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CREATION METHOD OF THE EXPERT SYSTEMS FOR ELECTRICAL INSTALLATION

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Abstract

The complex creation method of control and adjustment of equipment combining methods of traditional technical diagnostics and technology of expert systems is discussed. We describe the strategy for structuring the knowledge base of the expert system considering the use of diagnostic algorithms.

1. Complex Diagnostic Method

Setting up of equipment, the essence of which consists in bringing the output parameters of adjustment object (AO) to the nameplate values, may be regarded as a set of individual tasks, the most difficult of which is usually a diagnosis of AO. Currently, there are two approaches for diagnosis.

The first approach reflects the classical methods of technical diagnostics (TD), based on mathematical models of objects and special algorithms for

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diagnosis. This trend is considered in detail in [1, 2]. The second approach is connected with the use of knowledge-based professional expertise artificial intelligence techniques [3, 4].

Each of these approaches has its own strengths and weaknesses. For example, the classic TD involves pre-depth study of the diagnosis object (DO), in course of which, in one form or another its mathematical description (mathematical model) is made. Finally, based on the DO model and using various algorithms of defects search, it is possible to identify (isolate) failure with a minimal amount of search steps and with a minimum of expenses for this search. However, a detailed study of each specific DO requires a significant investment of time and effort; the use of methods of classical TD quite difficult for non-experts; also, while development of mathematical models, number of assumptions are usually made, inexorably moving away the model from a real object.

On the other hand, the application of technology of expert systems (ES) allows direct, without simplifications, use of empirical knowledge and heuristic methods of expert professionals, which leads to a significant reduction in search time of DO faults. The use of ready-made expert systems is quite accessible even to non-specialist in artificial intelligence area, and circle of diagnostic problems solved by the expert system is not limited to a specific DO, usually covering class of technical objects. However, the technique of creating the diagnostic expert systems is not fully developed; existing diagnostic ES is normally same and does not provide a complete guarantee of finding defects.

In view of the above it seems promising to develop a comprehensive diagnostic method based on the technology of expert systems using classical technical diagnostic algorithms. The resulting diagnostic method on the basis of this synthesis will keep these advantages as mentioned in the two approaches. The new method significantly reduces the complexity and number of assumptions in the development of DO mathematical model, and also allows to exploit the finished diagnostic ES in significant range of non-specialists.

Let us identify the main stages of this diagnostic method [5-7].

2. Synthesis of the Diagnostic Algorithm

At this stage, a functional model of the diagnostic object is developed and the most promising order of conducting elementary checks (the diagnostic algorithm) is determined, considering the information available about the object of diagnosis. This stage can be divided into the following steps:

(1) A mathematical model (functional diagram) of the diagnostic object is constructed considering the assumptions listed in [2] and the feasibility conditions of the method listed above, for which the following expressions are valid:

- the DO model can be represented as a finite partially ordered set A_M, consisting of the elements $a_i \left(i = 1, 2, ..., M\right)$, where M is the power index of the set, $M < \infty$;

- for any element a_i of the A_M model, there is a finite set Z_V of input signals z_{iV}, where $V \geq 1$, and the set Z_L of output signals Z_{iL} with the power index $L = 1$: $\forall a_i \in A_M \Rightarrow \left(z_{iV} \in Z_V\right) \wedge \left(Z_{iL} \in Z_L\right)$;

- for any element a_i of the A_M model, the dependences between the input z_{iV} and the output signal z_{iL} are known, as well as the set of their admissible values of Z_{VD} and Z_{LD}:

$$\forall a_i \in A_M \Rightarrow \left(z_{iV} \rightarrow z_{iL}\right);$$

- the external input signals x_i of the element a_i always refer to the set of admissible values X_D: $\forall x_i \in X_D$;

- if the output signal z_{fL} of the element a_f is the input signal z_{gV} for the element y_g, then the sets of admissible values of these signals Z_{FD} and Z_{GD} are the same:

$$z_{fL} = z_{gV} \Rightarrow Z_{FD} \equiv Z_{GD};$$

- if the input signal z_{iV} of the element a_i is outside the permissible values of Z_{VD}, an invalid signal appears at the output of this element:

$$z_{iV} \notin Z_{VD} \Rightarrow z_{iL} \notin Z_{LD};$$

- the element a_i belongs to the set of faulty elements A_W, if for admissible input signals z_{iV} at the output of the element there appears an inadmissible signal z_{iL}:

$$(z_{iV} \in Z_{VD}) \wedge (z_{iL} \notin Z_{LD}) \Rightarrow a_i \in A_W;$$

- DO model A_M is considered to be working if all its elements a_i belong to the set of non-defective elements A_D: $a_i \in A_D$.

(2) The mathematical model (functional diagram) of the diagnostic object transforms into a logical model in the form of an oriented graph, as to solve the problem of diagnosing an object it is usually enough to make a conclusion based on the evaluation of input and output signals of the type "normal - not normal" (within the limits of passport values or not).

(3) The logical model of the diagnostic object is represented as a system of logical equations of the form as follows:

$$\begin{cases} Z_1 = e_1 \wedge X_1 \wedge \cdots \wedge X_q, \\ Z_2 = e_2 \wedge Z_1, \\ Z_N = e_N \wedge Z_{N-1}. \end{cases} \tag{1}$$

(4) The graph of the logical model of the diagnostic object is ranked.

(5) According to the ranked logical model of the diagnostic object, the vertices of the graph are divided into ranks, lengths and bushes and the minimum set of elementary checks is determined by the method described in [1].

(6) A procedure of construction for graphs of algorithms for diagnosing

DO using binary single selections and corresponding to the basic diagnostic methods considered is provided in [5].

