Towards Intelligent Smart Grid Devices with IEC 61850 Interoperability and IEC 61499 Open Control Architecture

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Abstract-- **In this paper we report on developments and experiments conducted to prove the feasibility of using decentralized multi-agent control logic in the automation of power distribution networks. The utility network is modelled as communicating logical nodes following IEC 61850 standard's architecture, implemented by means of IEC 61499 distributed automation architecture. The system is simulated in an IEC 61499 execution environment combined with Matlab and proven to achieve simple fault location and power restoration goals through collaborative behaviour and interoperable devices.**

***Index Terms*-- Smart Grid, IEC 61850, interoperability, distributed intelligent automation, IEC 61499**

I. INTRODUCTION

The Smart Grid vision, outlined in EPRI's "Report to NIST on the Smart Grid Interoperability Standards Roadmap" [1], incorporates into the grid "the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level". This vision implies a multilayer information and control system architecture, with power transmission and distribution layer playing a crucial role in achieving the "smartness" of the grid.

The complexity of this task requires reconsidering grid control architectures, possibly changing them from the traditional hierarchical topology with distributed data acquisitions but central decision making, to decentralized decision making. For that, basic automation devices would need to become "intelligent". Most advanced version of such devices are currently based on microcomputers with communication capabilities, but the data flow is purely bottom up, from devices to the control center, and control flow is opposite: from the control centre to instruments. In Smart Grids this may need to change to horizontal communication, negotiation and collaborative decision making by the instruments.

There has been considerable amount of research on the corresponding computing architectures capable of implementing such distributed intelligence. For example, multi-agent system architectures for grid automation have been proposed in [2],[3]. Unfortunately these ideas cannot be implemented on current grid devices based on proprietary and closed hardware/software platforms. Besides, multi-agent implementations require high computation performance and still cannot deliver sufficient real-time performance and determinism. While multi-agent systems need powerful workstations to run, practitioners in the field are very conservative and insist on high reliability, determinism and performance of the microprocessor-based instruments. Reliable communication is crucial, and interoperability amongst IEDs (Intelligent Electronic Devices) is of paramount importance.

Thus, practical deployment of intelligent multi-agent solutions at the transmission and distribution layer of Smart Grid can happen if a new generation of IEDs appears that have open architecture based on industrially accepted standards in the areas of information, configuration, communication and distributed automation.

Our proposed approach to pave the way to multi-agent intelligent control of grid is using two standards: IEC 61850 and IEC 61499.

The focus of IEC 61850 standard (Communication networks and systems for power utility automation) [4] is on substation information, information exchange and configuration aspects mainly for protection, control and monitoring. The automation functions that produce and consume the exchanged information are outside the scope of the standard. On the other side functions are the key for the operation of a future Smart Grid which will be build on centralized and distributed automation functions.

A truly intelligent, self-healing distribution network will necessarily require "plug-and-play" self-reconfiguration, "self-awareness" in various forms, and collaboration between subsystems to achieve optimum performance and natural scaling with minimum risk. Subject to the availability of pervasive communications, this behavior can be achieved with a distributed automation architecture. IEC 61850 provides a

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solid standards base for a new generation of power system relaying and control functions. IEC 61499 (Function Blocks) [5] promises a framework for gluing those functions together in patterns of increasing capability and complexity.

The resulting ability to customize control and automation logic will greatly enhance the flexibility and adaptability of automation systems, speeding progress toward the realization of the Smart Grid concept.

The paper reports on the progress of a research project set following the ideas of [6] towards a new approach to power system automation, based on distributed intelligence rather than traditional centralized control. The particular aim of the project is to investigate the interplay between IEC 61850 and IEC 61499, and propose a way of combining of the application functions of IEC 61850-compliant devices with IEC 61499-compliant "glue logic" using the information models, interoperable information exchange methods and configuration language defined by IEC 61850. This involves the use of IEC 61499 as an integration, extension and verification mechanism for IEC 61850-based systems.

A running example of fault location, isolation and supply restoration (FLISR) scenario will be presented, and its implementation using IEC 61499 function blocks will be sketched. The choice of this running example is justified by the report [1] that clearly states that one crucial function of Smart Grids is that it "provides a reliable power supply with fewer and briefer outages, "cleaner" power, and self-healing power systems, through the use of digital information, automated control, and autonomous systems."

The rest of this paper is organized as follows:

In Section II we present the description of our running example. In Section III distribution of control functions across substation instruments is discussed. Section IV presents ideas of implementing IEC 61850 architecture provisions by means of the IEC 61499 distributed control architecture. Section V provides details of the intelligent functions of logical nodes, and section VI describes the testbed developed and tests conducted. The paper is concluded with a brief outlook and list of references.

