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# DEVELOPMENT OF MODELLING METHODS OF SOFTWARE AGENTS IN ELECTRIC POWER SUPPLY AND TRANSPORT LOGISTIC SYSTEMS

**Abstract of Promotional Paper**

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RTU Publishing House
Riga 2004

## 1. General description of the work

1.1.*Actuality of the subject* By the present moment research of Latvian and foreign scientists were connected with the tasks of decision making in the area of power engineering production, designing and maintenance. Techniques of the main tasks solving are presented in the works of the following Latvian scientists: L. Ribickis, A. Sauhatas, Z. Krišāns, V. Dāle, O. Paegle, I. Oleinikova and the following foreign scientific authors: R. Kini, L. Raifa, P. Fishburn, T. L. Saati, P. Humphreys, O. Larichev, M-J. Aracil, J-I. Castillo, L. Lopez - Valpuesta, T. Witting. It includes also the investigations of those electric power supply and transport tasks, for the solving of which the methods of operation investigation and the method of decision making in fuzzy conditions are applied, allowing to obtain the recommendations for an optimal (fairly) alternative choice.

The methods of vector optimization allow analysing and making of an optimal alternative choice for solving of complicated tasks, when an alternative together with contradictory features is considered.

"There is actual a question of such methods application, which presents particular preferences of electric power consumers. Designing of software agents functional features and structures provides the elaboration of the multicrilerial optimization methods for producers and consumers goals achievement in the conditions of liberal power market. The questions of functional interaction of software agents with vector optimization methods, methods of decision making and methods of scheduling theory are not investigated.

At the present moment the effectivity of the software in global networks mostly depends on the access of power consumers to data bases, questions they are interested in, efficiency of tasks solving in the global network, the degree of users preferences presenting in the set of databases in the global network. The priority of consumers in the data bases in the global network is not considered.

The problem of software agent application, methods of scheduling theory, methods of vector optimization theory and methods of mathematical statistics application got an actualization for the solving of the task of electric power supply in the case of data bases existing in the global network. That, in its turn, causes the problems of methodological elaborations for global network system technicians and designers of mathematic software in the searching of an optimal solution in the tasks of electric power supply not only in separate states but in large regions too.

1.2.*Goals and objectives.* The goal.of the promotional work is elaboration of models development methods for solving the tasks of electric power supply, taking into account the following features:

The essence of global networks with large number of objects including servers, computer units of suppliers and consumers; The essence of multicriterial objects; The essence of complicated dynamic topologies; Dynamic appointment of suppliers and consumers in risky conditions; The essence of consumers priority and its instability with time; The essence of dynamic process management with influencing effect; The essence of lack of statistical data for modelling.

1.3. *Methodology of the research.* The following theoretical and practical methods are used in the promotional work:

Methods of systems analysis; Methods of modern logistics; Methods of the set theory; Modern theory of decision making; Graph theory; Flow theory; Modem theory of measurements; Methods of vector optimization; Scheduling theory; Methods of mathematical statistics.

1.4.*Scientific novelty of jhe research.* .Scientific novelty of the research covers the following aspects of the promotional work: The task of the development of the software agents modelling methods for the logistic systems of electric power supply and transport in the situation of global networks has been formulated. Operation methods and procedures of multicriterial software agents in risky conditions have been developed. Procedures of evaluation for Supra agents formalized goals models are developed: for consumers profile choice; for making of feedstock supplying schedules; for the expert commissions forming and their interaction with Supra agents.

1.5. *Basic results.* The following results have been obtained in the work:

- The task of electric power supply and transport logistics is formulated as a formalized task of investigations of models.
- A complex of nine mutually related models has been analysed in the promotional work for the development and investigation of software agent models of electric power supply and transport logistics: functional model of feedstock sypply system - *Sum;* functional model of a transport system for power systems of feedstock supply - *Stm;* model of an electric power supply system for consumers- *Sem;* model of power consumers behaivour in the conditions of liberal electrical power market - *Spm*; model of software agent which interaction with the model of feedstock supply system solves the task of an optimal feedstock supply to power systems - $A^u$; model of software agents, which interaction with the model of transport - system solves the task of an optimal feedstock supply to power systems - $A^t$; software agent model which solves the task of electric power supply to consumers - $A^e$; model of consumers software agents wliich takes into account priority of the consumers in risky conditions achieving the goals of the real expert groups - $A^p$; model of expert group Supra software agent which takes into account goals of expert groups ensuring co-ordination of the consumers goals realization in uninterrupted regime - $A^s$.

- The interaction of software agents, Supra software agent with electric power consumers priority and order data bases, with power systems producers feedstock delivery data bases are analysed. Models of electric prognosis of power consumption quantity for the next time moment, model of electric power suppliers assignment for power consumers, model of power delivery path designation are defined for the task of electric power supply. Model of feedstock, suppliers assignment for power systems, model of feedstock delivery for power systems and model of schedule making for feedstock delivery for power systems are formulated for the- task of logistic transport.
- Different algorithms are considered for the solution of the task of electric power supply and logistic transport and prognosing methods, Pseudo Kening method, method of modified flows theory are suggested to be used for the solution of electric power supply task, modified Kening method, modified Little algorithm, modified methods of the theory of schedules, ,,the first is served the first" are used for the solution of transport logistics tasks.
- As a result of the developed methods application the descriptions of electric power supply modeling task in the Baltic region. The choice of power supply profile characteristics with the help of software agents for the Latvian power consumers. An example of practical application of the developed methods is considered for the tasks of suppliers choice, prifile choice, expert committee forming and electric power feedstock delivery.

