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# CĒLĀJMEHĀNISMU REGULĒJAMĀS ELEKTRISKĀS PIEDZIŅAS IZVĒLES EKSPERTU SISTĒMA

## EXPERT SYSTEM FOR THE SELECTION OF THE ADJUSTABLE ELECTRIC DRIVE OF LIFTING MECHANISMS

Y. Chaiko, N. Kunicina, A. Galkina, A. Zhiravecka, L. Ribickis

*Keywords: control, electrical drives, expert system, methods, modeling*

### Introduction

The article considers the problem of electrical systems elaboration taking into account a large variety of electric drives, motors and control systems accessible nowadays. During the development of the electrical systems the optimal components parameters are calculated for the further equipment selection by these parameters or the demands for the special machine production are formed. The application of electric drive is widened within the process of automatization of different industrial processes and with the use of modern control methods of industrial systems. The advantages of the industrial processes automatization are obvious thus the engineers often meet the necessity of development of such systems resulting in the designing of new production lines. Despite of the large number of existing types of electric motors, drives and control systems for the obtaining as high as possible effectiveness of the industrial process the design of the system or process should go according to the particular given parameters and the choice of all the elements should meet the requirements of these parameters as close as possible. For each specific production line from large variety of types of DC and AC motors such a motor should be chosen that corresponds to the technical-economic parameters, in other words the motor should be safe, simply maintained, with an appropriate cost, weight and size, having high enough power parameters. The article analyses the structure of an expert system on the base of knowledge on types of electric motors, drives and control approaches. The investigation is connected with the development of an automatized system for the selection of optimal lifting mechanisms performing the calculation of systems parameters and choosing an appropriate from a data base. The selection of adjustable drives for lifting mechanisms is provided with the use modern information technologies. The investigation resulted in the mathematical description of the selection procedure of the adjustable drives for the lifting mechanisms and the realization of a part of expert system (with a limited number of motors in data base) for the selection of it. The structure and operation of the expert system are experimentally examined selecting the equipment for the design of lifting system.

Lifting mechanisms [4] are widely used in industrial systems and for household needs (multy-storey living houses). Lifting mechanisms of short-time intermittent duty are used for the cargo and passengers transportation.

## Problem statement of the adjustable electric drive selection for lifting mechanisms

The construction of the systems of lifting mechanisms can be divided into several steps the most important form which is the calculation of power of an electrical drive. The load moment on the traction sheave is determined by means of the force differential at the circumference of the traction sheave. It is, therefore, useful to consider how this differential force can be reduced. The static differential force on the traction sheave thus falls to the calculated value. A distinction has to be made between translational and rotational masses that contribute to inertia. During acceleration and retardation of the masses moving up and down in the hoist way, the inertia force directly affects the differential force on the traction sheave. It is, therefore, wise to reduce all masses moving in the hoist way. Reducing the car mass results in an equal reduction in the counterweight; hence, the effect is doubled. However, there are two reasons that restrict this reduction: the lower the masses of car and counterweight in relation to the contract load, the smaller the traction will become. Secondly, the higher the car mass, the greater the traveling comfort the user will experience [6].

There are some measures that can be implemented to improve the efficiency of the elevator in the hoist way. The losses on the guides for the car and counterweight can be reduced by the use of roller guides instead of guide shoes. When guide shoes are used, preference should be given to materials with better coefficients of friction, i.e., polyethylene, and attention should also be paid to effective lubrication. The greater the forces that act on the guides, the greater will be the losses due to friction. The elevator car and counterweight should, therefore, as a matter of course, be suspended from the centre of gravity. The forces acting on the guides due to uneven loading of the cabin can be reduced by increasing the gap between the guide shoes. The worm gears chiefly used in elevator construction have a relatively poor efficiency by virtue of their design. Improvements brought about through new production methods, better materials, the use of roller bearings in place of friction bearings or more effective lubricants cannot fully compensate for this disadvantage.

After the lowest possible output required for the motor has been established, the choice of control system enables losses to be reduced in the drive region. A large number of publications have dealt with these possibilities. The approximate relationships given below can be taken from Doorlaard's measurements and roughly agree with other figures.

