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All-Digital Substation Design Automation Based on IEC 61850, 61131, 61499 Standards

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1 INTRODUCTION

Installation of automation control systems for substations using conventional computer-aided design methods is complex time-consuming task which can hardly be unified. An introduction of new international standards and information technologies opens possibilities for new approaches to solve this task allowing creation of digital substations. The main particularity of IEC 61850 is that it regulates not only communication between individual devices but also substation, protection and automation device description.

The possibility to describe substation structure emerged with introduction of IEC 61850. SCL-files allow describing of substation single line diagram, intelligent electronic devices, as well as communication between IEDs. Such a description significantly simplifies creation of integrated automation control system of digital substation. There are many SCL software products on the market today. All this software can be divided into three main groups:

- Universal SCL software. It generally provides the possibility to edit single line diagram in graphical form, creation and editing of logical devices, nodes, data objects, attributes, etc. (For instance, Visual SCL, Helinks LLC, Kalkitech SCL Manager, etc.).
- System configuration systems. It generally provides the possibility to merge several ICD files in one SCD, GOOSE publication configuration, CID file export (NPT Expert 61850 Configurator, Siemens DIGSI, ABB Communication Engineering Tool, SEL acSELERator Architect, GE Multilin IEC 61850 Configurator F650, etc.).
- IED and automation control systems vendor software: software to configure GOOSE, automation control systems tag binding (mapping) (Satec PAS, GE UR Setup, NPT Expert 61850 Configurator, etc.).

As well as with integration of IED using MMS protocol SCL editors from different vendors have compatibility issues. Main drawbacks of contemporary SCL usage are:

- “Bottom-up” design approach. This design approach is limited to merging ICD in single SCD and configuring of IP-addressing and GOOSE communication.
- Total elimination of SCL substation section. As for industry used systems only ABB CET has such functionality. Universal SCL software (which has such functionality by design) is rarely used in automation control systems of leading vendors because of compatibility issues and necessity of synchronizing of SCD.
- Main attention is focused on communication between IED (GOOSE) but not on engineering task. Well-known example is interlocking function. Engineering companies provide schemes of interlocking in form of ladder diagrams. To transform this schemes to bay control units one

needs to separate variables from neighbor bay. Then these variables are configured to be sent using GOOSE on another bay control unit and are received and bound to local variables in interlocking bay control unit. And only after all this process it is possible to write algorithm.

To overcome these difficulties it is possible to use different approach to digital substation design which is better suited to traditional engineering.

2 DIGITAL SUBSTATION DESIGN

The first step is creation of substation single line diagram. Single line diagram should conform to IEC 61850-6. It is necessary to apply system approach to allow this description to be used in different tasks. It is better to use universal format [1], which can be used to export substation description in SCL as well as in CIM RDF [2].

The second step is intended to select tasks which should be solved by IEDs (protection, control, interlocking, measurement, etc.) bound to elements of single line diagram. Tasks in IEC 61850 are logical nodes. In this case logical nodes are assigned to single line diagram elements. This step is finished by creation of SSD file according to IEC 61850.

The third step is used to merge IEDs using ICD files provided by device vendors. Logical nodes assigned to single line diagram are linked to IED logical nodes. On this step main problem arises which prevents IEC 61850 usage for design. The problem is that many IED do not confirm to standard requirements in part of information model. For instance, on the second step we have assumed that distance protection should be used to protect the outgoing line and we have used PDIS logical node. Then we discover that in real IED information about distance protection is located in GGIO logical node. In that case we can't link logical nodes. That is why digital substation design process is closely related to design of information model and support of IEC 61850-7 requirements in IED.

The fourth step is devoted to algorithm creation (distributed logic). Thanks to the second step of design some logic can be designed without IEDs. Actually if we have switch with interlocking function (CILO) and other apparatus with position functions (XCBB, XSWI, CSWI) then interlocking algorithm can be created without any knowledge about IED. After IED inclusion variables and algorithms can be automatically distributed between IED and GOOSE can be as well configured. Main problem of this step is that IEC 61850 focuses on communication and doesn't provide logic description. IEC developed two standards devoted to logic description: IEC 61131 и IEC 61499.

IEC 61131 was developed to be used in programmable logic controllers [3]. This standard provides several algorithm languages:

- IL – low level language (assembler);
- ST – high level language (Pascal-like);
- FBD – graphical language of functional block diagrams.
- LD – graphical language of ladder diagrams.
- SFC – graphical language to describe state machine.

LD and FBD are commonly used in contemporary design practice. SFC is more promising when used to describe sequence of operations with control on each step of algorithm.

