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DEVELOPMENT OF AN INTELLIGENT ALGORITHM FOR ELECTRICAL MOTOR CHOICE FOR INDUSTRIAL SYSTEMS

ELEKTRISKO DZINĒJU IZVĒLES INTELEKTUĀLĀ ALGORITMA IZSTRĀDE RAŽOŠANAS SISTĒMĀM

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1. Introduction

A lot of electrical equipment is produced all over the world today and the topical question is to select the only suitable one for a production process from this variety. It requires huge time resources. At the same time in this way targeted software could shorten the time spent for this, decrease human resources by developing the equipment for new production lines. The application of automation systems reduces expenses and increases its quality and effectiveness as well.

The purpose of the work is to develop a dynamic model that, with some given data of technical process parameters, can give a prognosis and suggest an optimal selection of the electrical equipment using a commercial data base of it.

Development of multi criteria decision making procedure for industrial system makes it more efficient especially in electric energy consumption. Energy saving problem is described in the article for industrial system. The importance of this problem lies in the electrical energy saving problem actuality in Latvia, because the self sufficiency of electrical energy is less then the consumption.

2. Problem statement

Design of the industrial systems is a complex and important process as it takes into account the present volume of production as well as the possibility to change the volume and type of the production. Therefore, not only an effective production line should be applied, but its control and adjustment possibilities also. Without these possibilities an enterprise can fail under the condition of market competition because the products should be often suitable for a concrete consumer. The order of the production operation of the industrial systems [1] is given in Fig.1.

