CONTROL CENTER STRUCTURES FOR THE COMPETITIVE ENVIRONMENT – BRAZILIAN POWER TRANSMISSION COMPANY EXPERIENCE IN THE NORTH / NORTHEAST AND NORTH / SOUTH INTERCONNECTED SYSTEM

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1. INTRODUCTION

The restructuring process of the Brazilian Electric Sector imposes several challenges to system operation and maintenance and a new relationship among the numerous market players. The new scenario has created specialized entities such as the National Operator of Electric System (ONS), Wholesale Energy Market (MAE), Electric Energy National Agency (ANEEL) and many new agents of transmission, generation, distribution and commercialization.

The National Operator of the Electric System (ONS) was created in 1998 by the Brazilian government through ratification of the law 9648 dated May 27th, with the following responsibilities: the planning and programming of the operation and centralized dispatch of energy generation aiming at the optimization of the interconnected electro-energetic systems, the supervision and control of the national interconnected electro-energetic systems and the international interconnections, the contracting and administration of transmission services, access procedures and ancillary services. These changes require that the Brazilian utilities make changes in their internal procedures to assure a continual, qualitative and economic supply of electricity to all users as well as the coordination of the installations to pay attention to the administration contracts of transmission services (CPST) and the Connection Contracts (CCT) to avoid penalties imposed by ONS depends on the unavailability of the equipments of the Base Network of the interconnected systems.

Eletronorte, aware of the need to review its internal processes, through the Direction of Production and Commercialization of Energy, initially decided to create the Department of Engineering of Operation and Maintenance of Transmission as well as the Center of Information and Analysis of Transmission (COT), inaugurated on March of 1999 in Brasilia, focusing on the new model of the electric sector. COT is interconnected to the Local System Operation Centers (COL) of the area covered by Eletronorte, and also to the Regional System Operation Center of the Northern Region (COSRN), Regional System Operation Center of the Southeast Region (COSR_SE) and the National System Operation Center (CNOS), both of which owned by ONS. COT concentrates all the supervisory information of the North/Northeast and North/South interconnected systems, updating all the information related to the operation of the system and installations using several tools that aid the managers to make their decisions, based on generated reports, forms and graphics. Several areas of the company also use these tools.
In 10/17/2000, COT received the NBR – ISO 9002 Certificate, and every certificated document is controlled by software named DINAMISO, used by all the Operation Centers of Eletronorte. Recently, management software for the supervisory and communication systems has been introduced in order to guarantee the availability of both data and communication channels in the whole area covered by Eletronorte.

The integration of the Management and Intervention System (SGI) of ONS with the Management and Maintenance System of Eletronorte, which uses the platform SAP/R3, is in its final stage of implementation.

2. GENERAL ASPECTS

The "Centrais Elétricas do Norte do Brasil S.A. - ELETRONORTE" is an electric energy utility which belongs to the ELETROBRAS System, the holding company of the Brazilian electric sector. ELETRONORTE is responsible for the generation and transmission of electric energy in all Amazonic Region, which corresponds to 58% of the Brazilian national territory, and comprises the States of Amazonas, Pará, Acre, Rondônia, Roraima, Amapá, Tocantins, Maranhão and Mato Grosso, as shown in the figure 1. The North - Northeast system is interconnected to CHESF, the Federal utility that serves the Northeast of Brazil. The Mato Grosso system is a part of the biggest Brazilian interconnected system, which embraces the Southeast, the South, and the Center East regions of the country. The North – South system is interconnected to FURNAS, the Federal utility that serves the Southeast and South of Brazil. The other four ELETRONORTE systems are isolated. The interconnected transmission system has radial characteristics with long transmission lines in 500 and 230 kV.

This system has three main Local System Operation Centers located in the states of Pará (COL-BE), Maranhão (COL-SL) and Mato Grosso (COL-CB). There are other Regional System Operation Centers in the states of Rondonia (COR-PV), Roraima (COR-RR), Amapa (COR-AP) and Tocantins (COR-TO). Figure 2 shows the control centers hierarchical structure interrelations adopted in the Eletronorte system with ONS and between COT and its isolated and interconnected Control Centers.

3. MANAGEMENT OF OPERATION SYSTEM
The need to follow the availability and operation of the systems in a more efficient way has led to the need to develop a faster and windows-based software, named Operational Informative (INFO–OPR), in order to make the acquiring and distribution of operational data through the corporate network of the company easier. Figure 3 shows the main screen of INFO–OPR.

The software presents the following characteristics: a) It receives and stores data of energy interruption and load, and hydrologic data from the interconnected and isolated transmission systems; b) It presents daily reports of Operation (DRO) and daily reports of Interruptions (DRI); c) Calculus of the performance indexes of the Systems and of the Installations according to what has been established by the network procedures defined by ONS; d) Calculus of the Variable Parcel, which is the penalty imposed by ONS if the contracted equipment breaks down; e) It provides standard and customized daily, monthly or yearly graphics, allowing comparisons with reference values; f) It provides single line diagrams of the Electric Systems, that can be zoomed in or out and printed; g) It makes available the registration of equipments and the relation between installations and main and secondary equipments; h) It allows full exporting of all the data to excel forms, defined by the user, who may use them for graphics (figure 5) or have a more specific use for them. The system stores data through a relational structure, like it is shown in figure 6.

