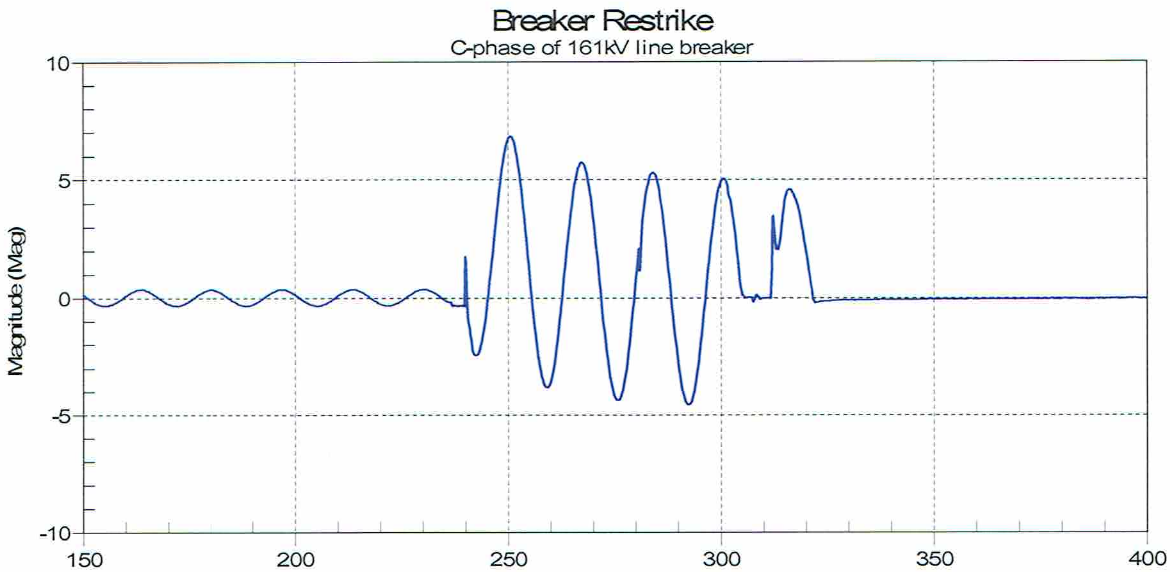

Figure 2. Breaker restrike on "normal" operation.

CASE 3: Normal 500kV CCVT energization event - improperly diagnosed as Ferroresonance.

March 23, 2005 - Engineers reviewed the DFR shot for a routine 500kV line energization. Ferroresonance was quickly identified and the maintenance organization notified. This improper diagnosis resulted in undue alarm over an event that occurs regularly and is of no harm. The trapped flux in the voltage transformer in the CCVT was in the same direction as the flux created by the applied voltage. The result was ac core saturation in the base of the CCVT (J. Chadwick). Regular experience reviewing oscillography will "educate" the analysis engineers so that they can quickly identify characteristic signatures of equipment under various conditions.

