A SURVEY ON ARCHITECTURES AND ELECTRIC ENERGY SYSTEMS

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Abstract : — In a micro grid (MG), an energy management control is essential in order to handle the variety of prime movers, which may include different types of renewable energy sources (RESs) and energy storage systems (ESSs).Their intermittent behavior and limited storage capabilities present a new challenge to power system operators to maintain power quality and reliability. Additional technical complexity arises from the large number of small distributed generation units and their allocation within the power system. Market liberalization and changing regulatory frame-work lead to additional organizational complexity. As a result the design and operation of the future electric energy system have to be redefined. Sophisticated information and communication architectures, automation concepts, and control approaches are necessary in order to manage the higher complexity of so called Smart Grids. This paper provides an overview of the state-of-the-art and recent developments enabling higher intelligence in future Smart Grids. The integration of renewable sources and storage systems into the power grids are analyzed. Energy management and demand response methods as well as important automation paradigms and domain standards are also reviewed. This paper introduces integrated research infrastructure that provides methods and tools for validating smart grid systems in a holistic, cyber-physical manner. The corresponding concepts are currently being developed further in the European project ERI Grid.

***IndexTerms* - Ancillary services, automation architectures, control concepts, demand response, demand side management, distributed generation, energy storage, inverters, micro-grid, Battery chargers, (PLS), voltage droop (VD) control.**

I. INTRODUCTION

Industrialization and economic development have historically been associated with man's ability to harness natural energy resources to improve his condition. Based on this definition, two industrial revolutions occurred in the 18th and 19th centuries, where natural resources such as coal (first revolution) and petroleum(second revolution) were widely exploited to produce levels of energy far beyond what could be achieved by human or animal muscle power. The electric energy systems worldwide have to satisfy a continuously growing demand for electricity and simultaneously provide a stable supply. Today, the world-wide power generation is dominated by fossil fuels resulting in an increase in CO2 emissions and global warming as indicated by the "World Energy Outlook 2013" from the International Energy Agency (IEA). In order to counteract, there is a clear trend towards a sustainable electric energy system. Minimizing greenhouse gas emissions caused by power generation will only be possible if renewable sources like photovoltaic systems, wind generators, biomass and combined-heat power systems, are being installed on a large scale. They are typically available in a decentralized way as Distributed Energy Re-sources (DER) [3]. Recent research results, technology developments, and regulatory alterations are fundamentally changing the framework conditions; the planning, management and operation of the power systems have to be redefined. This paper therefore discusses important automation architectures, smart devices, control concepts and energy management principles enabling intelligence, decentralization and robustness in the field of future electric energy systems as well as involved components. It provides a brief overview of the state-of-the-art, related work, important activities and achievements dedicated to Smart Grid systems and components.

II. LITERATURE SURVEY

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Sujan Adhikari et al. In the recent years, micro grid (MG) has been a promising solution for integrating distributed renewable energy resources, energy storages (ESs) and load in order to expedite the modernization of existing power system. This paper explores the interconnection of multiple micro grids with "tie-line". Tie-line control can be managed to control the power flow from micro grid and voltage at respective micro grid buses at the point of interconnection. Formation of such DC micro grid cluster ensures higher reliability of power supply and flexibility to manage distributed energy resources and loads in the system. Two identical MGs consist of photovoltaic (PV) and battery units interfaced by power electronic converters. The bus voltages of two identical DC microgrids act as indicator for the power flow monitoring the supply-demand balance. A decentralized control approach is proposed to control each micro grid and bus voltage fluctuation in allowable range.it is advantageous over traditional AC system due to the absence of frequency, phase and reactive power control in its operation.

