Contributions to improving equipment and technologies for monitoring and diagnosing power transformers

Summary thesis

The energy sector is the strategic basic infrastructure of the national economy and a public utility with a strong social impact. In the years 2000 - 2004, restructuring the entire energy sector was held in conditions of energy market liberalization, realizing the legal framework for medium and long term development.

In 2003 the final report prepared by the Technical Committee of the Union for the Coordination of Transmission of Electricity (UCTE) concluded that the National Power System (NPS) satisfies the conditions for the continuous synchronous system Union for the Coordination of Transmission of Electricity. National energetic system interconnection with National Union system for the Coordination of Transmission of Electricity requires operation at high standards of efficiency and quality of electricity supply. Power quality problem is a current concern of national and European research - the Framework Program 7, under "Energy". The union for the Coordination of Transmission of Electricity is the Association of Transport and System Operators (TSOs) in Europe and is characterized by:

- ensures the efficient and safe bus transport electricity from the interconnected system;
- includes carriers and system in 21 European countries, including a network of about 200,000 kilometers of 400kV and 220kV lines through which about 450 million people in Europe are supplied with electricity at high standards of quality and safety, with an annual power consumption of around 2100TWh;

The integration into the Union for the Coordination of Transmission of Electricity is a strong argument to attract more investors in the context of the start of privatization in the sectors of generation, transmission and distribution of electricity.

The privatization of electricity companies and large industrial enterprises has an effect on management of high voltage electrical power equipment to how to optimize the use of assets by collecting and processing relevant data derived from maintenance, the upgrading of investment decisions and asset performance monitoring.

Energy market competition forces electricity companies to reduce operating costs and minimize investment, a general reduction of investment funds being already observed. There are tends not to replace or modernize aging equipment but to exploit them until the end of life, increasing their risk of failure with age and with lack of equipment maintenance.

Preferences

In literature and scientific symposia and conferences, national and international, permanent works are being developed for monitoring the status of electric power transformers, insulation monitoring, monitoring of partial discharges, monitoring the gas content, monitoring crossings, winding condition monitoring, humidity monitoring, monitoring cooling system. CIGRE (Conseil International des Grands Réseaux Electriques à Haute Tension) promoted steadily, both the methods of description of monitoring and diagnosing power transformers and the review of the damage taking place in different countries.

In power stations, safe operation of power transformers is important because of unforeseen damage and interruptions, which can cause serious operating accidents, leading to high costs that are undesirable in - an increasingly competitive environment.

Power transformers are the most important and expensive assets in a high voltage station.

The knowledge at any time of a power transformer condition can be achieved by switching from preventive maintenance based on time-based maintenance to state maintenance, which also leads to a costs drop, an important element under market liberalization.

Developing new techniques for monitoring the state became one of the most important tasks for most energy companies, imposed by the occurrence of the following issues:

- projected life of power transformers is 25 to 30 years;
- the average age of power transformers in use in Europe is approaching the limit of nominal life. As you get older transformers, their internal condition degrades leading to increased risk of failure;
- failure costs can exceed up to five times the cost of a new transformer, through loss of revenue due to undelivered energy, high costs of energy purchased in emergency conditions, soil decontamination costs in case of oil leakage, costs for air pollution if there is a fire, pay accidents, decreased customer confidence in the quality of energy supplied;
- planned stoppages avoidance, which are not consistent with the possibility of occurrence of defects;
- with continuous monitoring of the state, power transformers are expected to remain in service up to 60 years, with minimum operating costs;

Proposed for solving problem

The purpose of the thesis is that of establishing monitoring and diagnostic equipment of processors to enable a continuous evaluation of the status of operation of these units.

Objectives of thesis

They consist of:

- analysis of conditions imposed to monitoring and diagnostic equipment;
- analysis of the current state of monitoring and diagnostic equipment of electric power transformers;
- contributions on methods and algorithms for monitoring and diagnosis status of transformers;
- contributions on completion equipment;
- verification results;
- experimental results obtained in real operating conditions and final conclusions.

Relevance

The research for thesis preparation has been materialized by creating an innovative product, new in Romania, which was established in an equipment distributed, open, of continuous monitoring of processors. The equipment contributes to the prevention of early damage, ensuring real-time management of hazardous situations by a proper alarm and even by disconnection of the processing unit. The solution proposed in the thesis can provide a control of the processing unit and an historic during its operation.