If the energy consumption of a traditional traction sheave elevator with a pole-changing motor is taken as 100%, then the now-widespread variable voltage control with an eddy current brake (ACVV) requires approximately 70% of this energy for the same output. If the still relatively expensive variable frequency control (VVVF) is employed, the value reduces for about 50%.

Currently, when an energy-saving elevator is offered, it is generally a traction sheave elevator with variable voltage control (ACVV). If the power supply rating or energy consumption has to be lowered further, then the recommendation is for an additional rope-equalizing gear or, on inclusion of a surcharge, for variable frequency control (VVVF). To date, proposals have rarely included higher-efficiency drives.

Compared to toothed-gear drives, the V-belt drive has the advantage that the brake is arranged on the slow-running traction sheave shaft. However, the crucial factor is that the author can offer the V-belt drive as part of an overall energy-saving concept, based on decades of experience in designing low-energy elevators.

The capacity and angular speed of electrical drive should be chosen before. The approximate capacity of electrical drive should be calculated

$$P = k_z mgv \cdot 10^3 / \eta \quad (1)$$

where  $k_z$  - stock coefficient, which is equal 1,2 – 1,3 and which takes in account dynamic moment influence; depending of value of speed of the lift -  $v$ , according formula  $v = \omega R$  the nominal angular speed of electrical drive are calculated.

### Description of vertical movement system [5]

The amount of constructions of passenger and cargo lifts are huge, but in each model the main block of lift the following: winch, ropes, lift car, counterweight, electrical drive, mechanical breaks, control equipment.

Fig. 1 demonstrates the scheme of the vertical transportation electric drive system.

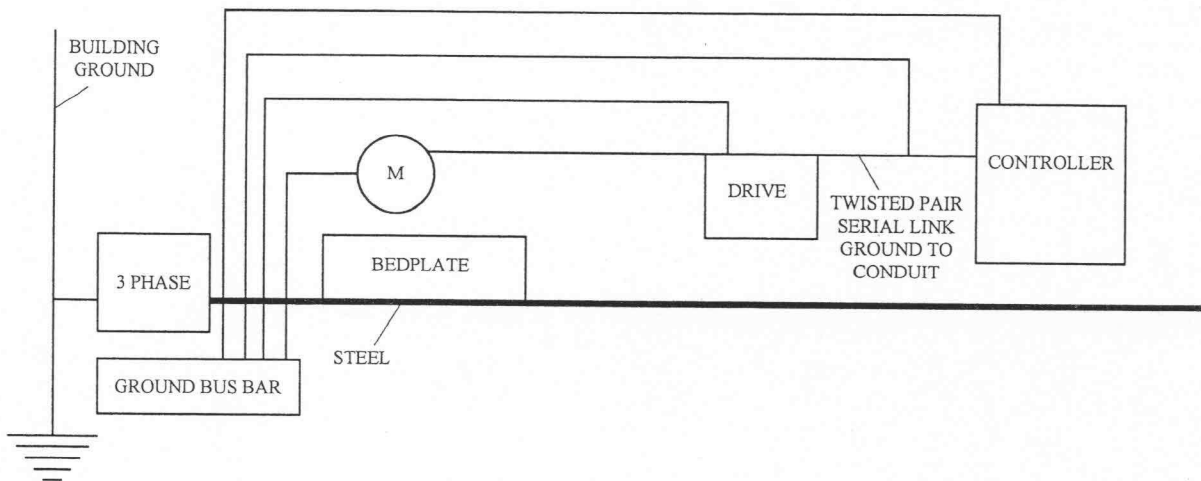


Figure 1. The block-scheme of the vertical transportation (lifting) electric drive

### Basic requirements to the electric drive of lifts

For the qualitative transportation of the loads and passengers together with the high effectiveness the electric drive of lifts should also provide: a reverse operation of the motor; soft-starting and braking regimes under the conditions that the acceleration and braking of the motor are not higher than the required norms; minimum time of transient processes; precise stop of the cabin.

The implementation of these requirements is connected with some particular features of the lifts operation, that are obvious from the expression of the passenger lift effectiveness (number of the passengers transported during an hour):

$$K = \frac{3600 \gamma E_k}{2H / v_k + \Sigma t} \quad (2)$$

$E_k$  - is a rated capacity of the cabin, i.e. the number of passengers;  $H$  - height of the transportation, m;  $v_k$  - speed of the cabin movement, m/s;  $\sum t$  - total time of all the stops, including opening of the doors, incoming and outgoing of the passengers, starting and braking of the cabin, s;  $\gamma$  - factor of the cabin loading depending on the intensity of the passengers flow, for the lift of 6-10-storey buildings -  $\gamma = 0,6 \div 0,8$ .

