

KNOWLEDGE BASE FORMATION FOR AUTOMATION OF DISPATCH CONTROL OVER POWER SYSTEMS OF THE MINING AND METALLURGICAL COMPLEX

Purpose. The research is aimed at developing and introducing methods of knowledge extraction concerning online control over power systems under emergency modes and building smart complexes of automatizing managerial decision making based on incorporated ontological knowledge bases.

Methodology. The authors use the calculated planned experiment method applied to building sensitivity matrices of controlled parameters of power systems in sensor points to controlled factors and introduction of sensitivity coefficients into knowledge bases.

Findings. The research suggests methods for obtaining and building a knowledgebase of professional ontologies for online control over power system modes. The problem of calculating sensitivity of controlled parameters to controlling actions is solved. Calculation results for the emergency mode enable building impact functions and determining sensitivity matrix coefficients. The smart system knowledgebase is built to provide decision support for dispatch control over power system modes under standard and emergency conditions. There are obtained sets of mode data used as knowledgebase components enabling efficient assessment of the emergency mode rate and its dispatch correction. Besides calculation parameters of intensity of controlling actions, the knowledgebase also comprises linguistic concepts, facts and rules of instructive dispatch materials. A knowledge base has been built on the basis of a subset of the linguistic corpus of concepts for the professional area of emergency response in the power system.

Originality. For the first time, there is suggested an approach to incorporating various linguistic knowledge forms represented by a single ontological model and numerical parameters of sensitivity of the power system mode to controlling actions into an integrated knowledgebase, which enables building effective smart systems of dispatch decision support and implementing them into the operating automatized dispatch control system.

Practical value. The ontological knowledgebase of online dispatch control is built that enables realizing a software complex of a decision support system aimed at automatizing online dispatch control over standard and emergency modes of power systems. Application of the suggested approach to building the knowledgebase and its use with online dispatch personnel's decision support enhance reliability and increase maximum accessible time of personnel's non-stop work by 1.5 years with absolute accident elimination, thus providing a significant economic effect.

Keywords: *emergency, dispatcher, ontology, decision support, thesaurus, power system*

Introduction. Nowadays, there arises a discrepancy between growing complexity of modern power systems and losses caused by accidents there, on the one hand, and existing constraints of using decision support systems (DSSs) for the operating dispatch personnel (ODP), on the other hand. Thus, there is a need for massive elaboration and stream-oriented implementation of the DSS into current automated dispatch control systems (ADCSs).

Yet, at present, the major problem of building DSSs is complexity of formalization and interpretation of their knowledge bases. Current practice of using industrial DSSs envisages their predominating individual design accompanied by high cost and time-consuming development. With this in mind, one should state that standardization of DSS production is required to automatize smart modes of power systems.

Thus, there is an urgent problem of extracting knowledge on operating control over power system modes in order to build ontological knowledge bases of dispatch smart complexes.

Literature review. Creation and replenishment of knowledge bases is an important stage of building and implementing a smart system. The research defines control objects – a power

system cluster and its functioning parameters, the ODP's data and experience, and regulatory documentation of power system dispatching – as a knowledge source of a professional field.

It is known that methods for acquiring knowledge can be communicative and textological, they form a separate trend in artificial intelligence studies – knowledge engineering dealing with the concept of knowledge management. Knowledge mining is the heart of knowledge management. Structuring of subject areas is becoming deeper and more complicated along with methods of knowledge extraction, this question being touched upon in numerous research studies.

Work [1] analyzes methods of knowledge control and reuse and provides classification of approaches to dealing with that at small and medium-scale businesses. It indicates that there are required innovative organizational structures of knowledge representation and use. Work [2] deals with specific features of applying knowledge control methods to various sectors and industries, systematizes methods and tools of knowledge control. It also admits that efficiency of businesses' investing into knowledge control systems is unsatisfactory.

Work [3] points out that application of professional knowledge has caused a new wave of digital transformation based on

artificial intelligence. Yet, 24 % of businesses do not have any projects of automatizing knowledge extraction and structuring. Work [4] deals with smart analysis of big data. Analysis reveals that in the continuously changing industrial environment and conditions of uncertainty, extraction and control of big data and knowledge face considerable challenges.

While extracting knowledge, it is important to standardize it on the basis of well formalized interpreted models. These models primarily include ontology formalisms. Work [5] accentuates importance of developing a set of ontologies to conform research for providing strategic decision support in power engineering. Within this framework, the notion of ontology engineering is detailed.

