SYNCHRONIZATION OF BUILDING AUTOMATION AND ADVANCE INFORMATION SYSTEMS AS AN ACCELERATION TOOL IN MOVING SMART GRID FORWARD

SHU XIAN TOH

University of Coimbra, Portugal.
E-mail: tsx@student.uc.pt

Abstract- A smart grid employs innovative hardware and software solutions, integrated with intelligent monitoring, control, timely communication and self-healing technologies. Two-way communication is vital in managing energy efficiency, reliability, supply security and sustainability of overall electric power grid infrastructure. This paper discusses the standards and interoperability that hampers utility and consumer to adaptation to the transformation of conventional power grid networks into multi objective intelligent grid. In order to achieve an efficient electrical delivery system and reliable benefit for both utilities and consumers; the combination of advanced Information Technology (IT) systems and automation devices is analyzed. The relevance of smart grid applications and sensor networks to support demand response management and utility communication is presented through the overview in current development electric grid infrastructure. Existing control technology components, sub-systems, and advanced metering infrastructure tools or devices will be evaluated with consideration to the importance of power system energy management system (EMS). The optimization and control functions developed upon reviewing supervisory control and data acquisition (SCADA) system and traditional data handling tools is presented in this paper; whereby, various costs, constraints, machine to machine (M2M) or big data support system are accessed. The outcome of the conceptual solution and changing philosophy on data management through digital networks in influencing balance in demand-side load is learnt with concerns to the transformation of smart grid system and need for energy consumer to obtain information on power availability as well as pricing options.

Index Terms- Information technology (IT), Smart Grid Systems, Supervisory control and data acquisition (SCADA), Machine to machine (M2M).

I. INTRODUCTION

Electricity is the charges of electrons moving or flowing. It is a form of energy which is measured in Ampere, Ohm or Voltage. Energy however, is measured in form of Joule or Kilowatt per hour. These measurements although correlate to each other; it is often misguided of its origin characteristics. The progress of technology and scientific innovation had defined the principles of electricity as a source of energy to consume or generate power. Electricity is the most widely used forms of energy which is also classified as a secondary energy source from the
conversion of other primary source like renewables (solar, wind, hydro, geothermal, etc.) or natural (coal, oil, etc.). Since the discovery of renewables and detrimental effects of greenhouse gas emissions in the environment, the focus on sustainable development emphasized several environmental policies and set economic frameworks which targets for a low carbon economy [2]. Coupled with increasing energy demand in the era of globalization, the electricity industry had evolved with rising implications of energy efficiency and energy savings besides addressing to load management barriers [10,14]. The centralized generation, transmission, and distribution is challenged in the emerging decentralized utility influence where the use of smart metering and automation sensing transmit information on energy savings and electricity pricing. In such intelligent electric grid, end users are able to monitor the energy generation and consumption level [12,13,16]. In effort to stimulate an integrated distribution of electric within the energy infrastructure, the reformation of electricity market unbundled the vertically integrated utilities into distinct generation, transmission, distribution, as well as retail supply companies. In this case, a competitive market barrier exist in the electricity infrastructure whereby commercial management principles and issue of ownership is often discussed. The reformation on electric industry restructuring causes a re-examination for regulators in deciding the optimal instruments or mechanisms to ensure load management and energy efficiency is addressed on a timely basis. In identifying the potential barriers of balancing the power grid and ensuring flexibility in intermittent distributed generation capacities; the restructuring in electricity market re-evaluates the ‘smart-grid’ concept which reveals the emphasis on investments for innovation in data management tools and advance automation inputs to dispatch reliability and adhere to the transparency or prudence in information distribution goals in light of the energy trilemma [1,7].

