Principles of building a system for automating the activities of a process engineer based on an ontological approach within the framework of the Industry 4.0 concept

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***Abstract*—In this article, an approach to the continuous development of automation of the processes of creating, developing and applying standards based on the OSTIS Technology is proposed. Examples of these processes due to the involvement of end-users of the system using the tools and mechanisms of the OSTIS Technology are considered. Examples of further formalization of standards within the framework of the proposed approach are given.**

***Keywords*—automation of manufacturing processes, information service, ontological production model, Industry 4.0, ontology, knowledge base, OSTIS Technology**

I. Introduction

The implementation of the Industry 4.0 concept at production facilities is accompanied by the development of a single ontological production model, which is the core of the complex information service of the enterprise. At the first stage of developing such an enterprise model, it is necessary to nest data on the lower level of production, namely on the manufacturing process and equipment. As the source of this data, P&ID-schemes of production can serve. Thus, the formalization of the ISA 5.1 [1] standard is necessary to work with P&ID-schemes, which are widely used in control systems together with the ISA 88 [2] standard and allow describing the lower level of production in full. At the same time, it is also necessary to consider the approach of formalization of the subject domain based on the ISO 15926 [3], [4] standard, which describes the integration of data on the life cycle of processing enterprises into a single ontological storage. New users will be added: an automation engineer and a master, who implement the new capability of the intelligent search together with the developed model. For the current user – the operator of the manufacturing process – the implementation of the mechanism for obtaining intelligent information that covers both particular and common issues of the manufacturing process, equipment, components and automated control systems becomes relevant. In this article, attention is paid to the continuous development of a system of complex information services by employees of a formulating enterprise on the example of the JSC "Savushkin product" using an Open semantic technology for intelligent systems. This article uses and develops the results represented in [5], [6].

II. Briefly about ISA-5.1

This standard describes the rules for drawing up functional schemes for the automation of manufacturing processes. Such schemes allow the graphical representation of the production technology and equipment as well as define the rules for identifying equipment and measuring and automation tools for design and service purposes. Figure 1 shows an example of a functional scheme.

The functional scheme shows: the coagulator itself (the unit), the lines (the machine) and the valves (the control device). Different colors indicate the purpose of the lines (red – washing, blue – mixture, green – whey, black – product). This fragment allows getting an insight into which devices are used and how they are connected.

III. Ontologies in production

The ISA-88 article described how to use the knowledge base on the basis of the OSTIS [7] ontologies to train the operator with complex concepts, search for objects according to ISA-88 and their interrelations. The need for knowledge bases for production is not restricted to the above. Among the most complex problems that can be solved using knowledge bases on the basis of ontologies, there are:

- decision support in unforeseen situations as well as start-ups and ends;

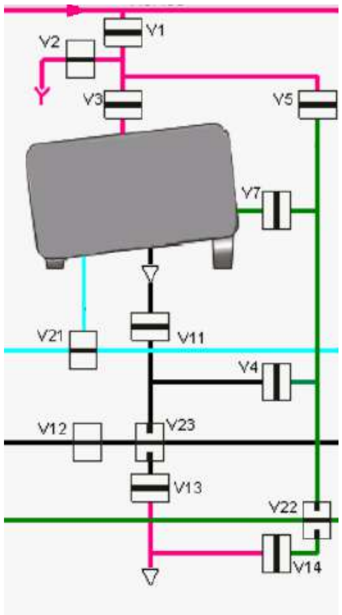

Figure 1. A functional scheme of the coagulator

- the determination of equipment failures and their causes;
- integration between systems with different data representation and functions of engineering problems.

Batch production is characterized by a high complexity of control systems – they should take into account the possibility of flexible development of various products on the same equipment. At the same time, it should be possible to develop the technology without making changes to the control program. This is why the ISA-88 standard was developed, which includes the best automation practices for this type of production. However, in addition to the fact that the creation of such systems requires a good understanding of the standard, the success of implementation depends on taking into account the capabilities of the equipment and the requirements of the technology. According to the standard, the automation of manufacturing operations and the running of equipment for their implementation are two interrelated but separate processes. This relation and engineering processes are shown in the ISA-88 standard in figure 2.

The choice of the role of the equipment in ISA-88 depends on what function it will perform in the production process. Thus, the technological procedural elements should be known. The equipment is designed and at the same time used to perform manufacturing operations. The knowledge base should be created to assist the technologist when generating a recipe (using PFC), that is, to provide the necessary choice of equipment, answering such questions:

- "What equipment can perform such a list of classes of procedural elements?";

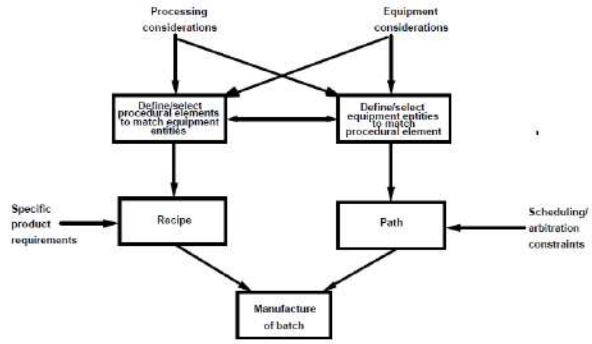

Figure 2. Relations and engineering processes of automation of manufacturing operations and the running of equipment

- "What methods can be available for developing a product?";
- "Which method is the most optimal from the point of view of the selected criterion?".