II. Running Example: a FLISR Scenario

In the reported work we have been following the FLISR scenario from [6] related to the typical distribution network in Figure 1 and briefly explained as follows:

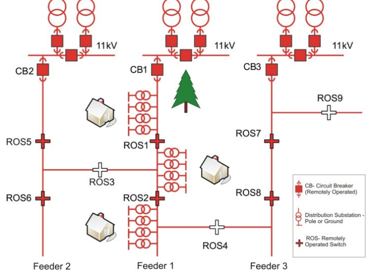

Figure 1. Sample power distribution utility.

The distribution utility consists of three 11kV feeders supplied by three different zone substations. The 11kV feeders are shown in simplified form, with only the backbone and ties to adjacent feeders. In reality, 11kV feeders have a branching structure such that the feeder and the associated LV feeders can supply a geographical patch. Distribution substations are positioned along each feeder as required to serve customers' loads.

In the initial state the switches ROS3, ROS4 and ROS 9 are open, as denoted by their white colour. All other switches are closed, as denoted by their dark colour. The switches are assumed to be "smart" and participating on an ongoing event-driven conversation.

The scenario begins with a tree falling on the 11kV mains, causing a permanent fault on feeder F1. The feeder protection *trips* (opens) circuit breaker CB1 at zone substation B. Sectionalising switches ROS1 and ROS2, being downstream of the fault location, do not register the passage of fault current. In anticipation of possible follow-up action, they remember the load currents that were flowing through them just before the fault occurred. After one attempted automatic reclosure, CB1 goes to lockout.

Tie switches ROS3 and ROS4 realise that feeder F1 is no longer energized, and they initiate a search for alternative sources of supply. Each switch is assumed to maintain a local connectivity map, so it is able to propagate the "call or help" towards a zone substation. CB2 at zone substation A, and CB3 at zone substation C, respond with information about the headroom (excess capacity) available. This information propagates back down feeders F2 and F3. It is updated at each switch so that, by the time it reaches ROS3 and ROS4, the available excess capacities can be compared with the loads in the unfaulted sections of feeder F1 (note that in order to achieve this, each switch must be aware of its own rating and the ratings of the downstream conductors).

The switches agree on the steps necessary to restore supply: The mid-section of feeder F1 will transferred to feeder F2; the tail-section will be transferred to feeder F3; the head-section will have to await repair.

In the meantime, the control centre has been eavesdropping on the conversation between the switches. When customers call to report a loss of supply, each can be fully informed as to when they can expect restoration. In fact, customers on the unfaulted feeder sections will probably be restored before they have time to call.

III. Decentralized Grid Control: Distribution of Control Functions

The goal of our work was to implement a prototype of intelligent distributed control of the utility. As a first step we allocate control functions to the instruments of the utility as illustrated in Figure 2.

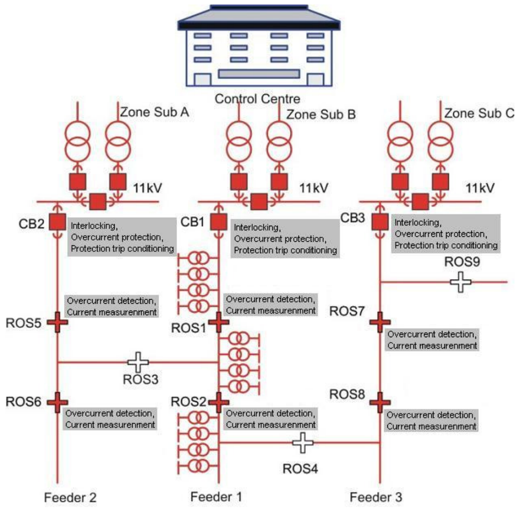

Figure 2 Sample power system sibstation with intelligent distributed control functions allocated to the instruments.

According to [6] the functions are as follows:

1. Protection (Instantaneous Over Current) PIOC LN
2. Protection (Protection Trip Conditioning) PTRC LN
3. Protection related (Autoreclosing) RREC LN
4. Monitoring of circuit breaker XCBR LN
5. Control of circuit breaker CSWI LN
6. Monitoring of Disconnect Switch XSWI LN
7. Control of Disconnect Switch CSWI LN
8. Measurement (current), Monitoring of Current Transformer TCTR LN.
9. Interlocking CILO LN

Second, we have represented the utility network in terms of the IEC 61850 architecture, i.e. as *logical nodes* as illustrated in the single line diagram (SLD) in Figure 3.

