On-line and Off-line Monitoring-Diagnosis System(MDS) for Power Transformers

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Abstract – **The safe operation and the extension of the remained life of power transformers have been dominant objectives during the last years. An accurate assessment of the remained life could be an important instrument for the safety of the power transformers in operation.**

The paper presents the structure and the using mode for an integrated monitoring-diagnosis system (SMD) for power transformers. The monitoring-diagnosis system allows on-line analysis on a desktop application, a web application and off-line analysis for determining the transformer condition, by means of which there are surveyed:

- **Cooling system condition;**
- **OLTC condition;**
- **Bushing condition;**
- **Insulation system condition;**
- **Partial discharge evolution;**
- **Transformer switching in/switching off;**
- **Exceeding of monitored parameter limits;**
- **Estimation of remained life.**

SMD allows determining accurately the transformer condition and the monitored parameters evolution in time, avoiding the appearance of incidents and failures and specifying certain type of maintenance.

Index term: **power transformers, on-line monitoring, diagnosis, maintenance.**

I. INTRODUCTION

In operation, the transformers are subjected to combined stresses (electrical, thermal, mechanical and environmental), finally leading to the decrease of their life and appearance of some faults with irreversible evolution. Taking also into account the fact that most transformers are in operation since more than 20 years, it results the necessity of fitting out the transformers with systems for monitoring and diagnosing their condition.

The operating safety of large transformer units within National Power Grid (SEN), and implicitly the extension of their lifetime, depends to a great extent on the degree of monitoring for their functional and state parameters, also on, setting the suitable maintenance measures, depending on the parameter interpretation[1]-[3].

For carrying out the monitoring as source of a diagnosis as correct as possible, a mode for collecting data on the surveyed process, saving and storing them, filtering and verifying and finally transmitting them to the user is necessary. A proper management of power transformers, based on acquiring continuously information from the monitoring equipment allows increasing permanently the energy efficiency by avoiding the accidental interruptions leading to summed costs which could exceed many times the price of new equipment. The latest achievements offer the possibility for the software configuration of the monitoring-diagnosis system, from designing until commissioning, also in service, its function being adaptable to different requirements in service. The monitoring system configuration offers the possibility to make it modular, by configuring the hardware resources, thus increasing its versatility.

II. TECHNICAL SOLUTIONS FOR THE MONITORING AND DIAGNOSIS OF POWER TRANSFORMERS

A. Presentation of the Monitoring Equipment

The system developed at present is designed in a modular structure. A complete variant of the system is presented in Figure 1 and has the following:
- input quantity acquisition and data processing;
- data recording in an own memory
- communication with a computer and visualizing on a monitor the monitored parameters
- setting the alarm levels for the monitored parameters;
- equipment testing ;
- possibility of diagnosing the transformer condition

