Managing Fault and Disturbance Data

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Abstract - The increased installation of digital recorders, recording relays and other devices capable of capturing power system data is providing more data on power system performance than ever before. How to make effective use of this data is a challenge being faced by many utilities.

This paper provides an overview of advances in Intelligent Electronic Devices (IEDs), communication technologies and software and discusses their application to the task of fault and disturbance analysis.

Index Terms -Transient, data, exchange, record, power systems, intelligent systems, data processing

I. Introduction

Recording systems have been used in the power utility industry for some time. The information they provide is valuable in the diagnosis and prevention of system failures.

Recorder data can be put to many uses: determining the cause of a misoperation, identifying coordination problems, building and verifying system models and detecting and preventing equipment failure, to name just a few.

The number of recording sources in use has increased over the last few years as utilities discovered the many uses of recording data. Unfortunately, so has the volume of recording data to be analyzed and managed.

The analysis and management of records takes considerable time and requires skilled personnel. For this reason, many records may not examined and much of their potential value is lost.

II. Typical Recording Systems Use

With present recorder technology, it is often necessary to record a lot of extra data in order to ensure that the desired data is captured. Recorder trigger criteria are relatively simple, so sensitive thresholds must be set up. As a result, recordings are often generated for 'non-events': occurrences that are not worth recording, but which meet the sensitive trigger criteria. As well, when a system event occurs, numerous records may be generated, with some being interesting, and many not relevant.

Due in part to this large volume of non-significant triggers, recorders are often ignored until some external event occurs. For instance, a relay operation, outage, or converter commutation failure may cause the user to consider that the recorder may have captured data relevant to the event. The user then communicates with the recorder, typically by dial-up modem, and sifts through the recorder's storage for records around the time of the event. Often several recordings must be retrieved through relatively slow data links to find one that contains data of interest.

Each record is then manually analyzed using interactive graphical display tools. Often records from multiple sources must be considered and somehow combined to obtain a whole picture of the event. Record data must be manually correlated and time-aligned with other system information, such as sequence of events lists. The actual analysis of the retrieved data is a lot of work, and often takes an expert user many hours.

Broad-based access to the analysis results and the recorded waveforms often requires the printing and distribution of paper reports. Although un-analyzed recorder data can be shared through the use of the IEEE COMTRADE record format, online access to the records is often limited and does not include the results of the analysis.

It has been said many times at past TRUC that every recording has a story to tell - sometimes it shows that a breaker is operating outside of parameters and may need service, or it could be simply saying that the recording trigger criteria are incorrect. The excess of non-significant recordings, the difficulty and time required to retrieve and analyze the data and the lack of support for broad access to the results means that much of the value of the recordings is unused. This is unfortunate, since this data could provide information critical to the utility's operation.

III. The Ideal Recording System?

The ideal recording system of the future might be very simple indeed. There would be three colored lights on the workstation - red, yellow, and green. The recording system would measure all relevant parameters for all system operations and use artificial intelligence techniques and user-defined parameters to assess the appropriateness of the system's response. The recordings would be automatically retrieved, reviewed, sorted and color-coded:

Presented at the Transient Recorder User's Conference 1998 Atlanta, GA

Green: Operation as expected. System nominal. Don’t bother reviewing records, unless you are bored.

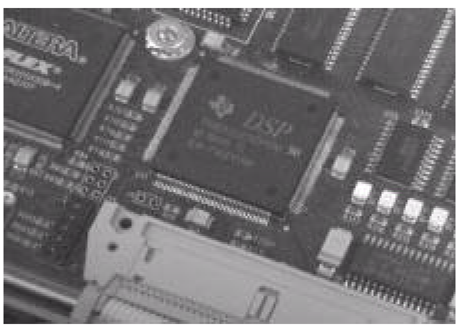
Yellow: Operation as expected but system maintenance may be required. Review records soon.

Red: Operation not as expected. System needs attention. You’d better take a look at this one!

