Standards-enabled Smart Grid for the Future EnergyWeb

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***Abstract*—An intelligent control architecture for the Smart Grid is proposed which combines two recently developed industrial standards. The utility network is modelled as IEC 61850-compliant logical nodes, embedded in an IEC 61499 distributed automation framework. We make the case that an incremental approach is required for the transition to the future EnergyWeb by bringing intelligence down to the level of substation automation devices to enrich the applications that can be created using interoperable Smart Grid devices. Using Matlab-based simulation environment we demonstrate that the collaborative environment achieves self-healing through simple fault location and power restoration.**

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

I. Introduction

The Smart Grid is expected to have robustness, adaptability, self–healing and self–protective capabilities to support highly dynamical networks of power producers and consumers (*prosumers*), Figure 1 through advanced Information Communication Technologies (ICT) infrastructures [3], incorporating 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" [1].

New architectural concepts for the ICT enabled Smart Grid have recently been proposed, e.g. EnergyWeb [2] and eNetworks [3]. The EnergyWeb concept is envisioned as a multi-layered large scale socio-technical system (Figure 1), in which the traditional distinction between producers, distributors and consumers of energy is replaced by the new role of *prosumers*, i.e., industries, cities, communities or individuals who can act both as producers and consumers of energy. Prosumers will become part of a global socio-ICT "ecology", in which they can negotiate the energy they produce and consume. They will obtain direct financial benefits while promoting at the same time the growth of renewable energy sources. In alignment with this vision, the eNetworks concept tackles the Future Internet as a pervasive infrastructure [4] enabling the deployment of techno-social systems which have three dimensions **physical** (or 'smart application' dimension: smart power grid, transportation network, building infrastructures, computing facilities), **cyber** (the underlying large scale management ICT control infrastructure) and **social** (the users and their ability to form dynamic coalitions mediated via a communication network).

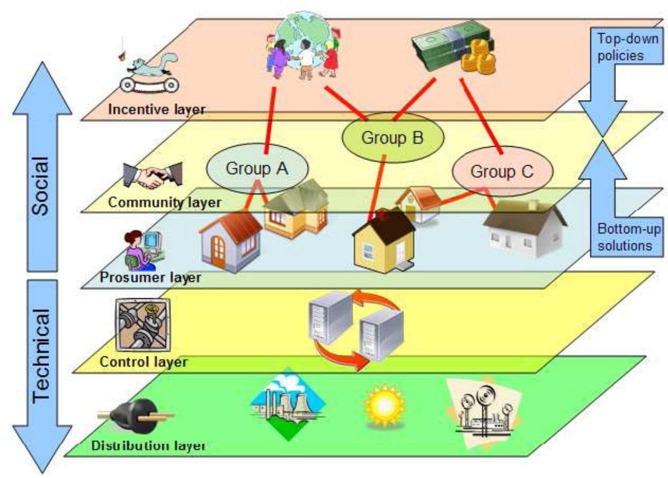

Figure 1. Multilayered EnergyWeb vision [2].

Since energy consumption by users and energy production by renewable energy sources are by nature unpredictable, utilization of the energy produced can be optimized by applying the idea of self-organization at the control level [14], influenced by the social network resulting from real-time involvement of prosumer communities in the operation of the grid. It can be based on persuasive incentives stimulating collaboration and facilitating socially flavored interactions with positive effects that target a carbon-free economy.

The interweaving of physical, cyber and social systems is expected to have a large impact on the future EnergyWeb. In this sense, conceptually it shares many common points with related problems that have received considerable attention in the domains of wireless sensor networks (WSNs) and sensor-

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actor networks (SANETs). In these fields, different clustering strategies (hierarchical, distributed, bio-inspired, etc.) have been employed to help organize large-scale unstructured networks of small devices into well-defined geographical groups that optimize resource allocation to save time and energy [5].