An example of locating within the substation the components of the monitoring system their interconnection with the transformer transducers and accessories, also the monitored parameters are presented in Figure 2[4],[5].
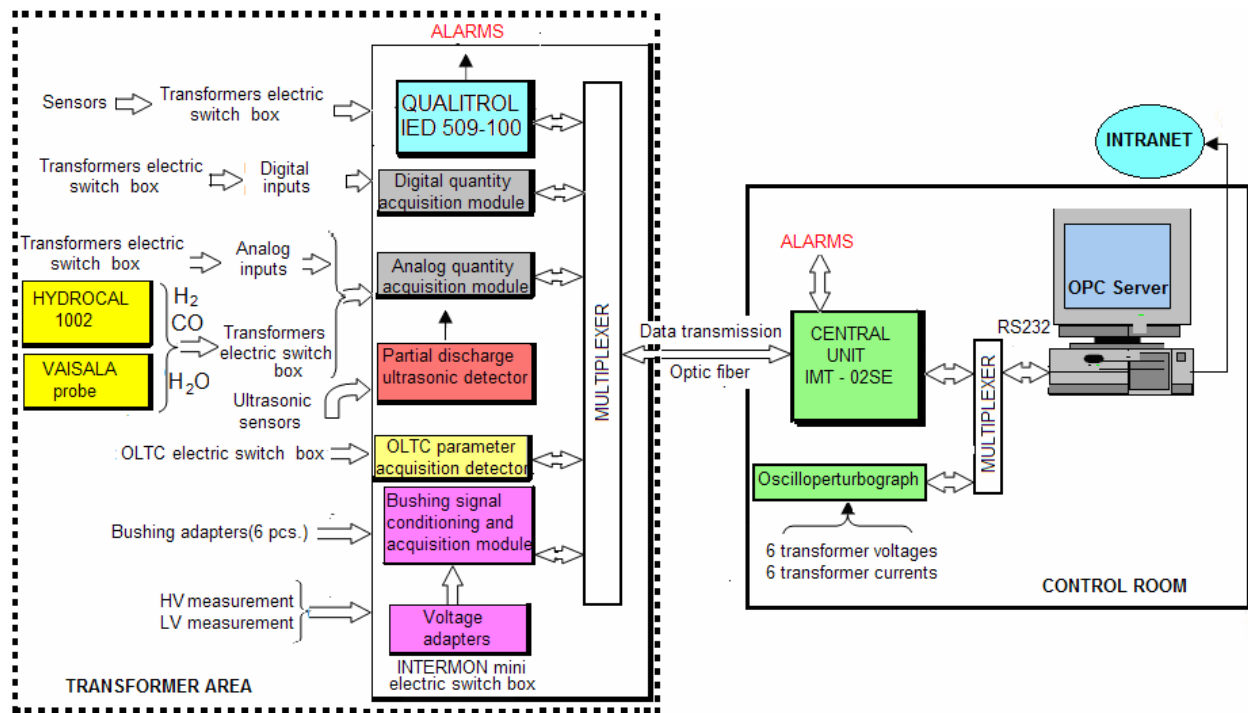
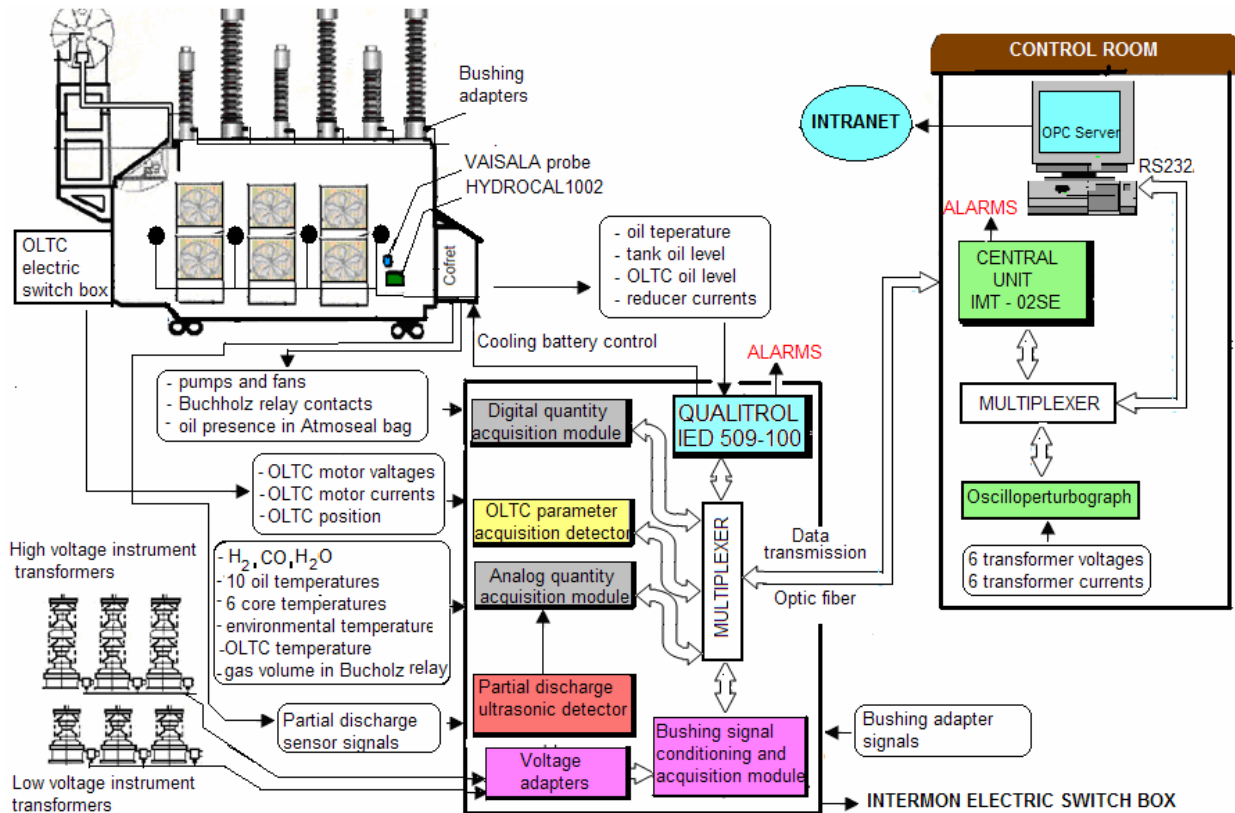Fig.1. Block diagram of the monitoring equipment

