ASSET MANAGEMENT

THIRD PARTY'S TECHNICAL SERVICES ON ELECTRICAL EQUIPMENT AND THEIR INSTALLATIONS

INTRODUCTION

CESI has developed an innovative strategy for the optimal technical management of electrical and mechanical equipment installed in electric power system facilities (power plants and substation). CESI, thanks to his 50 years long multidisciplinary involvement in testing and condition assessment of electrical equipment as well as in detailed power system studies on a large number of cases all over the World, has the right expertise and adequate tools to provide these services by very effective approach.
Dealing with the most recent developments of diagnostic techniques and international acknowledgements on plant management, CESI strategy is an integrated approach to all required activities to characterise and follow the equipment for their entire life cycle long.

By adopting this new strategy, particularly suitable for all situations where quality, continuity and reliability of production are crucial requisites, serious damage or even failures of critical equipment, which may impair requested production or endanger the environment, the plant and the operating personnel, can be duly and timely prevented

WHY A NEW STRATEGY ?

The request for electric energy is experiencing a major growth all around the World. The expansion of urban and suburban areas as well as industrial sites and plants, requires solid networks for both transmission and distribution of electric energy. As power plants, substations and networks service is obtained by the contemporary operation of a wide variety of electrical and mechanical equipment, the operation of which is subjected to different problems and follows different rules, a global approach dealing with all subjects of their life cycle is necessary to be applied per each step of the life.

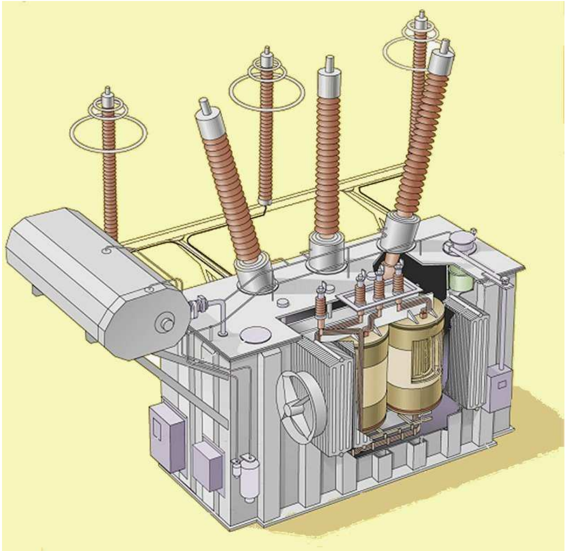
There are three major steps characterising the entire life cycle of electrical and mechanical equipment, namely manufacturing, normal operation and end-of-life operation.
Each step has direct influence on others and, as the equipment are considered as a whole, on other equipment installed in the plant or substation, thus determining a direct influence on the operation of the entire system.
The complexity of actual meshed networks and the level of power demand impose a global approach rather than focused on single equipment.
Hence, CESI has developed a new strategy for the management of equipment, so that each step of life cycle is suitably taken under control, allowing people involved in equipment operation - from operative to managerial level - to take prompt and effective decisions, thus preventing the occurrence of faults and maximising the ratio cost/benefits.

DESIGN REVIEW

Design review activity is normally carried out prior to put the equipment in operation, but sometimes is a useful tool for failure analysis, to understand direct causes for a fault.
CESI services for design review of equipment apply to transformers, circuit breakers, GIS, cables and busbars.
The approach to design review is aimed at verifying that the equipment have been properly designed and enough safety margins have been set by the manufacturer.
On the basis of CESI experience, the following items will be considered in the frame of the activity:

- Compliance of design with technical specifications;
- Verification of crucial and known weak points of equipment;
- Estimation of safety margins adopted by the manufacturer.

Design review belongs to the first steps of the life cycle of an electrical equipment.



