FUTURE TRENDS FOR FAULT RECORDING AND ANALYSIS IN BRAZIL DUE TO MARKET DEREGULATION

Sérgio Luiz Zimath
sergio.zimath@reason.com.br

Jurandir Paz Oliveira
jurandir.oliveira@reason.com.br

Gilmar Krefta
gilmar.krefta@copel.com

Adriano Pauli
pauli@eletrosul.com.br

Florianópolis and Curitiba
BRAZIL

Presented in
GEORGIA TECH FAULT AND DISTURBANCE ANALYSIS CONFERENCE
2007 April 30 – May 1,
Atlanta, Georgia, USA

ABSTRACT

Deregulation of electrical sector is a worldwide process and motivates competition between power companies. However, direct impacts in companies' technical areas have not been completely defined nor understood.

In this new scenario, Brazilian transmission companies are penalized for the unavailable time of transmission lines. Causes of a fault and its consequences become a way to indicate the responsible for the system asset unavailability as well as for the fine. This value over the company income represents a change in the way of operating, maintaining and reestablishing the system during a fault. Thus, brings new requirements and procedures.

In the deregulated environment, waveform records are used as evidence for litigation among utilities, system operators and Regulatory Commissions. For this purpose, new features are required for the fault recorders. In the USA 2003 blackout, event reports were already presented with some functional items of this: need of time reference and definition of standard nomenclature in order to facilitate fault records analysis from more than one recorder in a reduced and acceptable period of time.

Most of the concern about fault analysis is the immediate reestablishment of line transmission. Some cases of permanent fault require the use of helicopters and teams for a fast response time to restore lines. However, time for assessing the needed location information of a fault can be long due to communication channels used. The time taken into consideration to set the fine value has not yet been understood by some companies.

This paper aims to describe some of the situations above mentioned and list new technical specifications for fault recorders in order to fulfill changes in the deregulated environmental such as secure communication, log messages, records with digital signature, optical interfaces for communication, increase of the acquisition accuracy, auto upload reports, power supply backup, etc.

INTRODUCTION

During 100 years of existence, Brazilian Electrical System has generated 5,000 TWh. This amount corresponds to to half Brazilian petroleum reserves in therms of thermal generation only, evaluated in 20 billion bbl. In this century, the System had different growth rates due either to hydrological regimes or to economic difficulties (14).

Currently, the Brazilian Electrical System has continental dimensions with hydro electrical and thermal power plants with multiple owners and still strong predominance of hydro electrical energy. In the end of 2005, the installed capacity in the NIS (National Interconnected System) reached the total power of 82,110 MW, being 69,760 MW from hydroelectric plants, (including one half of Itaipu Power Plant installed capacity, that is a joint Brazil- Paraguay enterprise totalizing 12,600 MW), and 12,350 MW from thermal plants (2,007 MW of nuclear fuel). (15)

Following the world-wide effective trend in the 90's, the utilities property transference from the state for the private sector, opened an electrical energy market competition and instituted free access. The coming of deregulation in the electrical system have created a competitive atmosphere among the utilities. Technical excellence began to dispute space with the need of the companies to profit from their investment. The aim of deregulation is to have the best energy at the lowest price to the end user. Therefore, it is necessary establish technical standards in order to improve or maintain the level of quality in the supply and, also, create rules, imposing penalties in the case of non-compliance with such levels.

Brazilian Electrical Sector was restructured from a model with few regional state utilities acting in generation, transmission and distribution, to a segregated model with well defined only in generation, transmission or distribution companies. It is established that a company will be honored with an "Allowed Annual Income" from its line and equipment availability for the transmission system. On the other hand, an income reduction, called "Variable Payment", was established for any function not fulfilled in the contract. As an example of the importance of "Variable Payment" for the company Table 1 shows the rate per hour in case of unscheduled shutdowns of 500 kV transmission line at Furnas (Brazilian company). Furnas Allowed Annual Income is US$ 64,39 million (10):

Transmission functions	rate for unscheduled shutdowns
Lines and reactor banks	US$ 373,070,57 per hour
Transformer banks	US$ 49,244,97 per hour
Capacitor banks	US$ 110,187,14 per hour

