Using the ObjectARX programming environment for modular information-measuring systems design and simulation

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Abstract. This article deals with the development of tools for configuring and modeling modular information and measurement systems. The use of standard solutions for the industrial facilities automation requires the use of special tools – configurators. It is advisable to use one of the popular CAD systems, for example, AutoCAD, as the basis for creating the configurator. Authors analyse various ways for creating and managing AutoCAD projects using built-in tools and external programs. It is shown that ObjectARX environment is the most powerful means of solving such problems, providing maximum integration and performance. The results obtained by the authors during the modular systems configurator development allow recommending ObjectARX for creation of specialized CAD systems based on AutoCAD.

1. Introduction
At present, many large organizations pay serious attention to the development and application of standard technical solutions for the design and construction of production facilities. For example, the Russian Federal Grid Company of Unified Energy System (FGC UES) for several years has been using the organization standard [1], which regulates the application of standard solutions for the power substations design. PJSC “Rosseti” plans in the near future to focus its efforts on R&D in the standard solutions development for digital substations of various voltage classes [2].

The production facilities typification makes it beneficial to develop standard automation tools for such facilities, including information, measurement and control systems (IMCS). In this area, attempts are made to standardize at least at the level of organizations [3].

Typification significantly simplifies the development process; however, to adapt the IMCS to a specific technological equipment, a large amount of routine work is still required: drawing up wiring diagrams and lists of elements, calculating the length of connecting cables, estimating the throughput of communication channels, etc. Automation of this work will significantly reduce development time and the number of errors in the documentation. To automate these tasks when creating IMCS for power substations, the authors developed a special software tool - the configurator - described in this article.

2. Results

2.1. Detailed problem description
Let us consider the features of using typical solutions with the example of creating a power substation IMCS. According to [1], in newly designed and upgraded substations, switchgears must be implemented according to standard schematic diagrams. One of them is shown in Figure 1 and consists of a number...
of functional cells, such as input line cells (TR1, TR2) and output line cells (LINE1…LINE4). The cells include switches (QS, QSG), transformers (TA, TH, AT) and other equipment. Each scheme type has significant distinctive features, but allows for several implementation options. For example, the standard schematic shown in Figure 1 may use a different number of output line cells or different types of switches, differing in the number of control inputs and signal outputs. Therefore, the IMCS of such substation can have a typical modular structure, according to the type of standard scheme used, refined in accordance with a specific switchgear implementation. As a result, it becomes possible to formulate clear recommendations that allow the IMCS developer to choose the structure of the system, the equipment composition, its layout and connection methods, and to solve other tasks arising during the design.

![Image of standard switchgear schematic diagram example](image)

**Figure 1. Standard switchgear schematic diagram example.**

However, the use of standard solutions in the field of automation, greatly simplifying the design process and shortening the time for their implementation, does not exclude completely such routine operations as the development of documentation, evaluation of congestion, the calculation of cable lengths and some others. The authors' experience shows that in such operations the probability of unintentional errors is very high. In this regard, it became necessary to create a tool that automates these operations.

### 2.2. Ways to solve the problem

Typically, such tasks are resolved using computer-aided design (CAD) systems. One of the most flexible CAD systems currently used is AutoCAD [4]. A variety of design and modeling problems are solved with it [5], including the tasks in the energy industry [6, 7]. Another popular system specifically designed for energy engineering is EPLAN Electric [8]. It allows completing the layout of equipment, cable routes, load calculation and many other similar tasks [9, 10].
However, due to their versatility and multifunctionality, these CAD systems when used without any additional tools require a high developer qualification and do not allow reducing the selection, adaptation and evaluation of a typical technical solution to a sequence of simple actions. Consequently, there is a need to develop a special tool – a configurator – that allows adapting a standard modular IMCS to a specific production facility and evaluating the degree of its compliance with the technical task.

2.3. Configurator Basics
The work of the configurator developed by the authors can be divided into three stages: the input of the initial data, the construction and study of the IMCS model and the documentation forming. Main configurator interface used for data entry is shown in Figure 2. During the data entry phase, the following actions are performed:

- selection of the substation switchgear circuit from the list of typical schemes according to [1] (Figure 2, a);
- selection of one of several typical options for automation of this scheme (Figure 2, b);
- specification of the circuit diagram parameters: number of switched lines, equipment used (Figure 2, c);
- parameters specification for the designed IMCS – for example, the list of additional functions provided (Figure 2, d).

Using this data, at the second stage configurator forms an IMCS model that includes information on:
- the system equipment composition (types and number of instrument racks, controllers, I/O modules);
- intrasystem and external connections (IMCS elements connections to each other and to substation equipment);
- the intensity of information flows formed by the system elements;
- the heat generation of elements and the parameters of the cooling system.

The model is based on a previously prepared library of configurable sample blocks. At the same stage, the system parameters are evaluated, such as, for example, the communication channels load or the instrument racks thermal modes.

In the third stage, the configurator generates the documentation using the obtained model: specifications, wiring diagrams, lists of elements, equipment layout diagrams (layout of racks), and cable logs preparation. It is also possible to create auxiliary materials, such as, for example, marking tags of cables or preparation of technical and commercial offers.

2.4. Development platform selection
Due to the large volume and complexity of the documentation being generated, the authors decided to make the configurator based on a CAD system capable of creating the necessary documents. When choosing a basic CAD system, the following factors were taken into account:

- popularity among IMCS developers;
- presence of a software API that allows to access the generated document elements and general CAD functions.