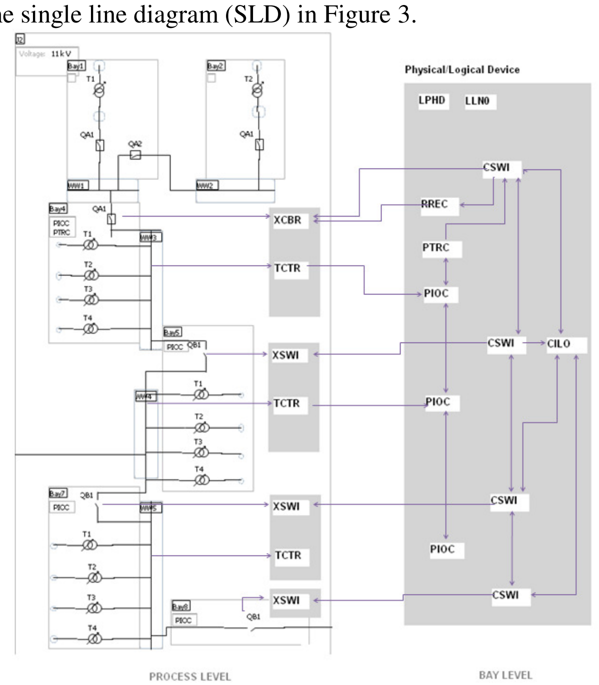

Figure 3. One feeder example from sample substation with functionality mapped to logical nodes.

On the process level, circuit breaker, switch and current transformer are used, and in the bay level there are substation automation functions monitoring and controlling primary equipment and substation itself.

XSWI represents sectionalising and tie switches, XCBR represents circuit breaker, and TCTR corresponds to current transformer. These are information models of primary devices. Switches are categorised into 2 types: sectionalising switches and tie switches, differing in purpose and functions. A sectionalising switch divides substation into sections, so it is easier to locate and isolate faults. Feeders are connected to the adjacent ones through tie switches. The sectionalising switches are used to isolate faults, and tie switches to restore supply to unfaulted sections.

CSWI denotes control functions for switches and circuit breakers. CSWI performs opening and closing connected switch, decision making is based on the information provided by the protection LNs.

CILO designates interlocking conditions for switches, in this project all interlocking is implemented at the bay level.

PIOC is instantaneous overcurrent relay, which has to detect the fault and give a signal to trip XCBR.

PTRC is protection trip conditioning connecting the "operate" signal of PIOC to trip signal of XCBR. If condition of tripping the XCBR is met then the circuit breaker is to trip.

RREC is an information model of auto reclosing function.

Note that the logical nodes used in this example are extended to model some additional information required by the FLISR scenario.

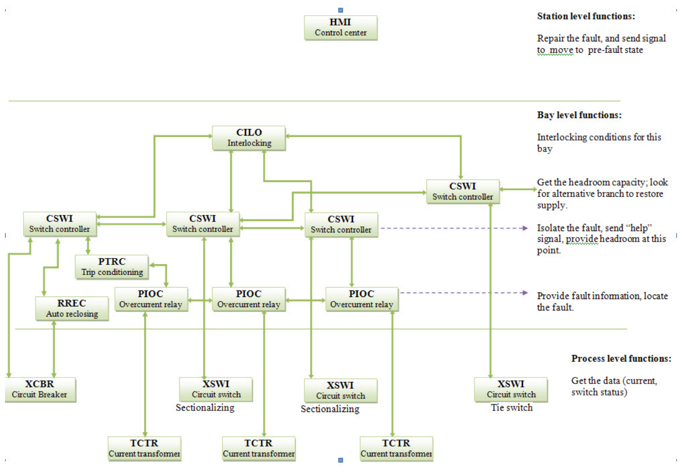

Figure 4. Substation automation functions mapped to LNs, their interaction and tasks

Process level functions

XCBR and TCTR are simple LNs, representing device specific data and providing services as defined in the standard. They are objects to be controlled and provide information needed for the bay level control. TCTR senses the current and XCBR provides status information, changing its position by the command from the control LN.

As mentioned in [7] "Smart" CT can transmit data, so that any device can use the data as needed. In this project, current transformer (TCTR) senses the current and sends the sampled values to the PIOC. The PIOC is aware of previous current value and calculates the fault status.

Bay level functions

The bay level functions are divided into 3 layers and Interlocking. Interlocking is a bay interlocking, and it checks whether requested switch operation (open/close) violates network constraints and gives permission to operate if it does not.

The first layer of the functionalities is provided by intelligent protective relays, in this case Instantaneous Overcurrent Relays (PIOC). The function of this level is to locate fault.

Once RREC goes to lockout, the "lockout signal" has been transmitted and PIOCs start to collaborate in order to locate the fault. The fault detection and reclosing functionality of this layer is depicted in Figure 6 in more details and explained later in this chapter.