Tomislav Dragiˇcevi´ et al. power supply of remote sites like telecommunication stations and data centers, where reliability and power quality are of great importance, is almost exclusively achieved with utilization of dc distribution. A particularly interesting concept is to resolve the power supply of these kinds of systems only using RES. The control structure that allows the application of this method is revealed, and the optimal range of operating PLS frequencies is specified. In order to achieve a zero steady-state error of injected signals in the common bus, primary control of batteries has been extended with dedicated proportional–resonant controllers that are switched on only during injection period. Finally, a method for coordination among the units using the PLS concept was developed and experimentally tested, confirming its applicability for autonomous LVDC MGs. In a micro grid (MG), an energy management control is essential in order to handle the variety of prime movers, which may include different types of renewable energy sources (RESs) and energy storage systems (ESSs).

Mahesh Kumar et al. The DCMG system can be designed for independently feeding remote rural areas. Nowadays, the pulse width modulation (PWM) based voltage source converters (VSCs) are being widely used to provide effective voltage control, power flow control, high-quality power conversion, system balancing, fault protection and maximum power point tracking of various DGs. The DCMGs consist of wind turbines, solar-photovoltaic systems, solid oxide fuel cell, micro-turbine generators, battery energy storage systems and varying DC and three-phase as well as single-phase alternating current loads. The proposed control strategy of the BDC is aimed at managing the bidirectional flow of power between the DCMGs to balance the power under various operating scenarios and fault conditions, while maintaining constant DC voltages of both the DCMGs. Simulations are carried out to verify the robustness of the proposed control strategy under different operating conditions including fault scenario.

Jianjun MA et al. In comparison with AC micro grid, DC micro grid requires lower number of power conversion stages and no frequency/phase control is needed. Due to above advantages, an increasing number of DC micro grids can be expected in future power system. Concept of utility grid interfacing multiple DC micro grids is illustrated in Fig.1, where each of the micro grids is designed and operated as a discrete entirety. Effect of parasitic resistance on voltage regulation in directly DC linked type of DC micro grids cluster is revealed. To compensate the effect and achieve controlled power exchange, DC micro grids cluster based on DC-DC interlinking converter and the corresponding control strategy is proposed. Operation of the proposed DC micro grids cluster is verified through numerical simulation.

Nima Nikmehr et al. The MG is operated in two grid-connected and isolated types. In grid-connected mode, the MG remains connected to the main grid either totally or partially, and imports or exports power from or to the main grid. In case of any disturbance in the main grid, the MG switches over to stand-alone mode while still feeding power to the priority loads. In this paper, future distribution network operation is discussed under assumption of multi microgrids (MMGs)concept. The economic operation of MMGs is formulated as an optimization problem. A stochastically and probabilistic modelling of both small-scale energy resources (SSERs) and load demand at each micro grids (MGs) is done to determine the optimal economic operation of each MGs with minimum cost based on the power transaction between the MGs and main grids. The balance between the total power generation in each MGs and the load demand is determined regarding the sold or purchase power either by MG or by main grid. Based on the results, the mean, standard deviation, and probability density function of each generated power with SSERs is determined considering optimization constraints. A statistical analysis for generated power and costs is given. The power interchange between MGs is considered. The particle swarm optimization is applied to minimize the cost function as an optimization algorithm.

Luis Eduardo Zubieta et al. The use of distributed resources to power local loads combined with the capability to operate independently of the ac grid makes micro grids a technically feasible option to address the concerns of sustainability, resilience, and energy efficiency. Furthermore, micro grids can operate while completely separated from the grid, representing a lower-cost option to provide electrical power to regions in developing countries where conventional ac grids are not available or are too unreliable. When connected to the ac grid, micro grids appear as controlled entities within the power system that, instead of being a burden to the ac grid power-management system represent a resource capable of supporting the grid. Energy storage as the element responsible for balancing generation with load is critical to the success of the micro grids concept, and it is more important as larger penetration of renewable resources is present in the micro grids.

