

SmartGrid. What is really behind this word?

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1 INTRODUCTION

The electric grid is a key piece of critical infrastructure upon whose operation the economy depends. For that, always companies have tried to use the latest technology in infrastructure and operation optimization. Based on that, we can conclude that the electrical grid always was “Smart aligned with the technology available at every moment”

Today we can send enormous volume of data from and to any place at relative low cost in investment and operation. This allows us to have information in real time not only from big generation plants, also from domestic consumers. In other words, “Go from turbine to toaster”

But first question is what really we want to control and to do what? And second question is: Is the actual infrastructure prepared to deploy all the functionality required for a complete Smartgrid deployment. Are we pretending to “built a building on a basement prepared for a single house”?

Paper pretends to give a vision of the overall situation in order to show the enormous challenges that we have in front, if we pretend to apply new technologies in Grid optimization.

2 PROBLEM 1: DEMAND CONTROL AND OPTIMIZATION

The main problem of the electrical industry is how to optimize the use of the infrastructure 24 hours per day and 7 days per week. Load consumption is the key aspect, because this is the main variable that up to day we cannot control. Traditionally load is what it is and the utilities always accommodate investment and operation of the electrical infrastructure to load. This situation causes a lot of inefficiencies that could be eliminated if we were capable to control the load. The main difficulty is that load is linked with industry process, people needs and habits, among other circumstances.

Demand Response Management System (DRMS) is a smarter, integrated approach to managing demand. It uses data collection from a “smartmeter” and it can provide automatic control on the different switching devices that connect and disconnect loads. Additionally there is continuous-learning algorithms as part of a complete system of two-way communications, smart devices and dynamic pricing incentives to deliver a new level of precision and control to demand-side management. It's like moving from a sledgehammer to a laser for cutting away at demand

DRMS is its fresh objective. In addition to suppressing or shifting peak loads, this holistic solution enables an optimal balance between supply and predictable consumer demand, with smart load technologies like Programmable Communicating Thermostats (PCT), smart appliances, electric vehicle charging stations, in-home energy portals and home automation devices. It will also help to optimize the future integration of distributed renewables, like solar, wind and storage.

