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CURRENT MAINTENANCE USING GEOGRAPHICAL INFORMATION SYSTEM, PART OF THE GLOBAL SMART-GRID TECHNOLOGY SOLUTION

BY

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Abstract. The Electric Distribution Grid becomes more intelligent and more complex. From the design phase to the exploitation phase, there are different methods to approach the problems related to reliable, safe operating substations. The link between these stages is – or should be – the maintenance strategy applied to the electric energy distribution subsystem components. The main aim of the paper is to present a case study regarding a way of implementing a Reliability Centred Maintenance (RCM) program in an electric distribution company using a Geographic Information System (GIS), as part of the global smart-grid technology solution.

Key words: equipment evaluation; failure mode; geographic information system; reliability centered maintenance; smart grid.

1. Introduction

As concepts like “maintenance” and “maintenance management” evolved, there have been developed flexible methods, tools and techniques to realize better economic improvement (Collier, 2010; Jiyuan & Borlase, 2009;

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Hassan, 2010; Ipakchi & Albuyeh, 2009; Mallet *et al.*, 2014). A smart grid is a re-engineering electrical grid that uses information and communication technology for improve the efficiency, reliability and sustainability in power engineering. The recognition that the relation between ageing and maintenance is not simple, on one hand, and statistic studies showing that 80% of the lifetime cycle cost is determined in the designing stage, on the other hand, led to a re-evaluation of the traditional maintenance (Costinaş, 2007). Nowadays, maintenance and diagnosis tasks can be simulated using prototypes or models, failure analysis of safety-critical and mission-critical equipment in order to guarantee the maintainability (Drescher, 2003; Cai & Chow, 2009). In regard to the changes on the electric energy market it is imperious to put into practice the outcomes of these studies. Integration is key to Smart Grid management (Roncero, 2008).

2. Reliability Centred Maintenance. Overview

Maintenance has traditionally concentrated on preservation of equipment while Reliability Centered Maintenance (RCM) removed its focus to preservation of function. RCM considers not only the parameters describing the reliability of each part of the equipment (conditional probability of failure, failure rate, availability, reliability), but studies the dynamic behavior of the electric distribution system. The change of effort from equipment preservation to preservation of function led to critical operations monitoring and – as a consequence – to critical equipment monitoring (Moubray, 1997; Tapper, 2003).

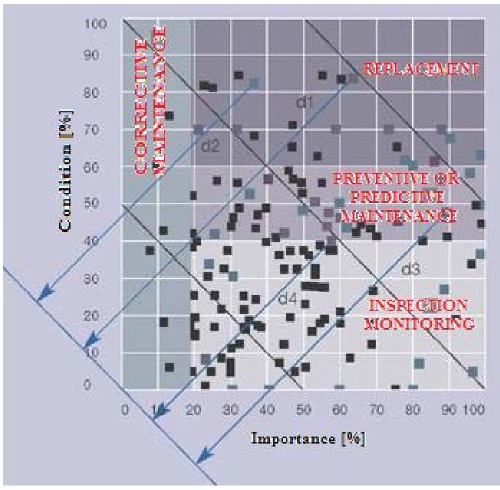

Fig.1 – The equipment evaluation with decision diagram CALPOS®-Main.

A simplified model containing the steps to be followed for the maintenance tasks selection was built by the Swedish experts, in order to minimize the initial work for the network companies. The RCM strategy, applied to an entire network, has been developed by EnBW (Germany) and implemented in software named CALPOS®-Main (Wang *et al*., 2004). The main procedure of RCM connects the evaluation of the equipment's technical condition with its importance within the network (Fig.1).

Because RCM's goal is preservation of function, it is necessary to create a hierarchy for the system's functions, equipment's and failure modes on a failures consequences basis, in order to correctly assign maintenance budgets.

According to Cai & Chow, (2009), when the loss of a function occurs, the effects of the failure may differ depending on one's frame of reference (*local effects* observed at the failure site; *system effects* are those impacts which affect the substation or electrical system; *remote effects* are those effects on equipment and systems outside the boundaries being analysed.

