RESEARCH PROJECT

TITLE

Reliability-Centered Maintenance of Substations

ENTITY

Cigré

STUDY COMMITTEE

B3 - Substations

CONVENER

To be elected by Cigré Committee B3

PARTICIPANTS

Task Force formed by specialists on:

- Reliability-Centered Maintenance (RCM);
- Maintenance and Operation of Substation Equipments;
- Project and Specification of Substation Equipments;
- Development and Construction of Substation Equipments;
- Repair and Refurbishing of Substation Equipments;
- Research and Development of Substation Equipments;
- Test and Simulation of Substation Equipments;
- Protection, Regulation and Monitoring of Substation Equipments.

INTRODUCTION

Substations play essential functions to the generation, transmission and distribution of electric energy. From voltage elevation for long distance transmission, to reduction, switching and regulation on urban, residential and industrial distribution, substations concentrate complex equipments that usually form the main assets and capital investment of utilities and electric systems. Due to ascending unit capacity, operation of these items

demand, besides intrinsic functions of transformation, regulation and switching, a complex set of support systems and functions, including protection, reactive compensation, load and voltage control, isolation, supervision, etc. This diversity, although necessary, result on a large number of possible failure modes, adding to those intrinsic to the basic functions of transformation, regulation and switching.

Among substation equipments, power transformers represent the main unit concentration of asset investments, and the main concern about maintenance and conservation. Identification and study of all failure modes of such complex items require a substantial work from agents entitled of their maintenance, design and construction. Existing studies report the possibility of occurrence of more then 150 types of failure modes on a large power transformer.

Traditionally, Failure Mode and Effects Analysis (FMEA) have been recognized as the ideal method to catalog and analyze the failure consequences of complex systems. Besides identification, it is necessary also to define the recommended maintenance activity to prevent, or correct, failures, or minimize their consequences. To achieve these goals, a structured methodology is needed to correlates each failure mode with the ideal preventive task.

Among all current maintenance methods, Reliability-Centered Maintenance (RCM) excels in defining an integrated set of tools to identify and analyze all failure modes of an installation, while suggesting preventive and corrective tasks to minimize failure impacts. RCM is also known to prioritize the attendance of strict criteria related to security and environment protection, seeking simultaneously to assure its economic viability. Qualitative methods for choosing maintenance tasks are well established by RCM, and standardized by international organisms (IEC, SAE, ISO).

OBJECTIVE

The main objective of this project is to avail the application of RCM methodology to the maintenance of substation equipments, by analysis of their failure modes and causal mechanisms and consequences, aiming to define the more suitable maintenance tasks. The project will also analyze the available methods for quantifying the best or optimum frequency of maintenance tasks, for each failure mode. Answers will be explored for each question proposed by RCM, for each type of equipment and system, such as:

- What system functions are significant?
- Which functional failures may occur?
- Which failure modes may occur?
- Which failure effects may result?
- Which failure consequences may result?
- Which tasks could prevent failures?
- What alternative tasks are needed?

- Which task frequencies to adopt?

While responding these questions, many others will have to be answered:

- What type of maintenance task is more suitable for each failure mode? Preventive maintenance? Predictive techniques? On-condition maintenance? Or just corrective maintenance?

- Periodicity should be different for each industrial environment? Distinct for each installation? According to production and voltage level? Specific for each type of equipment and unit size? Synchronized to other maintenance tasks?

In studying these questions, the project will seek general conclusions and consensus valuable to fabricants, researchers, consultants, maintainers and operators of these equipments. The research will start with a pilot project, aiming to apply RCM to power transformers, followed by other types of substation equipments. The following paragraphs present a sequential summary of the proposed methodology and pilot project.

METHODOLOGY

The pilot project will be developed in eight phases, typical of the RCM method, named as:

(0) Conceptual consensus about the RCM methodology;
(1) System selection and information gathering;
(2) Failure Mode and Effects Analysis;
(3) Selection of significant functions;
(4) Identification of applicable tasks;
(5) Evaluation of task effectiveness;
(6) Selection of applicable and effective tasks;
(7) Definition of activities periodicity.

