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REVIEW ARTICLE

REVOLUTIONIZING AN ERA OF 21ST - CENTURY SMART GRID

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Abstract:

“POWER GRID”-It is the largest machine in the world an electric behemoth built on a skeleton of early 20th century engineering. The rest is a hodgepodge, a century's worth of innovations grafted onto an outdated framework. Yet, for the longest time, the Indian power grid has slogged on unchanged and rarely challenged, with a growing population shackled to its hide by every electrical gadget and appliance imaginable. More than 300,000 miles (482,803 kilometers) of sprawling transmission lines twist and weave through our country. Yet despite the sheer size of the system, a few outages are enough to bleed us of at least $150 billion dollars annually. Meanwhile, a growing population continues to plug more and more power-hungry gadgets and appliances into the grid. To address the current power grid's shortcomings and prepare for the future, the DOE hopes to implement a number of changes in the years to come. The plan is to transition to a more efficient version of the current power grid, the smart grid. This paper discusses the key problems with the current system, How the smart grid will address these issues, and just what kind of short- and long-term methods figure in to the effort of revolutionizing the current grid to THE 21ST CENTUARY SMART GRID.

Key words: DOE (Department of energy), grid, transmission lines

INTRODUCTION:

The Indian electrical grid, consisting of over 5,000 power plants, over 200,000 miles of high-voltage transmission, and over 5.5 million miles of distribution lines, is one of the most complex machines in the world. While the population has grown and the equipment using electricity at the other end of the lines has become increasingly sophisticated.[1] Today's electrical grid suffers from a number of problems, including that it is:

- *Old* (the average age of power plants is 35 years)
- *Dirty* (more than half of our electricity is generated from coal& diesel gensets)
- *Inefficient* (the delivered efficiency of electricity is only 35%)
- *Vulnerable* (the 2012 blackout in the Northeast Bina-Gwalior & Agra-Bareilly affected 300Million people for up to two days)

The grid is ill-equipped to handle both renewable, which are intermittent and less predictable than fossil fuel-based generators, or distributed generation. Finally, the current state of the grid limits the potential of energy efficiency efforts, as there are significant lags in the system such that users of electricity typically are unaware of their usage level at any given time. At the same time we are getting more & more “ELECTRONIC FRIENDLY”. Thus making the appliances more sensitive to electrical variations. The growing chorous for building a new SMART GRID is simply a call to MORDERNIZE. Not only would a more efficient system sidestep many of the potential outages, but could also do wonders for the environment. The DOE estimates that if the grid were merely 5% more efficient, the energy savings would equal the fuel and greenhouse emission from 53 million cars. This inturn will go a long way toward reducing the effects of climate change.[2]

Intersection Of Energy, Information Technology, Elecommunication Technology, Electrical Power System

The Smart Grid is a combination of hardware, management and reporting software, built atop an intelligent communications infrastructure. The world of the Smart Grid, offers tools to manage, monitor and respond to energy issues.

The flow of electricity from utility to consumer becomes a two-way conversation, saving consumers money, energy, delivering more transparency in terms of end-user use, and reducing carbon emissions.

The importance of this concept could be understood from the fact that this innovation was a part of "OBAMA'S STIMULUS BILL OF 2009".[3]

1. FEATURES OF SMART GRID:- [4-6]

- **Reliability**

The smart grid will make use of technologies, such as state estimation, that improve fault detection and allow self-healing of the network without the intervention of technicians.

- **Flexibility in network topology**

This next-generation transmission and distribution infrastructure will be better able to handle possible bidirectional energy flows, allowing for distributed generation such as from photovoltaic panels on building roofs, but also the use of fuel cells, charging to/from the batteries of electric cars, wind turbines, pumped hydroelectric power, and other sources.