Similarly, the definition of procedural elements as the building blocks of recipes depends on the decomposition and capabilities of the equipment. For example, if the procedural element "preparation of a mixture of A, B, C" is created, then only the equipment that can automatically prepare a mixture from at least three components is required to use it. If a procedural element "batch up a component" is created, then the equipment that does not have automatic batching up functionality can perform manual operations or use the equipment sequentially. On the other hand, dividing into very small procedural elements can lead to lengthy and impractical recipes. A limiting case is the usage of a procedural element as a reference to basic functions, such as "unseat the valve", which does not correspond to the standard at all.

There are even more complex problems of creating an equipment hierarchy. Here are some examples. Let us consider the conditional P&ID-scheme of developing a food product. Though it is simplified, it is quite difficult to perform the decomposition of equipment. The criteria for creating the ISA-88 equipment hierarchy are considered below. There is one significant problem. It is logical to refer the valves that are located on the positions of the inlet to the tanks and the offset from the tanks to the tank as control modules, forming a unit. But what to do with the valves that are on the charging lines (V8, V7, V16, V23)? It cannot be said that V8 belongs to the unit with Tank 1, since it is controlled when loading any tank in the line. Then it might be logical to refer it to the process cell. But will it be convenient from the point of view of creating a recipe? In fact, there must be some kind of procedural control that coordinates the operation of these valves. Then it is necessary to create an equipment module that will combine the valves that participate in the same path (fig. 3).

What equipment should be referred to such paths? The

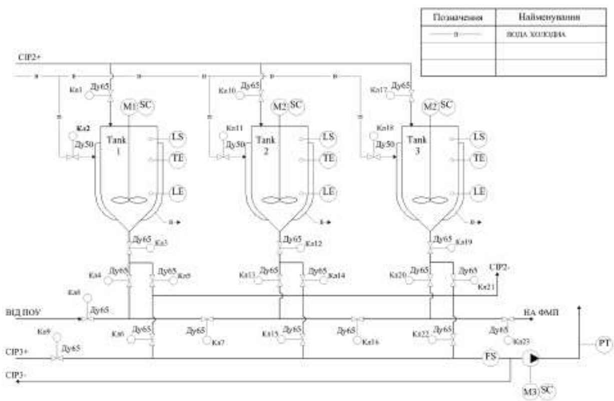

Figure 3. An example of an equipment module

answer to this question lies in the technological scheme itself. Even on such a simple scheme, it is easy to get confused about which of the control modules should be referred to which equipment and how to combine them into an equipment module or a unit. The analysis of many sources shows that the same problems lead to completely different solutions that can either fully comply with the standard or have certain differences from it. An engineer that develops a control system must take into account all technological connectivities and equipment specifications. This part is not part of the ISA-88 standard, it concerns more the field of equipment design.

Even the presence of a database can simplify and speed up the search process. But the best option would be the availability of a knowledge base about all production equipment. The developer of the control system could get the necessary information by asking the system various questions:

- to find the equipment that is involved in the charging/output/washing line of the tank;
- to find equipment at the crossing of the paths;
- to find the list of equipment for the specified set of conditions (for example, it is connected with Tank 1 and requires manual action).

One of the labor-intensive problems is the implementation of a Master Recipe for a certain process cell by the General or Site Recipe. The system implemented on the basis of the OSTIS Technology also significantly simplifies such a problem for the technologist.

Thus, in addition to the problem of creating a knowledge base for a system with ISA-88, there is a problem of creating a knowledge base of all production equipment. In the last 30 years, the issue of obtaining knowledge from industrial information, which the manufacture is aware of, has been actively addressed. One of the main and promising directions is the usage of ontological production models, which is confirmed by the development of international standards in this area.

The development and standardization of ontological systems was carried out by international organizations for standardization, such as ISO, IEEE, OMG, W3C and others. Some ontological structures have been developed, which, though have not been approved by international standards, have become standards de facto. They can be divided into several groups:

- ontological systems, models, languages and their parts for general and industrial purposes:
  - the ontological model of the hierarchical structure of production in the processing industry [3];
  - the technical dictionary [8];
  - a series of standards for the development of a top-level ontology [9], which is currently under development;
  - formal semantic models of global production networks [10];
  - a semantic approach for the computer-interpretable exchange of information related to production processes [11];
- general and specialized top-level ontologies:
  - MOF (Meta Object Facility) is a meta-object environment for model engineering [12];
  - BFO (Basic Formal Ontology) is a basic formal ontology, common for biomedicine [13];
  - ZEO (Zachman Enterprise Ontology) is the ontology of an enterprise for the description of its architecture;
  - DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) is a descriptive general-purpose ontology for linguistic and cognitive engineering, quite popular in the field of ontological engineering;
  - GFO (General Formal Ontology) [14];
  - SUMO (Suggested Upper Marged Ontology) is the proposed unified top-level ontology, a source document for a workgroup of IEEE employees from the fields of engineering, philosophy and computer science [15], [16];
- semantic Web: it includes all standards and rules for semantic processing of documents on the Internet, such as the Resource Description Framework (RDF) as well as its RDFS and RDF extensions; the Web Ontology Language OWL; the SPARQL query language; the Rule Interchange Format and a number of formats for saving RDF N-Triples, Turtle, RDF / XML, N-Quads, Notation 3 triples.