Realization of such a system may be some years away, but recent developments in technology make much of this ideal possible today.

IV. Changes in Technology

Advances in the technologies upon which recorders rely now permit significant improvements in what recorders can do for us.



A. *Increased Front-End Processing Power*

Modern recording systems use digital signal processors (DSP) at the front end where the incoming signals are digitized. Advances in DSP technology in the past few years have significantly increased the amount of processing that can be accomplished at the front end. A mid-range DSP can execute 30 million floating point instructions per second and costs around $15 [1].

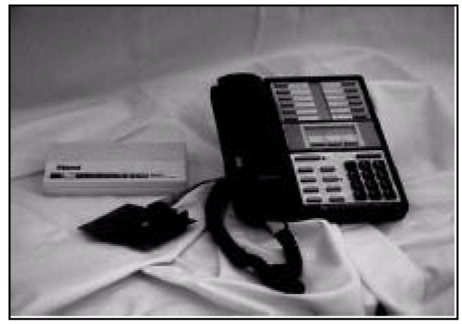
An even greater change has taken place in the density and cost reduction of computer memory. Chips supporting megabits of memory are now available in the same size as those which used to support 64 kilobits.

Impact:

Increased front-end processing power allows more accurate and sophisticated triggering algorithms to be run. Noise can be filtered out digitally, harmonics analyzed in realtime and logical combinations used to qualify triggering events. This serves to reduce “non-meaningful” recordings (such as a manual breaker opening without a corresponding relay trip or changes in the analog levels) while ensuring that relevant events are detected.

More processing power and more memory permits the recorder to operate at multiple timeframes simultaneously. Transient records (e.g. 1 second of 96 samples per cycle) and swing records (e.g. 120 seconds of 1 sample per cycle) can be obtained from the same device inputs. Each timeframe could have independent triggers and storage capabilities.

Larger numbers of inputs can be scanned at fast rates, giving recorders sequence-of-events capability to supplement the analog recordings. Statistical data can be collected for maintenance purposes, such as cumulative i^2t in a breaker. On-the-fly data compression [2] can be applied to increase storage capability and reduce transmission time.



B. *Fast, Seamless Communications Infrastructure*

Networked digital communications is becoming widespread and seamless. With the extensive local area networking (LANs) found in substations and offices, intranets and the Internet, communications between different computers is becoming common and accepted. The infrastructure is well developed, and technical skills relating to its implementation are readily available.

For long distance communications, telecommunications companies can provide high speed links like ADSL or T1 trunks that transfer data at a rate of 100’s of megabits per second.

Today, even modems used for plain old telephone service (POTS) can attain transfer speeds in excess of 33 kilobits per second. The connections between modems are more reliable, gracefully degrading as line conditions deteriorate.

In the near future, constellations of hundreds of low earth orbit (LEO) satellites will be launched, to provide high speed communications almost anywhere. Remote sites won’t need expensive phone lines installed, just compact, cost-effective satellite transceivers.

When interconnect is made, the languages that computers speak are becoming increasingly standardized. Most computer systems talk TCP/IP, which is the Internet standard. This allows different systems to at least exchange files.

Impact:

With the increased economy and reliability of data communications it is now feasible to have timely automated transfer of data, initiated by the recorder. Although the actual link may be created and broken as needed, the recorder can essentially be continuously on-line.

Automatic data transfer to a central location means that recordings could be automatically analyzed and classified shortly after they occur. Summaries and the raw data would both be available for immediate access from the central server.

The feasibility of continuous on-line access to recorders makes it possible to use recorder information as an operator support tool, providing such information as fault location almost immediately after the event.