The unprecedented complexity resulted from the multitude of interactions between the participants even within a single technical layer calls for large scale management techniques that challenge traditional engineering methods [6]. Lessons learned from biology [9] have recently been found very useful in managing the complexity of the plethora of competing and collaborating autonomous self-configurable units, similar to natural ecosystems where the balance between production and consumption of resources is achieved and maintained as a result of competition between populations.

This trends are aligned with the successful investigations of holonic control in the last two decades [7] paradigm that has been applied to various automation applications including the Smart Grid [6]. Holonic systems are characterized by autonomy, self-organization and low-level redundancy, which recently proved to be successfully implementable via new bio-inspired design patterns [2]:

- Phylogeny: design for evolution. Phylogenetic mechanisms can be embedded in the systems' fabric by including evolutionary properties in the system components (so that they behave as "artificial organisms"), and engineering suitable environmental pressure, through comparison with the expected behavior.
- Ontogeny: design for development. Ontogenetic mechanisms (in particular: embryogenies [7]) can be effectively used for ensuring extreme resilience and robustness in distributed systems.
- Epigenesis: design for learning. It relies on extensive interactions with the environments. The most well–known examples of artificial epigenesis are given by artificial neural networks and artificial immune systems.

As enticing such perspectives may be, at the moment their implementation remains but a big promise given the constraining reality of the power distribution infrastructure which is currently engineered and commissioned following thousands of regulations and standards. There is a seemingly insurmountable gap between holonic multi-agent control envisioned in some of the Smart Grid proposals [10], [11] and the state of the art, as situation is exacerbated by the huge imposts of safety requirements and other domain specific standards and practices which simply block any attempt to innovate. It is frustrating to have available technologies, [8],[9] and not be able to use them to improve grid automation simply because the existing control devices are based on proprietary hardware/software platforms.

One important concern regarding the sophisticated multi-agent controls stems from their inability to deliver sufficient real-time performance and determinism even on top-end hardware. While multi-agent controls require powerful workstations to run, practitioners in the field are very conservative and protective of the status quo, insisting on high reliability and determinism for microprocessor-based relays and controllers. Indeed, it is undeniable that the operation of a vital infrastructure such as the power grid reliable communication is crucial and interoperability amongst Intelligent Electronic Devices (IEDs) is of paramount importance. To facilitate the adoption of intelligent multi-agent solutions at the transmission and distribution layers of the Smart Grid demands an open architecture for the next generation of IEDs, based on industrially accepted standards in the areas of information, configuration, communication and distributed automation [1]. In alignment with these requirements, our work proposes an innovative integration of the IEC 61850 and IEC 61499.

The IEC 61850 standard (Communication networks and systems for power utility automation) [10] refers to substation information, information exchange and configuration aspects mainly for protection, control and monitoring. While the automation functions that produce and consume the exchanged information are outside the scope of the standard. when it comes to the future Smart Grid envisioned as a truly intelligent, self-healing distribution network [11] the core operational principles must be built on centralized and distributed automation functions to enable the necessary "plug-and-play" self-reconfiguration, "self-awareness" in various forms, and collaboration between subsystems for achieve optimum performance and natural scaling with minimum risk [3]. Subject to the availability of pervasive communications, we suggest that this behavior can be achieved with a distributed automation architecture provided by the IEC 61499 standard [12] which describes a general purpose *Function Block* architecture for industrial process measurement and control systems. A Function Block is a software unit (or, more generally, an *intellectual property* capsule) that encapsulates some behaviour. The standard provides a framework for gluing functions together in patterns of increasing capability and complexity. We believe that the resulting ability to customise control and automation logic will greatly enhance the flexibility and adaptability of automation systems, speeding progress toward the Smart Grid.

In [6, 13] we have proposed ideas for a Smart Grid ICT architecture that is based on a combination of these proven industry standards. In [14] we have discussed in detail the methodology of implementing the IEC 61850 data model by means of IEC 61499. This would replace the current stiff hierarchical structure of centralized decision-making with the decentralized flexibility and open nature of IEC 61499 seamlessly endowing the architecture with bio-inspired control patterns. However to realize this vision, in turn requires a revolution in how IEDs are designed, to accommodate a network approach [3] that enables horizontal communication, negotiation and collaborative decision making. Most advanced versions of such devices are currently based on microcomputers with communication capabilities, but the architectural focus – a legacy of current SCADA systems – is on the bottom-up flow of the data, from IEDs to the control centre, and the top-down flow of control (from the control centre to IEDs).