T. I. Strasser et al. In addition, power system operators are nowadays confronted with further challenges due to the highly dynamic and stochastic behavior of renewable generators (solar, wind, small hydro, etc.) and the need to integrate controllable loads (electric vehicles, smart buildings, energy storage systems, etc.). Furthermore, due to ongoing changes to framework conditions and regulatory rules, technology developments (development of new grid components and services) and the liberalization of energy markets, the resulting design and operation of the future electric energy system has to be altered. This paper introduces integrated research infrastructure that provides methods and tools for validating smart grid systems in a holistic, cyber-physical manner. The corresponding concepts are currently being developed further in the European project ERI Grid.

III. THE FUTURE ELECTRIC ENERGY SYSTEMS

The large-scale implementation of DER from renewable sources during the last years fundamentally changed the design, planning and operation of the power systems in various regions (US, Europe, Australia, etc.). It becomes already visible in power transmission and distribution grids. System operators and utilities have to manage the fluctuating power generation from DERs as well as uncoordinated responses to changing conditions of the power grids. In a number of countries (Denmark, Germany, Italy, Spain, Australia, etc.) levels of renewables (photovoltaic, wind, hydro) have already exceeded the local power grid's hosting capacity resulting in power quality disturbances. Smart Grids are one of the most promising solutions to use the existing power gird infrastructure extended with proper ICT methods in a more efficient way, allowing higher penetration levels of DER.

A.Towards Active Power Grids

In the past the power system operation has been done mainly manually. The integration of DERs with smart power converters, the possibility to handle peak loads on the demand side as well as technology developments in energy storage systems together with advanced ICT solutions result in a higher automation degree as outlined in Fig. 1.

All components in the future Smart Grid flexible loads, energy storages, smart substations with On-Load Tap Changers (OLTC), DERs, metering systems, etc. are interconnected in addition to the power system with a corresponding communication and automation infrastructure. Together with proper control approaches and strategies a Smart Grid system can be implemented which allows monitoring, managing and optimizing the future electric energy grids as well as its components and users in a more intelligent manner exploring the AI principles

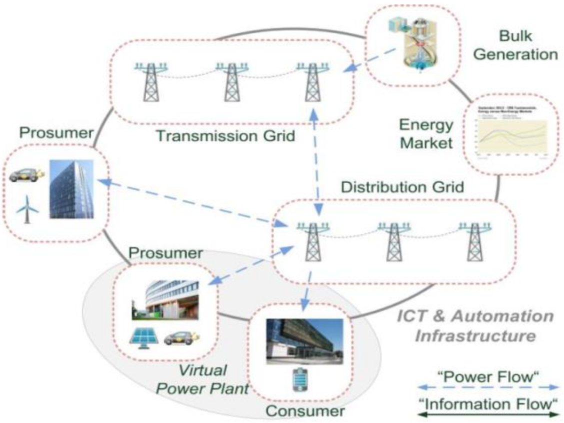

Figure1. Smart Grid vision: intelligent integration of all users/stakeholders.

B. Necessary Smart Grid Functions and Services

The management and operation of the future power system and its components especially active power distribution grids and micro grids require new and advanced control functions.

IV. Integration Of Renewable Energy Resources

Formation of such DC micro grids cluster ensures higher reliability of power supply and flexibility to manage distributed energy resources and loads in the system. Two identical MGs consist of photovoltaic (PV) and battery units interfaced by power electronic converters. In the recent years, micro grids (MG) has been a promising solution for integrating distributed renewable energy resources, energy storages (ESs) and load in order to expedite the modernization of existing power system .A stochastically and probabilistic modeling of both small-scale energy resources (SSERs) and load demand at each micro grids (MGs) is done to determine the optimal economic operation of each MGs with minimum cost based on the power transaction between the MGs and main grids. The most appropriate topologies, devices, control and modulation techniques are fundamental in order to fulfill grid codes/inter-connection rules and for avoiding the occurrence of instability or synchronization problems, faults and for obtaining high efficiency operations. However, the nonlinear behavior of PC causes the injection of harmonic distortions at the Point of Common Coupling (PCC).

