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Smart Grid Technology & Application

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ABSTRACT: **The Smart Grid, regarded as the next generation power grid, uses two-way flows of electricity and information to create a widely distributed automated energy delivery network. In this article, we survey the literature till 2017 on the enabling technologies for the Smart Grid. We explore three major systems, namely the smart infrastructure system, the smart management system, and the smart protection system. We also propose possible future directions in each system.** Understanding that vision, we can create the alignment necessary to inspire passion, investment, and progress toward the Smart Grid for the 21st century. The Smart Grid is a necessary enabler for a prosperous society in the future. Energy supply has become one of the most challenging issues facing the world in the 21st Century. Growing populations, more homes and businesses and a myriad of new appliances have caused energy demand to skyrocket in every part of the country. Utilities across the globe are trying to figure out how to bring their networks into the 21st century and the digital age. This effort to make the power grid more intelligent is generally referred to as creating a “smart grid”. The industry sees this transformation to a smart grid improving the methods of delivery as well as consumption. In This Paper ‘State of the Art’ of Smart Grid along with the vision, application and control are introduced. This Paper also identifies the advantage, Growth and the problem for Smart Grid. The Paper also presents a case study of Implementation of Smart grid Technologies.

KEYWORDS: Smart Grid, Vision of Smart Grid, Smart grid technology and application, Renewable energy sources.

I.INTRODUCTION

The "smart grid" is a term used to describe the rapid infrastructure replacement of the electrical wiring system in the United States. When the advanced system is completely implemented, it will allow for communication features across the grids that are not currently available--hence the term "smart"[2]. A “smart grid” is simply an advanced electrical distribution system that has the capability to balance electrical loads from diverse, and often intermittent, alternative energy generation sources. One key component of the “smart grid” is the capacity to store electrical energy; this allows the demand from consumers to be met [1].

The Smart Grid is: Adaptive, with less reliance on operators, particularly in responding rapidly to changing conditions, Predictive, in terms of applying operational data to equipment maintenance practices and even identifying potential outages before they occur, Integrated, in terms of real-time communications and control functions, Interactive between customers and markets, Optimized to maximize reliability, availability, efficiency and economic performance Secure from attack and naturally occurring disruptions [3].

Today’s power systems are designed to support large generation plants that serve faraway consumers via a transmission and distribution system that is essentially one-way. But the grid of the future will necessarily be a two-way system where power generated by a multitude of small, distributed sources—in addition to large plants—flows across a grid based on a network rather than a hierarchical structure [3].

In The Fig.1 Below [3], The Diagram illustrates this shift. In the first, we see today’s hierarchical power system, which looks much like an organizational chart with the large generator at the top and consumers at the bottom. The second diagram shows a network structure characteristic of the fully realized smart grid.

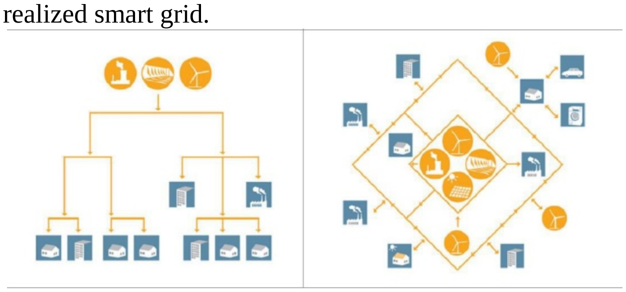
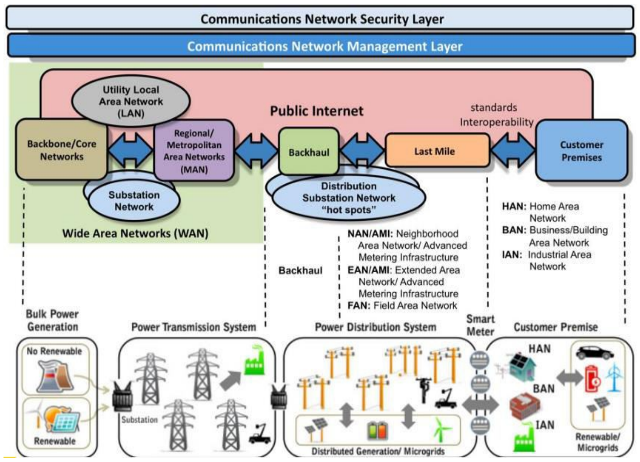


Fig.1: The Shift between today’s Power system (left) and Realized Smart Grid [3].