1.6. *Practical application of the investigation.* The methodology suggested in the promotional work ensures the organization of the decision making procedure in the order of electric power supply and transport logistics tasks solution in the conditions of liberal market in the Baltic region using mathematical models of software agents. A possibility to fulfil the electric power supply tasks with large amount of suppliers and consumers and solution analysis is ensured with the realization of the developed methodology in the global network.

The algorithm of structural elements adaptation allows the adaptation to the real delivery systems and solving new tasks without additional expences. A simplified information system of attached software which realises the functions of software agents for seven prognozing methods of electric power consumers for the city of Riga with the parameters of substations on the territory of Latvia and information on the power consumers of the other Baltic states is elaborated for the promotional work.

Practical experiments of the promotional work were realized with the server of the global network applying software agents for prognozing in the tasks of electric power supply. The elaborated mathematical models, procedures, algorithms and methods could be applied in VAS Latvenergo, VAS Latvijas Dzelzceļš as well as scientific project of Latvial Scientific Council Nr: 04 - 1182 with the title ..Development of multi - agents system for energy distribution".

1.7. *Approbation of the investigation.* The results of the investigation are presented and discussed at the following international scientific conferences:

- "Industrial Simulation Conference 2003", June 9-11, Valencia, Spain, 2003.
- "The International Workshop on Harbour, Maritime and Multimodaf Logistics Modelling & Simulation - HMS 2003" September 18-20, Riga, Latvia, 2003.
- 44nd International Scientific Conference, Riga Technical University, October 9 - 11, Riga, Latvia, 2003.
- 18 th international conference on CAD/CAM, robotics and factories of the future - CARS& FOF2002, July 3-5, Porto, Portugal, 2002.
- 43nd International Scientific Conference, Riga Technical University, October 11 - 14, Riga, Latvia, 2002.
- 15th European Simulation Multiconference, June 6-9, CTU Prague, Czech Republic, 2001
- 42nd International Scientific Conference, Riga Technical University, October 11-13, Riga, Latvia, 2001.
- 15th international conference on multiple criteria decision making, Middle east Technical university, July 11 - 14, Ankara, Turkey, 2000.
- Nordic-Baltic Transport Research Conference, 13 -14 April, Riga, Latvia, 2000.

The research is discussed at RTU seminars (at the Institute of Railway Transport and Department of Simulation Modeling), the negotiations with VAS Latvenergo and VAS Latvian Railway representatives are carried on the possibilities of the practical application of the research. The promotional work is also considered at the scientific seminar of EEM laboratory of Institute of Physical Energetics (IPE) of Latvian Academy of Sciences (LAS). The promotional work if presented at LAS IPE Scientific Council meeting.

1.8. *Publications.* Actuality and main results of the research during the last four years are represented in 11 author's publications in international conferences issues:

- N. Kunicina, A. Levchenkovs, L. Ribickis "Algorithm for Software agents to power supply modeling in Baltic region" EPE - PEMC, 11 th International power electronics and motion control conference, Riga, 2004., 6 p. (in the process of printing).
- N. Kunicina, "Software agents algorithm for logistics models of power supplay companies with adaptation" RTU zinatniskie raksti, Riga, 2004., 8p. (in the process of printing).
- N. Kunicina, A.Levchenkovs, , "Scheduling and program agents algoritms for e - logistics""Industrial Simulation Conference 2003", Valencia, Spain, 2003., pp 243-256..
- N. Kunicina, "Software agents modelling for power energy company" Scientific proceedings of Riga Technical University, "Computer Science Information Technology and Management Science" Riga, 2003., pp 179-183.
- N. Kunicina, A. Levchenkovs, L. Ribickis "The use of software agents in power energy logistics" "The International Workshop on Harbour, Maritime and Multimodal Logistics Modelling & Simulation - HMS 2003" Riga, 2003., pp 367-371.
- N. Kuņicina, "Sarakstu programmu aģentu pielietošana loģistikas uzdevumu risināšanai", Scientific proceedings of Riga Technical University, 2003., pp 149 - 153.

- N. Kunicina, A. Levcenkovs "The use of Program agents to choose supplier for multicriterial problems", Scientific proceedings of Riga Technical University, "Transport and engineering", series 6., volume 12., Riga, 2003., pp 141 - 148.
- A.Levcenkovs, V. Yansons, N. Kunicina, "Coordination between programs agents for e - commerce", Scientific proceedings of 18 th international conference on CAD/CAM, robotics and factories of the future - CARS& FOF2002, Porto, Portugal, 2002., pp 661-667.
- N. Kunicina, A. Levcenkovs, V. Jansons "Intelligent agents for information transport systems", Scientific proceedings of Riga Technical University 'Transport and engineering", series 6., volume 4., Riga, 2001., pp 102-107.
- N. Kunicina, A. Levchenkovs, "Modelling of Multicriterial Group Decision Making in Transportation Logistics Systems", "Modelling and Simulation 2001", 15th European Simulation Multiconference, CTU Prague, 2001., pp 892 - 894.
- Kunicina N., Levcenkov, A., "Logistics Decisions Systems for Railway's Intermodality Traffic Management "Nordic-Baltic Transport Research Conference, Conference Proceedings,Volume II, 2000., Riga, 5p.

*1.9. .Structure and volume of the promotional work*

Promotional work contains 29 figures, 13 tables, full 113 pages. 56 units in references.

## 2. Content of the promotional paper

*The introduction* contains a short summary of the subject, its actuality, goals, novelty of the research, methods of the research, main results and the author's publications as well as approbation of the work.