II. LITERATURE REVIEW

Schneider Electric defines the success to modelling a smart grid encapsulates five attributes “visions, solutions, integrations, innovation, and collaboration” [1]. For the pathway for innovation in developing smart cities and communities, the European Commision sets quantitative goal to increase deployment of integrated energy, transport, and ICT solutions to fulfill the low-carbon targets. Smart grid is a universal concept that is defined based on the boundaries, capabilities, and aspirations of each practicing organization or nation. However, smart grid will hold similar connotation which are driven by real needs. Taking account of the evolution in energy efficient product such as electric vehicles and green buildings with fitted heating or cooling systems; the innovative progress widens the functionalities and scope of a smart grid system. The methodology framework of a smart grid involves the characterization of intelligent sensing technology to provide two-way communication or service between the generation, transmission, distribution, and consumption among utilities, end users, or aggregators network [5]. Figure 1 shows the interoperability of different domains, influencing zones within a integrated electric infrastructure, and its functionalities which domains a distributed regeneration smart grid architecture to be a bi-directional real-time communication network that serves a stable and efficient energy exchange. ICT entities [2,4,10] impose the harmonization process in the smart grid model to achieve technical equivalency and enable interchangeability between different standards with overlapping functionality in various domains.

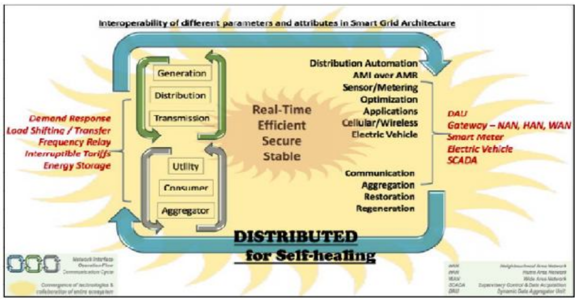


Fig 1. Parameters within the Smart Grid Systems

III. ROLE OF ICT AND PROMINENCE OF DIGITALIZATION

A fully-fledged smart grid will implement machine to machine communications (M2M) that will match supply with demand of the power algorithm. The challenge to prevent energy loss in power generation and increase efficient use of energy can be solved through the installation of high end informatics transfer tools. Information can be transferred through digital platforms in between power station, green energy buildings, and consumer automation devices. Information and communication technologies (ICT) plays a matchmaking role to the supply and demand curve. In relation to the demand side management (DSM) cycle, sufficient information needs to be quantified and justified through vigorous stages of real-time data. Advance ICT tools is prominent in smart electricity grids to allow consumers to be passive receivers in the energy consumption. Besides pressure on sustainable corporate responsibility and adapting to the evolution of Internet of Things (IOT), the smart grid initiative unraveled possibilities for utilities, producers, and service providers to innovate solutions. The competitive market sets a platform for different technology and ICT based firms or organizations to participate in the market. As more interactive participant respond to the incentive renewable or sustainable energy programmed, utilities will have the capacity to influence consumers and shift the load diagram in demand side management approach; provided accurate measured results are communicated through the information network [6]. In Europe, a developed project known as “Energy-saving information platform for generation and consumption” (ENERSIP) supports the data matching and monitoring processes. Valuable information can be forecasted to reduce wastage throughout the production and consumption flow in energy market. An open digital platform is vital in ENERSIP to provide such control services that improves the reliability and responsiveness in intelligent electricity grid. This relates to a digital concept as the necessary development and integration of variant technologies includes the sensor network or wireless communication devices. The data derived from ICT tools provide feedback algorithms to consumer, empowering changing consumption patterns that will summit to energy savings. In Europe, Intelligent Electrical Grid Sensor (INTEGRIS) was introduced to overcome the complexities of smart grid. ICT applications and topology transfers the unidirectional network flow to a bidirectional flow, allowing flexibility control over voltage of supply points [13]. The new plethora functions of smart grid with different requirements poses further complexities in latent demand electrical protection systems which is common in today’s diverse macro operation distribution grid that is introduced by the increase in renewable energy power plant. Fortunately, the increase in deployment in both ICT and digital support tools are integrated into the power distribution network which address better information and decision outcomes for all market players in the power distribution network.