IN-PROCESS QUALITY ASSURANCE

Besides its experience in laboratory tests and power system studies, CESI has a well-established World wide experience in quality assurance services and in particular in in-process inspections during manufacturing of electrical equipment. Such experience is allowing CESI to compile detailed quality control plans for almost all electrical equipment ranging from LV up to UHV both in AC and DC. Such plans are continuously upgraded and updated, following the evolution of production processes and techniques.
In-process quality assurance will deal with the main aspects of the Company's production process, such as:
Organization evaluation;
In production inspection;
Sub suppliers qualification;
Sub suppliers monitoring.

With reference to the ISO 9001:2000 Standard, the approach described in the following is usually adopted to carry out the in-process quality assurance of the involved electrical equipment.
Step one: an initial quality assurance pre-inspection will be carried out at the Manufacturer's facilities before the beginning or at a very early stage of aimed at:
Defining the scope and the boundaries of the quality assurance work with the Management of the involved Company,

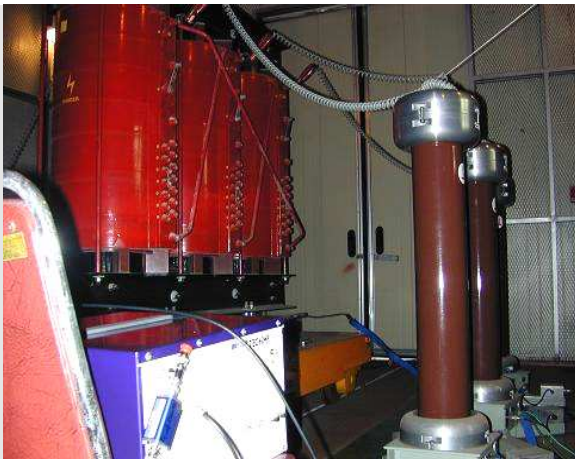
Collecting the documentation for understanding the manufacturing processes (quality manual and relevant procedures),
Verifying the capability of the Company, by means of a general visit of workshops.

Step two: successive "sample inspections" will be carried out at the Manufacturer's facilities, covering, for each product considered, all manufacturing phases and/or processes having an effect on the compliance of the final product with the operational requirements and guaranteed performances. This part of the service is aimed at:
Checking the compliance of the processes inspected with the quality management system documents of the Company,
Pointing out all possible non-conformities relevant to manufacturing phases and/or processes having an effect on the compliance of the final product with the operational requirements and guaranteed performances.

IN-FACTORY TEST WITNESS

Routine and type tests carried out in the in-factory laboratories are the last steps of equipment manufacturing. The correct performance of this activity is of paramount importance to assure that the equipment have been properly manufactured.
As aid to Utilities who require high quality and high performance equipment, CESI draws up a team of expert inspectors, able to closely and strictly follow-up the test activities carried out by Manufacturers in their in-factory laboratories thus duly and timely evaluating test results and pointing out defects and weak points, if any.

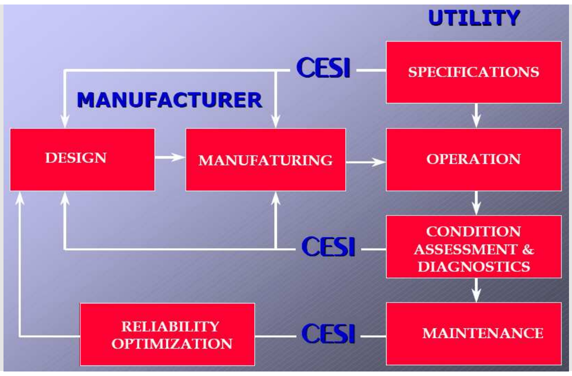
The specific activity of witnessing type and/or routine tests will be accomplished by means of highly trained personnel having a strong experience in testing activity and a high level of knowledge (membership in international WG) as regards to basic themes linked with the equipment involved in the present Project.
Key points on which usually test witnessing activity is based are:
Accurate check of the calibration of the test instrumentation;
Deep check of test procedures;
Accurate heck of test layout (circuits and connections);
Continuous check of test parameters;
Critical evaluation of test result;



As for the test procedures, the Manufacturers will be asked to strictly follow the agreed test procedures, as deviations could result in overstress of the equipment.
The experience of CESI inspectors is available for quite all electrical equipment, ranging from transformers, circuit breakers, GIS up to cables, switchgears, VTs, CTs and HVDC thyristor valves.