IEC 61131 or its parts are commonly implemented in IEDs. CAD for digital substations should allow creation of algorithm using IEC 61131. It should also provide functionality to export this algorithms to IED specific format.

IEC 61499 was designed to provide distributed logic description. IEC 61499 offers new approach to algorithm logic design:

- Event-driven evaluation instead of cycle evaluation.
- Communication between blocks using events.

IEC 61499 can be also described in graphical form and consist of functional blocks. However these functional blocks differ from IEC 61131 functional blocks. Each functional block has input events and data. Algorithm execution is triggered on input event emergence and provides output events and data.

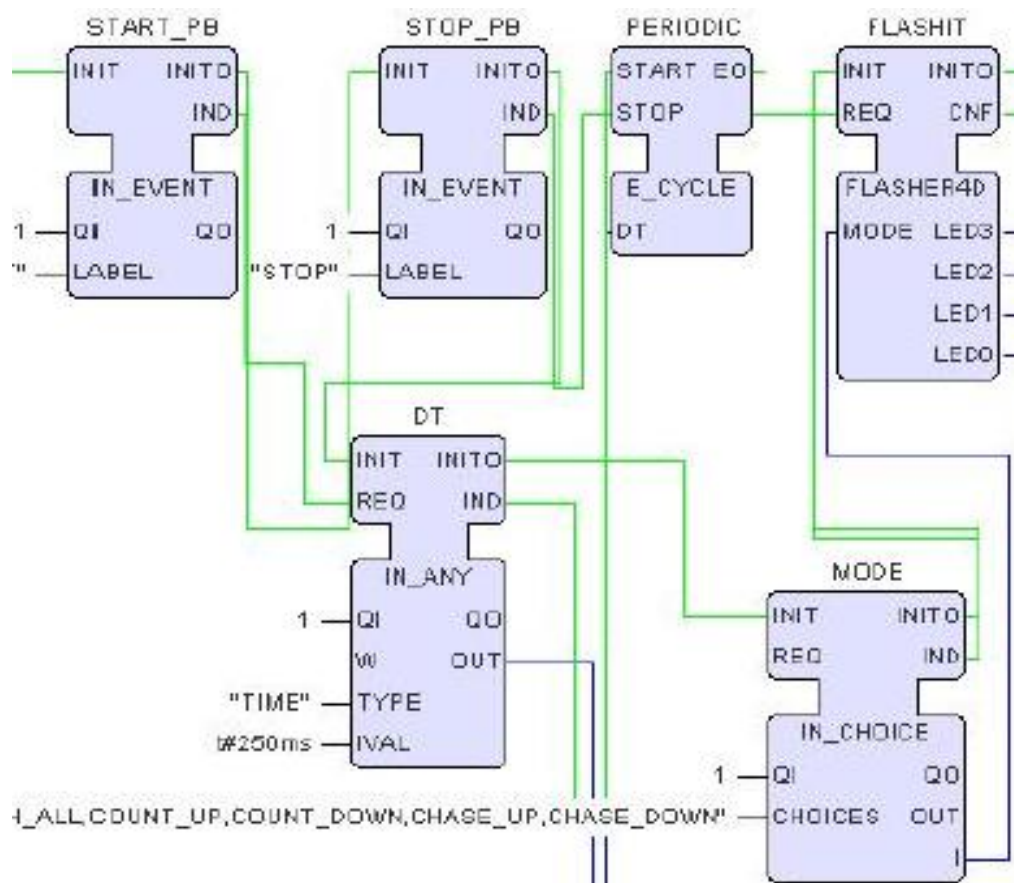


Fig. 1: IEC 61499 algorithm example

Event-driven communication between functional blocks is well suited to IEC 61850 [4] and resembles communication using GOOSE. CAD should provide final scheme of logical node communication using IEC 61499 functional blocks. However event-driven execution has its own disadvantages (for instance, difficulties with time delay implementation), but this direction is very promising to provide formal description of logical node communication (in local device as well as network communication using GOOSE).

The fifth step is devoted to digital substation modelling. After all IEDs have been included and communication between them is configured it is time to carry system tests. This process can be automated using IEC 61850 and IEC 61131. Substation description with all logic description allows modelling:

- All technological processes with different detailing.
- Separate algorithms (for instance, interlocking function).
- LAN load test (if we have enough computers).

To simplify modelling CAD should be integrated with IEC 61850 device emulator: allow exporting configuration to emulators. It should as well have possibilities to debug separate algorithms or groups of algorithms.