This paper extends the proposed ICT architecture from [13, 14] by focusing on the following research questions:

- How can distributed intelligence help to achieve such characteristics as self-healing [11]?
- How can this intelligence be defined/organized?
- How can it co-exist with fully deterministic control and protection behavior?
- How can IEC 61499 help in achieving bio-inspired design and behavior?
- How to expand the Cyber-Physical aspect of the Smart Grid with the social layer and communities of prosumers to achieve a *socially smart* ICT component that targets a preset and/or dynamically changing goal set (e.g. carbon footprint, lifestyle aspirations, etc)?

The rest of this paper is organized as follows:

In Section II we present the description of our case study example and discuss distribution of control functions across instruments equipment. Section III briefly describes the benefits of an IEC 61499-based function block architecture. Section IV presents the idea of embedding the IEC 61850 architecture within IEC 61499. Section V provides details of the intelligent functions of logical nodes, and section VI describes the tests conducted. The paper concludes with a brief outlook and a list of references.

II. Illustrative Example: a FLISR Scenario

As illustrated in Figure 2, the distributed grid control infrastructure will be connected with the households' control infrastructure. It is envisaged that homes will be equipped with interoperable sensor networks and smart appliances all integrated by a control device with broad internal and external connectivity. Single households may form clusters in order to optimize their overall power usage, as per Figure 1Figure1.

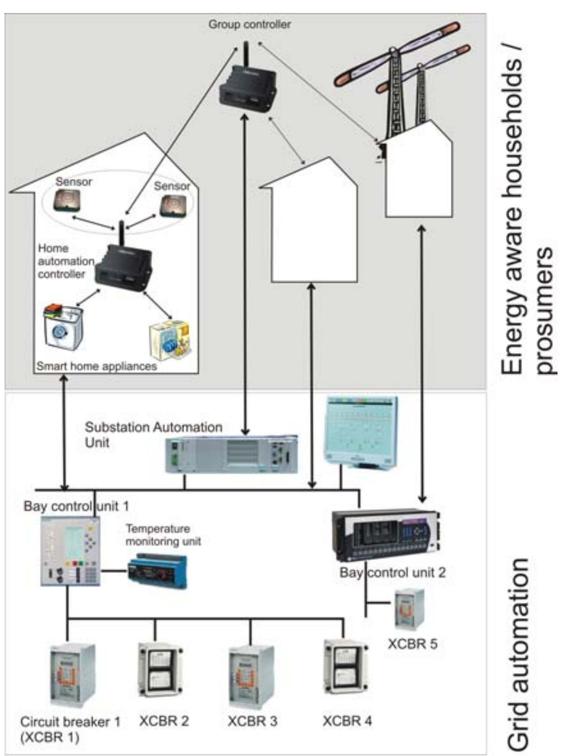

Figure 2. Intelligent Electronic Devices involved in the EnergyWeb at the household layer and distribution layer.

We will use a simple case study of a fault location, isolation and supply restoration (FLISR) scenario to illustrate the use and working of the proposed architecture. The choice of this running example is justified by the report [1] that outlines one crucial function of Smart Grids to be 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." In the reported work we have been following the FLISR scenario from [6] related to the distribution network in Figure 3.

