Smart Grid Technology

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Abstract: The awareness of the greenhousegas effect and rising energy prices lead to initiatives to improve energy efficiency. Micro- and Smart-grids, virtual power plants, distributed generation, large shut-downs of grid areas and "blackouts" – all these special topics are in the focus of discussions about operation and development of electrical transmission and
distribution networks in the near future.

Depending on historical reasons over several years the current electricity system was developed as a large scaled technology with focus on centralized generation and control. The load flow from large power plants and strong high-voltage transmission grids to low voltage customers has been the base of the power-system since a long time. Nowadays besides these large scale technologies the economical and ecological use of energy is in the focus of the public awareness and the increasing connections of decentralized generations using renewable resources to bring new challenges into the power system.

In this paper, we propose a decentralized framework named SmartGRID to tackle high-level grid resource management and scheduling a simulation study of operation and control of distributed generators (DGs) in power islands in Smart Grid environment.

1)Introduction: The utility industry has been utilizing advances in communication and information technology over the years in order to improve efficiency, reliability, security and quality of service. Increasing complexity in managing the bulk power grid, growing concerns for environment, energy sustainability and independence, aging asset base, demand growth and quest for service quality continue to accentuate the need for a quantum leap in application of such technologies.

This leap toward a "smarter" grid is now widely referred to as "smart grid". Smart grid (SG) is envisioned to take advantage of all available modern technologies in transforming the current grid to one that functions more intelligently to facilitate:

• Better situational awareness and operator assistance.
• Autonomous control actions to enhance reliability by increasing resiliency against component failures and natural disasters, and by eliminating or minimizing frequency and magnitude of power outages subject to regulatory policies, operating requirements, equipment limitations and customer preferences. Such control actions can be more responsive than human operator actions.
• Efficiency enhancement by maximizing asset utilization
• Resiliency against malicious attacks by virtue of better physical and IT security protocols.
• Integration of renewable resources including solar,wind, and various types of energy storage. Such integration may occur at any location in the grid ranging from the retail consumer premises to centralized plants. This will help in addressing environmental concerns and offer a genuine path toward global sustainability by adopting "green" technologies including electric transportation.
• Real-time communication between the consumer and utility so that end-users can actively participate and tailor their energy consumption based on individual preferences (price, environmental concerns, etc.).
• Improved market efficiency through innovative solutions for product types (energy, ancillary services, risks, etc.) available to market participants of all types
and sizes.
• Higher quality of service – free of voltage sags and spikes as well as other disturbances and interruptions – to power an increasingly digital economy. The momentum for the "Smart Grid" vision has increased recently due to policy and regulatory initiatives, as exemplified by.

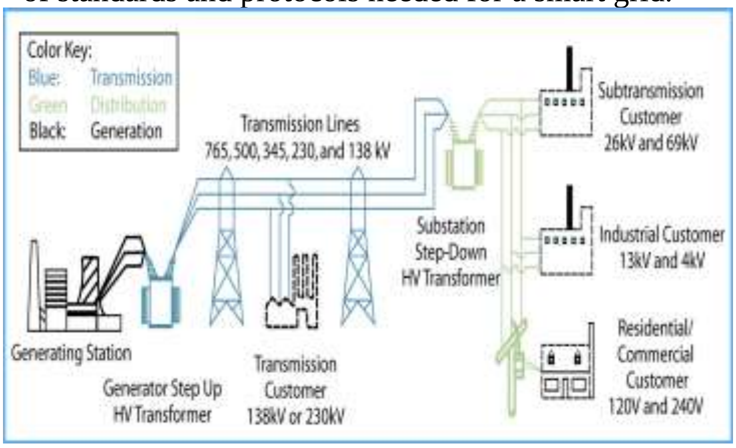
Numerous and diverse stakeholders are striving to realize the above smart grid goals by advancing and deploying various technologies. These efforts can be categorized into the following trends:

- Reliability
- Renewable Resources
- Demand response
- Electric storage
- Electric transportation

This paper first provides an overview of the grid reliability challenges and then presents a critical review of the salient reliability impacts of the four smart grid resource types identified above. We observe that an ideal mix of these resources that flattens net demand would eventually accentuate reliability issues even further.

Meeting reliability challenges requires a grid-wide IT infrastructure that provides coordinated monitoring and control of the grid. We then present an architectural framework for such IT infrastructure. The architecture is designed to support a multitude of geographically and temporally coordinated hierarchical monitoring and control actions over time scales ranging from milliseconds to operational planning horizon. Such capability is necessary to take full advantage of the modern measurement technologies (e.g. PMUs) and control devices (e.g. FACTS).

The architecture is intended to serve as a concrete representation of a common vision that facilitates the design and development of various components of the IT infrastructure and emergence of standards and protocols needed for a smart grid.