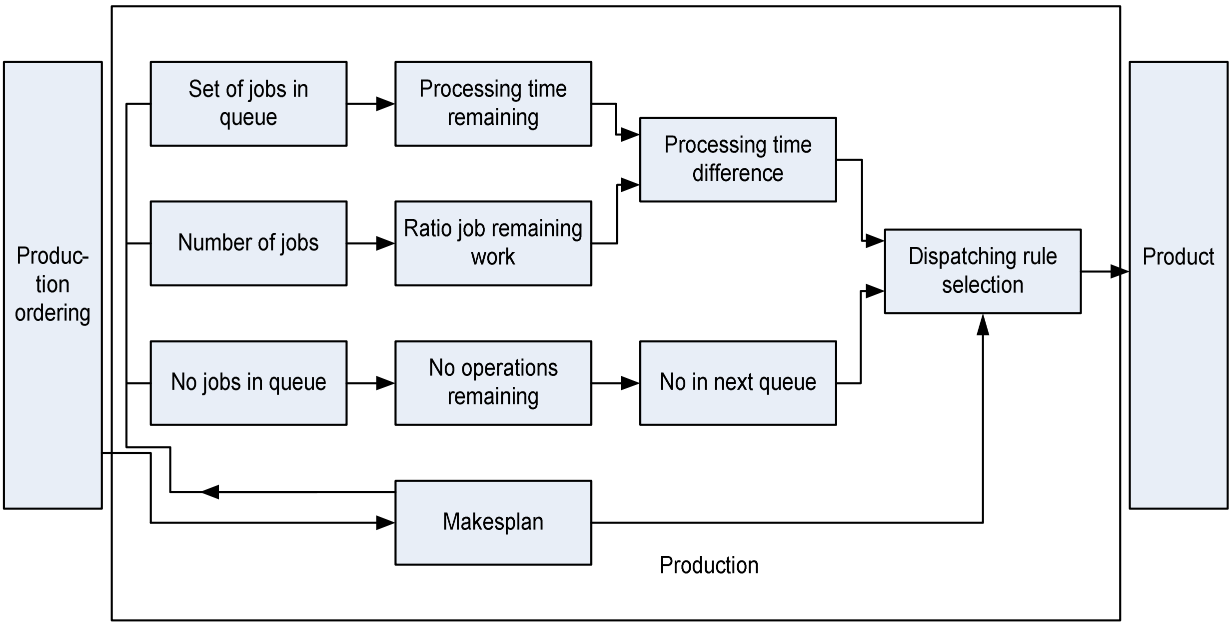

Fig. 1. Industrial system production sequence, according to the making plan

3. The analysis of the production system

The intelligent selection of motors for industrial systems is completed at the stage of systems development and redesign or improvement as well. The task of the electric motor selection can be formulated as an identification of the object of optimization [2]. Under an object identification process one can realize a mathematical description of the process – the development of the mathematical model of the object. The mathematical modelling is necessary for the decision on the electric motor selection, made on the basis of system's objects and their functions. The article describes the case when the features R(X) of an industrial productive system are under consideration (for more accurate searching for the extremum of the function of electric energy consumption X*). For this aim such a system of qualitative factors R(X) evaluation and such $X_1, ..., X_N$, which allow with a set N and known system's parameters obtaining description of the model R_M (X), that minimally differs from a real R(X):

$$M=\min_{X\in I}\{\,|\,R(X) - R_M(X)\,|\,\} \quad (1)$$

I – X factor of presence.

A model with a finite number of parameters $P=(p_1, ..., p_m)$ is defined with the description of the industrial process $R_M(X)=F(X/P)$,

Where F – a function defined according to the prior information on the system.

It is described in square form

$$F(X/P)= p+[X, P'X] +[P'', X] \quad (2)$$

where p – a constant term, P' – a matrix with coefficients nxn, P" – vectors of n – order, square brackets describe a scalar multiplication. This description contains m=1/2(n+1)(n+2) unknown coefficients: one absolute term, 1/2n(n+1) matrix elements $P(p'_{ij}=p'_{ji})$ and P" vector elements.

Describing the conditions of the term R(X) with $x_1, x_2, ..., x_k$;

$x_k=f_k(x_k+1, x_k+2, ..., x_n)$, using the expression of quality R=R(X), we will obtain: $R=F(x_k+1, x_k+2, ..., x_n)$. Therefore the calculation task for selection of electrical motors for industrial systems could have such target function $F(x_k+1, x_k+2, ..., x_n)\rightarrow\max$, if $(1/x_e \rightarrow\max)$ x_e – is a consumption of electric energy.

4. Analysis of the power effectiveness

The power effectiveness of the system is provided by the effective selection of the electric equipment and the choice of the control way as well. The system can be built with the use of different motors and other elements.

As a rule methods of position control of the dynamic systems are applied for the control of electric drives. As a result control system have been developed.

The use of modern information technologies (neural networks, fuzzy logics, genetic algorithms, expert systems) can significantly improve the quality of complex control systems. The built-in regulators of the classical methods do not always allow a necessary system control. The article analyses the development of an intelligent multi criteria algorithm for electrical motors calculation problem for industrial systems, solved with the use of systematic knowledge processing.

The design of an intelligent control system applies two basic principles: the control of situation (control based on the analysis of external situation and events) and using technologies of modern knowledge processing. The development of electrical drives calculation algorithm arises the necessity of production systems control according to the analysis of the external situations.
Let us consider a principal scheme of the dynamic braking of a squirrel-cage motor, fig.2, the motor in these systems operates in a mode of changing load, where maximum loading periods are replaced with idle running periods. This is periodic intermittent duty:

$$P_E = \sqrt{\frac{\sum_{i=1}^{n} P^2{}_i \; t_{i_i}}{\sum_{i=1}^{n} t_{p_i}}} \tag{3}$$