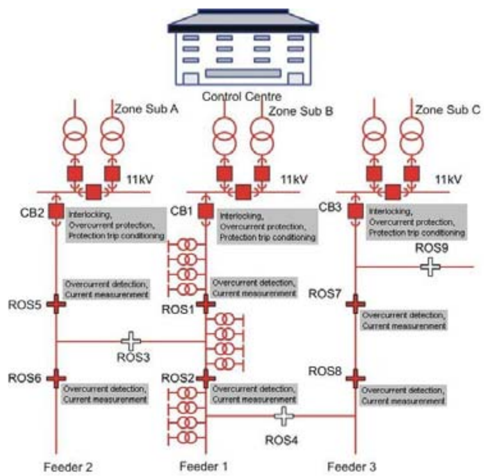

Figure 3. Sample power distribution utility, intelligent distributed control functions are allocated to the equipment.

The distribution utility consists of three 11kV feeders supplied by three different zone substations. The 11kV feeders are shown in a 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 demanded by customers' loads.

In the initial state the switches ROS3, ROS4 and ROS 9 are open, as denoted by their light 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 between CB1 and ROS1. The feeder protection trips 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 a "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 fault-free 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.

Control functions are allocated to the utility's equipment as illustrated in Figure 3 and described as follows:

1. Protection (overcurrent): PIOC LN
2. 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 load break switch: XSWI LN
7. Control of load break switch: CSWI LN
8. Current measurement: TCTR LN.
9. Interlocking: CILO LN.

We have represented the utility network in terms of the IEC 61850 architecture, i.e. as *logical nodes*. At the process level, circuit breaker, switch and current transformer are used, and at the bay level there are substation automation functions monitoring and controlling primary equipment and the substation itself.

The IEC 61850 logical node type XSWI represents load break switches; XCBR represents circuit breakers; and TCTR represents current transformers. These are information models of primary devices. Switches are categorised into two types: sectionalising switches and tie switches, differing in purpose. Feeders are divided into sections by sectionalising switches, so it is easier to locate and isolate faults. Feeders are interconnected by tie switches. Sectionalising switches are used to isolate faults; tie switches are used to restore supply to fault-free sections.

CSWI denotes control functions for switches and circuit breakers. CSWI performs opening and closing functions based on information provided by the protection LNs.

CILO denotes interlocking functions for switches; in this project all interlocking is implemented at the bay level.

PIOC represents an overcurrent relay, which detects the fault and gives a signal to trip XCBR.

PTRC denotes protection trip conditioning located between the "operate" output of PIOC to the "trip" input of XCBR.

RREC represents the autoreclosing function.

Process level functions

XCBR and TCTR are simple LNs, representing device-specific data and providing services as defined in the standard.

XCBR provides status information, and changes its position on command from the control LN.

As mentioned in [15] a "smart" CT can transmit data, and any other device can use the data as needed. In this project, the current transformer TCTR senses the current and sends sampled values to the PIOC.

Bay level functions

The bay level functions are divided into 3 layers and interlocking. The first layer is provided by intelligent protective relays, in this case overcurrent relays (PIOC). The function of this level is to locate the fault. Once RREC goes to lockout and the *LOCKOUT* signal is transmitted, the PIOCs start to collaborate in order to locate the fault. The fault detection and reclosing functionality of this layer is depicted in more detail in Figure 4 and explained later in this section.

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

Tie switches in the third layer get a request for alternative supply, initiate the search for excess capacity, make a decision as to whether or not the excess capacity is enough to power up the load, and then offer it to the requesting section.

Interlocking is bay level interlocking: it checks whether a requested switch operation (open/close) violates network constraints and gives permission to operate if it does not.

Station level functions

The operator sends the "go back to pre-fault configuration" command after a permanent fault has been repaired.

Figure 4 illustrates interaction of PIOC, PTRC, RREC and CSWI logical nodes and signals they use.