Fig.2. Architecture of the monitoring equipment, with OPC server

B. Monitoring Software "SM Console"

It is a desktop application, used for the monitoring-diagnosis of power transformers within substations. The data are acquired by the monitoring equipment and then offered to the application "SM console" by means of an OPC server. Each transformer substation is endowed with an own data base server, where "SM Console" stores the acquired and calculated data. The application runs on MS Windows and

offers an accessible presentation of the measuring data, many combinations and zoom possibilities, visualization of historical data and detection of the alarms, also storage of the data acquired in a data base. The following functions are provided:

- • On line data displaying
- • Real alarm displaying
- • Alarm configuration
- • Historical data displaying as graphics
- • Creation of reports for historical data
- • System data displaying

"SM Console" is a complex and complete environment for visualizing the parameters monitored on transformers, having one second the rate for updating the measured parameters, depending on the time constants of each one. The possibility of visualizing simultaneously many parameters, irrespective of their nature, was taken into account.

"SM Console" offers also information on the variable evolution in time, giving the user the opportunity to choose a starting time, a final time and a resolution identified by the time step when the graph plotting is wished. The graphics have the auto-scaling and zoom option.

The window for transformer contains the analysis blocks, lists of calculated and measured parameters, information on the possible alarms appeared and the mechanisms for setting the limits own to each transformer
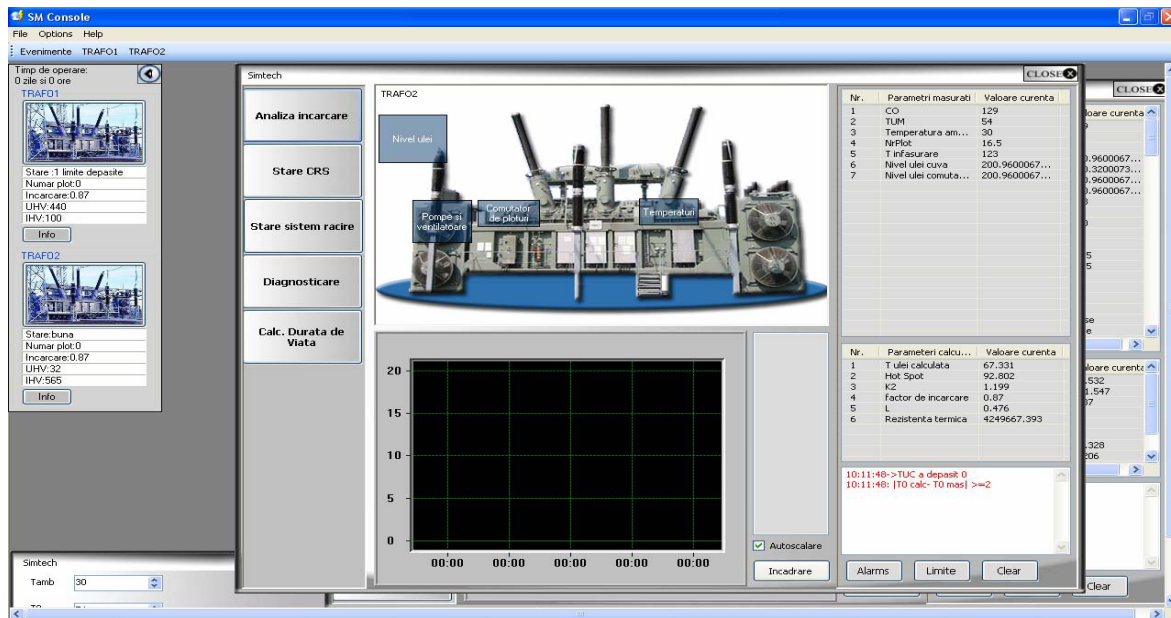

