INTELLIGENT SYSTEMS FOR OPTIMISATION OF CLIMATE PARAMETERS USING MULTI-CRITERIAL DECISION MAKING IN TRANSPORT VEHICLES

TRANSPORTA KLIMATA PARAMETRU OPTIMIZĀCIJAS INTELEKTUĀLĀS SISTĒMAS AR DAUDZKRITĒRIJU LĒMUMU PIEŅEMŠANU

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***Keywords:** intelligent agents, modelling, intelligent mechatronic systems, electrical processes, climate control, energy saving, decision making*

Introduction

In this article interest is concentrated on the climate parameters optimization in passengers' salon of public electric transportation vehicles. The main idea of this paper is to use artificial intellect and intelligent multi criteria decision methods (MCDM) to create an algorithm and coordination mechanism for climate parameters control to save electrical energy, and it increases the level of comfort for passengers. This paper provides the mathematical model and algorithm for optimal control of the heating, ventilation and air conditioning (HVAC) system.

Problem Formulation

Mechatronic process is characterized with several controlled energy flows (electrical, mechanical, heat, etc.) [1]. Energy flows can be controlled by changing variable characters of low voltage. Thus with the help of electronic devices the flow of energy influences climate parameters in object. Several detectors control measurable variables. The purpose is to define the optimal HVAC system working regime, taking in account priorities of consumers. Deep and detail investigation of the behaviour of such a system, its operation and running processes requires its generalized mathematic modelling, taking into account all possible regimes of the operation of compressor, fan motors, heater and setting an algorithm of their control in all possible regimes under any condition. Possible problem solution is intelligent coordination mechanism – intelligent agent system with the superagent, which gives possibility to avoid these charges and can give economy of the electrical energy [2].
The following steps are taken for problem solving: to analyze the methods of interactive decisions evaluation, to apply the theory of lists, artificial intelligent [3], application efficiency for solving of the air conditioning system control taking into account consumer's priority.

HVAC system

The modelling and investigation are based on the typical architecture of HVAC (Heating, Ventilation and Air Conditioning) system with a traditional application of AC induction motors for driving both compressor and fan of the conditioner [1]. The well-known field-oriented method has been considered for the modelling (Fig.1) [5,6].

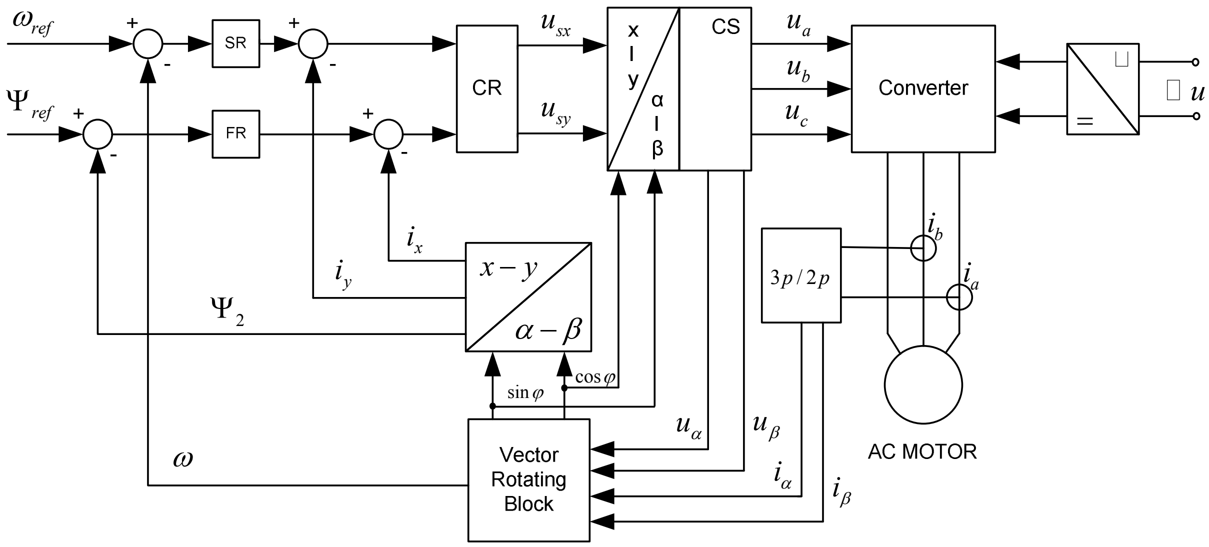

Figure 1. Field-oriented control system.

