

INFORMATIONAL FEEDBACK – IMPROVING THE MAINTENANCE STRATEGIES AND SERVICE PERFORMANCE IN THE ELECTRICITY TRANSMISSION GRID

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Abstract: -The paper describes the manner in which the data and information obtained from equipment & installations monitoring and the informational feedback are used in the quantification of the technical condition of equipment with a view to take efficient measures to increase equipment reliability and to determine the best maintenance policy adapted to different categories of equipment.

The consideration of such aspects allows providing the elements required in the assistance to the decision-making process under asset management and objective maintenance or investment (refurbishment) options, as well as the measures to increase the operational safety and the service performance.

Keywords: maintenance, monitoring the technical condition, operational safety, performance

1. INTRODUCTION

One of “Transelectrica” ’s (National Power Grid Company) missions as Transmission and System Operator is to ensure the National Power System operation under conditions of quality, safety, economic efficiency and environmental protection, while keeping neutral to all customers on the electricity market.

The mission of “Transelectrica” SA is to grant regulated third party access to the electricity transmission network to all market participants under transparent, non-discriminating and equidistant conditions, as well as competitive electricity transmission and system services while observing the quality standards, under safe conditions for the National Power System (NPC) and at minimum reasonable costs, limiting the environmental impact to the admissible level in Europe.

The uninterrupted feature of the decision-making process requires the best information in due time. The quality and coherence of such decision-making process have to be ensured, as well as the validity of data and information.

The system monitoring the operational behaviour of electric power equipment and organising & processing the data collected from operation allows making reliable analysis in order to quantify the performance at equipment level and at

installation (ensemble) level, using accurate input data, thus enabling the assessment of technical condition of equipment.

Data and information are used with respect to the history of failures, results of measurements and of maintenance operations.

The liberalisation of power markets has pointed out how important it is to cut down costs and to increase the reliability of the Electricity Transmission Grid (ETG).

CIGRE Study Committees recommend electricity companies to use and develop reliability analysis techniques and to institute data gathering about the operational behaviour of equipment and methods to process them.

“Transelectrica” has organised maintenance based on a Maintenance Insurance Plan. To this effect, it has implemented a monitoring system of equipment behaviour.

2. ENSURING THE INFORMATIONAL FEEDBACK

The experience and practice point out the need to use credible reliability data to sustain the safety analysis.

To obtain the reliability data it is preferable to use a strict analysis of the operational experience, by means of an efficient feedback. A proper use of the feedback improves the operation and maintenance of installations and the operational safety in general. These are the reasons why there are sustained concerns at international level for feedback management using general recommendations and procedures within specialized informational systems, as it was done in the case of Electricity Transmission Grid as well.

The accuracy of reliability analyses depends to a great extent on the precision of primary data and on the estimation techniques used for reliability parameters. In general, the truest and most numerous information comes from operation, then their proper acquisition and processing is a must.

Each failure mode of a piece of equipment is attributed a distinct defecting intensity, the same as there are various modes of restoration after a defect, with distinct restoring intensities. It follows that reliability calculations have to be sustained by correlating the statistical observations to the information requested.

Mention should be made that the electricity sector has recorded for several years the concern to promote investments and upgrade the power installations, taking into account the reliability analyses, and hence the need to develop a computerized system to process the operational data on equipment and installations behavior.

The information needed is obtained at the level of component equipment of installations, by supervising their operational behavior and especially their degree of defecting. Then these are used in analyses at installations level in the assembly (system) by monitoring the manner in which the quality of service is provided (especially the continuous operation), as described by the indicators given in the Technical Code of power grid [1].

In accordance with the tasks from Technical Code, the transmission and system operator has the following obligations:

- To observe the quality technical parameters of the electricity transmission service and the safety and availability requirements for transmission power grid, according to the technical code
- Is responsible for the safe operation of the National Power System and of its components and for the uninterrupted balancing of generation and consumption in the National Power System
- To monitor, register and report the quality technical parameters of the transmission and system services
- To report to ANRE (National Energy Regulatory Authority) the events resulting in important material damages, victims of significant interruptions of service occurring in installations.

Monitoring the operational behaviour of equipment and installations, as well as that of the entire National Power System (NPS), is organised within “Transelectrica” as shown in Figure 1 (a manner resembling the concept presented in CIGRE [3] report), the respective activities being carried out in specialised compartments also by using IT systems and proper software.

It was ascertained that equipment suppliers and network operators need to share their experience. To this effect recommendations are for manufacturers and operators to- use reliability techniques, describe their experience in the feedback process, as the reliability studies required information on the equipment behaviour; to describe the processing of data gathered from feedback in order to evaluate and quantify damaging modes; to share their experience and the data on equipment and systems reliability.

Table 1 shows the performance indicators, in accord with Technical Code, of the electricity transmission system in 2005-2009.