The system has a database centralized in COT, in Brasilia, with operational information from all the interconnected and isolated transmission systems. The local systems have their own database, which makes the software flexible and quick, matching the needs of not only the operational areas but also of the maintenance and other areas of the company that have an interest to follow the performance of the systems. Figure 4 shows a graphic generated by the software that indicates availability of the equipments of the Base Network including the yearly goal defined by the company and the results from the last three years.
4. MANAGEMENT SYSTEM OF THE SUPERVISORY AND COMMUNICATION SYSTEM

To guarantee the operation of the electric system, it is necessary not only a good supervisory system that guarantees the observability of the system but also a fast and reliable system to the managers and engineers that need to transmit these information not only to the higher levels in the company but also to the external entities such as the National Operator of the System – ONS and regulatory agency like the National Agency of Electric Energy – ANEEL.

Eletronorte, in its Center of Operation of Transmission – COT, has integrated its real-time supervisory system, Open System of Energy Management – SAGE, to the corporative network through a web-based system, making available through its intranet important info, such as real and reactive power flow from interconnected system with other companies, generation from Eletronorte power plants and information from other transmission companies and power plants connected to its installations.

The system allows its user to keep a record of virtually every point monitored by the system using client-server architecture. The integration to the corporative network is done by access from SQL consults, using ODBC connections and the display of data is made through graphics, when dealing with analog variables, and through tables for digital events such as circuit breaker openings and the action of protections. With this, the engineers responsible for the analysis of events have quick and reliable access to the information from any part of the company.

The storage of historical data of the electric system is made in an Oracle data bank installed in a Linux platform. The software was developed using PHP language and made available through an Apache server that is also installed in a Linux platform. The clients can access the information through either Windows or Linux-based web-browsers.

The storage of information in the data bank is made by a process that is incorporated to the supervisory system itself, to guarantee the reliability of data. The sampling frequency of data is configurable to each variable of the system and for events it is also made by exception, i.e., the event is notified to the process that sends it to the data bank.

Although the updating rate of data is very quick, sometimes it is necessary to follow in real – time a maneuver that may present risks to the operation of the electric system. In these situations, it is necessary to have information from the supervisory system itself to analyze and make decisions that will not compromise the operation of the electric system. For these situations, terminal emulators were installed in the computers of engineers, managers and directors of the company, directly connected to the supervisory system through the corporate network. This way, everyone interested can visualize the system on real-time in their offices and watch the maneuvers being executed.

This solution also aids technicians and engineers that need to follow integration tests in remote installations and the beginning of operation of new installations without the need to travel to these locations.

To make this solution possible, a reliable telecommunications system was needed. So, a management system of the supervisory and communication system was developed to guarantee the availability of data and communication channels in the whole area covered by the company. Using both rented and owned telecommunications infrastructure to guarantee the needed availability, the management system of the supervisory and communication network monitors all the equipment involved in the supervisory process, sending alerts for events in the system such as loss of either a link or a router, or in loss of operation of a computer terminal. Figure 7 presents an overview of the management of the supervisory and communication system and figure 10 shows a dynamic screen of the Pará supervisory system.
The system uses the SNMP protocol to manage events and was also developed in a Linux platform. Besides the notifications, the performance records of equipment are also stored and several graphics are displayed, such as daily, monthly and yearly busy rate of links, number of collisions in the network, and broadcasts, among other variables, as it can be seen in figures 8 and 9.

As a consequence of the installation of this software, it was possible to verify how much band was being used in the communication links and to make decisions to reduce the bandwidth, reducing the cost of the rent of third-parties channels. Besides, the automatic notification of occurrences to the user has diminished greatly the time of unavailability of supervisory data due to the quicker action of the maintenance teams to not allow discontinuity.

For the calculus of availability of data on the supervisory system, a system similar to the one of historical data storage was developed. For this tool, it was decided to use a faster and lighter data bank, since the volume of data is much inferior than the one in the historical bank. Keeping the philosophy of using freeware, the data bank MySQL was chosen, along with the same developing tools used for the other systems, i.e., web server Apache, PHP language and client-access via browsers. The system uses the alarm files generated in real-time by the supervisory system that indicates unavailability of data and fills in the tables of the data bank. Whenever a client is connected through his web-browser and requests the display of availability of data, an application in the server selects and calculates individually the daily and monthly-accumulated availability up to the requested date from each existent link in the system. This way it is possible to follow the performance of the system connections and act not to allow that the index of availability does not get below the value demanded by the regulatory entities. Figure 9 shows a graphic of the connections availability.

Alongside the development of these tools, a system of search and recovery of documents (such as contracts, norms and procedures) was implanted to reduce the circulation of such documents on paper and to speed up the process of spreading internal reports among the several managements and also to provide a quick and efficient way of locating them. The documents were archived in PDF format and all the public documents were converted and made available for consulting and reference. Initially only the documents that were already in digital media were made available, while documents that were
not in a magnetic medium were slowly digitalized with a scanner. As a benefit of the implantation of this tool, we can mention the easiness of consulting documents and norms for the elaboration of reports and the consulting of contracts clauses that had been archived in files inside of closets as well. Besides, it is possible to consult these documents from anywhere within the company with no need to have a physical access to its location of storage.