*The first chapter* is devoted to the observation of the methods, it analyses a complex structure of the models for electric power supply in the global network. The software agents systems characteristics are considered. The formalized target setting of the model investigation is demonstrated. It is demonstrated in the work that for the solving of the task of software agent modelling the models of management goals, management process and multicriterial evaluation are necessary to be elaborated; For the development and investigation of the software agents models of electric power supply and transport logistics a complex of nine mutually co-ordinated models is investigated in the promotional work:

- A functional model of feedstock supply system is shown - *Sum;*
- Functional model of the transport system for resources delivery to the electrical power producers - *Stm;*
- Model of electrical power supply to the consumers - *Sem;*
- Model of electrical energy consumers behaviour in the conditions of liberal electrical power market - *Spm;*
- Model of software agents which interaction with the model of feedstock supply systems solves the task of optimal feedstock supply to power systems -$A^u$;
- Model of software agents which interaction the model of transport system solves the task of optimal feedstock supply to power systems - $A^t$;
- The model of software agents which solves the task of electric power supply to the consumers - $A^e$;
- The model of consumers software agents which takes into account priority of the consumers in risky conditions, reaching the goals of the real expert groups - $A^p$.

Modelling of electric power consumers priority in risky conditions taking into account the liberalization of the electric power market is a very actual question in the nearest ftiture. The model of Supra software agent which provides the reaching of the goal nominated by the expert group with the help of software agents in the processes of electric power supply and transport logistics is also analyzed in the promotional work.

In the promotional paper the following notions and marking are applied:

*Software agent A* is: a performed data set in data cell or data set in the computer operative memory. The main feature of the software agent is connected with the fact that software agent fulfils a particular work which is stated according to the client's task without break in twenty-four hours regime. The operational environment of the software agent is global network server (the user's computer for particular operations). The set of the software agent is marked *with* $A = \{ A^i, i\in l\}, I=\{ l, 2,..., n), A^i =\{ A^i_k, k\in K \}$.

*Supra software agent:* it is a software agent, which provides a series co-ordination of the other software agents operation, fulfilling the task of the consumers. The set of the Supra software agent is marked with $A^s=\{ A^s_i , i\in 1) I\}, 1=\{1, 2, ...,mj\}$.

Feedstock delivery system Su is a physical system, which ensures feedstock delivery to power system. Feedstock delivery system is marked in the promotional paper as $Su(t_i) =\{Su_i(t_i), i\in l\}, l=\{ l, 2,..., s\}$. System of feedstock delivery $Su(t_i)$ is connected with the environment $Sv(t_i)$. System of feedstock delivery $Su(t_i)$ has set of output signals $Wu^1(t_i)$, which come to the input of transport system $St(t_i)$, from which can go the opposite set of output signals $Wu^{-1}(t_i)$. Feedstock delivery system $Su(t_i)$ has a particular set of input signals $Wu(t_i)$ and set of input material flows $Wuv(t_i)$ for the time moments $t_i\in T, T=(t_i\ i\in l\}, 1=\{1, 2,..., s\}$, which come from environment $Sv(t_i)$. System of feedstock delivery $Su(t_i)$ can influence the environment $Wuv^{-1}(t_i)$. Feedstock delivery system $Su(t_{i+1})$ can be influenced by the model of feedstock software agents $A^u(t_{i+1})$.

Transport system *St* is a physical system, which ensures feedstock transportation from feedstock suppliers to the power systems. In the promotional paper the transport system is marked as: $S(t_i)=S(t_i)$ , $i\in 1=\{I, 2,..., s\}$. Transport system $St(t_i)$ is connected with the system of feedstock delivery $Su(t_i)$. Transport system has $St(t_i)$ a set of output signals $Wt^1(t_i)$, which come to the input of power system $Se(t_i)$ from which can go the opposite set of output signals $Wt^{-1}(t_i)$. Transport system $St(t_i)$ has a particular set of input signals $Wt(t_i)$ and set of input material flows $Wtu\ (t_i)$ for the time moment $t_i\in T, T=\{ t_i\ i\in l\}, l=(l, 2,...s)$, which go from feedstock delivery system $Su(t_i)$. Transport system $Si(t_i)$ can influence feedstock delivery system $Wtu^{-1}(t_i)$. Transport system $St(t_{i+1})$ can be influenced by the model of transport system software agents $A'(t_{i+1})$.

Power system *Se* is a physical system, which ensures electric power production and supply to consumers. In the promotional work power system is marked as $Se(t_i)= \{Se_i,(t_i), i\in l\}, 1=\{1, 2,..., sj\}$ .Power system $Se(t_i)$ is connected with transport system $St(t_i)$. Power system $Se(t_i)$ is connected with environment $Sv(t_i)$. Power system $Se(t_i)$ has a set of output signals $We^1\ (t_i)$, which come to the input of consumers system $Sp(t_i)$ from which can go the opposite set of output signals $We^{-1}(t_i)$.Power system $Se(t_i)$ has a particular set of input signals $We(t_i)$ and set of input material flows $Wet\ (t_i)$ for the time moment $t_i\in T, T=\{ t_i\ i\in l\}, l=\{ l, 2,...s\}$ which come from transport system $Si(t_i)$. Power system $Se(t_i)$ can influence transport system $Wte^{-1}(t_i)$. Power system $Se(t_{i+1})$ can be influenced by the model of power system software agents $A^e(t_{i+1})$.

Consumers system *Sp* is a system which consumes electric power. In the promotional work consumers system is marked as *Sp(ti)=(Spi(t,), iel}, I=fl, 2,..., s}*. Consumers system $Sp(t_i)$ is connected with power system $Se(t_i)$. Consumers system $Sp(t_i)$ has a set of output signals $Wp^1(t_i)$, which come in the environment $Sv(t_i)$, from which can go the opposite set of output signals $Wp^{-1}(t_i)$. Consumers system $Sp(t_i)$ has a particular set of input signals $Wp(t_i)$ and set of input material flows $Wpe\ (t_i)$ for the time moment $t_i\in T, T=\{t_i\ i\in l\}, I=\{\backslash, 2,..., s\}$, which come from power system $Se(t_i)$. Consumers system $Sp(t_i)$ can influence power system $Wpf^{-1}(t_i)$. Consumers system $Sp(t_{i+1})$ can be influenced by the model of consumers system software agents $A^p(t_{i+1})$.

