



Visual management of Sags and Incidents gathered in Distribution Substations for Power Quality Management

D.Macaya and J.Meléndez

Department of Electronics, Computer Science and
Automatics

University of Girona (UdG)
Girona, Spain

dmacaya@eia.udg.es, quimmel@eia.udg.es

J. Sánchez and M.Castro

Endesa Distribución SAU

Endesa

Barcelona, Spain

jlosada@endesa.es, MCastro@endesa.es

Abstract— Monitor a distribution network implies working with a huge amount of data coming from the different elements that interact in the network. This paper presents a visualization tool that simplifies the task of searching the database for useful information applicable to fault management or preventive maintenance of the network.

Fault management; Preventive maintenance; Data management; Visualization tools ; Casebased Reasoning

I. INTRODUCTION

Managing all the incidents that occur in a distribution network implies to work with a huge amount of data contained in several containers like databases, graphical data, registers, etc. Mining all these data in order to find useful information to improve the management of the network is a very time consuming process for the expert.

For a better data structuring and information visualization the information is presented in a timeline based visualization tool using a structure in the form of cases. Cases will be composed by the information obtained from the registers of incidents and sags of the distribution network, adding time as one of its attributes. This representation allows displaying the information in a more intuitive way for the expert comparing with those based on plain table representation, with several

added advantages like the possibility to establish a similarity measure between cases in order to retrieve the most similar ones for case comparison.

This tool has been developed in order to reduce the search time in the data mining process, present information in an easy way, make an on-line tracking of the network events, and predict future incidents. The final objective of this application is to provide a tool for the expert to monitor the distribution network and make a planning of the preventive maintenance of the distribution lines.

This paper describes the data gathering process of all the elements used by the tool, the visualization tool itself and some results from its application.

II. THE DATA GATHERING PROCESS

A. The distribution network

Data is gathered from the distribution network in Catalonia. The part of the network being monitored contains 162 lines registered by 24 power quality monitors that capture a wide variety of power quality events ranging in frequencies from DC to a few mega hertz. In this work power quality monitors have been considered located in the transformers of a substation (High Voltage /Medium Voltage) whereas protective systems

considered are those that are capable to send event information to operation centre.

B. Data gathered

Typical measured quantities in the power quality monitors are instantaneous voltages and current waveforms, fundamental frequency, power factor among of them. Thanks to the advances in data storage and software technologies, power quality phenomena manifested in voltage and current can be continuously measured and recorded resulting in a tremendous amount of data. In the order to reduce the size of these data which are COMTRADE format waveforms, a preprocessing algorithm is applied to convert them to database register. A Matlab based algorithm extracts attributes related to duration and magnitude of r.m.s. value for both single and three phase sags (See fig.1) . The result is later stored in an Access database and the graphical representation of the waveforms is stored in the form of a JPG image. In the visualization tool all these information will be called *Events*, because it represents the different fault attributes of sags registered by the power monitor. Attributes associated with sags usually are duration, voltage drop, time stamp, etc. [1]. [2].

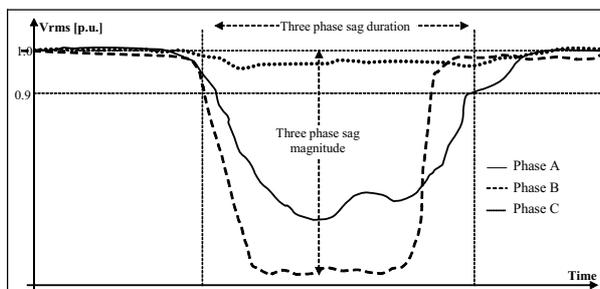


Figure 1. Event attributes in a three-phase voltage sag: duration and magnitude

On the other hand, protective systems based on digital relays are capable to report trips. Both registers are provoked by the presence of perturbations in the network, resulting in complementary information gathered by equipment far away from each other. Information related to protective system operation gathered by relays (or manually) is transmitted to control centre where they are stored as database registers databases. In the visualization tool these registers are known as *Incidences*.

C. Data conciliation

The stochastic nature of sags ([3]) makes feasible the assumption that sags are not concurrent (in time). Consequently, the registers of events and incidences can easily be associated according to their time stamp. In practice this is not always possible due to several drawbacks inherent in the utility installations and procedures:

- Inexistence of a unique temporal reference in the events: Every power monitor has its own clock that is

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synchronized once a month by modem. Although the system tries to compensate the delays, a variation (seconds or sometimes minutes) among clocks is always introduced.

