Correlation Between Meteorological Conditions and Subtransmission and Distribution Networks Faults

L. C. Magrini, J. A. Jardini, Fellow, IEEE and C. A. B. Pariente
Escola Politecnica - USP - São Paulo, SP - Brazil

F. M. Cunha
AES Eletropaulo, São Paulo, SP - Brazil

Abstract. This work describes a correlation experience between meteorological data and occurrences of the electric network, arousing considerations about data particularities in their origin and the impact of such particularities in the physical dimensions of the database as well as in the performance of the queries that might be executed. Graphical and tabular queries offer an additional resource to the electric network dispatcher which has to promote the reconnection of the circuit that suffered an unexpected outage whose cause wasn't detected.

Keywords: Distribution Management, Electric Power Distribution, Power distribution faults, Service interruptions, Lightning data.

I. INTRODUCTION

In most cases of outages of the electric network it's not possible to identify the reason for it. This causes a great turmoil to the utilities as well as to the customers, for the last ones have to face the discomfort and even prejudice due the lack of energy and the first ones are forced to move vehicles and maintenance groups in order to travel along the circuit and try to discover the fault's reason.

The time spent in the attempt of finding the fault location over network, besides encumbering the utility due the sudden stop of the profits, brings serious damage to its image, worsening the supply technical quality indexes that are now monitored by the federal agency ANEEL.

Analyzing the outages experienced by a great utility's distribution network along 1999, it was observed that the occurrences amount of unknown cause oscillates between 20 and 30% per month, producing a medium value of 26,7%. This high percentage of unknown causes demonstrate its economical importance for the utilities, that after becoming private suffer even a greater pressure concerning the optimizing allocation of their economical resources. Therefore, to identify the causes of outages in the electric system can be a considerable contribution to promote the affected faster circuits reclosure.

II. OBJECTIVE

In order to provide the dispatchers with a computational tool for the analysis and detection of such sort of fault, a software was developed based in the AM/FM technology ("Automated Mapping and Facility Management") which can overlaps in a single graphic environment, the network topology and the meteorological phenomena mapped in the immediately previous and subsequent instants of the outage. The identification of atmospheric discharges or high intensity pluviometric precipitation in the neighborhood of the main extension, or in the derivations of the circuit feeder that suffered an apparent reasonless outage becomes an important indicative. Maintenance groups can be sent to the vicinity of the identified place in order to make a quick inspection and determine the possibility of damages in the network or in associated equipments, allowing a fast re-establishment of the energy supply.

If only rain was verified, without lightnings, dispatcher can authorize the immediate circuit reconnection, contributing to the improvement of the company's EFC (Equivalent Frequency for Consumer), since interruptions inferior to one minute are not considered in the calculation of such index.

In this article we'll discuss the elaboration of a correlation system between the electric system outages and the meteorological phenomena, that aims to become another tool available in the DMS (Distribution Management Systems) systems, and to support their decisions. To do that the system ponders:

- The electric network topology,
- The occurrences registered in the electric network,
III. DATABASES

As the equipments used in the electric power distribution are geographically dispersed, the distribution concessionary companies already have a computational structure that allows the storage and manipulation of a very large amount of information.

The main computational tool used is called Database Management System (DMS) and provides resources for the methodical and reliable storage of information concerning all the consumers and installed equipments, with every sort of details, from their electric characteristics to its geographical location, acquisition date, maintenance historical, etc.

Such storage needs can be supplied by a unique global database or by many different databases.

IV. OUTAGES DATABASE

This database seeks to store the electric system occurrences as well as the services accomplished for the re-establishment of the network and all the equipments and substituted components conditions. It also controls the activities of the maintenance groups.

The occurrences are stratified in the subtransmission primary and secondary classes, and to each occurrence is attributed a code that identifies its probable cause.

V. ELECTRIC NETWORK TOPOLOGY DATABASE

The database of the network topology seeks to assist the needs of the technical, planning, construction, supervision, control, operation, customer care and maintenance managements of an electric utility. To attend these needs the database stores information about the branches of the primary, secondary and public lighting distribution circuits. It also stores the characteristics of all the equipments and used components, such as pole, lamps, transformers, capacitor banks, reclosers, switches, etc., detailing to the electric power delivery to the customer.