The basic idea of Smart grids is about information and control as much as power management. Much of the information is sent over the power lines using broadband over power Lines (BPL), which superimpose information on top of the Electrical power. This information can reroute electricity around problem spots until the problem is fixed, and adjust power levels to match demands. Both power suppliers and power consumers can be accommodated by smart grids. Wind and solar power can add to the grid, and consumers can be charged higher rates during peak consumption hours and lower rates when consumption is low. Smart grids can even adjust for reduced output from solar cells on cloudy days and from wind turbines on still days, in addition to the increased demands from air conditioners on hot days.
Smart grids can also quickly respond to natural failures “Disaster Avoidance” or terrorist attacks by rerouting around problems or closing down the network entirely. They also manage rolling brown outs to save electricity when demand exceeds production.

II SMART GRID DRIVERS

The forces now driving the development of the smart grid are as varied as they are influential. Environmental

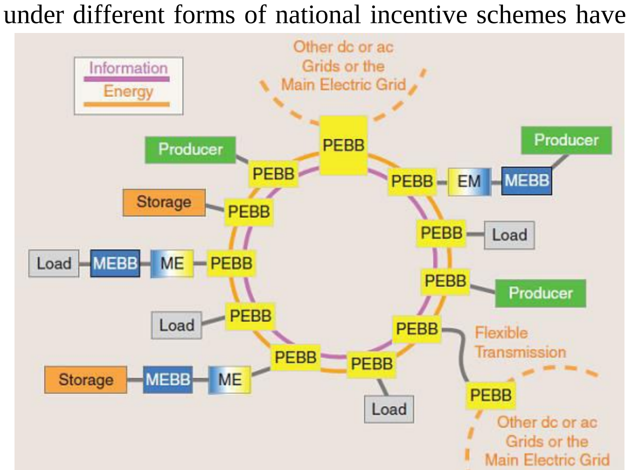


concerns are increasing around the globe, and that is driving the expansion of renewable energy on a larger scale than ever before. The widespread addition of wind, solar and other renewable presents operational challenges due to those sources' intermittent nature. A grid that can handle a generation mix with a high percentage of renewable, therefore, will become a necessity for those technologies to realize their full potential [6].

III STATUS OF SMART GRID

The smart grid is more than any one technology, and the benefits of making it a reality extend far beyond the power system itself. The transition from the grid we know today to the grid of tomorrow will be as profound as all of the advances in power systems over the last hundred years, but it will take place in a fraction of that time. It will require a new level of cooperation between industry players, advocacy groups, the public and especially the regulatory bodies that have such immediate influence over the direction the process will take. In the end, though, a fully realized smart grid will benefit all stakeholders [3].

Up until now smart integration of grid-connected photovoltaic (PV) systems is a concept that has been neglected in part due to the availability of subsidies. These subsidies given under different forms of national incentive schemes have made PV the fastest growing energy source in the last few years. In the future, as direct financial incentives and other types of subsidies to PV systems are gradually phased out, smarter grid interface will become an essential feature of future PV systems design [4].



IV SMART GRID TECHNOLOGY

Renewable energy systems (RESs) cannot directly replace the existing electric energy grid technologies. The latter are far too well established to abandon, while the new technologies are not sufficiently developed to meet the total energy demand. Therefore, it is sensible to gradually infuse renewable energy sources into existing grids and transform the system over time [5].

Fig. 2: Intelligent Energy Conversion nodes

A smart grid is modelled by two concentric circles the outer circle represents energy flow and the inner circle models information flow over communication networks. Different approaches to the management of energy flow in active grids integrating distributed power generation have been proposed. One of the most interesting ideas employs energy hubs to manage multiple energy carriers (e.g., electricity, natural gas, and district heating). Within each hub are energy converters that transform part of the energy flow into another form of energy. Fig. 2 is a possible scenario of the future power system based on smart-grid technologies, with power electronic building blocks (PEBBs) and With the development of smart grid technology, the intelligent meters will be likely to control home appliances, when users can adopt more sensible strategies to reduce the cost of electricity during the high electricity price. So peak load shifting can be achieved, and the system will tend to be more economic, intelligent and environmental friendly [1].