IV. EVOLUTION OF ADVANCED INFORMATION SYSTEMS

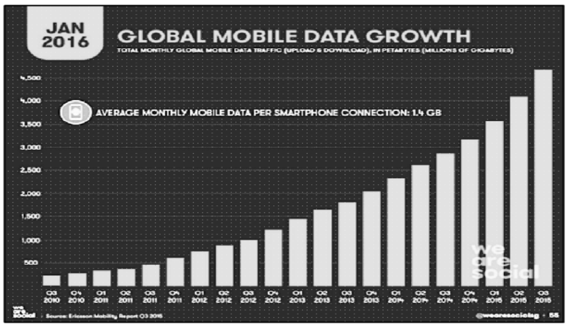


Fig 2. Global Trend of Digital Data [16].

By 2020, Internet of Things (IOT) will scale to 26 billion connected devices [4]. As of 2016, 3.79 billion mobile users exists among the 51% penetration of digital products, software, and hardware tools [16]. Simultaneously, 146% global population are exposed to the internet as there is a steady uphill trend in data acquisition and data transition (Figure 2). Thus, the prominence of digitalization exists within the smart grid architecture as connectivity focuses on mobility, big data and cloud storage technologies like Google Drive Analytics. Accordingly, Intel solve substations complexities in the smart grid system through its gateway solutions combined with its advance processor-based servers [10]. The 2020 targets call 80% of EU citizens to be quipped with smart meters [9,11]. Besides the benefit to reduce electricity bills and balance consumption level to generation capacity; real time information through smart metering also ensure quality of service through detection of faults, frequency stabilization, and to stabilize the operations of power transmission in the energy grid. Automation and sensing tools which are fitted and integrated in the components of smart grid (eg. : power station, transmission line, pluggable electric vehicle, residential subdivision, charging stations, green residential or commercial buildings, etc.) deliver seamless interaction between these components. The velocity, frequency variations, and information volume that each domain weighs require advance leveraging and balancing instruments to ensure efficiency, reliability, system monitoring or control for outage detection throughout the networks. Advanced Metering Infrastructure (AMI) implementation for automation in the smart meter offers operational efficiencies in field and power outage management. Distribution Management Systems (DMS) frames a series of modular that builds a flexible platform for the market actors. Distribution Automation Systems encompass multi-sites substation which is scalable to various size or unit of industrial sites. Schneider Electric markets an advanced load control system known as “Telvent”, which reduces peak load and assist in management of unplanned circumstances for the utility network. The Telvent Solution includes remote terminal units which operates as substation control systems in optimizing the network operations. Siemens on the other hand, sells a Distribution Feeder Automation System (SDFA) which allow utilities to locate, isolate, and restore any faults automatically [14]. Both systems minimize outage time and dispatch services to the viable corners of the distribution network. Innovative SCADA solutions like Siemens Spectrum Power Microgrid Management System (MGMS) maximizes both operational and economic returns of decentralized energy resources. Furthermore, the greater control in automation systems dispatch costs as well as overcome voltage and reactive power complexities on electric distribution systems through the integrated use of Volt Var Optimization controls. The innovation in technology continue to progress as Cisco introduces a router known as IR500, which connect distribution automation (DA) sensors and controls further to evaluate its protocols through an internet protocol based network [6]. The exploration these different management systems with interconnection to a variety of wide-area network (WAN) choices holistically unite the operations of utility control rooms and back-office systems.