TECHNICAL SPECIFICATION REVIEW

Technical specifications are the basis to achieve top level of performance of any equipment. For this reason, CESI provides accurate analysis of specifications and, on the basis of system, environmental and operational data will provide the following judgements:
Consistency of nameplate data;
Adequacy of equipment characteristics with reference to ambient conditions of the sites it will be installed in;
Adequacy of equipment rating (rated characteristics and insulation levels) with reference to the characteristics of the power system in which it will be put in operation;
Adequacy of foreseen type or routine tests;
Consistency of equipment accessory characteristics.
Technical specifications review belongs to the first step of the life cycle management of any equipment



and its performance is then allowing Utilities to purchase equipment which then will be perfectly adequate for the operation in their specific power system

RELIABILITY ANALYSIS

Substation failures usually involve multiple outages of transmission devices and, therefore, substation reliability plays an important role in the assessment of the overall transmission system reliability. Moreover, nowadays substation reliability is becoming a key issue in systems where, for various reasons, the operating configurations might be modified with respect to the normal arrangements to face specific problems (e.g.: preventive maintenance of some components, limitation in short circuit currents, etc.).

This is the reason why CESI developed and uses a computing tool, called SISTAZ, devoted to substation reliability assessment for both design and operation purposes.

The main scope for the application of SISTAZ is to streamline maintenance practices and maintaining or improving system reliability, availability and safety.

The fields of applications of SISTAZ computing model can be classified in the following three areas:

Design stage of new transmission systems for the choice of the most suitable substation lay-out;

System operation to perform Failure Modes and Effects Analysis (FMEA) for Reliability Centred Maintenance (RCM) applications;

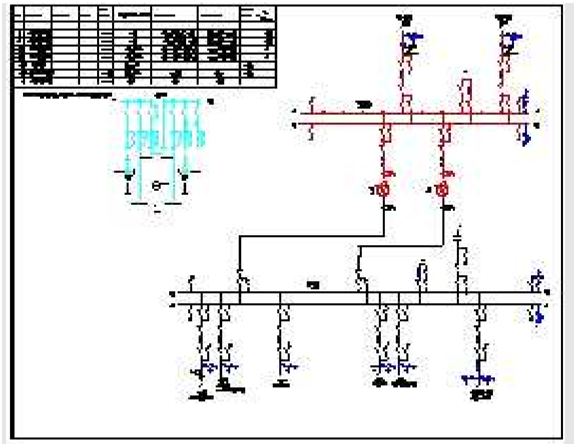
Planning stage to provide figures of station originated forced unavailability of transmission devices (lines and transformers) to be used for composite system adequacy analysis.

The computational tool is suitable for the analysis of:

Local networks including several substations and their connecting lines;

Industrial power supply systems;

HVDC transmission systems (multi-terminal too).



The methodology used in SISTAZ computations refers to the Reliability Centred Maintenance technique. More specifically, the computation tool of SISTAZ resorts to direct probabilistic techniques and adopts the method of the “minimal cut-set” to detect the fault events which cause situations of unavailability of the substation to fulfil a predetermined operating condition.

The main results of the SISTAZ code are:

Reliability and risk indices for a given Operating Condition, i.e. the Probability of its accomplishment (reliability) and the expected frequency and duration of the non-reliable states;

Failure effect analysis, i.e. the analytical assessment of frequency/duration of the substation unavailability, the analytical assessment of frequency and probability of single or multiple failures leading to substation failure and the normalized weight of the component outages on the substation failure indices.

From what above, criticality of each single component can be quantitatively calculated by using the SISTAZ code.

Reliability analysis belongs to the second step of the life cycle of equipment.

MAINTENANCE PLAN REVIEW

Maintenance of equipment plays a crucial role within substation operation. Each utility has its own maintenance rules and, therefore, each substation has a maintenance plan tailored on its structure and characteristics.

