Intelligent Systems for Transformers Tests

Ana Cristina Bicharra Garcia[1], Inhauma Neves Ferraz[1] and Renato Belhot[2]

Abstract - Device tests are important checkpoints in total quality control programs. Large-scale production, strong competition and high manpower flotation challenge the task of maintaining a company's know-how updated. Computers have shown to be an effective tool for the transference of specialized knowledge. As an attempt to make the diagnosis of knowledge more practical to engineers, we have developed an intelligent multimedia tutorial attached to a knowledge-based system for the domain of distribution transformers. This paper describes the use of artificial intelligence techniques as a knowledge medium to propagate and maintain expertise. A prototype system applied to the domain of distribution transformers is used to show the feasibility of the proposed model. Initial results have shown the potential use of a knowledge-based system as a constructive training tool.

Index Terms - Expert systems, knowledge acquisition, tutorial

System Definition

Transformers test procedures are described by standards determined according to specific environments (country or line of business). The execution of all tests obeys defined rules, but the interpretation of their results is a complex subject. These tests follow methods of execution and interpretation that are both deterministic and analytical. The large number of tests and their complexity make the results prone to mistakes and misunderstandings. Studies have demonstrated the power of artificial intelligence techniques in assisting task execution and training.

In this paper, we show the suitability of AI techniques in creating an integrated environment for task assistance and training. We use an engineering domain (distribution transformer diagnosis) to convey our claims in a concrete manner. Our system develops a transformer diagnosis from the interpretation of test results. In addition, the system offers explanations about the results and their environmental consequences. Finally, a tutorial teaches tests procedures and interpretation. The proposed goals of our system are:

- To collect, organize and model an energy distribution system for transformers' test procedures;
- To develop a system for the diagnosis of transformers' failure through a periodically enhanced database;
- To develop an explanation model to justify the conclusions of the system, therefore increasing the conclusions' reliability;
- To develop a tutorial on transformers' test procedures; &
- To foster quality standards (ISO-9000, ISO Guide-25, etc.) in transformers' test execution.

The incessant progress of technology demands continuous recycling if users and professionals are to absorb its most effective use. Periodic regular training courses are important, but do not solve specific problems such as punctual low absorption or meet the need for refreshing specific elucidation points. Conventional training techniques are designed for large groups and their format and content must address the group's average needs. Specific needs are thus overlooked by a behavior focused on the collective. In this scenario, computer systems become an interesting tool to personalize training. Knowledge based systems are natural candidates for connecting users to specific complex solutions, by offering:

- a systematic manner of exploring the solution space;
- a novel solution; and
- a sound explanation that enhances the user's culture and self-confidence to accomplish a task.

[1] Universidade Federal Fluminense
[2] Universidade de São Paulo - São Carlos

The Artifact: A Power Distribution Transformer

Transformers are electrical static devices used to transform energy voltage and the current. In this paper, we deal with power distribution transformers, which generally transform high voltage and low current into low voltage and high current. Figure 1 presents a schematic view of the artifact. In Figure 2, besides presenting the physical artifact, we present a hierarchical classification of its parts. Part tests evaluate one or more characteristic of the transformer, such as its ability to transform, insulation safety, and energy loss, among others. Following, we present a set of lab tests performed on the device to diagnose failures.

Artifact Test description

Transformers' tests can be classified in routine, type and special tests. Routine tests are executed in all artifacts. They cover several tests like winding electric resistance, voltage ratio, insulation resistance, polarity, angular displacement, phase sequence, empty loss and excitation current, charge loss and short circuit impedance and dielectric tests. Type tests are conducted in a sample selected from the entire group. The results of the experiments on the transformers' sample usually cover temperature elevation, atmospheric impulse nominal supported voltage, noise level and insulation oil test. Special tests – usually destructive ones -- are performed when there is a suspicion about the performance and effectiveness of a lot of transformers.