Work [6] considers an ontology model applied to weakly-formalized areas. It substantiates development of generalizing ontology models to be applied to decision support processes in weakly-formalized professional areas. Work [7] suggests an original mathematical model of preparing knowledge representation models to be used on the basis of a fractal approach. Formation of levels of the ontology knowledge space is given with the fractal approach applied to building DSSs. Work [8] presents approaches to applying ontology models to professional data search and extraction. There are formulated problems of data extraction based on algorithms of assessing data relevancy.

Extraction, structuring and application of knowledge from various professional areas are becoming more and more applicable to building smart DSSs. First of all, these areas include essential strategic industries – mining, metallurgy and power engineering.

Work [9] considers formation and application of accumulated knowledge about geology to building geoinformation and communication systems to train skilled engineers. Topicality of implementing information systems, accumulated data and knowledge at mining enterprises is focused on.

Work [10] is dedicated to systems of representing the knowledge used for controlling integrated power systems based on smart DSSs. There are developed methods for extracting knowledge on power grid modes. The authors suggest integration of the DSS into the hard- and software environment of the ADCS.

Work [11] investigates into application of calculation data on mineral mining and processing to reducing power consumption in the mining industry. It is pointed out that effective power distribution among mining company consumers is of great importance. Results of the suggested technological schemes and analytical calculations reveal regularities of power distribution. This provides the basis for building a knowledgebase to automatize control over technological processes in mining production.

The analysis reveals that development, implementation and application of smart DSSs to controlling large power engineering systems are of particular significance. This fact is conditioned by a specific role and responsibility of power systems for ensuring the state's power security.

Mention must be made of significant contribution of the following national and foreign scholars into smart software theory and methods in dispatch control of power systems: Vagin V.N., Venikov V.A., Voronenko D.I., Voropay N.I., Gelovani V.A., Yermeev A.P., Yermeev L.P., Koshcheev L.A., Kupersmidt Yu. Ya., Larin O.M., Lebedev L.S., Lyubarskiy Yu. Ya., Massel L.V., Morzhin Yu.I., Pospelov D.A., Samoylov V.D., Stogniy B.S., Terelyanskiy P.V., Khoroshevskiy V.F., Chachko A.G., Badami M., Daniel J., Ragsdale C.T., Yao F.S.

Smart grids [12] and smart DSSs can be called generally accepted and effective solutions of problems of increasing efficiency of dispatch control in power systems and reducing damages caused by accidents [13]. The analysis of studies and practical works in the given professional fields demonstrates considerable success and significant results. On the other hand, there is an urgent necessity to develop innovative approaches and methods of digital application of professional knowledge to controlling complicated industrial complexes. Constant complication of the control structure, growing costs

of equipment and marked increase in damages due to accidents make the situation even worse.

Unsolved aspects of the problem. Analysis reveals that many studies focus on aspects of knowledge engineering and methods for their formation. Yet, knowledge extraction in various professional environments and in the field of controlling power system modes in particular, requires application of specific methods, which have not been studied properly.

There are considerable difficulties in direct applicability of recommendations to extraction of knowledge on power grid modes. Many research studies are of a general character and cannot be treated as direct recommendations on extracting knowledge in power engineering. Many research works deal with formalization of ontologies and their application to data extraction. Yet, the used models do not take account of professional terminology and slang which are an essential part of professional lexicon. Also, little attention is paid to methods for extracting knowledge about parameters of power system modes and their conformity with a certain context within a single model of knowledgebase ontologies.

The analysis conducted indicates that the methods for extracting and formalizing knowledge about parameters of power grid modes within a single ontology model are insufficiently developed and covered. Besides, there are no specific recommendations on incorporating knowledge about controlling mode actions and instructive dispatch materials.

Thus, there is a topical problem of knowledge extraction from data on a certain accident in the power system, its combination with instructive dispatch materials and formalization in the single ontology model.

Purpose. The analysis conducted and the problem specified make it possible to formulate the research aim in the following way: development, implementation and generalization of knowledge about controlling the emergency mode of a certain responsible cluster of the power system grid.

To choose the experiment object, analysis of the most loaded areas of the Ukrainian power system is required.

The Central Power System (CPS) is scarce in power. The general load of the regional power unit makes 4264 MW with capacity of 2358 MW. The analysis reveals degradation of voltage in 110-330 kV grids of the CPS with reduced power generation by Kyiv thermal power plants (TPPs). The maximum power shortage exceeds 2500 MW. The reason for this is insufficient grid capacity of the CPS (in particular, AT-3 of the ChNPP) and resulting additional load of Kyiv TPP-5, TPP-6 and Trypil'ska TPP.

