DASHBOARD AND SMARTPHONE APPLICATION TO SUPPORT OPERATION AND PLANNING OF ELECTRIC DISTRIBUTION SYSTEMS

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ABSTRACT

This article aims to describe a dashboard that presents relevant information to the operation, maintenance and planning of subtransmission systems, underground distribution systems and aerial distribution systems, developed as part of the "Smart Grid Project" of Brazilian utility AES Eletropaulo. Also, it was developed an application for smartphones containing information that were considered important to be viewed remotely by operators and field teams.

INTRODUCTION

The power distribution system of AES Eletropaulo currently consists of 152 substations, 38.352 km of distribution lines, 2.558 km of underground distribution network, 1.847 km of subtransmission lines and an installed capacity of approximately 14 MVA. To perform the supervision and operation of this extensive network, the company has continually invested in recent years in automation equipment and communication systems to acquire data and send it to substations and the operation center.

Data obtained from field equipment are sent to a SCADA (supervisory control and data acquisition) system installed at the substation level, and each substation send the collected information to the operation Center through a main SCADA system. The database used by the dashboard and the smartphone application is connected to the main SCADA system.

The dashboard presents the following features to users:

- Dynamic search system for substations and field equipment using Google Maps;
- Real time loading and frequency graphs of the electric system;
- Reports of equipment loading and voltage levels using graphs and tables;
- Real time visualization of existing alarms in the electric system;
- Log of events during a period of time;
- Graph plot application tool;
- Alarm message system that allows message exchange between operators and field teams.

The application for smartphones provides relevant information to remotely control and supervise the electric system. Among the information available on the dashboard, the following have been incorporated to the application:

- Dynamic search system using Google Maps;
- Reports of equipment loading and voltage levels;
- Log of events;
- Real time visualization of existing alarms in the electric system;
- Alarm message system.

This article presents the following topics: architecture of the system, data mining application developed in the project, results obtained for both the dashboard and the smartphone application and the conclusion.

ARCHITECTURE OF THE SYSTEM

Figure 1 presents the architecture and communication between systems to obtain the data presented in the dashboard and the smartphone application. Acquired data (analogic measures and status) from field equipment are sent periodically to the SCADA system located in the substation level before reaching the main SCADA system located at the control center. Every minute, the main SCADA sends an updated dataset to the database of the dashboard, which performs the storage and data processing through the data mining application developed in this project.

After a user request, the information from the database goes through a firewall that ensures network operational security, before being sent to the main server. This server sends information to both the dashboard server and the smartphone application server through webservice messages. Finally, those servers make information available to computers and smartphones connected to the operating network of the utility.