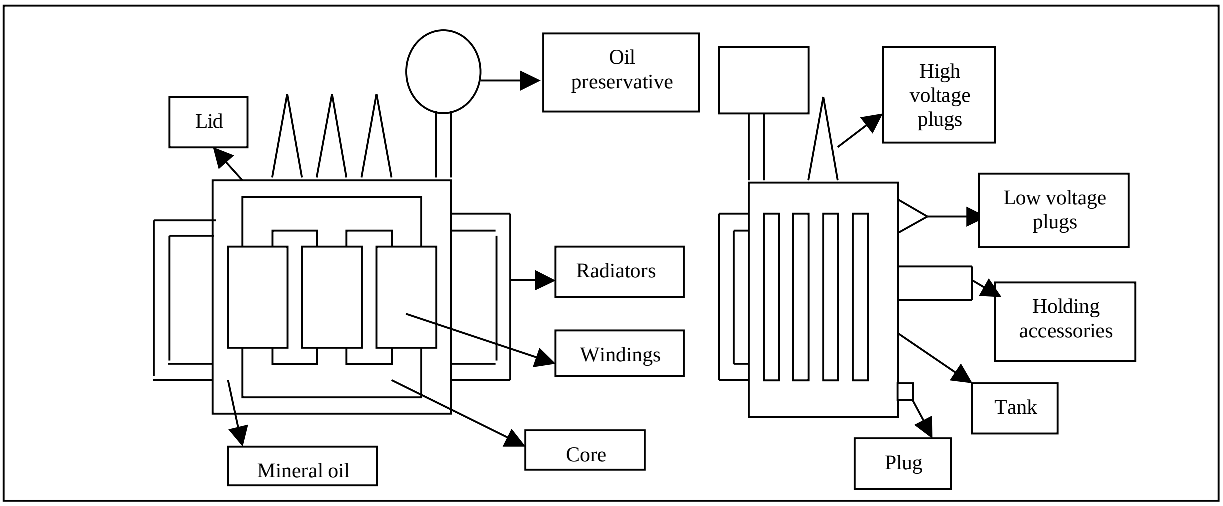

Figure 1: The physical artifact

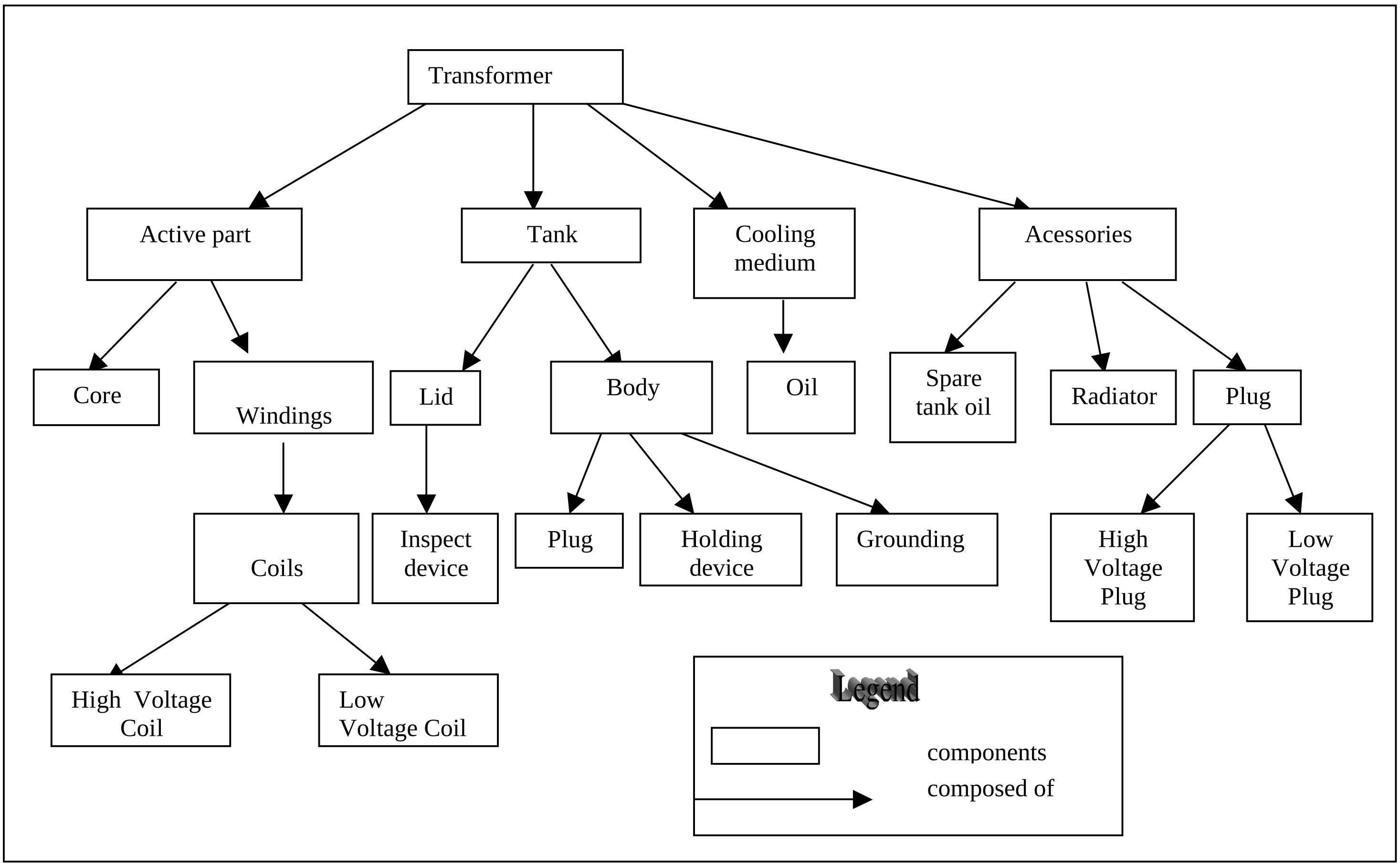

Figure 2: An artifact composition hierarchy.

Knowledge Based Systems as Training Tools

Knowledge based systems have a great potential for applicability in both business and academic environments because they can adapt to a great number of situations. These situations can range from their application as a method of knowledge systematization and diffusion (Tutorial Systems) to the solving of problems that require specialized knowledge.

The establishment of the decisive qualifications to define the usability of a knowledge-based technology is a complex issue, because it involves several subjective factors not well quantified as yet. The technical material on the subject is incipient and the applications carried out so far are not very clarifying. Nevertheless, some proposals to assist in the creation of solutions for inherent difficulties have already been made [Waterman, 1986].

Waterman proposes the analysis of knowledge-based systems' development in three dimensions, as follows:

- the task (dominion, complexity and cognitive aspects);
- the expert (as a source of knowledge); and
- the system's return (financial or social, theoretical or practical).

When considering this question, another alternative is to establish "classes of problems" or "functions of applications", which may be dealt with by knowledge based systems. Various categorizations are mentioned in literature, and one of the most accepted is Gevarter's proposal [Gevarter, 1987].

By combining Gevarter's proposal to aspects connected to the degree of structure (function) problems, it is possible to obtain interesting indicatives on when to develop knowledge based systems.

Considering the potential of knowledge based system technology and the richness and complexity of the distribution transformer domain, we propose a tool for assisting both diagnosis and training activities. This tool is described below.

ADDTRAFO : A Proposed System to Assist and Train Electrical Engineers in the Diagnosis of Transformers' Failures

As illustrated in Figure 3, the proposed system architecture incorporates the following components:

- A user diagnostic interface used by the system administrator for management purposes and by users for tests results data entry and other queries.
- A physical device model (parts & ports) that uses the data obtained from the interface to preview the probed equipment behavior.
- An ideal behavior model fed by technical norms, specifications and heuristics.
- A database of completed tests.
- A controller module managing the whole system.
- Two explanation and tutorial modules; one on tests procedures and the other on diagnostics.
- A fuzzy logic module to balance reading and parallax errors generated by the use of analog instruments when collecting test results.
- A knowledge acquisition module linking the tests' database and the physical device model.