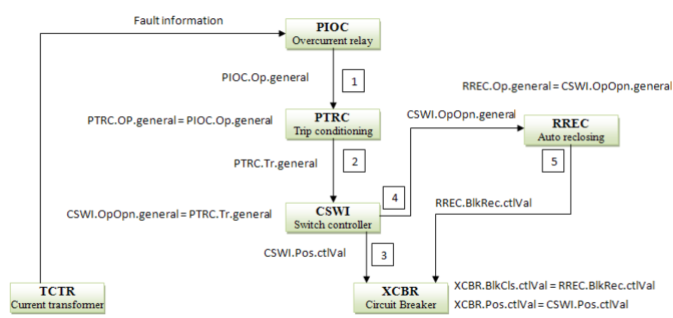

Figure 4. Fault detection and reclosing scenario and LNs involved

TCTR continuously transmits the current value (Amp.instMag). PIOC compares it to the set value PIOC.Str.setMag. If the current is higher than the set value then this indicates a fault. The steps are as follows:

1. A trip signal (PIOC.Op.general) is sent 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." ([16], p. 30].

2. When PTRC sees that PTRC.Op.general is triggered, it issues a trip signal (PTRC.Tr.general) to the switch controller CSWI.
3. CSWI notices that OpOpn.general has been triggered; it issues a command to open XCBR.
4. CSWI sends the same signal to RREC.
5. In accordance with the configured behavior, RREC decides to reclose the circuit breaker and sends RREC.BlkRec.ctlVal to XCBR. XCBR closes. After one attempted automatic reclosure, XCBR goes to lockout, which indicates that a permanent fault has been detected. On receiving the *LOCKOUT* signal, PIOCs start to locate the fault.

The standardised information is exchanged by means of the services defined in the IEC 61850 standard; the data like headroom and fault location used by the intelligence added in this work use services offered by Function blocks (implemented by events and associated data).

III. Benefits of the Open Function Block Architecture

The open function block architecture of IEC 61499 can help to achieve the properties of bio-inspired grid control. Intelligent electronic devices can be built “on top” of standard Programmable Logic Control (PLC) devices or Remote Terminal Units (RTUs) by adding function block libraries as shown in Figure 5.

The internal architecture of such controllers will be customisable during their life-cycle, thus providing for implementation of bio-inspired design patterns such as *design for learning, development and evolution.*

Moreover, validation of the control and automation functions will be possible by simulation of the corresponding function block applications, taking into account the structure and logic of the whole substation.

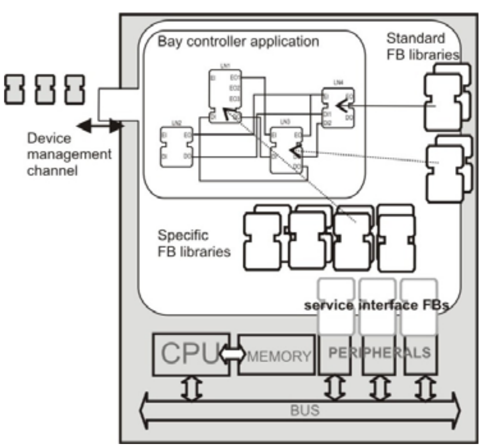

Figure 5. Domain-specific controller obtained from the IEC 61499-compliant controller by adding specific libraries of function blocks.

In terms of IEC 61499, the distributed utility control is represented as a system composed of a number of devices as illustrated in Figure 6. For simplicity, at this stage we have grouped the functions related to each feeder to one device, and implemented IEDs as resources in the IEC 61499 terminology.

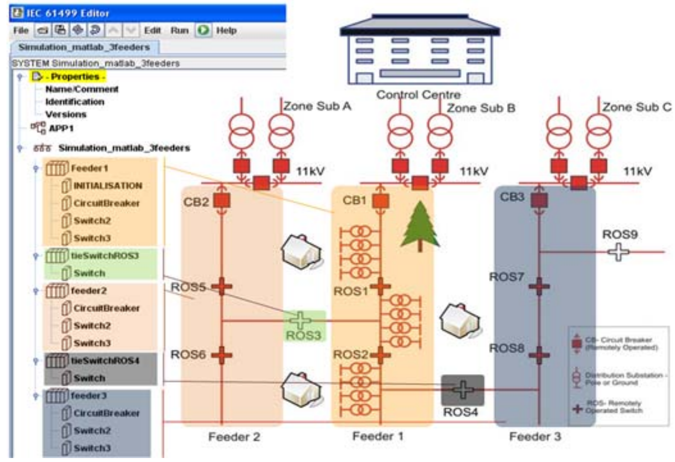

Figure 6. Distributed devices (in IEC 61499 terminology, left side) implement IEDs (in IEC 61850 terms, right side).