To guarantee power quality at the input AC mains, harmonic standards and engineering recommendations must be also adopted to limit the level of distortion at the PCC.

Power converters topology plays a significant role in full integration of renewable energies with the electrical power grid. Nowadays, there is a significant trend of considering Multi Level Converter (MLC) topologies for new Smart Grid related projects. They basically consist of arrays of power semiconductors in series and/or in parallel, producing output voltage with discrete stair stepped waveforms. Typical topologies of MLC are diode-clamped or Neutral-Point Clamped (NPC), Active Neutral-Point Clamped (ANPC), capacitor-clamped or Flying Capacitor (FC), and Cascaded Multilevel Converters (CMLC).

V. Energy Systems Storage Integration

The addition of an energy storage system (ESS), such as a secondary (rechargeable) battery, is an option for maintaining the power balance continuously in small and autonomous systems. Regardless of internal technology, the price of the battery string generally plays an important part in the overall cost here, and special care should be therefore taken to preserve its lifetime. In that context, it is the best practice to implement charging methods proposed from battery manufacturers and avoid frequent deep discharge cycles. However, once the regulated charging process is started, the battery loses its power-balancing capability as the current that it extracts from the grid is determined from its internal control circuit. If the activation of this event is enabled without monitoring, lack of available capacity for supplying load or stability issues can occur in small and weak systems. Moreover, if there is more battery strings connected in parallel, some kind of coordination strategy becomes mandatory. The number of possible applications for grid-connected stationary storage is large. Depending on the methodology and the granularity of the segmentation between 9 and 16 distinguished services are reported in the literature. Requirements to controls and ICT strongly depend on the necessary service or combination of services as well as the storage technology in use. A common picture showing the state-of-the-art for all services and control architectures is hence not possible.

This review focuses on the implementation and operation of ESS providing services for power quality. The most important service discussed is voltage control to maintain power quality and to allow for a higher hosting capacity of renewable sources. Fig. 3 shows a simulation study of an ESS providing volt-age control for a local Photovoltaic (PV) generator. It absorbs all active power above a defined threshold (e.g., 1.02p.u.) to avoid intolerable voltage levels. When they fall below the defined threshold the ESS starts the discharging. The storage system is not the only component participating in voltage control schemes. Often such functions are provided by DER-based inverter systems and/or OLTC. In a number of cases the analyzed storage systems also provide additional services such as local consumption of DER. For the case of voltage control different architectures, ranging from autonomous control with and without remote configuration ability to central control, are analyzed.

A. Autonomous Control with Central Configuration Ability

Control architecture based on pre-defined droop characteristics is discussed. It is shown that the simple adoption of the droop characteristics for single systems decreases the investment costs for the ESS by reducing the required capacity significantly. One approach to achieve this functionality is the implementation of a droop control function according to IEC 61850 or Sun Spec. Both the standard frame-works provide not only a definition of standardized input and output registers of inverter-based distributed generators and storage systems, but also define standardized functions and services. Each function defined in IEC 61850 or Sun Spec can be configured based on a pre-defined set of parameters.

B. Decision Support and Energy Management System

In contrast to autonomous control, central approaches need a functioning control unit and a communication network. Attached components do not make decisions by their own. An algorithm where storages provide voltage control with OLTC simultaneously on the low-voltage and medium-voltage levels is shown in. Single actions are rated based on their costs and impact with offline load flow simulations. A central controller optimizes component behavior based on measurements.