Although it is simple, has a low cost and easy installation, the use of these tools has proven to be very efficient, allowing managers, technicians and engineers to make decisions based on reliable information and to make analysis in a safe way with the necessary speed and agility.

5. REAL-TIME AUTOMATIC VOLTAGE CONTROL (AVC)

The implementation of an advanced automatic voltage control can be considered a very important tool to remove any voltage limit violations and to guarantee the voltage quality delivered to the consumers. Considering a new scenario in Brazil due to the changes in electrical sector, AVC is necessary to achieve secure economic power system operation.

AVC was developed and implemented by Eletronorte own engineers to maintain the system voltages at levels closer to optimum throughout the day, according to the grid procedures set by ONS. The AVC project produces the following objectives to Eletronorte: increase system security and reliability, reduce demand on operators time for voltage control through automation, reduce operator stress when manual control is replaced by automatic control, brush up voltage security, increase the availability of transformers and autotransformers and optimize system operation. Figure 11 shows a block diagram where it is possible to observe a basic line of the automatic voltage control with remote automatic operation of the regulator equipment.

![Figure 11 – Basic Line – Automatic Voltage Control](image)

AVC permits remote automatic operation of the following equipments: synchronous condensers, shunt capacitors, shunt reactors and load tapchanging (LTC) power transformers and autotransformers. Initially, AVC control actions make adjustments at the terminal voltage of the synchronous condensers to match reactive supply to electrical system demands. The last action, if necessary, is to change tap position on transformers or autotransformers to flatten the transmission network voltage levels in an acceptable values.

The AVC project started in 1999 and it was totally implemented in state of Pará in 2001. Figures 12, and 13 show some results we have gotten with it. It will be implement in all Eletronorte substations.

![Figure 12 – Yearly accumulated duration of the Voltage out of range in hours](image)
6. MAINTENANCE MANAGEMENT SYSTEM

Eletronorte, searching for excellence and considering the new scenario of the electric sector decided to implement a new maintenance management system integrated to the financial management system as shown in figure 14. This system provides bidding information according to several parameters of control, on real-time, optimizing the decision-making. This tool offers: control of planned and unplanned interventions, statistics of autonomous and planned maintenance, statistics of the adopted maintenance strategy, statistics of the indexes of abnormalities, causes of unsolved issues after maintenance, three of failures of equipment and families of equipments, control of the maintenance plan, management of maintenance costs, control of the acquisition process of materials and management of the necessary time to execute the maintenance services.

Figure 14 – Integrated Maintenance (PM) Module to the Financial Module

7. ANALYSIS SYSTEM OF DISTURBANCES IN THE ELECTRIC NETWORK

In 1999, due to the new scenario of operation of the Brazilian electric system and new regulatory demands, Eletronorte began a process of acquiring a digitalized system of collecting and availability of the information related to the disturbance of the electrical system. The field information is related to transient signals of disturbance or fault, dynamic behavior of the system (voltage, power or frequency) or sequential events (relay contacts or devices of maneuver and protection). These informations are obtained through a network of Digital Registers of Disturbances and analyzed using dedicated software. Figure 15 shows Central Analysis Architecture.
With the progressive implantation of the Analysis Center the expected results have already been reached, there was a significant reduction in the lead-time and in the simultaneous availability of the occurrences information to the technical areas, as we can see in 16.

It can be seen that the period of analysis was significantly reduced, due to the potentiality presented by the digitalized information, with all the available resources of graphical treatments and manipulation of information. The reflexes on the analysis process have been of great impact, since the correct identification of abnormalities, which are the source of disturbances, has caused not only a reduction of the need to intervene with research tests in the field but also a reduction of recurring disturbances by the same cause.

8. CONCLUSIONS AND CHALLENGES

The creation of the Information and Analysis Center of Transmission has been very important to the following and evaluation of the systems performance and of the Eletronorte installations to guarantee full availability of equipment and transmission lines with quality, reliability and security, according to the contracts CPST and CCT. It has reduced financial and technical losses, contributing not only for more effective actions from the several areas of the company but also providing a better decision-making by managers, directors, engineers and technicians involved in the diverse processes of operation and maintenance.

The development and the implantation of the information management software (INFO – OPR) has been fundamental to follow the systems performance and to reach the goals defined by the directors in their yearly strategic planning, bringing reduction of losses and also actions that minimize future impacts in the company’s income.

The future integration of the management software of maintenance with the management software of operational information will be important, since it will become a single base for technical teams of the maintenance and operation areas.

The next challenges to be faced in the future by Eletronorte will be the implantation of the control system of equipment diagnosis that will guarantee a full performance of equipment based on a predictive analysis and the adoption of a knowledge management model integrating all the tools and software that exist in the Operation Center of Transmission.
9. REFERENCES