where: P_i, t_i – value of power in separate cycles and duration of these cycles [3].
The functions of the production systems are the basic conditions in the process of selection of motor type and electric drive [4].
The selection of the squirrel-cage motors for the production machines of such type is based on the principles that the necessary loading process is provided, electric motor has less losses and less electric energy is consumed. In this case a dynamic braking is applied for the squirrel-cage motor. If there is no a separate DC link the production system looks as shown in fig.2. The scheme, as mentioned in [8] consists of well-known connection of induction motor to a non-reversible block that is completed with a unit of a rectified voltage. This unit consists of transformer T1, semiconductor rectifier U1 and braking closing switch K2, that operates according to time principle [8].
At the initial condition no one of the apparatus is operating. The control circuit allows starting and stop of the motor, controlling its braking process. With pushing the starting button S2, switch K1 operates and the motor's operation stars. In order to stop the motor button S3 should be pushed switching off K1, but with its switching on contacts preparing the circuit of the braking switch K2. Disconnecting from the supply K1 disconnects also the motor and K1 with its blocking contact is switching on the braking switch K2. It in its turn connects transformer T1 to the network and two phases of the stator are connected to the rectified voltage.

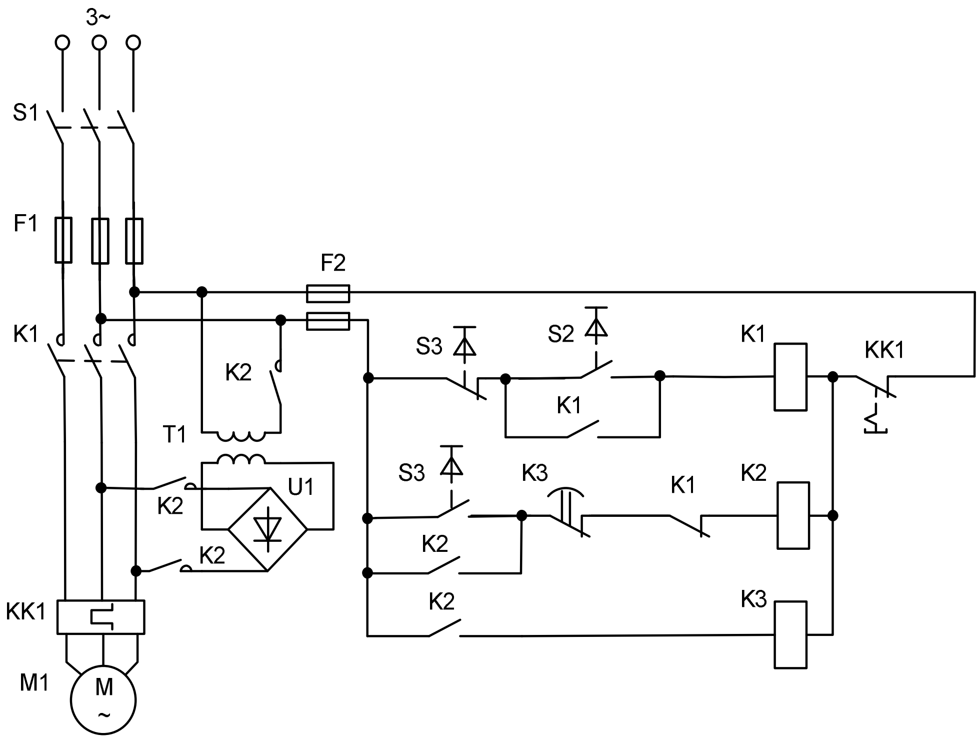

Fig.2. The principal scheme of the start, operation mode and dynamic braking of the squirrel-cage motor

Switch K2 connects the coil of the time relay K3 to the voltage, starting the braking time delay. At the end of the delay switch K3 disconnects the circuit of K2. The transformer thus is disconnected from the supply, but the rectified voltage – from the stator winding. The scheme is back to the initial condition. Time settings T_b of relay K3 can be defined as a difference between the motor calculated braking time t_b and time of K2 disconnecting t_o:

$$T_b = t_b - t_o . \tag{4}$$

There is an electric blocking in the circuit in order to prevent switches K1 and K2 from a simultaneous operating. The disadvantage of the scheme is a low braking torque at the speed close to the synchronous and its extreme increasing at only low motor speed that can cause damage of the mechanism.
To provide unchangeable braking torque the plugging braking is applied instead of dynamic one. For such systems an electric motors selection methodology is developed with the use of advantages of neural networks.