- **Efficiency**

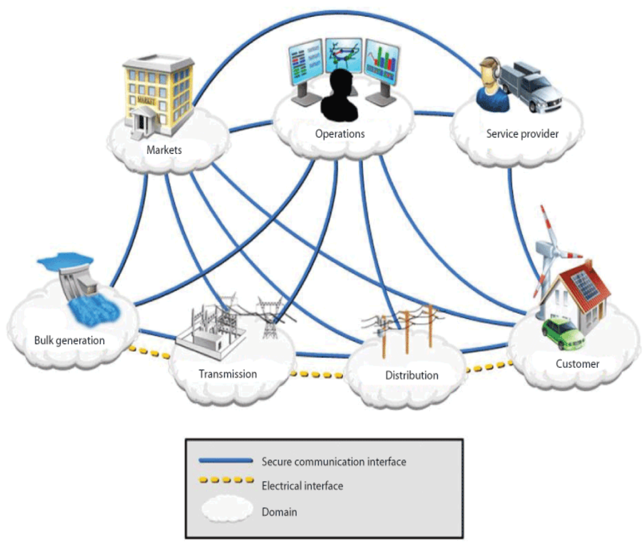
Improvement of the efficiency of energy infrastructure from the deployment of smart grid technology, in particular including demand-side management, for example turning off air conditioners during short-term spikes in electricity price, reducing the voltage when possible on distribution lines through Voltage Optimization, meter reading, and improved outage management using data from Advanced Metering Infrastructure systems. The overall effect is greater utilization of generators leading to lower prices.

- **Load adjustment/Load balancing**

Using mathematical prediction algorithms, it is possible to predict how many standby generators need to be used, to reach a certain failure rate. In the traditional grid, the failure rate can only be reduced at the cost of more standby generators. In a smart grid, the load reduction by even a small portion of the clients may eliminate the problem.

- **Peak curtailment/leveling and time of use pricing**

Prices of electricity are increased during high demand periods, and decreased during low demand periods. It is thought that consumers and businesses will tend to consume less during high demand periods if it is possible for consumers and consumer devices to be aware of the high price premium for using electricity at peak periods. Hence smart grid offers a more energy efficient system.



1. The basic conceptual model for the Smart Grid is useful in communicating the high-level concept. The detailed view in Figure 2 is messy, but vastly more informative.

Figure 1: Architecture of smart grid

- **Platform for advanced services**

As with other industries, use of robust two-way communications, advanced sensors, and distributed computing technology will improve the efficiency, reliability and safety of power delivery and use. It also opens up the potential for entirely new services or improvements on existing ones, such as fire monitoring and alarms that can shut off power, make phone calls to emergency services, etc.

2. CONCEPTUAL MODEL: -

The Smart Grid, a "conceptual model" describes the Smart Grid in terms of domains (customers, markets, service providers, operations, bulk generation, transmission, and distribution).The model also refers to actors, applications, associations (logical connections) i.e. physical connections. Figure 1 is a diagram that represents each domain.[7]

The functions & working of each domain is explained as:-

- **The market domain**

The market domain is what makes the Smart Grid smart. Actors in the markets domain exchange prices and balance supply and demand within the power system. The function of the market domain in setting electricity prices takes the Smart Grid beyond the "simple" role of a continent-spanning industrial-control system. Its financial aspect gives its communications aspects the imperative for traceability and auditability.[8]

- **The service domain**

In the service provider domain, "services" are functions like billing and customer account management that support the business processes of power system producers, distributors, and customers. Major challenges include maintaining the cyber security, reliability, stability, integrity, and safety of the electrical power network. Communication with the operations domain provides system control and situational awareness. Communication with the markets and customer domains will support new "smart" services, particularly customer interaction with the market(s).[9]

- ***The customer domain***

The Smart Grid is fundamentally about decreasing power consumption and increasing power generation as customers become active participants in the supply chain.

The customer domain is usually segmented by typical demand into sub-domains for home (less than 20 kW), commercial/building (20 to 200 kW), and industrial (greater than 200 kW). Each sub-domain has multiple actors and applications, and each has a meter actor and an energy services interface (ESI) that may reside in the meter, or an energy management system (EMS).

The ESI is the primary service interface. It may communicate with other domains via the advanced metering infrastructure (AMI) or some other means, such as the Internet.

The ESI communicates to devices and systems within the customer premises across a home-area network or other local-area network.

The EMS is the entry point for applications like remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems and the enterprise. It may also provide auditing/logging for cyber security. Importantly, the customer domain may also provide micro-generated electricity to the grid. So this technology makes us not only the consumers but producers of electricity as well.[10]

- ***The operation domain***

*A*ctors in the operations domain are responsible for the smooth operation of the power system.