C. Large, Inexpensive Storage Media

Storage media is rising in capacity and dropping in price and size. A typical hard drive ten years ago, in 1988, was 10 Mbytes; a top end drive was 30 Mbytes [3]. These drives were comparatively large and heavy, the size of a 5¼" floppy drive. Their access time was measured in the tens of mSec. Today, in 1998, a typical hard drive is 2.1 Gbytes, a top end hard drive is over 8 Gbytes. Today's drives are typically the size of a 3½" floppy, or smaller at 2½". Access time is 8 mSec or faster. MTBF is typically rated at 300,000 hours [4]

The use of RAID (Redundant Array of Inexpensive Disks) arrangements can readily provide secure storage for many Gbyte of data.

Impact:

The availability of inexpensive, fast, high capacity data storage makes it quite feasible to keep several years of data from multiple recorders online in a single database. For example, a Gbyte of storage could hold 2000 records of 1 Mbyte each (with compression).

D. Powerful, Graphics-Based Desktop Computers

In the past decade, desktop computers' processing power has grown at an astounding rate. In 1988, a typical PC computer system had a 286 CPU running at 10 MHz, with a Hercules MDA display. At that time, a top end system had a 386 running at 33 MHz with an EGA display (the Intel 486 was introduced in 1989[5]). It would be running DOS 3, and perhaps Windows 2.0 (Windows 3.0 was released in May, 1990[6]). In 1998, a typical system is a 200 MHz Pentium running Windows 95 on a 1024 x 768 SVGA display, while a top end system has a 333 MHz Pentium II running Windows NT or UNIX with X-Windows on a 1600 x 1200 SVGA display.

Impact:

In the past, slow and inflexible record display graphics have made the task of analyzing records frustrating. The powerful processing and graphics capabilities of today's typical desktop computer can make the this task significantly faster and easier.

Increased display resolution permits more data to be displayed simultaneously, giving a more complete view and making data relationships easier to see.

Calculation intensive analysis such as harmonic content can be displayed smoothly and without delay as a cursor is moved along a waveform. Features such as user-specific layout preferences, multiple record display and "undo" facilities can be implemented.

The graphical format of today's operating systems allows software to be designed to help the user work more intuitively. In addition to graphical recording display, data searches, record lists and report generation can benefit from a graphical layout.

E. Extensive Local Area Networking

Ten years ago, the task of sharing data between desktop computers was difficult. Networks were rare and often plagued by compatibility problems and poor throughput. Data was often passed via floppy disks, which held only 360 Kbytes - hardly enough to contain a typical fault record. Today almost every office has a network which provides almost seamless inter-computer communications at rates of 10 (or even 100) Mbits/second. In addition to data sharing, networks provide access to high quality printers and automated data back-up services. Even floppy disks have been improved to hold 1.44 or 2.88 Mbytes.

Impact:

With ubiquitous networks, it is possible to store and provide fast access to many thousands of recordings. Records can be readily available at any desktop node throughout the utility.

Perhaps more importantly, it is now possible to create a common workspace for disturbance analysis, with comments, analysis and reports being shared.

Networks also facilitate features such as automatic notification when new events occur.

F. Sophisticated Database Software Search Tools

Because of the tremendous wealth of data on the Internet, a great deal of research and innovation is happening in data search and categorization. 'Data mining' is a new technique for the exploration and discovery of information on the Internet.

This technology is being applied to desktop computers in the form of 'agents' and 'wizards', which are intended to help users to more easily access the complex features of the new, sophisticated software. An 'agent' is a search tool you tell what you want and it goes ands looks for data, based on some intelligent search criteria, like a web crawler. The technology is just now emerging. The aim is to combine intelligence and mobility to provide only the data you want, but from a wide variety of sources. A 'wizard' is an expert which guides you through a specific task, e.g. setting up a mail merge in your word processor. These tools can help provide intelligent sorting of a user's data. Powerful searching, grouping and display tools allow the user to do comparative analysis.

Impact:

Database tools can be used to sort and group disturbance records for quick access. Filters, such as timeframe or classification, can be applied to make data searches easier. Associated records - those taken from other locations in the same time period - can be readily called up during the analysis of a record. Search criteria such as fault type or clearing time, can be used to look for similar records to help identify system patterns.