At the automatization of the lifting mechanism the control of the precise stopping process is fully realized by the electric drive, that sometimes is a basic factor influencing the selection of its type.

Figure 2 demonstrates the dependence of the efficiency  $\eta$  of the mechanism on the load, where  $F_g$  is a factual active load but  $F_{gn}$  is a rated active load [7].

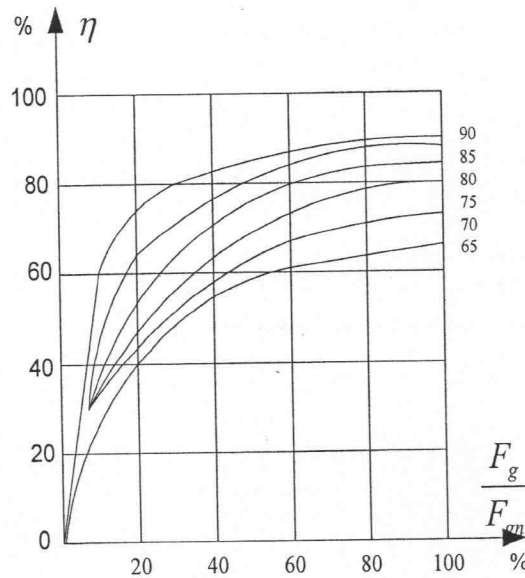


Figure 2. Dependence of the efficiency  $\eta$  of the mechanism on the load

### Safety Circuit Integrity

The electrical contacts of the most critical safety devices are typically connected in series to supply power to the elevator control system. This series of electrical contacts is usually referred to as the "safety circuit". A typical elevator safety circuit is shown in figure 3.

### Hardwired Circuits

The introduction of program logic controllers (PLCs) and microprocessors to control elevators requires special hardware considerations. Faults in the software programming or solid state hardware control should not affect the integrity or reliability of the critical circuits. The critical circuits directly initiate the movement of the elevator and the operation of the brake. As previously discussed, the safety circuit is a critical circuit. The failure of a single

solid state device, such as an output thyristor, should not render the safety circuit ineffective. In fig. 3 for example, a PLC should not serve as an interface between the sheave deck switch and the master control relay. When microprocessor or PLC elevator control is utilized a conventional, hardwired safety circuit must be installed. Furthermore, the safety circuit must immediately disconnect the brake circuit through hardwired relay control and cause the brake to apply. This will ensure that faults in the solid state devices or software programming will not result in unsafe operation of the elevator.

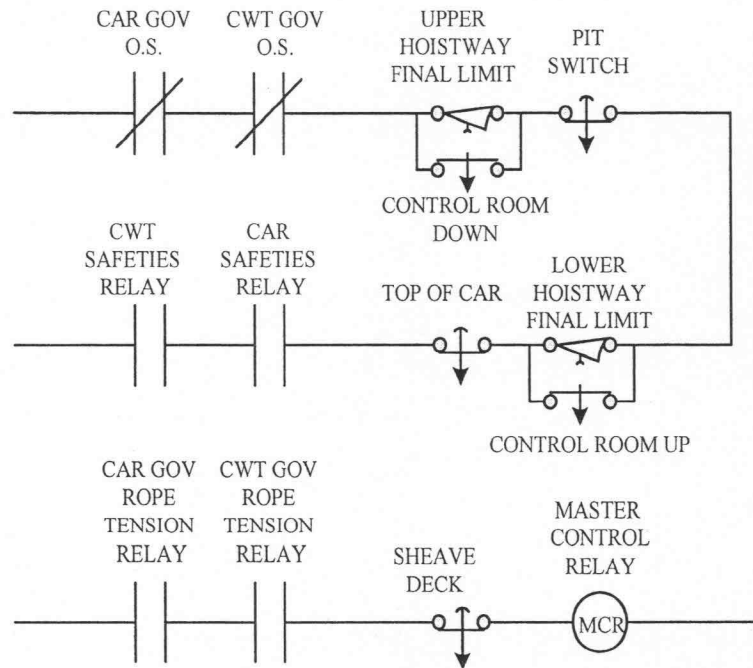


Figure 3. Elevator Safety Circuit

Typically the hardwired logic serves as a redundant circuit for the solid state logic and programming used to operate the elevator.

