ISOHEP - INTELLIGENT MAINTENANCE MANAGEMENT SYSTEM FOR CROATIAN NATIONAL ELECTRICITY (HEP)

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Abstract:
The foundation of the system lies in a technical database containing all the data relevant for the maintenance processes. ISOHEP helps the users to plan maintenance activities, to store and analyze the information about maintenance process. The outage management subsystem enables the minimization of the number and duration of outages. Embedded active mailing subsystem helps the users to be informed about all the relevant events in the power system.
Classical CMM systems enable tracing of every activity related with maintenance, but using of all these data for decision making in maintenance is rather difficult.In this article, building of data warehouse or data marts for maintenance processes is proposed. During the process of data loading into the data warehouse (data staging process), the data are cleansed by specific algorithms and integrated with other data from different sources. A special care is paid for data quality assurance. Using user-friendly analysis tools which enable operations like drill-down, drill-up, slicing and dicing, gives the user an opportunity to obtain useful information about maintenance related processes. Applying of analysis tools based on fuzzy logic and neural networks gives a solid foundation for knowledge-based strategic decisions.

1. INTRODUCTION

ISOHEP is an information system for technical maintenance [1], developed for Croatian National Electricity (HEP) and implemented in the Control and Transmission Department.

Within the Control and Transmission Department, the equipment maintenance is organized in four transmission areas. Every transmission area deals with the maintenance of its own equipment, and the only interfering points are the places where high-voltage lines cross the border between two areas. In such a case, every transmission area is responsible for its own part of the common high-voltage line maintenance, but a coordination of the maintenance activities becomes necessary.

Within each transmission area, there are different groups specialized for maintenance of specific device types, like:

- high-voltage equipment within the transformer stations,
- high-voltage lines: overhead lines and cables,
- protection relays,
- metering equipment,
- telecommunication network equipment,
- telecontrol system equipment.

The maintenance of some device types, like voltage transformers, is performed by different groups. In that case, a coordination of activities among different groups is very important.

In the described real-world environment, ISOHEP is helping to achieve the principal maintenance goals:

- availability and reliability of the power system,
- cost-effective maintenance,
- systematic maintenance planning,
- minimizing the need for outages.

ISOHEP is planned as a system that will cover three levels of the information pyramid in maintenance domain: operational level, operational planning level and strategic planning level.

2. ISOHEP BASIC STRUCTURE

The foundation of the system lies in a technical database containing the data relevant for the devices, transformer stations, high-voltage lines and the other subjects to the maintenance processes.

The maintenance technology is described by the maintenance rules. The system helps the users to plan and trace maintenance activities, to store and analyze the information about failures and repairs, to issue work orders and to store and analyze all the information about work results.

A very important part of the ISOHEP is the outage management subsystem, which enables the minimization of the number and duration of outages. In addition, the active alerting and message management subsystem informs the users properly and timely about all the relevant events and states in the power system.

3. TECHNICAL DATABASE

The technical database contains data about devices, where any equipment prone to maintenance is regarded as a device. Every device is described by all the data relevant to its maintenance processes.

The basic data are common for all the device types and are independent of the particular device type. Examples for such data are: the device producers, the year of production, a factory catalog number and so on. Depending on the device type, there are several data classes to be recorded. Therefore, a compound device, like the power transformer, is described by data classes that span across ten screens, while some elementary device can be described by only a few fields within one screen. For every device, depending on its class, there are some data about the function that it performs within the power system. The placement of a device, its maintenance, failures, repairs and comments are being recorded throughout the device history, what makes possible a comprehensive analysis of the functioning and the status of the device.