Expert commission system *Sk* is a physical system, which co-ordinates all logistic systems *Su, St, Se, Sp* in the order of the task solution. In the promotional work expert commission system is marked as: $Sk(t_i)= \{Ski(t_i), i\in l\}, I=\{1, 2,..., s\}$. Expert commission system $Sk(t_i)$ is connected with the environment $Sv\ (t_i)$. Expert commission system *Sk* has a set of output signals $Wk^l\ (t_i)$ which come to Supra software agent $A^s$ in the global network, from which can go the opposite set of output signals $Wk^{-1}(t_i)$. Expert commission system $Sk(t_i)$ has a particular set of input signals $Wk(t_i)$ for the time moment $t_i\in T, T=\{t_i,\text{-}i\in l\}, I=\{1, 2,..., s\}$. Expert commission system $Sk(t_{i+I})$ can be influenced by the model of Supra software agents $A^s(t_{i+1})$.

Model of feedstock delivery system *Sum* is a model of feedstock delivery physical system *Su*. In the promotional work model of feedstock delivery system $Sum(t_i)$ is marked as: $Sum(t_i)= \{Sum(t_i), i\in 1\}, I=\{l, 2,..., s\}$. Model of feedstock delivery system S«mff,j has a set of output signals $Wu^2(t,)$, which come to the model of feedstock delivery software agents $A^u(t_i)$ in the global network. Model of feedstock delivery system $Sum(t_i)$ has a particular set of input signals $Wu(t_i)$.

Model of transport system *Stm* is a model of physical transport system *St*. In the promotional work model of transport system is marked as $Stm(t_i)= \{Stm(t_i)\ i\in l\}, I=\{1, 2,..., s\}$. Model of transport system $Stm(t_i)$ has a set of output signals $We^2(t_i)$ which come to the model of transport software agents $A^t(t_i)$ in the global network. Model of transport system *Stm* has a particular set of input signals $Wt(t_i)$.

Model of power system *Sem* is a model of physical power system *Se*. In the promotional work model of power system *Sem* is marked as $Sem(t_i)= \{Sem(t_i)\ i\in l\}, I=\{1, 2,..., s\}$. Model of power system $Sem(t_i)$ has a set of output signals $We^2(t_i)$, which come to the model of power system software agent $A^e(t_i)$ in the global network. Model of power system *Sem* has a particular set of input signals $We(t_i)$.

Model of consumers system *Spm* is a model of physical consumers system *Sp*. In the promotional work model of consumers system *Spm* is marked as $Spm(t_i)=\{Spm(t_i)\ i\in l\}, 1=\{1, 2,..., s\}$. Model of consumers system $Spm(t_i)$ has a set of output signals $Wp^2(t_i)$ which come to the model of consumers system software agent $A^p(t_i)$ in the global network. Model of consumers system *Sem* has a particular set of input signals $Wp(t_i)$.

Model of expert commission system or Supra software agents $A^s$ is a model of expert commission system. In the promotional work model of expert commission system is marked as $A^s(t_i) =\{A(t_i), i\in l\}, I=\{1,2,..., s\}$. Model of expert commission system $A^s(t_i)$ is connected with expert commission system $Sk(t_i)$. Model of expert commission system $A^s(t_i)$ has a set of output signals $Ws^2(t_i)= \{Ws^2(t_i)_i, i\in l\}, l=\{l, 2,..., s\}$, which co-ordinates the operation of logistic system software agents $(A^u(t_i), A^t(t_i), A^e(t_i), A^p(t_i)$ in the global network. To the input of Supra software agent $A^s(t_i)$ the set of expert commission signals $Wk^1(t_i)$ and set of logistic systems software agents $A^u(t_i), A^t(t_i), A^e(t_i), A^p(t_i)$ come.

Model of feedstock delivery software agents $A^u$ ,the interaction of which with feedstock delivery system solves the task of optimal feedstock delivery to power systems, in the promotional work is marked as - $(A^u(t_i), A^u(t_i)=\{A^u_i(t_i), i\in l\}, l=(l, 2,...s\})$. Model of feedstock delivery software agent $A^u(t_i)$ is connected with the model of feedstock delivery system $Sum(t_i)$. Model of feedstock delivery software agents $A^u(t_i)$ has a set of output signals $Wu^3(t_i)$, which come to the input of Supra software agent $A^s(t_i)$ in the global network as well as to the model of feedstock delivery system $Sum(t_i)$. Model of feedstock delivery software agents $A^u(t_i)$ has a particular set of input signals $Wu(t_i)$ and $Wu^2(t_i)$ as well as influencing set of the set of Supra software agents $A^s(t_i)$.

Model of transport software agent $A^t$, the interaction of which with the model of transport system solves the task of optimal feedstock transportation from suppliers to power systems, in the promotional work is marked as - $(A^t(t_i),A^t_i(t_i)'=\{A^t_i(t_i), i\in l\}, I=\{I, 2,..., s\})$. Model of transport software agent $A^t(t_i)$ is connected with the model of transport system $Stm(t_i)$. Model of transport software agent *A'fa)* has a set of output signals $W^3(t_i)$ which come to the input of Supra software agent $A^s(t_i)$ in the global network, as well as to the model of transport system $Stm(t_i)$. Model of transport software agent $A^s(t_i)$ has a particular set of input signals $Wt(t_i)$ and $Wt^2(t_i)$ as well as influencing set of the set of Supra software agents $A^s(t_i)$ .