The function of the second layer (CSWI), once a fault has been located, is to isolate the fault, send request for alternative supply and provide headroom capacity at switch position. This is done by collaboration of sectionalising switches.

Tie switches on the third layer get a request for alternative supply, initiate search for excess capacity and make a decision whether it is enough to power up the load or not, and then offer it to the requested section. Based on the response it will or will not restore the supply.

Station level functions

Operator sends the "go back to pre default configuration" command after the repairing of permanent fault has been completed. Figure 5 illustrates interaction of PIOC, PTRC, RREC and CSWI logical nodes and signals they use.

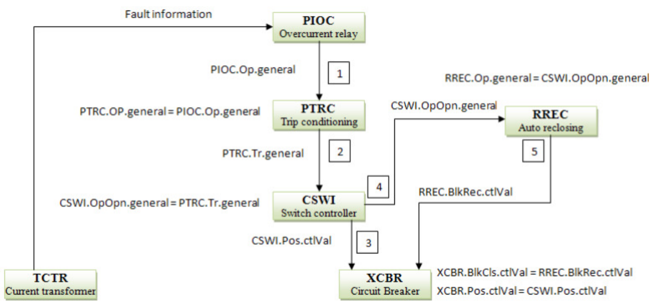

Figure 5**.** Fault detection and reclosing scenario and LNs involved

PIOC subscribes TCTR.Amp.instMag as current value and has set value StrVal.setMag, when current exceeds this value PIOC starts calculating trip condition. The steps are as follows.

1. TCTR is continuously transmitting current value (Amp.instMag), PIOC compares it to the set value PIOC.Str.setMag, if current is higher than the set value then this indicates a fault.
2. Consequently it issues start signal (PIOC.Str.general) to start calculate trip condition.
3. This results in a decision to send trip signal (PIOC.Op.general) to PTRC. "The LN PTRC shall be used to connect the "operate" outputs of one or more protection functions to a common "trip" to be transmitted to XCBR." ([8], p. 30]. When PTRC sees that PTRC.Op.general is triggered, it issues trip signal (PTRC.Tr.general) to switch the controller CSWI.
4. CSWI notices that OpOpn.general has been triggered; it issues command to open connected XCBR (circuit breaker).
5. CSWI sends same signal to RREC. According to the configured behavior, RREC decides to reclose circuit breaker and sends RREC.BlkRec.ctlVal to the XCBR. XCBR closes itself.
6. After one attempted automatic reclosure XCBR goes to lockout, which indicates that fault has been detected. By receiving "Lockout" signal PIOCs starts to locate the fault.

The standardised information is exchanged by means of the services defined in the standard; the data like headroom and fault location which were used by the intelligence added in this work uses services offered by Function blocks (implemented by events and data associated with events).

IV. Modelling of IEC 61850 Artefacts in Terms of IEC 61499

The ideas of IEC 61850 implementation by means of IEC 61499 control architecture were proposed in [6]. The IEC 61850 standard defines information and information exchange models for substation automation functions and primary equipment, captured in Logical Node and Abstract Communication Services accordingly. A function block (FB) of IEC 61499 is a program component whose behaviour is specified by an event-driven state machine and algorithms, associated with its states. A FB can have various types of input/output/internal variables. Function blocks can be composed into more complex structures: composite FBs, sub applications and applications. That makes them appropriate for representation of logical nodes.

In IEC 61850 data in a LN may have several attributes describing different features of the same data/data attribute. IEC 61499 has "structured data type" class that is intended to represent several characteristics of the same datum. We modelled the Common Data Classes defined in [8] (SPS, DPC and etc.) as structured data types of IEC 61499 (Figure 6).

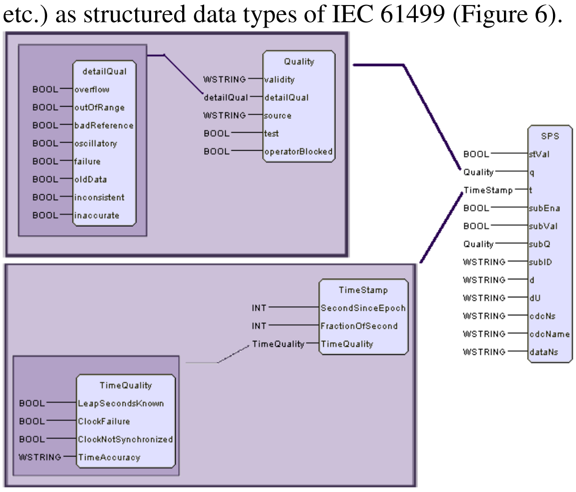

Figure 6. IEC 61499 implementation of Common Data Class (SPS).