2)Smart meters :

There is no single definition of smart metering. A smart-meter system comprises an electronic box and a communications link. At its most basic, a smart meter measures electronically how much energy is used, and can communicate this information to another device. For both electricity and gas, there are two main smart-meter types :

- AMR – One-Way Communication from the Meter to the Data Collector – as a minimum enabling Automated Meter Reading.
- AMM - Two-Way Communication between the Meter and the Supplier - enabling a wider range of functions known as Automated Meter Management.

A further refinement of the AMM meter is an Interval Meter - a two-way meter with a capability to store and communicate consumption data by time-of-use (e.g. half-hourly intervals).

The key distinction between smart-meter types is therefore determined by their communication – i.e. whether one-way or two-way - and data-storage capability. These basic meter capabilities then determine the functionality that the meter might offer. Functionalities range from basic remote meter reading and tamper-detection to remote activation and load-shedding, remote tariff-change and time-of-day tariffs plus datastorage. The following list captures the core capabilities that are consistently identified as particularly important for a smart meter system :

- Measures energy consumed - quantity and when (a time-interval basis)
- Records ‘billing-level’ readings
- Two-way communication
- Stores interval-data and transfers it remotely to a data collector / utility
- Capable of storing and displaying consumption and tariff information

Communications combinations are still evolving with fixed, mobile, wireless, narrow-band and broadband options available.

Reliability and data-accuracy are a recurring theme, whatever the chosen communications technology. Broadly speaking, communications from the meter to an *initial* data-collection point can be grouped between :

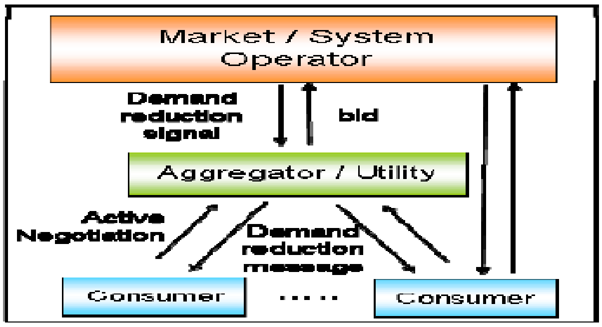
- fixed - e.g. telephone landline - PSTN, ISTN, Cable/ADSL ; or the electricity distribution wires - Power Line Carrier (PLC)

• wireless – e.g. GSM (system used by mobile phones); various forms of radio communications such as GPRS and Low Power Radio(LPR)
Different communications technologies seem best suited to different needs as follows.
• **GSM** - would allow Suppliers considerable flexibility in targeting particular customer groups, including SMEs, pre-payment or remote residential customers.
• **PLC – LPR** – are well suited to geographic-based smart meter rollout and are being extensively and successfully deployed in Italy and Scandinavia, for example.
In a number of countries where smart meters are being installed a range of communications technologies are being deployed to meet different needs, and many valuable lessons are being learned.

3)Demand Response / Load Management

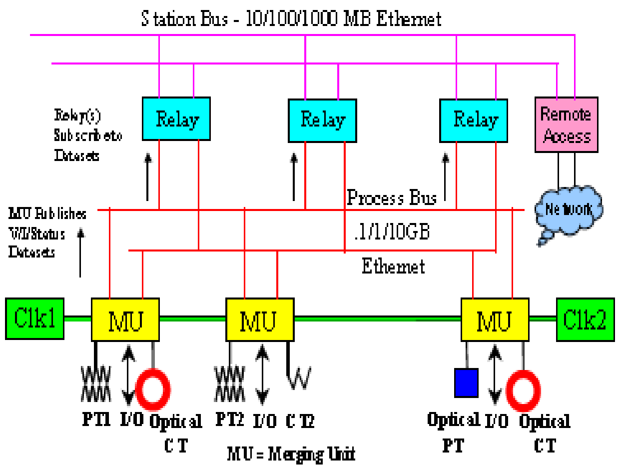
Demand response allows consumer load reduction in response to emergency and high-price conditions on the electricity grid. Such conditions are more prevalent during peak load or congested operation. Non-emergency demand response in the range of 5 to 15% of system peak load can provide substantial benefits in reducing the need for additional resources and lowering real-time electricity prices Demand response does not substantially change the total energy consumption since a large fraction of the energy saved during the load curtailment period is consumed at a more opportune time – thus a flatter load.