Maintenance actions, to be effective, need information, the most complete is possible. This task is accomplished by monitoring actions.
Monitoring actions are suitable to detect and follow all main failure causes of equipment, leading to all key failure modes of the component itself.
The higher is the percentage of failure causes detected by the monitoring tasks and/or repaired by the periodic maintenance operations, the lower is probability of experiencing an unexpected failure mode.

MV Circuit Breakers				
Parameter: presence of relay protection				
Relay protection	Yes	X		Ref. to document A6002182 to get limit values, test procedure, evaluation method and CB actions
	No		X	
Modality	**Type of action**	**Frequency**		**Notes**
Condition Based Monitoring Actions				
in-service	**Record** and store the number of operations of the related line overcurrent relay	6 M	n.a.	
	Record and store the number of operations of the CB counter	6 M	6 M	
	Visual inspection: check of the external conditions of the CB	6 M	6 M	*Oil CBs*: check for oil leakages *SF_6 CBs*: check the gas pressure indicator
	IR thermography: check the temperature of power connections, cable connections and poles	1 Y	1 Y	The IR thermography shall be applied only with CB closed, and visible
out-of-service	**Test:** conductivity measurement on the external insulating surface	1 Y	1 Y	On representative samples only
	Test: coil current profile measurement & analysis	1 Y	3 Y	On representative samples only
	CB major overhaul or CB replacement	n.a.	n.a.	According to the maximum number of operations as per manufacturer's specifications
	CB major overhaul or CB replacement	n.a.	n.a.	According to the value of integrated current threshold, as per manufacturer's specifications
Time directed actions without component out of service				
Time directed actions with component out of service				
out-of-service	**Visual inspection:** check of the general conditions of the CB	3 Y	3 Y	
	Test: dynamic and static resistance measurement	3 Y	3 Y	opening/closing time shall be recorded

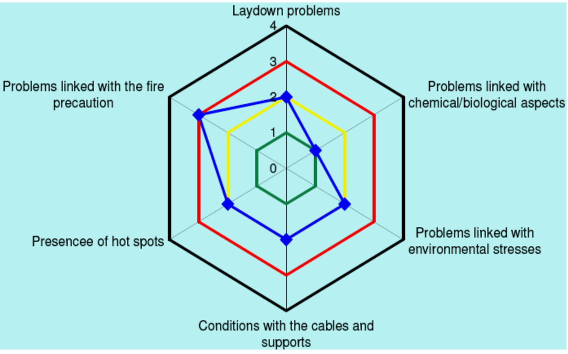
Table 4.1.1-2

CESI approach to maintenance plans review is based on five successive steps:
Evaluation of operational history of substation major equipment (power transformers, circuit breakers, GIS, VTs, CTs) aimed at assessing the stresses at which the equipment have been subjected during their service life;
Evaluation of most recent tests performed on such equipment, with the aim at assessing their present conditions;
Reliability analysis of the substation (ref. to Reliability Analysis), with the scope at pointing out both the present reliability index of the substation and the weight and contribution of major equipment in its determination;
Characterisation of suitable monitoring tasks, to better detect prevailing failure causes for each equipment;
Determination of the most suitable frequencies for monitoring actions of each equipment;
Maintenance plan review belongs to the second step of the life cycle of equipment.

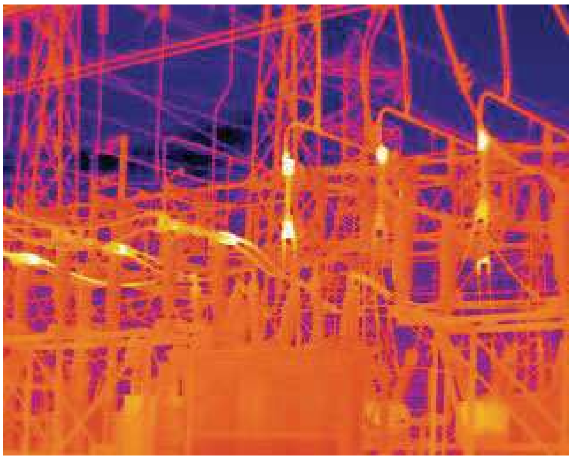
CONDITION ASSESSMENT & DIAGNOSTIC

The management of a substation implies the use of a large amount of resources for operation and maintenance, also due to the large number and complexity of involved components. Several actions have to be taken to optimise the management of substations and to streamline maintenance practices, maintaining or improving system reliability, availability and safety.

