Expert System for Accurate Diagnosis of Power Transmission Transformer

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Abstract – This paper presents a tool for managing, storing and processing of various experimental tests performed on power transmission transformers. Such devices represent one of the most valuable assets for utilities and their service removals (by non-scheduled ways or failures), result in long periods of disruption for consumers as well as large financial losses. Thus, there is a constant search involving the development of tools to accomplish the task of identifying prominent failures, especially those that combine conventional and intelligent tools for this purpose.

Keywords: fault diagnosis; expert systems; intelligent systems; power transmission transformer.

1 Introduction

Equipment belonging to the power transmission system has a complex maintenance plan, aimed at testing compliance.

There are specific procedures that enable investigate different scenarios of operation of these devices with or without the presence of failures. Such experimental tests are mostly performed manually, which can affect the accuracy associated with the metrological aspects [1].

The power transmission transformer is currently considered one of the critical points of the system, since its service removal promotes various disorders for consumers and also for utilities.

When submitted to failure condition, testing procedures become critical, because elevate the level of result precision to levels that do not allow incorrect diagnoses [2-4].

Such needs encourage the development of new tools to produce efficient results, which aim to solve these problems in an automated way, combining and enhancing existing tools or proposing new methodologies [5-9].

In this context, we can highlight the integration of techniques, methods and algorithms for obtaining optimal results.

The consistency between tools has proven to be one of the major challenges for the scientific and technical community, because the processes of detecting and locating failures in power transmission transformers are associated with various nonlinearities, besides infinity of data collected that need to be properly treated [5].

The combination of expert tools around a particular goal in order to get optimal results is known by Expert System [10].

In fact, in such systems, the great difficulty lies exactly in the processes involved in the evaluation of the results produced by the tools used in solving the subproblems. It is also important to highlight that the routines for the tests may display the results in different ways, where data in addition to having different formats also differ in volumes [11].

Thus, this paper presents all technical and scientific criteria involving the development of an expert system responsible for managing experimental tests performed on power transmission transformers, taking into account all aspects normative pointed in [12-14].

Additionally, we will present the main concepts involving the integration of conventional and intelligent tools, exploring aspects of data storage, signal processing, training of artificial neural networks, tuning of fuzzy systems and feature selection techniques, which effectively contribute to the processes of detecting and locating failures in power transmission transformers.

2 Data integration

As previously mentioned, data integration is a task of great importance in this study, since these data can be obtained either from preexisting databases in power utilities or by means of tests to be performed in transformers. Moreover, it is important to note that these tests may generate different data in various formats and, therefore, the integration of all possible data to be analyzed becomes a complex task.

Therefore, we developed a database that will be responsible for integrating these data. In addition, an attribute selection stage is employed in order to reduce the dimensionality of the data used as input for the expert system.

2.1 Database modeled and implemented to achieve integration of data

After carrying out experimental tests on the transformer to be analyzed, the data are then obtained and, therefore, it is pertinent to store them in a database that is reliable and safe from the point of view of the power utility. Therefore, we obtained an Entity-Relationship model of this database for this purpose. This model was derived based on the test reports provided by the utility. In order to better illustrate these reports, an example may then be visualized by means of Figure 1.
Observed that there are time and date fields, which are stored so that there is a history of testing for each transformer. Finally, it is possible to notice the field "Tipo Ensaio" represents a foreign key so that there is the relationship with the table "Tipo Ensaio".

Table "Tipo Ensaio" was created in order to register all possible tests to be performed. Therefore, this database becomes very flexible because it is independent of the type of test to be carried out, and could also be used for both transmission and distribution transformers.

In addition to the above tables, it is important to note the existence of the table "Oscilografias", which includes the paths of oscillography files and identifies the type of measurement that was performed and is stored in each file. For this reason, a table "Tipo Medidas" was also created, which is responsible for storing the registration of the possible types of measures that can be collected.

### 2.2 Selection of data to be integrated into the expert system

After the data is properly stored in the structure of the database proposed in Subsection II.A, these should be selected in order that the expert system can present a failure diagnosis more appropriate. This data selection procedure can be visualized by means of Figure 3.

Thus, the database has a main table named "Cadastro Ensaio", which are cataloged all tests for each transformer. For this reason, there is a field called "idTransformador", which should be related to a database of records of assets of power utility. Also, in this table are values stored as current and voltage (rms values), as well as measures of real, reactive and apparent power, power factor, and nominal frequency used for the respective test. It may still be observed that there are time and date fields, which are stored so that there is a history of testing for each transformer. Finally, it is possible to notice the field "Tipo Ensaio" represents a foreign key so that there is the relationship with the table "Tipo Ensaio".

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wrapper uses a supervised algorithm to check the cost of one attribute or subset of selected attributes. Due to this fact, in some cases, the wrapper achieves further satisfactory response than methods based on correlation or consistency. However, the computational effort of the wrapper tends to be much larger than the others, except for methods that employ exhaustive searches to obtain the best subset of attributes. In order to better understand the method wrapper, the same is then illustrated by Figure 4.

![Fig. 4. Wrapper method for attribute selection.](image)

It is noteworthy that some authors defend the idea that the selection of attributes is crucial for tasks aimed at identifying and classifying patterns, since the non-selection of the attributes can take the expert system to a low performance and high cost computing [19].

