A Survey on Voltage Dip Events in Power Systems

V. Barrera-Núñez, J. Meléndez-Frigola, and S. Herraiz-Jaramillo

***Abstract*— A general view of voltage dip analysis is presented in this paper. The objectives to perform voltage dip analysis, activities inside of this analysis and methodological aspects are described from a data mining perspective. Basic data mining principles were taken as the basis to identify similar steps in power quality works involving classification and knowledge discovery tasks. This paper is centred in voltage dip event diagnosis in order to reduce the study and focus the analysis.**

***Index Terms*— Fault location, voltage dip (sag), pattern classification, Power quality monitoring.**

I. Introduction

This article aims at surveying the techniques and methods used in the literature for knowledge discovery from registers of voltage dip event in power distribution networks.

Power quality data is generated at several locations in local utility's service territory, asynchronously during long periods of time. This information is continuously monitored and registered, causing a great volume of data [2]. Consequently, the amount of data is increasing daily, due to the advances in the data storage technologies too. The end-user has a large amount of data to assess and reduce the power quality problems. The technologies to transform in a short time raw data in knowledge or answers have been few developed. Hence, the new goal of monitoring systems is to transform automatically this huge amount of data into useful knowledge in order to assist the management of the network.

This paper is centred in voltage dip event diagnosis in order to reduce the study and focus the analysis. A review about the methods used to extract knowledge from dips registers is performed in this paper. These methods differ according the power quality monitoring goal but all of them follow data mining principles and steps [3]: (1) definition of the objectives for analysis, (2) selection, organisation and pre-treatment of data, (3) exploratory Analysis of data and subsequent transformation, (4) specification of the methods to be used in the analysis phase, (5) analysis of the data based on the chosen methods, (6) evaluation and comparison of the methods used and the choice of the final model for analysis, (7) interpretation of the chosen model and its subsequent use in the decision processes.

This work is part of a research project conducted by the University of Girona, Spain partilly supported by the Ministry of Education and Science – MEC under the project DPI2006-09370 and ENDESA DISTRIBUCION.

The authors are with the eXiT Group in the Institute of Informatics and Applications of the University of Girona, Spain, Girona, Campus Montilivi, 17071, e-mail: vbarrera@eia.udg.es, quimmel@eia.udg.es, sherraiz@eia.udg.es.

II. Data mining for analysis of voltage dips

In this section, the basic steps of data mining are used as guideline to survey the existing literature related with characterization and classification of voltage dips.

A. Definition of the objectives for analysis

1) *Objective 1: Determine the underlying cause or causes that led the voltage dip event:* Papers trying to achieve this objective are few in comparison with those focused on the classification of power quality disturbances (dips, swell, harmonics, etc.). From our point of view it is very important the development of techniques to infer the underlying causes of an event from its register and knowledge on the power system. The difficulty in this development is because analysis of dips is usually done without taking into account additional information of the power system (typology of loads, incidences registered at the same date and time, firing protections, etc.). On the other hand major efforts have been put in the classification of disturbances [4].

2) *Objective 2: Determine the location of the voltage dip origin.* This objective is treated under two perspectives: the first one tries to determine an *accurate location* of the voltage dip origin whereas in the second group of works, location is reduced to identify the propagation direction to determine the origin upstream or downstream with respect to the register equipment (*relatively location*).

3) *Objective 3: Assess the power quality.* Voltage dip events are being used to evaluate the vulnerability of the industrial equipments and to define power quality indices. For example, dips duration and depth are depicted in the ITIC[1] and CBEMA[2] curves to compare them with the sensitive curve of the equipments; the sensitive curves are supplied by the manufacturer of the equipment. To achieve this objective it is not required to perform all data mining activities. However, selection, organisation and pre-treatment of data before building the CBEMA and ITIC curves should be performed. A method to estimate the area of vulnerability due to voltage dip events in meshed network from ITIC curve is presented in [7].