The basic (fundamental) ontology or a top-level ontology is a general ontology that is applied to various subject domains. It defines basic concepts, such as objects, relations, events, processes, etc. The most famous fundamental ontologies are listed above. BFO and DOLCE are the most commonly used in the development of engineering ontologies. These two ontologies are formal and provide a logical theory for representing common assumptions. When forming an ontology of a subject domain based on one of the specified top-level ontologies, it can be more easily integrated with other subject ontologies. The problem is that there are quite a lot of top-level ontologies and giving preference to one of them becomes a certain search problem that requires a lot of time and effort. In addition, some of them do not have open access and are also badly compatible with the semantic Web.

The ISO 15926 ontology [17] is considered separately. This standard is not only a top-level ontology but also a thesaurus of the processing industry, including the structure of retention and access to the ontological base. Standardization is implemented by using well-defined templates for technical and operational information, that include classes and relations of the invariant and temporal parts of the ontology. The advantages of this ontological model are the typification and identification of data located on the Internet; information is stored in RDF-triplets, access to triplet storages occurs using the SPARQL query language, etc. When creating this model, the developers tried to cover all aspects of requests that may arise in manufacturing. As a result, the model has hundreds of nested classes and attributes at the lower levels of production (description of technological equipment), most of which may not be used in practice. The temporal part increases the complexity of the model several times.

Thus, the ontology according to the ISO 15926 standard is most suitable for the specified problem. However, it should be noted that, taking into account the need for a common equipment and ISA-88 knowledge base, it was decided to implement the equipment knowledge base using OSTIS. In addition, there are restrictions in the ISO 15926 standard that are not present in the OSTIS Technology.

IV. About ISA-88 and the criteria for the decomposition of technology and equipment

As already noted above, when creating the equipment hierarchy, an engineer faces a number of problems related to the need to take into account many factors. The larger the technological scheme in terms of the amount of equipment and the more connectivities it has, the more difficult it is to allocate logically related equipment in it. The difficulty also lies in the fact that the standards do not and cannot have all the criteria for allocation. Therefore, this problem should be considered both from the point of view of the limitations and functional requirements of the ISA-88 standard and from the point of view of experience from best practices. Both can be put into the knowledge base [18].

To begin with, let us highlight clear restrictions, using which it is quite easy to determine whether the equipment belongs to one of the hierarchy levels. According to ISA-88, these levels are:

1) the level of the process cells;
2) the level of units;
3) the level of equipment modules;
4) the level of control modules.

According to the standard, “a process cell is a logical grouping of equipment that includes the equipment required for production of one or more batches”. Exactly from the point of view of batch production, the process cell is distinguished. If the entire batch of semi-products is not developed in the framework of the process cell, the equipment that is needed for this should be included. Within one process cell, there may be several connected elements of equipment capable of producing several batches in parallel. If they cannot be separated, they remain within the same process cell. In addition, the process cell must contain at least one unit.

The allocation of units is a little less obvious. There are several clear criteria:

1) one unit cannot contain several batches;
2) each technological action occurs immediately (simultaneously) with all the material within one unit;
3) the technological operation begins and ends within the same unit.

Even less obvious conditions for choosing and combining are the statements:

- the unit can include all the equipment and control modules involved in technological actions;
- the unit can work with part of the batch.

All equipment, except for the control module, can implement procedural control. That is, from the point of view of technology, it contains some procedural elements that perform a technological operation, separating itself from the method of its implementation. There are operational directives, for example, “heat to the required temperature”, as opposed to the directives “open valve 1” or “if TE101 > 23, close the valve”. The last control directive refers to equipment, not technology, and is called “basic control” in the standard. This is the main criterion that determines the principle of allocating the control module – this equipment does not contain procedural control. In addition, this part of the hierarchy enables real interaction with concrete equipment, while the other levels are more role groups. Therefore, the level of control modules cannot be omitted in the hierarchy.

The concept of procedural control per se is also not clear enough. It is difficult to formalize it as well as to define in an ontology. However, according to the standard, there are certain features inherent in it, in contrast to the basic control, such as visibility at the recipe level, a characteristic state engine, abstraction from equipment, etc.

As for the control module, there is one indirect but very useful property as a selection criterion – this type of equipment is shown in the P&ID-schemes as instrumentation. According to the standard, the control module can include other control modules, creating combined control modules.

