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ELECTRIC MOTOR SELECTION METHOD DEVELOPMENT FOR EFFICIENCY INCREASING OF ELECTRICAL DRIVES SYSTEMS

ELEKTRODZINĒJU IZVĒLES METODES IZSTRĀDE ELEKTROPIEDZIŅAS SISTĒMU EFEKTIVITĀTES PAAUGSTINĀŠANAI

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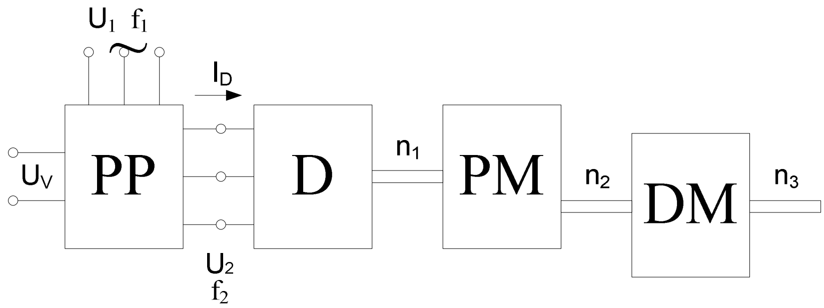
1. Introduction

Electric motors are the main consumers of electric energy in the industry and its effectiveness depends on the requirements of the system and methods of its control allowing a flexible adjustment to a variable load. The choice of electrical motors in construction of systems now is done by engineer approximately [1, 2]. Furthermore, electric motor systems development requires high scientific and technological personal education level. Due to the inherent multidisciplinary of electric drive systems and flexibility this required to solve any designing task. In order to avoid the contradictions mentioned in [3], mathematic methods and computer software must be involved to increase the quality of designer work and methods used for the design, thus the conception stages will be done automatically. It in its turn will simplify the diffusion and the application of new methods that take into consideration the entire constructor advising. Furthermore, the problem of the induction motors (which are used most frequently) lies in its mathematical model. Indeed, it is characterized by a high no-linearity and high coupling between its working states, particularly between torque and flux. In addition, its electric parameters are time-varying because of the thermal effect and saturation phenomenon [4]. To overcome these difficulties of coupling and nonlinear effects, new methods have been suggested. One of the most known, nowadays, is the field oriented control. These methods allow controlling the induction motor easily, and therefore the possibility to use this latter in variable speed drives. On the other hand, the advanced technology realized in power electronics and signal processing allows to provide variable frequency and magnitude of current and voltage which are required by the field oriented control methods. The two above factors have been combined to implement automatic control technique of induction motors. However, even though the high performances were obtained, some disadvantages appeared such as: the need for exact modeling, high speed calculation to implement its complex algorithm, sensibility to parameter variations. These problems have boosted many researches in hope to obtain more reliable and simplier control methods. For this reason artificial intelligence-based decision making procedure techniques have been investigated. These methods are preferred by the fact the motor model is needless. In the other hand, in order to integrate diagnostics and decrease the analysis time of fault and maintenance costs, the expert system should be associated to the measure subsystem, acquisition subsystem and information treatment subsystem. The intelligent tasks of diagnostics are done by the expert system. The article suggests the development of decision making procedure [5] for an expert system to improve power efficiency in the motor systems.

1. Problem statement

The problem of decision making procedure modeling for motor selection and energy consumption efficiency increasing of electric motor systems is multi criteria decision problem. A structure scheme of a modern electric motor [5] system is in fig. 1, where a semiconductor converter (PP) controls or dispenses the supplied electric power and supplies it to an electric drive (D), and then mechanical energy through a direct connection or gear (PM) is supplied to an operational machine (DM).



1.Figure. Structure scheme of the controlled AC drive.

PP – controlled power electronic converter, D – motor or electric mechanical converter, PM-gear and DM – operational machine. Uv – control voltage, U1 and U2 – input and output voltages, f1 and f2 – input and output frequencies, I_D – current of the motor, n1 – rotational frequency of the motor, n2 – output rotational frequency of the gear, n3 – output rotational frequency of the operational machine.

