BI & ANALYTICS FOR SMART PLANNING IN DISTRIBUTION SYSTEMS

Mário MIGUEL Filho
Daimon Eng. and Systems – Brazil
mario@daimon.com.br

Carlos César BARIONI DE OLIVEIRA
Daimon Eng. and Systems – Brazil
barioni@daimon.com.br

André MEFFE
Daimon Eng. and Systems – Brazil
andre.meffe@daimon.com.br

Wladmir SYBINE
Daimon Eng. and Systems – Brazil
sybine@daimon.com.br

Olívio CESÁRIO DOS SANTOS
EDP SP – Brazil
olivio.santos@edpbr.com.br

Eduardo DUTRA DA SILVA
EDP ES – Brazil
eduardo.dutra@edpbr.com.br

ABSTRACT

The objective of this work is to present the design, development and main results obtained in the definition and implementation of an IT solution for EDP's Brazilian distribution companies (EDP SP and EDP ES), whose main objective was to automate and integrate to the maximum the calculation processes performed by the various technical areas of the company, and enable the efficient sharing of relevant information, significantly increasing the quality of the studies proposed in each of these areas, besides the elimination of repetitive activities and the consequent misuse of hand of work.

The solution was also designed to produce results with a more managerial approach through extensive use of dashboards, causing relevant information to flow more smoothly and reach the various hierarchical levels of the company. Certainly the final product that this work deals with can be adapted and deployed in any other electric energy distributor, since the problems identified are general.

INTRODUCTION

Since the 1990s, several authors have addressed planning models for the expansion of the electric power distribution systems. At that time, when georeferenced databases were not yet widespread in the sector, it was common to use simplified models for network representation. With the passing of time and the emergence of these georeferenced databases, new models were developed, which started to use the specific data of these networks.

In this way, numerous developments were related to the planning theme. However, it is notable that developments often focused on specific points in the planning process, such as load forecasting (per feeder or geographic region), and models for substation, voltage regulator, or capacitor bank allocation. Models for prioritizing and selecting improvements on the network were also developed.

It is noticeable that the focus of those developments has always been the technical area of the distributors, so there is a lack of more strategic and corporate systems that allow a more effective interaction between the technical area and the direction of the company.

In a medium or large power distribution company, the various technical areas are dedicated to carrying out activities for specific studies, aiming to achieve a certain objective, such as network expansion planning, technical and non-technical losses estimation, protection coordination studies, among others.

Considering the origin of the information used in the tasks of each of these areas, and the nature of the electrical calculations required by the various technical studies, one can perceive not only a strong intersection between the large mass of data processed in each of these specific processes, but also cases where the activity of one area depends heavily on the results produced by another.

However, in spite of this strong dependence on information, it is difficult to find in companies' day-to-day a systemic integration between areas and processes, avoiding a standardized global analysis of the inputs and results obtained at the operational, tactical and strategic levels.

The two EDP companies in Brazil comprise 3.3 million consumers, 85 thousand km of MV and LV networks, 980 feeders, 209 thousand distribution transformers, 300 power transformers, 76 generators in the LV level, 16 generators in the MV level and 136 substations of distribution. These assets are represented by about 5 million nodes (bars) and 4.4 million network segments (segments).

The activities of this work were conducted in parallel with another large project carried out by EDP in the two Brazilian companies of the group: the updating of Technical Information Systems (SIT), which are the set of applications and technical attributes classified in entities for the representation, management and control of the assets of the distribution system.

The SIT comprises the georeferenced data, information history, network projects, quality tools, management reports and interfaces with other systems. This updating of the technical systems required the redesign of numerous processes and interfaces, as well as the re-adaptation of the hardware in general, which was the foundation for other procedural improvements to be evaluated and implemented in a complementary way to the main project.