The data attributes "q" and "t" represent quality (source of the data, is this data valid) and time stamp of data, for instance, "Loc" of circuit breaker LN - XCBR. In turn, data attribute "detailDual" of "q" and "TimeQuality" of "t" have their own characteristics defined in the "PACKED LIST" type in IEC 61850 and modelled in IEC 61499 as structured data types.

Logical node is described by the data of the Common Data Class and communication services operating over this data. The services are defined for categories of classes such as status information, controllable data, measurements, etc. Common data classes, belonging to the same category, have same services. However each data attribute has a functional constraint (FC) termed as *ST* (standing for *status information*) and this data is only allowed to be used in the *GetaDataValues* service. Thus Abstract Communication Services in this implementation are defined for structured data types, such as Common Data Class, common data attributes and packed list type. Also FCs can be taken into account at that level, so when reusing the data class and service, there is no need to pass FC as a parameter; instead it will be already counted by default according to the standard.

Different logical node types can be organized using the inheritance relation as in object-oriented programming. More complex nodes can inherit data and services from simpler ones and add new data elements and services.

In our IEC 61499 implementation a Logical Node type is implemented as a function block type (FBT), with services implemented as event inputs of this FBT. Parameters of the services can be implemented as input data of the function block associated with the corresponding event input denoting the service. Although there is no inheritance concept in function blocks, it may be useful to keep this relation additionally. It is actually quite easy to introduce this relation as a design time concept without any restrictions or extensions of IEC 61499.

The interface of database for the logical node is exemplified as a part of Figure 8, which represents the structure of the XCBR logical node, also typical for other LNs.

We have built a library of function blocks corresponding to the IEC 61850 Logical Nodes required for the running example scenario. Each LN is modelled as a composite function block that includes three main blocks as shown in Figure 8:

-DataBase, containing data and services of this LN,

-ServiceInterpreter that parses name of requested service of string type,

-Intelligence – the part responsible for decision making and negotiation with other LNs.

LN also may also contain HMI function block (not shown in Figure 8). DataBase and ServiceInterpreter are wrapped into the composite block called "*DB_ServiceInterface_XXX*", where XXX – is logical node's name like CSWI.

V. Intelligence and Control of Individual Nodes

In this section we discuss concepts for creating the "*Intelligence*" blocks which define behaviour of the distributed component and operate only within the boundary of responsibility area.

The Intelligence of the central control on coordinating all the components of the substation is distributed across these components. Instead of simple passing of all information to the higher level of hierarchy, the component makes decision by itself if the available information is sufficient and informs higher level about the results. The decision is made based on the information available, if the accessible data is not satisfactory to make a decision then the information is passed to higher levels and authority to decide is given to them.

Such empowering the low levels first **simplifies** the decision making algorithms as there is no need to decide for lower layers, as an obvious consequence the algorithms are more reliable and relatively easy to debug. The components become more independent within the operating area, the system is more reconfigurable without considerable changes in the operating algorithms.

At this stage of the research the following assumptions are made to simplify the collaborative algorithm.

1. Sectionalising switches can only be connected to one downstream and one upstream sectionalising switch.
2. Sectionalising switch can be connected to single downstream tie switch.
3. Tie switches can only be connected to upstream sectionalising switches (in total 2).
4. Overcurrent relay can be connected to one downstream overcurrent relay.

Primary equipment does not perform complex behaviour; it sets initial position, responses on request from bay level LNs, and make a simple decision based on information available, letting the upper layer know what decision has been made instead of transmitting data over the bus.

The bay level LNs are distributed and need to interact to neighbours to estimate situation and make a decision. They require more "complex" intelligence.

As it was mentioned before there are ***sectionalising*** switches and ***tie*** switches, they differ in their purpose in the scheme and as a result in the algorithm of their behaviour. The important difference is that sectionalising switches are to isolate faults, whereas tie switches are to find an alternative source of supply on request.

There are two layers in the bay level. The layer of PIOC LNs locates the fault, LNs within this layer "talk" to each other to determine fault position, and provides this information to upper layer. The upper layer consists of CSWI LNs, which collaborate to each other, and supply tie switches with necessary data for alternative supply evaluation.

CSWI Intelligence (sectionalising switch)

CSWI has two modes of operation: normal state and fault state. When the section where a switch is located does not have fault the switch is operated in normal state. This applies even if there is a fault in another part of distribution network. It moves to fault state if alternative supply has been restored. CSWI moves to the fault state if the responsibility area has a fault. Figure 7 demonstrates the concept. Initially the CSWI is in the normal state. Once PIOC announces "LOCKOUT" to the connected CSWIs those switches move to fault state, or if the tie switch has been commanded to restore supply then this switch closes itself and moves to the fault state. When fault has been repaired, substation is commanded to return to the pre-fault state.

