Novel Approach based Smart Grid Involved in Energy Consumption using Signal Transmission

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Abstract— The objective of this deliverable is to explore several cases for smart grid in the ICT point of view and identify necessities and architectural consideration. There is a use case for demand response signal generation for scheming home appliances. Electricity service provider's operating system makes several of DR (Demand Response) signals that is generated by multiplication of individual CBL (Customer Baseline Load) in lieu of the customer's electricity usage patterns and dynamic pricing from power exchanges. And DR signals in the operating system are transmitted to the gateway in customer houses. DR signal pass to the consumer electronics and appliances. Power consumption of appliances varies depending on DR signal.

Key words: Smart Grid, Networks, Wireless Technologies

I. Introduction

In the 20th century local grids grew over time, and were eventually interconnected for economic and reliability reasons. By the 1960s, the electric grids of developed countries had become very large, mature and highly interconnected, with thousands of 'central' generation power stations delivering power to major load centre's via high capacity power lines which were then branched and divided to provide power to smaller industrial and domestic users over the entire supply area. The topology of the 1960s grid was a result of the strong economies of scale: large coal-, gas- and oil-fired power stations in the 1 GW (1000 MW) to 3 GW scale are still found to be cost-effective, due to efficiency-boosting features that can be cost effective only when the stations become very large. Power stations were located strategically to be close to fossil fuel reserves (either the mines or wells themselves, or else close to rail, road or port supply lines). Sitting of hydro-electric dams in mountain areas also strongly influenced the structure of the emerging grid. Nuclear power plants were cited for availability of cooling water. Finally, fossil fuel-fired power stations were initially very pollute and were cited as far as economically possible from population centers once electricity sharing networks permitted it. By the late 1960s, the electricity grid reached the overwhelming majority of the population of developed countries, with only outlying regional areas remaining 'off-grid'. Metering of electricity consumption was necessary on a per-user basis in order to allow appropriate billing according to the (highly variable) level of consumption of different users. Because of limited data collection and processing capability during the period of growth of the grid, fixed-tariff arrangements were commonly put in place, as well as dual-tariff arrangements where night-time power was charged at a lower rate than daytime power. The motivation for dual-tariff arrangements was the lower night-time demand. Dual tariffs made possible the use of low-cost night-time electrical power in applications such as the maintaining of 'heat banks' which served to 'smooth out' the daily demand, and reduce the number of turbines that needed to be turned off overnight, thereby improving the utilization and profitability of the generation and transmission facilities. The metering capabilities of the 1960s grid meant technological limitations on the degree to which price signals could be propagated through the system. During the 1970s to the 1990s, growing demand led to increasing numbers of power stations. In some areas, supply of electricity, especially at peak times, could not keep up with this demand, resulting in poor power quality including blackouts, power cuts, and brownouts. Increasingly, electricity was depended on for industry, heating, communication, lighting, and entertainment, and consumers demanded ever higher levels of reliability. Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air-conditioning led to daily peaks in demand that were met by an array of 'peaking power generators' that would only be turned on for short periods each day. The relatively low utilization of these peaking generators (commonly, gas turbines were used due to their relatively lower capital cost and faster start-up times), as one with the necessary redundancy in the electricity grid, resulted in high costs to the electricity companies, which were passed on in the form of increased tariffs. In the 21st century, some developing countries like China, India, and Brazil were seen as pioneers of smart grid deployment.[7]

II. Reconstruction Opportunities

Since the early 21st century, opportunities to take advantage of improvements in electronic communication technology to resolve the limitations and costs of the electrical grid have become apparent. Technological limitations on metering no longer force peak power prices to be averaged out and passed on to all consumers equally. In parallel, growing concerns over environmental damage from fossil-fired power stations has led to a desire to use large amounts of renewable energy. Dominant forms such as wind power and solar power are highly variable, and so the need for more sophisticated control systems became apparent, to facilitate the connection of sources to the otherwise highly controllable grid.[8] Power from photovoltaic cells (and to a lesser extent wind turbines) has also, significantly, called into question the imperative for large, centralized power stations. The rapidly falling costs point to a major change from the centralized grid topology to one that is highly distributed, with power being both generated and consumed right at the limits of the grid. Finally, growing concern over terrorist attack in some countries has led to calls for a more robust energy grid that is less dependent on centralized power stations that were perceived to be potential attack targets.[9]

