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Smart Grid-Future for Electrical Systems

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Abstract: **A smart grid is an evolved grid system that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved. In the world of the Smart Grid, consumers and utility companies alike have tools to manage, monitor and respond to energy issues. The flow of electricity from utility to consumer becomes a two-way conversation. Smart grids will provide more electricity to meet rising demand, increase reliability and quality of power supplies, increase energy efficiency, is able to integrate carbon free energy sources into power networks. One of the most important ways you can get involved with the Smart Grid is to take advantage of time-of-use programs. Smart meters and home energy management systems allow customers to program how and when their home uses energy. Throughout the day the *demand* for energy changes. It's usually lowest in the middle of the night and highest from about noon to 9 p.m., but it can vary according to weather patterns and what's happening during that time. Power plants and utilities have to work harder to meet the needs of electric consumers when the *demand* is highest. Time-of-use rates encourage you to use energy when the *demand* is low by giving you a lower price for electricity during those times. With a home computer or hand-held mobile device, you will be able to see when prices are highest and be alerted when prices go up, so you can remotely turn off unnecessary appliances until *demand* lowers and prices go back down. So because of these benefits smart grid is future for electrical systems.**

Keywords: **Smart Meter, Smart grid, PMU, time-of-use programs.**

1. INTRODUCTION

The **electricity sector in India** had an installed capacity of 237.742GW as of February 2014[1]. Non Renewable Power Plants constitute 87.55% of the installed capacity, and Renewable Power Plants constitute the remaining 12.45% of total installed Capacity [2]. India generated around 911 BU (911,652 MU i.e. 911 TWh) of electricity [3] (excluding electricity generated from renewable sources). The total annual generation of electricity from all types of sources was 1053.9 TWh in 2012. In terms of fuel, coal-fired plants account for 59% of India's installed electricity capacity, compared to South Africa's 92%; China's 77%; and Australia's 76%. After coal, renewable hydropower accounts for 17%, renewable energy for 12% and natural gas for about 9%. This is the Electricity sector in India.

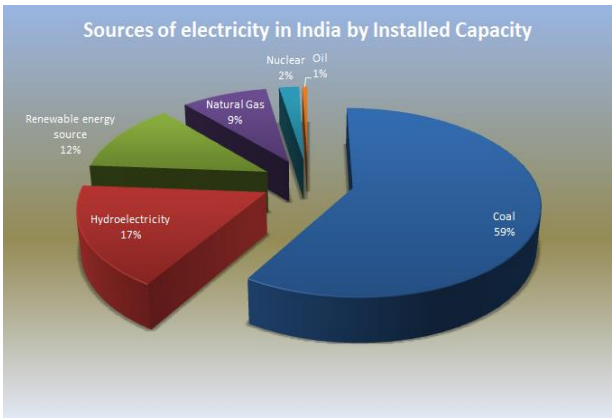

Fig. 1

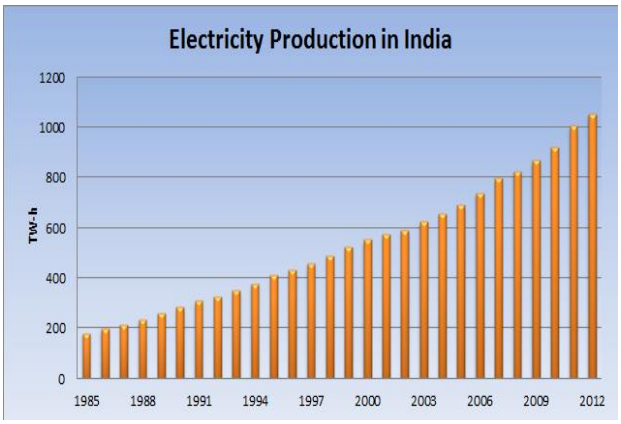

Fig. 2

May be you have heard of the Smart Grid on the news or from your energy provider. But not everyone knows what the grid is, let alone the Smart Grid. "The grid," refers to the electric grid, a network of transmission lines, substations, transformers and more that deliver electricity from the power plant to your home or business. The first alternating current power grid system was installed in 1886 [4].