Fig.3. Window for transformer visualization

For opening the relevant analysis block, it is necessary to click one of the buttons. Another window will appear for each block separately.

The visualization of certain parameters could be done from the sensors attached to the transformer, appearing on the central image, thus: one clicks on the sensor containing the wanted parameter, then one clicks to right on the parameter, and after that clicks from the menu which appears on "data on-line visualization" and voltages, currents, values given by the sensors could be visualized.

The analysis functions could be performed on each transformer separately; these functions are:
- cooling system condition;
- OLTC condition;
- Bushing condition;
- Insulation system condition;
- Partial discharge evolution;
- Transformer connection/disconnection;
- Exceeding of the limits imposed to the monitored parameters;

- Calculation of the consumed/remained life;
- Off-line diagnosis

"SM Console" allows warning the user if an alarm is produced, by visual means, when one of the parameters is beyond the limits. The alarm will contain the data and time when it started, description (the parameter which exceeded its limit) and duration. The alarm window displays the alarms appeared until the moment when the displaying is required. Each alarm is characterized by the alarm starting moment ("Alarm staring": date, time - hour, minute, second), duration of the period when the alarm was active ("Alarm duration") and parameter which got out of the range limits ("Alarm description").

The button "Limits" opens the window where the limits for parameters are established. For each parameter, maximum 3 upper limits and 3 lower limits could be set. When setting is finished, the button "Save" should be pushed.

The configuring window is meant for establishing the port for communication with the web application, establishing the way of reading the data through OPC server, for the

calculation and synchronous reading periods and for the selection of the off-line diagnosis application "path", if any.

The window "System condition" displays the events appearing during running; by example, a client connection or errors.

C. WebConsole Monitoring Software

WebConsole is a web application serving to visualizing and analyzing the parameters monitored in a transformer substation. The parameter analysis and visualization could be done from anywhere worldwide, by accessing the URL where the application is installed, from a web browser. WebConsole could work for many transformer substations, which at their turn could contain many transformers under monitoring. WebConsole has an intuitive and friendly interface, allowing utilization without requiring specialty knowledge.

The control menu has 5 main sections:
- *Monitored substations* -> contains the list of all the substations monitored by the monitoring system
- *Transformers*-> contains the list of all the transformers monitored within the chosen substation
- *Alarm history*-> contains a list of all the recorded alarms
- *Backup*-> accesses the safety duplicates made for the current substation
- *Help* -> the on-line documentation system which helps the user

When choosing a transformer substation, the WebConsole application verifies the substation existence and shows on the screen those transformers from the substations which are under monitoring (fig4).