- Different operation of protective system in the incidences: when protective systems are automatically tripped in presence of a fault, time stamp is correctly registered. On the other hand when operation is manual, usually provoked by (i.e., switches or sectionalizers) a programmed work or maintenance needs instead of a fault, incidences are registered with large and variable time delay (minutes) with respect to the event generation.

Notice that in the first case delay can be both positive and negative, whereas in the second situation usually is positive. Due to the variation between the actual clock time and timestamps of events and incidences, a conciliation algorithm has been developed to associate events and incidences depending on its timestamps and nature. This conciliation algorithm was already described in [4].

As a result of the conciliation algorithm several situations can be achieved according the nature and location (High Voltage/Medium Voltage/Low Voltage) of faults:

- Event – Incidence: Direct association of one event to one incidence, like a cause-effect relation.
- Events associated with multiple incidences: It can occur in both transmission and distribution. In such situations, time stamp associated with all these incidences must coincide exactly.
- Event without associated incidences: When the origin of the fault is located in points where information is not always available (Red Electrica, generation, short circuits in consumers, etc.) or when sags do not trip any protective system.
- Incidence without events associated: when sags are produced by programmed discharges in transformation centers, sags occurred in distribution lines different from which the transformer where installed, trip of intermediate protections in consumers (fuses) , and similar.

The visualization tool only works with conciliated elements (Events conciliated with one or multiple incidences) and only distribution (and clients) faults are considered. For this subset, it is possible to verify if the affected line corresponds to a line feed by the transformer where the power monitor that gathered the event is connected..

III. THE VISUALIZATION TOOL

An application has been especially designed to manage and analyze information related to voltage sags and associated incidences. The purpose is to assist substation management in the identification and location of faults in the network

facilitating the knowledge management in decision making. Consequently, the application is conceived to integrate and to exploit this complementary information registered during the occurrence of faults (events, waveforms and incidences).

The most relevant issue of this application is the utilization of a timeline presentation to treat information in a visual way, instead of using the table representation used in databases (Fig. 2).

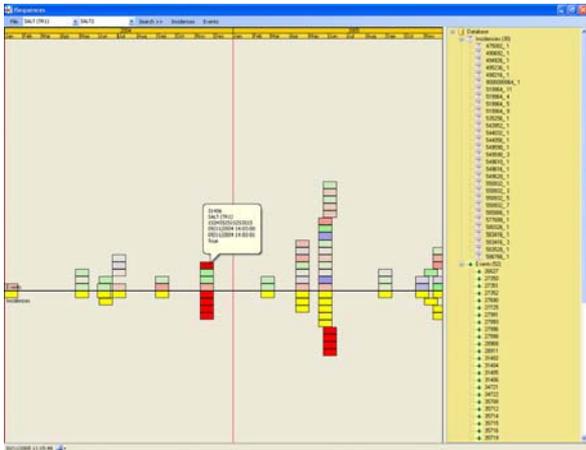


Figure 2. The visualization tool

A. Implementation of the application

The application has been designed in Visual Basic.NET due to the fact that the information provided by the electrical company was in Access database format and because of the facility to draw graphical elements in this environment.

The application acts as a graphical interface specially designed to interact with the database. By means of using different queries and different graphical objects present the information in an intuitive easy way.

B. Objects and controls

Several objects and controls have been specially designed for the application in order to improve the presentation of the elements:

- A timeline: Presents events or incidences in a timed representation. It allows zooming from years, because it is necessary to see the number of events or incidences occurred during a year, until milliseconds because it is necessary to see the order of very close events.
- A cursor: This element is present in the timeline control to select a specific date, event or incident.
- Events: Are designed as a button control with added attributes extracted from the correspondent register in the database. The most relevant attributes used are the identification number, the beginning time, the ending time, the power monitor which has registered the event and the shape of the event. The shape of the event will

be later explained because it is used to build sequences of associated events.

