HIGH VOLTAGE EQUIPMENT MONITORING: A TOOL FOR FIXED SERIES COMPENSATION PREVENTIVE MAINTENANCE IN POWER SYSTEMS

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ABSTRACT

The main purpose of this article is to present monitoring techniques for high voltage equipments that compose fixed series compensation, one of the Flexible AC Transmission Systems (FACTS). Fixed series compensation employs capacitors to compensate the inductive reactance of transmission lines. It is a highly effective and economical means of improving power transfer. Suitable for both new and existing lines, fixed series compensation increases power transfer capability by raising the transient stability limit as well as improving the voltage stability and reducing transmission losses by optimizing the sharing of active power between parallel lines. Monitoring systems represents a tool for preventive maintenance of the equipments that compose the fixed series compensation, minimizing risks of blackouts in a power transmission system.

Key words: *High Voltage Equipment, Monitoring, Maintenance, Fixed Series Compensation.*

INTRODUCTION

The Brazilian Electric System legislation, elaborated by the National Agency of Electric Energy - ANEEL foresees heavy penalties for equipments that affect the performance of basic power transmission networks: 10 times the revenue value for programmed outages, 150 times the revenue value for the first 5 hours of non scheduled outages and 10 times the revenue value for the subsequent hours [1].

In consequence of these high discharges penalties, the electric power concessionaries are being stimulated to review their operational procedures and preventive and corrective maintenances, with the objective of minimizing the programmed outage periods and mitigate risks that generate the non programmed outages.

There are some options that can result better mitigation of these interruptions:

- Protection systems refinement;
- High voltage equipment redundancies;
- New dimension planning for electric power systems;
- Improvements in the periodicity of preventive maintenances;
- Diagnosis of future defects (preventive maintenance) using equipments monitoring, reducing the preventive/corrective maintenance interventions costs and increasing the equipment availability in the power system.

The monitoring of equipments that compose the power system is a powerful tool to supply the necessary equipments conditions information, providing a premature diagnosis of possible defects and allowing a programmed maintenance, avoiding undesirable energy supply interruption. The monitoring of the reactive power compensators installed in power transmission systems begins to be a more applicable practice to increase the equipment maintenance, and consequently, all the reactive power compensation system availability.

FIXED SERIES COMPENSATION

The power demands of Brazilian national industries need an economical solution to increase power transmission capacity of existing transmission lines. Due to environmental and economical difficulties to construction of new power transmission lines, the use of Fixed Series Compensation (FSC) has turned into a common practice of power transmission companies in Brazil.

The series compensation is presented as the best choice, because not only it makes possible increasing power transmission capacity as well as it stabilizes the interconnected energy nets through reduction of the impedance of the transmission line [2].

A simplification of a Fixed Series Compensation single line diagram [3] is presented on Figure 1 below.

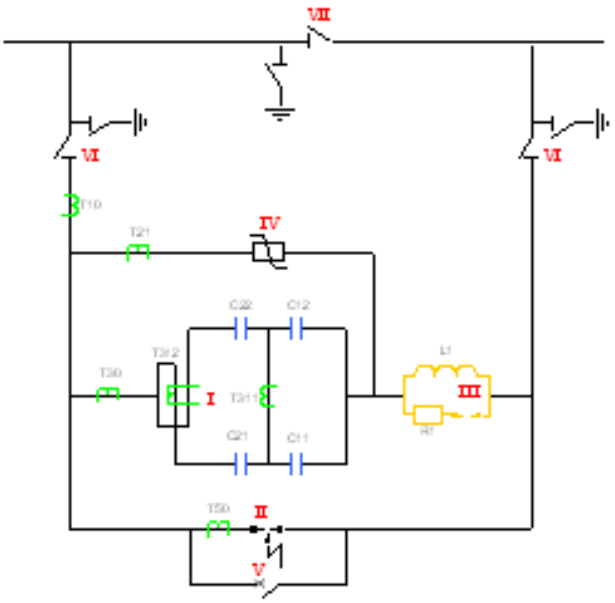

Figure 1 – Fixed Series Compensation single line diagram

The single line diagram presents:
I – Capacitors Banks
II – Spark Gap
III – Damping Circuit
IV – MOV (Metal Oxide Varistors)
V – Bypass Circuit Breaker
VI – Line Isolation Disconnecting Switch
VII – Bypass Circuit Breaker
From these equipments, the following are the main events that are monitored [4]:

Capacitors Banks

- Unbalance currents;
- Currents discharge at the damping circuit;
- Capacitive element fail.

Metal Oxide Varistors (MOVs)

- Non programmed currents discharges;
- High currents (generating high temperature).

Circuit Breakers

- Contacts operation times;
- Interruption current value;
- Number of operations;
- Insulation gas density;
- Open and Closing circuits' continuities;
- AC and DC auxiliary supply;
- Oils pressure;
- Motor starts ups.

Disconnecting Switch

- Real contacts position;
- Motor currents;
- Number of operations;
- Accumulated time in opened or closed position;

THE HIGH VOLTAGE EQUIPMENT MONITORING SYSTEM

The maintenance of high voltage equipments is indispensable to assure a reliable operation and with larger quality in power supply to the final consumer. When preventive maintenance is not executed or it doesn't happen in an appropriate period, interruptions in the power transmission supply may happen, that in most cases are only solved with long duration corrective maintenances. The Fixed Series Compensation Monitoring has the objective to provide knowledge of the current physical status of the reactive compensation system and to diagnose the evolution of the waste of its components, to foresee the equipment's maintenance need.