Model of power system software agents $A^e$, the interaction of which with the model of power system solves the task of optimal production volume of electric power and its transportation to the consumers, in the promotional work is marked as - $(A^e(t_i)', (t_i)=(A^e_i(t_i), i\in l\}, I=\{l, 2,..., s\})$. Model of power system software agents $A^e(t_i)$ is connected with the model of power system $Sem(t_i)$. Model of power system software agents $A^e(t_i)$ has a set of output signals $We^3(t_i)$, which come to the input of Supra software agent $A^s(t_i)$ in the global network as well as to the model of power system $Sem(t_i)$. Model of power system software agents $A^e(t_i)$ has a particular set of input signals $We(t_i)$ and $We^2(t_i)$ as well as influencing set of the set of Supra software agents $A^s(t_i)$.

Model of consumers software agents $A^p(t_i)$, which takes into account priority of the power consumers in risky conditions, achieving a particular goal of expert groups, in the promotional work is marked as - $(A^p(t_i), A^p(t_i)=\{ A^p_i(t_i), i\in l\}, l=\{l, 2,..., s\})$.. Model of consumers software agents $A^p(t_i)$ is connected with the model of consumers *system* $Spm(t_i)$. Model of consumers software agents $A^p(t_i)$ has a set of output signals $Wp^3(t_i)$, which come to the input of Supra software agent $A^s(t_i)$ in the global network as well as to the model of electric station system $Spm(t_i)$. Model of consumers software agents $A^p(t_i)$ has a particular set of input signals $Wp(t_i)$ and $Wp^2(t_i)$, as well as influencing set of the set of Supra software agents $A^s(t_i)$.

Model of expert group Supra software agent $A^s$ in the promotional paper is an expert commission system. Goal of consumers $G^p$ in the promotional paper is marked as - $(G^p(t_i), G^p(t_i)= \{G^p_i (t_i), i\in l\}, 1=\{1, 2,..., s\})$. The goals of consumers are the power supply conditions defined by the consumers. Goals of expert commission $G^k$ in the promotional paper are marked as - $(G^k(t_i), G^k(t_i)= \{G^k i(t_i), i\in l\}, I=\{l, 2,..., s\})$. The goals of expert commission are the power supply conditions defined by the experts $(G^k(t_i)$ $G^k(t_i) = \{ G^k(t_i), i\in 1\}, I=\{l, 2,..., s\})$ Goal of consumers $G^p$ and goals of expert commission $G^k$ in the promotional paper are marked as a set of goals - $(G \{ G^p, G^k\})$. O - satisfactory factor, which defines acceptable condition of the systems. $O_w^i$ -the set of different correlations of systems outputs. D, B - systems with relations.

Logistic systems in the promotional paper are marked as set of systems $S \{ Su, St, Se, Sp, Sk\}$ and they are connected with the set of systems inputs $W \{Wu, Wt, We, Wp, Ws\}$, set of system outputs $W^1 \{Wu^1, Wt^1, We^1, Wp^1, Ws^1\}$, with the set models $Sm \{Sum, Stm, Sem, Spm, A^S\}$ with the set of software agents $A \{A^u, A^t, A^e, A^p\}$ and set of Supra software agents $A^s=\{ A^s_i , i\in 1 \}, 1=\{1, 2,..., n\}$.

Ratio $\xi$ is called an adequate data in the systems with relations $(W, O_w^i, i\in 1), (\Psi, O_\Psi^i, i\in l)$,if for alia, $\sigma,\sigma'\ \Theta$ *and* $w_1, w_2,... w_k\in W$ ir: $\xi\sigma(w_1),..., \sigma' w_k))=\xi\, \sigma'(w_1),..., \sigma'(w_k))$

*Adequate criterion.* Ratio $\xi$ for the systems $(W, O_w^i, i\in l), (\Psi,O_\Psi^i, i\in 1)$ is adequate only when the following corresponds to the fixed representation $\sigma$*:*

$$\Theta(\bar{W},\bar{\Psi}) = \Theta\{W,O_w^i, i\in 1,\sigma_k^{-1} (\xi),(\Psi,O_\Psi^i, i\in 1,\xi)\}.$$

Thus each system $(W, O_w^i\ i = \overline{1,k}$ in homomorphic system $(\Psi_w, O_\Psi^i, i=\overline{1,k})$ there are systems $(W, O_w^i, i=\in 1)$, improved with the ratio $\sigma_k^{-1} (\xi)$ homomorphic system with the relations $(\Psi_w, O_\Psi^\omega, \omega =\in \upsilon)$ improved with the ratio $\xi$,.

*Models of the managed process V* in the organisationally technical system, which is adequate to ratio $\xi$ from the defined systems with relations $(W,O_w^i, i\in 1,\sigma_k^{-1} (\xi)$, are called ere $\sigma\in\Theta$ homomorphic system with relations $(\Psi_w, O_\Psi^i,i=\in l, \xi)$.

*Models of management goals* Z in the organisationally technical system, which is adequate to ratio $\xi$, from the defined systems with relations $(D, O_D^i\ i\in l, \kappa^{-1}(\xi)$, are called $\rho\in\Gamma$ homomorphic system with relations $(\Psi_z, O_\Psi^i,i=\in l, \xi)$ .

*Models of management process criteria evaluation Vm* , which is adequate to ratio $\xi$, from the defined systems with relations $(B, O_B^i, i\in l, \upsilon_K^{-1}(\xi)$, are called $\upsilon\in\Phi$ homomorphic system with relations $(\Psi_B, O_\Psi^i, i\in l, \xi)$,where $Vm\cap W\neq\varnothing$.