The electrical brake control is extremely critical to the safe operation of the elevator. On virtually every static control elevator and many motor-generator set controllers, the brake is the sole means of stopping the elevator when overspeed and overtravel conditions occur. Therefore, it is essential that the brake control design be rugged, reliable and fault tolerant.

The elevator brake is typically released by a large electromagnetic solenoid and applied by coil spring tension. Therefore the brake is automatically applied when the brake circuit is interrupted.

The dc brake coil inductance may measure several Henrys. Therefore, careful consideration must be given when selecting a dc brake circuit relay to ensure the contacts are capable of interrupting this highly inductive load. Fig. 4 demonstrates Governor Protection-Limit Switch scheme.

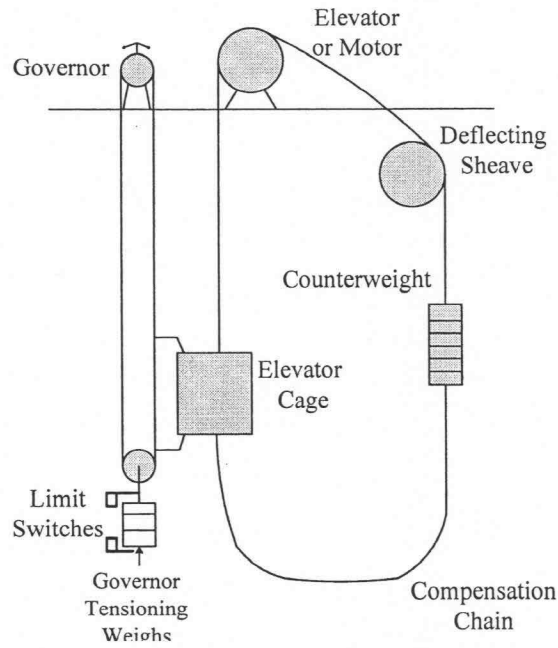


Figure 4. Governor Protection-Limit Switch scheme

### Structure of Expert System

Electric motor selection method [1] 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 [3] 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 fig. 5.

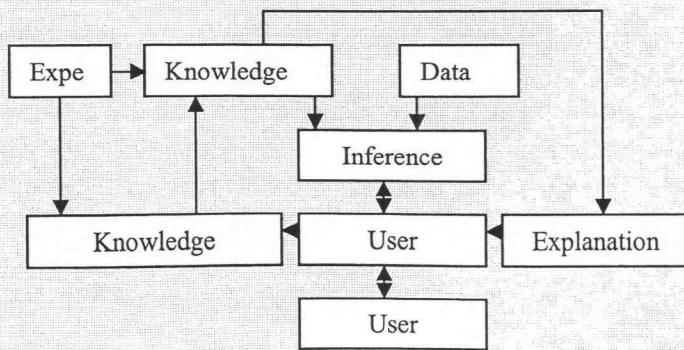


Figure 5. Architecture of expert system

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. In this investigation the fact was realized, that expert system performance for energy efficiency increasing is effective in static expert system case for electric drive systems design and management.

### Mathematical model of Expert System design

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, which could formalize this knowledge. From the other side the expert system design could decrease electric energy consumption in the case of electrical drives system design activities. The task of system design is analyzed in the article.

Output procedure for expert system is often as rules interpretation by planning. 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:

$$F = \{f_1, \dots, f_n\},$$

It is important to know, that the new facts can not be achieved as results of system functioning. The main aim of system is to define relations for real situation facts.

The two existing set  $F$  subsets will be defined in the article  $F_0, F_1$

$$F = F_0 \cup F_1, F_0 \cap F_1 = \emptyset$$

The subset  $S_1$  will be named as subset of marked (known) facts, but subset  $F_0$  – the subset of unmarked facts. The subset  $F_1$ , sometimes could be considered as a working field of decision support system. In the beginning of the work the system has some facts, for example:  $F_1 = \{f_1, f_2, f_3\}$ .