VI.DEMAND RESPONSE AND ENERGY MANAGEMENT

Future electric energy systems endowed with smart metering, intelligent electronic devices and advanced ICT will be characterized by greater responsiveness and efficiency decisions by the costumers and the utility provider. Recent researches confirm, indeed, that Demand Response (DR) is essential for the operation of future Smart Grids. DR denotes variations of the electric consumption by customers when the price of electrical energy changes over time or in presence of financial incentives or reliability signals. Regulatory and policy frameworks, such as the Energy Policy Act of 2005 in the US, have been recently enacted that promote DR and allow customers and load aggregators taking part by means of DR resources in energy, capacity, and ancillary services markets. Also, the FERC Order 719 contributed to remove obstacles to the participation of DR in wholesale markets by allowing load aggregators bidding DR on behalf of retail customers into markets. In 2011, FERC Order 745, determined that DR resources should be compensated at the Locational Marginal Price (LMP) for their participation in wholesale markets, thus establishing an equal treatment between demand-side resources and generation.

A. Demand response Program

Mainly due to both new regulatory and policy frameworks and new technologies, a great share of the end use electrical loads can be engaged in DR programs in a more con-trolled manner. Automated control systems operating on a continual basis are replacing traditional load control systems and these new systems are now available for commercial, industrial, and also individual residential customers. Often, residential DR should be aggregated in order to compete in the wholesale energy markets.

While the direct control of the end use electrical loads existed for decades, price-driven response programs, using a price signal as a means for demand control, are beginning to emerge and to be the subject of study at the distribution level. Combining the automation of the demand bids and the strategies to respond to the growing user empowerment with respect to its domestic consumption, DR programs are the ideal solution to reduce demand power and prevent grid congestions.

B. Central Control Concepts

In propose a Decision Support and Energy Management System (DSEMS) that can be used for residential, commercial and industrial customers. This concept is modeled as a finite state machine and consists of some scenarios that can be selected according to the customer’s preferences. The inputs of the systems are the measured energy from available resources (i.e., from the distribution network, local or other electrical or thermal energy sources) and information related to hourly electrical and thermal energy tariffs, status of the network in terms of components availability, users requirements, contract constrains, messages from the DSO, and environmental parameters. The system generates the command signals for the management of thermal and electrical loads and the messages for the end user (i.e., information about con-trolled devices, load state information, energy consumption and energy saving suggestions for achieving energy saving, messages from the DSO).

The DSEMS is also endowed with a climate control, both used during summer and winter seasons. The temperature set point of the split is progressively modified in order to decrease the power absorption when the maximum power limit is exceeded or during periods when the cost of energy is high.

C. Demand Response Provider Implementation

Customers can take part to DR programs through an intermediary or directly with the utility. In the case when end use customers are gathered by intermediaries, generally called Demand Response Providers (DRP), the end use customers’ aggregated capability is presented to an organized market by DRPs. Automated response technologies, generally classified as control devices, monitoring systems, and communication systems are required in order to actuate the functionalities of a DRP and allows remote managing of peak load demand and energy consumption. An infrastructure to implement a DRP in a Smart Grid is presented. As shown Fig. 4, it consists of Energy Management Systems (EMSs) and DRP, Supervisory Control and Data Acquisition (SCADA), Remote Terminal Units (RTUs), Advanced Metering Infrastructure (AMI), State Estimation Algorithms (SEAs) as well as Generation and Load Forecast System (GLFS). Measurement data provided by AMI and RTUs are transferred to the EMS by the SCADA system. The EMS performs monitoring, control and optimization tasks by using SEAs and GLFS

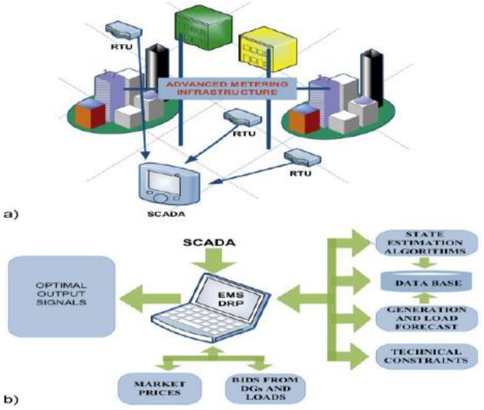

Figure2. Energy Management System in the Smart Grid infrastructure: a) hard-ware system setup, b) logical/automation architecture