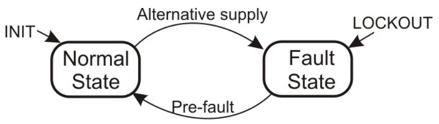

Figure 7. Algorithm defining CSWI intelligence

In normal mode a sectionalising switch only collaborates with upstream neighbour and the downstream tie switch. By request of the tie switch, the upstream sectionalising switches propagate headroom request signal and pass down the calculated headroom value (calculated according to the method given in [1]). By the “order” of the tie switch, upstream switches will be closed to allow supply restoration or to be returned to the normal state.

In fault mode a sectionalising switch only talks to downstream neighbours and the tie switch. In this mode any action and events related to headroom calculation are ignored. The switch which has fault on its sector of the feeder will isolate the fault by opening the adjacent downstream switch and controlled switch, and informs adjacent downstream switch that the fault is isolated. The switch that does not have fault, after the fault is being isolated, will initiate search for and restore alternative source of supply.

CSWI Intelligence (tie switch)

Tie switch collaborates with both upstream neighbour sectionalising switches. One of the sectionalising switches sends request for alternative supply and the tie switch “negotiates” about supply restoration. The other sectionalising switch replies to enquires about excess capacity. Based on this data the tie switch decides to “offer” supply to the requesting sectionalising switch or not.

PIOC Intelligence

PIOC layer is supposed to detect and locate the fault and provide related information corresponding CSWI and propagate *LOCKOUT* signal. It senses the current with defined frequency and applies predefined rules to detect the fault. If monitored current was in the acceptable limits before supply was stopped then there is no fault on its sector of the feeder. If the fault detected it provides this status information. It keeps the pre-fault value of the current It collaborates with neighbour PIOC, requesting fault status. Based on the data obtained decides whether the fault on its section or section below. It triggers PTRC Op.general data if there is a fault.

TCTR Intelligence

The purpose of TCTR is to sample the current and provide the samples to the PIOC.

PTRC Intelligence

PTRC sees the Op.general has been triggered and issues trip signal (Tr.general) to corresponding switch controller.

RREC Intelligence

OpOpn.general data of RREC is triggered by CSWI in case of fault. This makes RREC move to “fault” state, where it performs preconfigured behaviour. The behaviour is simply timer, when it is expired RREC tries to reclose XCBR, The shot is usually in the 1-2 seconds limit. If the attempt fails, RREC goes to lockout state. It restores to normal state by the “restore predefault state” signal.

VI. Testbed and Description of Tests

To validate the developed function block model of our running example system we created a testbed combining a function block execution environment with a model of the “uncontrolled substation” in Matlab as shown in Figure 9.

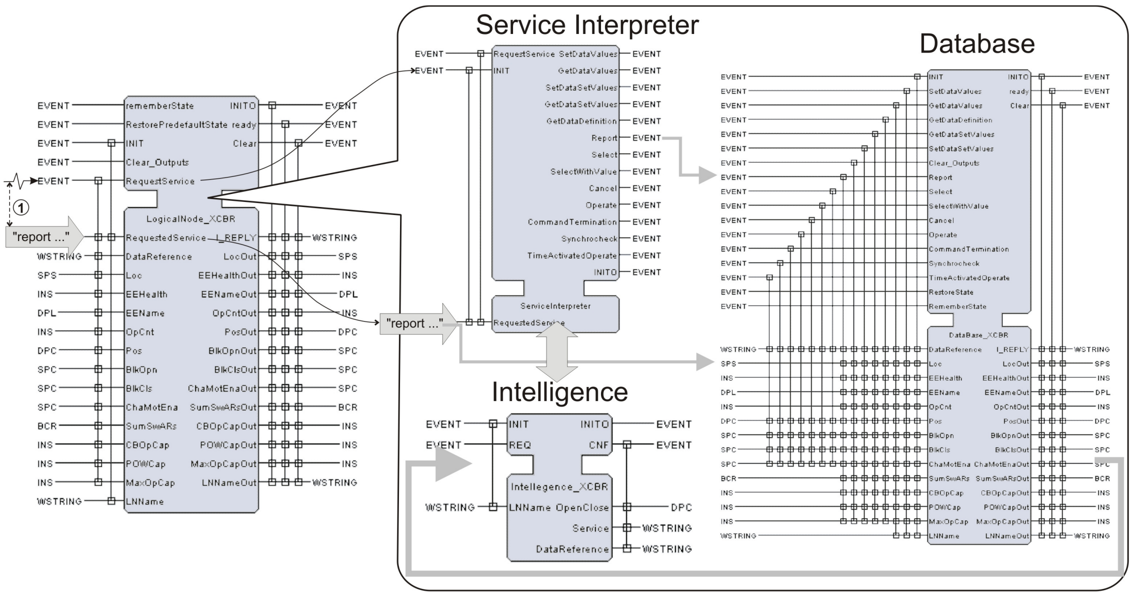

Figure 8. Generic structure of LOGICAL NODE that includes Service Interpreter, Intelligence and DB_ServiceInterface. Some interaction directions between the components are shown.