The subset  $F_1$  fulfilment 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 fulfilment from facts, which are true in right side of production  $P_i$ . The choosing 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 described as  $S'_1 \supset S_1$ .

### Numerical experiment

The developed software “Smart Engineer” will support the efficient electrical drives chosen for each system with electrical drive. The software “Smart Engineer” is developed as Expert system.

For example three-phase induction electric motors of the type AД 112 were taken (the rated parameters are given in Table 1 with the technical characteristics: voltage 380 V, frequency 50 Hz and protection class of terminal boxes IP55).

Table 1.  
The rated parameters of the three-phase induction electric motors of the type AД 112

type of motor	rated power, kW	rated speed, rpm	rated efficiency, %	Cos φ	starting torque	breakdown torque	starting current	average noise level, db	weight, kg IM 1081
112 M2	7,5	3000	88,0	0,9	2,5	3,4	9,0	72	44,2
112 M4	5,5	1500	86,0	0,81	2,3	3,0	6,0	62	43,2
112 MA6	3,0	1000	82,0	0,8	2,1	2,7	5,5	60	36,9
112 MB6	4,0	1000	82,5	0,79	2,1	2,8	5,5	60	40,4

Using the developed program “Smart Engineer” with the given rated parameters we can calculate the necessary data of the system configuration. The example of the calculation is demonstrated in fig. 6.

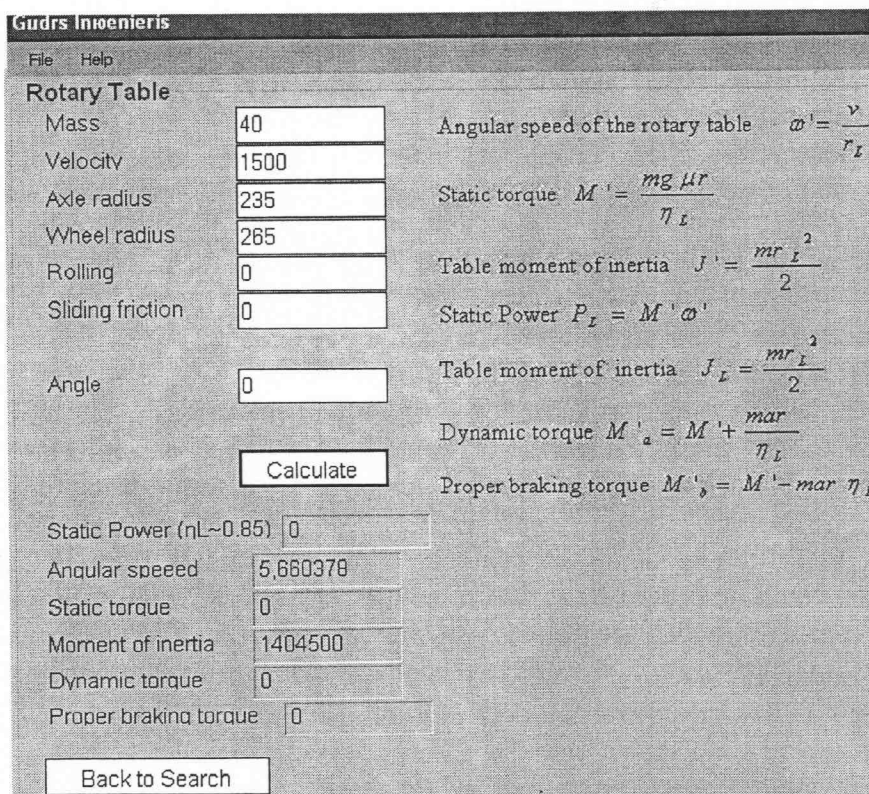


Figure 6. A part of the results of the software “Smart Engineer” operation

The principal factor of the software “Smart Engineer” Expert system is applied for the selection of motors from the existing data base. The calculation example has been developed with the use of motor ABB M2AA 132 SB parameters fig. 7.

