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Disturbance Recording Lessons Learned during the Investigation of the August 14, 2003 Incident

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Introduction

It is the intent of this paper to explain several lessons learned during the investigation of the major power system incident which occurred on August 14, 2003, including the subsequent restoration. The focus of the paper is on the disturbance analysis, specifically concentrating on the area of disturbance recording.

Perspective

In the context of this paper the authors discuss practices that apply to the entire power industry, or to that part of the industry with which we are most familiar. This paper describes certain aspects of disturbance recording which the industry as a whole could improve, and no attempt is made to assign responsibility or to identify or endorse any particular manufacturer of disturbance analysis recording equipment; our intent is to simply point out some valuable lessons learned during the analysis of the August 14th 2003 event.

Terminology

For purposes of this paper we will refer to the general area of disturbance recorder application. Disturbance recorders, or simply "recorders", will be classified into the two groups which are defined in the next two paragraphs: Digital Fault Recorders and Dynamic Swing Recorders. This terminology has not yet been standardized across the industry.

- Digital Fault Recorders (DFRs) are more common than Dynamic Swing Recorders, and are generally applied at all critical transmission switching stations. Typically they are applied for the purpose of analyzing performance of relays and circuit breakers in fault situations. Record lengths are on the order of one second, and typical sampling rates are 4 kHz.
- Dynamic Swing Recorders (DSRs) have been less universally applied. These recorders have been applied to aid in analyzing disturbances and oscillations involving a wide area of the power system. Record lengths are generally on the order of one minute or more, and typical sampling rates are 10 Hz.

Organization of the Ideas

Some of the lessons learned which follow relate to disturbance recorders in general, and some apply only to DFR or DSR applications. The individual items, outlined below, are presented in no particular order or priority:

1. Time Synchronization Sources
2. Time Synchronization Quality
3. Time Synchronization Monitoring
4. Time Zone Selection for Time Synchronization
5. Use of a Single Source for Recorder Signal Input
6. Recorder Power Supply
7. DSR Data Rates
8. "Long" Length DSR Records
9. DFR Triggering
10. Record File Format
11. File Naming
12. Plotting Data on a Common Axis
13. Recorder and Record Integrity
14. Working Environment for Personnel Performing Analysis

1. Time Synchronization Sources

There were numerous recordings triggered during the disturbance that were neither time synchronized to each other nor synchronized to a master time source. Furthermore, some recordings were inadequately synchronized; for example, in one case the free running clock in the recorder was time synchronized only once per day.

The most common time synchronization method is to use a Global Position System (GPS) receiver. Purchase prices for reliable rack-mounted GPS receivers have decreased over time and are now down to the one thousand dollar ($1,000) range. Such receivers can provide an IRIG-B (InterRange Instrumentation Group – the standard for transmitting time from one system to another) time synchronization signal to several station devices, such as DFRs, DSRs, and protective relays. It is true that the installation is complicated by the GPS antenna, which needs to be mounted with an unobstructed view of most of the sky, and the engineering and installation costs often exceed the equipment cost; however, the total installed cost should be on the order of five thousand dollars ($5,000). GPS receivers and the GPS system itself have been applied in the utility industry for more than 10 years and have been proven to be extremely reliable.

Having said this, all disturbance recorders should be connected to GPS synchronization. The only possible exception would be recorders that are already adequately served by previously installed GOES (Geostationary Operational Satellite Program) receivers. More information on the current status of the GOES program follows.

2. Time Synchronization Quality

It is very surprising that many recorders that had been provided with satellite synchronization were not actually synchronized. Some of these situations involved the older GOES satellite receivers. The GOES system may be less reliable that it once was, and the GOES receivers themselves may be less reliable that they were, mainly due to age. After loss of synchronization, these recorders' clocks were running on their own free running clocks alone, and somehow this condition was apparently not obvious to the operator of the recorder.

Additionally, the National Institute of Standards and Technology (NIST) has announced that it is ending its involvement with the GOES West and the GOES East satellites operated by the National Oceanic and Atmosphere Administration (NOAA) on January 1, 2005. The GOES time broadcasts began in 1974 and have served many applications. NOAA will continue to provide a GOES time code after January 1, 2005, and existing receivers should be able to decode the time signal; however, the code will no longer be controlled and checked by NIST and the controlled time is expected to be less accurate as NIST discontinues its involvement [1]. GOES receivers should be scheduled for eventual replacement.

3. Time Synchronization Monitoring

Some problems were also experienced with receivers which were somehow inoperative. The most likely explanation for this is antenna and feed line problems, as this area is more vulnerable than the receiver. For whatever reason, the loss of synchronization was not obvious.