At that time, the grid was a centralized unidirectional system of electric power transmission, electricity distribution and demand-driven control. Today, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines. Transmission and grid management are the essential functions for the smooth evacuation of power form generating stations to the consumers. Transmission function primarily consists of construction and maintenance of transmission infrastructure while the job of grid operator is to give operating instructions to the engineers in the field and ensure moment to moment power balance in the interconnected power system. Grid management involves taking care of overall reliability, security, economy and efficiency of power system. There are five regional grids in India; they are Northern, Western, Eastern, Northeastern and Southern. In previous days the first four of them are interconnected and operated in synchronous mode which implies that power across these regions flow seamlessly as per the relative load generation balance. On 31st December 2013, Southern Region was connected to Central Grid in Synchronous mode. Transmission line thereby achieving ONE NATION-ONE GRID-ONE FREQUENCY. This is the detailed information about grid.

Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air-conditioning led to daily peaks in demand that were met by an array of 'peaking power generators' that would only be turned on for short periods each day, resulted in high costs to the electricity companies, which were passed on in the form of increased tariffs.

Electricity - consumption (billion kWh) [5]

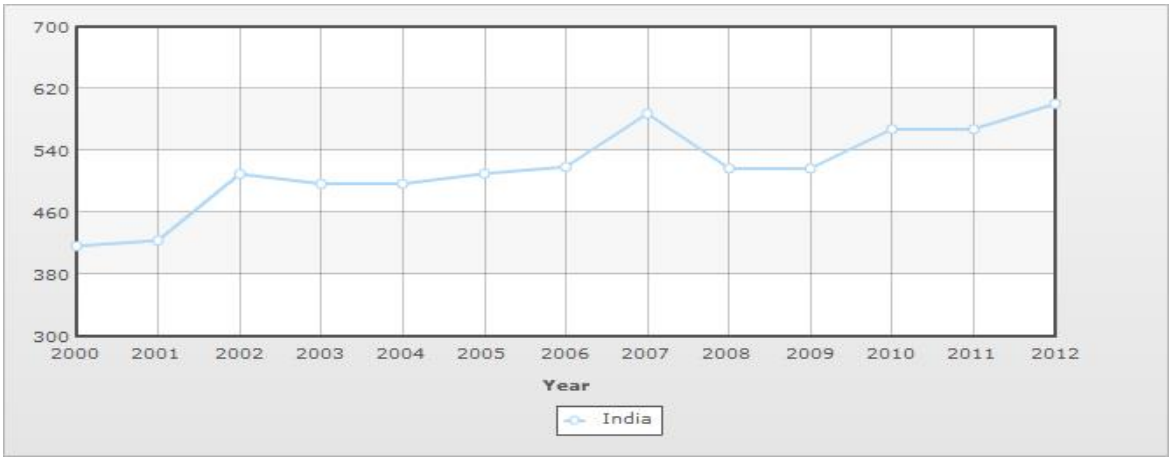

TABLE 1

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
India	416.35	424.03	509.89	497.2	497.2	510.1	519	587.9	517.2	517.2	568	568	600.6

To move forward, we need a new kind of electric grid, one that can automate and manage the increasing complexity and needs of electricity in the 21st Century.

2. DRIVING FACTORS FOR SMART GRID

Since the early 21st century, opportunities to take advantage of improvements in electronic communication technology to resolve the limitations and costs of the electrical grid have become apparent. Technological limitations on metering no longer force peak power prices to be averaged out and passed on to all consumers equally. In parallel, growing concerns over environmental damage from fossil-fired power stations has led to a desire to use large amounts of renewable energy. Dominant forms such as wind power and solar power are highly variable, and so the need for more sophisticated control systems became apparent, to facilitate the connection of sources to the highly controllable grid. Power from photovoltaic cells has also, significantly, called into question the imperative for large, centralized power stations. Growing demand led

to increasing numbers of power stations. In some areas, supply of electricity, especially at peak times, could not keep up with this demand, resulting in poor power quality including blackouts, power cuts, and brownouts.