III. CONCEPT OF SMART GRID

By integrating an end-to-end, advanced communications infrastructure into the electric power system, a Smart Grid can provide consumers near real-time in sequence on their energy use, support pricing that reflects changes in supply and demand, and enable smart appliances and devices to help consumers avoid higher energy bills.A more intelligent grid can also:

- reduce the duration and frequency of power outages
- lower generation requirements by reducing inefficiencies in energy delivery
- facilitate efficient charging of electric vehicles
- better integrate wind and solar resources
- Provide more effective management of distributed generation and storage.

A Smart Grid uses in sequence and communication technology to make the power grid more efficient, reliable, secure, and resilient while minimizing costly investments in new generation capacity. Power systems are fundamentally reliant on control, communications, and computation for ensuring stable, reliable, efficient operations. Generators rely on governors and automatic voltage regulators (AVRs) to counter the effects of disturbances that continually buffet power systems, and many would quickly lose synchronism without the damping provided by power system stabilizers (PSSs). Flexible AC transmission system (FACTS) devices, such as static VAR compensators (SVCs) and high-voltage DC (HVDC) schemes rely on feedback control to enhance system stability. At a higher level, energy management systems (EMSs) use supervisory control and data acquisition (SCADA) to collect data from expansive power systems and sophisticated analysis tools to establish secure, economic operating conditions. Automatic generation control (AGC) is a distributed closed-loop control scheme of continental proportions that optimally reschedules generator power set points to maintain frequency and tie-line flows at their specified values. Historically, sharing systems have had a minimal role in power system operation and control. Many sharing utilities have employed demand management schemes that switch loads such as water heaters and air conditioner to reduce load during peak conditions or emergency situations. The controllability offered by such schemes has been rather limited, however. This lack of involvement of sharing is largely a consequence of the technical difficulties involved in communicating (with sufficient bandwidth) with consumers. Smart grids promise cost-effective technology that overcomes these limitations, allowing consumers to respond to power system conditions and hence actively participate in system operations.

Smart grid concepts cover a wide range of technologies and applications. We describe a few below that are currently in practice with the caveat that, at this early stage in the development of smart grids, the role of control, especially advanced control, is limited:Advanced metering infrastructure (AMI) is a vision for two-way meter/utility communication. Two fundamental elements of AMI have been implemented. First, automatic meter reading (AMR) systems provide an initial step toward lowering the costs of data gathering through use of real-time metering in sequence. They also facilitate remote disconnection/reconnection of consumers, load control, detection of and response to outages, energy theft responsiveness, and monitoring of power quality and consumption. Second, meter data management (MDM) provides a single point of integration for the full range of meter data. It enables leveraging of that data to automate business processes in real time and sharing of the data with key business and operational applications to improve efficiency and support decision making across the enterprise.

Geographic in sequence system (GIS) technology is specifically designed for the utility industry to model, design, and manage their critical infrastructure. By integrating utility data and geographical maps, GIS provides a graphical view of the infrastructure that supports cost reduction through simplified planning and analysis and reduced operational response times.

A. Demand Response (DS):

Mechanisms and incentives for utilities, business, industrial, and residential customers to cut energy use during times of peak demand or when power reliability is at risk. Demand response (DR) is necessary for optimizing the balance of power supply and demand. Wide-Area Situational Awareness (WASA) Monitoring and display of power-system components and performance across interconnections and over large geographic areas in near real-time. The goals of situational awareness are to understand and ultimately optimize the management of power-network components, behavior, and performance, as well as to anticipate, prevent, or respond to problems before disruptions can arise.

IV. SMART GRID DEPLOYMENTS:

Outage management systems (OMSs) speed outage resolution so power is restored more rapidly and outage costs are contained. They eliminate the cost of manual reporting, analyze historical outage data to identify improvements and avoid future outages, and address regulatory and consumer demand for better responsiveness.