B. Selection, organisation and pre-treatment of data

Many studies with synthetic data have been performed by the researchers. This situation is comprehensible due to the

[1] ITIC - Information Technology Industry Council
[2] CBEMA - Computer Business Equipment Manufacturers Association

difficult to obtain raw data [4]. Also when raw data is available information richness is poor due to lack of variability on them. In this context, many works dealing with synthetic data avoid the tedious tasks of preparing, organizing and selecting (or filtering) the data to be used in the subsequent inference. This implies an additional problem in transferring research result obtained with synthetic data to the utilities since these steps have to be made when dealing with real and they are not trivial.

C. Exploratory Analysis of data and subsequent transformation

This activity focused on the treatment of dips is used to calculate attributes extracted from time signals and RMS sequences. Authors refer to the output of this processing as: features, indices or descriptors. These features are calculated to describe the behavior of the dip event waveforms. The features are defined in order to be representative of hidden information contained in waveforms. Therefore, a selection procedure has to be performed to take into account the representatives of those features with respect to desired goals.

Some authors propose a segmentation of the waveform to distinguish steady or stationary behaviours from the transients or non-stationary parts [5].

Later, the Exploratory Data Analysis is performed with the existent data base in order to find out relations or common behaviors contained in the whole data base.

D. Specification of the methods to be used and Analysis of the data based on the chosen methods

From this activity a model based on the available data will be obtained. Then, it is important to select the appropriate technique according to the desired goals (location, classification, etc.). In order to achieve the first and second objective, multiple methods have been used:

1) Strategies used by the researcher to achieve the objective 1 - Underlying cause: In the literature few papers about treatment of dips to infer the underlying causes have been found. A methodology to determine the cause that produces a voltage dip event in [6] is presented and tested. The methodology is able to discriminate if the dip is led for an induction motor, transformer or line fault.

2) Strategies used by the researchers to achieve the objective 2 - Source location: According to the objectives described in the section II, the dip source location results are given in two ways, so accurate or relative location is obtained. The source relative location will not be described here, because the relative location through several methods are being obtained, which from voltage and current waveforms determine the relative location, hence the data mining is not require to obtain it. The accurate source location methods for the same reasons will not be described either.

Three general strategies are being used by the researchers to find out the *accurate location* of the voltage dip source.

i. Using deterministic and statistic classifiers: This is the strategy widely used to classify power system events. When the amount data is limited, the deterministic classifiers are used; on the contrary, if the amount of data is large, the statistical classifiers are convenient use them [4].

The voltage dip *statistical classifiers* are conformed by one or combination of techniques based on statistical learning theory, for instance: Artificial Neural Networks – ANN (RBF), Support Vectorial Machine – SVM, Learning Algorithm Multivariable Data analysis – LAMDA and Finite Mixtures.

The voltage dip *deterministic classifiers* most common used are: expert system and fuzzy logic. A comparison between a deterministic classifier based on expert system and statistical classifier based on SVM is presented in [4].

ii. Making matching data or features: This strategy consists in matching extracted features from registered data and extracted synthetic feature from simulation tools. The source location will be determined by the simulated signals that best match the recorded ones.

iii. Using the network topology continuously: The difference between this group with the first and second group is that the others use the network topology one time; due to these need the network topology to generate the synthetic data only. The strategies in this group estimate the source location from a tree that represent the network topology, so synthetic data do not required for these strategies.

III. CONCLUSION

Nowadays, the main objectives which the researchers are analyzing voltage dip were identified. In the first objective, the classifiers commonly used to extract knowledge of the voltage dip events are: SVM, ANN of radial-basis function, LAMDA, Fuzzy logic, Expert systems and Finite mixture distributions. With few exceptions, the most papers propose methodologies to discriminate between the different power quality perturbations (harmonic, swell, dip, flicker, etc) and do not propose methodologies to determine the underlying causes that led a voltage dip event.

Due to the difficult to acquire raw data, the most studies with synthetic data are being performed. The use of synthetic data should avoid because reduce the applicability of the resulting classifier.

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