*As models of Software agent $A^e$ behaviour* during the process *V* of management time with the given sets of goals Z and alternatives *L* , which will be adequate to the ratio $\xi$, are called the systems with the given relations $(A^{La}, O_{Aa}^i, i\in l, \Theta^1 (\xi)$ of crossing point $K^*=\Theta\cap\Gamma\cap\Phi$ homomorphic system with relations $(\Psi a, O_{\Psi a}^i, i\in l, \xi)$.

If set *W* contains empiric objects and relations $O_i$ for *W* is defined empirically, then the systems $(W, O_w^i, i\in l)$ is called a systems with *empiric relations.*

*H measuring scale* is called empiric homomorphic system $\Theta, K^*,\Phi,\Gamma$ with the relations: $(W, O_w^i, i\in l, \sigma^{-1}(\xi), (Z, O_z^i, i\in l, \rho^{-1}(\xi), (Vm, O_M^i, i\in l, \upsilon^{-1}(\xi), (A^L, O_{AL}^i , i\in l, \Theta^1(\xi))$

As *H* measuring numerical systems with relations: $(\Psi w^H, O_\Psi^i, i\in l,\xi), (\Psi_z, O_\Psi^i, i\in l,\xi), (\Psi_{Vm}^H, O_\Psi^i, i\in l,\xi), (\Psi_L, O_L^i\ i\in l,\xi)$ where $\Psi$ - is a set of natural numbers. $\Theta,\Gamma, \Phi,\sigma,\upsilon,\rho,\theta$ - homomorphises.

Supra software agent $A^s$ interaction with the structural parts of the model during the probleir solving is described in the second part.

*The second pan* is devoted to the investigation of the software agent $A^e$, $A^p$, Supra software agent $A^s$ interaction models with the priority of electric power consumers and data bases of the orders, with data bases of electric power producers and its feedstock suppliers. The interaction takes place in the following order: The necessary amount of electric power at the time *t* is predicted, Supra software agent with the help of software agent sets a supplier to the consumer, according to the profile of the consumer and supplier costs and distance between them. By the choice of suppliers group the transport logistic task of an optimal way searching is solved to renew the feedstock reserve of the station for the particular producers of electrical power. During the solving of the electric power supply and transport logistic tasks an expert group is used to ensure Supra software agent regulations changing and additional definition of the task regulations, if the regulations are changed cardinally.

The promotional work investigates the features of software agent $A^e_1$ , which realizes the procedure of electric power order forecasting in the nearest time interval $t_{i+1}$, by functional $Wpe(t_{i+1}) = a_p + b_P \ln t_i$ . The functional describes the monotone increasing dependence, decreasing with the absolute increments. The features of software agent $A^e_2$ , which realizes the procedure of electric power order forecasting in the nearest time interval by functional $Wpe(t_{i+I}) = a_p. T_i^k$ .The functional describes the monotone increasing dependence with absolute increment increasing *(b>l)* or decreasing *(0<b<l)* or monotone decreasing dependence *(b<0)*, ). $Wpe(t_{i+I}) = a_p b^t_{pi.}$

The features of software agent $A^e_3$ which realizes the procedure of electric power order forecasting in the nearest time interval by functional $Wpe(t_{i+I}) = a+b/t$. The functional describes the monotone decreasing *(b>0)* or increasing *(b<0)* dependence. Horizontal asymptote at the point $Wpe = a$. The features of software agent $A^e_4$ , which operation if defined with the functional $Wpe(tm). = l/(a+bt)$. The functional demonstrates the monotone increasing *(b<0)* or decreasing *(b<0)* dependence. Vertical asymptote at the point $Wpe = a/b$. The features of software agent $A^e_5$ which operation if defined with the functional $Wpe(t_{i+I}) = 1/(a+bt)$. The functional describes the monotone increasing dependence with absolute increment at decreasing (b>0) or increasing (b<0). Horizontal asymptote at the point $Wpe=l/b$. Vertical asymptote at the point $Wpe=a/b$. The features of software agent $A^e_6$ which realizes the procedure of electric power order forecasting in the nearest time interval by functional $Wpe(t_{i+I}) = ab/(b+t)$. The functional describes the monotone increasing dependence with saturation at the point $Wpe=a$.

If there are data of four time intervals $t_{i+I}$ , $t_{i+2}$, $t_{i+3}$ *un* $t_{i+4}$ then the forecasting procedure is done by Supra software agent$A^J$using functional: $Wpe(t_{i+4}) = \lambda \quad Wpe(t_{i+3}) + (l-\lambda) \quad Wpe(t_{i+2}) + (1-\lambda)^2 Wpe(t_{i+1})(l5)$ , where $Wpe(t_{i+3})$, $Wpe(t_{i+2})$, $Wpe(t_{i+1}))$ and consumption data for the previous periods. The forecasting value is searching using the values with the correspondent factors $\lambda$ and $(1 - \lambda)$. Weighting coefficient *X* is defined by the expert commission *Sk* following the market situation and other factors.

This part also investigates the full procedure of setting of electric power resources suppliers for the electric power producers as well as setting the electric power producers for the consumers in the global network. The solution of the both tasks is provided by software agents in the global network: there are m electric power supply orders and m electric power suppliers. There is known i supplier payments then j order ($r_{ij}$) it is necessary to set for the fulfilment of the task of electric power supply, to make the full payment minimal. $c_{ij}$= (1, if i candidate is assigned to fulfil the task of power supply, 0 - if it is not assigned), where i, j= 1, 2,... m. With the help of Supra software agent the following functional is realised:

$Z(c)=\{\sum\sum Rep_{ij}Cep_{ij} ;\ i= l,2,...,k, j= l,2,..,n\}; \{\sum Cep_{ij} =1, i= l,2,...,kj; \{\sum Cep_{ij} =1, j= l,2,...,m\}$. In details this method is described in 131 ]. The numerical examples of the improved algorithm are given in the 4th part.