V. CHALLENGES IN ICT AND AUTOMATION

Although the parameters in a smart grid initiative is proven to be beneficial to the power distribution network, ICT infrastructure and automation system still require robust research and design process while it is in path to maturity in the economy context. Distribution Automation communication networks require pervasive infrastructure across service territories. For optimal performance, utilities will need to dispatch multiple applications with various network performance (eg. bandwidth and latency). For example, a conservation voltage reduction (CVR) application has latency of expectation of seconds, differing from object-oriented substation which require low latency communications. In each distribution automation, the applications involve have specific data requirement, payload, bandwidth capabilities, and frequency of communications. Thus, to achieve the best performance through harmonization of all inputs is a challenge in for integration into the smart grid. Cisco introduced Field Area Network (FAN) for pervasive monitoring and control of energy distribution networks. For this solution, it improves energy delivery and promote low carbon infrastructure as is built on a flexible multi-tier architecture that generates IP network with security and resilience [2]. In addition, the selection criteria of communication technologies to be integrated in the smart grid system will undergo a thorough analysis of costs and coverage capacity. Despite the development of renewable energy plant and incubation of smart cities, often it begins in rural or suburban areas which may not have stable cellular coverage. This increases the cost for ICT applications and automation inputs, as private network deployments or satellite-based networks for backhaul is required. In contrast in developed cities or cosmopolitan areas, coverage transmission is not an issue through high-speed mobile 4G or wired broadband technologies; thus, providing a good fit for the power distribution network in such areas. Every technology and applications draws a different cost structure [4,12]. For instances, private communication networks incur high initial capital cost with low operational maintenance cost. A service provider based public solution on the other hand such as cellular or satellite based networks will incur higher operation maintenance cost. Also, utilities will have different financing requirements and technology preferences over a time frame. Cisco (2014) states that deployed field infrastructures have average lifetime of 15 to 20 years which is subject to incompatible with the evolution pace of data communications and distribution automation innovation Accordingly, this aligns to to the smart grid architecture which requires different layers of system to be integrated [4]. The integration of ICT and automation have not only take account of the sophisticated intelligent products and solutions in future that will be deployed in the smart grid system. When newer protocols or remote terminal units are expanded in future, the synchronization of distribution automation devices and applications have to be forecasted and monitored in a long time span to ensure it provides an agile layer of communication support in the power distribution network.

VI. INNOVATIVE SOLUTIONS IN A MODERNIZED ELECTRIC GRID

Due to volume, velocity, and variety of data generated in the smart grid; it poses data storage and analysis as another challenge. Thus, the innovation in features of Data Warehouses (DWH) is significantly important, as every data will uncover hidden values which ultimately allow more accurate adjustments to the daily peak load management. The variation energy generation, information load management, as well as pricing highlights the need in big data analytic as diverse data sets are transmitted between the market actors and operation networks (Cisco 2014). The varying structure and sizes in varying processing modes summits to integration of map reduce system which envisage the volume and variation of data. Simultaneously, real time system allow analysis on event pattern and continuous tracking to prevent any potential power outage as well as to adapt to the shifting of demand and supply requirements within the electric grid. In effort to streamline processes to allow trading, fraud detection, outage detection and load management in the distribution network; the combination of data warehouses and real time processing provide information completeness and added accuracy for programming models in the smart grid domains. These contribute to a distributed transaction cycle within the power distribution network, where events are stored within the database, analyzed and actions are performed. Stream computing for load forecasting or scheduling are among the solutions to manage high velocity of data flow in real time. This can be assist through IOT and IP platforms like Siemens EnergyIp which enable demand response management, meter-to-cash applications, and management of electric vehicle charging network [14]. Utilities in this case, are able to take advantage of advanced analytics and big data. EnergyIP is a proven network platform that enable detection of potential fraud or unusual patterns in the algorithms of the power distribution network. This in turn solves the insecurity barrier for users and communicators in the trading line. Machine-to-machine (M2M) technology was prominently dominant before the advent of IOT. However, the unification in integrating the different functionalities of M2M and IOT is vital as it refer to direct communications between devices and allow bi-directional transmission. M2M communications allow electricity grid to transmit multiple feedback loops among value chain functions in the smart grid infrastructure [10]. IoT widens the defined set of M2M solutions through example cloud-based analytics solutions like Schneider's Electric Wonderware or KiSense solutions by Virtual Power Solutions in Portugal.