- Incidences: Like events, incidents are built as a button control with added attributes extracted from the correspondent register in the database. The most relevant attributes used are the identification number, the beginning time, the ending time, the line where it has occurred, and kind of incidence.
- A tree view: Shows all the events and incidents that are drawn in the timeline in ordered by date or by identification number.
- Filters: With such amount of events (nearly 16000) and incidents (nearly 10000) it is impossible to represent them all in the timeline at the same time. For such reason filtering is necessary. Filtering is done by power monitor, by line, choosing only the conciliated events and incidences, and choosing only those events registered in star configuration. Using this filter the items that are drawn in the timeline are reduced from 26000 items to approximately a maximum of 500 items at a time, increasing considerably the speed of the application while redrawing the controls. It also allows a better segmentation of the presented information, restricting the showed elements to one power monitor.

Through the beginning and ending time of events or incidences is possible to resize them according to the zooming window. Due to the nature of events (usually milliseconds) a minimum width in pixels has to be applied to the event control otherwise they will not be visible in the timeline.

Incidences and events have also been colored according to the attributes they have. This way, elements are distinguished faster.

- Coloring in incidences: Red color is chosen for registered faults. Yellow color represents registered trips of the protective elements. Blue color represents timed works in the network.
- Coloring in events: The coloring of the events goes directly associated to the shape attribute. This attribute is composed by a string which describes the behavior of the three phases during the sag. The coloring of the event has been applied using RGB color (Red – Green – Blue) depending if the first fault of the event is in phase 1, 2 or 3. The intensity of the color is defined by the length of the shape string. For instance: “2S3S1H1S” represents that phase 2 is in overvoltage condition, phase 3 also, phase 1 is in undervoltage condition and finally phase 1 goes to overvoltage condition. This string will have an intensity of 8 while a shape like “3H” will only have an intensity of 2.

The abstraction of the power monitors waveforms into strings has been done according to the methodology described in [5].

IV. APPLICATION OF THE VISUALIZATION TOOL

A. Event tracking and preventive maintenance

As explained before, Events have the shape attribute which describes the behavior of the sag. Searching the events drawn in the timeline which share the same color intensity retrieves all the events that share the same characteristics in length and first phase to fail. By doing this operation the tracking of events with the same characteristics will help us to prevent a future failure. On fig. 3 a typical failure is presented. After repeated events of the same type, including its associated trip incidences in yellow, the line leads to a failure, presented as several incidences in red.

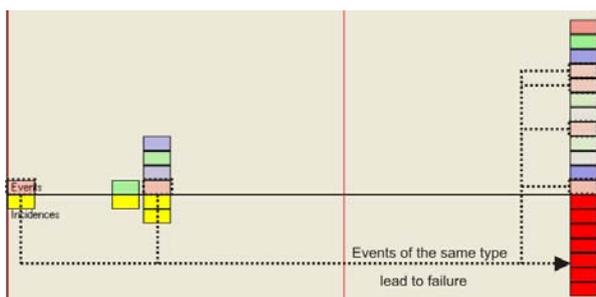


Figure 3. Events of the same type lead to failure

By observing repeated sequences of events of the same time allows predicting a future failure. As can be seen in figure 3 if preventive maintenance was applied after the appearance of the second sag the failure could be avoided, with the subsequent savings for the company.

Preventive maintenance will consist then in revising the protective elements corresponding to a line, depending on the repeated observed sags of the same type, which will correspond to observing similar waveforms on the power monitors. With the visualization tool this tracking is easily performed.

B. Case grouping for Case Based Reasoning

One step beyond is grouping these sequences of events to store them as expert knowledge for future exploitation in a Case Based Reasoning system.

Sags and incidents can be stored in a case container to report a particular situation (See Fig.4). These cases can be later retrieved to compare them with new situations in order to assess the possibility of having a future failure, or to determine the cause of sag with an unknown origin.

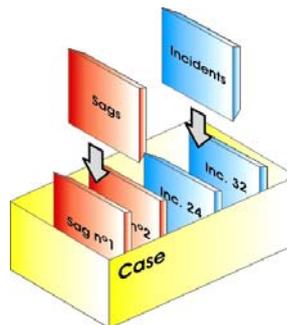


Figure 4. Sags and incidences could be grouped forming a case

The composition of these cases is obviously more complex than just using a plain database register, but it gives richer information. For that reason defining a similarity measure for the cases will be a complex task too, reserved for future improvements in the visualization tool.

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