5. Cascade-Correlation algorithm of neural network learning

Cascade-Correlation algorithm [5] begins with a minimal network, then automatically trains and adds new hidden units one by one, creating a multi-layer structure. Once a new hidden unit has been added to the network, its input-side weights are frozen. This unit then becomes a permanent feature-detector in the network, available for producing outputs or for creating other, more complex feature detectors. The Cascade-Correlation (fig.3.) architecture has several advantages over existing algorithms: it learns very quickly, the network determines its own size and topology, it retains the structures it is built even if the training set changes, and it requires no back-propagation of error signals through the connections of the network.

Cascade-Correlation combines two key ideas: The first is the *cascade architecture*, in which hidden units are added to the network one at a time and do not change after they have been added. The second is the learning algorithm, which creates and installs the new hidden units. For each new hidden unit, we attempt to maximize the magnitude of the *correlation* between the new unit's output and the residual error signal was eliminated.
The purpose of the learning is to decrease the output root-mean-square error of the supply net:
$E=1/2\sum_{op}(y_{op}-t_{op})^2$,
where y_{op}- the real output of the net for the sample r and t_{op}- an expected output for the particular sample [6].
Describing the productive system in this case we assign P – as a set of system's parameters, where decreasing the output root-mean-square error of the supply net we achieve the optimum of the target function $F(x_k+1, x_k+2, ..., x_n)\rightarrow max$, if ($1/x_e \rightarrow max$) x_e – decreasing of the electric energy consumption.

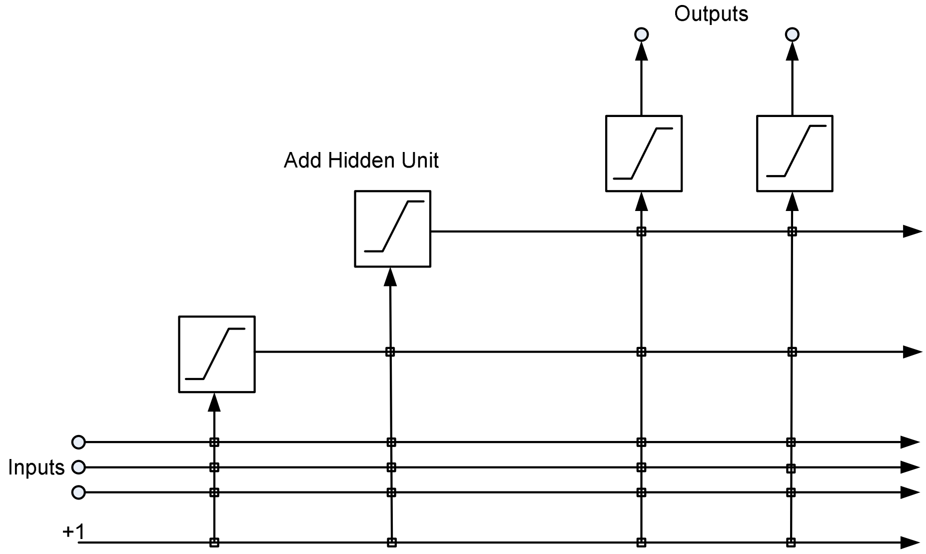

Fig.3. The Cascade architecture, initial state and after adding hidden units

6. Algorithm for choosing of a motor

The problem solution algorithm is modelling of water pump systems, using multi criteria model [7] by energy consumption effectiveness criteria.
Step 1. Task formulating.
Step 2. To formalizing set of possible decisions.
Step 3. To define the set of criteria's.
Step 4. To define the set of efficacy criteria measurement scale. Steps 3, 5.
Step5. Possible alternatives efficiency measurement by criteria scales. Steps 3, 4, 6.
Step 6. Getting and sequencing information about priorities.
Step 7. To define the set of decision making rules.
Step 8. Possible decisions ordering.
Step 9. Analysis of ordering results.
Step 10. Sequence satisfactorily priorities? If yes Step 12, If no Step 11.
Step 11. Non – satisfactorily reasons analysis, and definition of improvements. Steps 2, 3, 4, 5, 6.