The most uncertain criteria relate to the equipment module. Firstly, the presence of them is not necessary. Secondly, this group of equipment consists of an equipment module or other control modules, which may contain procedural control but at the same time does not meet the criteria for either a unit or even more so for a process cell. The presence of the word "may" is confusing, since the equipment module without procedural control has the same meaning as the control module. If we accept this as a strong restriction, then it is required to introduce criteria that determine how the equipment module differs from the unit. It is possible to use the criteria for belonging to the unit, and thus the most important selection criteria are as follows:

- it performs procedural control;
- it does not work with the entire batch or part of the batch at the same time.

Thus, if the technological action should take place in the flow, for example, heating/cooling in heat exchangers or batching up in the flow but within the process cell, then it should be related to the equipment module. If it is necessary to batch up the component into various units, then the batching up system is an equipment module, since it cannot belong to any unit.

All objects of the equipment hierarchy, except for the lower level, are always a group of control modules that are combined to perform a specific role. The design engineer of the control system should understand how a group of equipment can perform these roles jointly. To do this, the knowledge base that supports this should contain all the necessary knowledge about the lower level of equipment. As mentioned above, this can be done by transferring the knowledge from the P&ID-schemes to it, which are always present in the project documentation for batch production.

V. Analysis of existing approaches to the formalization of standards in the field of formulating

As already described above, there are solutions for formalizing the ISO 15926 standard based on OWL [19]. However, they have a number of disadvantages inherent in OWL-based systems [20]:

1) The need to describe metadata, in either case, leads to duplication of information. Each document should be created in two copies: marked up one for reading by humans and one for a computer;
2) An important issue is the openness and validity of the metadata used – such systems are more fragile to threats from the outside;
3) The multiformat representation of fragments of knowledge complicates the process of their processing;
4) The lack of tools for viewing and using the information provided by media resources.

The usage of the OSTIS Technology allows getting a solution without these disadvantages and with the following advantages:

1) The variety of types of knowledge stored in the system knowledge base;
2) The variety of types of questions that the system can answer;
3) The presence of a built-in intelligent help system for end-users, which provides a substantial improvement in the efficiency of the system operation;
4) The possibility of using the terminology of various natural languages;
5) Availability of comprehensive facilities for visualization of knowledge, including different styles of visualization of fragments of semantic space and convenient means of navigation through this semantic space;
6) The ability to easily extend the knowledge and skills of the system by the hands of developers;
7) System integrability with other related systems including ones built on the basis of the OSTIS Technology [21];
8) Availability of means of self-diagnosis, self-analysis and self-improvement [22].

The OSTIS Technology (an Open semantic technology for the component design of compatible computer systems controlled by knowledge) is based on a unified version of encoding and representation of information based on semantic networks with a basic set-theoretic interpretation called an SC-code and with various formats of representation of information based on it (SCg, SCs, SCn) [23]. The systems that are the target of formulating enterprises are developed on the OSTIS Technology platform.

VI. Ontological model of the ISA-5.1 standard on OSTIS

A. Content of the KB

The knowledge base according to the ISA-5.1 standard [24] describes the system of notations and symbols of tools, processes and functions, that is, it describes the lower level of control of manufacturing processes and includes a specification of the notation conventions of a toolkit.

The ISA-5.1 standard solves the problem of unification of notations and descriptions of the toolkit of manufacturing processes of various types of production including batch one. The system of notations allows describing the process and its components of production of any industry. Characters and notations are used as auxiliary means for conceptualization as well as brief and concrete means of connection between instances of various classes of the toolkit.

The knowledge base on the ground of the OSTIS Technology is based on a hierarchy of subject domains and their corresponding ontologies, which allows, on the one hand, localizing the area of solving certain problems and, on the other hand, describing the interrelations between different concepts and ensuring the inheritance of their features. Within the framework of the considered knowledge base, the hierarchy of subject domains was formed in such a way that the concepts studied in a particular domain correspond to entities that have some common function (purpose). At the top level of the hierarchy, the following set of subject domains that correspond to the ISA-5.1 standard is highlighted (fig. 4).

Figure 4. A hierarchy of subject domains of the ISA-5.1 standard

The subject domain of hardware and software, which is the key sc-element of the corresponding section of the knowledge base, which in turn is decomposed into particular subsections, describes general concepts and features that are characteristic of instruments, devices and other systems. From the point of view of the subject domain, these features are nonmaximal classes of objects of research or the relations under investigation. The degree of detail of the description of the concept depends on the problems, for the solution of which it is planned to use this information.

Each subject domain has a corresponding structural specification, which includes a list of concepts studied within this domain. Figure 5 shows the structural specification of the root subject domain – the Subject domain of hardware and software.

B. Hierarchy of subject domains

Let us consider in more detail the particular subject domains. Each type of hardware or software contained in the standard is described at the level of a certain subject domain (fig. 6).