The decision making procedure development for motor selection for energy consumption efficiency increase of electric motor systems takes into account motor parameters and their regulation possibilities. The decision making procedure development of expert system for

selection of an efficient motor is analyzed. Three-phase asynchronous electric drives with a squirrel-cage rotor (AD) now are the most widespread electric drive machines in the world that can be explained by their small cost and excellent reliability.
Now the share of adjustable electric drives with ADs is continuously growing. There is an indicative tendency of frequency converters (FC) installation not only in new installations, but modernization of the working electro technical equipment with a view of power saving or reliability increase, and also at replacement of the worn out control system. Here we shall note that alongside with functional equipment, reliability and simplicity of commissioning, cost of the frequency converter and simplicity of adjustment are critical.

2. Structure of expert system

Electric motor selection method development based on information system based on expert system. Expert system consists of the following elements: Knowledge base, user interface, designer, explanation subsystem, intelligent editor of knowledge base, user, expert, knowledge engineer. Expert system [6] is a knowledge based system that provides expertise, similar to what expert in a closed data application is doing. The main blocks of expert system are shown in figure 2.

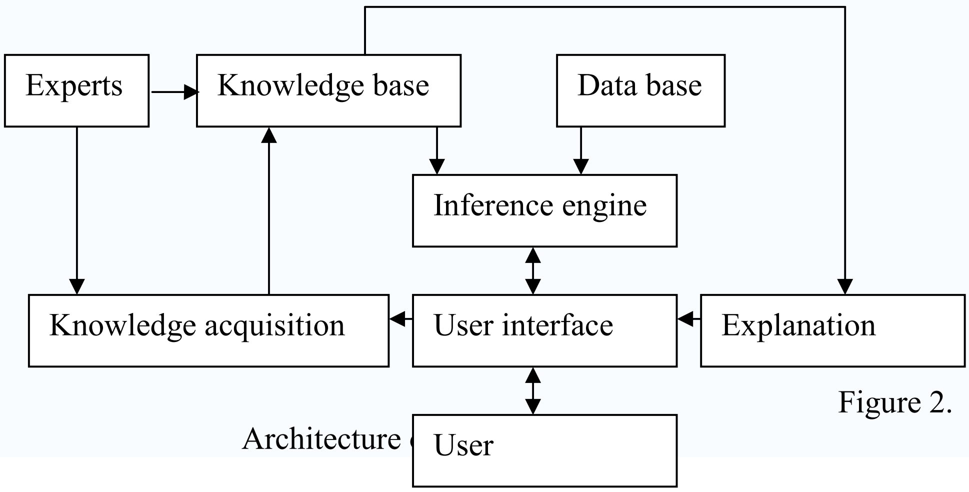


Figure 2. Architecture

The main tasks, when it is useful to use expert system are: data interpretation, diagnostics, monitoring, system design, forecasting, planning, learning, management, decision making support. The problems of system design, management, and decision making support are very important for system functioning in optimal energy consumption regime. This investigation allowed to realize, that expert system performance for energy efficiency increasing is effective in static expert system case for electric drive systems design and management.
There are the following stages for electrical motor expert system design:

1. step - Identification of the problem
2. step – Conceptualization: what is given and what should be inferred?
3. step – Formalization - answer for question are the data and knowledge are reliable, accurate and precise, or not? What kind of explanation is needed?
4. step – Realization: what methods and tools are appropriate for representing data and knowledge?
5. step – Experiment and validation results.

The expert system design is a complex task. Using of expert system for electrical drive system design is useful, if we have knowledge about motors, there is an expert having ability to formalize this knowledge. From the other side the expert system design could decrease electro energy consumption in case of electrical drives system design activities. The task of system design is analyzed in the article.

