Smart Grid – A New Paradigm to Power Grid

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Abstract

The smart grid has been using more and more power electronic devices as an improvement to the current electrical power system along with plug-and-play integration of alternating sources of power. It has adopted the latest wired/wireless technologies incorporated into electric devices for timely information flow, control and on-demand interaction with customers. So, smart grid is reliable, efficient, and user as well as environment friendly. The grid keeps on getting smarter with better availability of new materials, storage systems, and alternative sources of energy. Though, this paper encompasses all sectors of smart grid, not limited to, smart transmission line, smart distribution generation, smart storage, smart communication, cyber security, and environment friendliness, it has demonstrated the wireless prototype of remote interaction between the consumers and the utility company.

Index Terms— *Smart Grid, Smart Transmission Line, Smart Distribution Generation, Smart Storage, Smart Communication, Cyber Security, Environment Friendly Smart Grid*

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I.   Introduction

Power Grid is an electric power infrastructure of bulk power system consisting of generation, transmission, and distribution systems that provides electrical energy to the consumers safely, reliably, and as economically as possible, through complex but coordinated control networks. The Power Grid, upgraded with green design, efficient power electronics components, and two-way communication system for better protection, automation, monitoring, control, and intelligent decision making, is actually the Smart Grid paradigm.

Necessity is the mother of invention and the long hours of load shedding in Nepal have encouraged Nepalis residing in urban areas to look for alternate sources of energy such as battery power backup system at least to light their houses. The batteries are charged by the regular utility electricity (using ac-to-dc inverter) by solar panels. The system then provides power for home during the load shedding (using dc-to-ac inverter). The lack of electricity infrastructure in remote villages of Nepal has forced people to use biogas produced from animal manure and toilet waste for burning their stoves. Few of them have access to micro hydro for lighting their houses. Though smart grid is the cutting edge technology, Nepal should not overlook the feasibility of deploying it considering the generation of scanty 1.5% out of the total 40,000MW economically feasible hydro-power potential.

The incorporation of alternative energy sources and the integration of intelligence in the existing power grid components, result in smart grids. The characteristics of a typical smart power grid are included, but, are not limited to:
- Fault Tolerant and Self-healing
- Active participation of the consumer
- Resistant to attacks and disasters
- Improved Power Quality
- Accommodation to Distributed Generators
- Reduced carbon footprints

The smart grid has the ability to assess equipment condition as well as manage equipment configuration which optimizes the assets and reduces energy loss i.e. increase power grid efficiency. The fault can be detected and electric flow can be redirected and adjusted accordingly, so the system will be fault-tolerant. The self-assessment by the faulty device and reconfiguration will help in self-healing. The assessment information also expedites the replacement of faulty device if the device

is unable to be reconfigured or auto-configured. According to GENI (Green Electricity Network Integration) [1], the reduced power outage can save one out of every five electric dollar. Also, the grid hardware replacement will be drastically reduced; currently 30% hardware replacement estimated by GENI.

The smart grid allows customers to make better decision about their power usage. They can schedule the run time of their appliances according to the financial incentives provided by the suppliers (time of use programs) and can even contribute to the grid during peak time, which not only reduces their electric bill but also generates money, depending on the amount of their contribution to the grid.

Few layers of security are incorporated in the smart grid both for physical and cyber attacks. Besides, physical monitoring for intrusion and natural disaster, redundancy is also incorporated. The introduction of more components in the grid, with networking as a backbone, introduces security risk into the system. So, smart grid also evaluates the security objectives – confidentiality, integrity, and availability.

Smart grid maintains a constant voltage and power factor besides the availability of electricity at all times from power grid. Many renewable sources such as wind power, solar energy, fossil fuels, micro hydropower, to name a few, can be integrated into the smart grid as plugged-and-play sources. The use of renewable sources drastically reduces energy consumption bringing down the carbon footprints.

Each section covers different components of smart grid with Section V demonstrating the wireless prototypes. Section X talks about the current trends in smart grid followed by conclusion section.

II.   Smart Transmission Lines

A. FACTS: Flexible Alternate Current Transmission System
FACTS is a power electronic based AC transmission system and is defined by the IEEE as a power electronic based system and other static equipment that provides control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability.