Fig. 4. Transformer presentation

For choosing a transformer, one clicks on left the transformer picture or the transformer is chosen from the control menu. After choosing the transformer, the WebConsole Interface is displayed (fig. 5).
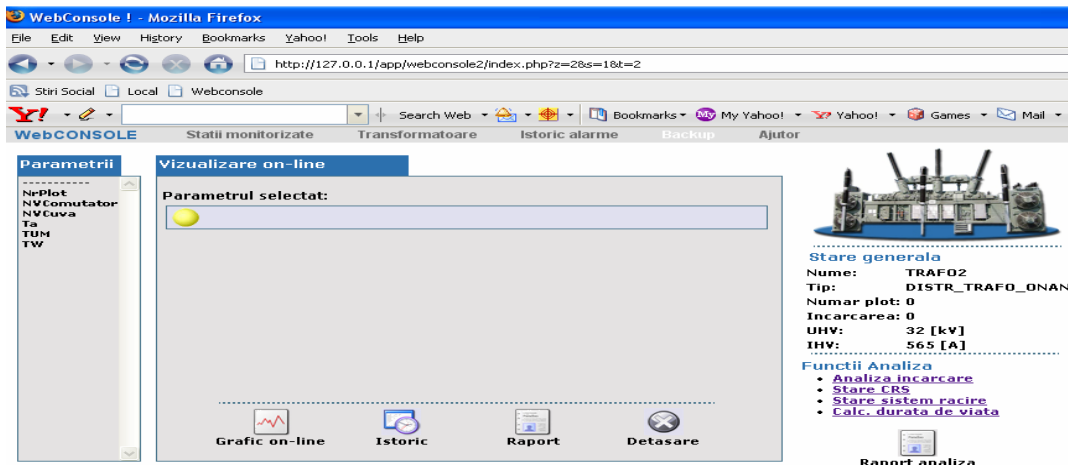

Fig.5. *WebConsole interface*

The WebConsole interface is divided into three parts:
- list of parameters under monitoring
- zone of working with parameters
- zone of general information and analysis functions

The list of the parameters under monitoring is presented in Figure 5, at "Parameters". These ones are alphabetically sorted.

The zone of working with parameters comprises all the functions which could be performed on the parameters. These functions are:

- real-time visualization (digital/graphical)
- history
- parameter report on a time interval

For visualizing in real time certain parameter, one selects it from the left side and clicks the "Attachment" button located up in the right side. If the rectangle where the parameter is displayed becomes red, it means the parameter got out of the limits accepted for that transformer.

For visualizing a parameter in real-time, one checks on graphic the "Selection box" and then clicks "On-line graphic". A new window will be opened, where the real time graphic could be seen.

For seeing a time evolution of the parameters, one selects the relevant parameters and then clicks the "History" button. After that, one sets the duration for tracking by selecting 2 calendar dates. By clicking the button "Displays graphically", a window with a graphic of the parameter evolution during the set duration will be opened. The report will be opened in another browser windoe. It can be printed by means of the option "Print" within the browser file menu. The analysis functions could be performed on each transformer separately, and they are the same as for „SM Console". WebConsole allows warning the user if an alarm is produced. If an alarm appears, the user is warned by a window where the parameter which produced the alarm, also the limit which was exceeded, are specified. By means of the alarm window, the user may visualize the values of all the parameters for the alarm period.

WebConsole has also a special section for visualizing all the alarms since the monitoring software was installed on the transformer.

D. Off-line Monitoring and Diagnosis - DiagElectric.
  Data base.

The data necessary for achieving the data base are entered by the operator. The monitoring software carries out data processing, archiving and visualizing[6]-[11].

Within this stage there are determined:
- ✓ Oil-paper insulation system condition;
- ✓ Winding condition;
- ✓ Cooling system condition;
- ✓ Embedded-type transformer condition;
- ✓ On load tap changer condition.

By means of the software created for monitoring and diagnosing the power transformers, the transformer conditions could be determined and monitored anytime, and the reserve life could be assessed. The acquired data could be also processed for setting the time evolution trend for the parameter transformers (Fig. 6,7, 8).
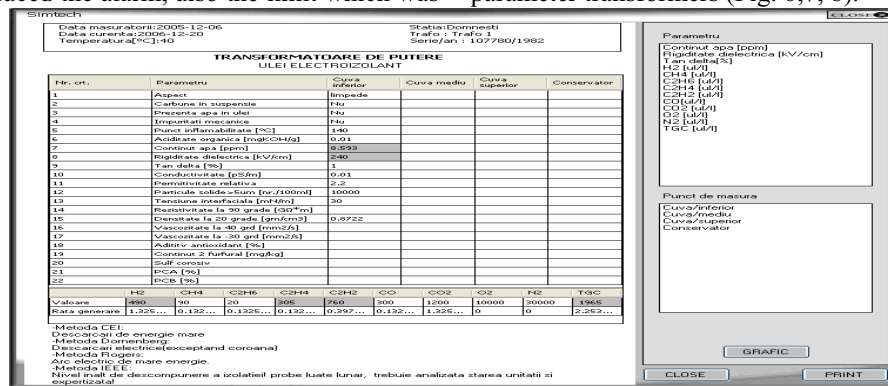