3. The task of decision support system design

For instance, the problem of controlled pump drives selection for water pump station could be solved, using decision support system, based on expert system with user interface. The controlled pump drives selection could be formalized by expert experience and alternative evaluation of the defined system parameters and consumer's request can be performed. Using modern information technologies helps to select the optimal drive in innovation study.
The actual problem of decision making selecting electric drives control in water pump station renovation is described.
The decision making person and system collaboration gives information based on solution decision making procedure. Decisions rules are interpretation as if s_i, then p_i.
The s_i, is chosen from p_i taking into account factors f_i, in a complicated way. The output procedure could be defined in the different ways; the main idea is to define set of factors:
$F=\{f_1, ..., f_n\}$,
It is important to know, that the new facts can not be achieved as the results of the system functioning. The main aim of the system is to define relations for real situation facts.
The two existing set F subsets will be defined in the article as F_0, F_1
$F=F_0 \cup F_1$, $F_0 \cap F_1=\varnothing$
The subset S_1 will be named as subset of the marked (known) facts, but subset F_0– the subset of unmarked facts. The subset F_1, sometimes could be considered as an operational field of the decision support system. At the beginning of the work the system has some facts, for example: $F_1=\{f_1, f_2, f_3\}$.
The subset F_1 fulfillment could be made by moving elements from F_0 subset. The rules interpretation could be described as $s_i \rightarrow p_i$ with facts from F_1, if the rule is subset F_1 will be fulfillment from facts, which are true in right side of production P_i. Selection of the best decision from $S_1=\{s_1(p_1(f_1)), s_2(p_2(f_2)), s_3(p_3(f_3)\}$ is the decision maker function, the best alternative we describe as $S'_1 \supset S_1$.

4. AC motor equipment selection

The general principles and criteria of electric motors selection can be illustrated for stochastic loading mode. Distinction of this mode is that the loading diagram of the electric drive in this case cannot be expressed in the form of certain determined dependence MH (t) and for an estimation of heating of the motor it is necessary to use methods of the random processes theory.
Characteristics of the static torque on which similar characteristics of motor currents and temperatures of its parts are defined. In this case the estimation of a thermal condition of the motor on average value of loading leads to understating of windings temperature and an error depends on dispersion of the static torque from its average value.
For the majority of random processes «three sigmas» rule is fairly correct, consisting that with high probability it is possible to speak that all possible values of function x (t) lay in interval $3st_x+m_x$, $-3st_x+m_x$ where m_x and st_x - are a expectation value and a root-mean-square deviation of random process x correspondently. Using this rule, it is possible to define the greatest value of winding temperature excess of the motor:

$D = \langle DE \rangle + 3\ st_e$;

Here $\langle DE \rangle$ - a expectation value of temperature excess st_e - a root-mean-square deviation of temperature.
Check of electric motor selection correctness on conditions of heating for values of the equivalent torque or equivalent power can be made in view of that M_z and P_z are defined as follows:

$Mz = \langle M \rangle^2 + a^2_m$; $P_z = \langle P \rangle^2 + a^2_p$,

Where $\langle M \rangle$, $\langle P \rangle$ - expectation values of the torque and power correspondently; a_m and a_p - their root-mean-square deviations.
It is possible to calculate also M_z and P_z which are fair for processes M^2 (t) and P^2(t), taking place in many cases at long work of the electric motor on random loading. Such random processes are defined on one realization, i.e. for such processes finding the probability characteristics averaging on ensemble of realizations is replaced with averaging in time.
At greater fluctuations of a random component of process concerning the average torque main value is reloading ability of the motor. In this case the important criteria of selection correctness is the maximum rotating torque.
$M_{max} > M_{smax}$.