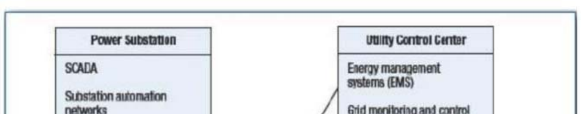
V SMART GRID PLATFORM

The smart grid can be conceptualized as an extensive cyber-physical system that supports and significantly enhances Controllability and responsiveness of highly distributed resources and assets within electric power systems. Renewable generation will make an increasingly important contribution to electric energy production into the future. Integration of these highly variable, widely distributed resources will call for new approaches to power system operation and control. Likewise, new types of loads, such as plug-in electric vehicles and their associated vehicle-to-grid potential, will offer challenges and opportunities [5].

The EU's Smart Grids technology platform summarizes the benefits of smart grids as follows. They [5]:

1. Better facilitate the connection and operation of generators of all sizes and technologies.
2. Allow consumers to play a part in optimizing the operation of the system.
3. Provide consumers with greater information and options for choice of supply.
4. Significantly reduce the environmental impact of the whole electricity supply system.
5. Maintain or even improve the existing high levels of system reliability, quality and security of
6. Supply and Maintain and improve the existing services efficiently and Foster market integration.

Fig.4: Control centre in all parts of the Grid [1]



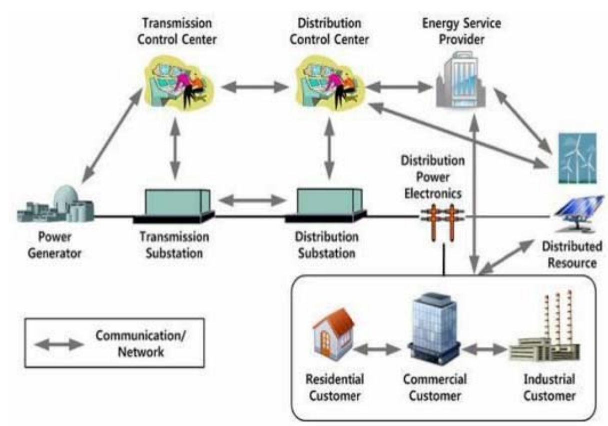
Modern Hardware for Smart Grids	Modern Control Methods for Smart Grids
1 Power Electronic Devices • Unified Power Flow Controller (UPFC) • DVAR or DSTATCOM • Static Voltage Regulator (SVR) • Static VAR Compensator (SVC) • Solid State Transfer Switch • Dynamic Brake • AC/DC inverter 2 Superconductivity • 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 • Aluminium Conductor Composite Core Cable (ACCC Cable) • Aluminium Conductor Composite Reinforced Cable (ACCR Cable) • Annealed aluminium, steel supported (ACSS)	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

Fig. 5: An integrated communication system [1]

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 [1].

VI MODERN HARDWARE AND CONTROL FOR SMART GRID

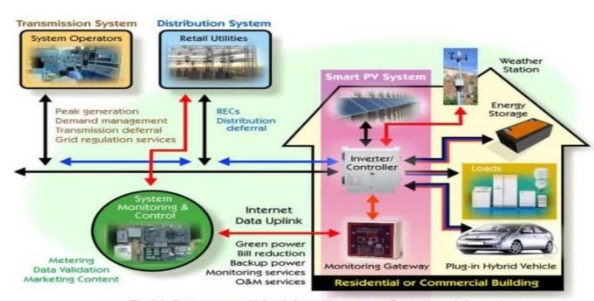
A smart information network the energy internet for the electric grid is seen as necessary to manage and automate this



new world.