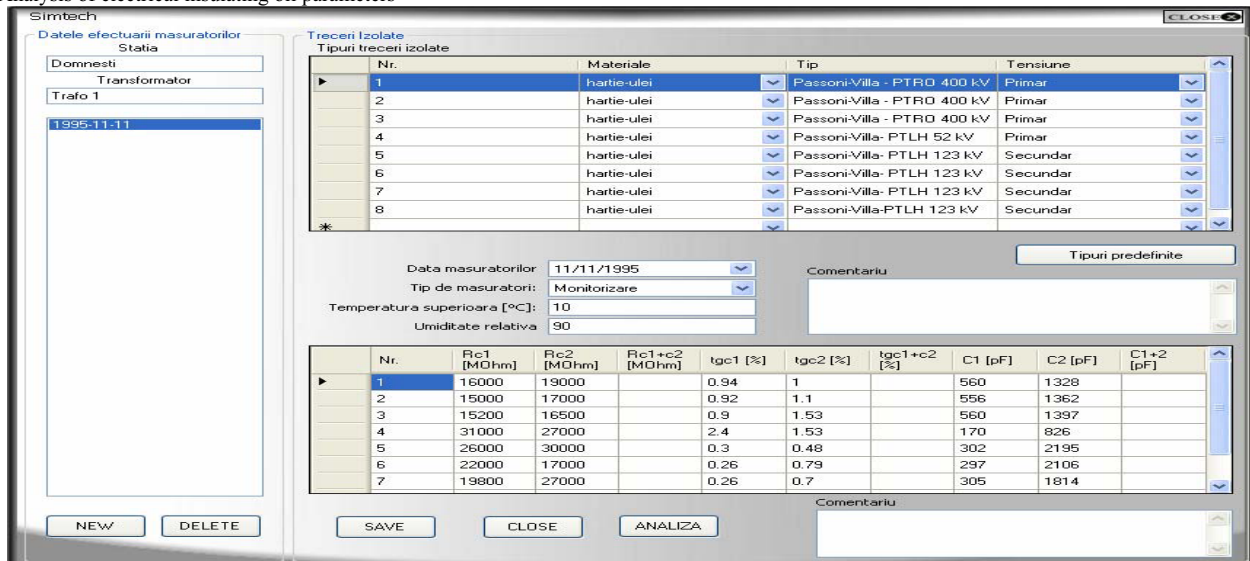Fig.6. Analysis of electrical insulating oil parameters

Fig.7. Bushing condition visualization

For each parameter monitored or entered, it is possible to visualize its evolution in time. If the condition of certain component (insulation, winding) of the transformer is monitored, it is possible to print a report (bulletin) where the got values are specified, mentioning also if they are beyond the limits set by the norms in force.
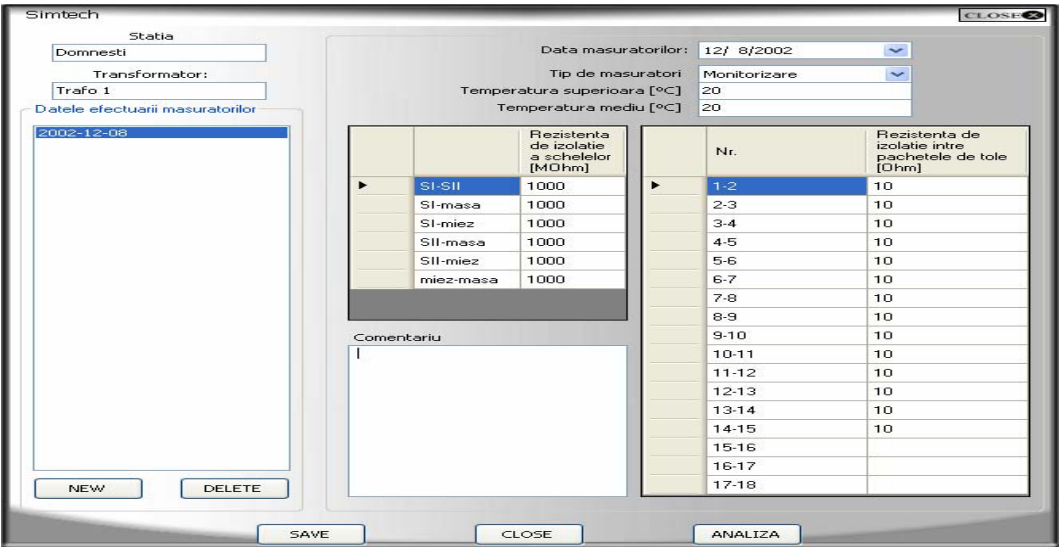

