Ontological approach to batch enterprise within Industry 4.0

Valery Taberko, Dzmitry Ivaniuk
JSC “Savushkin Product”, Brest, Republic of Belarus
Email: id@pda.savushkin.by

***Abstract*—This article provides an review of the current situation of ontology use the techniques of creation, development and practice standards and digital twins with help of OSTIS Technology, examines in more detail the issues of current approaches to standards evolution, maintenance and application, with particular consideration to standards in the field of Industry 4.0, such as ISA-88, ISA-95 and ISA 5.1. Current standards-specific issues in this area are taken into account.**

***Keywords*—Standards, Ontologies, Industry 4.0, OSTIS, ISA-88, ISA-95, ISA-5.1.**

I. Introduction

This work expands on the ideas discussed in [1], [2] and includes descriptions of current issues and new versions of suitable tools for developing and using standards. Also connection with Industry 4.0 is considered - it is typically characterized by its complexity, requiring multidisciplinary knowledge of models, techniques to achieve an integrated solution [3]. With the advent of Industry 4.0, the scenario of reliable and safe interaction of various intelligent systems with each other becomes a reality that technical systems must take into account [4].

Each developed area of human activity is based on a set of standards that formally describe different aspects of it. It includes a system of concepts (including terminology), a typology, and a model, the sequence of actions taken during the process of applying appropriate methods and means. Production site, types and structures of project documents, accompanying activities, etc. The existence of standards allows us to solve one of the key problems associated with any technology. Especially the rapidly developing computer information technology, **compatibility problem** [5] can be solved. Compatibility can be considered in many aspects, from the consistency of terminology in the interactions of process participants to the consistency of actions taken in the process of technology application. On the one hand, the problem with cohesion of digital twin models lies in the fact that a large number of disparate, unrelated and heterogeneous models are required. On the other hand, connecting digital twins in a single system [6] requires their interaction, and awaits conceptual unification of this interaction. It also require from Supervisory Control And Data Acquisition (SCADA) systems a higher level of integration, scalability and technological modernity [7].

Despite advances in information technology, most standards are now presented in the form of traditional linear documents or Web resources containing a series of static pages connected by hyperlinks. This approach to expressing standards has many serious drawbacks, and ultimately the overhead costs of maintaining and using standards actually outweigh the benefits of using them [8].

II. Problems and state of art

An analysis of the work has made it possible to formulate the most important and common problems related to the development and application of modern standards in various fields [8], [9]:

- Above all, the complexity of maintaining the standards themselves due to the duplication of information, especially the complexity of changing terminology.
- Duplicate information in the documentation describing the standard.
- Standards Internationalization Issues – translating a standard into multiple languages actually requires supporting and coordinating independent versions of the standard in different languages.
- As a result, inconsistencies in the format of different standards. As a result, automating the process of developing and applying standards is complicated.
- The inconvenience of using the standard, especially the complexity of finding the information you need. As a result, the complexity of studying standards.
- The complexity of automating the verification that an object or process complies with the requirements of a particular standard.
- etc.

These problems are mainly related to the presentation of standards. The most promising approach to solve these problems is the transformation of each specific standard into a knowledge base, which is based on a set of ontologies corresponding to this standard [5], [8]–[11]. This approach allows us to significantly automate the development processes of the standard and its application.

As an example, consider the ***ISA-88*** [12] standard (the basic standard for batch production). Although this standard is widely used by American and European companies and is actively implemented on the territory of the Republic of Belarus, it has a number of drawbacks listed below. The author's experience with the ISA-88 and ISA-95 standards revealed the following issues related to the versions of the standard:

- The American version of the standard – *ANSI/ISA-88.00.01-2010* – has been updated and is now in its 3rd edition in 2010;
- *ISA-88.00.02-2001* — contains data structures and guidelines for languages;
- *ANSI/ISA-TR88.00.02-2015* – describes an implementation example of ANSI/ISA-88.00.01;
- *ISA-88.00.03-2003* – an activity that describes the use of common site recipes within and across companies;
- *ISA-TR88.0.03-1996* – shows possible recipe procedure presentation formats;
- *ANSI/ISA-88.00.04-2006* – structure for the batch production records;
- *ISA-TR88.95.01-2008* – explains using ISA-88 and ISA-95 together;
- At the same time, the European version approved in 1997 – *IEC 61512-1* – is based on the older version *ISA-88.01-1995*;
- Russian version of the standard – *GOST R IEC 61512-1-2016* – is identical to *IEC 61512-1*, that is, it is also outdated. Also raises a number of questions related to the not very successful translation of the original English terms into Russian.