RCM's goal is to classify likely failures as *functional failures* or *potential failures*. The potential failure represents an identifiable physical state indicating an impending functional failure.

The steps for RCM implementing are (Costinaş, 2007): identifying the analysed system's boundaries; analysing the operational context (substation's diagram of connections); identifying the equipment's' functions; building the physical and functional diagram; identifying the specific failure modes; analysing the failures' consequences on the reliability of the power distribution system; identifying the components that are critical to the operation of the substation; analysing the failures' features; selecting the tasks for the maintenance team.

3. Geographic Information System. Overview

A generation of graphics software was developed – the Geographic Information System (GIS) – in which the data are visualized, explored, queried and analysed geographically (Longley, 2006).

GIS handles graphic and non-graphic data contained into a unique and non-redundant database namely: *spatial data*, containing the geographic location of features on the Earth's surface (co-ordinates), connected with alphanumeric descriptive data, stored in attributed tables; *image data* (photographs, graphics, scanned documents) associated to spatial data; *tabular data* in various formats, the SQL (Structured Query Language) access to external databases being carried out according to the ODBC standard (Open Database Connectivity).

A GIS provides capabilities to manage the connectivity of linear and point facilities through a configurable set of graphic and logical rules that defines how the electric network facilities connect to each other. Connectivity rules provide definition in terms of what facilities can or cannot connect to others, where they can connect and what actions are to be performed when they connect. Most of the great electric energy generating, transmission and distribution companies in the world – but especially the distribution companies

– became dependent on using GIS, both for day-to-day network operating and network extending planning or maintenance planning (Zorrilla, 2011; Ma *et al.*, 2011; Sinoda *et al.*, 2012). That is why some GIS developers created dedicated software modules for electric distribution.

4. Case Study: Using GIS for Electric Distribution Networks Maintenance Planning

From over 950 substations with rated voltages of 35 ... 750 kV operated in the Romanian energy system, about 90% are 110 kV substations. Maintenance planning for electric distributed grid has two types of activities: strategic planning and operational planning.

In this paper is presented a sample from a city's electric distribution network, starting with the 110 kV underground cables supplying a 110 kV/MV substation, passing through the medium voltage distribution network and ending with the consumers supplied at low voltage, showing how are related to one another the objects representing equipment or electric lines.

The 110 kV underground cables displayed on the map in Fig. 2 are represented as incoming circuits in the single wire diagram of the 110 kV/MV substation. The correlation between these two graphic objects representing the same physical object, is made through a unique identifier (ID).

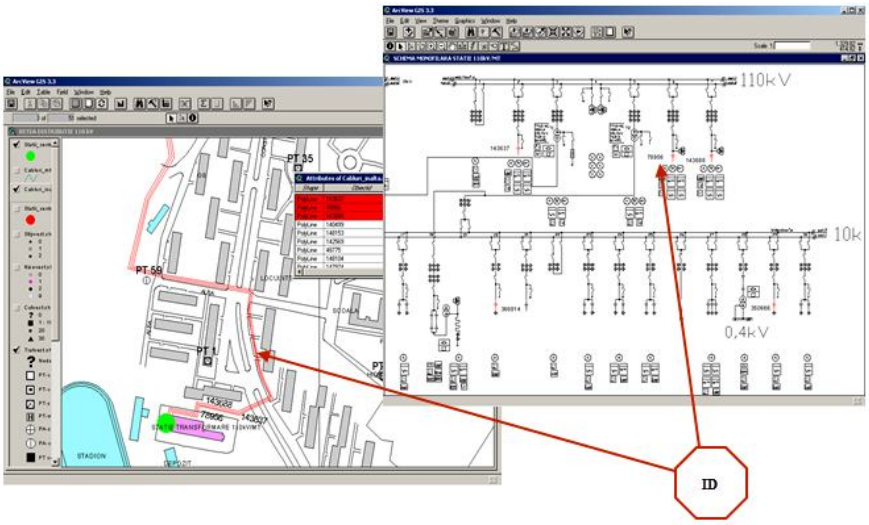

Fig. 2 – Correlation between geographical representation of the 110 kV underground cables and incoming circuit in the single wire diagram of the 110kV/MT substation.