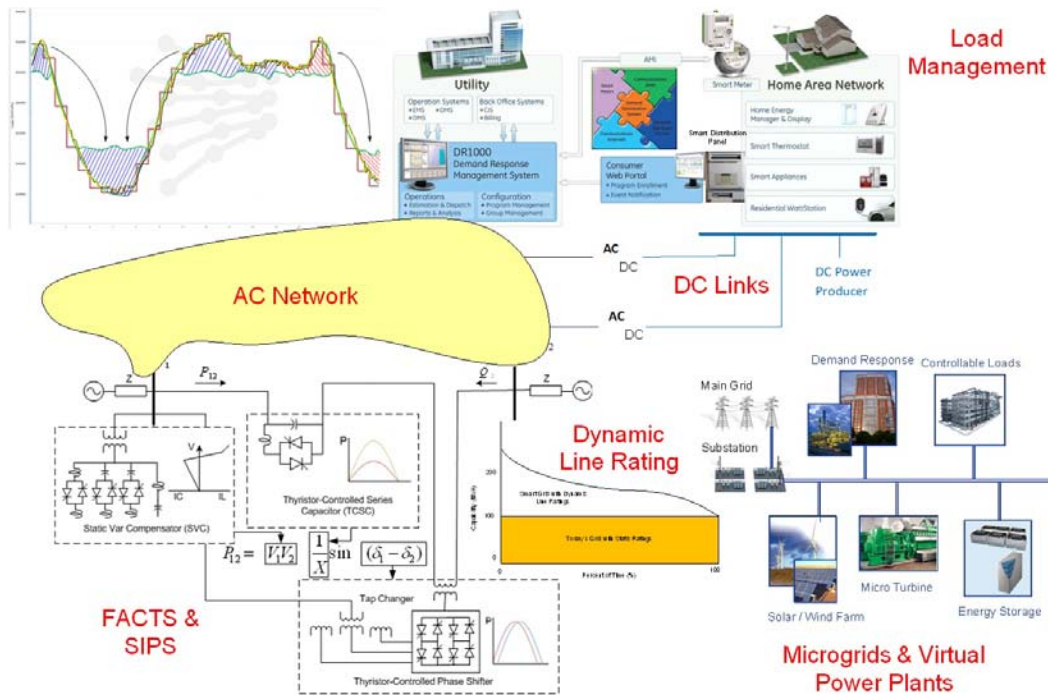


Figure 1: Overall vision of Smartgrid

Studies show that utilities can experience peak demand reduction between 10% and 15%. GE estimates this could save up to \$18 million per year in avoided capital expenditure for a utility with one million customers. From a GE research among customers in US, nearly 80% are willing to change daily habits, 88% are willing to use smart appliances. Main motivations are cost, control, and comfort. 75% residential electricity demand can be “controlled” with little/no impact on service.

In Europe the typical consumption and energy mix is most of the times really far from US. For example, in many countries like Italy, Greece, Spain, it is very extended the use of Gas to heating and how water and less electricity. It leads to average power contracts for residential that are really low (e.g. in Italy there is something like 3Kw/family). From this situation, the latest studies in EU, mainly on the ADDRESS’s advanced active demand initiative proved low benefits. It seems a 20% peak reduction would just lead to 26€/family/year payback ... so accordingly with DSOs, it is not currently viable. In the future, when EVs, and other stuff will show up, something will change. Summarizing seems that diffusion of DRMS in Europe will be behind US in the next 2 years.

There another strongly huge different between US and Europe that will really lead to different usages and technologies: the energy marketplace model. In US utilities are still “vertically integrated”, meaning that it will be easier for them to implement DRMS from back office to end uses (including in-home). In Europe it is not currently possible due the separation of responsibility between DSO and Retailers, which means a more complex and sophisticated end-to-end system. Just in support of that, just think to the Aggregator role.

3 PROBLEM 2: MORE RESTRICTIONS IN RIGHT OF WAY FOR NEW TRANSMISSION AND DISTRIBUTION LINES

As in homes we have more electrical consumption and new industry needs more energy, there are needs to increase the capability for transmission and distribution of energy: At the same time that we manage the load, we need to increase our capability to send and receive energy w/o practically modify the transportation infrastructure. In other words, we need dynamically to accommodate our operating criteria to maintain the reliability and quality of service with a major traffic of power and energy. In this area, new systems as the Wide Area Monitoring Systems (WAMS) based on synchrophasors, System Integrity Protection Schemes (SIPS) and other Flexible AC Transmission Systems (FACTS) are emerging as tools to optimize the operation of the grid.

3.1 WAMSS/SIPS

As the existing transmission system infrastructure is challenged to support loads beyond original design limits, the implementation of “wide area” Power System Protection Systems (PSPS) also called System Integrity Protection Schemes (SIPS) are often needed to maintain transmission system integrity. The SIPS encompasses Special Protection Schemes (SPS), Remedial Action Schemes (RAS), as well as additional schemes such as, but not limited to, Underfrequency (UF), Undervoltage (UV), out-of-step (OOS), etc. These take the form of automatic actions that instigate load shedding in a specific area of the network or reduction of Generation Output in order to prevent instability or overloads in interconnections that could affect the circuit or Power System stability, etc

3.2 FACTS

Flexible AC Transmission Systems (FACTS) are power electronic based devices and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability of power systems. FACTS devices are therefore being increasingly employed in power system networks to satisfy these requirements

In a power system, the transmission of power in a transmission line is mainly dependent on the sending and receiving end voltage levels, the transmission angle and the transmission line reactance.

To increase the power flow through a transmission system, one or more of the above parameters must be changed. For example, the transmission angle can be increased with the use of a phase shifting transformer but such an item of plant is costly to purchase and install, and the transformer losses must be accounted for. Increasing the transmission angle also pushes a power system closer to its stability limit, increasing the likelihood of system instability. Also the transmission voltage level could be increased. Power flow could also be increased by reducing the inductive reactance of the transmission system by installing fixed series capacitors. This was in the past found to be one of the most economical ways of increasing the power flow of the transmission system.