Fig.8. Visualization of the condition for core, scaffolds and stack of sheets

Within the diagnosis section, marks are given to each analyzed components (fig.9), also to the transformer unit as a whole, providing both the visualization of its condition and the indication of the maintenance types. It is also assessed the remaining life, by monitoring the chosen parameters, by recording and rendering evident their evolution and analyzing the "history" of the transformer unit.
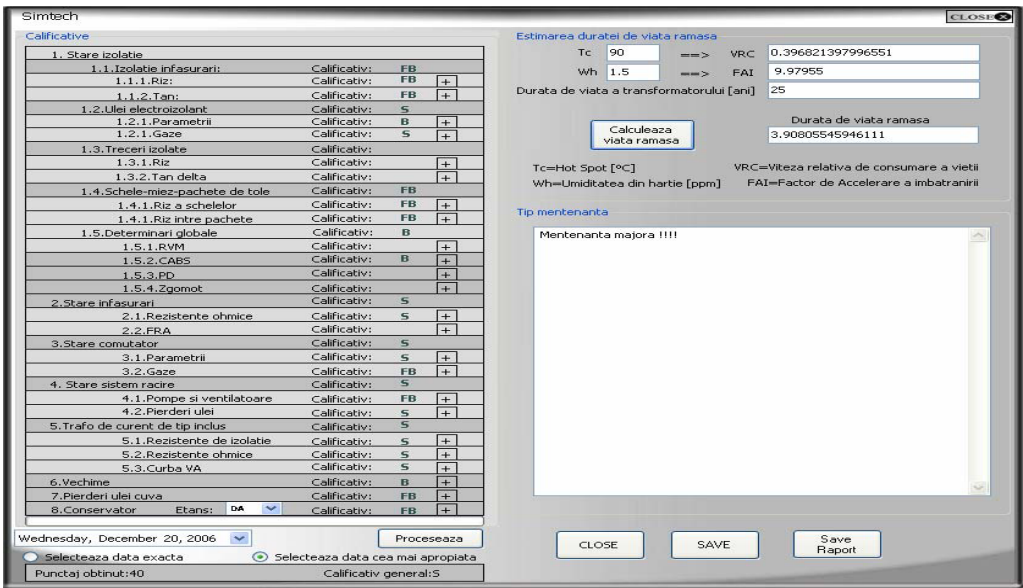

Fig.9. Determination of equipment condition

By pushing the "Save report" button, a complete report on the transformer unit condition is carried out and saved in the wanted location

III. CONCLUSIONS

-   The presented monitoring system is a modular one. The configuration of the monitoring equipment could be chosen depending on the transformer optimal monitoring needs and fitting-out degree;

-    The main operating parameters of power transformers are offered by OPC servers (Ole for Process Control);

- The extension of state parameter monitoring to the level of an electric substation opens the outlook of controlling the electric substations with no own personnel;

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Within the on-line and off-line monitoring-diagnosis system, on the basis of the acquired data, the following information is got: thermal ageing/hot spot temperature calculation, assessment of the remaining life, transformer thermal diagram, complex insulation condition, cooling system efficiency, bushing condition, automations and protections;

- The analysis of the measurement parameters is a real time one, being possible to alert the operators by warning messages when a potential danger appears;

- It is possible to follow the transformer units, both at the subsidiary headquarters and at company headquarters, depending on their condition, knowing exactly which type of maintenance should be applied. Thus the extension of the life is carried out, under complete safety conditions.

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