VI. METEOROLOGICAL DATABASE

The meteorological data that are appraised in this correlation study include precipitation rates, atmospheric discharges, besides the air humidity, wind intensity and atmospheric pressure. Due their peculiar characteristics, these data are collected individually by several entities that maintain them in proprietary format and with variable acquisition periodicity.

A. Atmospheric discharges

The localization and mapping of the atmospheric discharges demand a specific infrastructure typical of Meteorology Centers. For instance, in the south of Brazil is located SIMEPAR (Meteorological System of Paraná) whose System of Detection and Location of Atmospheric Discharges is composed by a network of six detecting stations interlinked through a microwaves communication network with their headquarters in Curitiba where the collected data becomes available.

This system allows to detect not just the instant of occurrence of a lightning flash but also to evaluate their intensity and location in UTM coordinates, with variable accuracy due the location of the reception antennas.

The geographical location of the bolt is described by the coordinates (expressed in UTM) in the center of an ellipse, their semi-axes major and minor (expressed in kilometers) and the angle of the ellipse's inclination regarding the vertical axis.

This way, in each discharge, it's possible to register the instant up to nanoseconds accuracy, as well as its coordinates, intensity and the semi-axis of a probability ellipse which defines the region where the lightning may have fallen.

Each record also includes the rise time of the waveform (in microseconds from 0 to 99.9), the peak-to-zero time (in microseconds from 0 to 999.9), the amount of sensors used in the measurement and an indicator (flag) of clouds presence.

B. Atmospheric precipitation

Meteorological radars use electromagnetic waves of high energy that are partially contemplated by drops of water to determine the distance and intensity of the rain. Those reflectivity data feed computational programs that make the correlation between the observed drops spectrum and the corresponding precipitation rate at a level of constant height.

In São Paulo state, the meteorological radar belonging to DAEE (Department of Waters and Electric Power of the State of São Paulo) is installed in Ponte Nova's dam, in the municipal district of Biritiba-Mirim, covering an area of 129,600 km2.

Such radar is operated by the Hydraulics Center Technological Foundation (FCTH) and it offers a resolution of 2x2 km, with standard height of 3 km. Every five minutes a new picture of pluviometric precipitation is
taken, being attributed to each one of the matrix entries a representative value in a scale from 0 to 100 mm/h of rain. The data supplied by CTH obeys a proprietary format, consisting of binary files, due the great volume of data collected by the radar: the measurements are made every five minutes, for the whole metropolitan area of São Paulo, divided in pictures of 4 km², resulting in a matrix of 240 lines and 240 columns for each instantaneous measurement of 5 minutes. The 57,600 entrances of the matrix represent, in a scale of 15 values, the millimeters of rain per hour registered in the corresponding picture. A dummy value is used to indicate the absence of data, allowing the storage of all the elements of the matrix.

The data are saved in a file every five minutes, if at least one of the 57,600 matrix entries have some precipitation.

C. Meteorological data

The meteorological events are collected through terrestrial stations geographically spread and belonging to different institutions, such as airports, meteorology institutes, CETESB, SABESP, etc.

For this work, it was used the data supplied by USP's Institute of Astronomy and Geophysics (IAG-USP). These data present measurements for the period of 30 minutes every day and it regards: burst wind, maximum temperature, minimum temperature, humidity, wind speed and atmospheric pressure. For a single observation position located in USP's campus, the described data totalizes a maximum of 17,520 records for one year.

To these meteorological data was added the UTM coordinates of the measurement point, allowing the insertion of the same meteorological data from other sources (observation stations located in other points of the city), when they were available.

D. Relational Model

As the intention of the project is to establish the correlation between the electric network fault point coordinates and the meteorological events, it was considered convenient to associate to each record of meteorological data a primary key defined by the event's date and hour and also by the UTM's event's coordinates. Specifically for the lightnings, it was necessary to include also in the primary key the nanoseconds correspondent.