The hierarchy at this stage is not comprehensive, it is assumed that the knowledge base will be further developed. To achieve this goal, it is necessary to increase the number of connectivities between the concepts, thereby eliminating the incompleteness and improperness of the knowledge described by the standard. Let us consider the structural specification of some of the above subject domains. They describe not only the roles of the concepts

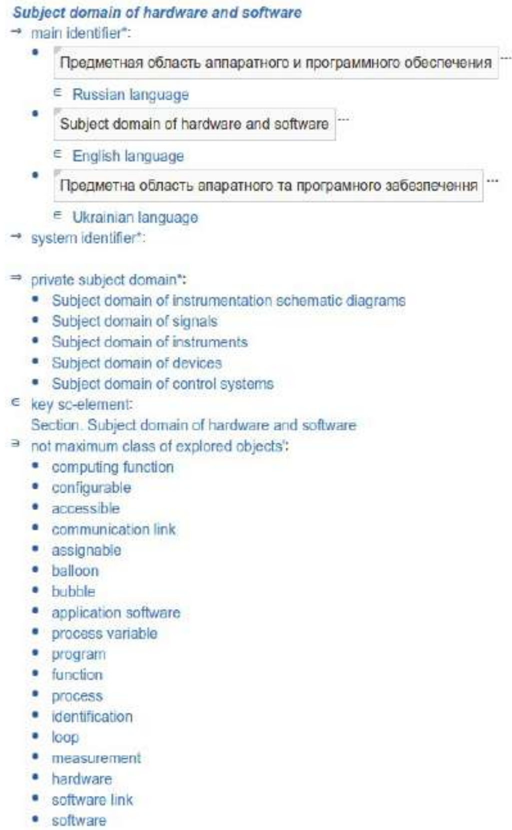

Figure 5. The specification of the subject domain of hardware and software

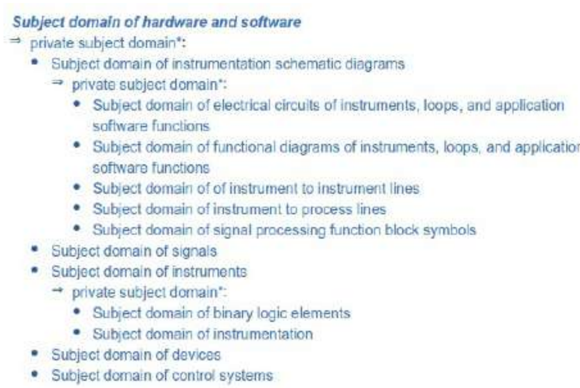

Figure 6. A hierarchy of subject domains of the ISA-5.1 knowledge base

that build up them but also the relations with other subject domains.

C. Description of a particular concept, its relations with others.

The subject domain allows obtaining only that knowledge that can and could be common to the concepts contained in it. Thus, the more information about the object there is, the more clear it is to the user. Let us consider the principles of describing a specific concept and its relations with others using the example of the following system of concepts: a discrete tool (SD of instruments) $\longrightarrow$ a device (SD of devices) $\longrightarrow$ hardware (SD of hardware and software) $\longrightarrow$ a controller (SD of devices).

The specification of the concept "device" is shown in figure 7.

Figure 7. The absolute "device"

A device is the maximum class of objects of research in the Subject domain of devices. It is worth considering that the knowledge base includes the internationalization of systems of concepts necessary for the end-user of this system. In this case, an employee of a manufacturing enterprise or an engineering company may be the end-user. It is possible to map back not only the concepts of the same subject domain but also the interrelations of the subject domains themselves.

Let us consider the concept "discrete instrument" from the subject domain of instruments, which is also a subclass of the device class. It has the main identifier in three languages – Russian, English and Ukrainian – and a single system one. The "instrument" class includes entities of the "discrete instrument" class. The definition of this concept is given in a hypertext format with links to the used concepts described in the knowledge base. Different understanding of this term is incorrect, and it is inadvisable to divide it into synonyms or homonyms (fig. 8).

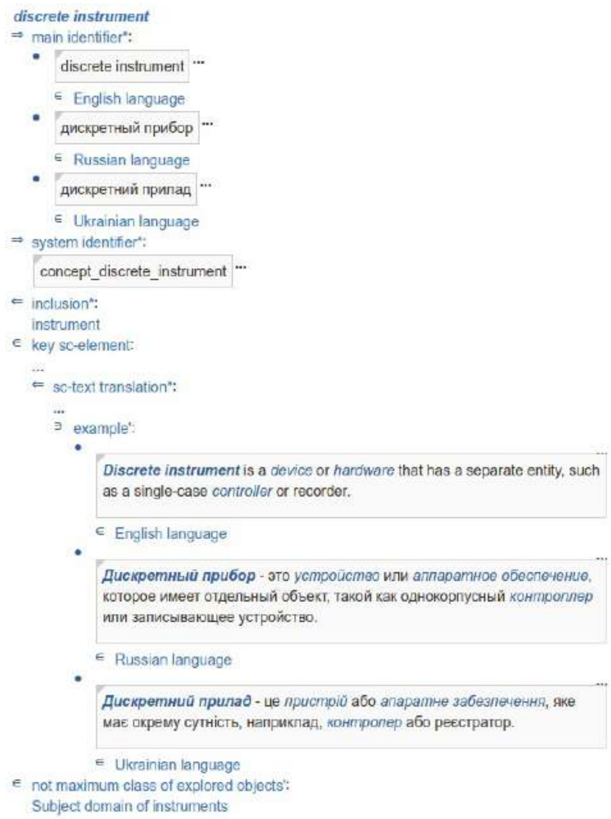

Figure 8. The absolute "discrete instrument"

Similarly, it is possible to investigate other connected concepts, for example, "software" (fig. 9), "controller" (fig. 10), etc.