Mathematical approach gives the voltage vector components u_{sx} and u_{sy} for the control system [5,6]:

$$u_{sx} = R_s \left(i_{sx} + T_{sx} \frac{di_{sx}}{dt} \right) \tag{1}$$

$$u_{sy} = R_s \left(i_{sy} + T_{sy} \frac{di_{sy}}{dt} \right) \tag{2}$$

$$M = \frac{3}{2} p_n k_r \Psi_{rx} i_{sy} , \tag{3}$$

$$\Psi_{rx} = L_{sr} i_{sx} , \tag{4}$$

Where: M - electromagnetic torque, Ψ_{rx} - and flux linkage, T_{sx}, T_{sy} – is motor time constant, p_n – number of motor poles pairs, k_r – rotor magnetic factor, L_{sr} -stator inductance, i_{sx}, i_{sy} - vectors of stator currents, R_s -stator active resistance, t - time.

Control System Design

Control system structure is shown in Fig. 2. The fuzzy logic controller (FLC) developed here is a two-input single-output controller. The structure and work principle of FLC are described in [1]. The two inputs of FLC are the deviation from setpoint error, d(k), and error rate, Δd(k). FLC output crisp signal is delivered to DMU, which using received information about available energy sources and climate parameters in controlled object performs proceeding of the situation using multi criteria decision methods, and as a result set appropriate control regime. For adjust of this signal with HVAC system control signal converter- (CSC) is used as shown in Figure 3. Heat got during vehicle moving process from warming up of motion drives, their brake resistors and control system is used as extra source of heat (External heat).

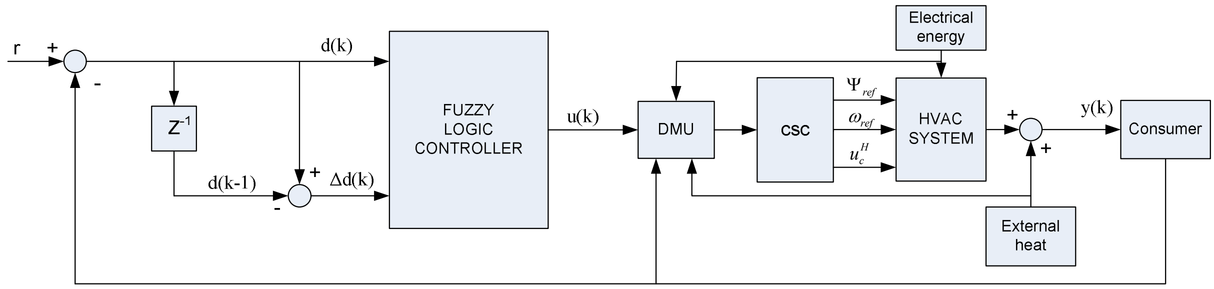

Figure 2. Control system structure.

Problem decision algorithm

Step 1. Determine consumers P^m heat perceiving slopes, write them down as alternative set $A(P^m)$;

Step 2. Evaluate correlation of consumers' wishes (decrease temperature for n degrees at decision making point and watch consumers reaction. This consumer's behaviour will be labelled as $A^k(t)$ – A, alternative, k – consumers set, t – continuous time).

Step 3. If consumer is performing activity U – set control regime $A_w^k(t)$ (determining it during planning stage with the help of correlation).

Step 4. Use improved Rastrigins' adaptation procedure f^{IR} (adaptation of temperature with learning according wishes of consumers) [1].

Step 5. Evaluation of climate parameters of object performed by consumers as linguistic variable is processed by fuzzy logic controller and control regime $A_w^{FL}(t)$ in output is set.

Step 6. Provide system parameters control with intellectual MCDM agents. Supra program agent provides system control with the minimal consumption of electrical energy accordingly priorities of consumer under control procedure $A_w^{DM}(t)$.

Problem decision methodology

For problem decision algorithm step 6 realization Nelder-Mead decisions making multi criteria decision procedure is used [4]. Adaptive procedures of decision making are based on hypotheses about existing "losses function" u(e), determined by initial set of alternatives E: $u: E \to R,$ where R is set of real numbers. This method solves the task of searching for minimizator e^* of some function $u: E \xrightarrow{u} R, E \subset R^n$.

$$e^* = \arg\min_{e \in E} u(e). \tag{5}$$

Function u(e) describes the aim of decision making operation- the smaller value of "losses function", the better. Function u(e) is supposed to be unknown before.

No evaluation of value u(e) for concrete $e \in E$ will be done, just comparison of two alternatives by their vector evaluations. It is enough to realize method of minimum zero sequence search. Decision making unit works as some kind measuring unit which does not need displaying of value u(e), only fixing: “worse”, “better”, “the same”. Basic operations of Nelder-Mead method is shown below.