Table 1: Available FACTS devices

Conventional Thyristor technology based FACTS devices	Voltage source convertors based FACTS devices
Static shunt compensator of the following types: thyristor controlled reactor (TCR) thyristor switched reactor (TSR) thyristor switched capacitor (TSC) Fixed capacitor-thyristor controlled reactor (FC-TCR) thyristor switched capacitor & thyristor controlled reactor (TSC-TCR)	Static synchronous shunt compensator (STATCOM)
Static series compensators of the following types: thyristor switched series capacitor (TSSC) Fixed capacitor in parallel with thyristor controlled reactors (FC-TCR).	Static synchronous series compensator (SSSC)
Thyristor controlled phase shifters.	Unified power flow controllers

3.3 Six Phase Systems

Multi-phase (employing phases more than three) power transmission systems have been investigated as a potential alternative to conventional three-phase systems for bulk power transmission at EHV and UHV levels in the past. The technology has been found to be effective to remove some of the limitations of three-phase system arising out of the use of extremely high voltages to increase power capability of lines, excessive rights-of-way (ROW) requirement and several environmental problems.

Six phase transmission provides a technique for reducing physical space requirements for transmission of Electrical Power, it provides a technique for increasing the power handling capacity of existing double circuit lines, reduce cost and minimize environmental effect with lower electrical fields.

Voltage operation level from individual phase-to-neutral is raised by $\sqrt{3}$ over that for three-phase operation without changing the phase-to-phase voltage. In a typical double circuit line, this allows a transmitted power increase in the same ratio with no increase in losses (same currents). In other words, capability is increased by 1.732 times compared with a double circuit line working in a classical three-phase scheme.

3.4 Line Loading Monitoring

Integrated control room solution incorporating dynamic rating of the overhead lines. Solution uses real-time telemetry data (current) plus thermal information from overhead cables.

Avoid major unplanned outages, Allows higher capacity in transmission lines, Deferred investment in HV lines can be combined with automated switching sequences to re-route power.

3.5 Links and DC Networks

In the past 50 years, the installed capacity of HVDC schemes has increases from 20 MW to 80 GW. About 30% of this capacity has been developed in the last 10 years. Most of the HVDC schemes are for point-to-point delivery over long distances. However, improved developments in converter technology have opened up possibilities of using DC systems in distribution networks. Such applications include back-to-back coupling of asynchronous networks or networks operating at different frequencies, connections to off-shore installations and interconnections across environmentally sensitive areas.

4 PROBLEM 3 : THE CLIMATE CHANGE IS A REALITY AND THE OIL ERA HAS BECOME TO END.

In physics, energy economics and ecological energetics, energy returned on energy invested (EROEI or ERoEI); or energy return on investment (EROI), is the ratio of the amount of usable energy acquired from a particular energy resource to the amount of energy expended to obtain that energy resource[8,9,10]. When the EROEI of a resource is less than or equal to one, that energy source becomes an "energy sink", and can no longer be used as a primary source of energy.

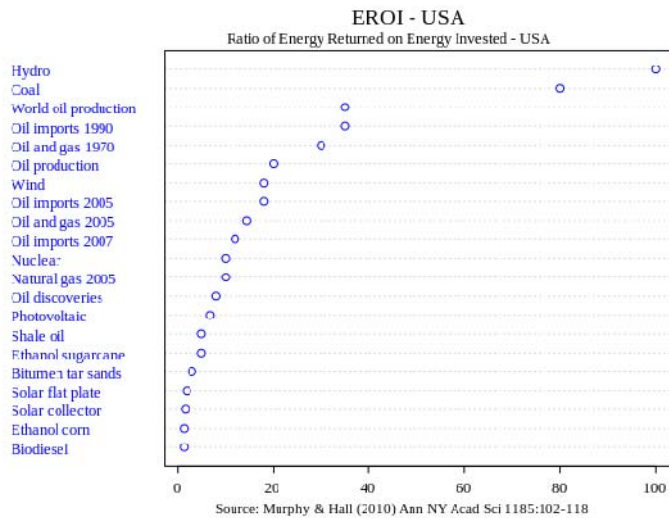
$$EROEI = \frac{\text{Usable Acquired Energy}}{\text{Energy Expended}}$$

High per-capita energy use has been considered desirable as it is associated with a high standard of living based on energy-intensive machines. A society will generally exploit the highest available EROEI energy sources first, as these provide the most energy for the least effort. With non-renewable sources, progressively lower EROEI sources are then used as the higher-quality ones are exhausted.