Power grids of DTEK are extremely responsible. The greatest loads of transformer links are observed at substation mains that supply consumers from Dnipro (Substation Dniprov'ska-330, Prydeniprov'ska TPP), Kryvyi Rih (Substations Hirnycha-330, Pivden'na-330, Kryvorizka-330, Pershotravneva-330 and Rudna-330) and Nikopol (Substation Nikopolska-330).

Power cross-flows in autotransformers of the mentioned substations exceed accessible loads in emergency modes caused by switching off OL 330kV L-234 (Pavlohrad'ska-330 – TPP Substation), OL 330kV L-236 (Pavlohrad'ska -330 – Substation Belitskaya-330) and emergency switching off AT-1, AT-2 at Substation Ferrosplavna-330.

It is evident that Dnipropetrovsk oblast of Ukraine is noted for industry-intensive regions, powerful mining and metallurgical enterprises. This fact causes increased responsibility of the power system and growing potential damages because of operating managerial personnel's false decisions and actions.

Thus, we find it reasonable to consider the CPS of Ukraine and DTEK power grids basic research objects.

To achieve the research aim, the following tasks are set:

- choice and reduction of a fragment of responsible power grid scheme;
- analysis and choice of a characteristic emergency mode of the power system grid;
- choice of sensor points and controlled parameters of the emergency mode;

- choice of control points and controlling parameters of emergency mode correction;
- planning and conduction of the factorial calculation experiment to assess emergency mode parameters;
- generalization of obtained results and creation of regressions of dependencies of controlled parameters on controlling actions to correct the emergency mode;
- building of sensitivity matrices as parameters of values and directions of dispatch corrections of the emergency mode;
- formalization and combination of extracted mode correcting knowledge with dispatch instructive materials;
- visualization of obtained calculation mode characteristics;

- brief assessment of operating and economic effects of using knowledge about the emergency mode of the power system.

Methods. Problems of existing and prospective power grid modes in Ukrainian power systems are analyzed. The analysis reveals that from the viewpoint of complexity of dispatch control over emergencies and accidents, loaded power grids of DTEK are of particular interest [14]. The analysis results enable choosing a characteristic fragment of the power grid with an evident severe problem. A fragment of the power grid is given in Fig. 1.

Conditions of the calculation experiment are as follows [14]:

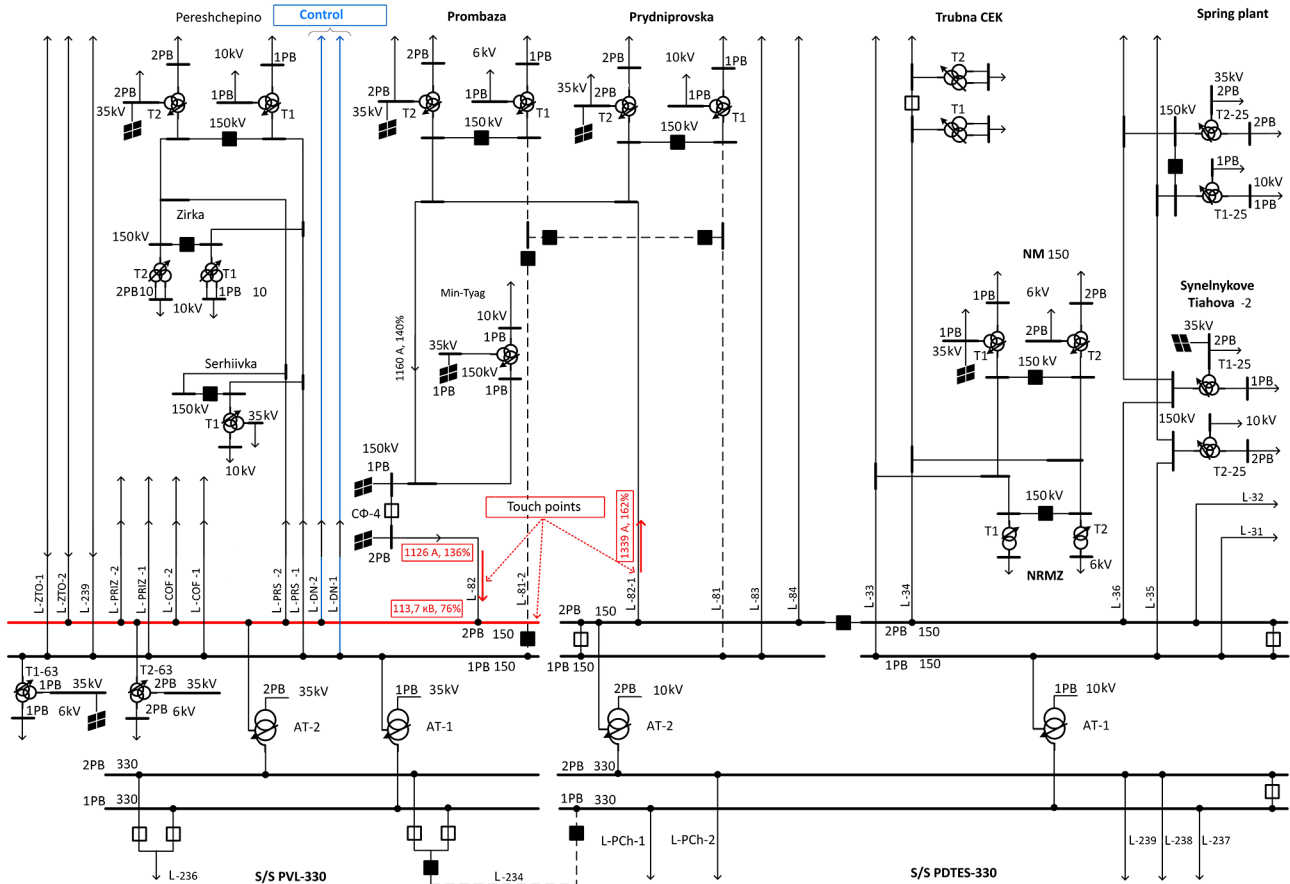


Fig. 1. The fragment of the JSC DTEK power grids. On the basis of power consumption data of Dnipropetrovsk oblast, there are detected problematic grid points in terms of voltage and loads of lines and transformers for standard and emergency modes, chosen sensor points, controlled parameters and those of the calculation experiment, which are presented in Table 1

Table 1

Parameters of controlling the calculated emergency mode

Sensor point	Controlled parameter	Nominal parameters	Emergency parameters
BS 150 kV of Substation Pavlohradaska-330	Reduced voltage at bus-bars – 2 BS 150 kV	Nominal voltage – 150 kV	Emergency voltage of BS 150 kV of Substation Pavlohradaska-330 is reduced to 113.7 kV (76 % of the nominal one)
1, 2 BS 330 kV Substation Pavlohradaska-330	Reduced voltage at BS 330 kV	Nominal voltage – 330 kV	Emergency voltage of BS 330 kV of Substation Pavlohradaska-330 is reduced to 237.4 kV (72 % of the nominal one)
OL 150 kV L-82-1 (ACSR-300) Substation Pavlohradaska-330 of PDTTP	Current overload	Current carrying capacity for air cables is $I_{cur} = 710$ A Working current in the standard mode is 278 A	Emergency current – 1339 A (162 % overload)
OL 150 kV L-82-1 (ACSR-300) Substation Pavlohradaska-330 of PDTTP	Current overload	Current carrying capacity for air cables is $I_{cur} = 710$ A Working current in the standard mode is 278 A	Emergency current – 1126 A (136 % overload)

Influence matrix for selected sensor points

Controlling factors	U (BS 150 kV of Substation Pavlohradska-330), kV	I (L-82-1), A	I (L-82-2), A
P (L-DN-1)	-0.2788P ₂₅ + 121.600	8.317P ₂₅ + 1093.2847	8.2212P ₂₅ + 883.6200
Q (L-DN-1)	-0.2077Q ₂₅ + 115.535	5.3824Q ₂₅ + 1279.7342	5.4382Q ₂₅ + 1065.3945
P (L-DN-2)	-0.2386P ₂₉ + 116.955	7.2892P ₂₉ + 1218.7947	7.1659P ₂₉ + 1008.6350
Q (L-DN-2)	-0.1815Q ₂₉ + 114.295	4.7302Q ₂₉ + 1319.2247	4.7637Q ₂₉ + 1105.5450

Table 3

Sensitivity matrix of mode parameters of sensor points in the power grid scheme

Control	Factor	$\frac{\partial U_{BS150\text{ kV}}}{\partial X}$	$\frac{\partial I_{L-81-1}}{\partial X}$	$\frac{\partial I_{L-81-2}}{\partial X}$
L-DN-1	P ₂₅	-0.2788	8.317	8.2212
	Q ₂₅	-0.2077	5.3824	5.4382
L-DN-2	P ₂₉	-0.2386	7.2892	7.1659
	Q ₂₉	-0.1815	4.7302	4.7637

- scheduled shutdown for maintenance of OL-150 kV (L-81) Substation Pavlohradska-330 – PDTTP-330 (Prydniprovska TPP);

- emergency shutdown of OL-330 kV (L-234) of Substation Pavlohradska-330 – PDTTP-330;

- the emergency mode is characterized by reduced voltage at BS 150kV of Substation Pavlohradska-330 and current overload OL-150 kV (L-82) of Substation Pavlohradska-330 – PDTTP-330;

- the seasonal scheme of the grid is summer.