- ***The Bulk generation domain***

The bulk generation domain involves any kind of electrical generation: combustion, nuclear fission, flowing water, wind, solar radiation, or geothermal heat. The boundary of this domain is typically the transmission domain, to which it is hard-wired. But the bulk generation domain also shares interfaces with the operations and markets domains.

- ***The transmission domain***

In this context, transmission is the bulk transfer of electrical power from generation sources to distribution through multiple substations. The domain may contain DERs such as electrical storage or peaking generation units. The network is typically operated by a regional transmission operator (RTO) or independent system operator (ISO) whose primary responsibility is maintaining stability on the electric grid by balancing generation (supply) with load (demand).[11]

- ***The distribution domain***

The distribution domain encompasses the electrical interconnection between the transmission domain and the customer domain. It includes the metering points for consumption, distributed storage, and distributed generation.[13,14]

3. BRINGING INTO ACTION: BABY STEPS TOWARDS SMARTER GRID [15]

In the era of smartphones, touchscreens our nation’s century old grid also ripe for an upgrade. A single fix cannot accommodate this change. Numerous concepts, philosophies & technologies go into steering the system to a more efficient future. Here are few of the big ones: -

Figure 2: Smart meters

- **Advanced metering infrastructure (AMI)-Smart meters & Thermostats** [16]

Instead of just waiting for the bill or staring dumbfounded at the spinning dials on the power meter outside, users can now use wattage readers to check how much juice their gadgets and appliances use. A smart meter is an electrical meter that records consumption -of electrical energy in intervals of an hour & communicates that information daily back to the utility for monitoring and billing purposes. Smart meters enable two way communication between meter and central system.Theycompose a neighborhood area network (NAN). Meter can be read remotely using network hand-held / walk-by, drive -by energy consumption calculation on annual, monthly, weekly, daily or even on an hourly basis.

Smart Thermostats are programmable & Wi-Fi equipped to keep track of the weather forecast. These features allow for a more fine-tuned and efficient use of home heating and cooling.

- **E-meters**

With the E-Meter system we connectsmart meters to smart phones.As smart phones are almost always connected to the Internet and within reach of every user. So by using smart phones to visualize electricity consumption enables households to easily understand their electricity consumption.[17]

- **The E-Meter Architecture:**

The E-Meter system consists of three independent components: - a smart electricity meter that monitors the total domestic load; a gateway that manages and provides access to the logged measurement data; and a portable user interface on a mobile phone that provides real-time feedback on energy consumption and enables users to interactively monitor, measure, and compare their energy consumption.[18]

- ***Micro-grids***

Microgrids, are localized grids that can disconnect from the main grid to operate autonomously and help mitigate grid disturbances to strengthen grid resilience, can play an important role in transforming the nation's electric grid. They are able to continue operating while the main grid is down & can function as grid resource for faster system response and recovery. They use the local widely available renewable sources of energy to serve local loads, helps reduce energy losses in transmission and distribution, further increasing the efficiency of the electricity system. In peak load periods it prevents utility grid failure by reducing the load on the utility grid**.**

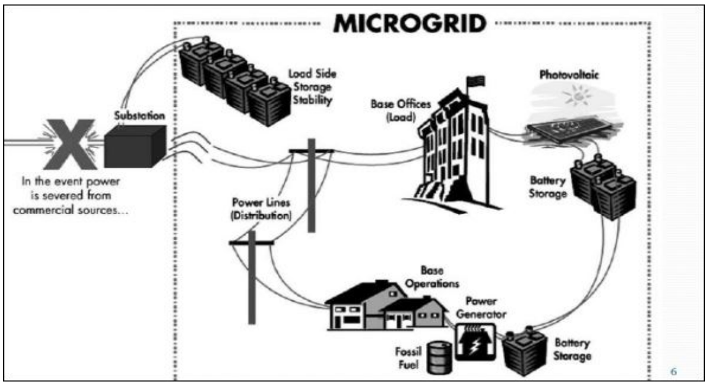


Figure 3:How micro grid works

- ***HVDC- High voltage direct current***

*T*he amount of electricity lost during DC transmission would be far less than with AC.