The losses in the transmission lines are the discrepancies in the total energy generated and total energy consumed. I^2R (Resistive losses) is due to inherent resistance of any

conductor. Corona Discharge occurs in the conductor carrying high voltage more than 2MV especially at transmission side with the ionization of air surrounding the transmission lines. It causes power loss, audible noise (spark), electromagnetic interference, ozone production, and insulation damage. The solution that has been in place uses bundled conductors. Reactive power losses are due to inductive and capacitive loads which can be injected using capacitive banks, phase shifting transformers etc. Transmission and distribution losses in US were about 7% in 2010 [2].

B. HVDC: High Voltage Direct Current

Superconducting HVDC power lines, which are super-chilled to boost capacity, can carry Giga Watts of electricity to minimize the transmission losses. For long transmission HVDC line, the lower losses (only the resistive losses and voltage drop) and reduced construction cost can offset the cost for converter stations at two ends – conversion of AC into HVDC at the generating end and back to locally synchronized AC at distribution end.

The only way to interconnect large AC power grids that are not synchronized (that is, of different phases), is via HVDC infrastructure. Synchrophasors have to be used for grid interconnection for AC. HVDC transmission will be aided by increased use of power electronics to improve system reliability and security, and to boost the efficiency and load of existing transmission and distribution infrastructure.

HVDC can carry more power at longer distance. According to ABB, a 2,000-kilometer-long HVDC line rated at 80 kilovolts loses about 5 percent of the electricity it carries, while an equivalent AC line would lose about 10 percent. The black start capability of HVDC stations can safely supply electricity to itself and blacked-out neighborhood during knocking out of power in an AC grid.

III. Smart Distribution Generation

In the short term, Distribution Generation (DG) involves small-scale generation sources such as roof top solar, micro wind turbines, micro-hydropower, bio-fuels, and other non-utility scale generation sources that meet local level demands through micro grid. However, in the long run, industrial-scale wind, solar generation plants, and PHEV (Plug in Hybrid Electric Vehicle) can feed the grid as well. Micro grid can serve communities like residential, industrial, and college campuses. DG does not

require new transmission but will be connected to the existing distribution grid. Electric distribution system has to be designed to easily accommodate large quantities of randomly installed distributed generation resources at customer sites.

A. Distribution Energy Sources – Solar Power

Electrical power is generated from sunlight, indirectly by Concentrating Solar Power (CSP) technology or directly using Photovoltaic (PV) technology. In CSP, reflectors usually parabolic will be used to concentrate sun's light onto a receiver containing heat transfer fluid which feeds steam to a power turbine to generate electricity. This technology is financially viable on a larger scale. In PV, electrons get detached from semiconductor material such as crystalline silicon, copper indium gallium selenide, and cadmium telloxide. When the sunlight falls into them, electricity is induced in the electric circuit. PV devices can be used ranging from powering smaller electronic devices to utility level power facilities (using solar farm).

Solar ADEPT (Agile Delivery of Electrical Power Technology) [2] is trying to reduce the cost of utility-scale solar system by 75% by the end of the decade by investing on researches like developing novel wafer manufacturing process that plucks wafers directly from molten metals.

B. Wind Power

Wind turbines are used to convert wind energy into electric power. The wind is the result of differential heating driving a global atmospheric convection - poles receiving less energy from the sun than the equator and dry lands getting heated up or cooled down faster than the water mass. The modern wind turbines have rated output range of 600KW-5MW [1]. A wind farm consisting of several hundred wind turbines can easily feed the distribution grid.

C. Micro Hydro or Run off the River

The flowing water is used to generate electric power. About 100kW of power can be easily generated without using dams from the river current itself.

D. Bio Fuels

Bio Fuels are the energy captured by photosynthesis. The fuel from biomass is used to produce steam to feed the turbine to generate electricity. Solid bio-fuels include wood, sawdust, charcoal etc. Bio-ethanol and oils belong to liquid biomass whereas biogas, landfill-gas are gaseous bio-fuels. PETRO (Plants Engineered To Replace Oil) [2] aims at creating plants that captures more energy from sun and converts that energy into fuels in an efficient manner.

E. Geothermal Energy

Hot underground steam or water is tapped and brought to the surface to generate electrical energy. This is viable from Earth's crust in volcanically active locations where the crust is comparatively thinner. ARPA-E [2] is also investing on drilling machine to penetrate ultra-hard crystalline basement rocks.

F. Plug-in Hybrid Electric Vehicle (PHEV)

For short term generation, ancillary services such as spinning reserve and regulation, a large fleet of PHEV can be used. BEEST (Batteries for Electrical Energy Storage in Transportation) [2] is resolute to develop high energy density batteries with short recharging time to increase the range of PHEV and EV vehicles from current 100 miles to 300-500 miles.