The equivalent fragment of the grid scheme provides a calculation scheme of substitution.

The lines with the largest currents under the standard mode L-DN-1 (200 A) and L-DN-2 (135 A) are chosen to be one of possible options of controlling parameters in sensor points. The load in these lines is formed by substations of Dniprovsk-mine, Svitlo-Shakhtaria mine, Substation Zakhidno-Donbaska.

Knowledge about controlling the emergency mode includes values of parametric actions in selected grid points. The values of controlling actions should be proportionate to the expected correction effect. So, the problem of determining sensitivity of controlled parameters to controlling actions is solved. In particular, the following sensitivity criteria are used

$$Q_v = \frac{\partial V_i}{\partial Q_j} \quad \text{and} \quad P_v = \frac{\partial V_i}{\partial P_j}$$

Sensitivity factors reflecting a set of controlling actions to a set of controlled parameters form a sensitivity matrix. In a first approximation, the sensitivity matrix elements can be expressed by factors of linear regression. Thus, the sensitivity matrix can be taken as knowledge of the expert controlling system about values and directions of controlling actions in terms of a certain power grid in a certain emergency. On this basis, dispatch controlling actions can be automatized.

Determination of reciprocal sensitivity factors requires massive calculations of the power system modes. To realize these calculations, current software packages are compared and RastrWin3 [15] is selected.

The factors and intervals of variation are determined and matrices of experiment planning are formed. A system of non-linear equations of nodal voltage in the form of power balance is used as a computational mathematical model of the power grid. The equations are presented separately for active and reactive values of power and conductivity. Modules and phases of voltage in nodes are unknown as is shown below.

The calculation is performed by the Newton method. The emergency mode calculations result in the data for building kernels and factors of the sensitivity matrix. In a first approximation, linear regressions are built. The nodes L-DN-1-150 kV and L-DN-2-150 kV are used as application nodes of controlling actions in the scheme. The influence matrix looks like it is shown in Table 2. The calculation factors of the sensitivity matrix are given in Table 3.

The sensitivity matrix is a matrix of regression derivatives of the influence matrix

$$\frac{\partial U}{\partial P_{25}}, \frac{\partial U}{\partial Q_{25}}, \frac{\partial U}{\partial P_{29}}, \frac{\partial U}{\partial Q_{29}}, \frac{\partial I}{\partial P_{25}}, \frac{\partial I}{\partial Q_{25}}, \frac{\partial I}{\partial P_{29}}, \frac{\partial I}{\partial Q_{29}}$$

The sensitivity matrix data enable building first-order approximated linearized regressions of intensities of controlling actions on parameters of sensor points shown in Fig. 2 (for Substation Pavlohradska-330 kV).

There are the following linearized dependencies in the Fig. 1 – impact of the active power of the controlling factor L-DN-2; 2 – impact of reactive power of the controlling factor L-DN-1; 3 – impact of active power of the controlling factor L-DN-2; 4 – impact of reactive power of the controlling factor L-DN-2.

While realizing controlling actions, distribution of controlled parameters along radii radiating from the point with fixed voltage is of particular interest. Data on these parameters can be used as knowledge about controlling the emergency mode of the power grid. Diagrams of voltage along characteristic radii of the grid are presented in Fig. 3.

The database is built on the calculation data of dynamics of intensities of controlling actions and diagrams along responsible radii of the power grid. The standard format XML is selected to store the data. The file fragment of voltage diagrams accepted as knowledge about controlling the mode and aimed at inputting into the knowledgebase is given in the listing below