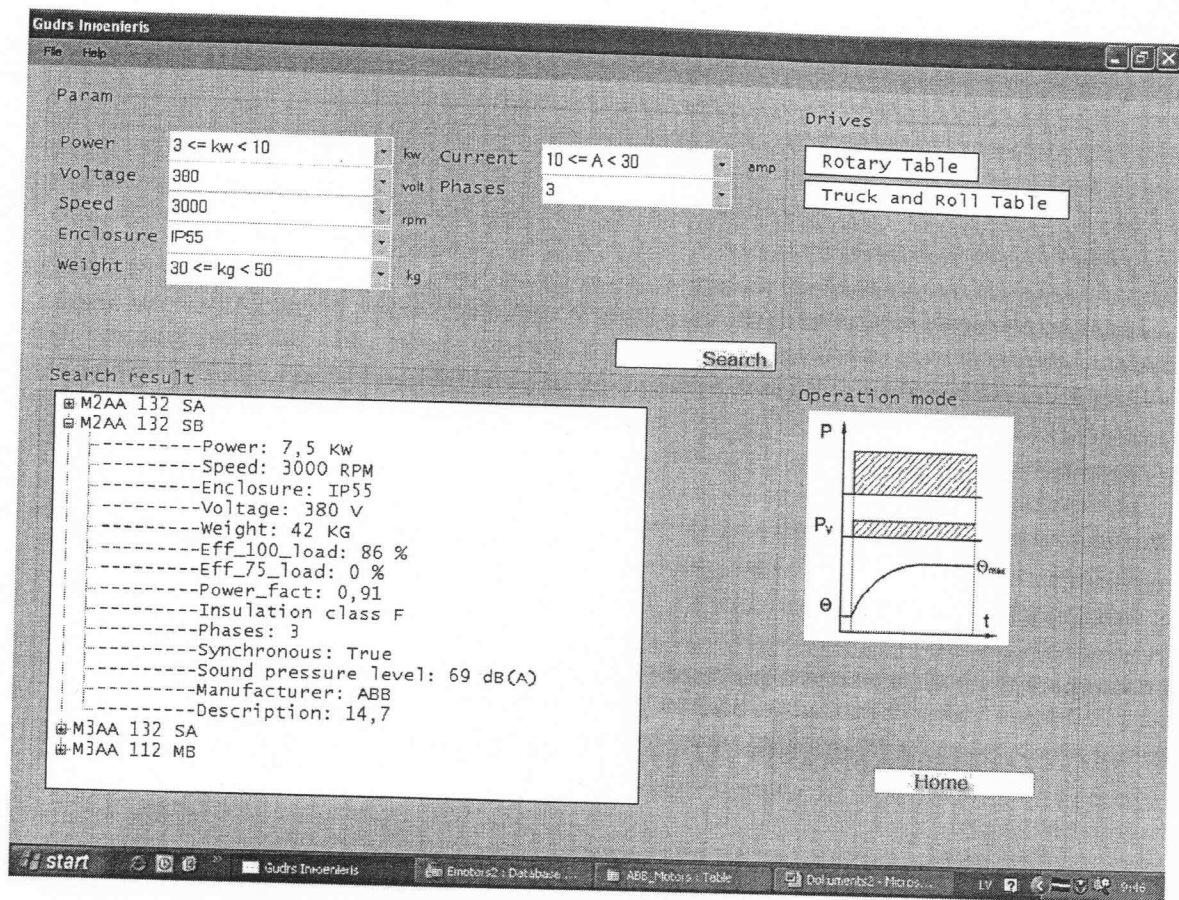


Figure 7. Example of motor selection results in software “Smart Engineer” environment

## Conclusion

The developed expert systems are based on the artificial intelligence approach. The result of this research were the development of expert system – program “Smart Engineer”, the data management subsystem — DBMS, the model management subsystem — MBMS. In the article the subsystem of model management is presented in the formalized mathematical type. Within the process of the model development of the electric drive selection for lifting mechanism not only the mathematical formalization of the selection process has been provided but also a module for calculation of the acceptable motor parameters has been developed for the use in the case if the system is in the process of elaboration. The set of both modules represents a passive system of decision making that helps in this process, but does not suggest an acceptable solution of the system development and electric equipment selection. The importance of the electric motor selection for the lifting mechanisms is in the reduction of electric energy consumption in the whole system. Therefore the correct selection of a correspondent motor provides fewer losses during the process of operation. This tool can help production process technical managers to do faster decisions for process efficiency improvement and quality increase.