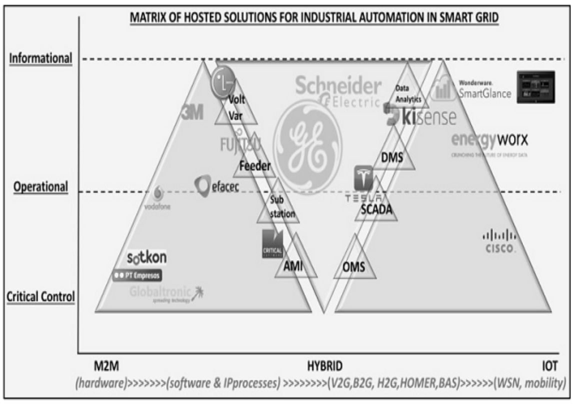


Fig 3. Solution Matrix for Industrial Automation.

In summary, the transition of traditional electric grid to an intelligent grid requires a matrix of hosted solutions through integration of industrial automation solutions or ICT approaches (refer figure 5). As the market parameters and decision from market participants in the power distribution network emphasis on different uses and priority, the interoperation of a variety key metrics in ICT and automation approaches is required to address the control, operational, and informational needs of all agents. Schneider Electric and General Electric, are two exemplary companies which had shown a significant progress in the energy industry, having successfully to stay above its competitors through its wide range of product and solutions which align to the smart grid standards. Among a paradigm of innovative solutions, feeder and key substations are deployed to different zones and coverage area of the electricity infrastructure. Furthermore, utilities implemented Outage Manage Systems (OMS) to replace reporting and tracking of outages. Likewise, Distribution Management Systems (DMS) drives forecasting and efficient respond to overloads. The modernization of deployment in SCADA systems extends for low to medium range feeder infrastructure to balance the transmission network [10]. Voltage and VAR control on the other hand optimizes voltage profile to reduce peak load and system losses. Accordingly, restoration for distributed generation can be achieved and through remote switching, the entire smart grid network is able to adapt to changing operating conditions. Electric vehicle and smart meters aids the awareness of efficient energy use within users. The integration of AMI and DMS applications with a hybrid mix of distribution automation or ICT solutions forms an ideal smart grid infrastructure. The competitive market playing field for M2M communications after energy legislation and electricity restructuring poses increase standardization and complex service options. Users and utilities requirements for connectivity requires advanced applications and devices to have remote asset diagnostics and performance monitoring which address to the mobility advantage. In the digitalization era and IOT upscale trend, users today are responsive to automated feedback response gateway devices and systems.

Thus, in winning the race for M2M applications and devices for producers or suppliers, firms have to anticipate user requirements and assess opportunities for portfolio expansion. Besides the issue of security and privacy whereby large data can be mishandled, standardization and regulation frameworks with conscious effort is pragmatic to address such challenges. Osma (2015) research proves the improvement of resilience in energy behavior through implementation of building automation systems. Automation systems allow real time monitoring in several variables which backtracks data to allow adjustment or rescheduling in the consumption and operation of devices within the electric grid.In addressing to the uncertainty of power outage in the smart grid, the use of backup energy storage or emergency power plant from a distributed generation is the alternative source to feed priorities loads. Osma (2015) research highlighted the benefits for an equipped building with automation applications and green fittings in the monitoring, access control, lighting as well as climatization. Results proven a successful reduced in energy consumption density and achieved energy savings is achieved.

VII. FINAL REMARKS

The rolling out of smart technologies for development of Smart Grid infrastructure is trending even in developing and non-developed countries as research report shown in figure 4. The procuring of investments in automation and sensor networks is implemented despite the city lack technology-related skills or capacity. In some states, utilities such as gas, electricity, water and public transportation are privatized which conflicts the commitment. Yet, through a standardization within the regulators and solving silos through set targets (eg. climate change policies or smartgrid roadmap), smart grid development is proven to progress as cities have manage to work across departments and boundaries.

