An Expert System for Fault Diagnosis, Repairing and Maintenance of Electrical Machines

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Abstract: - This paper presents an original software tool based on a model of expert system that has been developed to satisfy the requirements of fault diagnosis, repair and maintenance of electrical machines in industrial, educational or other applications. This software comprises an SQL server database and provides different user levels (simple user, power user and administrator). By the introduction of suitable weighting factors concerning the priority of knowledge base questions, an artificial intelligence approach is achieved. A simple, user-friendly and flexible interface is used, while low hardware requirements are needed. This software provides efficient monitoring of the operational condition of electrical machines, reduces time and cost of repair and improves maintenance procedures.

Key-Words: - Electrical machines, diagnosis, troubleshooting, repair, maintenance, expert system

1 Introduction

The faults of electrical machines have been studied thoroughly by the manufacturers, production engineers and many researchers [1, 2, 3, 4, 5]. For the overcoming of problems arising out of faults, expert systems techniques have been used [6, 7, 8, 9, 10], neural networks and fuzzy logic techniques have been applied on this area [11, 12, 13], while other techniques have also been developed [14, 15, 16]. A significant amount of data is required in order to locate fault possible causes and apply proper repairing actions. As a result, fault diagnosis and fault repairing procedures may become time-consuming. Besides that, an effective maintenance plan of machines is needed. The software presented in this study has been designed to achieve efficient management of fault diagnosis information reducing the fault locating time. It is based on database applications (SQL) supporting a secure multiple-user environment. Following a "Help Desk" procedure the software makes questions to the user and, finally, provides diagnostic information by use of its database knowledge tree. At the same time, it keeps a full fault record. Suitable weighting factors which have been applied to the database elements ensure the adaption of this software to the requirements of each case, thus achieving an expert system approach.

2 Methodology

The proposed methodology serves the representation, storage and processing of specialized knowledge in the field of fault diagnosis, repairing and maintenance of electrical machines. At the same time it is aiming at the optimization of the relevant on-site procedures. This approach leads to the development of an expert system application, which comprises a knowledge base with production rules applied through backward – chaining reasoning. The tree-type structure of the knowledge base is built onto various layers. By means of the corresponding rules of the knowledge base and by the use of an interactive user interface, possible causes of a specific fault are located and, finally, all necessary fault repairing actions are proposed. In addition, a preventive maintenance plan can be easily worked out, based on the expert system suggestions. Furthermore, through the introduction of fault weighting factors, which are directly related to the application of production rules of the knowledge base, all fault diagnosis and predictive maintenance procedures are improved.

2.1 Fault Diagnosis, Repairing and Maintenance of Electrical Machines

The knowledge base for fault diagnosis and repairing has been structured in a tree form with three main levels. The first level consists of the types of electrical machines, which can be processed by the system (i.e. three-phase induction motors, synchronous motors, direct current motors, single-phase motors, generators, etc.). In the second level, all failure symptoms referring to a certain machine type are noted down. In the third level, all possible causes of each one of the previously presented symptoms are determined along with the corresponding necessary actions in order to restore normal operation of the machine under consideration.

Similarly, the first level of the other part of the software (Predictive Maintenance) contains the same data structure of electrical machine types. In the second level, the equipment components (i.e. bearings, rings, windings, commutator and brushes etc.) corresponding to each machine type are noted down. In the third level, the necessary maintenance actions (on weekly, monthly or annual basis) are being proposed according to component type. By means of the knowledge base rules and the interactive user interface, the system locates fault causes and suggests repairing actions or predictive maintenance schedules.

2.2 Application of Fault Weighting Factors

In order to optimize fault diagnosis and predictive maintenance procedures, a weighting factor is corresponded to each production rule of the knowledge base. The weighting factors impose a priority level for each rule application. The expert system has the ability to "remember" the fault background of each machine and, according to historical archive data, can modify the weighting factor of each production rule, which has a direct impact in the sequence of questions asked to the user.

3 Software Analysis

3.1 Flow Chart

The flow chart of the proposed software for Fault Diagnosis, Repairing and Maintenance of Electrical Machines is shown in Fig. 1.