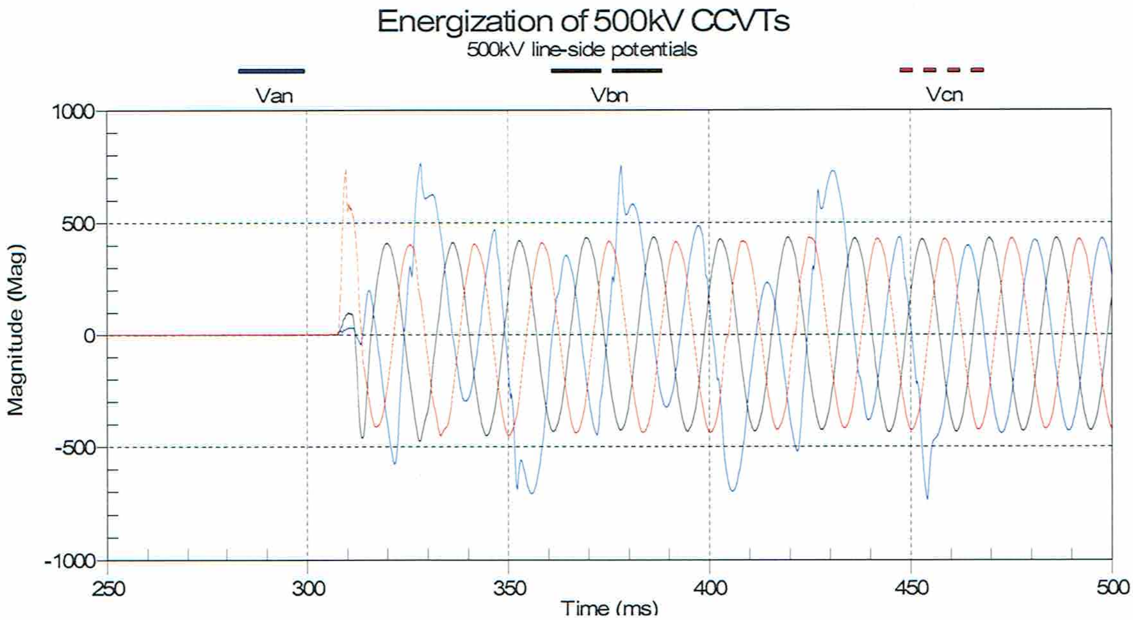

Figure 3. Energizing a set of 500kV CCVTs (three-phases plotted).

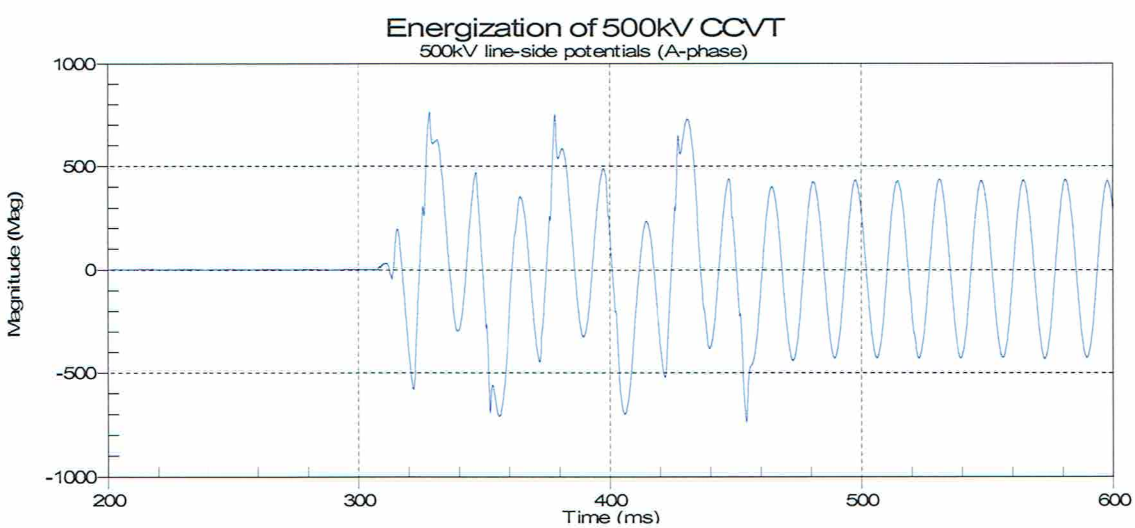

Figure 4. Energizing a set of 500kV CCVTs (A-phase only plotted).

CASE 4: "Normal" ground fault clearing - breaker pole on unfaulted phase fails to open.

February 24, 2005 - An analysis engineer reviewed the DFR shot for a routine 161kV line fault event. An A-phase to ground fault had occurred and was seemingly relayed properly. However, further review of the oscillography revealed that the B-phase pole on the breaker had failed to open during the event.