Intelligent electronics devices (IEDs) are advanced, application-enabled devices installed in the field that process, compute, and transmit pertinent in sequence to a higher level. IEDs can collect data from both the network and consumers' facilities (behind the meter) and allow network reconfiguration either locally or on command from the control center.

Wide-area measurement systems (WAMS) provide accurate, synchronized measurements from across large-scale power grids. They have been implemented in numerous power systems around the world, following initial developments within the Western Electricity Coordinating Council (WECC) through the early 1990s [19]. WAMS consist of phasor measurement units (PMUs) that provide precise, time-stamped data, as one with phasor data concentrators that aggregate the data and perform event recording. WAMS data plays a vital role in post-disturbance analysis, validation of system dynamic models, FACTS control verification, and wide-area protection schemes. Future implementation of wide-area control schemes are expected to build on WAMS.

Energy management systems (EMSs) at customer premises can control consumption, onsite generation and storage, and potentially electric vehicle charging. EMSs are in use today in large industrial and commercial facilities and will likely be broadly adopted with the rollout of smart grids. Smart grid implementations are occurring rapidly, with numerous projects under way around the world. Fortum's "intelligent management system of electric consumption" uses advanced metering devices to gather customer's consumption data and metering management systems to store and analyze this in sequence. Vattenfall's "automatic household electricity consumption metering system" is another example of a European project that is focused on remote measurement of consumers. Also, projects such as Elektra's "sharing management system" improve quality of service by implementing next-generation devices to manage and control in sequence (SCADA), DMS to plan and optimize sharing system operations, and ArcFM/Responder to improve outage response times.

This can challenge decision making as there is pressure to revisit project definitions and approaches. The report reviews several challenges affecting smart grid deployments. First among these is greater awareness of smart grid capabilities and their benefits for advancing energy efficiency and renewable resource integration policies. Another significant challenge is the speed with which new ideas and deployment strategies are being generated. Rapid changes in information and communications technologies and how they are being deployed in other areas of an economy (e.g., manufacturing, finance, healthcare) offers new solutions for consideration in smart grid deployments.

V. Rolling Of Smart Grid

The three main functionalities of Smart Grid can be identified

A. *Smart network management*

Smart network management comprises data acquisition, protection, switching and control of energy flows, and quality of supply within the network. Herewith, ICT is the basis of innovative control and monitoring concepts which are required to operate renewable energy sources in a reliable and safe way. The U.S. technology agency NIST (National Institute of Standards and Technology) speaks of wide area situational awareness (WASA) (NIST 2009), i.e., providing utilities with real time in sequence on current power flows and quality of supply, supporting power grid operation and predicting near time development within the grid.

B. *Smart integrated generation*

This category coveres energy storage solutions, distributed generation, integration of electric vehicles and other elements which will be integrated into a future grid.

C. *Smart Market*

Herewith functions like demand response (DR), load control, dynamic pricing, among others, are covered. These (customer-oriented) services require a new, advanced metering infrastructure. Today, standard electricity meters lack the feedback capabilities that are necessary to (1) balance energy supply and demand, (2) influence customers' behavior, and (3) enable variable tariffs. Therefore, electricity meters must be linked to gateways which support two-way communication. These meters are called Smart Meters.

VI. Requirements for Communication Technologies and Networks

A Smart Gird is an upgraded energy grid which enables sensing, monitoring, communication and control of middle and low voltage grids. Against this background, the communication infrastructure must address the following requirements (Yan 2013, Khan/Khan 2013, Plückebaum/Wissner 2013):

A. *Scalability*

The huge majority of sites requiring communication facilities are identified at the level of the end user and at the low voltage level (11kV) of the electricity grid. The communication infrastructure must provide utilities with the capability to accommodate a fast growing and ultimately very high number of M2M devices that are widely distributed in the field. Accordingly, the communication network needs to provide both comprehensive coverage and sufficient network capacity.