Step 12. Electrical drive satisfactorily problem decision? If yes Step 13, If no Step 6 ore 1.
Step 13. Finish of problem decision.

7. Example for electric motors choosing for production line

The software tool is designed for the users in planning and carrying out energy management and motor efficiency improvement actions. Software provides the motor chosing in three scenarios: new purchase, repair versus replace, and replacement of existing operable motors.
Software supports motor management functions at commercial and institutional facilities, water supply and medium-sized and large industrial facilities. Designed for utility auditors, energy managers, and plant or consulting engineers, "Gudrais Inženieris" supports motor and motor systems improvement planning through identifying the most efficient action for a given repair or motor purchase decision. "Gudrais Inženieris" can be used to compute the energy and demand savings.
The motor performance database includes the following information, when available, for each motor:

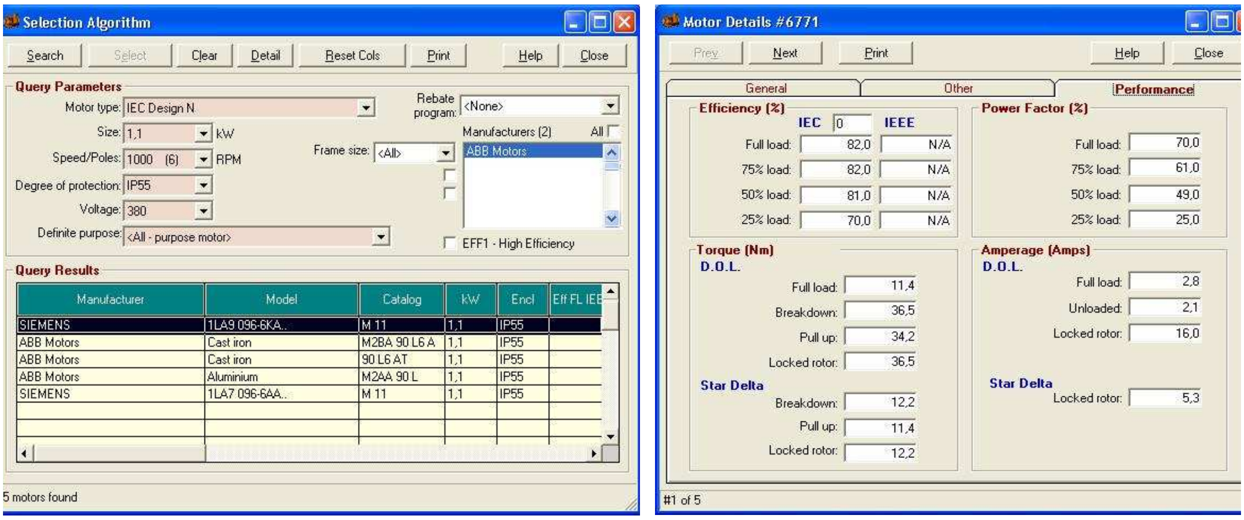

Fig. 4.Software "Gudrais inženieris"

Software "Gudrais inženieris" (fig.4.) could give such results Motor Selector: Motor Savings Analysis, Life Cycle, Best Available. The Energy Conservation Summary Report indicates the Energy Action date, title, type of action (motor replacement, rewind, systems improvement or process operating hours change); and the annual energy savings (kWh/year), instantaneous demand, reduction (kW), and annual savings.

Conclusions

The article considers the development of an intelligent algorithm of the electric motor selection for the productive systems: the topicality of the problem and importance of the increasing of the electric energy effective consumption is defined. The problem of electric motors selection is actual in the design of new systems and renovation of some existed systems as well. It is connected with the optimal selection of motors from a given data base using multicriterial selection algorithm taking into account a huge amount of the produced motors. The power of the motor and the controllability of the driving system are taken as a main criterion of the selection, that influence a lot of tasks of the production system including also the consumption of electric energy.