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**Caiko J., Kunicina N., Galkina A., Žiravecka A., Ribickis L. Cēlējmehānismu regulējamās elektriskās piedziņas izvēles ekspertu sistēma**

Rakstā tiek apskatīta elektrisko sistēmu izstrādes problēma, ņemot vērā elektrisko piedziņu, motoru un vadības shēmu esošo daudzveidību. Elektrisko sistēmu izstrādes gaitā tiek veikts optimālo komponentu aprēķins un izvēle no esošajām komponentēm, kā arī sniegti ieteikumi speciālas mašīnas izgatavošanai. Elektropiedziņas izmantošana paplašinās, automatizējot dažādus industriālos procesus un izmantojot jaunākās industriālo sistēmu vadības metodes. Ir aprakstīts ekspertu sistēmas matemātiskais modelis, formalizēta izvēles procedūra. Ekspertu sistēma tika izstrādāta, izmantojot mākslīgo intelektu. Modeļu vadības apakšsistēma tika aprakstīta matemātiski formalizētā veidā. Risinot problēmu, tika izstrādāts arī cēlējmehānismu regulējamās elektriskās piedziņas parametru aprēķinu modulis. Abu moduļu kopa izveidoja pasīvo lēmumu pieņemšanas sistēmu, kas palīdz pieņemt lēmumus, bet nevar ierosināt priekšlikumus. Vertikālās transportēšanas mehānismu elektrodzinēju izvēles uzdevuma aktualitāte ir visas sistēmas elektroenerģijas patēriņa samazināšana ekspluatācijas procesā. Atbilstoša elektrodzinēja izvēle dod iespēju sistēmai strādāt bez zaudējumiem. Izmantotā programma palielina tehnisko darbinieku darba kvalitāti un efektivitāti.

**Caiko Y., Kunicina N., Galkina A., Zhiravecka A., Ribickis L. Expert system for the selection of the adjustable electric drive of lifting mechanisms**

The article considers the problem of electric systems development taking into account the large variety of existing types of electric drives, motors and control systems. Within the process of the electric system development the calculation of optimal components and selection of the components take place or production of a special machine is suggested. The application of electric drive is widened with the automatization of different industrial processes and with the application of modern methods of industrial system control. The article provides the description of the mathematical model of the expert system and the procedure of the selection is formalized. The expert system has been elaborated with the help of artificial intelligent. The subsystem of the model management is mathematically described in a formalized way. Calculation modules of the parameters of adjustable electric drive of a lifting mechanism were developed while solving the problem. The set of both modules represents a passive system of decision making that helps in this process, but does not suggest an acceptable solution of the system development and electric equipment selection. The importance of the electric motor selection for the lifting mechanisms is in the reduction of electric energy consumption in the whole system. Therefore the correct selection of a correspondent motor provides fewer losses during the process of operation. This tool can help production process technical managers to do faster decisions for process efficiency improvement and quality increase.

**Чайко Е., Куницына Н., Галкина А., Жиравецкая А., Рыбицкий Л. Выборочные экспертные системы регулируемого электропривода подъемных механизмов**

В статье рассматривается проблема разработки электрических систем, принимая во внимание существующее разнообразие электроприводов, двигателей и схем управления. При разработке электрической системы производится расчет оптимальных компонентов, выбор из существующих компонентов, а также вводятся предложения по изготовлению специального двигателя. В ходе автоматизации различных производственных процессов с использованием новейших методов управления промышленных систем возрастает важность применения автоматизированного электропривода. В статье описывается математическая модель экспертной системы с формализованной процедурой выбора. Экспертная система разработана с использованием искусственного интеллекта. Подсистема управления описана математически - в формализованном виде. Разработан модуль подсчета параметров регулируемого электропривода подъемных механизмов. Совокупность обоих модулей создает систему принятия пассивных решений, т.е. такую систему, которая помогает принятию решений, но не выдвигает предложений. Актуальность задачи выбора электродвигателя подъемных механизмов состоит в снижении расхода электроэнергии системой в целом в процессе эксплуатации. Выбор соответствующего электродвигателя обеспечивает работу системы с меньшими потерями. Используемая программа позволяет увеличить продуктивность и эффективность работы технических работников.