VII.SMART GRID AUTOMATION AND CONTROL

The electrical grid undergoes a fundamental change with the introduction of the Smart Grid. Installation of end consumer smart meters, deployment of distributed renewable energy generation, and interconnection of operation and information systems require new solutions that can intelligently monitor and manage the infrastructure. The Smart Grid aims on raising operational efficiencies of operators by increasing the flow of information and automation in order to enable better and faster decisions, hence reducing operational cost. In order to achieve this, utilities are facing some challenges to improve the power delivery methods and utilization, including the integration of control room systems for better workflow, new consumer demands, and security of supply. The Smart Grid Architectural Model (SGAM) Framework aims at offering a support for the design of smart grid use cases with an architectural approach allowing for a representation of interoperability viewpoints in a technology neutral manner, both for current implementation of the electrical grid and future implementations of the smart grid .It is a three-dimensional model that is merging the dimension of five interoperability layers (business, function, information, communication, and component) with the two dimensions of the Smart Grid Plane, that is, zones (representing the hierarchical levels of power system management: process, field, station, operation, enterprise, and market) and domains (covering the complete electrical energy conversion chain: bulk generation, transmission, distribution, distributed energy resources, and customers premises).

A. Architectures

Automation architectures of future Smart Grids are being developed in a number of large-scale research programs worldwide. One significant research initiative is conducted by the center of Future Renewable Electric Energy Delivery and Management (FREEDM) funded by the National Science Foundation (NSF), USA. FREEDM center envisions the back-bone of the future grid to be a new power distribution infra-structure, allowing for integration of Smart Grid components in a “plug and play” manner and enabling bi-directional flow of electricity. This new energy delivery infrastructure is also denoted as “Energy Internet” or “Internet of Energy”. This vision is akin to the (information) Internet.

Experience so far has emphasized the need of open source, open standard-based software as well as communication platforms. Towards this goal, the center has proposed standard-based execution framework for IFM and IEM applications. This framework is based on IEC 61850 and IEC 61499 standards. The results have demonstrated successful deployment of agent-based power balancing DGI application on a network of ARM controllers.

B. Agent-based Solutions

To master the high complexity of future electric energy systems, where the intelligence is distributed over autonomously acting and interacting components, it is necessary to explore architectures and programming techniques based on distributed Artificial Intelligence. One of the most relevant technologies seems to be Multi-Agent Systems (MAS). They have al-ready proved its capabilities for developing robust, flexible, and adaptive industrial automation systems, with application domains including manufacturing control, dynamic product routing, production planning and scheduling, logistics, aero-space, air traffic control, and many others.

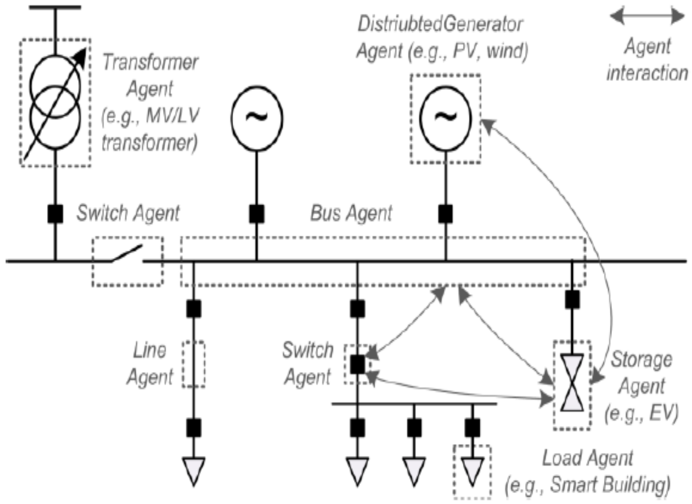

Figure 3. Multi-Agent Systems applied to active power distribution grids**.**

Using MAS principles, each component, device or actor is monitored and controlled by an autonomous agent. Each agent has a set of specific capabilities (like controlling house hold appliances) and local objectives (for example minimization of energy cost while preserving the end-user comfort). The agents interact via messages to coordinate their behaviors in order to achieve equilibrium between the local and the system-wide goals (such as demand-supply balancing).