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<data-set xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<record>
<P>2.00</P>
<P_unit>MBr</P_unit>
<node>3</node>
<U>116.02</U>
<U_unit>kB</U_unit>
</record>
<record>
<P>4.00</P>
<P_unit>MBr</P_unit>
<node>3</node>
<U>115.59</U>
<U_unit>kB</U_unit>
</record>
<!-- ..... -->
</data-set>
```

The file fragment of influence matrix factors for sensor points is shown in the following listing

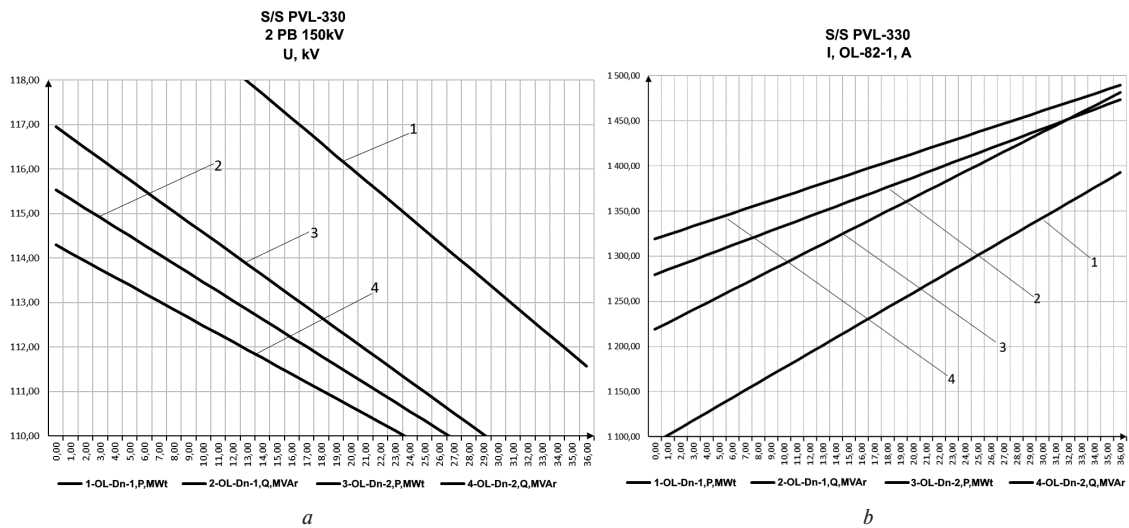


Fig. 2. Intensity dynamics of controlling actions:
 a – the sensor point and the parameter – 2 BS 150 kV (U, kV); b – the sensor point and the parameter – L-82-1 (I, A)

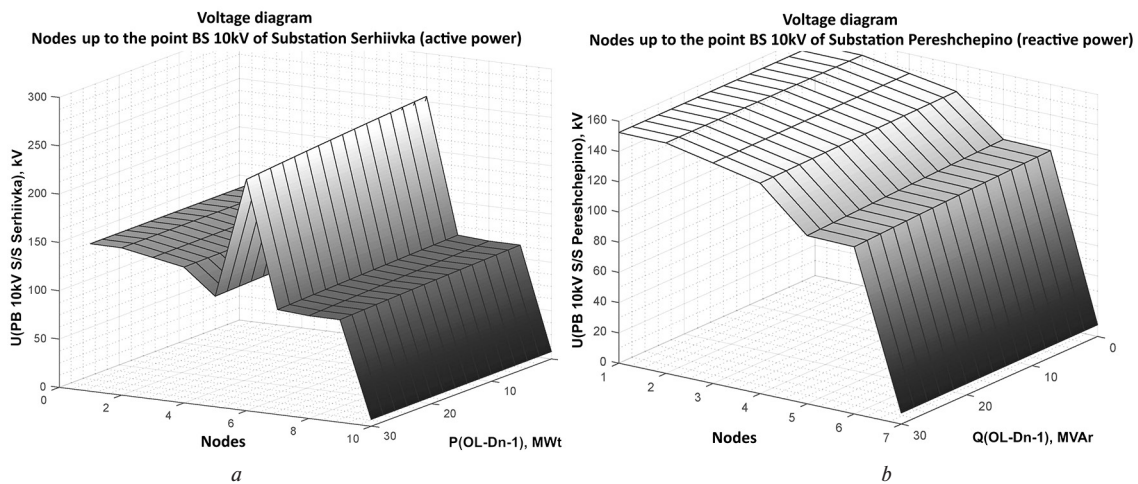


Fig 3. Diagrams of voltage along responsible radii of the grid with changed controlling factors:
 a – up to the point BS 10kV of Substation Serhiivka (active power); b – up to the point BS 10 kV of Substation Pereshchepino (reactive power)

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<data-set xmlns:xsi="http://www.w3.org/2001/XMLSchema-in-
stance">
<parameter U = "U (BS 150 kV Substation Pavlogradska-
ya-330)">
<factor name = "P (L-DN-1)">
<b0>121.600</b0>
<b>-0.2788</b>
</factor>
</parameter>
<!-- ..... -->
</data-set>
```

The obtained files of mode data as components of the knowledgebase enable assessing seriousness of the emergency mode and its dispatch correction.

Along with calculation parameters of intensities of controlling actions, the knowledgebase consists of linguistic concepts, facts and rules of instructive dispatch materials. To build the knowledgebase, there are also selected instructions treated as a source of reliable knowledge of operating control over the emergency mode.