As in a random load mode M_{max} also represents casual process that the condition was carried out with the greater probability, it is necessary to calculate M_{max} in view of a unilateral confidential interval, and aside reduction of average value M_{max}:

$$M_{max} = \langle M_{max} \rangle - \langle M_{smax} \rangle .$$

Similar principle is used to estimate the starting torque of the motor with analysis of start-up conditions.
Electric motor selection procedure includes power inverter and control system selection realizing the researched way of control. The power inverter considers separate control of inverter switches, type of power switches and presence of internal diodes - on a degree of the account of inverter real properties is close to optimum.
The greatest interest is in electric motor missing variables estimation on which control is made. Linkage is calculated on the basis of the Kirchoff's equation using digital integration.
The only parameter which should be entered during adjustment of a drive or identified is stator active resistance. Its identification is one of the simplest procedures with automatic initialization of modern inverters. Dependence of FC work on a conformity degree of stator identified and real active resistance is obvious from temperature changes. However selection analysis shows high stability of the system with introduction of obviously inexact parameters and high robustness of the electric drive as a whole.
Variables necessary for calculation are defined at evaluation stage of stator linkage dispersion. It is necessary to note, that realization of expressions in a digital control system is simple enough and does not demand essential computing power of the processor.
After the demanded linkage estimation and motor torque their comparison with task signals is made, considering hysteresis values to except high-frequency switching with slightest parameters change. On the basis of comparison results according to the previously established state table the control signal for inverter power switches is produced.
Resulting condition variable looks like:

$$U_S(S_a,S_b,S_c)=\frac{2}{3}U_{DC}(S_a+S_be^{j2\pi/3}+S_ce^{j4\pi/3}),$$

Where S_a, S_b, S_c describe three phase inputs condition, 0 means connection of phase to a negative feed input, means connection to a positive feed input.
Here it is necessary to note the basic differences and advantages of the torque direct control system:
- all calculations are made with feedback signals in fixed coordinate system without real time transition to rotating system;
- missing values estimation is made on the basis of the elementary equations, thus the sensorless AD control is realized;
- power switching is based on a tabulated principle, that also reduces computing resources;
- switching frequency automatically increases as required and is not always maximal, that reduces thermal losses and load on isolation of the motor.

Conclusion

1. The elaborated electric motor selection system, in one hand, allows specifying the electrical drives (taking into account the available varieties of motors, frequency converters and control strategies), in another hand, is characterized by the following:
Easy to be modified (flexible system);
Its data-base system and inference system are completely independent;
It has an explanation module of interpretation;
It is independent of its application module.
2. The obtained results permitted to conclude that the use of the proposed ANN for the induction motor control guarantees an adaptive and robust control. The adaptation rules offer to the two ANN the capacity of adapting with the various induction motor operation modes. In addition, these rules allow a fast compensation of the rotor and stator resistances without using any identification tool.
3. The problem of power loss in vector control induction motor is treated. Field oriented control provides a maximum torque capability available at any time by setting the flux level at its nominal value. However for light loads this advantage becomes a disadvantage. In fact, it provides poor efficiency which is explained by the excessive iron loss at small loads. For this reason a mechanism is elaborated in view to keep the efficiency higher even at low loading. The obtained relationship permits to set the optimal rotor flux level so that the power loss in the induction motor is minimal. On another hand, the efficiency is altered by the rotor resistance changes too. Therefore, a fuzzy controller is added to avoid this problem and to give an estimated value of the rotor resistance that the optimization mechanism needs to truthfully adjust the rotor flux level. The obtained equality between the stator current components confirms the quality of the proposed optimization mechanism.
4. The necessity of the information about electromechanical system behavior has required modeling as well as in digital forms both normal and abnormal operation therefore it became possible to construct curves of electrical and mechanical parameter changes. For this purpose the following parameters were used:
control voltage value, rotation speed and stator current. Their choice was justified, on the one hand, by availability of their measurement and, on the other hand, by the fact they changed essentially while failure occurrence (i.e. they characterized a failure more completely). The

obtained results allow a quantitative characterization of each type of defects (defects signature).

5. The defects appearance is associated with:

The values exceeding the allowable values of the characteristics; an increase in the energy losses; a risk of equipment break down.

