Steps to Smart Grid Realization

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Abstract:
In principle, the smart grid is a simple upgrade of 20th century power grids which generally "broadcast" power from a few central power generators to a large number of users to instead be capable of routing power in more optimal ways to respond to a very wide range of conditions. In this paper we introduce four essential steps for implementation of a smart grid and explain about various solutions and technologies. At the end one optimum solution is concluded depending to the case.

Keywords: Smart Grids, Distribution Networks, Automation, Power Management

I. INTRODUCTION

A realization is emerging that a new view of energy, beyond oil, coal and other fossil based fuels, will result in decentralized components of the electricity grid, a far cry from the central generation and structured system of the past. A smart information network the energy internet for the electric grid is seen as necessary to manage and automate this new world.

The integration of communications networks with the power grid in order to create an electricity-communications superhighway capable of monitoring its own health at all times, alerting officials immediately when problems arise and automatically taking corrective actions that enable the grid to fail gracefully and prevent a local failure from cascading out of control, as happened in 2003 Blackout in US.

We believe that increased reliability and efficiency in the low voltage power grid is an essential part of future energy efficiency efforts. However, the Smart Grid makes many customers wonder what it actually is, what it will cost to implement and within what time frame.

It is supposed to implement the Smart Grid from the ground up, starting with LV substations, smart meters and streetlights. Once we have full control of these components in the grid, we can detect leakages, provide streetlight dimming, enable smart households, and perform load balancing and a number of other Smart Grid features.

II. SMART GRID DEFINITION

A grid is a system of electrical generators connected by transmission and distribution lines and equipment to devices that consume electricity. The purpose of the grid is to supply consumers with enough power and energy to meet their demands with an acceptable level of economy, reliability, and quality. All of the generators, transmission and distribution lines, and energy consumption devices are often referred to in the singular as "the grid," although it is actually a collection of some smaller grids that are all connected. In some cases, the interconnections between and among the smaller grids are numerous and robust, while in others, the interconnections are few and weak.

The grid is not adaptable to dramatic changes in circumstances. Nor is the grid readily controllable in the short term outside of the bounding constraints of the fixed location, capacity, and operating characteristics. The only real option that utilities have to significantly address persistent or profound problems is to invest in more or different large fixed assets, something that has obvious adverse economic implications.

For implementation a smart grid, it should be realized in different parts of network. Some important parts of such implementation are as follow:

- Substation Automation (SA)
- Advanced meter reading (AMR)
- Advanced metering Infrastructure (AMI)
- Demand Response (DR)
- Distribution Automation (DA)
- Energy Management System (EMS)

III. SMART GRID BENEFITS

Smart Grid benefits can be categorized into 5 types:

1. *Power reliability and power quality:* The Smart Grid provides a reliable power supply with fewer and briefer outages, "cleaner" power, and self-healing power systems, through the use of digital information, automated control, and autonomous systems.

2. *Safety and security benefits:* The Smart Grid continuously monitors itself to detect unsafe or insecure situations that could detract from its high reliability and safe operation. Higher cyber security is built in to all systems and operations including physical plant monitoring, cyber security, and privacy protection of all users and customers.

3. *Energy efficiency benefits:* The Smart Grid is more efficient, providing reduced total energy use, reduced peak demand, reduced energy losses, and the ability to induce end-user use reduction instead of new generation in power system operations.

4. *Environmental and conservation benefits:* The Smart Grid is "green". It helps reduce greenhouse gases (GHG) and other pollutants by reducing generation from inefficient energy sources, supports renewable energy sources, and enables the replacement of gasoline-powered vehicles with plug-in electric vehicles.

5. *Direct financial benefits:* The Smart Grid offers direct economic benefits. Operations costs are reduced or avoided. Customers have pricing choices and access to energy information. Entrepreneurs accelerate technology introduction into the generation, distribution, storage, and coordination of energy.