In the work the improved method of electric power resources supply from power supplier to consumer is analyzed. There is given the flow capacity $l_{ij}$, distance between electric power supplier and consumer. It is necessary to define the shortest way from the supplier to consumer. The way is marked with the help of graph $Wt^g$ - The initial $Wt^s$ and gala points $Wt^1$ are marked. Numerical consequences $We_{ij}$ which are defined in the way sections $(Wt^{si}, Wt^{sj}) \in Wt^{sp}$, are called the flows of electric power supply, if the following restrictions are fulfilled:

$Z(w) = \{\sum Wt_{i\ j}\ ,\ _j \in Wt^{sp}\}-\{\sum Wt_{ki}\ ,\ k \in Wt^{-1(sp)}\}$; $Z(w)=a$. if $Wt^{si} = Wt^{s}$; $Z(w)= -a$, if a $Wt^{si}= Wt$; $Z(w)=0$, if $Wt^{si} \neq Wt^{s}, Wt^{1}$; $We_{ij} \leq Wt_{ij}$ for all $(Wt^{si}, Wt^{sj}) \in Wt^{sp}$ . Electric power supply could be calculated as follows: max $max\ a= \{\sum 2, Wt_{Si},\ _j \in Wt^{sp}\}=\{\sum Wt_{ki}\ ,\ _k \in Wt^{-1(i)}\}$. The maximal flow from s to t is similar to minimum cross section $(R_m \rightarrow R'_m)$, which separates $Wt^{g}$ from $Wt^{1}$ $\cdot$*Cross* section $R_0 \rightarrow R'_0$ separates $Wt^{\ s}$ from $Wt^{1}$ if $Wt^{\ s} \in R_0$ and $Wt^{1} \in R_0$. The volume of this cross section is from $Wt$ flow capacity sum initial peaks belong to $R_0$, but final - $R'_0$: the minimum cross section is when $min\ a(R_0 \rightarrow R'_0)= \sum_{(Wtsi\ Wtsj)} \in (R_0 \rightarrow R'_0)\ Wt_{ij}$. Software agents defines the minimum payment flow using the following functional relation: additionally way is defined.

The improved procedure of electric power resources supply to the power producers in the global. network.

Set of producers orders $Se^{1}$, having the duration $\tau^{s}_{i}(Se^{1}) = 1$ each, the number of means of $St^{s}_{i}$ , $Se^{1}_{i} < Se^{1}_{j}$ that means, the task $Se^{1}_{i}$ should be finished earlier than $Se^{1}_{j}$ fulfilment is started. $Se^{1}$ un katram $Se^{1} \in Se$ directive time $\tau\ (Se_1) \in Z^{+}$. It is necessary to develop an algorithm $St^{s}$ for the list of mean of transport with $Se^{s}$ tasks from $Se_1$, which satisfy the stated regulations and all directive times, i.e: $\tau\ (Se_1) + \tau^{S}_{i}\ (Se_1) \leq \tau\ (Se_1)...[\tau_{ij}]$ - matrix with the size $m$ x $n$, which elements $\tau_{ij} > 0$ are fulfilling time $(1 \leq j \leq n)$ of task $Se^{1}_{j}$ with transport $Se^{1}_{i}$ $(1 \leq i \leq m)$. It is accepted that $\tau_{ij} = \infty$, if $Se^{1}_{j}$ can not be fulfilled with $Se^{1}_{i}$ and for each $j$ there is at least one $i$, for which $\tau_{ij} = \infty$. In the case when all means of transport are identical $\tau_j$ marks the time of order $Se^{1}_{j}$ fulfilment with any mean of transport. The average fulfilled order number $N\ (Se^{1})$ at the interval $(0, \tau(Se^{1})]$, where $\tau(Se^{1})\ 1= \max_{1 \leq i \leq n} \{f_i\ (Se^{1})\}$ is the size of the list or the maximum

operation time, will be:

$$N(S) = \frac{1}{\omega(s)} \int_0^{\omega(s)} N(\tau)dt$$

where N($\tau$)- number of unrealized deliveries at the time moment $\tau$.

<u>*The third part*</u> is devoted to the developed procedures and algorithms, co-ordination of the software agent with Supra software agent, with electric power consumers, expert commissions, resources suppliers (suppliers of electric power producers), producers, into transportation involved systems.

*Procedure of expert group management goals defining with the help of software agent set* $A^{s}$.

l.part. The expert group management goal definition; l.step. Asking for management goal $Z_i$ , definition; 2.step. Input goal $Z_i$; definition (text not longer than gs symbols); 2.part. Objects sets $B$ representation; 3.step. Asking for set$B$; 4.step. Input $Z_i \in Z$; 5.step. Test $Z_i \in Z_0$; If yes go to 8.step; If no go to 6.steo; 6.step. Inform $Z_i$ in not accepted; 7.step. Define $i=i-l$. 8.step. If set $B$ is input, then go to 9. step; If no then define $i=i+l$ and go to 4.step; 3.part Representation of set $W$; 9.step. Asking for set $W$; l0.step. Input $w_i \in W$; 1l.step. Test $w_i \in W_0$; If yes goto W.step; If no goto 12. step; 12. step. Inform $wi$ is not found; 13.step. Define $j=j-1$; 14.step. If $W$ is input, go to 15.step; If no, define $j=j+l$ and go to l0.step; 15.step. The end of the algorithm operation.