Table 1 – rate per hour for unscheduled shutdowns

Regarding the technical requirements of the Brazilian NIS (National Integrated System), ONS (National System Operator) was created by federal law in August of 1998 as a nonprofit entity of private law. ONS is responsible for the coordination, control and operation of generation and transmission installations in the NIS, and has it performance supervised by the National Electric Energy Agency – ANEEL, the regulatory agency of the Government of Brazil. (15)

Grid Procedures and fault analysis sub-modules were created by ONS as technical requirements in order to operate in the NIS. It establishes formal procedures for fault analysis involving companies and ONS (1, 2, 3, 4). Nowadays, technical discussions take place to identify fault causes due to fine risks involved. Companies are interested in improving the electrical system to avoid fault occurrence and consequent fines.

In a deregulated environment, waveform records are used as evidence for litigation among the public utility companies, system operators and regulatory commissions because it is reliable information. Consequently, records generated should accurately represent the system during fault occurrence, without the risk of being changed or erased.

FAULT ANALYSIS IN A ELECTRICAL DEREGULATED MARKET

Fault analysis is one of the most interesting tasks performed by a protection engineer and, due to its investigative peculiarity, requires methodical thinking, reliable data and time for the analysis report.

Right after a fault occurrence, protections act in few milliseconds and the analysis should be based on data from a fault recorder, which are devices designed for monitoring electrical power generation system.

In the electrical system, fault recorders have evolved in the last years in order to attend the electrical sector fault analysis needs with advanced features to become the main equipment for information analysis. Hereunder, a picture of an old fault recorder waveform record.

Figure 1 – paper report of a waveform record

Whether fault analysis has an associated equipment, communication and personal costs, other hand is related to the direct impact on the fine value reduction as a result of a transmission component forced shut off. Time spent for fault analysis and line reestablishment results from the protection engineer work, which will help a defective line to recover by using the exact fault information and its position in the transmission line to allow maintenance teams repairs.

In this scenario, features such as communication channels, records reliability and, fault location algorithms are becoming even more important.

IMPACTS ON THE FAULT ANALYSIS PERFORMANCE

Time synchronism of fault records

Several equipment can record the same event. Therefore, a fault analysis should correlate data coming from diverse sources as well as from diverse fault recorders located in distant points of the interconnected system. Manually synchronized data can result in several errors and when it must be done in this way it takes long time and causes a delay in the analysis process.

Sub-module 25 of Grid Procedures in Brazil, has already established that fault recorders and automation systems must allow internal time based synchronism through an external clock in order to maintain precision in relation to GPS, one millisecond accurate.

In other countries, there was no obligation about on time based synchronism and companies did not invest in this kind of equipment. However, after 2003 US blackout, thousands of equipment records were analyzed from different companies and the first problem was to compare those available records since there was no time based synchronism among them. Consequently, final analysis report stated that fault recorders must be synchronized, which was finally done in the next two years.

A recent problem discovered related to records synchronization is that due to the difficulty on implementing the equipment time reception, accuracy is still far from the one millisecond expected, even in ultimate protection relay equipment as shown in the article (5). After the adoption of IEC-61850 standard, this problem has increased since the new NTP synchronism protocol for equipment time reference accuracy is about 10 milliseconds.

Nevertheless, an IEEE standard allows time reference accuracy up to one microsecond in Ethernet network (6). This standard should be incorporated into IEC-61850 to obtain a better time reference accuracy for fault analysis.

Assets and records nomenclature standard

Another problem is the lack of standards in the digital and analog channels of waveform records. Although, some companies follow their own standards, different nomenclatures were adopted. So that, it obliges channels to be renamed or that a conversion table be used to analyze an event. The final report of 2003 US blackout proposed the creation of nomenclature standard for records. However, channel names were not mentioned (7).

COMTRADE standard (8) is being reviewed and some of the following points were mentioned in order to be included on the next version:

- Adoption of COMNAMES standard for records nomenclature
- Grouping files into a single one
- Dynamic sampling rates
- Script inclusion for calculated channels
- Changing in the recording digital data
- IEC-61850 integration

Phasor measuring records

An important aspect of the electrical system after deregulation is that the system has worked near to its limits, in order to maximize available assets use.