IV. Smart Storage

The incorporation of distributed generators especially intermittent renewable sources can be very complex as it is difficult to predict the amount of wind and solar generation even an hour from now. So, there is a need for smart storage to collect generated power from these sources, store them, and release them as required. Moreover, storage helps to store electrical energy during times when production exceeds consumption which are then used when consumption exceeds production. This prevents the use of reserved spinning resources during peak time which is not only economical but environment friendly.

A. Electricity as Chemical Energy

Electricity is used to induce electrochemical reactions among the three participants – anode (carbon or graphite), cathode (lithium cobalt oxide, lithium iron phosphate, or lithium manganese oxide), and non-aqueous electrolyte (a mixture of organic carbonate such as ethylene carbonate or diethyl carbonate containing complexes of lithium ion such as lithium hexaflurophosphate, lithium perchlorate etc). When the battery is charged, the lithium is extracted from the cathode and inserted into the anode. The battery generates electricity when it is discharged reversing the chemical reactions.

More research is going on using new materials such as lithium-air [2] that stores many folds as much energy as lead-acid battery by weight with the relatively quick recharging time.

B. Electricity as Natural Gas and Hydrocarbons

The excess electricity is used to generate hydrogen through electrolysis and the hydrogen is combined with carbon dioxide to produce methane (a natural gas) [3]. About 50KWH of energy is required to produce a KG of hydrogen by electrolysis [1]. In other approach, hydrogen is combined with carbon dioxide to produce carbon monoxide which will then be combined with hydrogen reforming into liquid hydrocarbons.

C. Electricity as Compressed Air

Electrical energy is used to compress the air near isothermally; the compressed air is then stored in a gas storage facility [3]. When expanded nearly isothermally, compressed air drives the generator and generates electricity.

D. Electricity as Thermal Energy

In one approach, electricity is used to convert water into ice (refrigeration) during off-peak period. The ice stored in storage units throughout the area are used as air conditioning by melting that ice. One metric ton of water can store 93KWH of energy [3]. In another approach, electricity is used to heat saltpeter. The liquid hot salt can be stored up to a week in a well insulated tank. When at high demand, it can then be pumped to a conventional steam plant to produce superheated steam to feed the generator for producing electricity. HEATS (High Energy Advanced Thermal Storage) is also investigating on producing fuel from sun's heat.

E. Electricity as Kinetic Energy

Electricity is used to rotate the frictionless flywheel at high speed using motors. When the input to motor is turned off, the motor attached to the flywheel acts as a generator before the flywheel completely gets stopped. Beacon 25kwh flywheels can be used for voltage and transient stability support.

F. Electricity as Potential Energy

The electricity is used to power a pump (acting as a generator) that pushes water down the return pipe to raise the weight stack from the bottom of the deep storage shaft in a sealed water filled bore hole [3]. When the electricity is required, the weight shaft is released which pushes the water up the return pipe, reversing the rotation of the pump turbine (acting as a motor) to produce electricity.

The simple approach to generate electricity is to pump water to a high storage reservoir during off peak hours, which can later be used to feed the turbines.

The worm wheel, connected to the motor's shaft, drives the worm (gear in the form of screw) which compresses the spring wire. The lock will be used so that when the motor is stopped spring wire remains in compressed state. That compressed energy (elastic potential energy) can be used when needed to feed the motor to generate electricity.

G. Electricity as Magnetic Field

Direct Current (DC) when passes through a cryogenically cooled superconducting coil gets converted to magnetic energy. The amount of energy depends on coil dimensions, number of turns and the amount of current. Once the superconducting coil is charged, the current decays and hence magnetic energy can be stored indefinitely. When discharged, the stored energy is released as electric energy. Superconducting Magnetic Energy Storage System (SMES) can store and instantaneously discharge large quantities of power.

V.   Smart Communication System

The intelligent devices in the power grid such as smart meters, smart sensors, smart switch gears and other smart equipments applied to different segments of power grid will have either or both wired or wireless capabilities to form advanced secured communication system for network control which increases efficiency, reliability, and safety of the power grid. The communication algorithms, with extensive use of stochastic models and criteria, help in safety and reliability. The intelligent communication protocols can effectively utilize the transmission capacity of the network and help in efficient use of distributed energy resources allowing segregation of faulty parts and rerouting.