The application is based on expert system techniques and its main characteristic is specialized knowledge processing through automatic evaluation. A sample screen of automatic diagnosis procedure is shown in Fig. 2. The main parts of the software are described in the next sections.

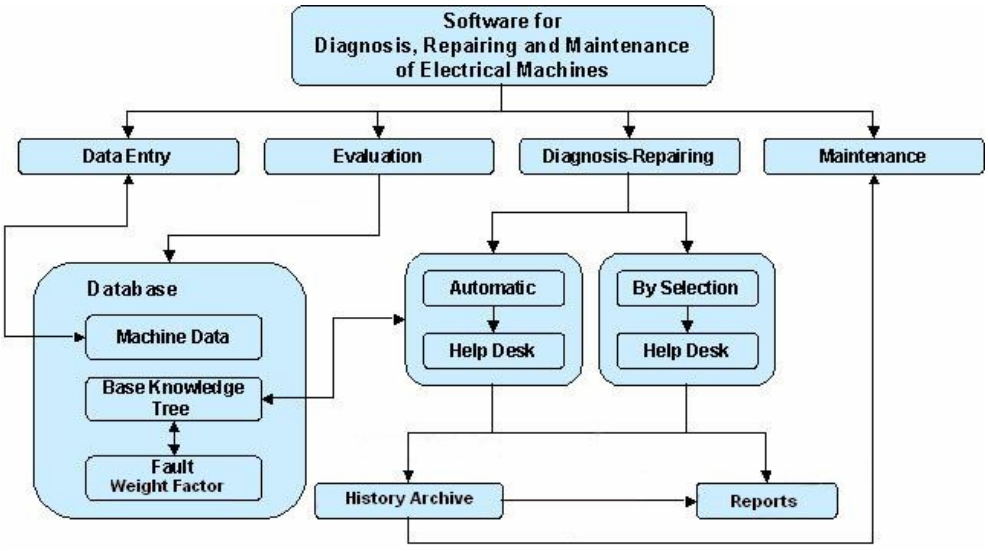

Fig. 1: Flow chart of the software.

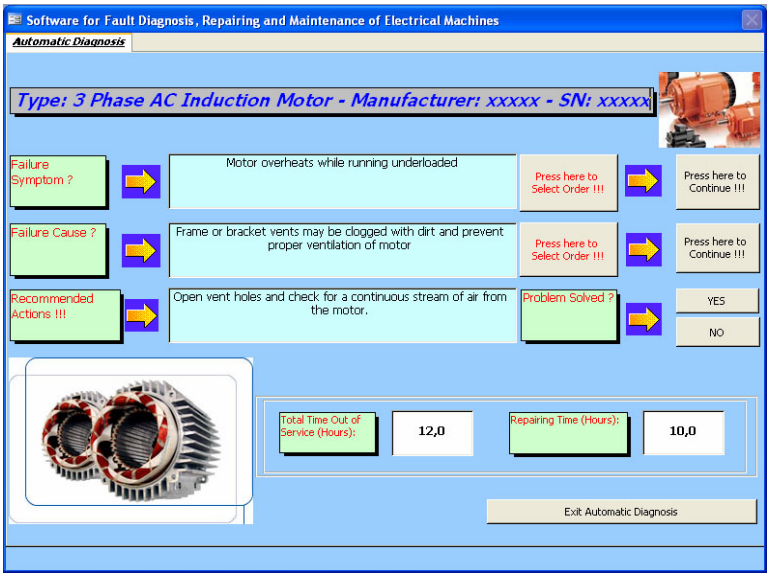

Fig. 2: Sample screen of Automatic Diagnosis process.

3.2 Database

The software is based on database principles and can operate independently or connect to an SQL server through an account creation with queries, panels and secure components. It allows multiple user operation through full access rights management. The initial application is based on Access with Visual Basic, which is recommended for operation with SQL server.

The database comprises two main parts. The first part includes the machine data read by the program (type, serial number, nominal values, date of entry, etc.). The second part includes all stored data of the knowledge base tree accompanied by fault weighting factors. During program execution, changes to the database elements can be made according to specific machine data.