Undoubtedly, the system is less robust than and phenomena related to the system dynamic are more frequently, which demands a close fault analysis during the process. However, waveform records are not enough for registering this kind of phenomena. For this reason, a PMU (Phasor Measurement Unit) equipment was developed to record system phasors that allows analysis such as: angle comparisons, frequency oscillations and others phenomena not recorded in the past.

Phasor measuring records functionality was designed since the first version of Grid Procedures, sub-module 11.6 – waveform and disturbance records. However, since such technology was just beginning, the installation of the synchronized phasor records in Brazil only now it is taking place.

Fault analysis events related to electrical system dynamic phasor measuring recording allows a better understanding of electrical system behavior and shows a higher monitoring capacity than others technologies for reflecting the electrical system operational reality (9).

Records modification

During the fault analysis, a point that must be took into consideration is that equipment based on generated records can be easily modify, making possible to change the final report. This situation is not expected from any company, though, considering values and financial impact of fine, precautions be taken.

Modern systems use digital signatures to check whether a record has been modified. This can be done through comparison between a number generated on a MD5 program and the number stored within the equipment.

Records exclusion

Another resource available to avoid problems of data modification, configuration or records exclusion is log messages. They allow a permanent register of date, time and access password.

Log messages difficult the intention of modification or exclusion a record and likewise, the responsibility. Cryptography also helps to avoid unauthorized access to the equipment. These features allow that protection engineer to perform the analysis with all records available.

Communication channels performance

Communication failure during data transference from equipment is an old problem for the protection engineer.

Modem links have been substituted by Ethernet links due to the faster and cheaper way of obtaining records than the voice channels (11). The use of optical fiber in communication channels is justified by the lower communication unavailability rate and undoubtedly will become standard.

IEC-61850 standard will allow equipment data integration in an effective way, simplifying occurrence analysis tasks by centralizing all information of events channels and protection relays into a fault recorder single record.

Management systems of record bases

A typical transmission power company has 100 and 800 equipment generating fault records. For fault analysis in the electrical system, it is desired to integrate data from fault recorders and protection relays from different models and manufactures in a common data base. This task is usually performed by scanner software, converting data on a common format (IEEE COMTRADE standard).

This system must to be prepared for dealing with lots of data and allow simultaneous access from more than one protection engineer. It should preferably have search engines, statistics and data management to facilitate engineer's work.

A negative point in this system is the abundance of communication protocols, most of them owner, avoiding its simple implementation. IEC-61850 establishes a protocol for exchanging records in a standardize way. Therefore, it is expected that in the near future, the integration of several equipment in a simplest way without protocol converters should be possible.

Fault Location Algorithms

One of the main tasks during a fault analysis with a permanent defect is to inform the fault location in the transmission line, allowing maintenance team should go fast to the place and proceed the repair.

One-ended fault location algorithms are used for this task but they present problems in several situations (12). Two-ended fault algorithms are not used due its difficult in integrate records from the two ends of a transmission line. However, for its accuracy this kind of algorithm is increasing. Even these two-ended algorithms present some errors in location, as an example, in serial compensated lines (13).

Meanwhile, the most effective way to locate faults is using fault locators based on traveling waves. Notwithstanding this equipment represents an extra cost in a transmission line, it is justifiable in contracts with fine clauses. For this reason, traveling waves fault location units will be installed in the future, informing fault position within 150 meters accuracy, regardless line length and fault type.

Automatic fault analysis

The use of record management systems will be the first step for the development of supportive fault analysis intelligent systems able to perform tasks such as records classification according to their relevance, automatic fault reports, protection performance statistics and maintenance tools integration through sophisticated and intelligent computer algorithms. These systems will not substitute the protection engineer work, but will permit to concentrate in records analysis task, leaving less complex tasks to the computers.

Records accuracy and reliability

Records information should be correct and traceable through analogical inputs calibration certificates, aiming to reduce analysis process occurrence of uncertainties with variation on the electrical current and near to the CTs saturation regions.

CONCLUSION

Fault analysis task aimed to identify forced shutdowns causes and protection performance analysis which intends to the technical system improvement, now has direct influence on company's income.

However, due to an inaccurate cost/benefit ratio analysis, some companies do not foresee investments in fault analysis equipment, thereby losing quality of service. Now, this is being reviewed to return in a balanced point because of fine's impact over company's income.