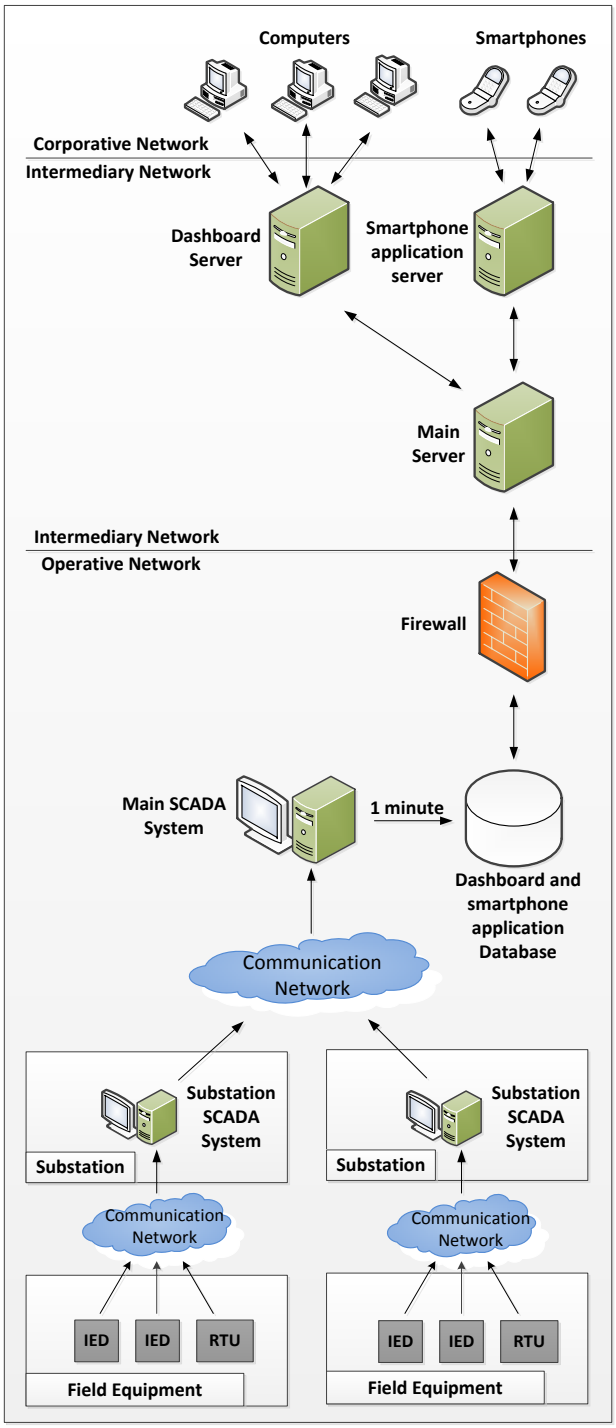

Figure 1: Architecture and communication between systems

DEVELOPMENT OF THE DATA MINING APPLICATION

Due to the large amount of data acquired from field equipment, it is interesting to have a resource to perform data analysis before it is presented to users. Thus, it is possible to decrease the data flow through the servers and even increase the amount of useful information made available [1]. With this in mind, a data mining application that performs data classification and summarization was developed in the project.

The other developments achieved during the project in both the dashboard and the smartphone application will be presented directly in the "results" section.

Data Classification

Data classification refers to organize information as normal or abnormal, according to various criteria [2].

This classification is performed using an algorithm that considers data from eight weeks prior to the current date, always using the same day of the week for analysis. It is worth mentioning that, as the data analysis is performed continuously, the eight-week dataset considered in the study is constantly updated over time. As a result, it allows the solution to identify a new topology of the network as the normal configuration after a certain number of weeks, when the measurement sample of this new configuration becomes more representative than the anterior one.

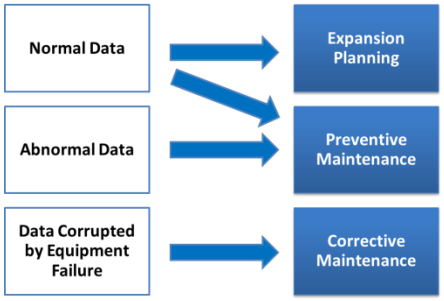

Figure 2: Data classification and its usage by each company sector

Data classification is important to provide useful information for different sectors of the utility, as shown in figure 2. For example, to execute the expansion planning of a substation or a distribution feeder, it is interesting to use just the data classified as normal. Without this distinction, abnormal data generated by temporary maneuvers, which may cause increased loading in a particular feeder, could signal the need for expansion of the grid, a different conclusion when using only the dataset for the typical configuration of this circuit.

On the other hand, for preventive maintenance, it is important to examine both normal and abnormal data, to estimate the efforts that the equipment was subjected to and determine an efficient maintenance plan.

Finally, the developed algorithm also identifies data corrupted by equipment failure. This data is used by people responsible for corrective maintenance of equipment and it is not shown to users.

Data Summarization

Summarization refers to organize data, presenting them in a way to facilitate the understanding by the user [2]. The data summarization feature has been developed to assist

the analysis of circuits and equipment with critical load. In addition to presenting the maximum loading and the time interval that the circuit or equipment was under loading violation (the limit value can be set by the user), it was implemented the calculation of a variable that determines the area under the loading curve and over the loading limit in a given period of time, which indicates the intensity of loading violation.

RESULTS - DASHBOARD

Dynamic Search System For Substations and Field Equipment using Google Maps

In the main page of the dashboard, it is possible to search for substations and field equipment using the "Google Maps" service. Figure 3 shows the search for automatic reclosers in the concession area of the utility.