The given linguistic corpus provides the basis for building a thesaurus of professional concepts of the knowledgebase. There are professional terms and abbreviations singled out

among the linguistic concepts. The file fragment of the professional thesaurus is given below

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<data-set xmlns:xsi="http://www.w3.org/2001/XMLSchema-in-
stance">
<thesaurus>
<base_info>
<base_date>22.08.2020</base_date>
<base_context>instruction_12</base_context>
<base_type>concept</base_type>
<base_admin>admin</base_admin>
</base_info>
<concept id = "0001">
<type>action</type>
<context_type>instruction_12</context_type>
<concept_date>22.08.2020</concept_date>
<content>трансформатор</content>
</concept>
<!-- ..... -->
</thesaurus>
</data-set>
```

In a similar way, a storage of professional terms, abbreviations, facts and products is built.

Generalization of the obtained results of extracting knowledge about control over the power grid emergency mode enables building a knowledgebase of the smart system to provide decision support of dispatch control of power system modes in standard and emergency situations.

The research results in developing a software DSS for the dispatch personnel.

The DSS allows elaborating normative-instructive materials of dispatch control resulted from levels of professional ontologies of the knowledgebase and recommendations in the form of controlling actions, their values and change directions obtained from the calculation sensitivity matrices. Besides, there is an opportunity to use the knowledgebase as a database with selected data to be analyzed.

The developed software is based on incorporation of unified professional ontologies, this implying its use as smart software DSS within the automatized control systems of power complexes. It can be applied to automatizing decision-making processes during switching over, controlling voltage and power flows in power systems under standard and emergency modes. So, this should solve the problem of implementing the DSS into the hard- and software tools of the current ADCS of power systems. To adjust the developed DSS to the ADCS blocks, one should consider the structure and specific features both of the DSS and data transmission paths of the operating informational controlling complex (OICC).

The following structural and technical solutions are characteristic of most operating DSSs:

- the decision-making block is structurally separated from the knowledgebase and its functioning algorithms do not change with the knowledgebase replenishment;
- the form of knowledge presentation is fixed and there is no option of changing it depending on the professional field;
- the knowledgebase is a storage and its structure does not affect decision making and generation of recommendations for the decision maker.

These facts cause constraints of functional potentials of the DSS, reduction of professional fields applied; increased costs of development and adjustment to new requirements of industrial complexes, deteriorated quality of recommendations and operating control.

To eliminate the mentioned defects, a new structure of arranging the DSS kernel is developed. It is noted for a block of hard- and software triggers, a block of transactions of metarules, a metarule transaction interpreter, an ontology block and a new scheme of arranging the knowledgebase and an inference block. The new structure of the DSS kernel is based on combining a logical input mechanism in the form of metaknowledge and the ontology knowledgebase, simultaneous incorporation and evolutionary compatibility of various knowledge representation forms into a single ontology knowledgebase, connection of inference and switching triggers associated with controlled objects' events.

Switching and the inference process directly conform with the state of controlled objects. With that, the dependency of the method of the DSS functioning on specificity of the professional field is eliminated. Fig. 4 shows a generalized structural scheme of the developed DSS with new arrangement of the knowledgebase kernel.

Considering arrangement of the DSS kernel, its possible points of incorporation into data transmission paths of the ADCS are determined. For this, a variety of architectural solutions of the ADCS is taken account of.

The resulted combination ADCS + DSS enables solution of problems of automatizing decision making and control over power system modes through creating a complex comprising a block of data collection and telecontrol connected with the OICC block of informational subsystems that interacts with the block of data exchange network through the data collec-

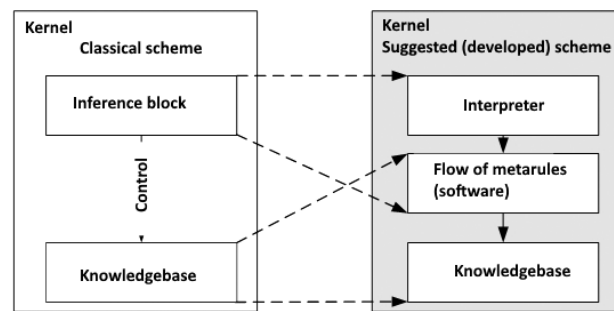


Fig. 4. Generalized structural scheme of the knowledgebase kernel

tion and reflection. The latter is connected to the block of operating and retrospective data storage, the block of software support of telecontrol systems and DSS blocks associated with them.

The inference problem in the DSS conditions is solved through realizing an algorithm based on a trigger model of the DSS's conditions and is expressed by a path on the graph of transition between transaction aggregation blocks.

The rule of starting a trigger is set. The trigger receives an input signal from the external environment and checks it. If the signal corresponds to the activation code, the trigger is activated and generates an input code relevant to the condition.