A comparison between traditional networks and smart grids is summarized in table 1:

Table 1: Comparison between Traditional Grids and Smart Grids

	Current Grid	Smart Grid
Communications	None or one-way typically not real-time	Two-way, real-time
Customer Interaction	Limited	Extensive
Metering	Electromechanical	Digital
Operation & Maintenance	Manual equipment checks time-based maintenance	Remote monitoring Predictive condition-based maintenance
Generation	Centralized	Centralized and distributed
Power Flow Control	Limited	Comprehensive
Reliability	Prone to failures and cascading outages	Pro-active real-time protection and islanding
Restoration	Manual	Self-healing
Topology	Radial	Network

IV. STEPS TO REALIZATION

A Smart Grid is essential to provide service that is reliable, secure, cost-effective, efficient, safe, and environmentally responsible. To achieve the vision of the Smart Grid, a wide range of technologies must be developed and implemented. Actually it needs to following steps to be realized:

1. Integrated Communication
2. Modern Hardware
3. Modern Control & Instrumentation (I&C)
4. Smart Software

1. *Integrated Communication system*– A true smart grid will not be possible unless each new major device and system that is part of the grid is able to communicate with every other system on the grid. This critical "interoperability" depends on a coordinated framework of protocols and standards that is in a very early stage of planning. Atypical platform for a smart grid is shown in figures 1 and 2:

Figure 1: A smart grid communication platform

The grid of the future will need something sophisticated like the most advanced IP-based systems of the communications industry. High-speed, fully integrated, two way communication technologies make the smart grid a dynamic, interactive for real-time information and power exchange. Communication media is in various types such as:

- Copper wiring
- Optical fiber
- Power Line Carrier (PLC)
- Wireless technologies
- Broadband over Power Line technologies (BPL)

In Summary, It can be categorized in three major groups for next generation and also available integrated communication system as table 2:

Table 2: Integrated Communicated Systems for Smart Grids

Group No.	Group Name	Technology
1	Broadband over power Line	• BPL
2	Wireless Technologies	• Multiple address system radio • Paging networks • Spread spectrum radio • WiFi • WiMax
3	Other Technologies	• Internet2 • PLC • Fiber to the home (FTTH) • Hybrid fiber coax (HFC) • Radio frequency identification (RFID)

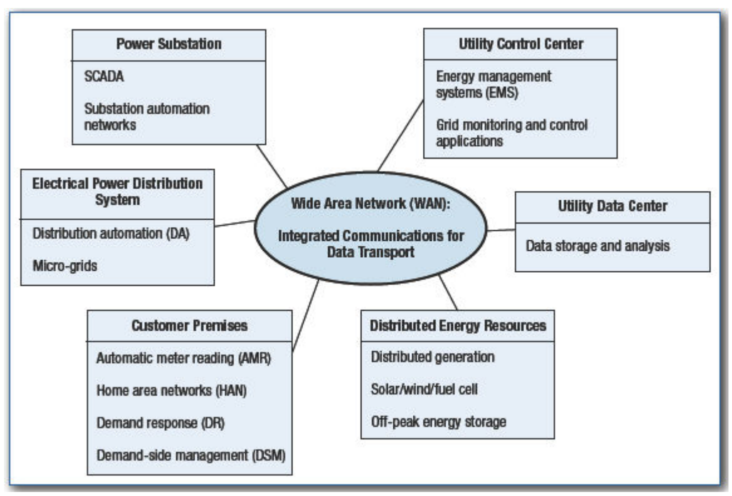


Figure2. An Integrated Communication System

2. *Advanced Hardware* – Hardware play an active role in determining the electrical behavior of the grid. These power system devices apply the latest research in:

- Materials
- Superconductivity

ISSN: 1790-5117

ISBN: 978-960-474-151-9

- Distributed Generation
- Energy storage
- power electronics
- Microelectronics (Grid Friendly Appliance)

to produce higher power densities, greater reliability and power quality, enhanced electrical efficiency that produces major environmental gains and improved real-time diagnostics. Table 3 summarized such devices in 5 groups:

Table 3: Modern Hardware for Smart Grids

Group No.	Group Name	Technology
1	Power Electronic Devices	• Unified Power Flow Controller (UPFC) • DVAR or DSTATCOM • Static Voltage Regulator (SVR) • Static VAR Compensator (SVC) • Solid State Transfer Switch • Dynamic Brake • AC/DC inverter
2	Superconductivity	• First Generation wire • HTS cable • Second Generation wire
3	Distributed Generation	• Microturbine • Fuel Cell • PV • Wind Turbine
4	Distributed Storage	• Nas battery • Vanadium Redox Battery (VRB) • Ultra capacitors • Superconducting Magnetic Energy Storage (SMES)
5	Composite Conductors	• Aluminum Conductor Composite Core Cable (ACCC Cable) • Aluminum Conductor Composite Reinforced Cable (ACCR Cable) • Annealed aluminum, steel supported (ACSS)

3. *Modern Control Methods and Instrumentation (I&C)* – New methods and algorithms monitor power system components, enabling rapid diagnosis and timely, appropriate response to any event. It consist devices and algorithms that will analyze, diagnose and predict conditions and determine and take appropriate corrective actions to prevent faults. Figure 3 shows that this control components present in all parts of grid.