1.Reflection. Projection of the worst vertex e^h through centre of gravity e^c of other vertexes. $e^r = e^c + \alpha\left(e^c - e^h\right), \alpha > 0$, where e^c is center of gravity point of vertexes A_2, A_3 .(Fig.3).

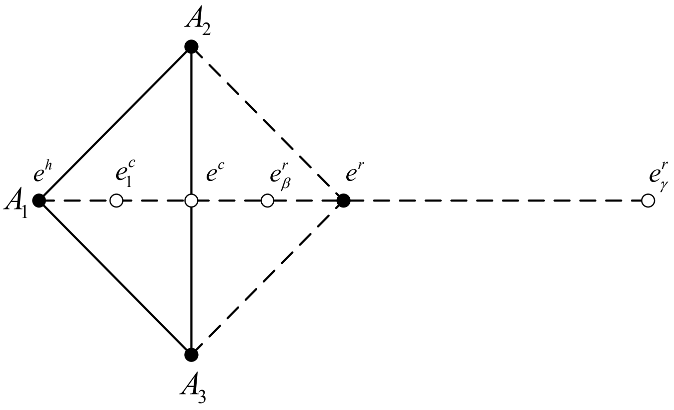

Figure 3. Reflection operation.

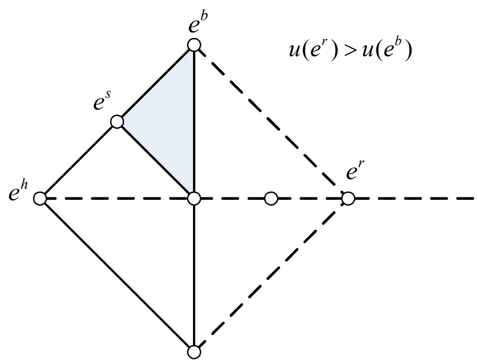

Figure 4. Shrink operation.

2.Expansion. If value of function u(e) at e^r appears to be better than at the best vertex from $\{A_1, A_2, A_3\}$ then expansion γ times ($\gamma > 1$- coefficient of expansion) is realised and e^r is replaced by e_γ^r .

3.Contraction. If the value of function u(e) at reflected vertex e^r is worse than at all other vertexes (except e^h) then contraction (with coefficient $0 < \beta < 1$) is realised and e^r is replaced by e_β^r .

4.Shrink. If the value of function u(e) at reflected vertex e^r is worse than e^h then the whole polyhedron is shrinked in two times in relatio to the best vertex e^b (Fig. 4).

*5.*In other situations operations 2, 3, 4 are not performed, but the process is continued for the new polyhedron $\{A_1, A_2, e^r\}$.

6.Ending of the process is performed when condition on approximate equality of values of function at vertexes of current polyhedron and in the center of gravity of polygon not taking into account the worst vertex is satisfied.

System Decision making control realisation.

DMU task is used for step 6 realization of problem decision algorithm to find optimal choice $Q^{OP} = f(E^{OP};t)$, with $Q(t) \to \max$. and $E(t) \to \min$. It is done following the structure of process shown in Fig. 5. Target is minimization of electrical energy consumption in compressor, fan motors and heater, considering consumer k with control regime W with decision making D under control procedure $A_w^{DM}(t) \to \min$. during time t: $E = E^C$ x E^F x E^H .

Step 1. Object O climate parameters and their influencing object mathematical models O^{MD} are concretized.

Step 2. Determine functional characteristics of system f^C, f^F, f^H (for cooler, fan and heater respectively) for coherences of the comfort level in the object $Q(t)$ and electro energy summary consumption of HVAC system $E(t)$ at time t, which are proposed as $Q = f(E;t)$.
Step 3. The aim of rational choice is defined. $E(t) \to \min.$; $Q(t) \to \max.$
Step 4. Optimal choice task using MCDM Nelder-Mead method is performed.
Step 5. Work regime of HVAC system $A_w^{DM}(t)$ is set according computation results.

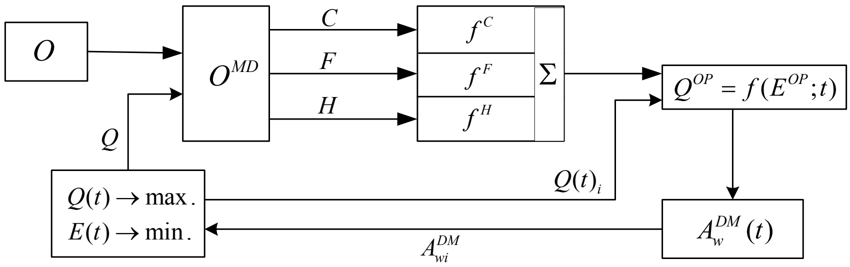

Figure 5. Control process structure.