There are several possible ways of solving the monitoring problem. The loss of synchronization should be visually obvious to someone who uses a disturbance record. Also, recorders should be able to provide a synchronization failure alarm, say to a remote or central location, via an output contact. The details are site-specific, and should be left to the recorder operator; however, the point is that the quality of time synchronization – or lack thereof - should be obvious. Investigation of actual power system incidents provides an opportunity to check synchronization among all recorders which triggered.

4. Time Zone Selection for Time Synchronization

There was some degree of confusion generated by time zone conversion problems. This issue was exacerbated by the fact that this disturbance affected many areas across multiple time zones. Additionally, some recorder owners remain on standard time throughout the entire year, and some recognize daylight savings time and hence change their recorders to daylight savings time (daylight savings time was in effect at the time of this disturbance). This changeover can be automatic.

The industry should eliminate this source of confusion by establishing a policy for the entire interconnection. Obviously there are many possible policies, but we recommend that all entities use the time zone of Universal Coordinated Time (UTC), which is the time zone of Greenwich, England, and is also known as Greenwich Mean Time (GMT) or Zulu time.

The use of UTC time zone has several advantages, one of which is that confusion related to time zones and observance of daylight savings time is removed. The several-hour separation between local time and UTC can actually be thought of as an advantage in the United States, because it helps users mentally separate UTC system time and local time. UTC has already been successfully employed in other industries which span multiple time zones, such as transportation and communications.

5. Use of a Single Source for Recorder Signal Input

In a few cases a single potential source to a recorder went dead even though power transfer capability remained through that station. An example of this would be a case where the recorder was connected to a single bus potential source and only that portion of the bus tripped.

To minimize the probability that useful information will be lost, the authors recommend that multiple sources of input be connected to as many recorders as possible, especially in the stations with the more complex bus configurations.

6. Recorder Power Supply

Recorder power supplies should be carefully engineered and of high reliability, which generally implies that they be connected to an individual station battery circuit. In the event it is not practical or possible to wire a recorder power supply to a station battery circuit it should be connected to a local Uninterruptible Power Supply (UPS).

7. DSR Data Rates

Some DSR sampling rates are relatively low, such as 10 Hz (or one sample every 100 ms). A sampling rate of this magnitude is a distinct advantage where large record sizes are of a concern. These smaller record sizes result in faster file transfer times and maximize the number of records that can be stored.

During the analysis of this disturbance we observed power system oscillations in the range of .25 to 3.0 Hz, and a 3 Hz slip frequency between areas which subsequently separated. Although the 10 Hz sampling rate was sufficient to record and analyze these frequencies, we may want to raise sampling rates in certain locations to 60 Hz, or possibly higher, as storage costs continue to fall and communication transfer rates improve.

8. "Long" Length DSR Records

In some instances DSR recorders produced extremely long records, mainly due to continuous or multiple re-triggering. In a few cases these records were 2 hours in length, and proved to be extremely valuable by providing a continuous thread running throughout the very complicated sequence of events. In some instances where we did not obtain a continuous record of long length but a series of shorter records in sequential order, we were able to obtain particularly useful information from plotting these shorter records on a common axis with the data from the longer records.

This event proved that if a recorder can handle long records, long records should not be inhibited or at least allowed long in some critical DSR locations.

9. DFR Triggering

In many cases DFRs did not trigger when transmission line protection groups operated on power swings. This is because some DFRs were set to trigger on ground current or voltage unbalance. DFRs are normally used for analysis of faults and these triggers reflect the emphasis on fault analysis; however, there were no faults in this situation. Similarly, it is possible that the DFRs were installed to exactly duplicate an earlier oscillograph installation, and oscillographs generally did not trigger except on digital inputs. Thus, for this incident, DFR records were not available to corroborate the transmission line trip times. This illustrates the point that DFRs should be set to trigger on any transmission line protection operation, not only fault operations.

10. Record File Format

During the course of this investigation it was necessary to transfer, forward and analyze a large quantity of recorder files. In many cases the files were in a variety of native manufacturers' formats, which made this process all the more difficult. Unfortunately, there is no extant conversion program for some types of disturbance recorder files, and in some cases there were simply not enough resources available to accomplish the conversions in the time available.

The "Common Format for Transient Data Exchange" (COMTRADE) standard is a means to consistently arrange the data within a record [2]. The COMTRADE standard is listed as a reference to this paper, and can be obtained by purchasing it on the IEEE website. Although this standard is well known, there were many cases disturbance recorder files had not been converted from manufacturers' native format to COMTRADE.

Disturbance recorder users should insist that COMTRADE conversion routines are provided for new recorders, and whenever possible, should obtain conversion routines for existing recorders. Conversion routines should be conveniently available, and be fast and convenient. Some users have had good results with routinely converting all disturbance recorder files to COMTRADE for storage.