4. MAINTENANCE PLANNING

Two fundamental types of maintenance activities have been implemented in ISOHEP. The distinction was made according to the source of stimulus for maintenance:

- **Periodical maintenance** is performed after predefined intervals of time. It is the preventive periodical maintenance, defined by the maintenance rules.
- **Event or status driven maintenance** is triggered by an event or by a predefined device status. It encompasses:
  - preventive status-indicated maintenance. For example, a prescribed number of accomplished device operations since its last maintenance triggers a maintenance activity.
  - corrective maintenance and urgent interventions are triggered by a failure report

4.1. Periodical maintenance rules

For every device type, a set of periodical maintenance rules is defined (2). These rules are user definable within the ISOHEP.

In general, a rule can be defined by the description of an activity and its period. However, the same activity can be applied with different periodicity, depending on some characteristics, location, or functions of the device. For that reason, to each activity more than one pair of conditions and respective periods can be attached.

4.2. Periodical maintenance planning

Basic information to calculate the periodical maintenance plan for a device is the date of the last performed maintenance activity, (or the date of commissioning, for devices that have not been maintained yet) and the respective maintenance period. According to that information, the due date of the next maintenance activity is computed. The planner within a specialized group has to fix a planned date for the maintenance activity, according to the outage plan, to the other group plans and in coordination with other participants in the maintenance process.

The maintenance plan consists of a large number of records (one record per device and activity). ISOHEP helps the user to retrieve the plan according to various criteria. In addition, it is very important to inform the user about the time discrepancy between the data, and the activity urgency level.

Different urgency levels are presented in different colors on the screen - late, very late and urgent activities are presented in red, reverse red and blinking reverse red fields in the screen. The user can also retrieve activities according to different urgency levels.

4.3. Status-indicated maintenance planning

Status-indicated maintenance activities are triggered by some event or by a change in the device status.

A trigger action can stem from the telecontrol system when the number of operations, requiring certain maintenance activities, was exceeded. Such an activity is included into the plan with its due date of maintenance set to TODAY. In addition, the system automatically sends an alert to the user responsible for planning of this type of activities within his/her specialized group. This person has to schedule the activity, according to the other elements of the plan in his/her own group and to the plans of other groups. Another possibility to trigger a certain activity arises from results of periodical inspections. After the inspection process, the findings are recorded, the status of the device is determined and a status-dependent activity is scheduled:

- as urgent,
- to be performed within a specified period of time,
- to be performed together with the next periodical maintenance activities.

When the need for an urgent intervention is detected, the system generates an alert to the user responsible for the required activity and he/she will issue a work order and all the accompanying documentation.

In the other two cases, the required activity is introduced into the plan to meet the specified due date.

4.4. Planning of repairs

When a failure occurs, a procedure analog to the state-triggered maintenance is performed. The trigger for an activity is a failure report. It can be obtained from the telecontrol system, or it can be manually introduced into the ISOHEP at the moment of the failure reporting.

5. WORK ORDERS

ISOHEP enables issuing of work orders and all the accompanying documents (check-lists, permissions, outage notification) needed for the maintenance. A work order can contain the activities for maintenance, installation and replacement of devices.

After the work has been done, the results are recorded. For all the periodical maintenance activities that have been accomplished, new due dates are computed according to their periods. Those activities that have not been accomplished, are postponed to wait for a future work order. The repairs, which have not been committed, have also to wait for a future work order.

The work report contains information about workers, their engagement, the vehicles used and distances traveled. The issued spare parts are recorded within the material management system. ISOHEP records only the respective document identifier, what enables a connection during the cost analysis.

6. OUTAGE PLANNING

During the maintenance of high voltage devices, it is necessary to switch off the appropriate part of the electric power system. The maintenance process has to be so organized, that the number and the duration of outages be as small as possible. Special care is paid to the outage planning and to the management of demands for outages.

At any time, every user can observe all the active outage demands and approvals. Whenever a date is to be entered, a calendar appears where the days bearing outage demands and approvals for a location or a position are highlighted. A planner in another department can review all the necessary information and he/she can try to schedule the activities of his/her department right for the same time.

7. EMBEDDED MAILING SYSTEM

A system has been developed to inform the users about some important event or status. It has been predefined:

- types of events or states,
- message text,
- users or user groups to be notified.