METHODOLOGY

The development of the work was carried out through three main stages, which are described as follows:

Mapping information and processes

Initially, the technical areas that had minimally engineering-related activities were identified, to map the main information used and produced in each one of them, as well as the processes of electrical calculations with the potential to be automated and linked.
This activity had as main objective identifying activities performed in a repetitive way, as well as information with high potential of sharing between the several areas. For the survey and mapping of information and processes, the following activities carried out by EDP's technical areas were considered: planning, market, operation and maintenance.
In this stage of work, it was noticed the need to use a work database, considering only the electrical information relevant to the various electrical studies, allowing any corrections in the defective information to be done centrally and perceived by all the consuming areas without updating the source system (GIS) with those corrections.
Analogously, the measured information of the electric quantities was considered, such as active and reactive demands and voltages in each of the relevant equipment of the distribution network, such as power transformers, feeders, reclosing switches, among others, meaning that all the information necessary for the various studies were gathered in one place, called the *data bus*. Figure 1 below shows a simplified diagram of the final solution:

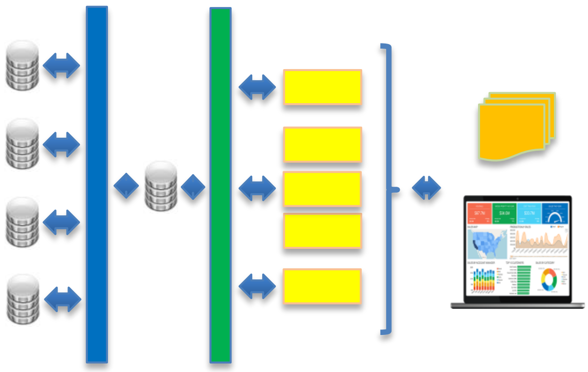

Figure 1: Simplified diagram of the solution

On the left side of the blue bar, the databases of the various corporate systems are represented, such as GIS, SCADA, SAP, etc. The blue bar represents the interfaces of the solution with these source systems, where the different connectors are located with these data sources, and where the initial transformations in the information are performed, updating the work database (*data bus*), indicated between the blue and green bars.
The green bar represents the *data bus* interfaces with the various calculation engines, represented in yellow, and where most of the business rules are implemented.
And finally, on the right side of the figure it is portrayed the indication of the main products generated by the solution, which are the various reports, thematic maps and dashboards associated with each specific process.

Modeling and implementation of calculation engines

Once the input data layer was defined, containing the necessary information for the various technical studies, the next step was to model and effectively implement the calculation engines, which allowed the automation of repetitive and basic activities, such as correction of topology information, treatment of measurements, calculation of power flow, calculation of technical losses, among others.
For each one of these engines a specific results database was also defined, in order to share the most relevant information among the areas, such as voltages in the bars for the power flow, and total technical losses per segment of the network. The following are the main calculation engines implemented, which were part of the final solution delivered to EDP:

Evaluation and sanitization of data engine

The large volume of data present in a GIS database, and the real difficulty in creating efficient and flexible business rules in this environment, mean that the topological data of a distribution company always has a considerable amount of registration errors. The same applies to measurements of electrical quantities, which may show values discontinuities in the range measured by data transmission faults, or even atypical values.
The database records evaluation engine was designed with the main objective of identifying the most common and relevant problems, and effectively performing its correction in the solution's work database, allowing considerable hygiene of the input information, thus ensuring better results. Among the main record errors, which have a direct impact on mapped processes and calculations, we can highlight the following:

- Incorrect phasing in network sections;
- Incorrect phasing in consumers;
- Existence of loops in radial feeders;
- Sections of isolated network (not energized);
- Nominal power of equipment not defined or incompatible;
- Incompatible electrical conductor with the network segment
- Incompatible values of nominal equipment losses;
- Incompatible values of the fusible links;
- Incorrect energy balance in feeders.

Power flow engine

From the work database, the power flow calculation is performed at each node and segment of the MV and LV

network, at each hour of the day, using typical load curves and measurements available in each one of the network equipment or even the consumers.
This way, a representative load curve is obtained for each of the power transformers and feeders of the distribution substations, as well as voltage and electric current values at any point in the MV or LV network. This process allows a daily operational diagnosis of the network, indicating in an objective and assertive manner the points where possibly the technical criteria of loading and voltage levels are being disregarded, indicating the possibility of punctual corrective actions.
In addition, this step will produce a picture of the present load of the distribution transformers, indicating the possibility of expansion through the connection of new consumers, or even the need to replace the equipment. Figure 2 shows 13-month historical results of a given distribution transformer, from the GIS interface:

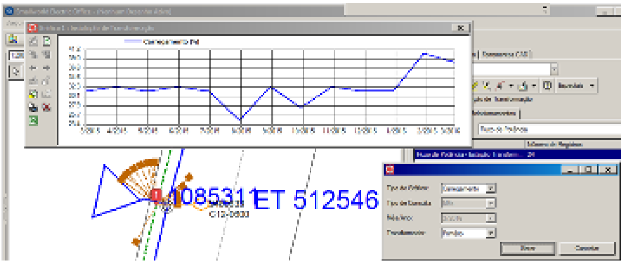

Figure 2: Load flow results in GIS

Technical and non-technical losses engine

The assessment of the amount of technical and non-technical losses was also a critical and relevant process in the information gathering and mapping phase, since it involved large amounts of money not accounted for by the company, mainly related to energy supplied but not billed.
This way, the engine for calculating technical and non-technical losses was modeled and implemented, based on network topology and energy measurements in the feeders, performing monthly estimation of losses in each of the MV and LV network segments. The percentage of losses in each one of the MV feeders is the main result of this process, allowing investigative actions to be directed to those with a high value of non-technical losses, for example, besides the indication of network segments and distribution transformers with overload.

Protection adjustment engine

This calculation engine performs the diagnosis of the coordination of the protection in the network, from the results of power flow and short circuit in the entire medium voltage network, indicating the zones of operation of each protection device and pointing out the existence or not of coordination and selectivity, automatically proposing adjustments for all protection devices that can be adjusted in the network, and indicating the need for changes of non-adjustable devices. It is also possible to perform the simulation in alternative topological configurations, different from the present configuration present in the GIS due to changes in the key states, previously informed by the user.

Planning studies engine

The main calculation engine, not only in terms of complexity but also the potential benefits to be obtained, was initially structured as an integration between the three calculation engines presented previously.
From the initial diagnosis of the problems obtained in these processes, and considering the load growth projections, among other inputs, the calculation engine proposes specific actions with the objective of improving operational, tactical and strategic indicators. Among the actions to be automatically proposed by the calculation engine, the following are highlighted:

- Reinforcement of network segments;
- Allocation of capacitor banks;
- Allocation of voltage regulators;
- Allocation of switches;
- Allocation of DG (Distributed Generation);
- Allocation of VPPs (Virtual Power Plants);
- Network Reconfiguration.

The actions for the construction of new feeders and distribution substations are proposed manually by the users, but they are considered in an analogous way to those proposed automatically by the solution in the prioritization process of the works, when the best set of actions proposed by the calculation engine is defined, maximizing the technical benefits and the return on investment, respecting the available budget.
In addition to this standard behavior of the calculation engine, the structure of an additional layer of intelligence was conceived, based on the use of BI and Analytics, allowing the creation of scenarios for the works in the network, considering diverse elements such as distributed generation, energy storage, free market, flexible tariffs, intelligent meters, among others, transforming the final solution into a smart planning system. This additional layer was not implemented during the project, given the budget constraints and deadline for execution.

New consumers analysis engine

In addition to the design and development of the aforementioned calculation engines, "*SeLiga*", a calculation engine already in place at EDP, was also refurbished within the scope of this project, allowing real-time analysis of requests for new connections made by clients at attendance.
From basic information such as the address of the new

connection and the estimated load, the process assembles the distribution network associated with the transformer closest to the given address, and through the execution of the power flow it identifies whether the inclusion of the new load brings some kind of violation in the technical criteria, indicating to the requesting consumer that a more detailed study should be carried out. *SeLiga* is activated by the attendant at the moment of demand and the response is provided within 8 seconds for loads below 25 kW installed.

Integration with legacy systems and processes

Once the construction phases of the calculation engines and work database were completed, the final stage of the work was dedicated to the assembly of the desired final solution, through the integration of each interface implemented with the respective existing corporate system.
Another point that demanded a great deal of attention was the chain of interdependent processes, as there were certain operational restrictions to be respected, such as the technical window available for extracting GIS data, for example.
The final activity of this stage was focused on the approval and validation of the results and processes, and consumed a considerable time of the teams in both sides (EDP and Daimon), having as main objective the guarantee of perfect operation and integration of the whole solution.

RESULTS

A solution of the size that was implemented in EDP, integrating several systems and processes, impacting so many areas and users, certainly brings a considerable number of benefits, but it is difficult to choose the most significant of them. However, as the main results of the solution implemented in the two companies of EDP the following benefits can be clearly indicated:

• Reduction of the use of engineers' workforce in ordinary and repetitive tasks, such as the transfer of GIS and SCADA information to specific computational tools of electrical calculation.
• Standardization and better sharing of information among the different areas and hierarchical levels of the company, ensuring greater agility in the execution of the main activities of each one of them.
• Execution of specific diagnostic processes, for the execution of objective actions of adequation.
• Use of BI in the execution of the planning studies, allowing a more comprehensive analysis of the scenarios, considering the impact of several factors not normally taken into account in the current studies.