6. The advantage for the proposed approach of diagnostics, is in one side, to capitalize, systematize and to formalize the experience acquired by experts in the field (through filing up card-indexes of defects) and, in the other side, to analyze and understand the flow of knowledge and information so that the system could allow precise identification of the defect type and localization. Therefore the compromise between cost and efficiency should be found for each concrete case.

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Ribickis L., Kuņicina N., Čaiko J., Elektrodzinēju izvēles metodes izstrāde elektropiedziņas sistēmu efektivitātes paaugstināšanai

Šajā rakstā tiek analizēta elektrodzinēja optimālās izvēles problēma, ņemot vērā tā enerģētisko efektivitāti un iespēju veikt regulēšanu. Izstrādā elektrisko motoru izvēles sistēma dod iespēju ņemot vērā visas elektriskās piedziņas sistēmas elementu: elektrisko motoru, frekvenču pārveidotāju un vadības shēmas specifiskos parametru. Elektromotoru izvēles informācijas sistēmā tika izveidota, ņemot vērā sistēmas elastības svarīgumu, datu pieejamība un to kvalitāte (vai ir pietiekams ziņu daudzu par motoru, lai pieņemtu lēmumu), paskaidrojuma moduļa esamība (terminoloģija), sistēmu var izmantot neatkarīgi no citas programmatūras. Iegūtie rezultāti var būt pielietoti elektropiedziņas sistēmu darbību uzlabošanai. Elektrodzinēju izvēlei tiek piedāvāts pielietot informācijas sistēmu, izmantojot mākslīgā intelekta metodes (ekspertu sistēmas), sistēmas uzbūve ļauj samazināt elektroenerģijas patēriņu ražošanas uzņēmumos. Rakstā tiek analizēta ekspertu sistēmas struktūra un tās izveides procedūra. Uzskaitīti elektrodzinēju izvēles principi un kritēriji stohastiskam noslodzes režīmam. Elektrodzinēja izvēle izveide ir viens no būtiskākiem efektīvās elektroenerģijas lietošanas nosacījumiem, jo dzinēji ir vieni no lielākiem elektroenerģijas patērētājiem.

Ribickis L., Kunicina N., Chaiko Y., Electric motor selection method development for efficiency increasing of electrical drives systems

The article analyses the problem of an optimal selection of the motors, taking into account its efficiency and control possibilities. The elaborated selection system of the electric motor allows considering of all the elements of the drive system: electric motor, frequency converter, and specific parameters of the control systems. The informational system of the motors selection takes into account the importance of the system's flexibility, accessability of the data and its quality, existance of the descriptive modules (terminology), the system coulde be applied independently on other software. The obtained results can be used for the improvement of operation of electric drive systems. The artificial intelligent methods (expert systems) are applied in the informational system, the architechture of the system allows decreasing of the power comsumption at the enterprises. The principles and criteria of the electric motors selection are defined for the mode of stochastic loading. The selection of the motors is one of the important regulations for the effective power consumption as the motors are the largest part of the energy consumers.

Рыбицкий Л., Куницына Н., Чайко Е., Разработка метода выбора электродвигателя для повышения энегоэффетивности систем с электроприводом

В данной статье рассматривается проблема выбора электродвигателя, принимая во внимание энергоэффективность и возможность осуществления регулировки. Разработанная система выбора электродвигателя позволяет принимать во внимание все параметры элементов системы электропривода (электродвигателя, преобразователя, системы управления двигателем). Система выбора электродвигателя разработана с учетом важности системы, возможности ее настройки, наличие и качество данных о двигателе для принятия решения о его использовании, наличие поясняющего модуля, систему можно использовать независимо от другого программного обеспечения. Полученные результаты позволят снизить потребление электроэнергии в системе с электроприводом. Для выбора электродвигателя предлагается использовать информационную систему, с применением методов искусственного интеллекта (экспертных систем), создание такой системы позволит снизить потребление электроэнергии на производственных предприятиях. В статье анализируется структура и процедура создания экспертной системы.