Another standard often used in the context of Industry 4.0 is ***ISA-95*** [13]. ***ISA-95*** is an industry standard for describing high-level control systems. Its main purpose is to simplify the development of such systems, abstract from the hardware implementation and provide a single interface to interact with the ERP and MES layers. Consists of the following parts:

- *ANSI/ISA-95.00.01-2000*, Enterprise-Control System Integration Part 1: "Models and Terminology" – it consists of standard terminology and object models that can be used to determine what information is exchanged;
- *ANSI/ISA-95.00.02-2001*, Enterprise-Control System Integration Part 2: "Object Model Attributes" – it consists of attributes for each object defined in Part 1. Objects and attributes can be used to exchange information between different systems and can also be used as the basis for relational databases;
- *ANSI/ISA-95.00.03-2005*, Enterprise-Control System Integration, Part 3: "Models of Manufacturing Operations Management" – it focuses on Level 3 (Production/MES) functions and activities;
- *ISA-95.00.04* Object Models & Attributes Part 4: "Object models and attributes for Manufacturing Operations Management". The SP95 committee is yet developing this part of ISA-95. This technical specification defines an object model that determines the information exchanged between MES Activities (defined in Part 3 of ISA-95). The model and attributes of Part 4 form the basis for the design and implementation of interface standards, ensuring a flexible flow of cooperation and information exchange between various MES activities;
- *ISA-95.00.05* B2M Transactions Part 5: "Business to manufacturing transactions". Part 5 of ISA-95 is still in development. This technical specification defines operations among workplace and manufacturing automation structures that may be used along with Part 1 and Part 2 item models. Operations join and arrange the manufacturing items and activities described withinside the preceding a part of the standard. Such operations arise in any respect ranges withinside the organisation, however the attention of this technical specification is at the interface among the organisation and the manage system.

Models help define boundaries between business and control systems. They help answer questions about which functions can perform which tasks and what information must be exchanged between applications.

The first phase of building a digital twin model requires embedding data at lower levels of production, such as production processes and equipment. The P&ID production scheme serves as the source of this data. Therefore the ISA 5.1 standard [14] has to work with the P&ID scheme and is widely used in control systems along with the ISA 88 standard to fully describe the lower production levels. This standard is useful when a reference to equipment is required in the chemical, petroleum, power generation, air conditioning, metal refining, and many other industries. The standard enables anyone with a reasonable level of plant knowledge to read flow charts to understand how to measure and control a process without having to go into the details of instrumentation or the knowledge of an instrumentation expert. It is intended to provide sufficient information so that SA5.1 The purpose of this standard is to establish a consistent method of naming instruments and instrumentation systems used for measurement and control. For this purpose, a designation system is presented that includes symbols and identification codes. The latest release from the ISA5.1 subcommittee is the updated *ISA-5.1-2022*, "Instrumentation Symbols and Identification".

Training is an easy way to reach these standards. The International Society of Automation (*ISA*) is a non-profit professional association and recognized leader in automation and control education, dedicated to preparing the workforce for technological change and industry challenges. However, the price is relatively high, around $1,000 per person per day. For 2 persons it is $10,000 for a normal course for 5 days. For some countries it is affordable, for others it is not.

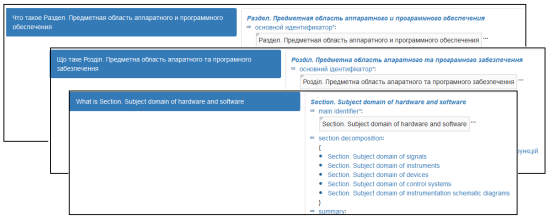

Figure 1. Start page

Figure 2. Ontologies for standards (ISA-88, ISA-95 and ISA 5.1)

Various established procedural requirements of different organizations are taken into account, but this is done by providing alternative symbology methods unless this conflicts with the goals of the standard. There are many options for adding information or simplifying the symbol if desired.

These and other standards now proliferate in the form of documents that are inconvenient for automated processing and, as noted above, are highly dependent on the language in which each document is written.

III. Examples of system operation with natural language information display

For information to be clear and understandable to the reader, it must be presented in a consistent manner. The recipe authoring system interface allows the structure of domains and ontologies to be expressed in natural language. This process of converting an internal knowledge representation to an external knowledge representation is performed by a graphical interface component. On the main page general information (in 4 languages) is displayed, Fig. 1.

Fig. 2 shows resulting ontologies for standards (ISA-88, ISA-95 and ISA 5.1).