The 110 kV busbar is connected to the medium voltage bus bar through the substation's 110 kV/MV transformer. The outgoing circuits of the substation's MV bus bar system have the same ID with the feeders supplying the transformer points (Fig. 3).

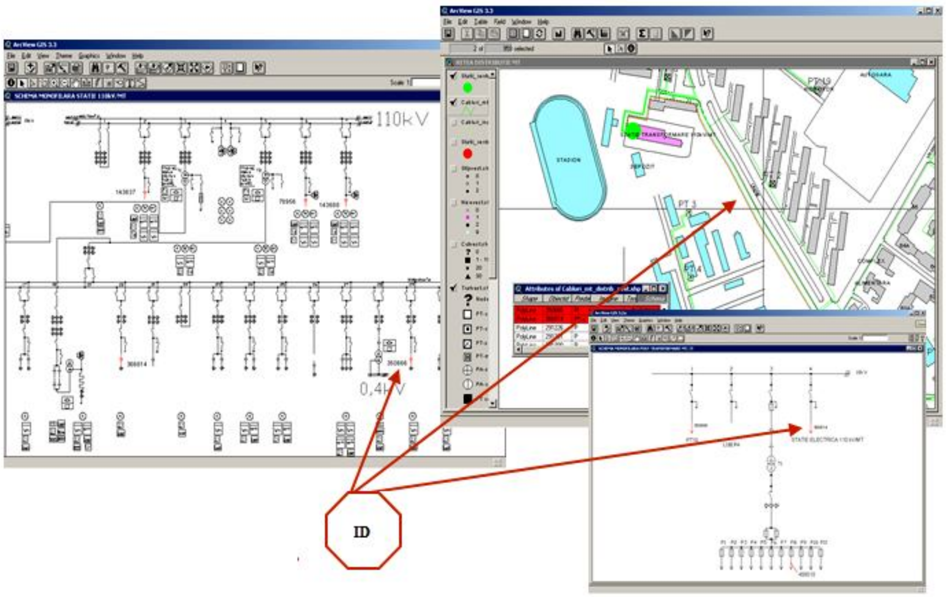

Fig. 3 – The outgoing circuits of the substation’s feeder bays have the same ID with the feeders supplying the transformer points.

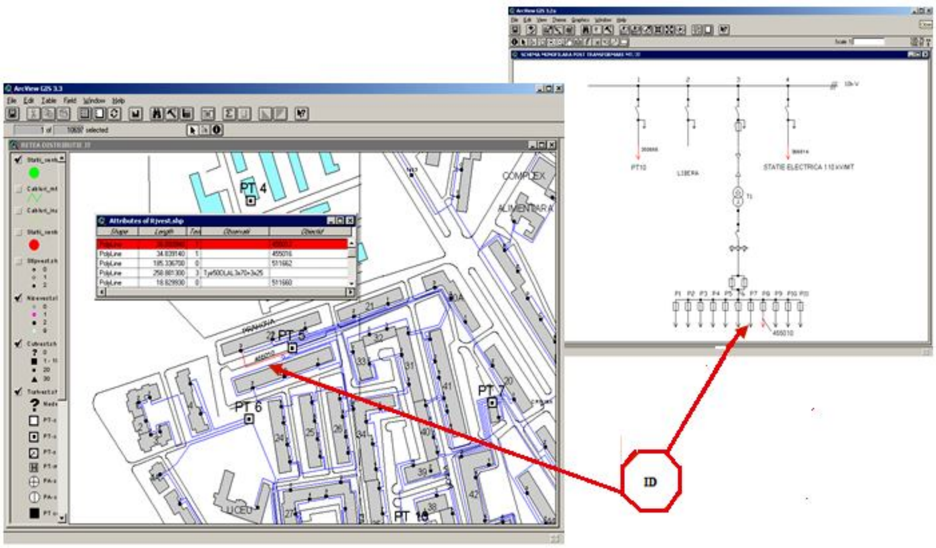

Fig.4 – The low voltage (LV) outgoing circuits of the transformer point have the same ID with the LV cables supplying the LV consumers.