3 Implementation of the decision support system

Since the data properly selected from those previously stored in the database, it becomes possible to analyze them. However, this analysis must be performed by the expert system, which is represented by a computational system which has been developed according to the block diagram shown by Figure 5.

![Fig. 5. Structure of the computer system with emphasis on the integration of data from experimental tests.](image)

It is noted by Figure 6 that the data may already be stored in the following media:
- File;
- Software;
- Database;
- Equipment.

However, if they are stored in the file, their readings can be taken and, through a computational implementation, this file can be read properly and the data stored in the database previously provided. If these data are already stored in a database, one can create a lookup table in the database proposal, which is a mirror of that in which the data are located.

Thus, the more complex cases are observed when there is a need for data export via software or when they are stored in the internal memories of those devices that perform the tests.

Also with respect to Figure 5, it is important to note that the database is represented by a module called DBMS (Database Management System), because this type of system has better management capacity and data integration. In order to systematize a DBMS, Figure 6 shows the same in the form of a block diagram.

![Fig. 6. Block structure for the data preprocessing.](image)

It is noteworthy that the systematics presented in this block diagram has some characteristics that make them attractive from the point of view of the storage, management and integration of data, i.e.:
- become more agile handling and access to information;
- reduces the time for software development;
- provides information on the time required;
- enables to integrate information from distributed databases;
- reduces redundancy and inconsistency of information;
- enables the sharing of data;
- applies security restrictions through the manager of the database, and
- reduces problems related to data integrity.
Finally, it should be noted the overall structure of the computer system, which comprises a module of data preprocessing, a processing core and a graphical user interface (Figure 7). Thus, each of the parts of this system will be explained in greater detail in the following subsections.

### 3.1 Data preprocessing module

The module of data preprocessing is mainly composed by attribute selectors. Therefore, the structure can be defined as shown in Figure 8.

![Fig. 8. Block structure for data preprocessing module.](image)

### 3.2 Data processing Core

The data processing core proposed in this research was designed employing intelligent systems, which are used fuzzy inference systems and artificial neural networks. Thus, it is possible to define this stage of the computer system as shown by Figure 10.

![Fig. 10. Startup screen for the computer system.](image)

Importantly, an expert system based on artificial neural networks need a previous training for a diagnosis to be provided to the operator. By contrast, systems based on fuzzy inference are adjusted via expert knowledge and require no training. So, in this case, the use of fuzzy inference systems becomes a more attractive alternative, since it allows to add expert knowledge to the ability of this class of intelligent system has to deal with imprecise and uncertain data.

### 3.3 Graphical user interface

Finally, this module is a Graphical User Interface (GUI), which will be responsible for handling all requests made by the user/operator. Thus, all necessary information will be available through the GUI. It is noteworthy that the interface is still being implemented; however, some parts have already been developed and can be viewed by means of Figures 10 and 11.

![Fig. 11. Main interface of the computational system with emphasis on the selection tree of experimental tests.](image)

This screen (Figure 10) shows the institutions and companies that are parts of this research and development project.

Through the main interface, the user can handle all the required information, which may also view test data that have already been performed on transformers, as well as insert new records of experimental tests.
It is important to note that there is a selection tree for experimental tests (left side of the interface), where the user selects the desired test.

It is necessary to highlight the selection tree for experimental tests, which allows the user to select as tests previously reported as to access the reports of inspection/maintenance of some of the assets of the power utility, namely:

- transformer accessories;
- switches;
- MCCP switches;
- mechanical thermometers.

In order to better illustrate the selection tree for experimental tests, it can be seen in Figure 12.

Thus, each of the experimental tests appears in the area on the side, as shown in Figures 13, 14, 15 and 16.

Some characteristics of the computer system proposed should be highlighted in relation to aspects of the graphical interface, which are connected to the possibilities of handling by the user. Among these characteristics include the following:

- management of experimental tests;
- historical experimental tests;
- integrated analyzes;
- estimation of tendencies;
- settings of the expert system.

The ability to manage the experimental tests is provided so that the user can register new experiments, change existing experimental tests, exclude experimental tests, conduct planning (standard step) and check the procedural consistency of experimental tests (Figure 17).

The history of experimental tests is now done important for the estimation of possible failures of transformers is perceived by the expert system (Figure 18).
Furthermore, there is the possibility of performing integrated analyzes, which constitutes a fundamental part of the software, since it is by this menu that any experimental tests data will be integrated so that a solution is provided on the condition of the equipment that is under analysis.

It is noteworthy that this menu will allow an analysis of the equipment, employing both current data from experimental testing as their historical data.

Finally, as a major feature of this interface, there is tendency estimation, which is responsible for analyzing the data from all tests has been conducted to the device and then provide an estimation of its useful life

These last two characteristics can be seen by Figure 19, which shows the graphical interface highlighting these tasks.

4 Conclusions

Due to the high cost of both acquisition and maintenance of power transmission transformer, the diagnosis of such equipment becomes thus imperative. Therefore, all tests and analyzes proposed in this research project are required in order, as well as the integration of data obtained for each of the tests. Thus, we note the importance of a system to provide the correct storage and data analysis and integration, which makes the transformer diagnosis even more accurate.

5 Acknowledgements

This work was developed under the Program for Research and Technological Development of the Power Sector, which is regulated by ANEEL.

6 References