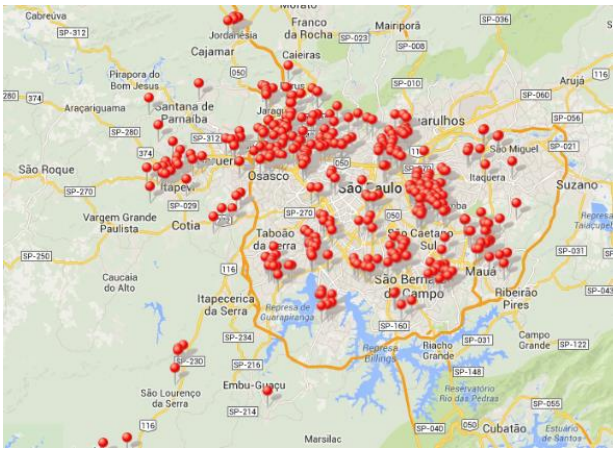

Figure 3: Dynamic search system using Google Maps

Also, it is possible to show multiple search results on the same map and use a filter to highlight (with a different color) the equipment with communication problems.

Real Time Loading and Frequency of the Electric System

Also in the dashboard main page, there are two graphs that provide real time information about the loading (MVA) and the frequency (Hz) of the entire system, as shown in figure. 4. In the loading graph, there is a comparison between the loading values at the present day (with real time update) and the values at the same day of the previous week.

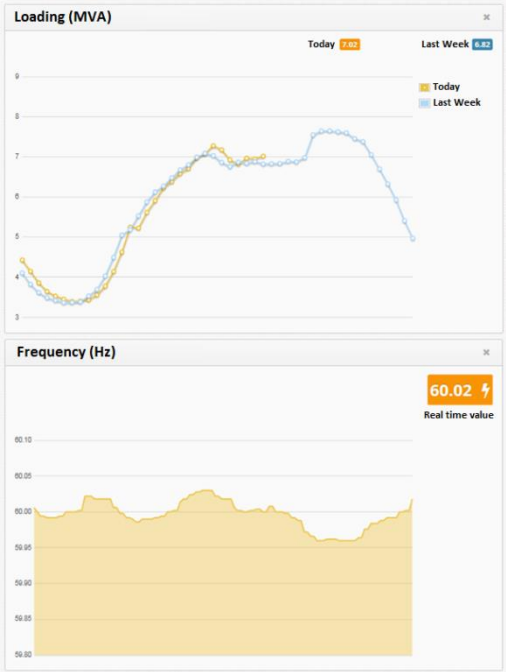

Figure 4: Real time loading and frequency information of the entire electric system

Loading and Voltage Level Reports

In this section, the user can generate reports with information about loading of transformers, feeders and subtransmission lines and voltage levels on distribution feeders.

For example, choosing the transformer loading report, it is possible to access an online report or an offline report with information from a certain period of time. In the online report, for each substation, it is presented: the number of transformers with loading equal or greater than 80% of the nominal value and the highest loading value (in percentage of the nominal value) between the substation transformers. Each substation is highlighted with different colors, according to the highest loading value between its transformers. Figure 5 shows the online loading report for transformers.

Loading - Transformers

Até 40% | De 40% a 60% | De 60% a 80% | De 80% a 100% | De 100% a 120% | Mais de 120%

Substation	Overloading Transformers	Highest Load Value (MVA)
DEMB	2	102.8
DGPR	1	94.85
DBAR	2	91.33
DVPA	1	86.5
DPEN	1	85.52
DITP	1	85.07

Figure 5: Online loading report for Substations and transformers

As shown in Figure 6, for each substation, the report presents the nominal value, the online loading and the loading in percentage of the nominal value.

DEMB

Equipment	Nominal Value (MVA)	Loading (MVA)	Loading (%)
TR1_SEC_B1	30	30.84	102.8
TR1_SEC_B3	30	19.39	64.63
TR2_SEC_B2	30	25.35	84.5
TR2_SEC_B4	30	17.29	57.63

Figure 6: Online loading report for a specific substation

In the off-line report, after selecting the time period for the study, it shows to users:

- Nominal value of the transformers;
- Highest loading value recorded in the chosen period;
- Total number of hours that the equipment was submitted to overloading;
- A variable that represents the intensity of the loading violation (as explained in the the data summarization section).

Figure 7 shows the off-line loading report for substations.