However, for the rain data such model demanded too much disk space for the database, because the data regarding the rain, that originally comes in a compacted binary format, when unpacked are saved as a record for each matrix entry corresponding to the 240 lines and 240 columns of the matrix generated by the radar. And even if it's not considered the inputs of the matrix without precipitation, the number of resulting records for each scanning of the radar becomes enormous.

As an example, for each one of the 1,055 files on September of 1999, 57,600 records were introduced with the same date and hour; and consequently the space used to store the data about precipitation in that month is around 300 megabytes, plus other 300 megabytes allocated by the indexes. That month was chosen by presenting the smallest level of atmospheric precipitation.

Another inconvenience is the low performance of the response time for the queries caused by the high number of records to be searched. Therefore, it was considered convenient to rebuild the database model in order to use a more compact storage format, save disk space and, consequently, to improve its answer time.

Among the alternatives for the new model, it was chosen the use of tables with LOB (Large Object Binary) fields which is a technology that allows to save binary data in the database. However, although it was possible to insert the data already compacted as it is received, it was necessary to uncompress it on-line when queries were made.

Therefore, it was decided to do a previous processing of the compacted files to generate the rain matrix of each one of them. This way each instant of the radar's scan would correspond to a single record and the LOB field would always store the 57,600 bytes representing the rain intensity registered in each matrix entry. With such modifications it was possible to reduce the requested space for a fifth of the value demanded by the initial model.

VII. APPLICATION OF THE CORRELATION

The intention of the correlation is to cross the outages of the electric network distribution and subtransmission with the meteorological phenomena, allowing the investigation of the possible outage origin.

Following the architecture of client-server database systems, an application was implemented in MS Visual Basic that provides human-machine interface with graphical and tabular resources. This client module allows the user to make consults about any of the following themes: coordinates of any point, substation, primary circuit, subtransmission line and high-tension customer.

For each one of these options the user will still define an interval of time for consult's the initial and final date and hour, besides the distance to be applied around the analysis point, defining the extension of the meteorological phenomena.
The atmospheric precipitation data that were collected for the whole area of São Paulo city offer an opportunity for wide correlation, but it must also be considered that the registered outages might have been caused by wind bursts that preceded the rain. Another point to be considered is the variation of the precipitation index along the time for a same area. Therefore, when trying to correlate the occurrences of the electric system with rain periods, it must be taken into account a time window that includes periods previous to the date of the outage record.

In the analysis of the atmospheric discharges it has to be considered the probabilities ellipse parameters of its geographic location. Tests shown that the calculation of that ellipse in the query resulted in a low performance because the semi-major axe of the ellipse can present dimensions of dozens of kilometers, what could involve dozens of matrix entries.

For this reason it was considered more convenient to calculate not an ellipse, but a circumference with the same center of the ellipse, leaving the user specify its radius. Such modification also allowed to make compatible the queries of lightnings with the consults of other meteorological events. So all the queries, of the point of view of the meteorological events, are formulated, in general, as searches around a point, following a radius specified by the user, as it is shown in the figure 3.

Initially the results of this kind of consults are presented as tables in the query developed in Visual Basic, as it can be appreciated in the figure 4. The results show all the records of meteorological events whose geographical location has intersected with the circumference specified by the user. Continuing the development it was implemented a graphic presentation that overlaps the meteorological events in a

![Fig. 1 – Overlapping of lightnings on some circuits](image1)

The consult defined graphically by the user is converted by the application in SQL commands that will be processed by the database server and returned in the form of occurrences details and meteorological phenomena intensity according to the entity whose coordinates were selected.

The meteorological data originating from of IAG-USP represent a special case regarding fixed stations atmospheric measurements that aren't always located in the proximities of the electric network. Being referred to a unique position, they can only be compared to the electric system occurrences of the circuits that attend the same area, which represents a very limited opportunity of analysis.

Even so, these meteorological data are very handful to determine electric network outages caused by a broken wire: defects of such sort can be caused by very strong wind bursts or for abrupt temperature variations.

![Fig. 2 – Overlapping of precipitation levels on some circuits](image2)

![Fig. 3 – Specification of the queries for coordinated UTM](image3)
map of the electric network to allow a visual analysis of the data, as it can be visualized in the figures, 1, 2 and 5.

