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A Brief Survey on the Advancement of Smart Grid

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Abstract
The Smart Grid, regarded as the next generation power grid, uses two-way communication of electricity and information to create a widely distributed automated energy delivery network. In this article, a review work on different aspects on the enabling technologies for the Smart Grid is being presented. Infrastructure of Smart Grid can be broadly classified into three terms namely the smart infrastructure system, the smart management system, and the smart protection system. We also presented a review work in which implementation strategy of Smart Grid in different countries was briefly highlighted. In this paper then some advantages and hindrance of Smart Grid was also explained. Specifically, we focused for the smart infrastructure system, we explore the smart energy subsystem, the smart information subsystem, and the smart communication subsystem. For the smart management system, we explore various management objectives, such as improving energy efficiency, profiling demand, maximizing utility, reducing cost, and controlling emission. We also explore various management methods to achieve these objectives. For the smart protection system, we explore various failure protection mechanisms which improve the reliability of the Smart Grid, and explore the security and privacy issues in the Smart Grid.
Keywords: Smart Grid, bidirectional energy flow, Peak curtailment, demand side management, Sustainability

I. Introduction

A **smart grid** is a modernized electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.[1] The smart grid will add monitoring, analysis, control and communication capabilities to power generation and distribution. Real-time information on costs, demands and supply of power will provide control at every level of the system. Consumers will both receive and contribute power to the smart grid from ultimately anywhere in the world. There are many smart grid definitions, some functional, some technological, and some benefits-oriented. A common element to most definitions is the application of digital processing and communications to the power grid, making data flow and information management central to the smart grid. Various capabilities result from the deeply integrated use of digital technology with power grids, and integration of the new grid information flows into utility processes and systems is one of the key issues in the design of smart grids.

More specifically, the SG can be regarded as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable.

Existing Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

TABLE I: A Brief Comparison between the Existing Grid and the Smart Grid

II. Components of Smart Grid

2.1 Smart infrastructure system: The smart infrastructure system is the energy, information, and communication infrastructure underlying of the SG that supports

a) Advanced electricity generation, delivery, and consumption

b) advanced information metering, monitoring, and management.

c) Advanced communication technologies.

2.2 Smart management system: The smart management system is the subsystem in SG that provides advanced management and control services.

2.3 Smart protection system: The smart protection system is the subsystem in SG that provides advanced grid reliability analysis, failure protection, and security and privacy protection services.

Smart Grid Applications

Survey of implementation of Smart Grid

City /Country	Authority	Year of Start	Implementation Strategy	Results
U.S.A New York	NYSERDA	2001	Peak load reduction program(PLRP)	PLRP total MNV evaluation Adjusted demand reduction in 2001 – 2003 was 355 MW
U.S.A Califonia	Electric Power research institute and PG & E	2007	15 MW peak load reduction through auto DR.	22.8 MW reduction; goal exceeded by 52 %.
Canada Hydro Otawa Territorry	Ontario Energy board	2006	Consumer the regulated price plan RPP	There was clear evidence of load shifting on individual peak days for CPP and CPR price group. The statistical significance shows less evidence in the case of TOU price groups.
U.S.A Texas	Austin Energy		Direct Load Control(D.L.C)	The power partner program contributes an average of 45 MW of Peak capacity.
North East of U.S.A	PJM		Economic load response program(RTP)	At the end of 2007,4898 sites (2944 MW) were registered in the RTP and 705 sites (2144 MW) were in emergency load response program.PJM estimates a price reduction of about USD 650 million .
Singapore	National Electricity market of Singapore 2003	2006	Demand side beeding by licenced provider, incentive and penalty based structures of DR programs	Pilot Project Studding the effects of DR programs
Norway		2004	Peak Clipping,Determine External condition ,Test and evaluate different dear incentive Two Time of	0.6KWh/h saving per consumer

			Day(TOD) terrif.	
Sweden	Svenska Kraftnat	2003-2008	Pilot project involving 6 industries 3 of them reduced their demand by 1 MW.	13.6% of reduction VS.Non DSM apartments, 34% achieved VS. lower energy efficiency apartments.
Finland	National electricity transmission grid operator(Fingrid)	No exact date but enforced for long time.	Interruptable Programs. Different types of Time of Use (TOU) Rates.	15% ,2000MW peak load reduction
France	Electricite' de France's Tempo terrif		Days are distinguished according to price using a colour system together with an indication whether the hour is currently one of 8 off-peak hours or not	15 %on white days ,45% on red days and 10% on electricity bills of Customers.
U.K	National grid Flexitricity a 2008 U.K Company	2007	Short Term Operating Reserve (STOR) is a service for the provision of additional active power and demand reduction.	
Italy	Energy regulator,Italian TSO (Tema)	Around 2007	Interruptible Programmed ,Load Shielding Programmed	90% smart metering penetration.
Spain	Spain TSO	1988	Price led Programmed has been in place for some time ,with time of use ,Terrif providing economic signals	NA
Brazil	CASAN	NA	Installation of control system and automatic load shielding units with seasonal pricing in peak time.	NA
Chile	Ministry of Energy	Past Decade	Development of net-metering system that allowing in principle.	Not much effective due to less attractive cost structure
Denmark	Pilot Project	2004	Automated Peak Reduction +pricing Signal+Awareness.	82.5% reduction during interruption
Australia	CRA International Melbourne	2007	Voluntary Participation	61 agreement;81 MW of load reduction
China	NDRC	2010,2011	China Utility companies to achieve annual dual targets of energy saving and load reduction of 0.3 % respectively.	Progress

III. Features of Smart grid

Reliability -

The smart grid will make use of technologies that improve **fault detection** and allow **self-healing** of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack.