Table 1 : Modern Hardware control table of Smart Grid[6]

In the application technologies for SG, an Intelligent Universal Transformer (IUT) has been introduced by [7]. It is a power electronic base transformer introducing for Advanced Distribution Automation (ADA) in future. ADA is the state of art employing the new architecture based on both the flexible electrical network and open communication construction comprise the Future Distribution System. IUT is a basic resource enrolling a key point in ADA conceptual construction which is fundamental part in smart grid network. In [8] and [9], a distributed and integrated power systems, it is vital to ensure that each power source (generator, wind turbine, etc) is working within its allowed parameters. These parameters are normally based on



the current power load that are sometimes have been forecasted within regular intervals (weekly, monthly or yearly). Anyway, these non real-time forecasts have their drawbacks and may not supplying correct information when any of these events occurred[1]:

1. Sudden failure of any of the power sources.
2. Unexpected increase or decrease of power demand within a short timeframe

Fig. 6: Solar energy grid integration system integrated with advanced distribution systems [1]

The future electrical grids will consist of large small-scale generation units of renewable energy sources and other disparate energy sources. Highly scalable and decentralized integrated communication, computing and power networks will be necessary to monitor these smart grids of the future[1].

VII SMART GRID TECHNOLOGY AND APPLICATION

Smart grid concepts encompass 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 [6]:

1. 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 information. 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.
2. Distribution management system (DMS) software mathematically models the electric distribution network and predicts the impact of outages, transmission, generation, voltage/frequency variation, and more. It helps reduce capital investment by showing how to better utilize existing assets, by enabling peak shaving via demand response (DR), and by improving network reliability.
3. Geographic information 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.

i. Outage management systems (OMSs) speed outage resolution so power is restored more rapidly and outage costs are contained.

ii. Intelligent electronics devices (IEDs) are advanced, application-enabled devices installed in the field that process, compute, and transmit pertinent information 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.

iii. Wide-area measurement systems (WAMS) provide accurate, synchronized measurements from across large-scale power grids. WAMS consist of phasor measurement units (PMUs) that provide precise, time-stamped data, together with phasor data concentrators that aggregate the data and perform event recording.

iv. 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. Projects such as Elektra's "distribution management system" improve quality of service by implementing next generation devices to manage and control information (SCADA), DMS to plan and optimize distribution system operations, and Arc FM/Responder to improve outage response times [6].

VIII SMART GRID PROBLEMS

Smart grid power systems use digital technology to deliver electricity. They are being rolled out in the U.S. Though they are promoted as a means to create energy savings, some problems exist with this technology. Some of the problems inherent in smart grid power systems include customer privacy problems, security problems, grid volatility and inflexibility. Implementing a smart grid power system has considerable implications for personal privacy because the grid has the ability to control power access. Security experts believe that this technology may allow someone other than the customer to control the power supply. Some problems explained as [1]:

1. PRIVACY PROBLEMS: Security experts believe that smart grid technology may enable some people to get control of the power supply. Communication between utilities and the meters at residential homes and businesses increases the chance of someone gaining control over the power supply of a single building or an entire neighborhood.
2. GRID VOLATILITY: Smart Grid network has much intelligence at its edges; that is, at the entry point and at the end user's meter. But the grid has insufficient intelligence in the middle, governing the switching functions. This lack of integrated development makes the grid a volatile network. Engineering resources have been poured into power generation and consumer energy consumption, which are the edges of the network. However, if too many nodes are added to the network before developing the software intelligence to control it, the conditions will lead to a volatile smart grid.

IX CONCLUSION

Smart Grids are most comprehensive technology during recent years and it has been grown rapidly because of its benefits. It has many features and the transition to a fully implemented smart grid brings a host of benefits in an often symbiotic relationship:

GRID OPERATORS will enjoy a quantum improvement in monitoring and control capabilities that will in turn enable them to deliver a higher level of system reliability even in the face of ever-growing demand.

UTILITIES will experience lower distribution losses, deferred capital expenditures and reduced maintenance costs. CONSUMERS will gain greater control over their energy costs, including generating their own power, while realizing the benefits of a more reliable grid.

THE ENVIRONMENT will benefit from reductions in peak demand, the proliferation of renewable power sources, and a corresponding reduction in emissions of CO2 as well as pollutants such as mercury.

"Smart grid" enabled distribution could reduce electrical energy consumption by 5-10%, carbon dioxide emissions by 13-25%, and the cost of power-related disturbances to business by 87%. (Source: The Electric Power Research Institute). Smart grid enabled energy management systems have proven in pilots to be able to reduce electricity usage by 10–15%, and up to 43% of critical peak loads. (Source: The Brattle Group, SMUD and PNNL.) The Smart Grid vision generally describes a power system that is more intelligent, more decentralized and resilient, more controllable, and better protected than today's grid.

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