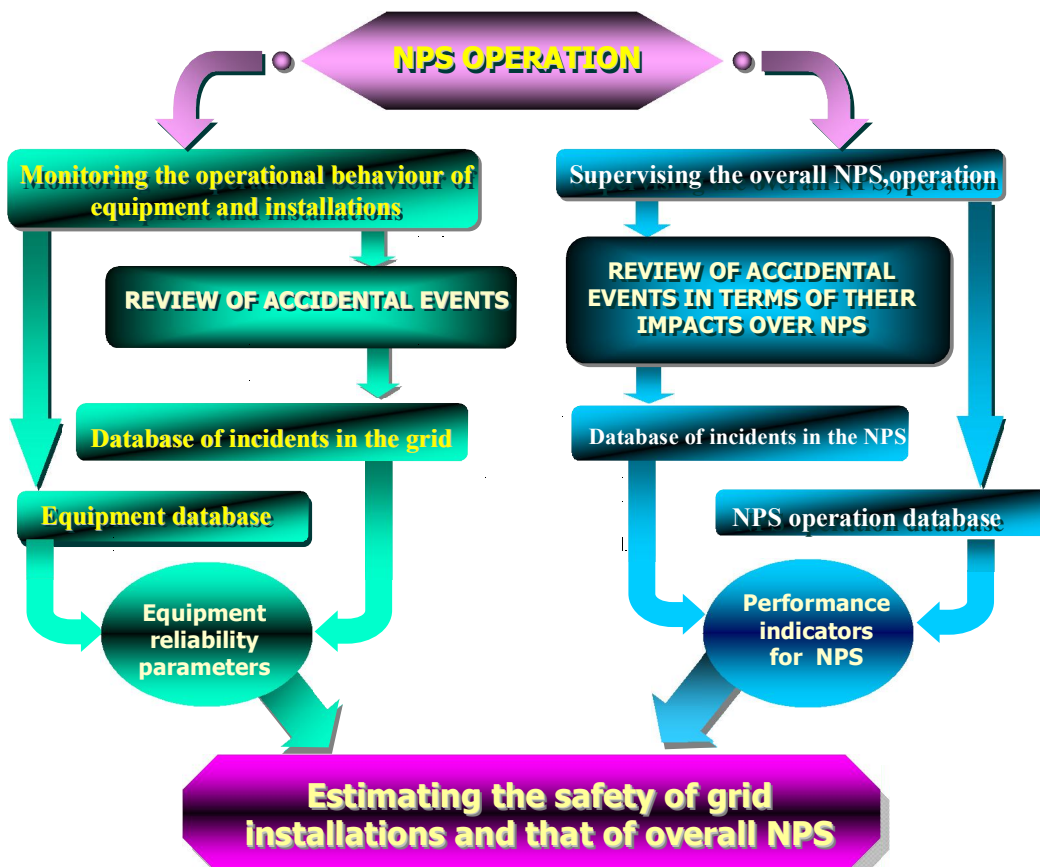


Fig. 1- Organisation of equipment operational behaviour monitoring

TABLE 1

Performance indicator/year	Measuring unit	2005	2006	2007	2008	2009
Seriousness index (SI)	minutes/interruption	4.434	1.185	0.0357	0.072	0.057
System minutes (SM)	minutes	0.369	0.043	0.555	1.167	0.504
Average interruption time (AIT)	minutes/year	2.606	0.704	0.8574	1.792	0.810

3. INFORMATIONAL FEEDBACK USED FOR IMPROVING THE MAINTENANCE STRATEGIES

The decisions to improve reliability and maintenance based on informational feedback have to be objective, to this end being taken into account the following [4]:

- analysis of damaging degree and of evolution of equipment operational characteristics in order to determine the technical condition;
- analysis of installation significance within the NPS;
- cost analysis.

All these are included in the general concept of reliability-centred maintenance - RCM, a systematic decision-taking process and standardised approach of maintenance used now within power grid [5]. RCM puts to use the conventional theory of reliability, directing the maintenance activities where the installation is vulnerable and where is economically justified. Thus the time-based maintenance was gradually replaced with condition-based maintenance, respectively reliability, within the preventive maintenance.

The main objectives of reliability-centred maintenance are as follows:

- best quality and quantity maintenance activities; cutting down maintenance costs;
- reducing interruption times;
- observing the requirements to promote investment work;
- coordinating the maintenance and rehabilitation programmes.

The priority of **preventive maintenance** is determined depending on the **technical condition** of equipment/ installations, quantified using the statistical processing of information on operational behaviour-frequency and duration of accidental unavailability intervals; development of operational parameters and characteristics; history of maintenance, costs and on the **installation significance** within the power system.