After activating the current condition, an internal code is generated. If the code corresponds to the switching condition, transaction starts running. Operations of setting up transactions are strictly sequenced. The transaction tact is activity of a current condition. Only one condition can be active in each functioning tact. To model parallelism of software processes, a single trigger is used to activate several parallel networks of conditions.

Thus, the software DSS complex to automatize operating dispatch control under standard and emergency modes of the power system is implemented. Testing of the software demonstrates increased reliability of the ODP's activity.

The DSS's economic efficiency in emergency modes of the controlled object is assessed. Assessment metrics are developed and quality of DSS software is assessed.

The increased reliability effect of the ODP from using the DSS for eliminating emergency breakdowns of the power system mode is measured. The practical increment of the ODP's reliability in accident elimination makes 37.2 %. Application of the DSS provides an increment of the maximum accessible time of non-stop functioning of the ODP of 1.5 years with guaranteed accident elimination.

Conclusions.

1. The responsible scheme of the power grid is chosen, the scheme loads are reduced in terms of section points, the basis voltage point is chosen.
2. The emergency mode characterized by considerable deviations of controlled parameters is selected.
3. Sensor grid points and controlled parameters of the emergency mode are selected.
4. Points of application of controlling actions for active and reactive power are selected for dispatch correction of the emergency mode.
5. The massive factorial calculation experiment is planned and conducted.
6. The obtained experiment results enable calculation of impacts of controlling actions on the parameters of sensor points.
7. The sensitivity matrices of the power grid modes to controlling actions of dispatch corrections of the emergency mode are built.
8. The sensitivity matrix factors are formalized and incorporated into a single knowledgebase together with dispatch instructive materials.

9. The operating and economic effect from using knowledge about controlling the emergency mode of the power system is assessed.

The obtained results allow concluding that extraction of sensitivity factors and their use as knowledge about dispatch correction of the emergency mode is quite efficient.

Expansion of methods for extracting knowledge about the control object's modes and their integration into current knowledge bases of linguistic concepts form the content of our further research.

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Формування бази знань для автоматизації диспетчерського керування енергосистемами гірничо-металургійного комплексу

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Мета. Розробка та впровадження методів добування знань про оперативне управління режимами енергосистем в аварійних ситуаціях і побудови інтелектуальних комплексів автоматизації прийняття управлінських рішень, заснованих на інкорпорованих онтологічних базах знань.

Методика. Використано підхід розрахункового планованого експерименту для побудови матриць чутливості контрольованих параметрів режиму енергосистеми в сенсорних точках до керування факторів і впровадження коефіцієнтів чутливості в базах знань.

Результати. У роботі запропонована методика отримання й побудови бази знань професійних онтологій оперативного управління режимами енергосистем. Розв'язана задача обчислення чутливості контрольованих параметрів до керуючих впливів. За результатами розрахунків аварійного режиму побудовані функції впливу й визначені коефіцієнти матриць чутливості. Побудована база знань інтелектуальної системи для забезпечення підтримки рішень диспетчерського управління режимами енергосистеми в нормальних і аварійних ситуаціях. Отримані набори режимних даних, використовуваних як компоненти бази знань, що дозволяє здійснювати оперативну оцінку складності аварійного режиму, а також його диспетчерську корекцію. Разом із розрахунковими параметрами інтенсивності керуючих впливів базу знань становлять також лінгвістичні концепти, факти та правила інструктивних диспетчерських матеріалів. Побудована база знань на основі підмножини лінгвістичного корпусу концептів професійної області ліквідації аварійних ситуацій в енергосистемі.

Наукова новизна. Уперше запропоновано підхід до інкорпорації в одній базі знань різних лінгвістичних форм знань, представлених єдиною онтологічною моделлю, і чисельних параметрів чутливості режиму енергосистеми до керуючих впливів, що дозволяє будувати ефективні інтелектуальні системи підтримки диспетчерських рішень і впроваджувати їх в інфраструктуру діючої автоматизованої системи диспетчерського керування.

Практична значимість. Полягає в побудові онтологічної бази знань оперативного диспетчерського управління, що дає можливість реалізувати програмний комплекс системи підтримки рішень для автоматизації диспетчерського оперативного керування нормальними та аварійними режимами енергосистеми. Застосування запропонованого підходу до побудови бази знань і її використання при підтримці рішень оперативного диспетчерського персоналу забезпечує підвищення надійності та збільшення гранично допустимого часу безперервної роботи диспетчерського персоналу на 1,5 роки при безумовній ліквідації аварії, що дає значний економічний ефект.

Ключові слова: аварійна ситуація, диспетчер, онтологія, підтримка рішень, тезаурус, енергосистема

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