The feeders have the same ID with the medium voltage (MV) incoming circuits of the transformer point. The LV outgoing circuits of the transformer point (supplied through the MV/LV transformer) have the same ID with the LV underground cables supplying the LV consumers (Fig.4).

In order to obtain an appropriate model of the electric distribution network, there must be analysed each component's function, as well as the information required to define the component's (status) (Hassan, 2010).

For example, switches allow current interruption to permit system maintenance, redirecting current in case of emergency or to isolate system failures. There are a number of steps to be followed for modeling a switch, which is a critical element of the electric network:

1. Making a list of the processes and activities that a switch participates in and how it is operated.

2. Describing in which way switches are used in the electric system.

3. Specifying the manufacturer's data for the equipment (rated current, rated voltage, breaking capacity, type, the manufacturer, etc.) and the operating data of the equipment (installation date, position of the switch – normal and present, a history of the maintenance task and repairs performed on the switch, a history of incidents, a summary of the checking reports, technical revisions reports, overhaul and rehabilitation reports for the equipment, etc.). Because GIS provides a geographically oriented view for the facilities, there must be made a difference between the map location and the physical item of equipment installed in that location at a specific moment. A piece of equipment may be installed in one location, removed (for different reasons), and then re-installed in another location. In order to develop an efficient maintenance program, it is important to keep an event history, both for the asset and for the facility location.

Therefore, there must be an event history record between the facility and the asset. Significant events include installation, removal, repair, inspection, and maintenance activities. By associating these historical records with both the facility and the asset (Cai & Choi, 2009) namely:

a) all maintenance work performed on a specific asset can be retrieved, regardless of where it may have been installed;

b) all of the maintenance work performed at a facility location can be retrieved, regardless of how many individual items of equipment have been installed at the location.

Using a geographically oriented representation of the electrical distribution network, an accurate study of different failure effects can be performed – from both technical and economic points of view. Using the electric network model, failure simulations can be performed, in order to create a better hierarchy of the equipment – assessing the impact of equipment failures on distribution network (unsupplied electric energy during breakdown, identifying the affected geographical area). Another useful GIS application is locating on the map the assets requiring inspection or maintenance work in order to develop optimized scheduling and routing for the work to be performed.

5. Conclusions

Fault detection, isolation, service restoration, integrated voltage/var control, RCM is an efficient management tool. For now, RCM methods are not used on a large scale by the electric energy transmission and distribution companies, even if RCM's efficiency is well known.

The implementation of RCM methods demands information about the operating system and the potentially critical events. RCM performances allow reducing the maintenance costs, without reducing the safety. That is why companies from various fields adopted RCM for asset management, in order to achieve their specific goals.

The effective use of a GIS coupled with a carefully designed asset database can enhance the effectiveness of the operation and maintenance for the electric distribution networks in many areas, such as:

a) keeping up to date the geographic database for the electric utilities;

b) tracking full asset lifecycle performance and history;

c) analysing routing for inspection and maintenance work;

d) getting information for asset management;

e) assessing the impact of equipment failures on distribution networks;

f) forming a basis for a more effective RCM program;

g) optimize grid operations and asset management by exchanging information between RCM and GIS;

h) reduce the number of unplanned outages and minimize the impact of all outages.

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MENTENANȚA UTILIZÂND SISTEMUL DE INFORMAȚII GEOGRAFICE, UNA DINTRE SOLUȚIILE TEHNOLOGICE PENTRU REȚELE INTELIGENTE

(Rezumat)

Rețelele electrice de distribuție devin din ce în ce mai inteligente şi mai complexe. Intre faza de proiectare şi cea de exploatare, există metode diferite de abordare a problemelor de fiabilitate şi de operare în siguranță a stațiilor electrice. Legătura dintre acestea este, sau ar trebui să fie, strategia de mentenanță aplicată componentelor rețelei de distribuție. Principalul scop al articolului este de a prezenta, pe un studiu de caz, implementarea unui program de memtenanță centrată pe fiabilitate utilizând o altă aplicație – sistemul de informații geografice, ca parte a soluțiilor tehnologice globale pentru rețele inteligente.