Monitoring System Data Acquisition

The necessary information to the monitoring is provided by the protection system or directly from currents transformers installed for that purpose. Because that work is vital to the process, the acquisition is accomplished through special plates of analogical acquisition, hard disks and redundant sources. The data acquisition may happen by two possible ways:

Hardware Acquisition
In this case, the analogical acquisition plate is monitoring the desired unit during the whole time. When a certain value is reached, the acquisition process and storage begins.

Software Acquisition
In this case the acquisition is made during pre-determined periods by the monitoring software.

Monitoring System Data Processing

With the variables obtained by the equipments, the monitoring software executes the algorithms that will supply the system's answers, that is, the bulletin of operation conditions of the Fixed Series Compensation.
Those units are divided in accordance with the equipment they refer to; therefore the system has defined monitoring functions for each one of those equipments.
Concisely, what the software does, in each function, it is to use the units obtained, with a group of equipment parameters defined by the manufacturers or along with the customer, in a mathematical model of the equipment operation, to obtain an answer in terms of a value that is of relevance for the knowledge of the operation conditions. This value is compared with normal limits of operation and as result of this comparison, the equipment is found to be working properly or not. In case a problem is detected, warnings are emitted to the maintenance personnel, visible in the system interface. It is important to point out, however, that the system monitoring doesn't influence directly on the operation of the Fixed Series Compensation, that is, it doesn't activate protection devices.

Monitoring System Data Analysis

After processing the values obtained, the system emits the bulletin with the Fixed Series Compensation state. It is exhibited in the screens of the monitoring system, through a group of warnings and alert of the noticed events and the problems detected in the equipments, and also reports values of the units monitored that allow evaluation of their evolution, also in a graphic form.
Besides, whenever an event happens, every time that an item is out of its range of normal values is identified, the system processes information to generate:

Diagnosis
It is the cause of the event (fault, deviation, etc.) it can indicate the equipment/component that is probably presenting defect and which defect may it be. It is important to point out that, in some situations, the monitored data may be noticed out of normal occurrence range, without the occurrence of a defect in the Fixed Series Compensation. In this case, a diagnosis doesn't exist. The system will verify all the possible defects sources before confirming this hypothesis.

Prognostic
An estimate of the effects that the Fixed Series

Compensation will face if maintained in operation with the diagnosed fault. In some cases, it is possible to also estimate the remaining time until foreseen effects take place. When an equipment fault is shown, through the continuous variation of a monitored value, the system is capable of informing the necessary time to the operation limit through lineal extrapolation of the evolution curve of the measured value. The operation limits are defined by the equipments manufacturers to guarantee a safety margin for the operation and attend specifications.

Providences

Are actions that should be taken by the Fixed Series Compensation maintenance personnel to fix the identified flaw and to re-establish the equipment's normal operation conditions, to avoid effects foreseen in the prognostic. The providences, many times, will be equipments´ inspection and maintenance, as the manufacturer's instructions contained in the operation and maintenance manual of the Fixed Series Compensation.

Monitoring System Interface and Communication

The equipments maintenance teams interact with the monitoring system through web pages that contains the information available. They allow the accomplishment of monitoring all the equipments that compose the Fixed Series Compensation. Communicating with the database, the pages receive and send data, supplying to the equipment maintenance personnel the visualization of the whole monitoring through graphic screens.

A webserver station has the function to communicate with the database where the reports are stored as events and graphs. It accomplishes the interface of the data with the equipment maintenance personnel, displaying the monitoring system results.

To guarantee the system's stability, the monitoring is developed without the need of plug-ins installation. As programming tools, the Visual Basic, ASP, HTML and SQL languages are used. Still aiming safety the webserver's access is monitored and controlled by a Firewall [4].

HIGH VOLTAGE EQUIPMENTS MONITORING EXPERIENCES APPLIED TO FIXED SERIES COMPENSATION IN BRAZIL

Nowadays in the Brazilian Electrical System, the Fixed Series Compensation installed in some of the power transmission systems in 500kV and 230kV are supplied with monitoring systems [4]. Besides the FSC, almost all the equipments (circuit breakers, disconnecting switchs and autotransformers) of the substation where the FSC is been installed are monitored too, using the same system of the FSC (just adding some acquisition data equipment).

The application of monitoring systems is helping the transmission utilities regarding maintenance programs, avoiding non programmed power supply interruptions.

CONCLUSIONS

The high voltage equipment monitoring system becomes not just the supervision of measured values in the several events of the electric system where the fixed series compensation is installed (on system operation or occurrences), but the measurement and registration of these events and dynamic operation data, later analysing the data automatically to verify the need of immediate maintenance action or not of the equipments between the programmed maintenances intervals.

This monitoring function should not be confused with protection or control systems, but it can be considered as being a fourth function to be used in the electric system, besides protection, control and measurement ones already used and known.

The Fixed Series Compensation high voltage monitoring advantages are appropriated to be applied to Electrical Power Systems, as with the same equipment it is possible the acquisition and analysis of data, preventing system outages and consequent decrease of difficulties resulted by the interruption in the electric power supply.

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BIOGRAPHIES

André Luiz Pereira de Oliveira was born in 1978 (Brazil). He received his BSEE degree in electrical engineering from the Itajubá Federal School of Engineering (EFEI), Brazil, in 2001. Obtained Specialist's title in Power Systems Protection and MSc in electrical engineering, in 2004 and 2006, respectively, from Itajubá Federal University (UNIFEI), Brazil. Project Management Professional (PMP®) certified by the Project Management Institute® - PMI® (USA) since 2004. He works at SIEMENS Ltda. as a Project Manager (PM) since 2001 at PTD H (Power Transmission and Distribution - High

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