The 31 July 2012 India blackout was the largest power outage in history. The outage affected over 620 million people, about 9% of the world population or half of Indian population, spread across 22 states in Northern, Eastern and Northeastern India. At the time of failure electricity use was "above normal". Increasingly, electricity was depended on for industry, heating, communication, lighting, and entertainment, and consumers demanded ever higher levels of reliability. Therefore it calls for smart grid.

Some of key market drivers for smart grid are-

1. More efficient transmission of electricity
2. Quicker restoration of electricity after power disturbances
3. Reliable power-Maintain grid stability
   - Mitigate blackouts and outages impacts
4. Improve energy efficiency
   - Maximize energy flows
5. Renewable power-Integrate CO2 free energy
   - Enable renewable DER (wind ,solar) grid connection & dispatch
   - Develop backup energy asset flexibility (generation & distributed storage)
   - Integrate distributed renewable and electric vehicles
6. Reduced peak demand, which will also help lower electricity rates.

3. SMART GRID

Technology has transformed our way of life, but our electric grid — which we trust to keep power flowing to our homes, schools, workplaces, and hospitals — hasn't been modernized to match. Now it can be, with a new investment in our nation's energy infrastructure called smart grid. It combines **information technology with power transmission** to benefit your home, your community, and your nation.

What does Smart Grid mean?

A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via **two-way digital communication**. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. The smart grid was introduced with the aim of overcoming the weaknesses of conventional electrical grids by using smart net meters. In this smart grid technology consumers turns to "Prosumers"

Fig. 3-One way communication

Fig. 4-Two way communication

4. FEATURES OF THE SMART GRID

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. Some of its features are

1. Reliability
2. Flexibility in Topology
3. Efficiency
4. Load adjustment/Load balancing
5. Peak curtailment/leveling and time of use pricing
6. Sustainability
7. Demand response support
8. Platform for advanced services

1. 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.