IV. Intelligence and Control of Individual Nodes

In this section we discuss concepts for creating the “*Intelligence*” blocks which define the autonomous behaviours of the distributed component.

The (previously centralised) intelligence for coordinating all the components of the substation is now distributed across these components. Instead of simply passing of all information to the next level of hierarchy, each component makes a decision by itself as to whether 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.

This decentralization empowering the low levels **simplifies** the decision making algorithms while giving more independence to the components and makes the system more flexible and more easily 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. A sectionalising switch can only be connected to one downstream and one upstream sectionalising switch.
2. A sectionalising switch can be connected to a single downstream tie switch.
3. A tie switch can only be connected to two upstream sectionalising switches.
4. An overcurrent relay can communicate with one downstream overcurrent relay.

Primary equipment does not perform complex behaviour; it sets initial position, responds to requests from bay level LNs, and makes simple decisions based on the available information, 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 with their neighbours to analyse the situation and make a decision. They require more “complex” intelligence.

As mentioned previously, there are ***sectionalising*** switches and ***tie*** switches, which differ in their purpose in the scheme and as a result in their behaviour algorithms. The important difference is that sectionalising switches are used to isolate faults, whereas tie switches are used 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 the fault position, and provide this information to upper layer. The upper layer consists of CSWI LNs, which collaborate with each other, and supply tie switches with data necessary 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 the normal state. This applies even if there is a fault in another part of distribution network; however the switch moves to the fault state if it is involved in the alternative supply restoration process (Figure 7). When the feeder that the switch belongs to has a fault, then the switch moves to the fault state. Figure 7 demonstrates the concept. Initially the CSWI is in the normal state. When PIOC replicates the *LOCKOUT* signal received from RREC to the connected CSWIs, those switches move to fault state; also when the tie switch has been commanded to restore supply. When the fault has been repaired, the substation is commanded to return to the pre-fault state.

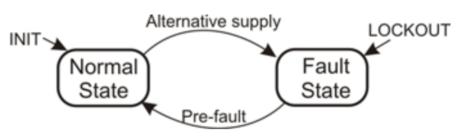

Figure 7. Algorithm defining CSWI intelligence

In normal mode a sectionalising switch only collaborates with its upstream neighbour and the downstream tie switch. By request of the tie switch, the upstream sectionalising switches propagate a headroom request signal and pass down the calculated headroom value (calculated according to the method given in [1]).

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

CSWI Intelligence (tie switch)

A tie switch collaborates with both upstream sectionalising switches. One of the sectionalising switches sends a request for alternative supply and the tie switch "negotiates" about supply restoration. The other sectionalising switch replies to enquiries about excess capacity. Based on this data the tie switch decides whether or not to "offer" supply to the requesting sectionalising switch.

PIOC Intelligence

PIOC detects and locates the fault, provides related information to the corresponding CSWI, and propagates the *LOCKOUT* signal. It triggers PTRC.Op.general data if there is a fault on the feeder. If there is a permanent fault, RREC goes to lockout and sends the *LOCKOUT* signal to PIOC, which replicates the *LOCKOUT* signal to let the downstream switches know about permanent fault somewhere on the feeder and initiate fault location algorithm. It senses the current with defined frequency and applies predefined rules to detect the fault. If monitored current was within acceptable limits before supply was interrupted then there is no fault on its section of the feeder. If a fault is detected it provides this status information. It keeps the pre-fault value of the current. It collaborates with the downstream PIOC, requesting fault status in order to locate the fault. Based on the data obtained it decides whether the fault is on its section or the section below.