B. *Performance*

Latency, data throughput and reliability. For the performance of a Smart Grid, data volumes of only a few Kbytes per data transfer, and latency less than 100ms are critical for network-oriented applications. End-customer-oriented services, like metering, are less demanding. Here, higher latency rates can be accepted. For network-oriented applications the suggested time for resiliency ranged from 8-12 hours up to 72 hours for the most critical services and sites.

C. *Availability*

End-to-end service availability for Smart Grid and smart metering applications depends on location and time availability. Whereas location availability of fixed networks only depends on homes connected and implemented redundancy, the location availability of wireless networks is connected to radio coverage. Some Smart Grid applications, for instance connecting secondary subsystems, require a service availability ranging from 99.5 to 99.9 per cent. In a commercial network this can only be achieved by reserving capacity for or prioritizing Smart Grid services.6 Service availability for the advanced metering infrastructure is less demanding in respect to time. Since data will be stored on customer devices for a certain time period, availability below 90 per cent could be acceptable.

D. Costs

The Smart Grid, with its unprecedented communication capabilities, should not significantly increase the price of electricity. Here, two categories of costs are relevant: (1) the price of the single communication service (e.g., connectivity costs for transport of 1kByte). The cost per application thereby depends on the cost of coverage, the cost of capacity and the cost of operation with different technologies having advantages and disadvantages in the one or other cost category. It is therefore important to look at the average unit cost per application for the expected number of smart assets in the grid taking into account coverage of all assets, capacity for all applications and the operation thereof. (2) The costs incurred with the installation of a communication interface at the customer premises. Main cost drivers are communication device and installation effort, in particular related to in-house cabling.

E. Security

One of the emergent requirements facing the deployment of Smart Grid is related to security issues. Firstly, the design of a Smart Grid has to ensure that consumer related data cannot be misused.Secondly, the interconnection of the multiple entities in a Smart Grid might attract cyber-attacks. To mitigate the risk, there is a need for a security system especially when commercial networks enable Smart Grids. Finally, all data in a Smart Grid must be subject of a secure and guaranteed message delivery. Governments generally prescribe security features/implementation requirements for Smart Metering, which in principle are independent of the communication technology and can be implemented in public and private networks. However, private networks provide an additional layer of security which enhances security substantially and may reduce the need for additional security features to be implemented on higher layers, lowering cost and complexity.

F. Availability

The communication technology has a negative impact on midterm costs. Swapping millions of devices might easily exceed capital and operation expenditures for the whole communication infrastructure. Furthermore, the main underlying technology should be standardized and established so that there is no lock-in-effect with any single supplier but a large enough ecosystem to ensure long-term supply alternatives.

VII. STUDY OF WIRELESS TECHNOLOGIES:

This chapter analyses how radio spectrum and wireless technologies enable Smart Grid functionalities. Utilities have two alternatives:

1) The first alternative is to use the services of public, commercial mobile networks, where it is doubtful whether operators can offer a dedicated service with high SLA in principle (issue of net neutrality) and at an acceptable price level.
2) The second alternative is to realize Smart Grid in a private wireless network. A private network could either be deployed (owned and controlled) by utilities or by third parties who offer dedicated capacity to market players in the power market. The difference of the latter to the first alternative is that within a private network there will be no competition with radio resources. The study does not focus on all kinds of spectrum available for Smart Grid applications. Firstly, unlicensed spectrum is not the subject of the analysis; the operator has no exclusive use which could lead to congestion, making performance of the network potentially unreliable. License-exempt spectrum is therefore not regarded as a viable option for the wide area communication network (WAN). As a consequence, RF Mesh is not analyzed in this paper. However, RF Mesh may be an option to connect gas, water and electricity meters within a building to the WAN network. Secondly, due to propagation characteristics, only spectrum below 1 GHz provides the opportunity for indoor coverage (in particular basements). Spectrum above 1 GHz has weaker in-building penetration and is used primarily to increase capacity which is less relevant in the context of Smart Grids. Below 1 GHz the following spectrum bands are traditionally used and available for mobile services and therefore considered in more detail: 450 MHz, 800 MHz and 900 MHz.900 MHz band and GSM/GPRS (General Packet Radio System). Although the European Law provides for the possibility of operating mobile technologies other than GSM/GPRS in the 900 MHz band, the majority of mobile operators have not switched to another technology (like UMTS or LTE). For example, the German mobile operators have constantly repeated that from a short-term perspective GSM/GPRS remains the prevailing technology in this frequency band. Hence, Smart Grid in the 900 MHz frequencies uses GSM/GPRS. Other technologies might be deployed after 2020. Currently, trials in Germany and in other EU Member States use GSM/GPRS as the WAN for the Smart Grid.9 The use of this technology reflects primarily the fact that GPRS is currently the only mobile technology which is accessible almost everywhere in the country. Furthermore, GSM/GPRS networks at 900 MHz are able to provide reasonable indoor-coverage and data services are available at reasonable cost. However, observing the requirements outlined above and taking into account results from trials (Ernst & Young 2013, 49) it becomes obvious that GPRS has some significant limitations; certain performance requirements are not met by GPRS (e.g., latency). The indoor coverage of GSM networks is probably the best of any commercial networks, given its 900 MHz spectrum band and comprehensive area coverage, but pilots have shown that the coverage is often insufficient for Smart Meters. Since in the 900 MHz band all frequencies dedicated for mobile telephony (or mobile access to the internet) have already been allocated, there is no possibility to deploy a private network. As a consequence, GSM/GPRS in 900 MHz is only available as a service on commercial networks with shortfalls in terms of security, control, availability and resilience. Here we have to bear in mind that GSM/GRPS networks have been designed, dimensioned and deployed to offer mobile voice

telephony to end users. The networks are ill prepared to handle the signaling traffic of millions of devices which occurs with the advanced metering infrastructure on top of mass market voice services. Service guarantees and dedicated quality of service to ensure priority message delivery cannot be guaranteed by mobile operators. In addition it is expected that GSM/GPRS will be substituted by other technologies in the mid-term which are more efficient. Thus, it can be assumed that mobile operators will not invest in this technology to improve the network quality for just one class of service.

GSM/GPRS is generally seen as an inferior solution when a full-fledged roll-out of the AMI is considered.The opportunity costs arising in the event Smart Grid traffic crowds out mass market applications in the retail market will impact pricing of the Smart Grid traffic making it more expensive. The better LTE succeeds in the market, the higher the opportunity costs which subsequently have to be reflected in the wholesale prices for Smart Grid services. The telecommunication operator has to bear in mind that M2M traffic with a high number of installed devices, like the Smart Meter, uses a large part of network resources. Congestion in commercial networks can only be avoided if the network concerned is operating with sufficient resources in frequency bands below 1 GHz and is optimized for M2M traffic pattern.The 450 MHz frequency band is available in many European countries (being either underutilized or unassigned) and has in comparison with 800 MHz and 900 MHz a striking benefit: due to its lower frequency range, the propagation characteristics enable much better building penetration than GSM 900 and LTE 800. Moreover, mobile networks in the 450 MHz spectrum require approximately four times less base stations than mobile networks at 800 and 900 MHz (irrespectively of the technology deployed), thereby offering much better stand-alone economics. Currently, the standardized CDMA (3G) technology is available at 450 MHz. In the mid-term, LTE technology will become an alternative. Standardization of LTE for 450 MHz is on the way and first suppliers have LTE equipment available. It is likely that operators in Brazil will deploy LTE in this frequency band starting in 2014. However, LTE has yet to be optimized for M2M use cases. CDMA EV- DO Rev. A provides a data throughput of 1.8 Mb/s in the uplink and 3.1 Mb/s in the downlink. The latency criteria of network-oriented applications are also met. Existing CDMA450 networks in more than 60 countries and a well-developed supply ecosystem ensure longer term equipment availability. CDMA technology is being further optimized for M2M use by new standard developments such as CDMA 1X Rev F.

VIII. Conclusion

Energy demand has been fulfilled in this case study.The Smart Grid is an electrical grid that communicates our electrical system far more pliant to problems like blackouts, better accommodate unusual power sources, and ease energy demand. It is not only technically, but also from a spectrum/network availability standpoint, very well suited for deploying/operating networks that are wholly or partially dedicated to Smart Grid.

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