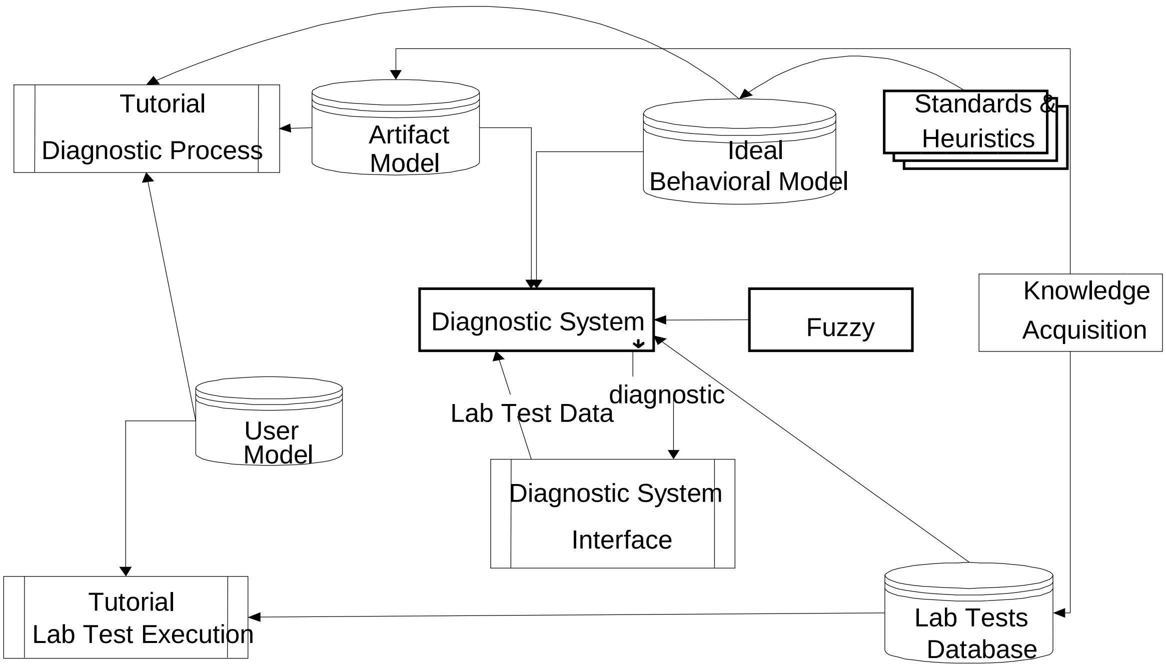

Figure 3: The proposed ADDTRAFO architecture.

Knowledge Base Representation

The distribution transformer knowledge domain was represented by the use of parametric dependency networks. As Figure 4 illustrates, there are three types of nodes:

- primitive parameter -- its value comes from external input data;

- derived parameter -- its value is obtained through a deterministic function; and
- decided parameter -- its value is obtained through a rational decision-making process.

Links reflect dependency between parameters, nposing either a restriction or a set order. Due to heuristic process, inference uncertainties are propagated through Bayesian rules.

In addition to dependency parametric rules, we used an artifact composition hierarchy to enrich decision and tutorial explanations.

Even for experts, the organization and understanding of knowledge represented some important byproducts generated by the domain modeling process.