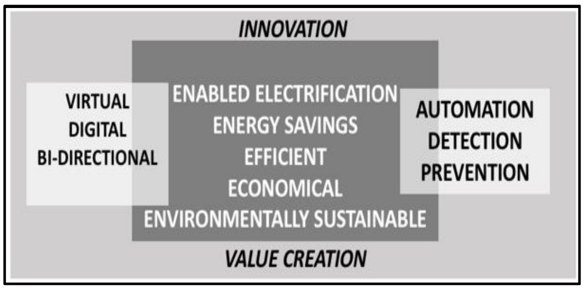
Figure B1: Smart Grid Top Market Report Rankings Comparison, 2015-2016 Overall

Ranking	2015	2016	Change
1	Canada	Canada	---
2	Japan	Mexico	+9
3	Saudi Arabia	Japan	-1
4	Australia	Saudi Arabia	-1
5	U.K.	Australia	-1
6	Singapore	U.K.	-1
7	China	China	---
8	Chile	India	+13
9	Philippines	Vietnam	+1
10	Vietnam	France	+3
11	Mexico	Chile	-3
12	Turkey	Turkey	---
13	France	Korea	+4
14	Malaysia	Malaysia	---
15	Netherlands	Spain	+16
16	Germany	Netherlands	-1
17	Korea	Philippines	-8
18	Austria	Germany	-2
19	Brazil	New Zealand	New in 2016
20	Colombia	Singapore	-14

Figure 4. Smart Grid Systems Solutions Global Ranking [8].

The issue of security poses a long challenge for ICT as it phases into different roles in the smart grid systems. Taking account of the progress in internet of things (IOT) and big data management, privacy issues and risk management calls for an innovation in various optimization models. In this case, layers of security solutions are integrated. Different types of security approaches which tackles different threat zones can be implemented to the safety precautionary model. For example, within the IOT landscape encrypted host security and air gap security such as firewall increases protection to misuse of data. Despite big information is difficult to unbundle, a networking on security of data flow pipes that is multi direction helps to unwire the traffic flow of data. Accordingly, the implementation of Bluetooth technology a have a pivotal role as a personal area network within a short range transmission. It had been proven that Plug-in-Hybrid Electric Vehicle (PHEV) and sustainable green products if integrated with Bluetooth system as an alternative communication function, will result in a more efficient latency and low data size [16].

Figure 5. Relation of ICT Integration in Accelerating Smart Grid.



As the European Commission set up Smart Grids Task Force (SGTF) since 2009, the policy and regulatory directions for deployment of Smart Grids under the

Third Energy Package framework have made recommendations for standardization, user data privacy and security, while similarly addressing to the increase in asset management for investments in technology. The examples and research results as discussed throughout this paper reflects on the relation of ICT dynamic functionalities and the role of automation, whereby when both is integrated into the power distribution network act as trajectory key drivers in pushing the development of smart grid forward in the most reliable and desirable outcome. The current INTEGRIS project which was set out by European Union [13] provides an exemplary movement of improving the performance of electricity distribution grid under a thematic approach by implementing cross-cutting ICT solutions into the smart grid platform. Smart metering data collection and analysis through the synchronization of ICT and automation tools poses a challenge in designing a comprehensive data management model that simultaneously host huge variable data volumes while ensuring its security and providing benefits to all players in the energy value chain.

There's a need for strong citizens' engagement and encouragement for investment opportunities to accelerate the deployment of automation and ICT applications in leveraging the data and communication networks. In addressing the current energy trilemma by advancing in smart grid development as a part of the solution, it is pragmatic for the harmonization in ICT and advance automation as it plays significant key drivers. Despite the high incurring cost and limited architecture in a short time frame for distributed automation applications, the uptake of Smart Grid is incomplete without the progress in ICT systems which ultimately provides enhance quality of service, reliability, and securing communication links for all market participants. As accordance to EU's Smart Grids Technology Platform, smart grids annotates intelligently integrated electricity networks surrounding the actions of all users connected in purpose to efficiently deliver sustainable, economic and secure electricity supplies. Thus, the uncertainties regarding to consumer acceptability and market tolerance to a change of introducing new market models requires a unified act of all Member States to address the different perspectives before converging to the best solution where various objectives and standards is achievable.

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