Electric utilities have been utilizing their own private WANs (Wide Area Network) for communications, especially for safe and reliable operation of mission critical protective relaying for high voltage lines such as Supervisory Control and Data Acquisition (SCDA)/ Emergency Management System (EMS), mobile fleet voice and data dispatch, plant automation, Distribution Automation (DA)/ Demand Side Management (DSM), physical security, and, currently, Automated Meter Reading (AMR). The smart grid requires these applications being pushed deeper into distribution system as feeder and customer level applications – DA/DSM and AMR/Advanced Meter Infrastructure (AMI). As a result smart grid has to utilize the Internet Protocol (IP) de facto standard for data transport as well as technologies like

meshed Wi-Fi (802.11 WLAN), Zigbee (802.15), WiMAX, GPRS, Broadband-over-Power-Line (BPL), to handle the proliferation of information, on top of overlaying its existing point to point constant bit rate Time Division Multiplexing (TDM) networks having high latency such as narrowband Power Line Carrier (PLC) or dial-up phones. TDM network uses the circuit switching technology where two network nodes establish a dedicated circuit through the network prior to the communication with fixed number of channels (time multiplexed) and constant bandwidth per channel. So, it is not suited for point-to-multipoint burst data traffic as required by smart grid.

A. *Substation Automation System (SAS)*

IEDs (Intelligent Electronic Device) are implemented in smart substations that contain both operational Supervisory Control and Data Acquisition (SCDA) data and non operational data (event summaries, oscillographic event reports) valuable to many user groups within the utility. IEDs with their networking capability provide both substation integration (integrating protection, control, and data acquisition functions) and automation. Automation involves the deployment of substation and feeder operating functions and applications ranging from SCADA and alarm processing to integrate Volt/Var control for efficient operation with minimum human intervention.

B. *Electric Power Distribution System (DS)*

Distribution Automation (DA) at medium voltage distribution system improves reliability through better situational awareness, outage management, remote diagnostics and switching with the use of IEDs, controls, software, and intelligent communication networking facility to different applications – re-closures, capacitor controls, switch controls, faulted circuit indicators, voltage regulators and breakers. It can also report over to customer premises via AMI (Advanced Metering Infrastructure).

C. *Advanced Distribution Automation (DA)*

With the integration of Distributed Energy Resources (DER) in a micro-grid, ADA is required to extend control network for:
- automatic addition of DER during high demand without destabilizing the grid
- controlling industrial and residential load through Demand Response (DR)
- enabling Demand Side Management (DSM)

The goal of ADA is automated real-time adjustment of changing loads and monitoring and isolation of failures of the distribution system.

D. *Demand Response (DR) at Customer Premises*

Smart grid tries to improve operational efficiency and reliability through the information from customer providing them sustainable options by employing Demand Response (DR). During times of peak demand, usually during the occurrences of forecasting errors and unforeseen events, the utility control center can directly interfere with the customers' appliances to avoid service interruption. For example, raise thermostats of the houses without significantly affecting their comfort.

In general, demand response can be employed by letting customer curtail the consumption during peak hour with financial incentives. Such programs consisting of planning, implementing, and monitoring activities of electric utilities come under Demand Side Management (DSM). Advanced Metering Infrastructure (AMI) as in Fig. 1 has to be established to provide two way communications between the utility and the customer's meter. AMR (Automated Meter Reading) technology allows electric utilities automatically collect consumption, diagnostic and status data from smart meters to implement DSM.
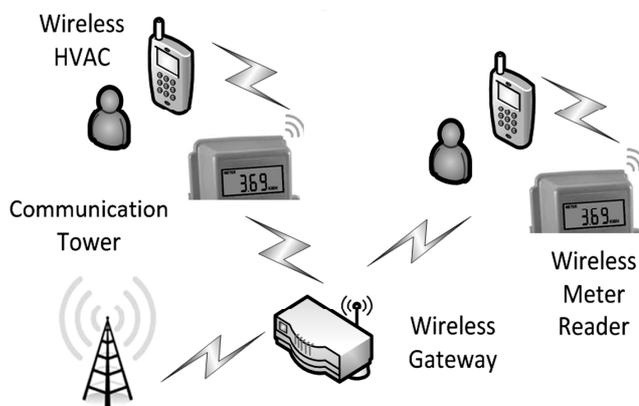

Fig.1. Wireless prototype showing communication among the utility and the customers

The prototype in Fig. 1 is built by programming the Commercial-Off-the-Shelf (COTS) wireless devices such as Freescale's MKW01Z128 having integrated RF transceivers operating over a wide range of frequencies in the license-free ISM frequency bands where the meter reading from different customer premises are collected via Gateway and is wirelessly transmitted to utility company through the communication towers. The utility company can not only send billing and other information but also control the HVAC unit, if required, remotely.