DBAR

Equipment	Nominal Value (MVA)	Highest Loading Value (MVA)	Overloading time (hours)	Intensity (Ah)
TR2_SEC_B2 [MVA]	27	27.42	0.28	0.06
TR2_SEC_B4 [MVA]	27	27.7	1.22	0.28

Figure 7: Off-line report for transformers

Alarm Message System

The alarm message system assists the operation and supervision of the electrical system. An alarm can be created by authorized users to communicate relevant information, or created directly by the SCADA system when an event is detected. Thus, with the initial alarm message and the subsequent comments, it is possible to monitor in detail the actions taken to solve the problem. Figure 8 presents examples of alarm messages and other features of this system.

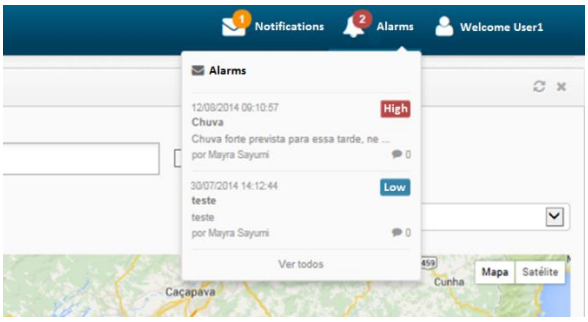

Figure 8: Alarm message system

Each alarm has a title, brief description and a classification by the severity of the event. When a new event happens, a pop-up message appears in the bottom of the page and it changes the event counter in the top.

Real Time Visualization of Existing Alarms in the Electric System

In this section, the user can access real time information about existing alarms in the electric system. As shown in figure 9, equipment in normal operating status are highlighted with the color green, while purple is used to highlight equipment in abnormal status of operation. The red box alongside the equipment status shows that there is a message about the abnormality written by an authorized user.

DASHBOARD - ALARMS IN THE ELECTRIC SYSTEM

Substation	Equipment	Status	Date and Time
DNMU	DJ17 NMU102 B2 13.8		08/08/14 09:42:27
DCAM	DJ49 CAM16 BF 3.8		08/08/14 09:36:39
DSAC	DJ13 SAC101 B1 13.8		08/08/14 09:22:17
DCAM	DJ50 CAM14 BF 3.8		08/08/14 09:21:43
DCTA	DJ17 CTA102 B2 13.8		08/08/14 09:17:22
SJUQ	DJ15 JUQ103 B3 13.8		08/08/14 08:54:09
DCLE	DJ22 CLE107 B3 13.8KV		21/07/14 16:41:05
DALV	DJ38 ALV114 13.8		19/07/14 09:12:56
DITP	DJ28 ITP100 B4 13.8		01/04/14 01:30:06
DMON	DJ19 MON112 B2 13.8		02/12/13 16:05:07
DLUB	DJ28 LUB100 B4 13.8		02/12/13 02:36:44
DLUB	DJ15 LUB113 B1 13.8		12/11/13 12:45:36
DTMR	DJ27 TMRVAGO B4 13.8		12/10/13 00:13:41
DSAM	DJ33 SAM FUT7 B5 13.8KV		04/09/13 11:32:26
DJAG	DJ27 JAG105 B4 13.8		24/07/13 11:16:29

Figure 9: Visualization of existing alarms in the electric system

Log of Events During a Period of Time

The user can search for all the events in a substation or equipment within a given period of time. As shown in figure 10, for each event, the dashboard presents the date and time of the occurrence, substation where it happened, type of equipment and a detailed description of the event.

Date and Time	Substation	Equipment type	Event Description
Buscar por Data e	Buscar por S	Buscar por Equipam	Buscar por Descritivo do Evento
2014-08-01 15:57:46	DTAM	CB	DJ11 BCA3 B3 13.8 EST Closed
2014-08-01 17:45:11	DTAM	CB	DJ11 BCA3 B3 13.8 EST Opened
2014-08-02 05:42:06	DTAM	AR	CBTA-DJ8 INT-B3-B4 CBTA Blocked
2014-08-02 05:42:22	DTAM	AR	CBAL-DJ7 INT-B1-B2 CBAL Blocked
2014-08-02 05:48:58	DTAM	CB	DJ5 TR1-SEC-B3 13.8 EST Opened
2014-08-02 05:48:58	DTAM	CB	DJ8 INT-B3-B4 13.8 EST Closed
2014-08-02 05:49:42	DTAM	AR	CBAL-DJ7 INT-B1-B2 CBAL Maintenance
2014-08-02 05:50:04	DTAM	AR	CBTA-DJ7 INT-B1-B2 CBTA Blocked

Figure 10: Log of events

Graph plot application

This application allows the user to plot graphs of loading and voltage level of network equipment during a period

of time, and also provides several tools for data manipulation. Data from field equipment are stored every minute and users can access information from the last two years in the database of the utility.