Figure 9. The absolute "software"

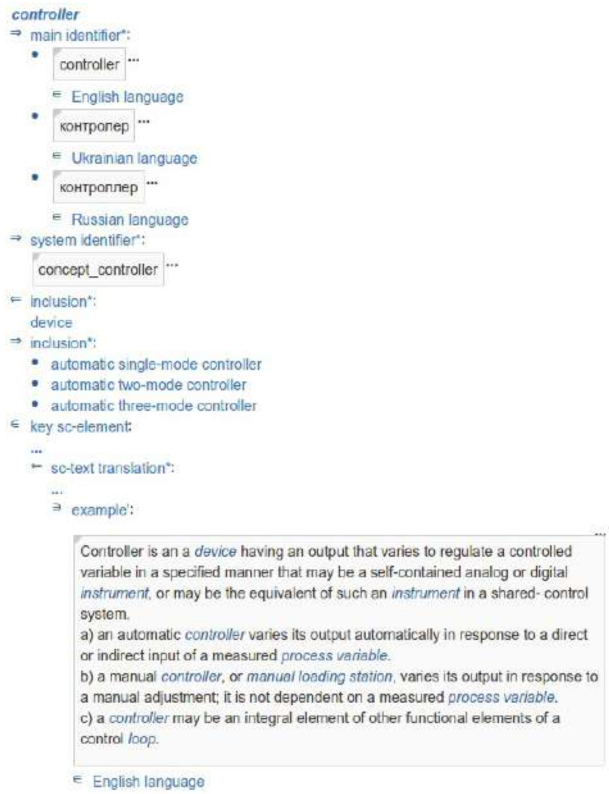

Figure 10. The absolute “controller”

An outstanding feature of the knowledge base according to the ISA-5.1 standard is the usage of logical formulas that allow describing logical conformities that characterize the features of the entities being described. Within the framework of the knowledge base according to the ISA-5.1 standard, the most interesting from this point of view are the features of binary logical elements, which are central to the subject domain of instruments and are the basis of hardware and software of formulating. To write logical statements about binary logical elements, the SCL – a sublanguage of the SC-code – was used. As an example, let us consider a qualified logical element OR, equal to “n” (fig. 11).

The KB fragment describes this concept and includes an identifier both in text format and in the form of an illustration accepted by the ISA-5.1 standard, a definition, inclusion of a binary logical element in a more general concept as well as a logical formula that describes the principle of operation of this device.

A logical formula is a structure that contains sc-variables. An atomic formula is a logical formula that does not contain logical connectives. By default, the existential quantifier is superposed on sc-variables within the framework of the atomic logical formula. Thus, the formula below means that there is a _gate entity that is a qualified logical element OR, equal to “n”, which has a set of inputs of power “n”, and if at least one input has

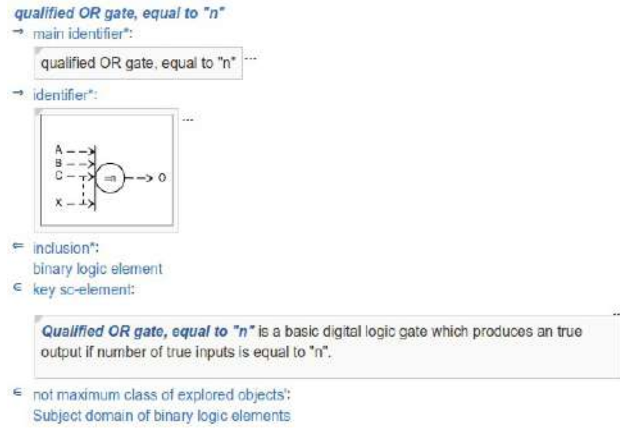

Figure 11. The semantic neighborhood of the “qualified logical element OR, equal to n” concept

the logical value “true”, then the output of the formula is also “true” (fig. 12).

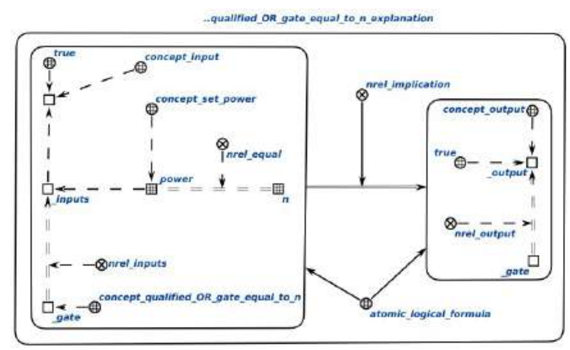

Figure 12. The logical formula of the “qualified logical element OR, equal to n” concept

VII. Examples of the operation of the system of formulating with the display of information in natural languages

The easiest way to convey information, including knowledge, to the user is a welcomed and understandable interface of the used system. For this purpose, a component was introduced into the interface of the system of formulating, which allows displaying structures written in the SC-code representation forms into natural languages familiar to the user.