Statistical reports can be generated for maintenance purposes. The number of faults on a line over a specified period could be shown. The distribution of clearing times could be graphed.

G. Expert Systems - Neural Network, and Fuzzy Logic Tools

These techniques of data categorization and system control were mostly theory a decade ago. Today, however, these technologies are in use, organizing data and making predictions.

Expert systems are being used in many diverse ways: for the recognition of handwriting and voice, for robotics and automatic control systems, and for medical diagnosis, to name a few.

In our own industry, there are a number of initiatives presently being made to apply expert systems to the analysis of fault recorder data.

Impact:

Although automated analysis is not about to replace the engineer any time soon, the ability to classify and categorize records can be a tremendous help.

In a system that retrieves records from remote sites, automated analysis can be used to extract key characteristics that can be used to create a record summary, to facilitate meaningful database searches, or to bring important records to an engineer's attention.

Even without expert systems, it is often feasible to automatically determine fault classification (e.g. single line to ground) or clearing time or to identify recordings taken due to a manual breaker operation (i.e. no corresponding relay trip or change in the analog quantities).

If the automated analysis could even do a good job at classifying 50% of the records, make an 'educated guess' on 25%, and leave the other 25% of the records for user review, a significant amount of time and effort could be saved. These percentages could no doubt improve as technology improves.

H. Software and Information Inter-Operability

Information sharing between different computer systems, or even different software packages running on the same computer, has traditionally been difficult. In recent years, the dominance of Microsoft Windows and a push to standardization has made significant improvements in inter-operability.

Standards like Common Object Request Broker Architecture (CORBA) and Distributed Common Object Model (DCOM) are allowing dissimilar systems and databases to work together and exchange information. The COMTRADE record format standard (IEEE C27.111-1997) makes it possible to view transient records from different recording sources with the same program.

Impact:

Development of inter-operability standards means that it will be possible to share data between tools. Engineers will be able to perform more sophisticated analysis, using data available from many different sources, like SCADA, recorders, relays, SER, and even field workers' log books.

Data will be transferred back to relay setting software, to allow verification of relay settings, operating margins, and coordination between different protection schemes. Engineers will be able to verify critical equipment parameters against manufacturers' specifications, to monitor for maintenance that might be required - for instance, checking fault clearing times.

Different sources of data can be used to verify and corroborate each other. SCADA readings can be verified against relay and recorder readings, to both ensure that all agree.

V. A DATA MANAGEMENT SYSTEM FOR POWER SYSTEM DISTURBANCE RECORDERS

A disturbance recorder data management system is not about to replace a utility's engineers. It can, however, allow engineers to work more efficiently.

Improvements in the underlying technologies now support the automatic collection, classification, central storage and widespread distribution of recorder data. These capabilities can allow recorder systems to move from being passive repositories of data - accessed only when a problem is reported from another source - to an active part of a utility's monitoring, maintenance and planning process.

A recorder data management system could:

- Reduce non-significant data using more sophisticated front-end triggering algorithms and combinational logic
- Retrieve data quickly and automatically to a central repository
- Classify and summarize incoming records based on criteria such as fault type and clearing time.

- Organize and manage records, summaries and reports in a database
- Make record data available throughout the utility
- Search for records based on criteria such as time, source, fault type, clearing time, priority.
- Bring significant events, such as marginal operation of equipment, to the users' attention.
- Provide statistics and summaries for maintenance and planning
- Provide a common workspace for sharing comments and analysis results
- Link to external information sources, e.g. SCADA

VI. REFERENCES

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VII. ABOUT THE AUTHORS

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Dean received his B.Sc.(EE) with honors from the University of Manitoba in Winnipeg in 1984. He has been employed since then by Vansco Electronics in Winnipeg, doing design, implementation and troubleshooting of utility electronics, control systems, network systems, and vehicular electronics. Since 1995 he has been serving as Engineering Manager in the APT division of Vansco.

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