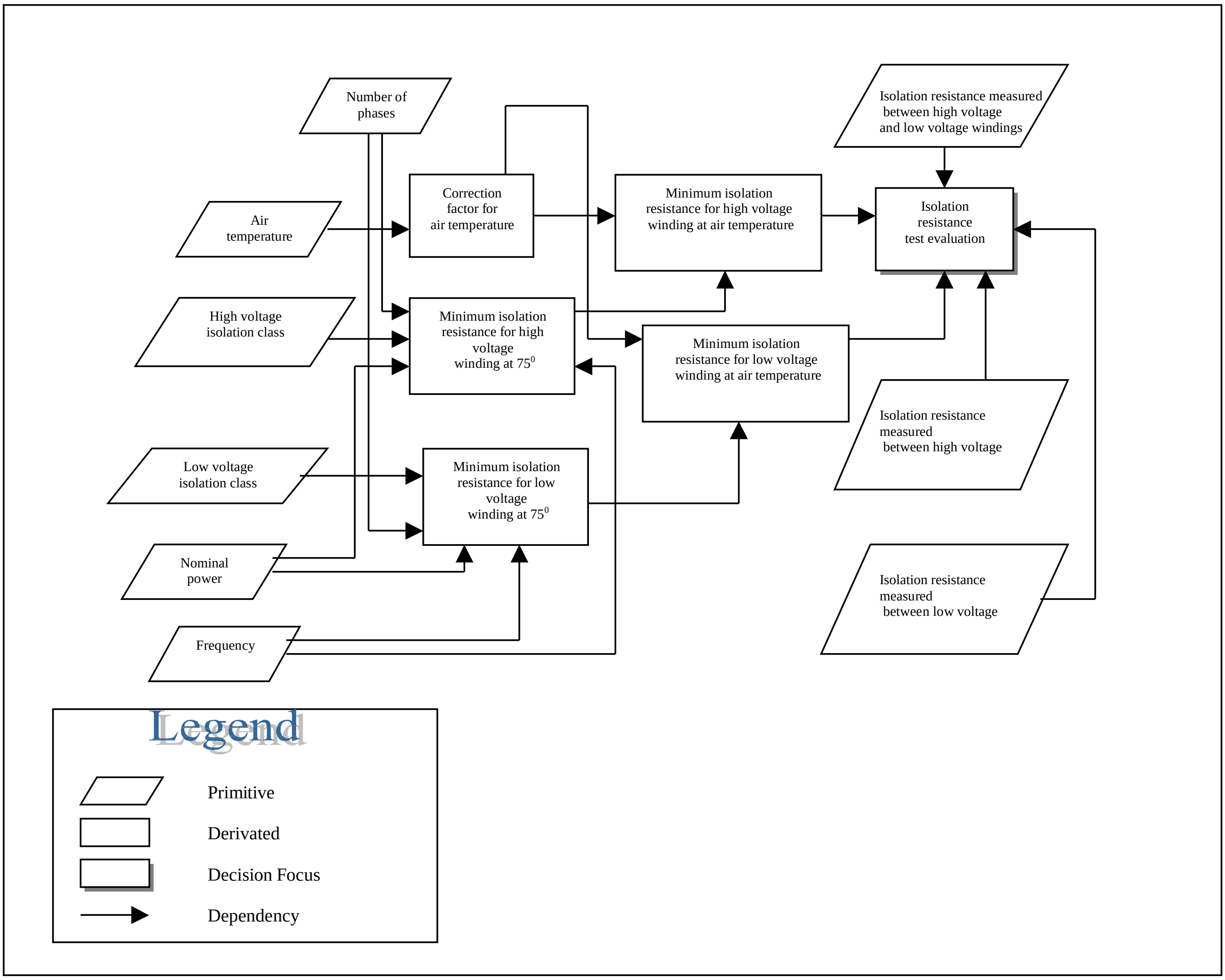

Figure 4: A sample of the parametric dependency network of the distribution transformer domain.

The Inference Engine

Transformer's diagnosis is a classification task. Based on a set of symptoms, a type of failure can be detected and/or mapped. We use Clancey's classification model [Clancey, 1985].

The interface

We realize the interface must be multimedia in order to be efficient and to increase users' perception of the output data. We use text, graphics, pictures and video as the media to compose the interaction. The multimedia aspect plays an important role to maintain users' attention.

In addition, to accomplish their task, users must have access to the knowledge base (through the explanation interface) and the databases (through a query system) feeding the system. Knowledge transparency is crucial to guarantee the system's use.

In our prototype system, users specify the artifact (a distribution transformer) by filling a form, select a test to apply by direct object manipulation and demand system's actions, such as getting a diagnosis or presenting an explanation. Figure 5 presents a screen dump of our prototype system, which is available at http://addlabs.uff.br/projetos/addtrafo.