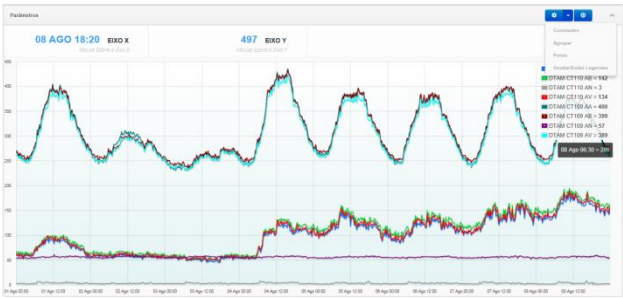

Figure 11: Graph of equipment loading using the graph plot application

RESULTS – SMARTPHONE APPLICATION

The application for smartphones provides relevant information to remotely supervise and operate the electric system. Among the information available on the dashboard, the following have been incorporated to the application:

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- Reports of equipment loading and voltage levels using graphs and tables;
- Real time visualization of existing alarms in the electric system;
- Log of during a period of time;
- Alarm message system.

Figure 12 shows the main menu of the application and the search system using google maps.

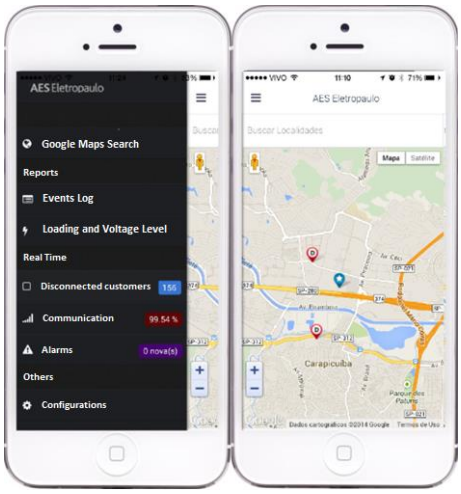

Figure 12: Main menu and search system of the smartphone application

From left to right, figure 13 shows the loading report and the log of events.

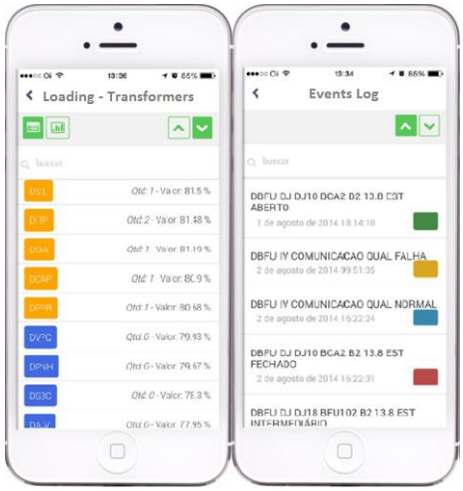

Figure 13: Screens (loading report and log of events) of the smartphone application

CONCLUSION

With the increased demand for electric power and the expansion of the electrical system to meet this demand, data collection and storage have grown exponentially in recent years. Thus, it is important to have applications that analyze the obtained data and provide relevant information for the various sectors of the energy distribution company.

Developed as part of the "Smart Grid Project" of the Brazilian utility AES Eletropaulo, the dashboard and the application for smartphones were developed exactly to present relevant information to the employees, contributing to increase the productivity in the their activities and to the company to provide adequate quality service to consumers and fulfill the regulatory goals established by the Brazilian regulatory agency (ANEEL).

The dashboard and the application for smartphones are concluded and the company workers have been using those features since the end of 2015.

REFERENCES

[1] C.L. Stimmel, 2015, "Big Data Strategies for the Smart Grid", CRC Press.

[2] S.C. Cortes, R. M. Porcaro, S. Lifschitz, 2002, "Mineração de Dados – Funcionalidades, Técnicas e Abordagens", PUC-Rio inf. MCC10/02.