11. File Naming

File names, generally speaking, are not very useful in describing the file contents and as such, other means had to be used. For example, an e-mail might be written to describe the files attached to it. Later, if the file was written to a CD, some other means would have to be found to include the content description. With the large number of files handled during investigation, this process became very time consuming and cumbersome.

There exists a recognized system to name disturbance recorder files, but it has been used in relatively few cases. This system is described in a reference to this paper, and the referenced paper may be obtained for free on the website of the Transient User's Council (TRUC) [3]. At this time the common file naming system report has been published, but it is not yet an industry standard. The following is an example of a pair of COMTRADE files names using this file naming system:

030814,161048,-4d,dev703,nscot,nyiso.dat
030814,161048,-4d,dev703,nscot,nyiso.cfg

The filename contains information on the date and time of the first record in the file, a time zone code which, in this case, is four hours behind UTC, with daylight savings time in effect at the recorder location. Following these are codes for the recording device, the station where it is located, and the company which operates the recorder. The extension is available to specify the file type.

This file naming convention may be used for manufacturers' native format files, and actually for any type of time sequence data files, not only for COMTRADE files. This format convention is being referred to as "COMNAMES" although this designation is not official.

It should be noted that the use of the standard filename would also alleviate some of the confusion generated by time zone problems, discussed elsewhere in this paper.

12. Plotting Data on a Common Axis

It was very helpful during the investigation to place many recordings on a common axis in order to get a sense of what was happening over a wide area. This was particularly helpful with recordings of frequency and voltage magnitude. To do this, it is necessary to understand in detail how various recorders work. Most do not sample synchronously; however, some do. Sampling rates vary from device to device. Users need software tools that make it convenient to bring together these different kinds of records onto a common axis. Also it would be very helpful to have some dynamic analysis tools conveniently available.

13. Recorder and Record Integrity

The best way to insure that a disturbance recorder will function properly when it's most needed is by regularly accessing it and analyzing its records. One might say that it's not useful to procure and install a recorder if the resources are not available to make regular use of it. There are frequently interesting events occurring on our power system, and the recordings from various locations can assist with the analysis of these events and can be included in reports on these events to illustrate the conditions. Regular access in important to make sure the installation are working properly, time synchronized, and calibrated.

14. Working Environment for Personnel Performing Analysis

The time immediately following a major disturbance, including the time spent during restoration, is extremely important to the personnel directly involved with the analysis. In some cases recording devices need to be unloaded (or they will begin to overwrite the extremely important records from the beginning of the disturbance), the records need to be analyzed, and the initial results need to be communicated. For these reasons, it is imperative that normal power supply is restored to the portion of the building in which the engineering staff is working. That is, that portion of the building should have the ability to be powered by stand-by generators.

Our experience is that the working environment during this period should be as normal as possible. Certainly the computers used for disturbance recorder access should be powered by uninterruptible power supplies. There are other building services that are important, but can be interrupted briefly during the changeover to stand-by generator power. Examples would be lighting, heating, ventilating, air conditioning, and various appliances. A third category of load would not be operated at all during the emergency, and these loads would be the ones which are not essential to the working environment. The point of all of this background is to set the stage for recommending that the working conditions should be planned carefully, and even practiced, and should be essentially normal.

Acknowledgments

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References

[1] National Institute of Standards and Technology website, www.nist.gov, March 2004.

[2] "IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems," IEEE Standard C37.111-1999, a revision of IEEE Standard C-37.111-1991.

[3] "File Naming Convention for Time Sequence Data," Report of Working Group H8, Presented at 2001 Fault and Disturbance Analysis Conference, available on website of Transient Recorder Users' Council (www.truc.org).

Short Author Bibliographies

Jim Ingleson began his electric power career working for the municipal electric utility in his hometown, Jamestown, New York. He received his B.S. and M. Eng. degrees in Electric Power Engineering from Rensselaer Polytechnic Institute in 1970 and 1975. He worked for General Electric Company in various capacities, including construction and design of substations and generating plants, HVDC projects, and system protection engineering. Jim is now with New York Independent System Operator, Inc. (NYISO) near Schenectady, NY as Senior Operations Engineer. He is a registered professional engineer, an IEEE Senior Member, and has been an active member of the IEEE Power System Relaying Committee for 25 years, where he is currently Chairman of the Relaying Practices Subcommittee.

Dean Ellis began his electric power career working for Orange and Rockland Utilities and Central Hudson Gas and Electric Corp in New York. He received his B.S. degree in Electric Power Engineering from Rensselaer Polytechnic Institute in 1991. He has also worked in the engineering consulting field, focusing on the design and construction of electric power facilities. Dean is now with New York Independent System Operator, Inc. (NYISO) near Schenectady, NY as Senior Operations Engineer. He is a registered professional engineer in the State of New York.