To achieve this aim, CESI has developed an innovative cost-effective approach to the Condition Assessment of electrical substations in view of the determination of the best run-refurbish-replace options.

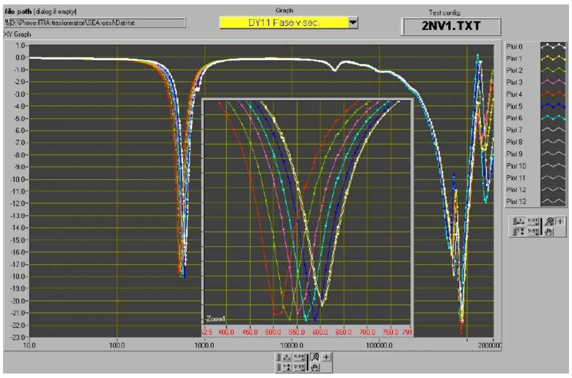


The activity is centred on a reliability approach leading to the implementation of advanced diagnostic techniques on the major substation equipment and concluded by a multi-criteria analysis, allowing the selection of the most appropriate action, in terms of diagnostic controls and maintenance policies, to be taken on the major substation equipment.
Basically, the overall activity consists in the revision of the condition assessment practices adopted by the electrical substation by applying an innovative approach that allows the assessment of the residual service life of equipment and the improvement of.



the operational conditions of the substation while reducing costs of fulfilment. Residual life calculation is based on the average equipment life and related confidence level. Equipment useful life is considered as an average of the historical commercial life of similar equipment, as reported in available databanks (e.g. EIREDA). This matches the age of the component on which the cumulative distribution function of the chosen Weibull distribution and confidence level (e.g. 50% or 90%) takes a value equal to 0.5.
Once established this “average useful life”, a correspondent equivalent maximum failure rate can be calculated and, as the value of a failure rate multiplier is derived from the results of

available monitoring tests, the actual failure rate of the the component is calculated. The actual failure rate corresponds now on the chosen Weibull distribution to an Actual Age of the component, so that the residual life of the equipment is simply assessed.



Outcomes of this activity are, on the basis of client's needs:
Present conditions of analysed equipment;
Expected residual life of equipment;
Most effective monitoring tasks to be applied to achieve a suitable monitoring of their conditions;
Corrective actions to be taken on the equipment;
Corrective actions to be taken on the system where equipment are installed in, as immediate actions (actions to be taken to prevent further failures on that or similar equipment, which are likely to occur in case no actions are taken);
Mid-term (actions aimed at improving performances of same equipment class, e.g. monitoring tasks or field tests to assess present conditions of all equipment of the same class) and long-term actions (actions aimed at improving performances of the entire electrical system, e.g. review of maintenance strategies or reliability analysis of the system).

FAILURE ANALYSIS

When a failure has occurred, is generally necessary to perform a failure analysis in order to understand failure causes and prevent them.

The aim of preventing further occurrences of same or similar failures is a priority for this kind of activity, which is carried out by CESI, at first, with a visual inspection of the failed equipment.

Subsequently, on the basis of the outcomes of the visual inspection, further and deep analysis of the equipment, or parts of it, could be requested in order to deepen failure origination.
In case no cause is found to be directly due to the equipment, system data are analysed in order to point out possible weak points in the plant the equipment are installed into.

The outcomes of a failure analysis are as follows:
Formulation of an hypothesis of failure, as a result of the visual inspection of the failed equipment and of the plant where the equipment is installed in or of further analysis or studies;
Recommendations for actions to be taken to improve both equipment and system reliability.

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