The start phase, **Conceptual consensus about the RCM methodology**, entails discussion and exchange of experiences among participants about the methodology, aiming to establish a common conceptual reference for the project. In special, the following resources will be discussed for the remaining phases:

- Reference materials and manuals about the methodology;
- Printed forms for applying RCM;
- RCM software and databases for project support;

The first phase, **System selection and information gathering**, will identify and document all typical systems of a power transformer. The following products will result from this phase:

- System documentation;
- Operational context definition for each system;
- Identification of system borders and interfaces;
- Organizational diagram of systems, subsystems and components;
- Functional and logical diagram of all systems.

The second phase, **Failure Mode and Effects Analysis**, will identify and document all functions of each system of a power transformer, and their failure modes, with associated adverse effects. Using the FMEA method, the following treats will be documented:

- Functions played by each system;
- Possible failures of each function;
- Modes of each failure;
- Effects of each failure mode;
- Severity of each effect.

Several tools may be used, such as Failure and Event Trees, derived from Logic and Functional Diagrams of the systems, and documented on standards FMEA forms.

The third phase, **Selection of significant functions**, will apply the RCM structured process to analyze each function, to determine if a fault has a significant effect, availing its impact on environment, security, operation and economy of the installation. The previous analysis of failure effects will serve as input to the risk and consequence analysis, to prioritize them according to significance. As a final product of this phase, a document with all significant functions will be generated, to be used in the remaining steps of the method. All other functions (classed as non-significant) will not be further analyzed.

In the fourth phase, **Identification of applicable tasks**, maintenance activities will be determined that are technically suited to power transformers, to prevent or correct each failure mode, or alleviate their consequences. As a result, one of the following options will be determined:

- The preventive maintenance task that is applicable;
- Preventive maintenance is not applicable;
- Other alternative action (default) is suggested.

The fifth phase, **Evaluation of task effectiveness**, will use a structured process to determine if the preventive maintenance tasks of the previous phase are effective to reduce, to acceptable levels, all anticipated consequences of a failure. One of the following actins will be chosen in this phase, for each failure mode:

- A preventive maintenance task is recommended;
- Preventive maintenance is not necessary; or

- Other alternative action (default) is suggested;

The sixth phase, **Selection of applicable and effective tasks**, will use a structured process to determine the best task, based on:

- Process results;
- Operational impacts;
- Physical security;
- Environment impacts.

In the seventh and final phase, **Definition of activities periodicity**, optimization methods and criteria will be used to define the periodicity or frequency of execution of the selected tasks, after an analysis of the following aspects:

- **Reliability** – analysis of descriptive statistics about transformer reliability;
- **Maintainability** - analysis of descriptive statistics about transformer maintainability;
- **Productivity -** analysis of descriptive statistics about corporate results impacted by maintenance and failure of transformers.

Statistics will be collected mainly by sampling from historical operation and maintenance databases, or by estimates made by *a priori* knowledge of experts.

DELIVERABLES

The following products will be generated in the pilot project:

- Guide of Reliability-Centered Maintenance of Power Transformers
- Database of Reliability-Centered Maintenance of Power Transformers;

The Guide of Reliability-Centered Maintenance of Power Transformers will be a printed manual with the results of all project phases. The Guide will be structured as a reference document about applying RCM to these equipments. It will be suitable as a reference to maintenance planning of power transformers.

The Database of Reliability-Centered Maintenance of Power Transformers will be an informational base with all data used on the different phases of the analysis process. The base will be designed to be updated periodically, and accessed by RCM analysis software, as an integral part of the Guide.

After its completion, the pilot project will be evaluated to be extended to other substation equipments, by the Substation Committee, according to the work plan of the Task Force.

CONCLUSIONS

The application of RCM to power transformers may serve as a pilot test to other equipments and technological processes of the electric industry. Many of these generalizations can be proposed, and suggested as additional research, as part of the Task Force work plan. These results will be published as papers authored by the task force members, on congress and colloquium promoted by Cigré.

CHRONOGRAM

The activity chronogram will be defined by the Task Force, with deadlines for the following suggested topics:

- Conceptual consensus about the RCM methodology
- System selection and information gathering
- Failure Mode and Effects Analysis
- Selection of significant functions
- Identification of applicable tasks
- Evaluation of task effectiveness
- Selection of applicable and effective tasks
- Definition of activities periodicity
- RCM Database of power transformers
- RCM Guide for power transformers
- Process evaluation and extensions to other equipments.

BIBLIOGRAPHY

The following main references are proposed to start the work. Others may be added during the Conceptual consensus phase and execution of the research project.

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