**Fig. 4 – Presentation to tabulate the result of the query**

The case of the consults for primary circuit represents a specialization of the general query, commented above, around of the UTM coordinates. In this case, the server database is searched to determine all the outages happened in some point of the considered primary circuit; then, each one of these outages is associated to its UTM fault location; after that, the corresponding meteorological events are searched according to initial and final date/time criteria and a radius's specified by the user. The results of this query are finally presented, in a tabular format, as a main table that contains the entire electric network services records and auxiliary tables contain the meteorological events associates to the service selected by the user.

**Fig. 5 – Location of lightnings with the uncertainty ellipse**

**VIII. CONCLUSIONS**

This work describes a correlation experience between meteorological data and outages of the electric network, arousing considerations about particularities of the data in its origin and the impact of such particularities in the database size as well as in the performance of the possible queries that might be accomplished. Although our experience indicates that a solid volume of data implicates in a performance loss on the part of the query applications, it is possible to use technology of binary storage (LOB) in the database for best use of the storage space; at the same time, however, that alternative implicates in a treatment - and even a pre-processing - of the binary data. Other detail directly linked to the performance is the geometric particularity of atmospheric discharges that, though it can be exactly calculated, it can mask data that should be correlated with occurrences in the electric network. In such case, it's better to opt for the relaxation of the geometry to allow the query to provide a research much wider and precise. A detail of interest in the customer's application development is that though they represent the same data, results of queries presented as a graphic has much greater impact in the analysis than those presented as tables. In matter of fact, the visual analysis permit the correlation of an atmospheric discharges sequence by area with the protection of a transmission line; however, this kind of graphical interface requests geoprocessing technology, in general propietor, with the rising increase in the development costs and the application customizing necessary adaptation the such technology.

Finally, for a future development, it is convenient to consider the transformation of the correlation application to work on-line: in that way the dispatcher of the electric network would have the information right when the defect is communicated, being able to take providences in order to speed the reconnection of the affected circuits. For such an on line correlation it is necessary that the meteorological events data are always available in real time by the organs that collect them.

**IX. BIBLIOGRAPHICAL REFERENCES**

X. - BIOGRAPHIES

José Antonio Jardini, born March 27 1941, graduated at EPUSP- The Polytechnic School of São Paulo University in 1963. MSc in 1970 and PhD in 1973. Associate Professor in 1991 and full professor in 1999, all of them at PEA (The Department of Energy Engineering and Electric Automation). Worked at Themag Engineering Ltd in the area of power systems studies – lines projects and automation. At the moment he is a professor at the Department of Energy Engineering and Electric Automation where he teaches “Automation of the Generation, Transmission and Distribution of Electric Energy”. Represented Brazil at SC38 of CIGRE, CIGRE member, Fellow Member of IEEE and Distinguished Lecturer of IAS/IEEE.

Luiz Carlos Magrini was born in São Paulo, Brazil, on May 3rd, 1954. He graduated from Escola Politécnica da Universidade de São Paulo in 1977 (Electrical Engineering). From the same institution he received the MSc and PhD degrees in 1995 and 1999, respectively. For 17 years he worked for Themag Engenharia Ltda, a leading consulting company in Brazil. He is currently a researcher at Escola Politécnica da Universidade de São Paulo - GAGTD group.

César Alberto Bravo Pariente was born in Callao, Perú, on March 23rd, 1964. He graduated from Facultad de Ciencias Matemáticas de la Universidad Nacional Mayor de San Marcos in 1987 (Operations Research). He received his master degree from Instituto de Matemática e Estatística da Universidade de São Paulo in 1996. He is currently a PhD student at Escola Politécnica da Universidade de São Paulo.

Fernando Mirancos da Cunha received his Electrical Engineering Degree from the São Judas Tadeu University (São Paulo - Brazil, 1992). He also attended a post graduation course in business administration at Administration Institute, São Paulo University, São Paulo - Brazil, 1999. Have been working for 17 years at AES Eletropaulo, in the areas of Transmission Line Projects and Network Operation. Currently he is Technical Manager of networks operation department.