In the intelligent electric motor selection, Cascade-Correlation neural network learning methodology is used which allowes the necessary optimal selection of motors from completed before data base. The definition of functions of production system and of object is a very complex process; thus it should be made for precise information obtained from the information base by learning of the neural network that has been confirmed with the experiment.

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Kuņicina N., Galkina A., Čaiko J., Ribickis L. Elektrisko dzinēju izvēles intelektuālā algoritma izstrāde ražošanas sistēmām.

Elektrisko dzinēju un piedziņas izvēles problēma ir aktuāla gan jaunas ražošanas sistēmas projektēšanā, gan esošās sistēmas renovacijā. Problēmas aktualitāte ir saistīta ar elektrodzinēju izvēli ražošanas sistēmām no esošās zināšanu bāzes ar daudzkriteriālo izvēles algoritma palīdzību, ņemot vērā lielu ražotu elektrisko dzinēju skaitu. Kā galvenais elektrodzinēju izvēles kritērijs tiek izmantoti dzinēja jauda un sistēmas elektropiedziņas vadības iespējamība, kas lielā mērā ietekmē ražošanas sistēmas ekspluatācijas izdevumus, tai skaitā elektroenerģijas patēriņu. Elektrisko dzinēju izvēle tiek izmantota Cascade-Correlation neironu tīklu apmācības metode, kas ļauj no esošās zināšanu bāzes pēc ražošanas sistēmas funkcionālām prasībām atlasīt nepieciešamos elektromotorus un elektriskās piedziņas un atlasīt optimālo elektroiekārtu, jo neironu tīklu pielietošana ļauj efektīvi un ātri izdarīt nepieciešamo izvēli. Rakstā tiek veikta elektrisko dzinēju intelektuālā algoritma izstrāde ražošanas sistēmām: tiek definēta problēmas aktualitāte, un elektroenerģijas izmantošanas efektivitātes paaugstināšanas svarīgums.

Kunicina N., Galkina A., Chaiko Y., Ribickis L. Development of an intelligent algorithm for electrical motor choice for industrial systems.

The problem of the electric motors selection is important for the designing of new production systems and the renovation of the existed systems as well. This is connected with the selection of electric motors for the production systems from an existed data base with the help of multicriterial selection algorithm taking into account the large amount of the produced motors. The power of the motors and control possibilities of the drive systems are taken as the main criteria for the motors choice that significantly influence the tasks of the productive system maintenance including the consumption of the electric energy. The intelligent selection of electric motors applies Cascade-Correlation neural network learning method allowing the selection of the electric motors and drives from the given data base according to the production system functional requirements *and the optimal electric equipment as the application of the neural networks quickly and effectively performs this choice. The article describes the development of the intelligent algorithm of the electric motors selection for the production systems: the importance of the problem and increasing of the electric energy consumption effectiveness are defined.*

Куницына Н., Галкина А., Чайко Е., Рыбицкий Л. Выбор интеллектуального электродвигателя путем разработки алгоритма производственных систем.

Проблема выбора электродвигателей и привода актуальна как в новых производственных системах проектирования, так и в существующих реновированных системах. Актуальность проблемы связана с выбором электродвигателя производственных систем из существующей базы с помощью выбора многокритериального алгоритма, беря в расчет большое число произведенных двигателей. Как главный критерий выбора электродвигателя используют мощность двигателя и возможность управления электропривода, которая в большой мере влияет на систему эксплуатации, в том числе на потребление электроэнергии. Для выбора электродвигателей используют метод обучения Cascade-Correlation нейроновой сети, который позволяет из существующей базы используя функциональные требования производственной системы отобрать необходимые электромоторы и электропривод, а также выбрать оптимальное электрооборудование, т.к. использование нейроновой сети дает возможность это сделать быстро и эффективно. В статье произведен выбор электродвигателя путем разработки интеллектуального алгоритма производственных систем: дефинирована актуальность проблемы, а также важность повышения эффективности использования электроэнергии.