3.3 Data Entry

In this part, the user may enter data corresponding to a new machine (fig. 1). During data entry, an automatic check is made whether the specific machine has been examined in the past. In this case, the program informs the user on the machine status, the number of previous entries and the last diagnosis results.

Various well-known machine types, selectable by the user, also exist in the expert system database for comparison reasons. The user has the option to search among previously examined machines in order to get data regarding the historical archive of the selected machine (previous diagnoses, reports etc.).

3.4 Diagnosis and Repairing

The diagnosis and repairing section is divided into two parts, defined as automatic diagnosis and diagnosis by selection (fig. 1). If the "automatic diagnosis" procedure is selected, the expert system is automatically updated from the last entry of the machine under consideration. Consequently, it asks questions to the user about the symptoms which have been probably appeared. Automatic diagnosis is based on a "Help Desk" process (set of questions – answers). The historical archive of the machine is updated only in the case of successful diagnostic and repairing actions. The user is informed about this update in the beginning of the next run regarding the same machine. Furthermore, the corresponding fault weighting factor is changed along with the priority queue of the questions to the user.

In the "diagnosis by selection" option, a general diagnosis pattern for a specific machine type is provided. This pattern is based on questions contained in the knowledge base tree, which are not affected by the weighting factor application.

3.5 Evaluation

In this section of the program (fig. 1), there is an option of database update upon new data regarding fault diagnosis, such as correction or deletion of questions already stored, entry of new questions, entry of new machine types, questions evaluation via priority changing of data base knowledge tree question queues. The fault weighting factors play a significant role in the evaluation procedure.

3.6 Maintenance

The results of the Diagnosis and Repairing part are automatically saved in the historical archive of the specified machine. This information concerning faults, which have been appeared during machine operation, is used in order to modify maintenance planning.

3.7 Reports

In this stage, the user is informed via special *reports* about the operational status of the machine under consideration. For example, sample screens of the expert system application in the case of a three phase induction motor are shown in the following figures 3, 4 and 5.

MOTOR HISTORICAL DATA — Type: 3 Phase AC Induction Motor - Manufacturer: xxxxx - SN: xxxxx

AA	DATE	SYMPTOM	CAUSE	ACTIONS
1	16/3/1990	Motor overheats while running underloaded	Motor may have one phase open	Check to make sure that all leads are well connected.
2	16/3/1992	Hot bearings ball	Deterioration of grease or lubricant contaminated	Remove old grease, wash bearings thoroughly in kerosene and replace with new grease.
3	16/3/1994	Motor runs and then dies down	Power failure	Check for loose connections to line, to fuses and to control.
4	16/3/1996	Motor fails to start	Short circuited stator Poor stator coil connection	Indicated by blown fuses. Motor must be rewound. Remove end bells, locate with test lamp.
5	16/3/1998	Noisy operation	Airgap not uniform	Check and correct bracket fits or bearing.
6	16/3/2000	Motor overheats while running underloaded	Frame or bracket vents may be clogged with dirt and prevent proper ventilation of motor	Open vent holes and check for a continuous stream of air from the motor.
7	16/3/2001	Motor vibrates	Defective bearings	Replace bearings.
8	16/3/2003	Hot bearings ball	Overloaded bearing	Check alignment, side and end thrust.
9	16/3/2005	Hot bearings ball	Broken ball or rough races	Replace bearing, first clean housing thoroughly.
10	16/3/2006	Motor does not come up to speed	Broken rotor bars or loose rotor	Look for cracks near the rings. A new rotor may be required, as repairs are usually temporary.

Fig. 3: Sample screen of the Motor Historical Data Report.