The **technical condition** is determined using calculation algorithms specific to each operational assembly and equipment, also taking into account their constructive parameters and main components. Qualitative information is also quantified with respect to visual examinations, experience with such equipment based on questionnaires with pre-set answers.

Algorithms use statistical-probabilistic calculation methods.

Limit values/margins used for comparison of measurement results are taken from the norms.

The **importance** in terms of National Power System operational safety from ETG installations and equipment is determined starting from the significance of nodes (bus bars in electric substations) and connections (electric lines and transformers / autotransformers) obtained from processing with a specific software based on steady-state regime calculations (current and voltage values, power blocking in power stations, power undelivered to consumers, power non-wheeled between system areas), static and transient state of all equipment / operational assemblies managed by each transmission branch.

Thus by integrating the results on the technical condition of all operational equipment/assemblies under the management of each branch and the importance of such installations at grid level, the result is the annual maintenance schedule as required by each category of functional assembly spread on 4 levels of maintenance activities, as well as proposals for the retrofitting/investment plan.

The final maintenance programme and that for equipment taking out of operation follow by an **iterative process**.

Maintenance management under all aspects of interest (management of work orders; locating the installations undergoing maintenance; other installations de-energised as labour safety measure to carry out work; date, period, type and content of activities; costs; manpower; parts and materials used; transport and tools; invoices of service and products suppliers etc.) is performed using specific methods and software.

The computer applications allow knowing and storing the history of maintenance activities performed to each operational assembly, issuing and sending work orders.

Primary information on the operational behaviour of ETG installations is capitalised by processing that results in reports including data obtained from behaviour monitoring.

Corrective maintenance activities to remove defects and restore installations to their functional condition as designed are initiated by means of an operational system that detect, record and notify the accidental events (incidents, technical defects) within electricity transmission installations and is regulated under the Technical Norm „Regulation for analysis and recording of hazards in the electricity and heat generation, transmission and distribution installations” and under its specific application guidelines for the transmission grid, as well as under specific procedures.

Operational behaviour monitoring is carried out systematically in the transmission branches and consists

in acquiring, recording, validating, storing, processing and sending the information regarding the operation, maintenance and repair of installations, equipment and components from the ETG, being particularly useful within the equipment supplier - end-user dialogue.

Maintenance results are checked by operational behaviour monitoring, respectively by the review of behaviour before and after maintenance. The history of maintenance and of operational behaviour points out the operational tendencies of equipment, the weak points and needs for improvement.

Since there is an obvious need to have a single and transparent flow of data and information regarding the maintenance activity, which should provide all available data and control facilities for their quality, a specific database was set up for maintenance.

An IT system was established as well in order to manage, optimize and coordinate all maintenance activities, with also the possibility to have an interface with the other IT systems, as used within the specialized IT system.

Maintenance is carried out under the „Maintenance Insurance Programme” in accordance with the regulations of ANRE (National Regulatory Authority in the energy field).

The proven performance of equipment is essential for the design stage of a new project and also for the installation maintenance. A major concern of maintenance activities is to keep performance in time.

All types of maintenance contracts are found in “Transelectrica”'s case - with many pieces of equipment of long operational life, but also with new or retrofitting projects.

The efficiency of maintenance can be assessed using the following:

- Technical criteria of maintenance efficiency
- Economic criteria of maintenance efficiency
- Criteria of service quality
- Statistical indicators

4. SERVICE PERFORMANCE

The quality of service (especially the uninterrupted operation) is quantified and reported every year using the Key Performance Indicators (KPI) from the Technical Code of the ETG [1] and the Performance Standard for electricity transmission and system services [2]:

- OHL and transformer units unavailability:

$$INDLIN = \frac{\sum_{i=1}^n (L_i \times D_i)}{L_t} \text{ [hours/year]}$$

n – number of events (planned and unplanned);

Li – length (km) of the unavailable line - due to the event i;

Di – unavailability time (hours) - event i;

Lt – total OHL length (km) of the EPG;

$$INDTRA = \frac{\sum_{i=1}^n (S_i \times D_i)}{S_t} \text{ [hours/year]}$$

n – number of events (planned and unplanned);

Si – apparent power (MVA) of the unavailable transformer – due to event i;

Di – unavailability time (hours) - event i;

St – total apparent power (MVA) of the transformers in the EPG;

- Average Interruption Time (AIT)

$$AIT = 8760 \times 60 \times \frac{ENS}{AD} \text{ [min/year]}$$

ENS – energy not supplied (MWh)

AD – Annual Demand [MWh]

- Energy Not Supplied (ENS)

Table 2 shows the KPI s in 2008 – 2009.