TCTR Intelligence

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

PTRC Intelligence

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

RREC Intelligence

The OpOpn.general input of RREC is triggered by CSWI in case of a fault. This makes RREC move to "fault" state, where it performs preconfigured behaviour. The behaviour is simply a timer; when it expires RREC tries to reclose XCBR. If the attempt fails, RREC goes to the lockout state. It is restored to normal state by the "restore pre-fault state" command.

V. SIMULATION TESTS

To validate the function block model of our example system we have created a test bed by combining a function block execution environment with a model of the "uncontrolled substation" in Matlab.

Measurements are sent to the controllers and control signals are delivered back to the substation model using a TCP/IP communication channel. Thus, the test bed 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 the IEC 61850 communication methods sampled measured values, GOOSE and client/server.

Several tests of increasing complexity were done to verify correctness of the collaborative control architecture and algorithms.

Figure 8 illustrates the operation of two sectionalising switches (CB2, ROS5) in a test scenario (in this case circuit breaker considered as a switch). The fault is on the adjacent feeder. The switches operate in the normal state and respond to a request from tie switch ROS3 for available headroom.

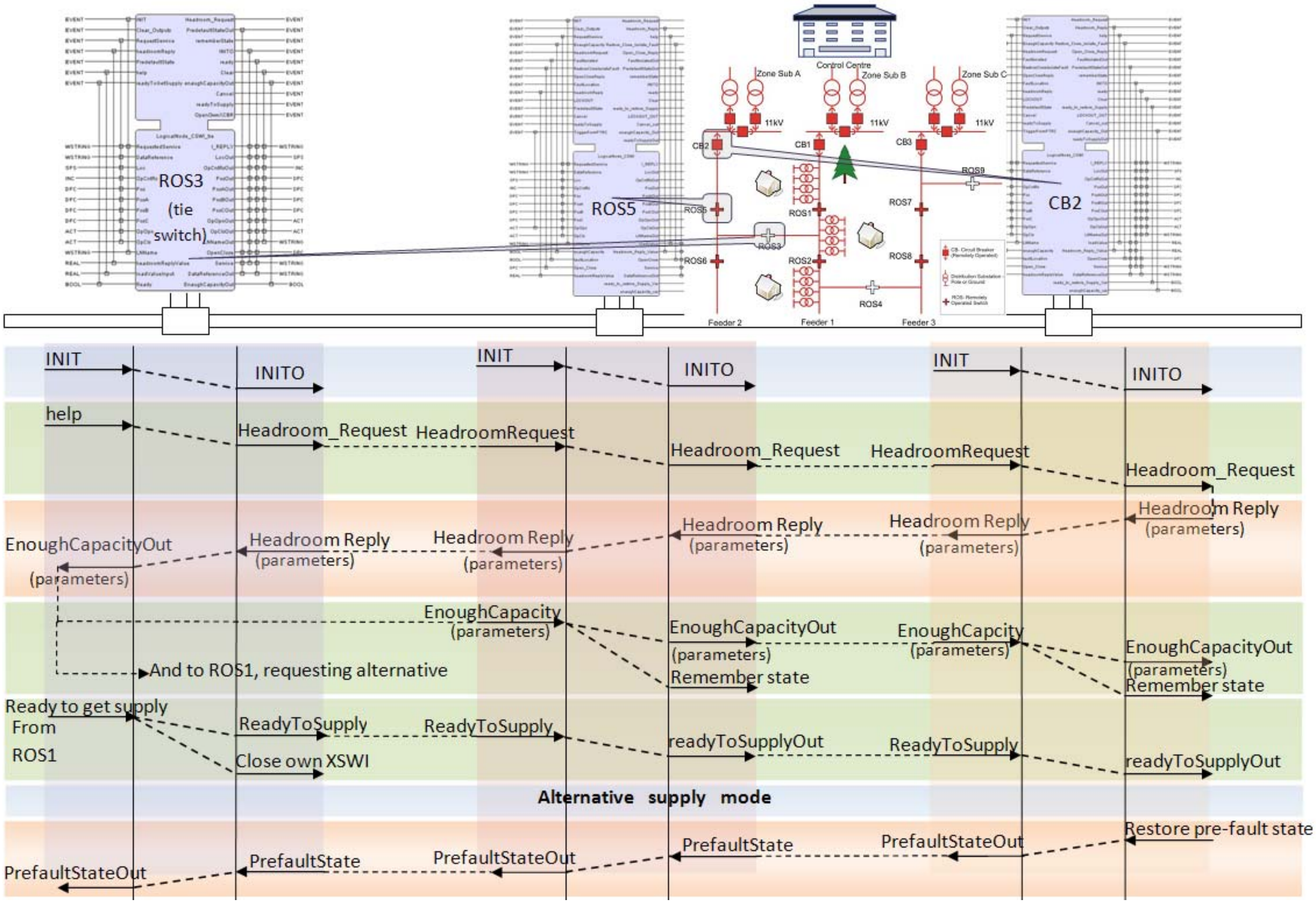

Figure 8. Alternative supply search: trace of the negotiation between logical nodes.

ROS5 receives the request and propagates it upstream. The upstream switch would normally propagate the same signal upstream again, but since it does not have an upstream switch the signal is looped. A receiving switch calculates the headroom available at its location and propagates the information downstream. The downstream switch gets the headroom value, uses it to calculate headroom available at its location and sends it to the tie switch. The tie switch compares values and decides whether there is available capacity. The result is sent to the switch which requested alternative supply. After the tie switch gets acknowledgement to restore supply, it sends a command to the adjacent upstream switch to move to the alternative supply state. The “restore pre-fault state” command moves switches to the normal state.

The communication between the switches goes completely via the IEC 61850 stack. The lower part of the figure shows the trace of events and message passing history between the FBs implementing LNs during the negotiation.

This and other similar tests validate the operation of the function block implementation of the IEC 61850 architecture and prove feasibility of distributed Smart Grid control.