Let's say you're transmitting a given amount of power by high-voltage DC: When you double the voltage, you need only half the current of a comparable AC system, thus reducing your line losses by a factor of four. You also need a lot less wire, because DC current penetrates the entire conductor of a power line, whereas AC current remains largely near the surface. [19]

Put another way, for the same conductor size, the effective resistance is greater with AC, and more power is lost as heat. In practice, that means the overall transmission infrastructure for AC far exceeds that for DC. To transmit 6,000 megawatts using a 765-kilovolt AC system, for instance, you need three separate single-circuit transmission lines, which would cut a right-of-way path about 180 meters wide. Compare that with an 800-kV DC system, which would require just one 80-meter-wide path.

HVDC also allows for the easy transfer of power between grids that are operating at different frequencies. HVDC also results in increase of system stability and system security. Today HVDC has spread only modestly in North America, but it has taken off in other parts of the world, most notably Brazil, China and Western Europe.

Distributed generation

Distributed generation is the use of small scale power generation technologies located close to the load being served, capable of lowering costs, improving reliability, reducing emissions and expanding energy options. An automated distributed energy network is characterized by a two way flow of electricity and information and will be capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid the benefits of distributed computing and communications to deliver real time information and enable the instantaneous balance of supply and demand at device level.

Others

Advanced sensors which report line conditions in real time and enable more power to flow over the existing lines.

Superconducting power cables, wireless technology & “set it and forget it” energy management tools along with increased access to energy data thus enables the customer to gain more control on the electricity cost anduse.

TODAY's GRID. AND TOMORROW's.

Characteristic	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uninformed and non-participative with power system	Informed, involved, and active consumers - demand response and distributed energy resources.
Accommodates all generation and storage options	Dominated by central generation- many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug-and-play convenience focus on renewables
Enables new products, services and markets	Limited wholesale markets, not well integrated - limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets for consumers
Provides power quality for the digital economy	Focus on outages - slow response to power quality issues	Power quality is a priority with a variety of quality/price options - rapid resolution of issues
Optimizes assets & operates efficiently	Little integration of operational data with asset management - business process silos	Greatly expanded data acquisition of grid parameters - focus on prevention, minimizing impact to consumers
Anticipates and responds to system disturbances (self-heals)	Responds to prevent further damage- focus is on protecting assets following fault	Automatically detects and responds to problems - focus on prevention, minimizing impact to consumer
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

ADVANTAGES OF SMART GRID [20-22]

- ***Economic Development: -***The manufacture, installation, operation and maintenance of the smart grid and its components will create new jobs within the state.
- ***Innovation****:* **-** Smart grid innovation will enable the growth of business while rewarding customers with valuable new products.
- ***Lower Costs:-*** Costs rise over time and energy is no exception, but the smart grid should provide less costly energy than otherwise would be possible. As such, it will save customers money.
- ***Higher Customer Satisfaction:-***The combination of lower costs, improved reliability and better customer control will raise satisfaction among all types of customers.

- ***Improved Reliability*:** Smart grid will reduce and shorten outages and improve the quality of power.
- ***Customer Energy/Cost Savings:*** As pricing becomes more transparent and is aligned with the underlying economics of generation and distribution, customers' decisions to save money will benefit society as well.

CHALLENGES

- ***Biggest concern***: Privacy and Security.
- Some types of meters can be hacked.
- ***Hackers*** may gain control of thousands, even millions, of meters, Increase or decrease the demand for power.
- Not simply a single component, various technology components like software, the power generators, system integrators, etc. are involved.
- ***Expensive*** in terms of installation.

CONCLUSION

'City of mirrors, City of mirages, at once solid and liquid, at once air and stone. My Dream is of a place & time where India will once again be seen as, The Golden Bird- The last best hope of the world.'

Smart grid is an emerging technology to provide next generation power grid and should be promoted as a way of addressing Energy Independence, global warming and emergency Resilience issues. In the 21st century, if India dreams to emerge out as a developed nation, energy efficiency and energy conservation integrated with IT infrastructure is required to be implemented. Smart grid strongly pose one option which can drive India an inch closer to be once again The Golden Bird of 21st centuary.

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