Flexibility in network topology-Next-generation transmission and distribution infrastructure will be better able to handle possible **bidirection 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.
Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues. A smart grid aims to manage these situations.

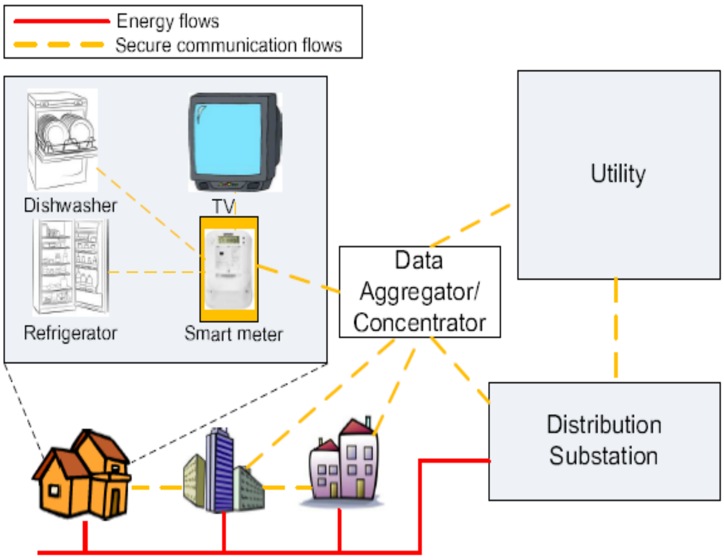
Efficiency-Numerous contributions to overall improvement of the efficiency of energy infrastructure is anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during short-term spikes in electricity price. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

Load adjustment-The total load connected to the power grid can vary significantly over time. Although the total load is the sum of many individual choices of the clients, the overall load is not a stable, slow varying, cement of the load if a popular television program starts and millions of televisions will draw current instantly

Peak curtailment/leveling and time of use pricing- To reduce demand during the high cost peak usage periods, communications and metering technologies inform smart devices in the home and business when energy demand is high and track how much electricity is used and when it is used. It also gives utility companies the ability to reduce consumption by communicating to devices directly in order to prevent system overloads. Examples would be a utility reducing the usage of a group of electric vehicle charging stations or shifting temperature set points of air conditioners in a city.[12] To motivate them to cut back use and perform what is called peak curtailment or peak leveling

Sustainability-The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage.

Market-enabling-The smart grid allows for systematic communication between suppliers (their energy price) and consumers (their willingness-to-pay), and permits both the suppliers and the consumers to be more flexible and sophisticated in their operational strategies. At the domestic level, appliances with a degree of energy storage or thermal mass (such as refrigerators, heat banks, and heat pumps) will be well placed to 'play' the market and seek to minimize energy cost by adapting demand to the lower-cost energy support periods. This is an extension of the dual-tariff energy pricing mentioned above.



IV. Some challenges of Smart grid-

4.1 Short term issues-

Voltage management- Voltage management-Heavy reactive power draw by RE generators pose spurious voltage management issues. In case when the variations are large grid stability limits may also be infringed. This affects the reliability and stability of the power system.

Real Power Imbalance-Uncertainty in demand always poses a challenges .System operators often rely on spinning reserves or other sources of power supply services to come into operation instantaneously when needed.

Commercial impledIants to real power balancing- When wind generation increases: Host utility in which the wind generator is located has no incentive to allow the wind generator to generate if the UI prices are below either the FiT rates or the regulated prices.

Sub-Optimal Coping Strategies- Procurement of Power from tertiary reserves / or from short term markets loss of quality of supply due to load shedding or UI power draw result in high cost that have to be borne by the consumers in the host state.

Sub optional coupling strategies-Sudden ingress or withdrawal of wind based generation from the grid would require tertiary resources with ramp up rates for balancing. Sudden loss of wind can be made up by withdrawal from the grid. UI mechanism thus provides perverse incentives for grid integration of RE based generation , and hence needs to be replaced by a more formal Ancillary Services Market.

4.2Long term issues-

Transmission capacity Expansion- Integration of RE generation require investment in transmission capacity, reactive power resources to support the flow of power over long lines and the reactive power Requirement of the wind generator. While transmission capacity is required to balance the variations in active power output of wind turbines, reactive power resources are required “locally” to prevent imbalances in the grid.

Generation Planning- With the increasing incorporation of RES into the system , the generation planning activity will also require a modified approach .Planning only for requisite MW capacity may not be adequate if such generation is not flexible to respond to system variability.

V. Conclusion

Due to the potential importance of SG, this survey comprehensively explores the technologies used in SG. We have surveyed the major SG projects/programs/trials and three major technical systems in SG: the smart infrastructure system, the smart management system, and the smart protection system. We have outlined challenges and future research directions worth exploring for each of these three systems. We also discussed about its benefit and effectiveness of Smart Grid. We also presented a report on survey of implementation of Smart Grid in different countries which shows a reduction of consumption of power in industries as well as in our daily life.

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