Methodological and theoretical scientific support

In order to perform the research there were consulted technical scientific works, books, patents, PhD thesis, reviews, internet sites and interest norms in domains of maintenances of the units of transformation.

Scientific novelty for the results obtained

The novelty characteristic in the domain of monitoring the processors is given by the equipments architecture, algorithms of monitoring and diagnostic, the complete of monitored parameters, the patented solutions and experimentally verified.

The applied value of the work

The equipments of monitoring and diagnostic realized permit the evaluation and permanent control of the processor as also resorting to a history of its running. The results application obtained in the thesis was demonstrated by the experiments made in the power stations Lacul Sărat and Piteşti Sud.

The dissemination of the results

The main results of the thesis, consisting of a number of 28 scientific works were published in professional journals or in books of some national and international conferences.

Accumulation and work structure

The present work contains a number of pages and is structured in 6 chapters where there are enounced the results of the research, accompanied by figures, tables, relations, a chapter of final conclusions and contributions, a bibliography and the works published as main author or joint author.

The first chapter **„Analysis of the actual stage of the monitoring and diagnosing equipments for the power transformers"** presents the analysis of equipments for monitoring the electrical power transformers produced by constructers well-known such as ABB, AREVA, Maschinenfabrik Reinhausen, MTE, Qualitrol, in the following way: analysis for the equipments structures, analysis of the monitored parameters, analysis for the software solutions, analysis of the solutions adopted for envisioning the monitored measures.

In chapter 2 of the thesis **„Analysis of the conditions enforced to monitoring equipments and diagnosing"** we presented"

- the concepts of monitoring and diagnosing the condition and the implications upon the predictive maintenance;
- the main components of the transformer and the rate of breakdown;
- the set of parameters whose monitoring, permanent but also by measurements in the periods of revision can contribute to avoidance of accidental cut-offs, failures, but also the extension of the life of the transformer.
- the demands concerning the procession information concerning a correct and fast data analysis by the operating personnel;
- the types of perturbations that can impact upon the good performance of the monitoring equipments in real conditions from the high voltage power stations. There have been highlighted measures to increase the immunity of monitoring equipment in a judicious organization of the household of cables;
- the means of interlinkage of a monitoring equipment with SCADA systems, a necessary interlinkage for supervision at hierarchic superior levels and a fast command of the shields.

In the third chapter **„Contributions concerning the methods and algorithms for monitoring and diagnosis of the transformers condition:** there are presented aspects concerning:

● analysis of the monitoring process for the coil isolation, consisting of:

- the heating and cooling equation of the transformer with the assumption that it is a homogenous body;
- the method of temperature determination for the hottest point coil;
- aspects concerning monitoring and analysis of the dissolved gases and the water content in the oil;
- aspects concerning monitoring of the partial disruptions;
- aspects concerning monitoring the factor for dielectrical losses for isolated passages;
- elaboration of the monitoring algorithms and diagnosis:
  - the monitoring algorithm and analysis of the oil temperature;
  - the monitoring algorithm and analysis of the coil temperature;
  - the diagnostic algorithm of the efficiency of the cooling system;
  - the monitoring algorithm of the oil level in the tub and the switch setting;
  - the algorithm for monitoring the level of aging;
- the algorithm for monitoring and diagnostic the H2 content dissolved in oil;
- the algorithm of monitoring and diagnostic the CO content dissolved in oil;
- the algorithm for monitoring and diagnostic H2O content from oil and paper;
- the algorithm for monitoring and diagnostic the partial disruptions;
- the algorithm for monitoring and diagnostic the isolated passage condition;

● monitoring the oil level in the transformer and the switch setting under quantity;

● monitored parameters and the algorithms used in the process of monitoring of the switch setting under quantity;

● the methods of acquisition and dressing of the measures purchased view to monitoring;

● the principles of numerical conditioning for a sinuisoidal measurement process;

● the possibilities usage of the numerical equipment for monitoring the transformers condition and there were presented proposals of block diagrams and equipment structures for monitoring.