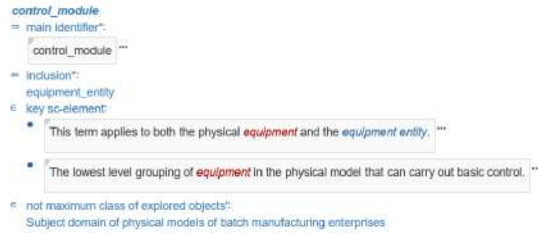

Figure 3. Control module

IV. Integration of third-party solutions with a knowledge base

A standard system built on the basis of OSTIS Technology can be easily integrated with other systems in the workplace. To integrate ISA-88, ISA-95 and ISA-5.1 standards system with other systems running on JSC "Savushkin Product", a web-oriented approach is used – the ostis-system server is accessed with the use of the following queries:

```
http://ostis.savushkin.by?sys_id=
control_module
```

where "sys_id=control_module" defines a term (the name of an entity) whose value we want to find out (in this example, in fact, the answer to the question" What is a "control module"?). This approach makes it relatively easy to add support of the knowledge base for current control systems projects, for this it is enough to indicate the names corresponding to the entities in the knowledge base within the control system. The answer is shown on Fig. 3.

In addition, it is possible to ask more complex and intelligent questions with several arguments, for example, "What is the difference between the concepts of "unit" and "control module"?

The corresponding query to the ostis-system server looks like:

```
http://ostis.savushkin.by?command_id=
ui_command_difference
&arg1=unit&arg2=control_module
```

Also possible to ask answers questions about questions. Fig. 4 shows result for question "How do two given entities linked directly to each other?"

Thus, an interactive intelligent help system for control systems projects is implemented, allowing employees to simultaneously work with the control system and ask questions to the system directly during the work.

Fig. 5 shows an illustration of the display of information in the form of a HMI page (from the control system project).

Fig. 6 shows a web page that displays the same information as a PFC chart (from the knowledge base).

Figure 4. System answer on question about question [15].

Figure 5. Example HMI from SCADA [15].

Another example is the integrated help subsystem within corporate Add-In EasyEPLANner [16] for CAD EPLAN. It helps to describe technological objects (Tank, Boiler, etc.), operations, etc. according to the ISA-88 standard. Fig. 7 shows a short preview of the project functionality.

Fig. 8 shows UML-model of EasyEPLANner objects to be described in OSTIS.

Fig. 9 shows UML-model of EasyEPLANner control modules to be described in OSTIS.

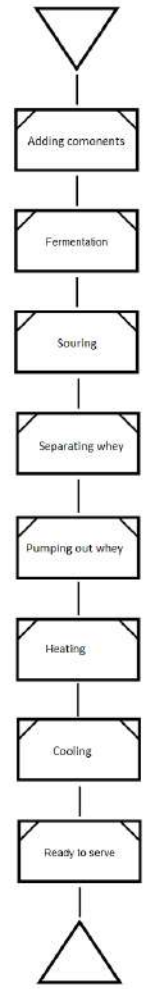

Figure 6. Corresponding PFC chart from OSTIS.