For example, when oil was originally discovered, it took on average one barrel of oil to find, extract, and process about 100 barrels of oil. That ratio has declined steadily over the last century to about

three barrels gained for one barrel used up in the U.S. (and about ten for one in Saudi Arabia [8]
Currently (2006) the EROEI of wind energy in North America and Europe is about 20:1[8] which has driven its adoption.

Joseph Tainter [8,9] suggests that diminishing returns of the EROEI is a chief cause of the collapse of complex societies. Falling EROEI due to depletion of non-renewable resources also poses a difficult challenge for industrial economies.



For that, some countries are doing a lot of investment to reduce the oil dependence in the generation of electrical energy and now there is massive develop of wind and solar energy as the main alternatives to oil, but these energies have a problem. They are not a predictive energies, in other words, they depend of the climatic conditions that not always are aligned with the energy consumption needs at every moment. Frequently during the day, there is excess of energy available that cannot be used. For that, the new renewable energies need to be complemented with storage systems that warrant energy availability when this is needed. In the last years there are emerging different energy storage possibilities.

4.1 Storage Systems

Technical content/scope: Innovative solutions are needed for higher energy efficiency and improved connection between storage systems, smart grids, buildings and vehicles/mobility systems, as well as methodologies for interconnectivity between smart grids and other networks (e.g. heat networks), in line with the SET Plan. The interconnection between systems in buildings (including room conditioning equipment as well as home appliances) is a key challenge in improving energy recovery, in particular through the integration of water management and ventilation systems, by developing new energy and water management strategies at community level. New methods for real-time management of energy demand and supply are required. In this framework, new technologies and approaches are needed to enable effective Building-to-Building and Building-to-Grid interactions as it should be in a real energy market. Energy-efficiency interoperability of buildings with other urban domains (transportation, energy grids, etc) has to be achieved. Methodologies and tools for reduction of CO2 emissions and improved energy efficiency, keeping at least the same comfort level as well as certification procedures at district level are required to contribute to a low carbon economy. This integrated approach requires considering simultaneously storage of energy of different types: thermal, electrical or other (e.g. chemical, hydrogen, mechanical, biogas, magnetic). Specific solutions are needed, allowing the best solution to be selected to store renewable thermal or electrical energy at district level or at another scale including seasonal, geological or geographic specificities. Storage capabilities are expected to be combined with systems and equipment for energy production and distribution at building and district level.

Solutions are needed for achieving the highest coverage of built environment energy demand by renewable (heat, cool and electrical) energy production at building and district level. This has to come along with new methods of predicting well in advance the renewable energy production and use, choosing accordingly the best storage and usage strategy.

Power Application: Ancillary Services (Frequency regulation, Spin & non-spin reserve, Transient stability / inertia, Voltage regulation, Blackstart (short-term)), Reduce thermal unit maneuvering

Energy Application: Asset Investment Deferral (T&D lines, Transformer upgrade, Generation capacity), Spin & non-spin reserve, Peak shifting / load leveling, Capturing & shifting wind energy, Blackstart (longer-term), Islanding / UPS

5 COMMUNICATIONS INFRASTRUCTURE

Majority of utilities (at least the European Utilities) are thinking to use the actual communication infrastructure to support the dataflow for the Smart Grid. In Distribution and for Data management the particularities of the communication system of some European Utilities are as follows:

Communication with the Smart meters: PLC, GPRS, DLMS Cosem (PRIME)

Communication from the Concentrator with the Distribution Center: GPRS, GMS, Radio, PLC, Fiber Optic.

Interoperability: PRIME (Iberdrola- Spain, EDP-Portugal, Gas Natural-Spain), G3 (EDF-France), Meters and More (Enel- Italy)

Communication Protocol at higher levels: IEC61850

Communication with FACTS: As FACTS are generally installed in the HV network, majority of communication system is based in Fiber Optic. As communication protocol, IEC 61850 is taking major protagonist.