MAS’ technology has been employed for developing the distributed ICT infrastructure within various projects like the FREEDM initiative as well as the CRISP project. A concept of grid cells was developed to divide the network into independently managed sub-networks. The agent assigned to each grid cell is responsible for managing the current and future production/consumption, and handling the reconfiguration tasks in case of fault detection. A very similar approach considering micro-grids as small scale electricity grids operating in low-voltage networks is presented . Each house in the micro-grid is equipped with the Intelligent Load Controller (ILC) that can communicate with house devices over the power line in order to intelligently control their load. The agent embedded in ILC communicates with the Micro grids Central Controller agent, which task is to balance production and consumption within the micro grid.

C. Service-oriented Architecture Concepts

Service-oriented Architecture (SoA) is a principle based on discrete parts of software that provides functionality as a service to other applications. SoA is therefore designed to be in-dependent of any vendor specifications, products or underlying technology. Loose coupling of software parts provided by SoA, provide flexibility and interoperability to a system and enables dynamic reconfiguration possibilities. As mentioned before, Smart Grids can be thought as the “Energy Internet”. From this point of view, SoA can become a core technology to enable easy interaction between heterogeneous devices and system integration. SoA can also be used for integration with the legacy systems. Moreover, it can enable flexible integration of various actors like distributed generators at industrial and residential levels, market players (auctioneers, buyers, sellers, regulators, etc.), consumers, government bodies, power grid operators and etc.The ability of service discovery and its advertisement as the key intelligent features would facilitate dynamic nature of Smart Grids. At the level of heterogeneous system components (DER, EES, etc.), SoA can provide interoperability. Each node pro-vides a set of services with a defined interface.

D. Holonic Control Principles

Holonic principles known from the AI field and general systems theory are being applied to the Smart Grids do-main, trying to capitalize the intrinsic characteristics to model complex large distributed systems into potential benefits. An architectural model based on holonic MAS is proposed by to structure the software entities within the ICT infra-structure of Smart Grids. The whole network is assumed as a Holon that consists of some domain holons, namely focusing on generation, transmission, distribution, control and operation, service provider, market and customer domains.

Apply the holonic approach to structure the Smart Grid organized on autonomous producers that are recursively clustered at various aggregation layers. These Holon’s, named control holons, are organized in a bottom-up structure to form a complete control holarchy of the Smart Grid. Many functions are included in this Holon structure, namely the environment state acquaintance, state analysis, database management, forecasting, steering sub holons and scheduler. This holonic approach is extended by considering a Service-oriented Architecture (SoA) framework to support interoperability and reusability challenge, defining five major services: database service, State evaluation service, optimization service, transaction service, and stability service. For this purpose, they identify three main integration patterns for conflict resolution in self-managed systems, namely hierarchic, collaborative, and stigmergic. These patterns are complementary and could be used successively according to the environmental conditions and the working mode of the power grid.