VI. Conclusions

In this paper we have demonstrated that self-healing of Smart Grid can be achieved via distributed intelligent control in a multilayered ICT architecture combining IEC 61850 interoperable communication and IEC 61499 distributed control. Other intelligent functions possibly can be easily added. The developed architecture simplifies adding intelligence to logical nodes as an extra layer extending the capabilities of substation automation devices and not interfering with their safety-critical functions.

The function blocks language of IEC 61499 and the test bed that we have created allow immediate simulation of the distributed intelligent control scheme. After the simulation, the function blocks can be deployed to the corresponding equipment 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). The proposed architecture can be easily expanded further with other intelligent functions.

Future work will be dedicated to the implementation of IED prototypes based on the combination of IEC 61499 and IEC 61850 as well as to extending the framework by adding the intelligence required to combine energy production and consumption in micro-Grids. Further we plan to investigate measures of success that will support decision makers on the path to adoption of these novel technological advances when taking the risk in transitioning from the current power infrastructure to the Smart Grid.

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VIII. 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.

Mihaela Ulieru (M’95–SM’02) received the M.Sc. degree in Electrical Engineering and Computer Science from Politehnica University, Bucharest, Romania, in 1985 and the Dr.-Ing. from the Control Engineering and Computer Science Department, Darmstadt University of Technology, Germany, in 1995. She was a Postdoctoral Fellow with the Intelligent Robotics and Manufacturing Systems Laboratory, School of Engineering Science, Simon Fraser University, Vancouver, BC, Canada, from 1996 to 1998 and Junior NORTEL Chair in Intelligent Manufacturing at the University of Calgary (1998-2000). Since 2005 she is Canada Research Chair, Professor and the Director of Adaptive Risk Management laboratory at the University of New Brunswick, Canada. Her research targets the design and implementation of adaptive information infrastructures fuelling tomorrow’s e-Society. Dr. Ulieru chairs several International R&D initiatives and was on the IEEE AdCom board of the Industrial Electronics Society, in charge of the emerging area of Industrial Informatics. Dr. Ulieru is a Member of the Science Technology and Innovation Council of Canada.

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.