Where: Q - passengers comfort level, E - summary energy consumption, Q^{OP} - optimal choice of comfort level parameters, E^{OP} - optimal choice of energy consumption.

Conclusions

The provided results prove that the use control system with application of the fuzzy logic controller and Nelder-Mead multi criteria decision making algorithm can be very useful for solving HVAC technology control problems in public electric transport.
Usage of created models and algorithms in air temperature control systems in salon of public electric transport will raise possibility to increase efficiency of electro energy usage, so exploitation costs of transport will reduce as well as passengers' comfort level will be increased. Appropriate for this purpose are systems working using control core developed on the basis of artificial intelligence which can control current condition of all system, environment parameters independently on operator, and taking into account predictable changes of these conditions to take decision on necessary system actions.

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Beinarts I., Ļevčenkovs A. Transporta klimata parametru optimizācijas intelektuālās sistēmas ar daudzkritēriju lēmumu pieņemšanu.
Publiskais elektrotransports šajā publikācijā tiek skatīts kā mehatroniska sistēma. Galvenā uzmanība ir koncentrēta uz klimata parametru optimizāciju pasažieru salonā.
Publikācijas pamatideja ir multikritēriju lēmumu pieņemšanas un intelektuālo aģentu algoritmu pielietošana elektroenerģiju taupošā klimata parametru kontroles vadības un koordinācijas mehānismā. Publikācijā ir aplūkota mehatroniskās sistēmas klimata parametru optimālās intelektuālo aģentu kontroles matemātiskā problēma, kā arī sniegtas problēmas risināšanas metodes un algoritms .
Īpaša uzmanība ir pievērsta pētījumiem un turpmākajām izstrādnēm, kas skar intelektuālās gaisa sildīšanas, kondicionēšanas un ventilācijas sistēmas ar daudz elastīgāku sistēmas kompresora un ventilatora vadību un līdz ar to uzlabotu efektivitāti un samazinātu elektroenerģijas patēriņu. Izstrādātajā sistēmas modelī izmantotā daudzkritēriju lēmumu pieņemšanas metode var tikt pielietota mikroklimata uzturēšanai dažādās ēkās un publiskajā elektrotransportā. Raksta nobeigumā ir doti svarīgākie secinājumi.
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Beinarts I., Levchenkov A., Intelligent systems for optimisation of climate parameters using multi-criterial decision making in transport vehicles.
The authors consider the public electric transport vehicles as mechatronic systems. The focus of interest is the optimisation of climate parameters in passenger salons. The main subject of this paper is the use of multi-criteria decision making and intelligent agent negotiation algorithms for creation of a system and a coordination mechanism for control of climate parameters that would allow saving of electrical energy. The paper formulates a corresponding mathematical problem using intelligent agents of mechatronics for the optimal control of climate parameters. The authors present methods and algorithms for solving the problem. Of a particular interest for investigations and further development are intelligent systems of heating, ventilation and air conditioning, which would allow for more flexible regulation of a system’s compressors and fans, and, therefore, for efficiency improvement and energy saving. The developed model of multi-criteria decision making can be used for providing a sustainable microclimate in different facilities, buildings and public electric transport.

Бейнарт И., Левченков А., Интеллектуальные системы оптимизации климатических параметров с применением многокритериального принятия решения для транспортных средств.

В этой статье электрические транспортные средства рассматриваются как мехатронические системы. Интерес сконцентрирован на оптимизации климатических параметров в салоне пассажиров. Главная идея этой публикации заключается в использовании многокритериального принятия решений и алгоритмов переговоров интеллектуальных агентов, чтобы создать систему управления и механизм координации для управления параметров климата, чтобы сэкономить электрическую энергию. Статья представляет математическую проблему использования интеллектуальных агентов в мехатронических проблемах для оптимального управления параметров климата. Методы решения проблемы и структура алгоритма проблемы решения предоставлены в статье. Специальный интерес для исследований и дальнейшего развития посвящен интеллектуальному управлению систем нагревания, вентиляции и кондиционирования, позволяющим более гибкое регулирование приводов компрессора, вентилятора и, в следствии этого эффективности использования и экономии энергии. Разработанная модель системы использования многокритериального принятия решений может использоваться для того, чтобы обеспечивать параметры микроклимата в различных помещениях, зданиях и общественном электрическом транспорте. В окончании статьи даны основные заключения.