E. Important ICT and Automation Standards

As an international standardization organization the International Electro technical Commission (IEC) plays a very important role by providing common rules for the planning and operation of Smart Grid systems. The “IEC Smart Grid Standardization Roadmap” suggests different core standards important for the implementation of Smart Grids, like (i) IEC TR 62357 (service-oriented integration architecture), (ii) IEC 61970/IEC 61968 (Common Information Model – CIM), and (iii) IEC 61850 (power utility automation). Other organizations also provide similar roadmaps for the implementation of intelligent power grids. The “NIST Framework and Roadmap for Smart Grid Interoperability Standards” the “DKE German standardization roadmap for Smart Grids” as well as the “IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads” are important examples of such roadmaps and guidelines. Under the scope of the 4DIAC initiative distributed, reconfigurable control software for Smart Grids and components was implemented based on IEC 61850 and IEC 61499. Especially, low-level control algorithms and reconfigurable interfaces for the on-line update/adaptation of control functions in DERs are covered by the introduce an automation architecture that supports distributed multi-agent intelligence, combining IEC 61850 object-based modeling and interoperable communication with IEC 61499 function block executable specification. The proposed architecture was applied to achieve self-healing grid through collaborative fault location and power restoration.

CONCLUSION

The future electric energy system consists of a huge number of interconnected components and supports bi-directional electricity flow through the electrical network and an ICT in-Fra structure. Important factors in such a Smart Grid system are inverter-based DER, ESS and flexible/controllable loads. Compared to today’s power system the future infrastructure is characterized due to a higher amount of distributed components (in hard- and software) whereas the hierarchical structure of the power grids will still exist. The Smart Grid ideas have appeared to enhance the capabilities of the power distribution systems as reaction to growing requirements on better exploration of (distributed) energy re-sources. The Smart Grid visions are supported by the latest achievements in the field of AI and software engineering, namely on holonic, MAS and SOA principles. The trend is to use holonic control principles on the lowest, near to the physical equipment automation level to ensure very fast reactions, especially reconfigurations of the network. Both the MAS and SOA approaches are used to support services and decision making on a higher automation level and requires an addition-al communication infrastructure. From the philosophical point of view, the latter two approaches converge and are in some sense complementary [96]. As a rule, the MAS or SOA architecture is being considered to ensure higher level optimization based on negotiation and cooperation principles in a highly distributed communication environment. The trials to explore the semantic web or big data technologies to support the distributed decision making in the MAS or SOA architecture rep-resent an up-to-date trend.

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REFERENCES

[1]Thomas Strasser “A Review of Architectures and Concepts for Intelligence in Future Electric Energy Systems” IEEE Transactions on Industrial Electronics 2013

[2]Sujan Adhikari “Decentralized Control of DC Micro grid Clusters” 2017 IEEE

[3]Tomislav Dragiˇcevi´c “A Distributed Control Strategy for Coordination of an Autonomous LVDC Micro grid Based on Power-Line Signaling” IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 7, JULY 2014

[4] Mahesh Kumar “Development of a control strategy for interconnection of islanded direct current microgrids” Published in IET Renewable Power Generation Received on 28th November 2013 doi: 10.1049/iet-rpg.2013.0375

[5]Jianjun MA “Configuration and Operation of DC Micro grid Cluster Linked through DC-DC Converter” 2016 IEEE

[6]Nima Nikmehr “Optimal Power Dispatch of Multi-Micro grids at Future Smart Distribution Grids” IEEE TRANSACTIONS ON SMART GRID 2015 Digital Object Identifier 10.1109/TSG.2015.2396992

[7] T. I. Strasser “An Integrated Research Infrastructure for Validating Cyber-Physical Energy Systems”

[8] Felix F. Wu “Smart Grids with Intelligent Periphery: An Architecture for the Energy Internet” Engineering 2015, 1(4): 436 – 446DOI 10.15302/J-ENG-2015111

[9]EunKyu Lee “Advancing Building Energy Management System to Enable Smart Grid Interoperation” Hindawi Publishing Corporation International Journal of Distributed Sensor Networks Volume 2016, Article ID 3295346, 12 pageshttp://dx.doi.org/10.1155/2016/3295346

[10]Saifur Rahinan “Artificial Intelligence in Electric Power Systems A Survey of the Japanese Industry” IEEE Transactions on Power Systems, Vol. 8, No. 3, August 1993

[11] J.G. Slootweg “Smart Grids - Intelligence for Sustainable Electrical Power Systems”