As examples of the usage of the component, answers to questions in any language can serve. Figures 13 and 14 show a variant of the decomposition of the section of the SD of formulating enterprises in the SCn-editor and in natural language, respectively.

Any of the standard questions to the ostis-system can be a question in a natural language. Figures 15 and 16 show the answer to the question about the set, to which the specified concept belongs, and about the roles that it performs in this set.

Figure 13. The decomposition of the section of the SD of formulating enterprises in SCn

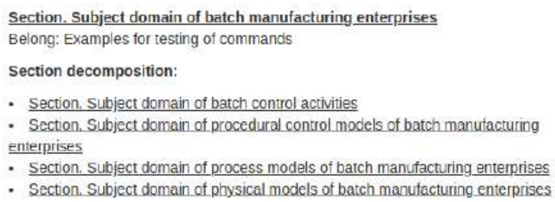

Figure 14. The decomposition of the section of the SD of formulating enterprises in the Russian language

Using this component, it is possible to represent the semantic neighborhoods of absolute and relative concepts in the knowledge base of the system. Knowledge about the concepts "unit" and "equipment phase" can have the representation forms shown in figures 17, 18 and 19, 20, respectively.

The main problem of developing this component is the need to expand the dictionary of key concepts used to make connections between fragments of neighborhoods of other concepts. The possibility of internationalization of systems of concepts causes the problem of storing and representing the used means of detecting and making such connections.

VIII. Conclusion

In this article, the principles of building a system for automating the activities of a process engineer based on an ontological approach within the framework of the Industry 4.0 concept are highlighted. The developed system includes a number of international industrial standards that are used to build a subject domain, and therefore the system can easily be combined with other ontological subject domains of the enterprise (MOM, ERP, etc.). The complex of tools and methods for developing ontology bases on the ground of the OSTIS Technology is a powerful tool for designing systems of formulating enterprises. The technology used, with many of its principles and the resulting advantages over other technologies, allows developing and multiplying the potential of existing formulating systems. At present, the

Figure 15. The answer to the question "What sets is control module an element of and what roles does it take on there?" in SCn

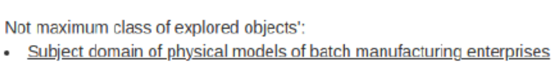

Figure 16. The answer to the question "What sets is control module an element of and what roles does it take on there?" in the Russian language

Figure 17. The absolute "unit" in SCn

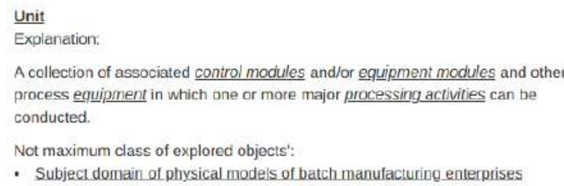

Figure 18. The absolute "unit" in the Russian language

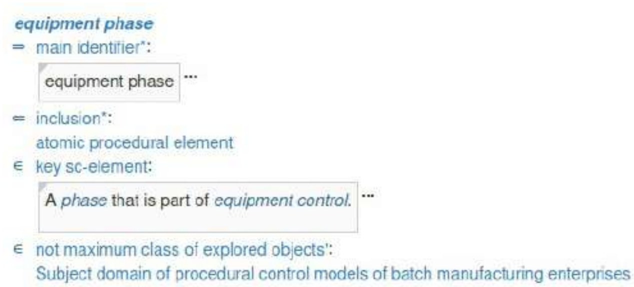

Figure 19. The absolute "equipment phase" in SCn

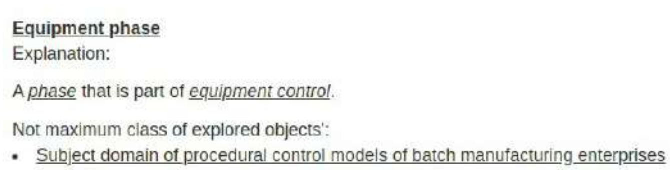

Figure 20. The absolute "equipment phase" in the English language

complex of information management systems is not just a knowledge base with a subsystem for processing user, including engineering, issues – it also has the right to be considered as a major help system of a process engineer. The general purpose of the following problems of system design is to achieve the maximum level of integration of the accumulated knowledge.