As a result, the CAD selected was AutoCAD, used by most designers in the energy sector. This CAD software has the following software controls [4]:

- built-in interpreter of AutoLISP language (dialect of Lisp language used in AutoCAD);
- an additional module supporting VBA (Visual Basic for Applications);
- COM interface that provides access to CAD functions and documents using OLE Automation technology;
- ObjectARX (AutoCAD Runtime Extension) - a programming environment that provides direct access to AutoCAD database structures, graphics system and built-in commands.
Figure 2. The main configurator interface: a – switchgear circuit selection field; b – circuit variant selection field; c – circuit parameters field; d – pages for detailed parameters input; e – image and description of the selected circuit.

All these software controls provide approximately the same opportunities. At first, authors tried to use the COM interface as the most universal tool. However, the experiments with the configurator prototype showed that even for simple IMCSs the time for creating documentation is unacceptably long and amounts to tens of minutes. For example, for the simplified circuit shown Figure 1 (with two lines only), these operations took 34 minutes. This is due to the specifics of the COM technology: the work of the configurator and AutoCAD in different address spaces, the use of data marshaling, etc. AutoLISP and VBA languages have limited features and are not popular among developers [11].

As a result, the preference was given to the ObjectARX environment, because it provides the maximum performance: the ARX-application works in the same address space as AutoCAD itself, as a dynamically linked library (DLL) and has direct access to the AutoCAD graphical database. Using this technology, many tasks to adapt AutoCAD to specific problems have been solved both in the energy sector [12, 13] and in other industries [14, 15]. In addition, ObjectARX allowed using the C# language, which had previously been used to develop the configurator. By using ObjectARX, the execution time of the above example was reduced to 2.6 minutes (i.e. more than 10 times).

2.5. Implementation description

The implementation description of the data entry and the construction of the IMCS model is beyond the scope of this article, because at these stages only the C# language and the .NET Framework capabilities were used. We will dwell only on the stage of creating documentation that actively uses the functions of the ObjectARX programming environment.

As noted earlier, configurator generates documentation using a pre-created library, which was developed as part of the configurator. The library is an AutoCAD document containing graphic schematic symbols of IMCS elements: controllers, I/O modules, connectors, operator panels and others. Each symbol is an AutoCAD block and has a unique name. For those elements that need to be shown in the mechanical rack layout diagram, in addition to the symbol, an image of the appearance is also
specified (Figure 3). Each element has a set of mandatory and optional parameters. Mandatory parameters are represented by separate attributes of AutoCAD blocks, some of which are displayed in documents, and some are hidden. This includes such parameters as a reference designator, name, element type, order code, designation of connection points, names of connected electrical circuits and some others. All optional parameters are represented by one attribute that contains text in XML format with an arbitrary set of tags. Specifically, tags are defined to indicate the amount of data transmitted over the communication channels, as well as for the transmission frequency. Other tags can be added in the process of configurator improving.

**Figure 3.** Example of configurator library element – measurement module: a – schematic symbol; b – image of the appearance.

Another library part consists of several files - document templates for wiring diagrams, layouts, specifications, a list of elements and others. For each version of the document, several templates can be used, depending on the number of options for the IMCS implementation.

Automatic documentation generation will be considered on the example of creating the most complex document - the wiring diagram of the instrument rack. First, the configurator loads the necessary document template, corresponding to the chosen standard solution. Then, based on the data of the IMCS model, it extracts used system elements from the symbols library and places them in a free drawing field, adding new sheets if necessary.

At the next stage, it assigns reference designators to each symbol according to the type of the element and its arrangement on the document page. Next, the configurator creates electrical connections between the elements on the diagram. To simplify the task and improve the visual clarity of the circuit, they are presented in the form of buses, each connection being named according to certain rules, including the indication of the connection address (that is, the designation of the element and the number of the contact to which the connection is made).

The general management of AutoCAD, as well as access to the properties of the documents and its components (blocks coordinates, text, color, etc.) is performed using the ObjectARX API. All information obtained during the creation of the wiring diagram, configurator stores in the IMCS model.
and subsequently uses for the automatic creation of other documents: specifications, lists of elements, equipment layout diagrams (layout of racks), and cable logs. An example of one of these documents is shown in Figure 4. The drawing shows the instrument rack of the designed IMCS with an exact placement of the controllers, I/O modules, indicators, switches, fuses, terminal blocks. If there are several instrument racks, then a configurator creates a drawing for each of them. Other documents are more complex and are not given in this article.

![Figure 4. The example of the instrument rack layout.](image)

3. Discussion
The described approaches and algorithms were implemented by the authors in the IMCS configurator [16] and showed their effectiveness and practical significance. Using the configurator, the full preparation of project documentation for a typical power substation IMCS now takes several hours instead of several days. In addition, the number of unintentional errors in the documentation was reduced to almost zero.

The authors used the same algorithms to create and study the model of a modular vibration monitoring system described in [17], which underlines their universality and applicability in many branches of technology.

4. Conclusion
The article analyzes various ways of creating and managing AutoCAD documents using built-in tools and external programs. It shows that ObjectARX environment is the most powerful means of resolving such problems. The results obtained by the authors during the IMCS configurator development allow us to recommend ObjectARX for creation of specialized CAD systems based on AutoCAD.

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