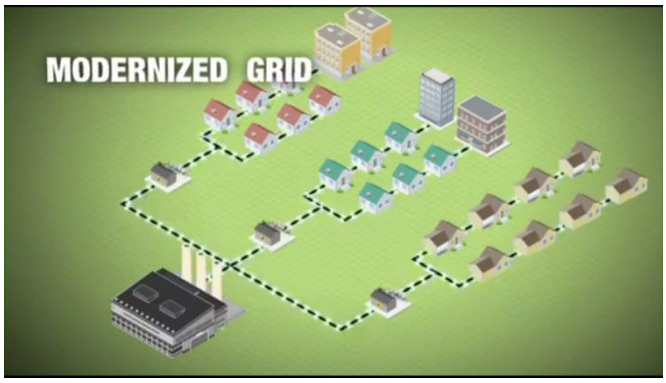

Fig. 5-Normal operation

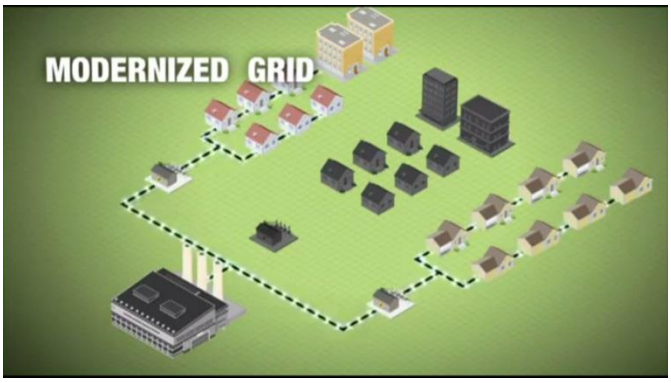

Fig. 6-Fault condition

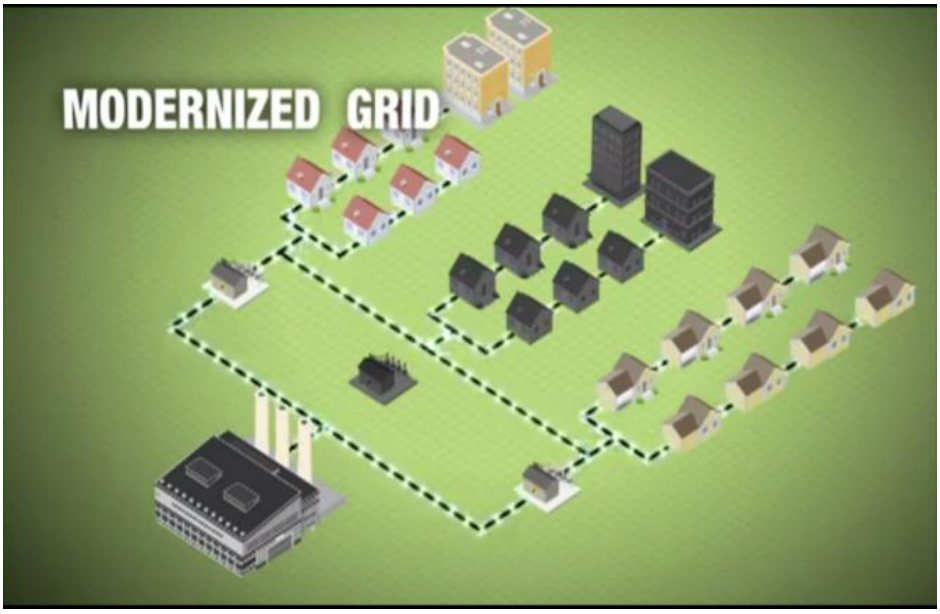

Fig. 7-Self healing

2. Flexibility in network topology:

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.

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.

3. 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.

4. Load adjustment/Load balancing:

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 and it is varying. Traditionally, to respond to a rapid increase in power consumption, faster than the start-up time of a large generator, some spare generators are put on a dissipative standby mode. A smart grid may warn all individual loads, or another larger customer, to reduce the load temporarily (to allow time to start up a larger generator) or continuously (in the case of limited resources). 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.

5. 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. 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.

6. 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. Current network infrastructure is not built to allow for many distributed feed-in points, and typically even if some feed-in is allowed at the local (distribution) level; the transmission-level infrastructure cannot accommodate it. Rapid fluctuations in distributed generation, such as due to cloudy or gusty weather, present significant challenges to power engineers who need to ensure stable power levels through varying the output of the more controllable generators such as gas turbines and hydroelectric generators. Smart grid technology is a necessary condition for very large amounts of renewable electricity on the grid for this reason.

7. Demand response support:

Demand response support allows generators and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators and allows users to cut their energy bills by telling low priority devices to use energy only when it is cheapest.

8. 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.

5. SMART GRID COMPONENTS

To meet the above features the smart grid system involves some of the following components

1.1 Smart meter

1.2 Phasor measurement unit

5.1 Smart meter:

Smart meters are advanced meters that identify energy consumption in more detail than a conventional meter. They look much like the electric meters that are in your home now, but their technology is far more advanced. They have the ability to communicate information via a secured network back and forth between your home and utility.

Fig. 8

Smart meters are foundation for updating existing electrical system into smart grid because they have two way communications between utility and user that is it receives information from utility and also transmits energy usage information to utility.

Smart meters are safe and secure:

Smart meters have been thoroughly tested for safety and reliability. They have undergone extensive tests by utilities in USA. Smart meters operate at a level that is much lower (1.4%) than the maximum permissible exposure limits for radio frequency.

5.2 Phasor Measurement Units:

A **Phasor measurement unit** (PMU) or **synchrophasor** is a device which measures the electrical waves on an electricity grid, using a common time source for synchronization. Time synchronization allows synchronized real-time measurements of multiple remote measurement points on the grid. High speed sensors called PMUs distributed throughout a transmission network can be used to monitor the state of the electric system. Phasor are representations of the magnitude and phase of alternating voltage at a point in the network. Using a PMU, it is simple to detect abnormal waveform shapes.