JSC «NIPT» develops CAD for digital substations. Today these functions were implemented:

- Algorithm description in IEC 61131 FBD.
- Automatic export of algorithms to Satec bay controller.
- Automatic export of configuration to IEC 61850 emulators to provide distribution logic testing.
- Local debugging of separate algorithms or groups of algorithms.
- IEC 61850 device emulator.

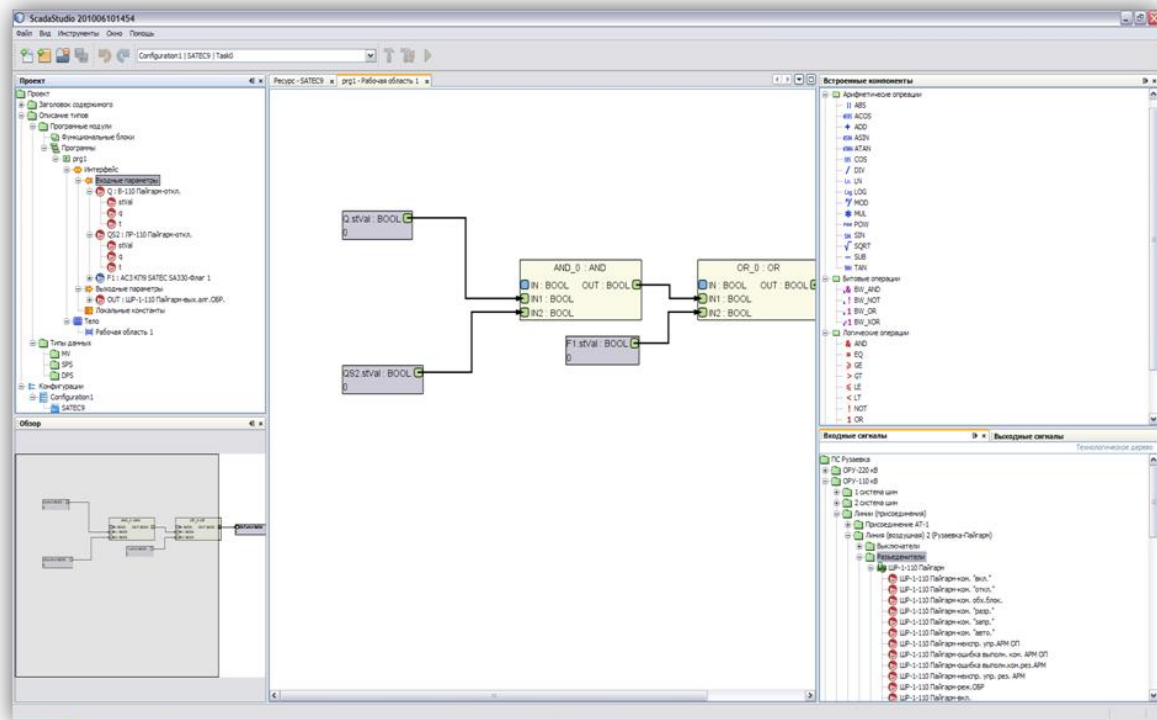


Fig. 2: Main window of algorithm editor

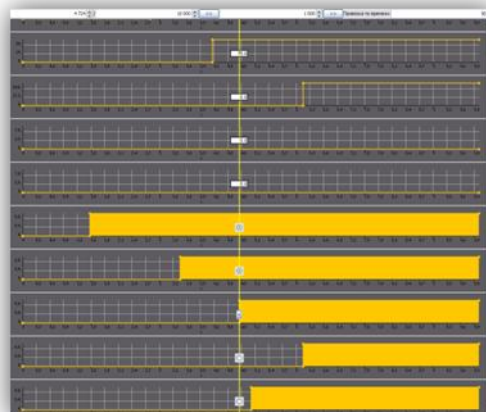


Fig. 3: Algorithm debugger

Main features of SCADA Studio CAD are:

- Modular design (possibility to extend export possibilities).
- International stanarts support (like IEC 61131 and Open PLC).
- Possibility of flexible testing of automation systems in digital substation using IEC 61850 device emulators.

3 CONCLUSION

Creation of digital substation requires CAD. This CAD should be based on open standarts IEC 61850-6 SCL, IEC 61970 CIM, IEC 61131, IEC 61499. Main advantage of using CAD compared to traditional approach is possiblitiy to configure system directly using results of design minimazing manual work. Another advantage is possibility to carry out tests of automated system with different level of detailing. Usage of open international standarts raises compatibility between sotware of

different vendors of IED and automated control systems. Modular design allows functional extension in future.

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