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REFERENCES

[1] (2021) ISA5.1 standard. [Online]. Available: https://www.isa.org/standards-and-publications/isa-standards/isa-standards-committees/isa5-1/

[2] (2021) S88 standard. [Online]. Available: https://www.isa.org/isa88/

[3] (2019) ISO 15926 Industrial automation systems and integration - Integration of life-cycle data for process plants including oil and gas production facilities. [Online]. Available: https://www.iso.org/standard/68200.html

[4] (2008) GOST P/ISO 15926-1-2008 integration of life cycle data for processing enterprises, including oil and gas production enterprises. [Online]. Available: https://docs.cntd.ru/document/1200076803

[5] Taberko, V. V., Ivanyuk, D. S., Kasyanik, V. V., Golovko, V. A., Rusetsky, K. V., Shunkevich, D. V., Grakova, N. V., "Principy postroeniya sistemy kompleksnogo informacionnogo obsluzhivaniya sotrudnikov predpriyatiya recepturnogo proizvodstva," *Open semantic technologies for intelligent systems*, pp. 215–224, 2019.

[6] Taberko, V. V., Ivanyuk, D. S., Shunkevich, D. V., Pupena, A. N., "Principy povysheniya effektivnosti processov razrabotki i ispol'zovaniya standartov v ramkah koncepcii industry 4.0," *Open semantic technologies for intelligent systems*, pp. 167–174, 2020.

[7] Golenkov, V. V., Gulyakina, N. A., "Semanticheskaya tekhnologiya komponentnogo proektirovaniya sistem, upravlyaemyh znaniyami," *Open semantic technologies for intelligent systems*, pp. 42–50, 2015.

[8] (2016) GOST/ISO 22745-1-2016 – open technical dictionaries and their application to the main data. [Online]. Available: https://docs.cntd.ru/document/1200143361

[9] (2021) ISO/IEC 21838-1:2021 industrial automation systems and integration – open technical dictionaries and their application to master data. [Online]. Available: https://www.iso.org/standard/71954.html

[10] (2018) ISO 20534: 2018 Industrial automation systems and integration - Formal semantic models for the configuration of global production networks. [Online]. Available: https://www.iso.org/standard/68274.html

[11] (2004) ISO 18629 PSL: Industrial automation systems and integration (ISO TC 184 SC4) - Process Specification Language. [Online]. Available: https://www.iso.org/obp/ui/fr/#iso:std:iso:18629:-1:ed-1:en

[12] (2016) Meta Object Facility (MOF). [Online]. Available: https://www.omg.org/spec/MOF/

[13] Arp, R., Smith, B., and Spear, A.D., "Building ontologies with basic formal ontology," p. 220, august 2015. [Online]. Available: http://basic-formal-ontology.org/

[14] (2013) Zachman Enterprise Ontology (ZEO), Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), General Formal Ontology (GFO). [Online]. Available: https://www.zachman.com/resources/zblog/item/the-zachman-framework-requires-zero-documentation

[15] Niles, I., Pease, A., "Towards a standard upper ontology systems," pp. 2–9, 2001.

[16] Niles, I. and Pease, A., "Linking lexicons and ontologies: Mapping wordnet to the suggested upper merged ontology," pp. 2–6, 2003.

[17] A. Jordan, M. Selway, W. Mayer, G. Grossmann, and M. Stumptner, "An ontological core for conformance checking in the engineering life-cycle," pp. 358–371, 2014. [Online]. Available: https://15926.org/topics/

[18] Knowledge base for the isa-88 standard. [Online]. Available: https://github.com/savushkin-r-d/s88-ostis

[19] (2021) ISO 15926 templates and the Semantic Web . [Online]. Available: https://www.omg.org/spec/MOF/

[20] Semantic web. [Online]. Available: https://semantic-web.com/

[21] Shunkevich, D. V., "Modeli i sredstva komponentnogo proektirovaniya mashin obrabotki znanij na osnove semanticheskih setej," *Open semantic technologies for intelligent systems*, pp. 272–274, 2017.

[22] Ims metasystem. [Online]. Available: http://ims.ostis.net

[23] Golenkov, V. V., Gulyakina, N. A., Davydenko, I. T., Shunkevich, D. V., "Semanticheskaya model' predstavleniya i obrabotki baz znanij," *Data analytics and management in data-intensive fields: a collection of scientific papers of the XIX International Conference. DAMDID*, 2017. [Online]. Available: https://libeldoc.bsuir.by/handle/123456789/295039

[24] Knowledge base for the isa-5.1 standard. [Online]. Available: https://github.com/savushkin-r-d/isa-5.1-ostis

Принципы построения системы автоматизации деятельности инженера-технолога на основе онтологического подхода в рамках концепции Industry 4.0

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В данной работе внимание уделено непрерывному развитию системы комплексного информационного обслуживания сотрудниками предприятия рецептурного производства на примере ОАО «Савушкин продукт» с использованием открытой семантической технологии проектирования интеллектуальных систем.

На примере стандартов ISA-88 и ISA-5.1 рассмотрена структура базы знаний и пользовательского интерфейса системы поддержки процессов рецептурного производства. Приведены методы для построения единой онтологической модели комплексного информационного обслуживания предприятия. В работе освещены принципы построения системы автоматизации деятельности инженера-технолога на основе онтологического подхода в рамках концепции Industry 4.0.

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