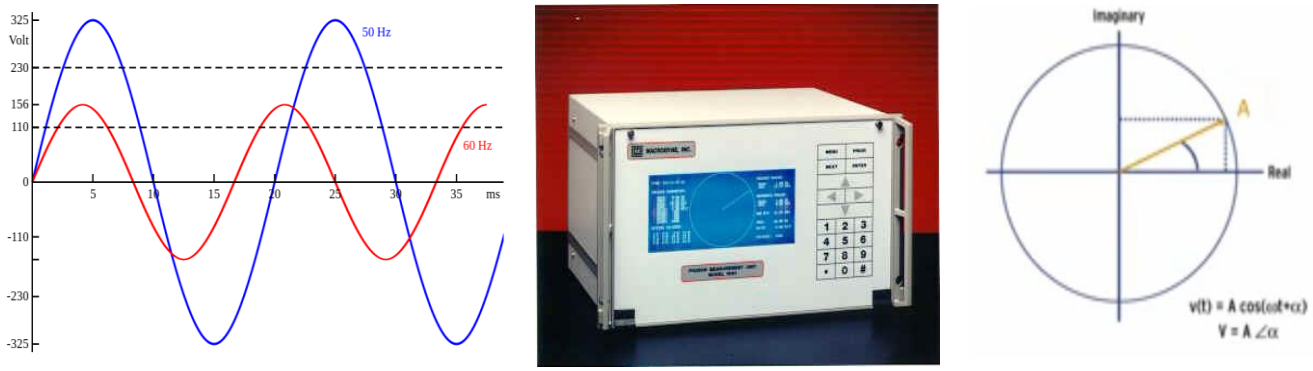

Fig. 9

Benefits of PMU:

1. Using a PMU, it is simple to detect abnormal waveform shapes.
2. Time synchronized sub-second data
3. Dynamic behavior observing
4. High data rates and low latency due to computation

6. SMART GRID IN GENERATION, TRANSMISSION & DISTRIBUTION

6.1 Smart grid in generation:

Integrates all sources of energy and advanced plant controls

- Hydro power plants
- Wind farms
- Solar farms
- Thermal power plants etc.,

6.2 Transmission:

It uses Smart power electronics having following features:

- Unmanned station with comprehensive diagnostic facilities using real time telecommunication
- High reliability-99% efficiency of power transmission
- Shunt and series line compensation
- Improved AC power quality
- Digital substation (AIS & GIS)-Compact optical sensor intelligence
- PMUS
- Integrated signal processing for advanced equipment diagnostic and monitoring
- Improved substation safety and reliability
- Transmission control room-Energy management system
- Advanced generation scheduling
- Wide area automation

6.3 Distribution:

- Integrated distribution management system
- Real time monitoring using smart meters
- Real time management of distributed renewable, storage and electric vehicles
- Real time management of demand response

7. SMART APPLICATIONS

7.1 Plug-In Electric Vehicles:

Plug-in electric vehicles (PEVs) are now being rolled out to consumers throughout the United States. The Smart Grid will have the infrastructure needed to enable the efficient use of this new generation of PEVs. PEVs can drastically reduce our dependence on oil, and they emit no air pollutants when running in all-electric modes. However, they do rely on power plants to charge their batteries, and conventional fossil-fueled power plants emit pollution. To run a PEV as cleanly as

possible, it needs to be charged in the wee hours of the morning, when power demand is at its lowest and when wind power is typically at its peak. Smart Grid technologies will help to meet this goal by interacting with the PEV to charge it at the most optimal time. But sophisticated software will assure that your PEV is still fully charged and ready to go when you need it. And you'll still be able to demand an immediate recharge when you need it.

Fig. 10

In the future, PEVs may play an important part in balancing the energy on the grid by serving as distributed sources of stored energy, a concept called "vehicle to grid." By drawing on a multitude of batteries plugged into the Smart Grid throughout its service territory, a utility can potentially inject extra power into the grid during critical peak times, avoiding brownouts and rolling blackouts. Financial incentives may be available for PEV owners that allow their batteries to be used this way.

One of the key factors for acceptance of PEVs in the marketplace will be the availability of charging stations. Currently, a number of entities are building charging stations in cities throughout the United States. For now, many municipalities and private companies are offering free recharges to PEV owners as an incentive for these clean vehicles.

With the Smart Grid, PEVs can identify themselves to the charging station when they are plugged in, and the electricity used can be automatically billed to the owner's account. The technology will not only simplify transactions for the charging station owners, but also allow PEV owners to charge up without the need for cash or a credit card.