(7) We select an algorithm for diagnosing DO, which leads to the minimum average costs determined by the expression (2):

$$C(Z_0,\ E_T) = \sum_{i=1}^{N}\left[p(e_i)\sum_{k=1}^{K} c(Z_k) \right], \tag{2}$$

where Z_0 is the first elementary check of the diagnostic algorithm and $\sum_{k=1}^{K} c(Z_k)$ is the sum of the prices of elementary checks of the diagnostic algorithm from Z_0 to Z_k.

3. Structuring of the Knowledge Base (KB)

At this stage, the meta-rules[1] base of the expert system (ES) is formed, taking into account the chosen diagnostic algorithm. This process can be implemented using the following steps:

(1) General list of DO faults diagnosed by the expert system is as $D(d_1,\ d_2,\ ...,\ d_b;\ D_1,\ D_2,\ ...,\ D_c)$. The list of diagnosed faults is divided into two parts: intermediate $D_B(d_1,\ d_2,\ ...,\ d_b)$ and final $D_C(D_1,\ D_2,\ ...,\ D_c)$ diagnoses. In this case, the final diagnosis of D_C is the identification of a specific fault when the depth of diagnosis of the DO is reached with localization to the functional block; under the intermediate diagnosis D_B we will understand the message about the preliminary localization of the defect in a certain structural part of the DO, consisting of several functional blocks.

(2) Diagnosed malfunctions $D_1,\ D_2,\ ...,\ D_c$ from the list of final diagnoses D_C required to be arranged in accordance with the bypass of the graph of the diagnostic algorithm, which was given preference in the

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[1]Meta-rule - the rule that determines the order of application of rules in the expert system.

synthesis of the diagnostic algorithm. The actions undertaken above will allow in the desired way to form the structure of the knowledge base of the ES.

4. Formation of the Knowledge Base

At this stage, the structure of the ES KB is filled with theoretical and practical knowledge about the adjustment of the DO and the final structuring of the ES KB takes place. This process is realized by performing the following steps:

(1) On the basis of logical equations of the form (1), primary rules for the knowledge base of ES are formulated and formalized by way of produces (rules) such as “IF A, THEN B”. These rules describe the functional model of DO.

(2) Practical knowledge of the specialists in setup (experts) is also formalized in the form of the rules “IF A, THEN B”.

(3) The knowledge base is formed as a set of primary rules and rules, reflecting the practical knowledge of experts.

(4) All knowledge base rules are formalized in the form of expressions (3):

$$\bigwedge_{i=1}^{m} C_i \geq D_j, \text{ or } \bigvee_{i=1}^{n} C_i \geq D_j, \tag{3}$$

where $\bigwedge_{i=1}^{m} C_i$ and $\bigvee_{i=1}^{n} C_i$ are conjunct and disjunct relative to C_i and C_i are conditions for performing the action D_j.

A set of logical expressions of the form (3) is in compact form of recording the knowledge base about DO adjusting.

The setup model $M(R_1, R_2, ..., R_k)$ according to the principle of superposition is formed by two logical submodels:

- submodel of the functional state $M_u(R_{u1}, R_{u2}, ..., R_{um})$,

- submodel of the defective state $M_\partial(R_{\partial 1}, R_{\partial 2}, ..., R_{\partial n})$,

where $R_1, R_2, ..., R_k$ is the complete set of the system rules, $R_{u1}, R_{u2}, ...,$ R_{um} is the set of rules for the functional state of the system, $R_{\partial 1}, R_{\partial 2}, ...,$ R_∂ is the set of rules for the defective state of the system.

Submodels M_u and M_∂ can also be specified using logical expressions of the form (3), and the number of expressions will be determined by the quantitative parameters of the subsets.

These subsets constitute an open set of elementary rules that describe the behavior of the system (device) in both normal and abnormal modes of operation.

The KB developed in this way has general knowledge, i.e., structured according to the peculiarities of the converters types (controlled rectifier, pulse-width converter, frequency-pulse converter, etc.), without taking into account the specific features of these types of converters, namely the latter is important when setting up industrial equipment. But in the case when the installer is not experienced enough, he will have to specify, for example, which values of the output signals of the converter control system correspond to the “passport values” appearing in the rules, and, possibly, the measurement points for these parameters, using the documentation for that transducer model, with which he works at the moment. To increase the practical significance of the above-described ES, it is useful to provide the installer with more detailed information of the type described above, and also to clarify some diagnoses, if possible and appropriate.

Values of parameters that vary for different models of converters of the same type can be specified in two ways:

(1) directly in the rules of the knowledge base of the expert system;

(2) in the tables of the relational database.

“Minus” of the method (1) - increasing of the knowledge base, “plus” - no need to make changes to the output mechanism. The method is used if the ES was created in one of the finished shells. Changes in the rules cannot be avoided, even if we use the usual means of access to databases, spreadsheets or text files specially designed for storing the values of variables.

Method (2) seems more natural for ES developers, although this method has a “minus” - the need to make changes to the output mechanism in order to “teach” the ES to apply for parameter values in the consultation process. In the case where it is supposed to work with several models of converters, the application of this method is completely justified and will not be unnecessarily labor-consuming: the PostgreSQL database is used to store the knowledge base of the expert system, which makes it very natural to incorporate the proposed changes into the ES.

5. Conclusion

(1) The complex method of control and adjustment of equipment, combining methods of traditional technical diagnostics and technology of expert systems, is considered.

(2) It is described the ways of setting up an expert system for adjustment of specific models of converters in order to increase the practical significance of ES.

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