VI. Smart GRID Algorithms/ Protocols

A. *Wide Area Network (WAN)*

WAN carries a large volume of aggregated data at high speeds over long distances in

high-bandwidth backhaul networks of control centers. Smart grid WAN comprises high-bandwidth transport backbone network (fiber optics, digital microwave radio) having large number of channels to support applications from the utility service to the control centers. Lower bandwidth segments (copper twisted pair, PLC, VHF/UHF radio links, and licensed/unlicensed radio links) can be used to connect small facilities to the backbone. Also, public carriers and CATV (Cable TeleVision) like broadband modem, Digital Subscribers Line (DSL) and cellular-based wireless data networks can also be the viable technology options.

DNP3 (Distributed Network Protocol 3) is an IEC 62351-5 complaint bidirectional protocol used to connect HMI (Human Monitoring Interface) control stations to Remote Terminal Units (RTU) – PLC (Programmable Logic Controller), DCS (Distributed Control System), IEDs (Intelligent Electronic Device). DNP3 uses TCP/IP that has to be secured. IEEE adopted DNP3 as IEEE STD 1815-2010.

ICCP (Inter-control Center Communications Protocol) is a part of IEC 60870-6 allows for secure, unidirectional, real time and foolproof data exchange between utilities' control centers (SCDA Master Stations) protecting the critical part such as control centers or critical generation from outside attacks. Modbus over TCP/IP Protocol is a bi-directional protocol used to deliver control and monitoring information over SCADA network. It enables writing commands to the controlled equipment and reading responses as well as file related operations. Wi-Fi, IP based wireless protocol can be suitable for relatively low volume data for especially point to multipoint links using license free spectrum.

B. Home Area Networks

HAN connects smart meters, appliances (air conditioners, dishwashers, refrigerators, etc.), energy management tools (that run on intelligent remote controls, smart phones, etc), display units (or other computing equipments), alternate energy production equipment (solar and wind) and circuit breakers. Wi-Fi is inherently an IP-based network and is therefore, seamless across all segments of the smart grid. It can provide data throughput from 150Mbps (single antenna) to 600Mbps (4 antennas) at home operational range. ZigBee Smart Energy standard is based on IP which enables Advanced Metering Infrastructure (AMI) technology and Demand Response (DR) program at homes. Utilities will be able to remotely read and communicate with smart meters and in turn meters can use ZigBee wireless technology to communicate with the smart appliances at home. SOAP (Simple Object Access Protocol) for exchanging

structured electric data information via web providing system software API for smart devices.

VII.   Cyber Security

With the complexity added to the smart grid, the new potential security vulnerabilities have also been introduced. For example, with two way communications setup among the electric components, there are risks of communication failure and the components requiring real time data can have adverse affects on the grid. The malicious code can alter the software functionality that is managing the system state. Availability, Integrity, and confidentiality are the security objectives of smart grid [4].

The critical real time system in the smart grid has strict latency so the disruption in communication can cause the loss of power. Smart grid uses bulk of data collected by various sensors and agents which are not only used to monitor the current state but they can be the controlling signals too. These data if compromised (unauthorized modification, insertion from unknown sources) can cause failures or damage in the electric system. The privacy of customer information, general market information should also be maintained. The interception of such information can have negative impact.

The Process Control System (PCS) used in smart grid, SCADA system, responsible for monitoring and control physical aspects of grid in a networked environment (not as isolated system in the traditional grid) is vulnerable to cyber attack. This can not only damage equipments costing millions of dollars but can cause human injury or loss of life. So, some kind of security assessment and Intrusion Detection System (IDS) should be integrated in the system.

The smart meter, having feedback mechanism for implementing power usage requirements, besides reading the amount of energy that customer uses, if altered, can lead not only to incorrect billing but also false usage approximations. The Intrusion Detection System (IDS) and redundant reading techniques can be applied. Moreover, the meter reading information is the private information which should not be leaked. Smart meter Data Anonymization and Privacy technique can maintain the privacy.

Communication is the backbone of smart grid so it uses many communication protocols to meet the varying connection requirements. The functionalities of smart

grid depend on the seamless communication. Data can be injected and intercepted into the network causing malfunction of the components as well as breach in privacy. Some guidelines should be used to develop authentication protocols with secure cryptography technique to encode the data.