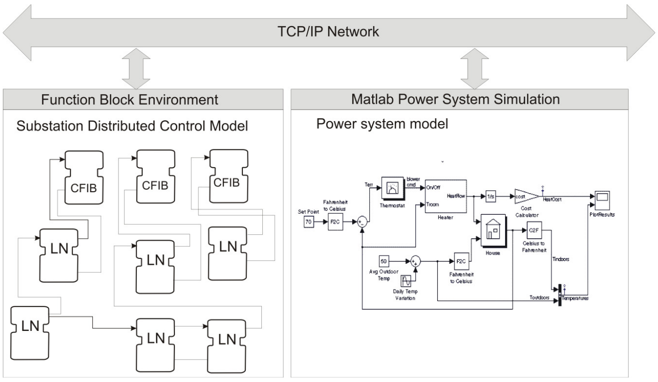

Figure 9. Testbed combining distributed control model in Function block environment (FBDK/FBRT) and uncontrolled substation model in Matlab.

Instruments' readings are sent to the controllers and control signals are delivered back to the substation model using TCP/IP communication channel. Thus, the testbed enables closed-loop control simulation and can be used for validation of the decentralized communicating multi-agent controllers. In real distribution networks the communication would be implemented with IEC 61850 communication methods sampled measured values, GOOSE and client/server. Several tests of increasing complexity were done to verify correctness of the designed collaborative control architecture and algorithms.

The test scenario 1 (Figure 10) includes working of two sectionalising CSWI with "manual" control. Two switches (CBR 1 – here XCBR 1, ROS1 – here XCBR 2) are sectionalising switches (here circuit breaker considered as a switch). CB1 (XCBR1) does not have downstream tie switch. Both receive "LOCKOUT" signal indicating the fault on the feeder. Both are informed by corresponding PIOC that fault has been located. XCBR1 is informed about fault on its section. It isolates the fault and stays in *FaultIsolated* state. XCBR 2 requests search for alternative supply and gets information that there is enough capacity (from tie switch). It isolates its own section and moves to alternative supply state.

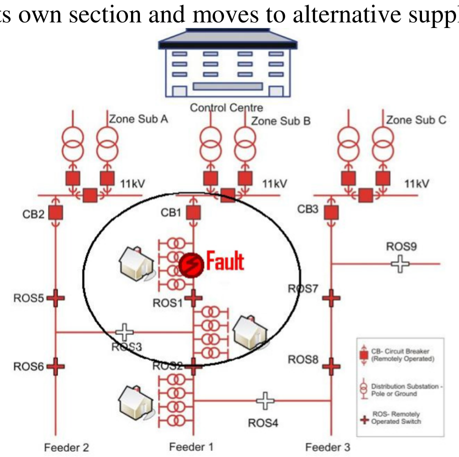

Figure 10. The place of the tested switches in the sample scenario.

Figure 11 illustrates the log of the test scenario running in the testbed. The function block system generates HMI panel with buttons corresponding to the events, such as LOCKOUT. At this stage, the control decisions are also entered from the HMI, but the communication between two switches goes completely via the IEC 61850 stack.

This and other similar simple tests validate the operation of the function block implementation of the IEC 61850 architecture. Subsequent tests also validated the "intelligence" part of logic nodes.

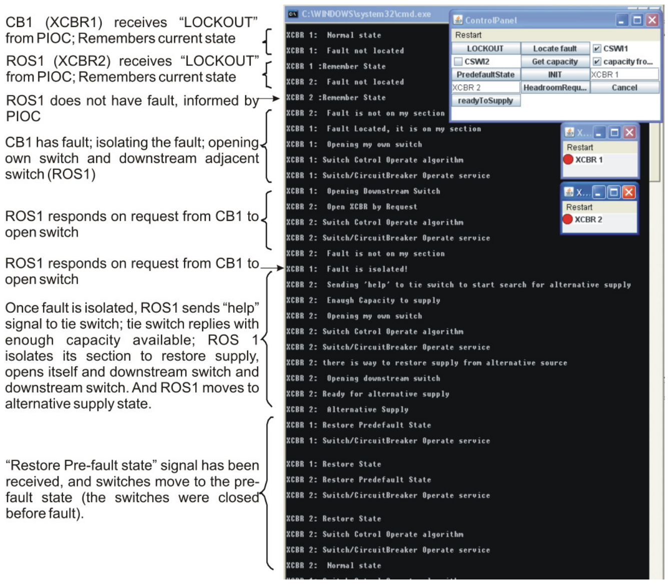

Figure 11. Log of the running substation model in the testbed of FBDK and Matlab.