Price based demand response/load management as a system resource to balance demand and supply has not been widely adopted yet. Contract based participation has been typically below 5% of peak load [14]. In a smart grid, real-time price information enables wider voluntary participation by consumers. Demand response can be implemented through either automatic or manual response to price signals, or through a bidding process based on direct communications between the consumer and the market/system operator or through intermediaries such as aggregators or local utilities



4)SUBSTATION AUTOMATION

The basic *functionality* of Substation Automation is given by its tasks and will not be changed by IEC 61850. On a first look, also the system architecture is not so much changed. Nevertheless, *communication* is the backbone of SA and, therefore, IEC 61850 the most important key for designing systems. A lot of inherent features in IEC 61850 like the use of object oriented data model, the selection of mainstream communication technology allow responding very dedicated to requirements stated in *customer specifications* not by chance but based on standardized rules. Therefore, these features support designing optimized systems. *Optimization* includes not only functional performance but also economic aspects like investment, availability, expandability and maintainability, i.e. all life cycle costs. For specification, design and engineering, the most important feature of IEC 61850 is its support to strong formal description of the substation and its automation system. The use of this strong description facility will be mentioned in all steps below if applicable. If the *customer* is not providing this formal specification, this task is left for the *system integrator* or *provider* to use its power for the SA system design.



5)The Design Procedure For Substation Automation Using Iec61850

5.1)Start

The design process can either start with the functional specification, in case of IEC 61850 preferably with an SSD description, or with the boundary conditions . When starting with the *functional specification*, the next step is to search for IEDs, which support the required functions. Then it has to be checked if the grouping of functions (LNs) on the found IEDs fulfills the availability and safety criteria. In the next step the boundary conditions and the availability conditions are used to design the connecting communication architecture in a cost optimal way. Now the overall system structure is known, and detail design can start. This kind of approach is mostly used if the types of available IEDs are well known, have relatively static configuration range, and are not too large.

5.2)Tools and formal specification

To get maximum benefit from tool support the specification has to be translated into the SCL based SSD (System Specification Description). The SSD has to be complemented with more detailed specification where needed. The SSD is an unambiguous input, which enhances the quality of the specification and allows functional simulation to see the interaction of LNs and to get a base for estimation of communication load, performance, completeness, etc. before the system exists.

5.3) Grouping LNs to LDs and non-functional requirements

If we start with given IEDs, the IEDs have to be allocated to these functions. During this allocation we have to prove that no constraints are violated and the reliability and availability goals are met. If we have a free choice of devices, we may first group functions, i.e. the LNs belonging together, in Logical Devices (LD). The next step is combining all LDs in IEDs in such a way that a minimum number of devices results but all constraints are fulfilled. Finally, we have to find proper devices for implementing this optimized solution. The device selection may be an iterative process for both approaches.

5.4)Detail engineering

The result of the design process for IEC 61850 based systems can formally be described in an SCD (System Configuration Description) file, which contains the logical communication connections between IEDs within subnetworks and routers between subnetworks. The detail engineering on system level has to determine the communication addresses and the detailed data flow between the IEDs in terms of data sets and signal inputs to clients. This signal-level data flow engineering replaces to a big extent the engineering of the conventional wiring. Due to the inherent semantics of the IEC 61850 data model, this step can also be supported with object based or even automated signal engineering [8]. The resulting SCD file contains individualized IED descriptions for the system under design. These descriptions have to be downloaded via the IED tools to the IEDs to make them aware of their place in the system and their connections to other IEDs.

5.5) Communication topology

Logically, communication according to IEC 61850 takes place between LNs. In any implementation, physical communication takes place between IEDs. Multiple communication ports may exist. IEC 61850 is based on Ethernet, and Ethernet allows different physical variants. Since the standard and Ethernet is supporting both client-server relations and peer-to-peer communication, any communication topology connecting all related IEDs fulfills the functional requirements. Therefore, the final determination of the communication topology is strongly influenced by constraints, i.e. by non-functional requirements like performance (section 3.4), availability and others (section 3.5).

5.6) The final system

The selected IEDs together with the communication architecture represent the final system. Different solutions are possible. Since all solutions have their functional and non-functional properties and their price tag, a proper trade-off can be made. Having the complete formal description of the system and all additional information needed, this evaluation can be made before any piece of equipment is ordered, e.g. already in the quotation phase. In case of ordering, the high level data and communication engineering is already made. However, IED detail engineering like configuration, parameterization, process interface and human interface engineering still must be performed.

6)Conclusion:

Deregulation and privatization are posing new challenges on high voltage transmission systems. System elements are going to be loaded up to their thermal limits, and wide-area power trading with fast varying load patterns will lead to an increasing congestion. Environmental constraints, such as energy saving, loss minimization and CO_2 reduction, will play an increasingly important role . The loading of existing power systems will further increase, leading to bottlenecks and reliability problems. As a consequence of “lessons learned” from the large blackouts in 2003, advanced transmission technologies will be essential for the system developments, leading to Smart Grids with better controllability of the power flows.

Presentation includes the evolution of smart grid and related technologies need for a smart grid and the concepts of smart metering followed by substation automation technologies.