Communication with Dispersed Generation (DG): Radio, GPRS or Fiber Optic with IEC61850

Communication at Home: One protocol originated in USA, that is becoming popular in Europe to integrate the different devices at home is ZigBee Smart Energy Profile

Communication with Electrical Vehicles: (EV) (USA), WiMax, WiFi, RF Mesh, Cellular, HomePlug AV, Zigbee, WLAN . EV from the perspective of the Electrical Grid performance is as a Storage System

6 CYBER-SECURITY

The widespread use of communications for remotely accessing IEDs increases the possibility of a malicious attack on the electrical infrastructure. Historically, electromechanical and static relays did not include a communication interface and consequently there were no means to access and modify these devices remotely. Any changes, including removing protection from service, required staff to be physically present within the station.

Critical Points: *Critical Assets* - Facilities, systems and equipment which if destroyed, degraded or otherwise rendered unavailable, would affect the reliability or operability of the Transmission Network. *Critical Cyber Assets* - Cyber assets essential to the reliable operation of Critical Assets and can be accessed using a routable protocol or a dial-up connection. *Cyber Assets* - Programmable electronic devices and communication networks including hardware, software and data.

7 NEW TECHNOLOGIES

7.1 SmartSubstations

The goals:

- Reduce the use of cooper and the project execution time to a minimum by moving field labour to the factory. *Solution Proposed: Process Bus based on IEC61850.*
- Reduce the time of data collection to SCADA from the current typical time of 1 second to 1 power cycle, providing an effective real time system. *Solution Proposed: Synchrophasors.*
- One communication protocol for all the access levels. *Solution Proposed: IEC61850.*
- Facilitate the data access for an easy asset management implementation. *Solution Proposed: Standard Databases prepared for SCADA, EMS, GIS, etc.*

7.2 Microgrids

Microgrids are envisioned as local power networks that utilize dispersed energy resources (DER) and manage the local energy supply and demand. As such, microgrids increase the viability of DER in the bulk grid by aggregating these resources into clusters and managing them as a single entity like a virtual power plant (VPP). This provides better grid stability properties than a multiplicity of standalone generators. This would increase customer reliability by reducing their susceptibility to grid disturbances, while offering desirable security features. While microgrids would typically operate connected to the national bulk-power transmission and distribution system, they would have the ability to disconnect from the grid and function in “island mode” when necessary.

When connected to a Utility-owned power system, power may flow in either direction between the utility power system and the microgrid through a Point of Common Coupling (POCC). An example of microgrid architecture may include a mix of conventional generation sources (e.g. diesel generators) with renewable energy sources (wind, hydro) and energy storage facilities (electrolyzer and hydrogen-conversion) owned by a local operator.

Optimization of a microgrid balances dispatchable DER with the availability of renewable sources to minimize energy cost and thus emission cost. A microgrid allows better usage of the renewable power sources, while providing increased energy security for the microgrid. An optimized microgrid, when fully implemented, can reduce fossil fuel usage in the range of 10–20%, depending upon the power level and mix of renewables, energy storage, and conventional generation.

7.3 Smartcities

A typical Smartcity has 6 main areas of focus: 1. Intelligent Mobility 2. Smart Energy Grids, 3. eGovernment, 4. Smart Buildings, 5. Environmental Intelligence, 6. Intelligent Services [7]. These six axes connect with traditional regional and neoclassical theories of urban growth and development. In particular, the axes are based - respectively - on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of citizens in the governance of cities.

A city can be defined as ‘smart’ when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory governance.

8 PEOPLE EXPERTIZE

Additionally to the immense needs of investment in new technologies, one of the main barriers in the implementation of the Smartgrid, is the availability of enough expertize and tools to afford the implementation and management of new applications. Today, only a reduced number of people in companies is capable to deal with the different aspects comprising in the Smartgrid. As we can see, specialties comprise from the Power System Analysis up to Communication Systems. As an example, a Utility (that manage more than 50 GW) reported that among its 6.000 workers, only two (2) were capable to deal with all the application aspects for IEC61850 communication protocol. For that, we can observe the need of a different kind of engineers and technicians whose preparation must start from the school, if we want to take advantage of the enormous possibilities of new technologies applied in the optimization of the Grid.

9 CONCLUSIONS

- The present paper pretends to illustrate people on solutions for the problems commented and how they are triggering develop of new products as the “Smart meters”, communication systems, supervision and control devices, etc.
- A more efficient grid has a big impact in the environment. We can see in the illustration the impact caused in the US network.

- The overall idea is to make more with less in order to convert our home in a self-sustainable place. The best energy is the non-lost energy.



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