TABLE 2

KPI	2008	2009	2010
► OHL and transformers unavailability			
▪ OHL – INDLIN [ore/an] TOTAL	445,68	372,84	270,0
Unplanned	6,7	4,79	2,85
Planned	438,98	368,05	267,15
▪ Transformers – INDTRA [ore/an] TOTAL	504,66	386,08	628,81
Unplanned	86,11	90,39	80,56
Planned	442,47	295,69	548,25
► ENS [MWh]	167,1	69,3	267,936
► AIT [min/year]	1,79	0,81	3,09

5. SOME ASPECTS ON DECISION-MAKING PROCESS

The uninterrupted decision-making process requires the best information in due time. Such process

has to use qualitative, coherent and valid data and information.

Asset management requires assistance in decision-making for each category of activities (planning, development, operation, maintenance,

refurbishment, modernization), risk analyses, correlation and integration of all activities within the ETG so that in the end the best solution can be selected from several possible options. An important aspect is decision-making at the level of overall ETG and then at asset levels, which needs a systemic approach.

Taking into account the retrofitting policy for the electric grid installations, as well as the implementation of new technologies and of up-to-date tele-control and tele-management systems, decision-making processes require many criteria.

The decision-making process involves:

- evaluating the condition and the risks
- decision-making algorithm

Decision-making can be considered as a continuous process based on technical, economic and sociological data.

Technical data refer to the condition of equipment. Financial data combine economic and technical details on assets, being especially oriented to reliability. The social data combine the company's information with sociological data in order to take decisions on risks.

Such data categories are:

- technical data: stocks, characteristics, operational parameters;
- economic data: assessing costs for the entire life cycle (investment, operation, maintenance, taking out of operation), costs of failure results;
- sociological data: social and environmental aspects - impact of accidental events, criticality: number and interval of accidental events, respectively estimating the binomial probability (frequency) x severity (amplitude), thus getting the social impact - the image over the public and the feeling of 'security'.

Taking into account the critical nature of the ETG infrastructure, an important issue is that of managing the high risk levels of old assets (although wide refurbishment programmes have been applied, a great number of installations within the ETG were manufactured in the 60s – 70s), which means:

- knowing the current technical condition, the performance and risks associated to such risk levels;
- quantifying the performance tasks;
- systematising risk aspects and proposing measures to reduce them;
- monitoring the operation and risks;
- priority classification, planning and implementation of proposed measures.

Mention should be made of the close relationship between risk management principles and those of least cost management, so as to maintain a cost-oriented direction during the entire lifetime and to provide least costs without deteriorating the risk profile.

The decision-making algorithm develops by hierarchical levels:

►Level 1: component (asset)

It consists of assessing the equipment condition based on the technical data and information. Many scenarios can be found to influence the assets performance in terms of reliability and availability.

►Level 2: network (ETG)

When technical information is combined to the economic and network ones, costs are quantified. These

are also expressed in terms of reliability, consequences of events, risks.

It is during this stage of the decision-making process that modern methods of (RCM) maintenance evaluation and planning are applied.

►Level 3: corporation (Company)

The costs and advantages of various scenarios are combined with the risks of each one in order to take the best decision.

Basic data refer to historical information obtained from supervising the operational behaviour.

A good feed-back process is needed.

Two types of information are required:

- behavioral performance of fixed assets;
- acceptable risk / availability levels.

There is need for a transparent single flow of data and information, as it has been shown previously and for a coherent feedback process.

6. CONCLUSION

- “Transelectrica” provides on the market the infrastructure required and the regulated and non-discriminating grid access for all market participants.
- “Transelectrica” furthers the tradition and experience gathered within 50 years of NPS operation and maintenance.
- Although the sector has been unbundled in commercial and legal terms into many entities, “Transelectrica” provides a unitary operation of the Romanian Power System, as well as its safe and reliable running.
- The Romanian electricity sector is integrated into the European and regional market by means of interconnecting the transmission grid to the ENTSO-E-member power systems.
- The informational feedback based on operational behaviour monitoring eventually results in grown operational safety, both by specific maintenance and operation activities and by joint operations with equipment suppliers in view of improving reliability.
- The goals to be achieved in a system concept are:
 - adapting to institutional changes,
 - maximising the availability of transmission network,
 - grounding the maintenance and / or retrofitting decisions,
 - determining the strategy, objectives, responsibilities, requirements and their mode of achievement in view of the maintenance activity,
 - providing reliability of equipment and increased operational safety,
 - extending the life cycle of assets within ETG,
 - setting up a coherent strategy to identify, assess, review and manage risks; providing the specific data and information needed to implement the risk management,
 - setting up and optimising the information flows needed for the activity and providing a proper feed-back,
 - providing interfaces between different entities,
 - identification, control and optimisation of costs,
 - documenting the activities,
 - determining, assessing and supervising the performance criteria; determining efficient measures to improve performance.

►“Transelectrica” included exigency in its maintenance and operation activities and in relationships to partners and equipment and/or service suppliers, based on informational feedback. All these measures are to increase the operational safety and the service performance.

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