Within ISOHEP, the triggers have been defined for each specified event or status. They initiate the sending of messages to the predefined users or user groups.

Mailing groups are defined to be informed about specific events and/or states. Each user can subscribe to one or more mailing groups or message types.

The ISOHEP mailing system supports also the communication among the users. Receipt of each message is signaled by a visual and audio notification. The users connected to Internet/Intranet can receive their ISOHEP mail via their standard mailer.

8. THE DATA WAREHOUSE

An ideal system supporting the maintenance data analysis should offer following options:

- Simple and intuitive interface which enables extracting the interesting data, and their grouping into some meaningful logical units,
- Data representation using user-defined tables
- Different graphical presentations and diagrams,
- Showing discrepancies, for example with different colour,
- Analysis of detailed data, when needed,
- Hiding the detailed data,
- Possibility of discovering presently unknown rules in the collected data.

All of the desired analyses, users want to perform immediately, when the need arises. It is desirable that one can perform new analyses based on currently obtained data. The final goal of such a system is discovering the knowledge about the system on which will be based strategic decisions within the company.

The classical CMM systems cannot give the answers to all the questions posed by the analysts, as that kind of questions are beyond the scope of these systems.

On the operative level, the data structures are optimised for the transaction processing. The data are stored in “atomic” way, to speed-up the transaction processing. Such a normalised structure facilitates maintenance of the integrity rules and prevents errors during the inserting, updating or deleting the data. The basic requirements to the OLTP systems are rapid transaction processing and assuring the high level of data availability. Typical OLTP database consists of over hundred tables, integrity rules and different business rules described and maintained by the stored procedures and triggers.

Usually, OLTP systems offer standard reports that are designed and implemented in advance. However, every new report has to be designed and implemented by the programmers. Users cannot pose their own queries due to data complexity and unknowing the details and rules embedded into the system.

The data warehouse is the place where all the data are integrated. Usually, the data sources for the data warehouse are heterogeneous, the same data are stored in different ways and the quality of the data may vary considerably.
In contrast to OLTP systems that are data oriented, the data warehouse is problem-oriented. The main subjects of the business processes are described by star-join schemes. Star-join schemes describing the different subjects are usually interconnected.

During the analysis, users are interested in some facts that can be observed from different points of view, or, in different dimensions.

The schema can be visualized as a “cube” of three, four, or more dimensions. With that kind of data structure users can imagine slicing and dicing the cube along each of its dimensions.

The schema consists of the fact table describing the facts that user wants to observe, and relationships to the dimensions of that facts. Dimension tables describe dimensions with all the details that users can be interested in.

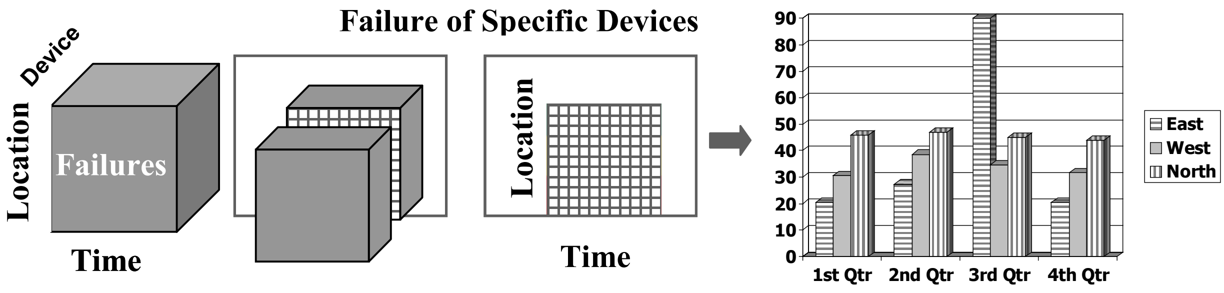

Figure 3. Slicing – selecting a specific device or group of devices

Dimension tables contain huge amounts of data, practically all the data users may need during the analysis. They contain the data that are stored in tens of tables within the transaction system. Dimension tables are denormalised, to fulfil their main goal - flexible browsing.