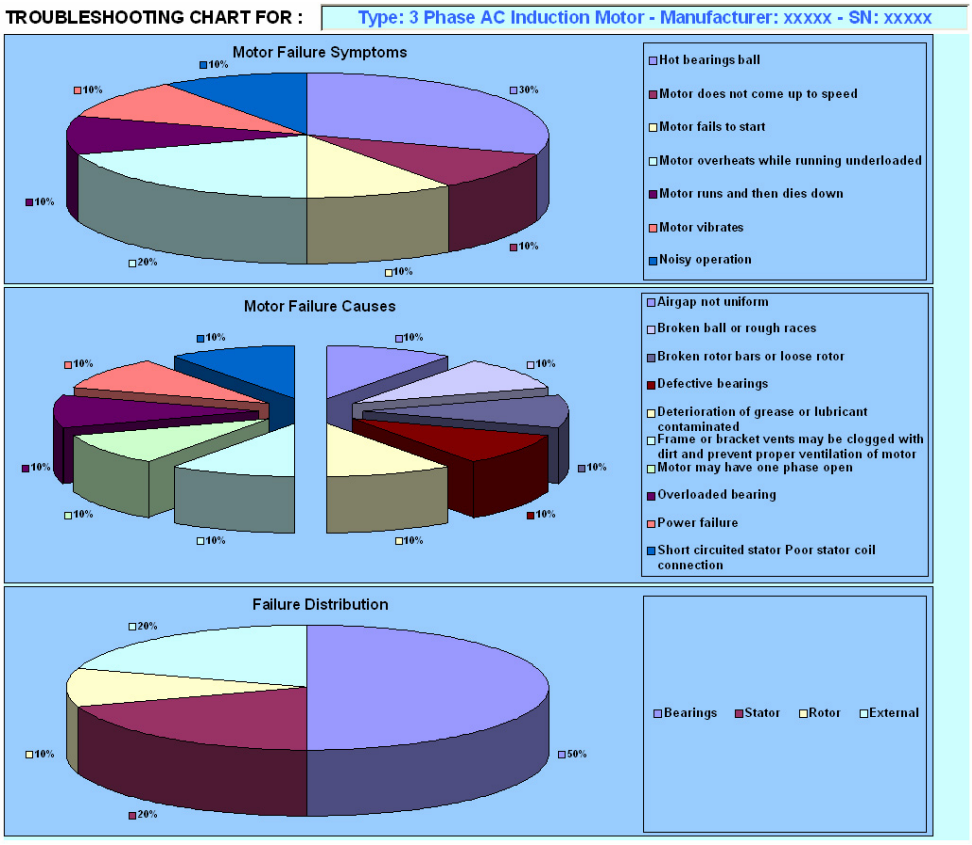

Fig. 4: Motor Troubleshooting Charts (sample screen).

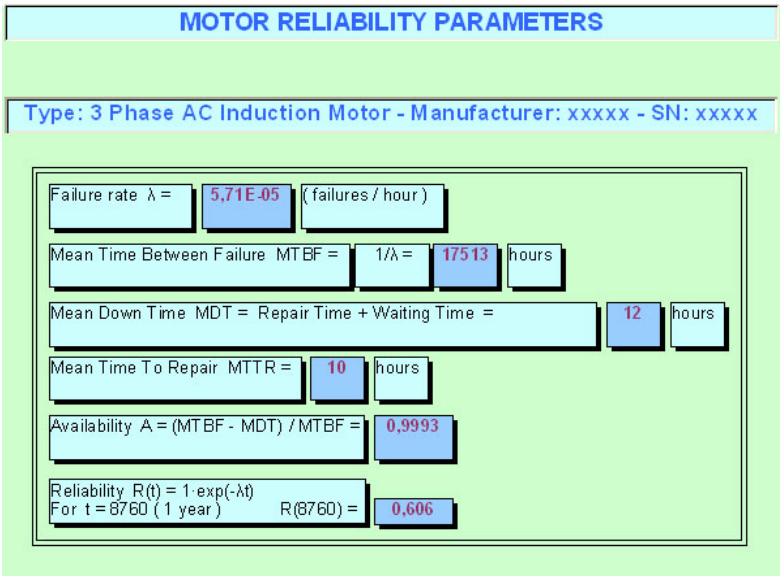

Fig. 5: Reliability Parameters of the Machine.

4 Conclusions

The software presented in this paper, which has been developed for electrical machine fault diagnosis, repairing and maintenance purposes, provides a multi-user environment in various levels (user, power user, administrator) attaining efficient carrying out of relevant on-site procedures and tasks along with satisfactory security standards.

By the option of automatic evaluation and the application of weighting factors, knowledge tree data structure may be modified according to historical archive data resulting in the minimization of the repairing time and cost.

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