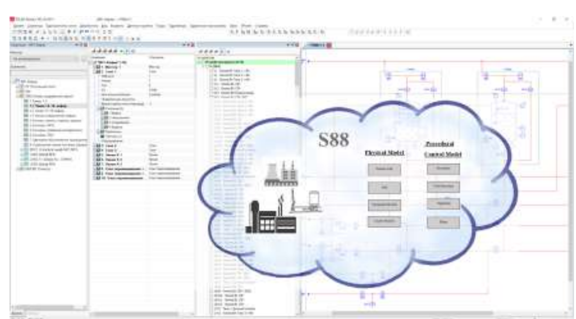

Figure 7. Add-In project EasyEPLANner

Figure 8. EasyEPLANner objects

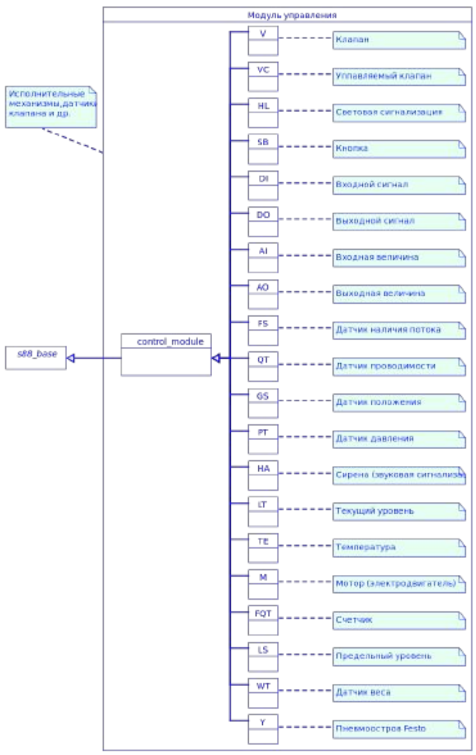

Figure 9. EasyEPLANner objects

V. Use in control system

It is very important to correct and fast react on different events during process control, especially on critical accidents. But when we have complex distributed system it is rather complicated and in normal way require help of the human operator. It may leads to variety of problems. So usage OSTIS-based system can helps to solve as described on Fig. 10. Project #3 has a valve failure but the project does not know what to do. Then it makes a request to the OSTIS server, which already knows which projects also use this line (with this valve). The OSTIS server polls the rest of the projects (projects #1 and #2). Each project has information about which operations are currently active and gives an answer on what to do - pause the operation, do nothing, etc. After that OSTIS-server sends back to project #3 answer with

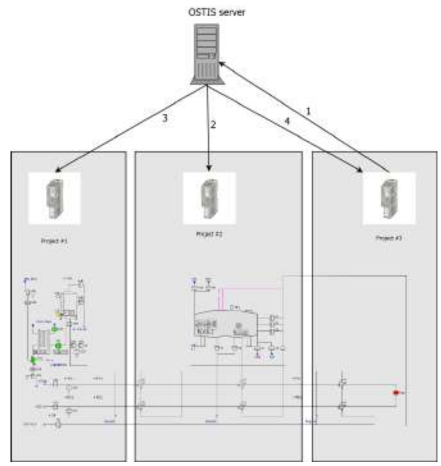

Figure 10. OSTIS in control system

result actions to be used. These are going in automatic way - no need of human operator.

VI. Future development

Current project issues can be found on GitHub ([17], [18] and [19]). Main problems to be solved are:

- Improving system performance and especially accelerating system response time to user requests. It is connect with productivity and overall user satisfaction.
- Continuous updating and refactoring ontological models (further formalization of missing concepts, fix typos and etc.);
- Enhancing PFC-visualisation - not only displaying, but also editing diagrams. Adding rich navigating between PFC-diagram and according text representation;
- Further formulation of questions (typical) to the system from the user and their formalization at the level of the existing knowledge base;
- Adding more description of parts of real control projects based on the existing knowledge base.

The implementation of answers to complex questions is necessary to make easier the work of not only process operators, but also maintenance personnel - instrumentation engineers, mechanics, electricians, etc. Therefore, it is planned to implement the system's answer to the question of the following type - in what operations of which objects this actuator is used (for example, valve "T1V1"). This question is very important when a device failure occurs and it is necessary to determine the criticality of this situation. For analysis, it is necessary to compare the time of the accident and the history of operations. Since, for example, an accident of the mix-proof valve during the line washing operation and the active product dosing along the other line, should lead to a stop of these operations and stop the preparation of the batch in the corresponding unit. The operator must report this to the appropriate maintenance specialist to fix it. After the fault has been eliminated, the operator continues to perform operations. This is the correct events order, which is very important to avoid mixing of detergent and product. If the device malfunction occurred within the line, which is now inactive, then this situation has a low priority, does not lead to a stop in operations and can be eliminated later if the service personnel have free time.

VII. Conclusion

The paper considers an technique to automating the process of creating, developing and making use of standards primarily based on OSTIS Technology. Using the instance of the ISA-88, ISA-95 and ISA-5.1 standards used on the Savushkin Product enterprise, the structure of the knowledge base, the features of the problem solver and the user interface of the support system for these processes are considered. It is proven that the developed system can be easily integrated with other enterprise systems, being the basis for building an information service system for employees in the context of Industry 4.0. The approach proposed in the work allows us to provide not only the ability to automate the processes of creation, agreeing and development of standards, but also allows us to significantly increase the efficiency of the processes of applying the standard, both in manual and automatic way.

Acknowledgment

Authors would like to thank to the research teams of the Departments of intelligent information technologies of the Belarusian State University of Informatics and Radioelectronics and the Brest State Technical University.

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Онтологический подход к рецептурному предприятию в рамках Индустрии 4.0

Таберко В.В., Иванюк Д.С.

В работе рассмотрен онтологический подход к пониманию, интеграции и развитию стандартов на основе Технологии OSTIS. Уточнена формальные трактовки основных понятий, используемых в стандартах, что позволяет упростить описание реальных задач. Также описаны варинты интеграции базы знаний в используемые программные средства разработки и сценарии её использования непосредственно в системах управления.

Received 20.10.2022