Within the data warehouse there are data integrated from the different sources, for example, a database about maintenance, financial data, data about spare parts, data about production, production planning, maintenance planning, spare parts purchases, etc. The data structures in the source databases usually are different, different coding systems are used and some of the data are stored within the legacy systems.

During the data staging process, the data are cleansed, unified, integrated and loaded into the data warehouse. Data, once loaded, remain unchanged in the data warehouse and constitute a stabile foundation for different analyses. The data are loaded periodically, usually over night, which enables calculating of the summary data about daily activities.

The basic analyses of the data are performed using the data reporting tools. Typical data reporting tools enable:

- Selecting the fields using their names which are understandable to the users,
- Data selection according to user defined formulas, or picking from the lists of possible values,
- Derived values defined by mathematical functions,
- Drill-up – browsing the data by ignoring the details,
- Drill-down – browsing the data by giving more details,
- Drill through different hierarchies, for example: device, – device type – sort of devices,
- Drill-across – correlating the data from different fact tables.

The data from the data warehouses are analysed by data mining tools, where the data warehouse's tasks are preparing of the data for the analysis, accepting and interpreting the results.

The data mining tools make available various statistical analyses and analyses based on neural networks and fuzzy logic. These tools enable knowledge discovery within the data collected during the maintenance processes, other processes influenced by the maintenance and vice versa.

Main characteristics of data presentation tools based on the data warehouses are the following:

- Simplicity of performing ad-hoc queries – user specifies the elements of the report and criteria for the data selection,
- Performance – due to simple data structure, denormalised data, built hierarchies and aggregations stored into the warehouse, the execution of ad-hoc queries can be fast,
- Clearness – special cases, like maximum value, minimal value, etc. can be marked
- Graphical representation – using different charts and diagrams.

9. MAINTENANCE INTELLIGENCE

As well as in basic business processes, business intelligence approach can be used in the field of maintenance. According to main processes in maintenance, the data marts are built. The fact tables are derived from main processes in maintenance, as follows:

- Preventive maintenance,
- Condition based maintenance,
- Corrective maintenance.

Dimension tables are common for all the fact tables and they are:

- Device,
- Location,
- Time,
- Work order,
- Workers and their working time,
- Used spare parts,
- Other costs.

Additional fact tables are connected with other processes affecting maintenance and vice versa, like production, product quality, material consumption, energy consumption, other production costs.

The data needed for analyses and discovery of the knowledge about maintenance and relationships between the maintenance and the production are usually placed in different databases. They are classified on the different bases and different coding systems are used. Usually the vast amount of time and effort is needed to build and parameterise procedures needed for data profiling, data reengineering, and data cleansing.

Analyses that are performed comprise main maintenance processes and their costs, to discover the knowledge about system, find anomalies and using the knowledge in decision-making. Performing analyses of the maintenance facts along with other processes one can obtain clearer view about relationships between maintenance and other processes within the company. Based on discovered knowledge, importance of maintenance may be shown and proved. These results can help in establishing of different position of the maintenance within the organisation.

10. CONCLUSION

ISOHEP is a computerized system to help the maintenance personnel. At any time, every user can achieve all the necessary information to make the decisions regarding maintenance.

Maintenance intelligence means applying the business intelligence methods in the area of maintenance. It consists of integration of the data from different sources and performing various analyses.

The main goal of the maintenance intelligence is decision-making in maintenance based on the discovered knowledge, understanding the importance of maintenance in the wider context and obtaining knowledge as the basis for changing the position of maintenance within the organisation. That knowledge can be used in the process of recognising the maintenance processes as the key factors in making the profit and establishing a customer relationship management based on the knowledge and the quality of the products.

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