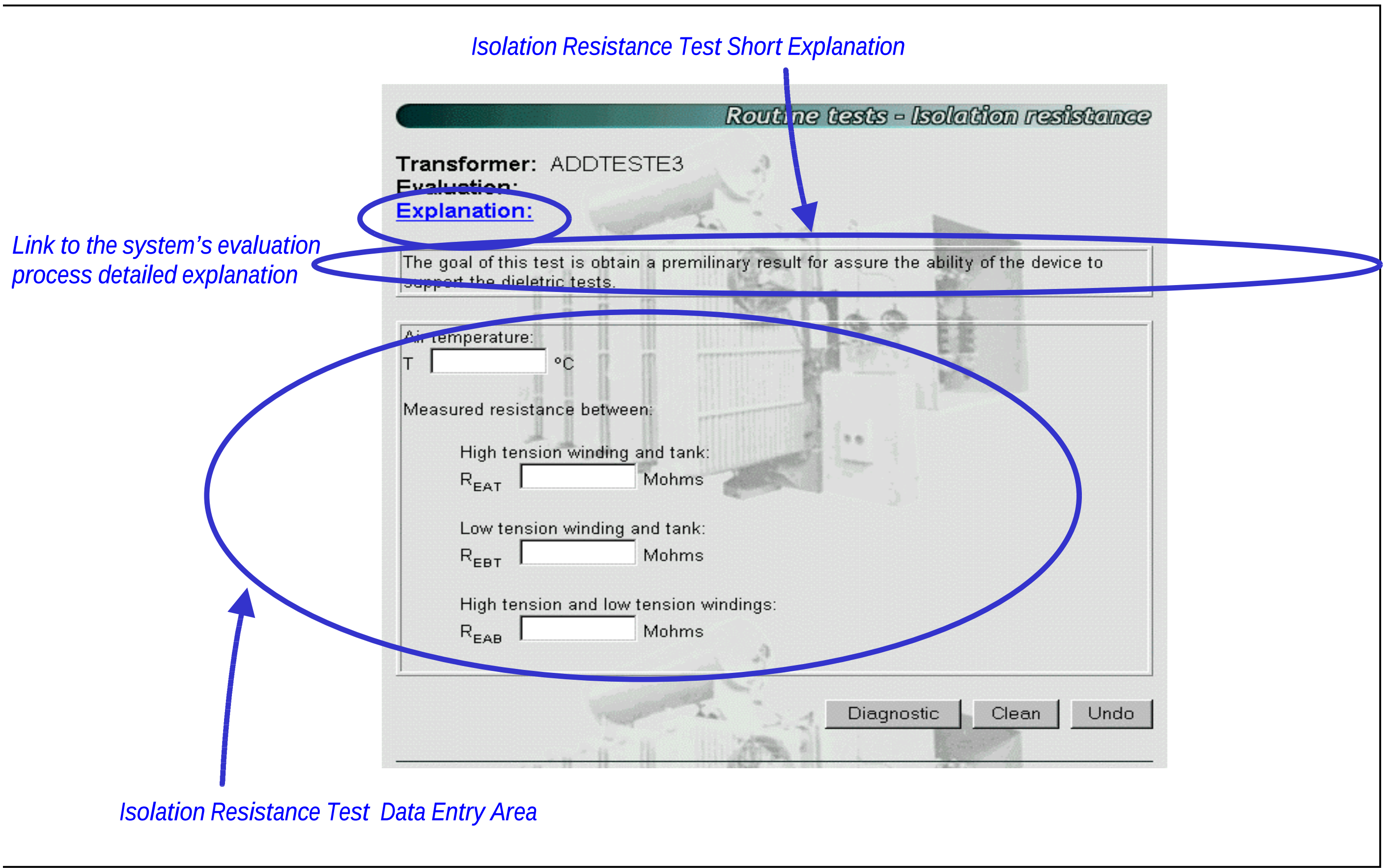

Figure 5: A screen dump of the prototype interface.

The Tutorial

A tutorial system, associated with our assistant tool, amplifies the learning abilities offered by a knowledge-based system. There are two attached tutorials:

- tutorial on the distribution transformer diagnostic process; and
- tutorial on the lab test execution.

In both tutorials, it is important to notice the extra abilities allowed by attaching the knowledge based system technology; i.e., users may experiment different scenarios and make subjective questions to the computational tutor agent. The existence of the knowledge base allows the simulation of different contexts. Consequently, it upgrades the teaching abilities from pure descriptive to a more constructive approach. We believe the success of this system comes from the integration of task and training, which provides a rich environment for maintaining and updating a company's know-how.

Conclusion

In this paper we discussed the role of a knowledge-based system as a tool to maintain and update a company's know-how. An integrated system that assist users in diagnosing an artifact failure based on lab tests and that teaches users the method to interpret and execute those tests was presented. A prototype system developed for the domain of distribution transformers illustrated our discussion. The ideal behavior, the technical standards and heuristics' database can be adapted to any country or environment. The stored knowledge in the parametric network can also be adjusted to new formulas or new methods. Small adaptations are easy to be made in order to cast the system to other equipment or devices. In fact, it acts as an expert systems shell.

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