In the following table, it is presented a summary of the main problems that were identified at the start of the work, showing the status “before” and “after” the solution was deployed:

Before	After
The same process was executed by several users.	A unique process has been defined, which is executed in a corporate environment.
The information was not shared in a simple and standardized way, and there was no systemic integration between the areas.	A results database has been created for each of the relevant processes, and any user / area can consume the necessary information.
Engineers' working time was used in activities of low value-added, such as in data transformation processes, for example.	Repetitive and low-complexity processes were migrated to a corporate level, leaving engineers' time available for more elaborate analysis.
The studies were not carried out jointly, and thus the case studies of planning did not consider variables in a broader way.	The use of BI in the scope of planning has allowed the creation of more elaborate scenarios, taking into account DER technologies and tariff aspects, for example.
Little or no transfer of relevant information to tactical and strategic levels.	Creation of dashboards and specific thematic maps, including consolidated information of the main technical indicators.

CONCLUSION

The work showed that, by analyzing and managing the technical processes and information in a global and corporate way, it was possible to optimize not only the use of IT resources as well as the time of the engineers, used primarily in analysis activities, and it also allowed a perceptible integration between the various technical systems, creating effective channels for sharing and transferring inputs and results.
It is also important to highlight that the solution developed can be applied in a standardized way in any other electric energy distributor, regardless of the GIS and SCADA systems that are used.

REFERENCES

[1] OLIVEIRA, C. C. B.; KAGAN, Nelson; GUARALDO, J. C.; HAGE, Fabio S.; MEFFE, A.; MIGUEL FILHO, M.: "INTERPLAN - A Tool for Planning High, Medium and Low Voltage Networks." In: IEEE/PES T&D 2004 - TRANSMISSION AND DISTRIBUTION, 2004, São Paulo.

[2] KAGAN, N.; OLIVEIRA, C. C. B.; ROBBA, E. J.:

"SISPLAN - metodologia de planejamento de expansão de sistema de distribuição primária de energia elétrica." In: SEMINÁRIO DE INGENIERIA DE POTÊNCIA IEEE CHILE, 4. / SEMINÁRIO DE DISTRIBUCCION DE ENERGIA ELÉTRICA, 1, 1994, Santiago de Chile.

[3] OLIVEIRA, C. C. B.; KAGAN, N.; MEFFE, A.; JONATHAN, S. ; CAPARROZ, J.; CAVARETTI, J. L.: "A new method for the computation of technical losses in electrical power distribution systems" In: CIRED - INTERNATIONAL CONFERENCE ON ELECTRICITY DISTRIBUTION, 2001, Amsterdam.

[4] MEFFE, A.; OLIVEIRA, Carlos César Barioni de; ANTUNES, A. U. ; BAUMANN, P. H. ; LANGE, F. L. ; UYEKITA, A. H. ; ANTONELLI, D. ; HAGE, F. S. E. ; DELGADO, M. A. P. ; FERREIRA, A. N. . Technical losses calculation using simplified models for regulatory purposes. In: 23rd International Conference on Electricity Distribution, 2015, Lyon. 23rd International Conference on Electricity Distribution, 2015.

[5] ANTONELLI, D. ; OLIVEIRA, Carlos César Barioni de; PEREIRA, D.; MEFFE, A.; WADA, R.. Determination of descriptive attributes used to calculate technical losses of medium and low voltage networks according to the Brazilian regulatory model. In: 21st International Conference on Electricity Distribution, 2011, Frankfurt. 21st International Conference on Electricity Distribution, 2011.

[6] DOMINGUES, Ivo Teixeira; MEFFE, A.; OLIVEIRA, Carlos César Barioni de; PENIN, Carlos Alexandre de Sousa ; TORRES, M. A. H. ; JONATHAN, Sunny. Previsor de energia em tempo real nas subestações considerando as perdas técnicas dos circuitos primários do sistema de distribuição. In: V CIERTEC - Seminário Internacional Sobre Gestão De Perdas, Eficientização Energética E Proteção Da Receita No Setor Elétrico, 2005, Maceió. V CIERTEC, 2005.