7.2 Home Energy Management Systems

How will the Smart Grid affect your home? It won't look very different, but behind the scenes a lot will be happening. Even right now, in many cities across the USA, new equipment, appliances, and software are available that use emerging Smart Grid technologies to save energy, seek out the lowest rates, and contribute to the smooth and efficient functioning of our electric grid.

8. BENEFITS

Benefits of the Smart Grid:

TABLE 2

Benefits to Utility	Benefits to Consumer
• Reduction in losses • Increased Grid stability • Peak load management • Renewable integration • Self-healing grid • Reduced Capital & operational cost • Increased employee safety • Increased revenue • Higher customer satisfaction • Opportunities to leverage its resources and enter new markets • Increased asset utilization	• Prosumers (Producer & Consumer) enablement • Improved quality of power supply • User friendly & transparent interface with utilities • Reduction in electricity bills by shifting loads from peak hours to non-peak hours • Opportunity to interact with the electricity markets through home area network and smart meter connectivity • Opportunity to purchase energy from clean resources, further creating a demand for the shift from a carbon-based to a "green economy"

9. RESULTS OF THE STUDY OF SMART GRID

Comparative study results made from the summer 2011 by US department of energy of the three projects [10]

- Oklahoma Gas and Electric (OG&E)
- Marblehead Municipal Lighting Department (MMLD)
- Sioux Valley Energy (SVE)

TABLE 3

Project Elements	OG&E	MMLD	SVE
Number of customers	6,000 residential customers	500 residential customers	600 mostly residential customers
Time-based rate(s)	Time-of-use and variable peak pricing with critical peak pricing components	Critical peak pricing	Critical peak pricing
Customer systems	In-home displays, programmable communicating thermostats, web portals	Web portals	Web portals
Peak demand reduction during critical peak events	Up to 30%	37%	Up to 25%
Customer acceptance	Positive experience, many reduced electricity bills	Positive experience, but did not use the web portals often	Interested in continued participation, many reduced electricity bills

The MMLD analysis showed that more than 85% of the participants reported having positive experiences with smart technology.

SVE analyzed that customers reduced their peak demand by 5%-25%

OG&E study analysis showed peak demand reductions of as much as 30% from a sample of about 6,000 mostly residential customers.

10. CURRENT IMPLEMENTATIONS

1. Now there are 30 million smart meters in operation in U.S.A as of spring 2012

2. The status of worldwide installation as of spring 2012

3. NEW DELHI: Tata power Delhi has become the first Indian power utility to launch the Automated Demand Response (ADR) Project with smart meters in the capital.[9]

Under the project, Tata Power Delhi Distribution's select Industrial and Commercial Consumers having load greater than100 KW. The project covers an area of more than 100 sq. km in the industrial, commercial and institutional belts of Tata Power Delhi Distribution like Lawrence Road, Narela, Delhi University, Civil Lines, Naraina, Wazirpur, Pitampura

etc. covering industry sectors like Flour Mills, Food Processing Industry & Cold Storages, Commercial establishments, Plastic & Footwear Industry etc. A Total of around 250 consumers are participating in this project and will contribute towards a collective shed potential of 20 MW. This project involves around hundred 11 KV feeders, fed from 40 grid stations spread across the Tata Power Delhi Distribution's distribution area.

4. Smart Grid in Pondicherry - A Reality [8]

Power Grid Corporation of India jointly with **Electricity Department, Govt. of Pondicherry**, is developing smart grid pilot project at Pondicherry through open collaboration.

11. CONCLUSION

It's smarter for you- The more you know about your electricity consumption, the more control you have over your usage and your bills .When it comes to manage electricity, knowledge really is a power. **It's smarter for planet-** The technology will provide daily estimation of greenhouse gases associated with electrical usage. At the same time the technology will improve and provide how renewable energy sources are integrated with electrical grid. **It's smarter for us all-** Smart meters and smart grid can make your electricity supply more reliable, with fewer and shorter outages. We need to start planning for the future today, by building smarter grid and giving people smarter ways to control their energy consumption

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