VII. Conclusion

The function block implementation of the IEC 61850 model of power transmission and distribution systems has several immediate benefits. It allows adding intelligence to the logical nodes in function blocks sitting beside the function blocks implementing standard LN functions.

The function blocks language and the created testbed allow immediate simulation of the distributed intelligent control of the whole utility. After the simulation, the function blocks can be deployed to the corresponding instruments without changes. This approach combines the benefits of both standards and allows for a high level of function interoperability (IEC 61499) and communication interoperability (IEC 61850).

VIII. References

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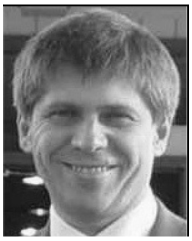
IX. BIOGRAPHIES



Valeriy Vyatkin (SM'04) graduated with a Diploma degree in applied mathematics in 1988, received the Dr. Sci. degree in 1998, the Ph.D. degree in 1992 from Taganrog State University of Radio Engineering (TSURE), Taganrog, Russia, and the Dr. Eng. Degree from the Nagoya Institute of Technology, Nagoya, Japan, in 1999. Currently, he is Senior Lecturer at the Department of Electrical and Computer Engineering at the University of Auckland, Auckland, New Zealand. His previous faculty positions were with Martin Luther University of Halle-Wittenberg in Germany (Assistant Professor, 1999–2004), and with TSURE (Senior Lecturer, Professor, 1991–2002). He is Program Director of Software Engineering and the Head of the infoMechatronics and IndusTRial Automation lab (MITRA). His research interests are in the area of industrial informatics, including software engineering for industrial automation systems, distributed software architectures (e.g. IEC 61499), multi-agent systems, methods of formal validation of industrial automation systems, and theoretical algorithms for improving their performance.

Gulnara Zhabelova attained the Bachelor in Mechatronics and Robotics degree in 2006, followed by the Master in Automation and Control completed in 2008, both degrees were completed in Karaganda State Technical University, Kazakhstan. Currently she is studying towards a Master's degree in Computer Systems in the University of Auckland, New Zealand.

Neil Higgins is a Senior Systems Development Engineer with ENERGEX. His duties include technology roadmapping, and the evaluation and introduction of new network technologies, especially those with a significant ICT component. Neil has worked with the ENERGEX, SEQEB and the Brisbane City Council Department of Electricity. His background includes Substation Design, Substation Circuitry, Protection, SCADA, Distribution System Automation, Distribution Management Systems, and Information Technology. Neil graduated with First Class Honours in Power Engineering from the University of Queensland in 1976.

Karlheinz Schwarz is president of Schwarz Consulting Company, SCC; Karlsruhe/Germany, specializing in distributed automation systems. He is involved in many international standardization projects (IEC 61850 – utility automation, DER, hydro power, IEC 61400-25 – wind power, IEC 61158 - Fieldbus, ISO 9506 – MMS, etc.) since 1984. He is engaged in representing main industry branches in the international standardization of real-time information modelling, configuration, and exchange systems. He provides efficient consulting services and training to utilities, system integrators, consultants, and vendors. He has trained some 2,000 experts from more than 350 companies in more than 50 countries. Mr. Schwarz is a well-known authority on the application of mainstream information and communication technologies in the utility industry.

Nirmal-Kumar C Nair received his BE in E.E. from M.S. University, Baroda, India and ME in E.E with specialization of High Voltage Engineering from Indian Institute of Science, Bangalore, India. He received his Ph.D. in E.E. from Texas A&M University, College Station, USA. He has held several professional, teaching and research positions. Presently, he is a Senior Lecturer at the Department of Electrical & Computer Engineering in University of Auckland, New Zealand. His current interest includes power system analysis, protective relaying & optimization in the context of electricity markets and integration issues of DG/renewable sources into bulk power system.
Dr. Nair is currently the Chair & Student Branch Counselor for IEEE New Zealand (North) Section. He is also currently the Vice-Chair of PES Life Long Learning Subcommittee and is also active in several working groups and Technical Task force of PES Committees.