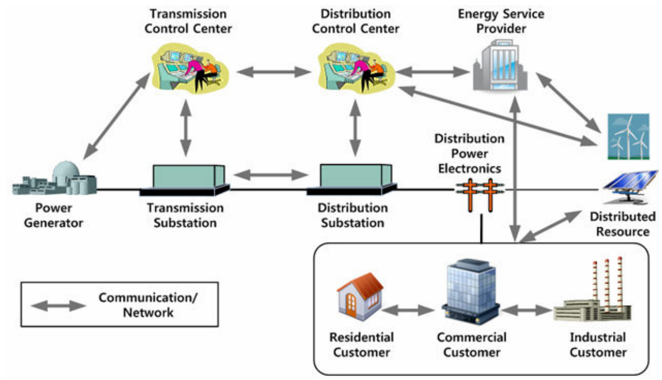


Figure 3: Control Center in all parts of grid

Some of the technologies in these areas are described in table 4:

Table 4: Modern Control Methods for Smart Grids

Group No.	Group Name	Technology
1	Distributed Intelligent Agents	• Digital Relays • Intelligent tap changer • Energy management system • Grid friendly appliance controller • Dynamic distributed power control
2	Analytic Tools	• System performance monitoring and control • Phasor measurement analysis • Weather prediction • Fast load flow analysis • Market system simulation • Distribution fault location • High speed commutating
3	Operational Application	• SCADA • Substation Automation • Transmission Automation • Distribution Automation • Demand Response • Outage management • Asset optimization

Sensing and Measurement –These technologies will support frequent meter reading, eliminate billing estimation and prevent illegally energy usage. It also reduces emissions by enabling consumer choice and demand response. Figure 4 shows a typical smart metering.

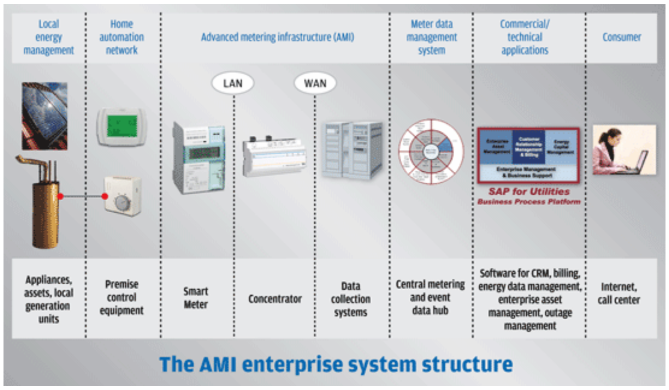


Figure 4: Smart Metering

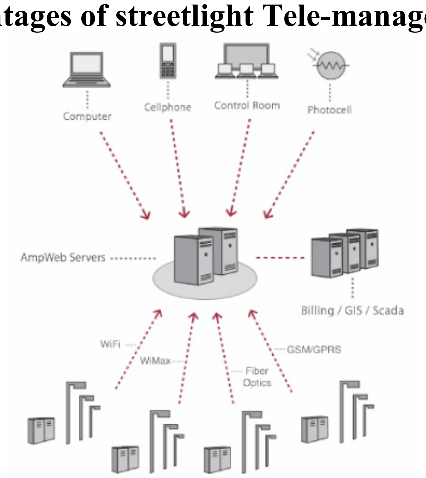
4. *Smart Software* –The modern grid will require wide, seamless, often real-time use of applications and tools that enable grid operators and managers to make decisions quickly. Such a decision support needs improved interfaces that will enable more accurate and timely human decision making at all levels of the grid, including the consumer level, while also enabling more advanced operator training and it also needs an advanced, intelligent software to make user friendly all events and situations as much as.