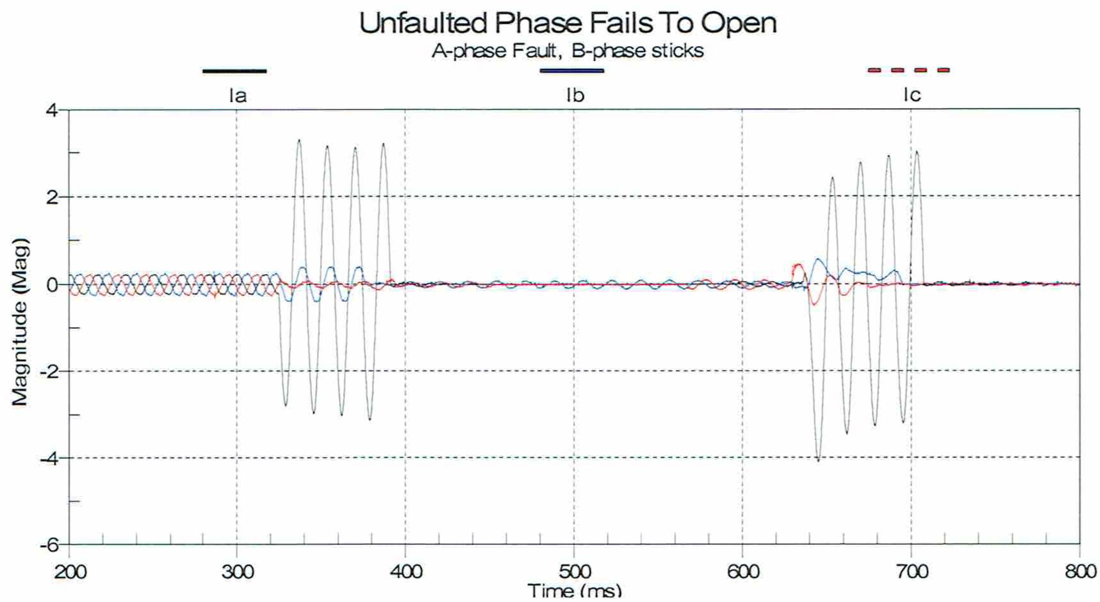

Figure 5. A-phase ground fault cleared, unfaulted B-phase remains closed.

Summary

Tell any "old timer" analysis engineer that you're utility takes the minimal approach to analysis and they will likely insult you - as they did me. They can't understand the mindset that discounts the importance of thorough analysis. They were use to doing analysis when it required developing the old paper oscillograph shots and using rulers to determine fault current levels. And they were much more thorough than we are today.

The typical relay engineer performs only pre-fault analysis: Performing fault studies, checking system impedances, and specifying relay settings. This is only half of a complete job. Post-fault analysis completes the loop, providing feedback on how the protective system operated, if the intended elements operated. This allows the engineer to make any necessary adjustments in relay settings or in overall scheme philosophy.

Today, in the year 2005, we have modern microprocessor relays and digital fault recorders that allow us to quickly display the oscillography on a computer screen. By simply making a small investment in time we can avoid possibly catastrophic and costly equipment failure and interruption to the bulk transmission system and/or end-use customers.

One estimate puts the cost of the August 14, 2003 blackout between $7 and $10 billion. It is astonishing to this author that there has been no increased emphasis placed on improving analysis of the data that is captured on a daily basis from digital fault recording devices and protective relays.

To only review oscillographic data after obvious misoperations is analogous to a doctor ignoring your reports of anxiety, tightness in chest, nausea and shortness of breath and only treating you for a heart attack if you actually experience cardiac arrest.

References

1) "Use Of Oscillograph Records For Analyzing Relay Performance", 17th Annual Georgia Tech Protective Relay Conference - 1963, John R. Boyle, Tennessee Valley Authority.

2) "Analysis of Oscillograms", Fault and Disturbance Analysis Conference, Atlanta, Georgia, May 2000, John W. Chadwick, Jr., Mehta Tech, Inc.

3) "Fault Analysis 101", Texas A&M University Fault and Disturbance Analysis Conference, April 15-17, 1992, R.O. Burnett Jr., Georgia Power Company.

4) "Use Of Oscillograph Records For Analyzing System Performance", Texas A&M University Conference for Protective Relay Engineers - 1980, John R. Boyle, Tennessee Valley Authority.

5) "Transmission Relay System Performance Comparison", a report to the Relaying Practices Subcommittee of the IEEE Power System Relay Committee. See PSRC website at http://www.pes-psrc.org/i/.

6) "Analysis of Substation Data", a report to the Relaying Practices Subcommittee of the IEEE Power System Relay Committee. See PSRC website at http://www.pes-psrc.org/i/.

Software

TOP - The Output Processor. TOP reads data from a variety of sources and transforms it into high quality graphics for inclusion in reports and documents. TOP was developed by Electrotek Concepts® to visualize data from a variety of simulation and measurement programs. It can be freely obtained at the following website: http://www.pqsoft.com/TOP/index.htm

Biographical Sketch

Russell W. Patterson is Manager of System Protection & Analysis for the Tennessee Valley Authority (TVA) in Chattanooga, Tennessee. He is responsible for the setting of all protective relays in the TVA transmission system and at Hydro, Fossil and Nuclear generating plants. He is responsible for ensuring that TVA's protective relays maximize the reliability and security of the transmission system. This includes setting and ensuring the proper application and development of protection philosophy for the TVA. Prior to his position as Manager Russell was a Project Specialist in System Protection & Analysis and was TVA's Power Quality Manager responsible for field and customer support on PQ related issues and disturbances. Russell has performed transient simulations using EMTP for breaker Transient Recovery Voltage (TRV) studies including recommending mitigation techniques. Russell is co-chairman of the Protection & Controls Subcommittee of the Southeastern Electric Reliability Council (SERC) as well as an active participant in the IEEE Power System Relaying Committee (PSRC). Mr. Patterson earned the B.S.E.E. from the Mississippi State University in 1991. Russell is a registered professional engineer in the state of Tennessee and is a Senior Member of IEEE. Russell can be e-mailed at rwpatterson@tva.gov.