VIII. Environment Friendly Smart Grid

A. Green Smart Grid

The smart grid offers clean renewable sources energy like solar, wind, PHEVs, and geothermal, integrated in the power grid, which reduces the carbon footprint to help slowing down the global warming. Smart grid deployment significantly reduces greenhouse gasses and pollutants such as NOx, SOx, and particulates [5]. The carbon capture technologies such as liquid chemistry dissolving CO_2 initiated by IMPACCT (Innovative Materials and Processes for Advanced Carbon Capture Technologies)[2], implemented in coal-fired power plants that generate 45% of electricity for US, will drastically reduce the carbon footprint. The reduction of energy consumption also leads to reduced carbon dioxide emission. Fig. 2 showed the EPRI (Electric Power Research Institute) report that estimates the reductions in electricity consumptions and the carbon dioxide productions for the seven topic areas for the year 2030. BEETIT (Building Energy Efficiency Through Innovative Thermodevices) [2] is focused on developing new technologies for HVAC and refrigeration to conserve energy.

B. Regulated Smart Grid

The materials to be used in electrical components and equipments are enforced by Environmental Protection Agency (EPA). For example, Askarel-Polychlorinated Biphenyl (PCB) which was used for electrical insulating liquid is now strictly regulated under Toxic Substances Control Act (TSCA). The use of solid state transformers for example avoid the need for Askarel which makes smart grid environment friendly.

Emissions-Reduction Mechanism Enabled by Smart Grid	Energy Savings, 2030 (billion kWh)		Avoided CO_2 Emissions, 2030 (Tg CO_2)	
	Low	High	Low	High
1 Continuous Commissioning of Large Commercial Buildings	2	9	1	5
2 Reduced Line Losses (Voltage Control)	4	28	2	16
3 Energy Savings Corresponding to Peak Load Management	0	4	0	2
4 Direct Feedback on Energy Usage	40	121	22	68
5 Accelerated Deployment of Energy Efficiency Programs	10	41	6	23
6 Greater Integration of Renewables	--	--	19	37
7 Facilitation of Plug-in Hybrid Electric Vehicles (PHEVs)	--	--	10	60
Total	56	203	60	211

Source: EPRI 2008
Note: Tg equals million metric tonnes (MMT)

Fig. 2. EPRI Report: Smart Grid Energy Savings and Avoided CO_2 Emissions Summary (2030) [5]

IX.   Power Electronics in Smart Grid

The emergence of high voltage SiC power devices such as MOSFET (MOS Field Effect Transistor), IGBT (Insulated Gate Bi-polar Transistor), and GTO (Gate Turn-off Thyristor) now replaced by IGCT (Integrated Gate-Commuted Thyristor), having low losses and high operational frequency, have a great impact on high power utility applications, especially for smart grid. IGBT is an amplifier that allows large collector current to be varied by a gate voltage requiring very little current i.e. little control power. Thyristors on the other hand are the switching devices composed of regenerative pair of transistors that can switch rapidly with the gate control. The adjustment of speeds at which anode voltage and current transit during switching – di/dt (turn-on) and dv/dt (turn-off) is adjusted via external components or intrinsic behavior of the device. Static Inverter and Rectifier, DC-to-DC converter, Short Circuit Current Limiter (SCCL), Dynamic Brakes Static VAR Compensator (SVC), Dynamic VAR (D-VAR), Solid State Transfer Switch (SSTS) are some power electronic devices currently being used

DOE (Department of Energy) has estimated that within the next two decades 80% of the electricity used in US will flow through Power Electronics with programs like ADEPT (Agile Delivery of Electrical Power Technology) [2].

X.   Trends in Distribution System Automation (DSA)

Though DSA is currently in its infant stage, it is on the rise with the fastest growing market segments starting with the AMI (Automated Metering Infrastructure), gearing towards feeder automation through automated power capacitors, re-closures, and voltage regulators, and finally, advanced power electronics as components in almost every segment of the distribution system networked through current state of the arts wired and wireless networking infrastructure. In U.S. [6], DA market segment will grow steadily from $2.2 billion in 2010 to $5.6 billion in 2015. Traditional vendors of electrical components such as ABB, GE, Areva, and SEL, as well as networking vendors Silver Spring, Trillant, and smartSynch, are advancing towards the automation trend. DAS has to grow to incorporate reactive demand with the growing technologies such as Electric Vehicles (EV), Distribution Generation (DG) and energy storage. DSA has yet to be advertised in a simplified form to state regulators, consumers, and, credit agencies so as to attract more investments.

XI.   REFERENCES

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