There is an increased interest in the development of a statistical and economical model in order to foresee investments based on cost/benefit ratio. Protection engineer should support the benefits of investments in his work, in a way to reduce fine's impact.

Equipment current technological advances, software and communication, in association with fault data management record allow a quick response in fault analysis and, consequently, reduction of profit loss.

REFERENCES

(1) Grid Procedures, Sub-module 22.1 – Occurrence and Fault Analysis – Introduction and Concepts, ONS, 2003

(2) Grid Procedures – Sub-module 22.2 – Elaboration of Preliminary Occurrences Report-RPO, ONS, 2003

(3) Grid Procedures – Sub-module 22.3 – Elaboration of Fault Analysis Report-RAP, ONS, 2003

(4) Grid Procedures – Sub-module 22.4 – Analysis of Installation Failures and Equipment Involved in Fault in Operation System, ONS, 2003

(5) Practical Approach for GPS Synchronized Time Systems – Zimath, S. L.; Vieira. G. R. – Technical Seminar on Protection and Control – STPC, Rio de Janeiro, RJ, 2005

(6) IEEE1588 Precision Clock Synchronization Protocol for Networked Measurement and Control Systems, IEEE, 2003

(7) IEEE C37.232 Recommended Practice for naming Time Sequence Data Files, IEEE, 2006

(8) IEEE C37.111 Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems, IEEE, 1999.

(9) Performance of a Synchronized Phasor Measurements System in the Brazilian Power System, ZIMATH, S. L. ; DECKER, I. C. ; DOTTA, D. ; AGOSTINI, M. N. ; SILVA, A. S. E., IEEE PES General Meeting, IEEE Transactions on Power Systems. New York, 2006.

(10) Impact of New Technologies on Power Companies, Lima, R., I Conference on the Course of Digital Protection of Electrical Systems, São Carlos, SP, 2006

(11) WG B5.20 Fault and Disturbance data Analysis including intelligent systems Final Draft, CIGRE, 2006

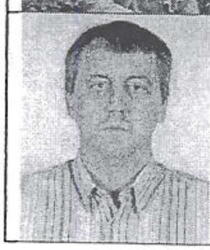
(12) Analysis of Error Sources in Fault Location in Transmission Lines using One-ended and Two-Ended Algorithms, Zimath S., L., Dalcastagnê A. L., Bettiol A. L. XII Eriac – Regional Iberian-American Meeting of Cigre, Foz do Iguaçu, PR, 2007

(13) IEEE guide for determining fault location on AC transmission and distribution lines, New York,2005.

(14) The Brazilian Electric System, Ferreira, O. C., Economy & Energy No 32: June - July 2002.

(15) ONS INTEGRATED DISTURBANCE ANALYSIS SYSTEM, Moraes, R. M., Giovanini, R., GEORGIA TECH FAULT AND DISTURBANCE ANALYSIS CONFERENCE, 2006 May 1-2, Atlanta, Georgia, USA

BIOGRAPHIES

	Sérgio Luiz Zimath. Born in Joinville, SC, on December 23, 1971. Majored in Automation and Control Engineering in 1997 at UFSC. Has worked for Reason Tecnologia S. A. since 1995. Responsible for several of Reason´s products development, such as RT1000 and RT2000 GPS synchronized clocks, as well as for RPIV digital fault recorder, among others. Has worked in many research projects and has published articles in several national and international congresses.
	Jurandir Paz de Oliveira. Born in Tubarão, SC, Brazil on March 12, 1965. He has been related with Reason Tecnologia since 1995, as partner and technical director. He earned his Ms.C. (1997) and Electrical Engineering (1988) degree at UFSC.
	Gilmar Francisco Krefta. Born on August 23, 1958, majored in Electrical Engineering at Universidade Federal do Estado do Parana, Curitiba, Brazil in 1985, specialization in digital systems from the same university in 1998. Has worked as a protection engineer of the electrical system at Copel – Companhia Paranaense de Energia since 1988.
	Adriano Pauli. Born in Antonio Carlos, SC, on October 12, 1967. Majored in Electrical Engineering in 1992 and Philosophy in 2002 at UFSC; took the course on Power Systems in 1996 at EFEI. Has worked for ELETROSUL since 1989. Currently, manages the Division of Protection and Study of the System. Co-author of various papers published in national congresses.