V. SOME SMART GRID APPLICATIONS

In the following part of paper, some applications of Smart Grids are introduced and it is shown how it will be effective in such applications:

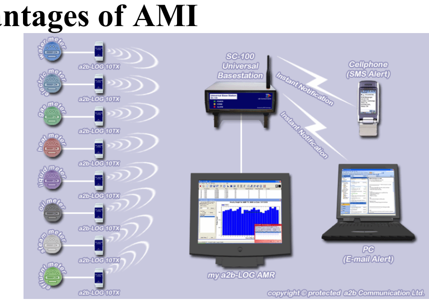
a. Streetlight Tele-management
b. Advanced Metering Infrastructure (AMI)
c. LV Network Automation

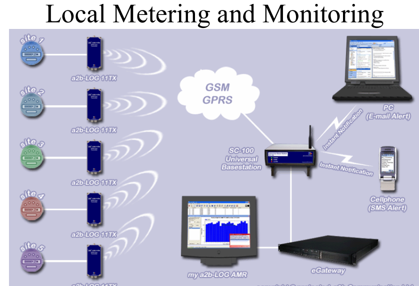
a. Advantages of streetlight Tele-management



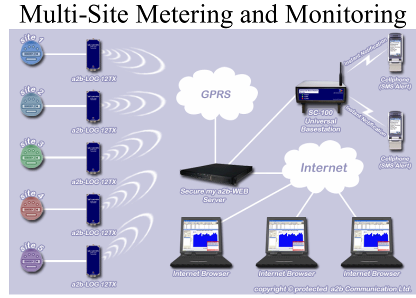
1. Overall quality improvement
2. Complete overview of the entire streetlight system
3. Minimal installation costs
4. Simple and fast installation process
5. Fast return on investment
6. Low operating costs
7. The need for costly visual inspections is minimized
8. One centrally located photo cell lowers maintenance costs
9. Proactive bulb change based on burn hour data
10. Lowered CO_2 emissions benefit the environment
11. Minimizes light pollution
12. Improves street safety by eliminating dark spots
13. Easily expandable to new areas or cities
14. Settings are easily changed by the operator, i.e. during special events
15. Fast reaction to bad weather or traffic accidents
16. Fast and easy access to 24-hour reports including burn hours and faults
17. Report format can be chosen by operator (Excel, html)

b. Advantages of AMI


Local Metering and Monitoring



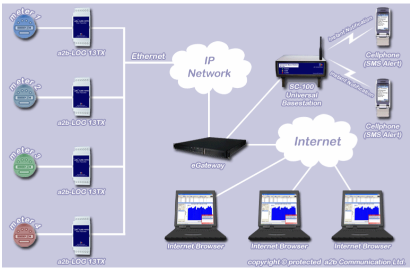
Multi-Site Metering and Monitoring



Managed Metering and Monitoring

ISSN: 1790-5117

ISBN: 978-960-474-151-9



Remote Metering and Monitoring over Ethernet

Electric utilities have historically communicated the costs of providing acceptable availability, reliability, and quality of service via long-term average pricing rather than reflect the reality that the magnitude of a utility's costs varies widely in the short term. Utilities measure consumers' purchases through long term macro indicators (i.e., monthly demand and energy readings) rather than measuring them in a way that would allow for short term price signals to match short term changes in consumption. Both the means of measurement and the method of pricing are complex, even arcane, and not well understood by consumers. A consumer who wishes to reduce the monthly cost of power cannot readily figure out how! Additionally, there is no information at all on other matters of interest to the consumer, such as the sources and kinds of fuel that are used to meet the consumer's needs, the environmental impact or carbon footprint resulting from such usage, or the short- or long-term effects for the consumer, the utility, and their community. So, not only is the grid not intelligent, it is mute. As a result, the consumer cannot be smart either.

1. Meter data is collected automatically instead of manually
2. Transferred data can be processed immediately
3. Data accuracy is improved
4. Electricity leaks and illegal use of electricity are prevented

c. LV Network Automation

1. Metering at every node enables total monitoring of the LV distribution network
2. Losses and non-revenue consumption are identified and can be corrected
3. Remote controlled, multi-functionality circuit breakers give total protection and control of the LV network
4. Intelligent SCADA system minimizes unplanned customer outages and ensures optimum network configuration
5. Integrated control room solution ensures continuity of monitoring between all distribution network systems - MV and LV distribution network, AMR and streetlight.
6. Improved network switching ability reduces overall customer supply downtime
7. Single monitoring point for all alarms (direct and indirect) provides complete control of LV network and enables fast response to incidents
8. Increased availability of network data (through meters) gives advanced network analysis and planning abilities

VI. CONCLUSION

Smart Grids are most comprehensive technology during recent years and it has been grown rapidly because of its benefits. To obtain a modern electrical network with reliable and secure consideration, it should be follow some necessary keys which are named smart steps in this paper. Five key steps are introduced and various items are brought in each step. Consequently, one optimum and effective solution is summarized for each of them.

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