The fourth chapter of this thesis **„Contributions concerning the execution of the equipments for monitoring and diagnostic of the electrical power transformers"** approaches elements concerning the conception and achievement the monitoring equipments and diagnostic of the power transformers such as :

- The equipment for monitoring the functioning of the power tranformers – the basic version;
- The equipment for monitoring the functioning of the power transformers – the complementary version;
- The equipment for monitoring the functioning of the power transformers – the extended version.
- Equipment for measurement, registration and diagnostic of the interruptors commutation related to switch settings under charge that fit out the power transformers. The equipment was realized during a research contract – The CALIST Programme. This one was tested at S.C. Electroputere Craiova – The Electrical Gear Division and at present completes the lab of trials for switch settings under charge

It was realized the architecture of the monitoring equipments, as systems distributed wh the sensors,ich include the transducers, the specialized equipments of monitoring, acquisition and communication. There were conceived three configurable architectures of monitoring, so as to adapt as well as possible to the real demands of monitoring the electrical power transformers. For these structures we realized:

- the hardware structure for central units;
- the interface for analogical entrances;
- the means of conditioning for monitoring the oil temperature;
- the means of conditioning the transformer monitoring;
- the means of conditioning for monitoring the oil levels;
- the means of conditioning for monitoring the dissolved gases, H2 and CO;
- the means of conditioning for monitoring the water content from the transformer oil;
- the means of conditioning for monitoring the partial disruptions;
- the means of conditioning the signals at the isolated passages;
- the means of conditioning for monitoring the functioning the pomps and exhausters;
- the interface for numerical and analogic exits.

For each of the architectures proposed we presented the structure and the functions, taking into consideration the aspetcs related to the assurance of functioning and the performances that it can offer them. There have been analyzed and chosen the components used for obtaining the equipments, for assuring for as much as possible the lowest price possible for the equipments, without touching the performances so that the implementation be viable.

We realized the hardware structure for the equipment in order to diagnostic the functioning of the oscilography, registration and time measurement for the switching times for the switch settings under charge associated with the electrical power transformers.

The fifth chapter of this thesis **„Results Examination"** presents the lab check of the performances for monitoring equipments for the electrical power transformers through sensors simulation and transducers that serve the equipment, with the help with electronical devices that generate the necessary signals.

The checkings were made in specified environmental conditions and standards, calibrators and inspection equipment standardized

It was carried out the checking of the following functions of the equipments obtained:

- function of measuring the oil temperatre;
- the function of measuring the currents;
- the function of measuring the oil levels;
- the function of measuring the gas content;
- the function of measuring the water content in the oil;
- the function of measuring the factor of dielectric losses to the isolated passages;

- the function of measuring the partial disruptions;
- the function of monitoring the numerical measures;
- the diagnostic equipment checking of the switch setting running under quantity;

The contributions refer to:

- dissimulation of the sensors and transducers;
- assuring the specific environmental conditions and the measurements equipments;
- registering the data in tables and oscillograms;
- adapting the data in curves of variation for each monitored parameter;
- demonstrating the corectness of the solutions adopted and the good running of the equipments realized

The sixth chapter „**Experimental Results obtained in contitions of real running**" present the experimentations from the power stations obtained with the equipments carried through:

- testing equipments of monitoring on two types of units of transformation:

- a transformer of 400 MVA, the main unit of take-up, from the power station Lacul Sărat, that was implanted with a monitoring equipment in the basic version;
- an autotransformer of 200 MVA, from the power station In Piteşti de Sud, implanted with a monitoring equipment in the complementary version.

- the testing was proceeded by registering the monitored measures from where there were retrieved data on a period of time, there were processed the measured values and drawn the variation curves with the help of the EXCEL Programme 2003
- testing equipment to diagnose the operation of adjusting switches on the two types of switches: a switch type 3 M I 501 and a switch type MIII 300 60/B.

Contributions are related to:

- installing and bringing into service of the equipment;
- registering of switches to local recording equipment;
- transferring records to the computer;
- processing and analysis of records;
- print records to issue tests bulletin;

In the last chapter **"Final conclusions and personal contributions"** were presented the main conclusions resulting from the doctoral disertation and the original contributions of the author's doctoral thesis. The paper is based on theoretical and experimental research as well as on the bibliographical information, which includes works published in the country and abroad.

Research results have been obtained / applied in 9 national research and development projects and an international research project.

For equipment produced and presented at national and international exhibitions were obtained 5 diplomas and medals. For "on-line monitoring equipment for isolated crossings type high voltage capacitor" has obtained patent 121620/2007.

Currently monitoring equipments presented in the thesis fit out transformation units in several power stations in the country: Tulcea, Medgidia, Slatina, Craiova, Işalnița, Ploiesti, Suceava, etc.