*Procedure of feedstock suppliers assignment for electric power producers, taking into account priority of consumers by Pseudo Kenig method with the help of software agent set* $A^{u}$.

l.step. Matrix *Sum* model transformation (in the case of multicriterial task criteria transformation is necessary); 2.step. Extraction of zero-containing column; 3.step. Test if i is equal zero, if yes - step 4, if nostep5;4.step. The end-the optimal delivery is obtained; 5.step. Test if zero-containing columns are not extracted, if yes step 7, if no step 6; 6,step. Development of the equivalent matrix, which contains not extracted zero columns. 5 step; 7.step. Zero marking; 8. step. Test if the marked zero is in the row containing zero? If yes step 10, if no step 9; 9. step. Zero circuits development and transformation of zero. To step 2; l0.step. Extraction of marked zero and removing zero-columns. Step ll. The end of the algorithm operation.

*The method of Supra software agent interaction with electric power consumers and software agents $A^s$ in the global network.* It suggests the algorithm of Supra software co-operation with other software agents, which allow to get solution of multicriterial tasks in twenty-four hours regime.

l.step. Consumer *(Sp),* applying computer with connection *(Spr)* starts to develop an order for electric power, using information function (procedure) $f_{SpSpr}$. If an answer is obtained from the server (proposal) the consumer can go to the following step. If the answer is not obtained then the solving of the task does not take place. 2.step. Server *(Srs)* starts to get answer from data base *(Srd),* using function (procedure) $f_{SrsSrd}$. 3.step. Server *(Srs)* starts to send solutions of the clients tasks (proposals) to server *(Srp ),* using function (procedure) $f_{SrpSrs}$; 4. step. Server *(Srp)stms* to send solutions of the clients tasks to Supra software agent $A^s$ which analyses the results *(Z)* and suggests to the consumer the best solution, using function $f_{Srp\ As}$.

<u>*Tiie fourth part*</u> states the practical results of the developed methods, it provides with the characteristics of the task of software agents electric power supply modelling in the Baltic region. A practical application of the developed methods in the case of electric power suppliers (producers) breakdown is considered.

The choice of characteristic features of electric power supply profile with the help of software agents for Latvian consumers is considered. There is an example of practical application of the developed methods for the tasks of suppliers choice, profile choice, expert committee forming and electric power resources delivery.

The task of schedules making for the systems of energy resources transport is stated as well.Jn the conditions of electric power market liberalization in the Baltic region the task of electric power supply delay is considered. Electric power supply delay $Sp_1$ to consumer is considered during the current year m month j day k interval. Necessary state $v_3$ power case is analyzed for electric power supply k to consumer at the time moment $t_a$ - Possibility $(v \neq v_3)$ of searching of suppliers free power of other states k is iconsidered. The task is solved in two steps.

1 .step. The quantity of electric power, which will be necessary in the nearest time period, for this consumer is forecasted.

2.step. In the situation of n-1 factor setting software agents algorithms with the method described in the 2nd part, which has been obtained modifying the method described in literature [56] a variant of the task solution is found by the x best variant criterion, where n-k (k - producers number from the order).

The <u>*Conclusions*</u> contain conclusions and summary of the main results and characteristics of the practical importance of the work:

Analysing the situation and development tendencies of electric power supply and transport systems of software agents modelling the following results have been obtained: The basis of the problem of multicriterial electric power supply is given; The necessity of the development of electric supply management goal, management process and model of Supra agent operation are proved; The task of a consecutive modelling of electric power supply goal achievement is considered; The task of electric supply process modelling is analysed taking into account the goals of management and possibilities of software agents.

The following results have been obtained analysing the applied methods and their mathematical structures; Features of models for different electric power supply topologies at the decomposing way are developed and investigated; Static characteristics and models of an object for static structures are elaborated; An algorithm of Supra software agent interaction with other software agents is worked out; A modelling methodology of multicriterial evaluation with a co-ordination of the process of complicated tasks solving is elaborated

Modelling the software agent of the electric power supply and transport in the global network the following results have been obtained: The methodology of power suppliers delivery to the power consumers with the help of software agents is elaborated. Procedures of making schedules of electric power feedstock delivery for software agents are developed. Procedures of expert-groups forming are developed. Methodology of electric power consumption prognosis is elaborated. Procedures of adaptation are elaborated.

The following results have been obtained with the experimental testing of software agents modelling methodology: for the task of electric power supply in the Baltic region; for the task of electric power supply redistribution according to a profile chosen by the consumers of the power at the demonopolized market, using prognosis; for the task of the choice of electric power delivery route; for the task of expert commission forming in the cases of complicated problems solving.

The obtained experimental results totally prove the theoretical and practical conclusions stated in the promotional paper. Procedures of software agents application for the evaluation of power consumers multicriterial requirements, that allow making practical evaluation of the consumers profile variants taking into account special features of the consumer needs and market situation, are developed.

A method of expert group forming with the help of software agent is developed and experimentally tested. The task of the expert group is to ensure an evaluation of electric power suppliers. A method which allows algorithmic making of an expert group structure selection, taking into account qualification and experience of the experts in a particular field. A procedure of software agent application for making of a schedule for electric power feedstock supply transport is developed and experimentally tested.

The algorithms, elaborated in the course of the promotional work, could be applied for the solving of a large group of electric power supply and transport logistic tasks. The elaborated methods could be applied in the solving of the following power supply and transport logistic tasks: Conception of electric networks optimization at the free electric power market; Optimization of electric networks reliability at the free electric power market; Development of multiagent systems in the distribution of electric energy; Using of the distributed power resources in Europe; Choice of the optimal mathematical structures for the solution of electric power supply and transport logistic tasks. Application of the developed methods allows improving effectiveness and validity of the electric power supply and transporting logistic tasks solving. Method of Supra agent interaction with consumers and software agents is developed and experimentally proved.

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