Smart Grid

Research Blog

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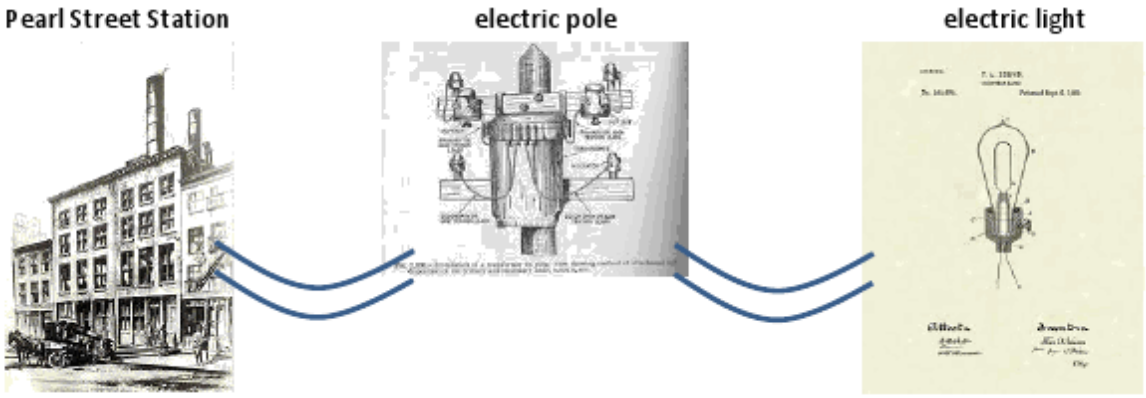
A Bit of History

Electricity is an inevitable part of our lives, almost everything today runs on electricity. We have come a long way, since 1831 when Michael Faraday created the first electric dynamo, which made generation of electricity practical. Thomas Alva Edison later set up the first power plant to produce direct-current system (DC) which illuminated the first New York electric street lamps in September 1882[1]. Later in the 1800's and early 1900's, Nikola Tesla invented the AC motor. Later, George Westinghouse developed Tesla's AC motor for generating alternating current, this brought about a revolution which led to AC power displacing DC[2].

Increase in its demand raised many new concerns as how could we get a system to transmit and distribute electricity over large distances. Throughout the early 1900's, local and state governments started to unify to form regulatory groups[3].By the 1930s, electric utilities started expansion, hence forming different aspects of the grid i.e. the power plants, transmission lines, and distribution.

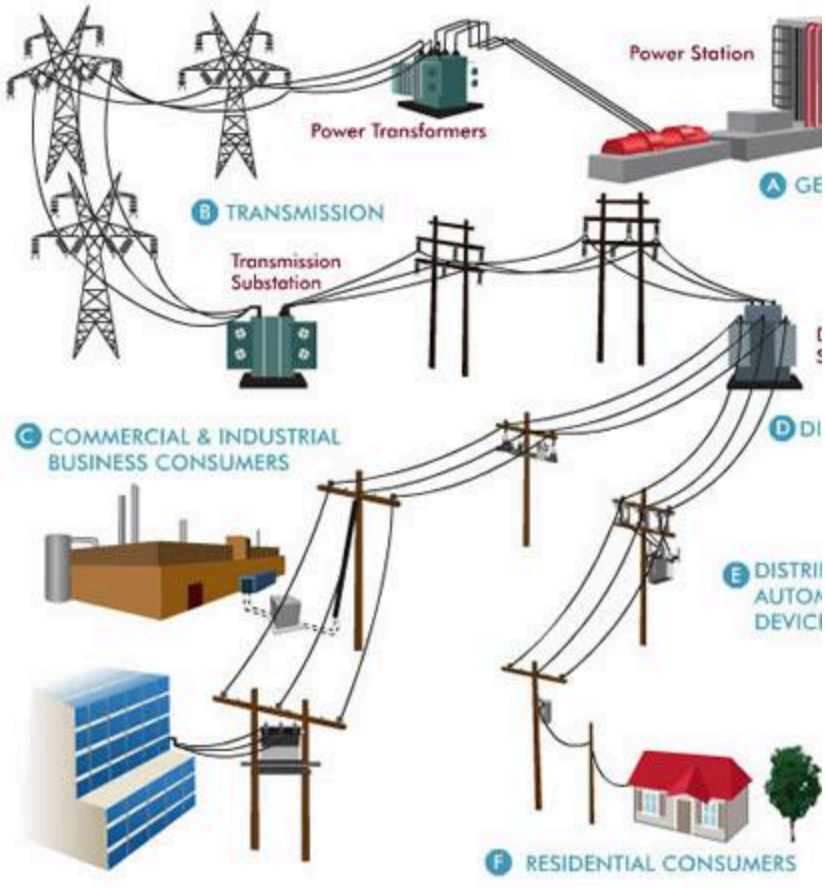


https://power2switch.com/blog/wp-content/uploads/2012/10/first-incarnation.png

Conventional Grids

As electricity became more prominent in daily lives, larger plants were constructed to provide more electricity, and bigger transmission lines were used to transmit electricity to farther distances. By the 1980's, privatization entered the power market and governments started making it possible for power plants owned by non-utilities to sell electricity too.

The trend in transmission and distribution have changed over the years with increase in demand and technology. Since then the utility companies have adopted new approaches for better service. With advances in electronics we have the opportunity to automate grids and operate them remotely. Several energy saving schemes have been planned out by the utility company which help you to monitor your load and save money. Governments have also put effort to enact laws which could help consumers to save energy.



http://www.altenergymag.com/articles/09.04.01/smartgrid/grid.jpg

Limitation of Conventional Grids

In spite of all the technological advances we have, our conventional grids have some limitations. They are as follows:

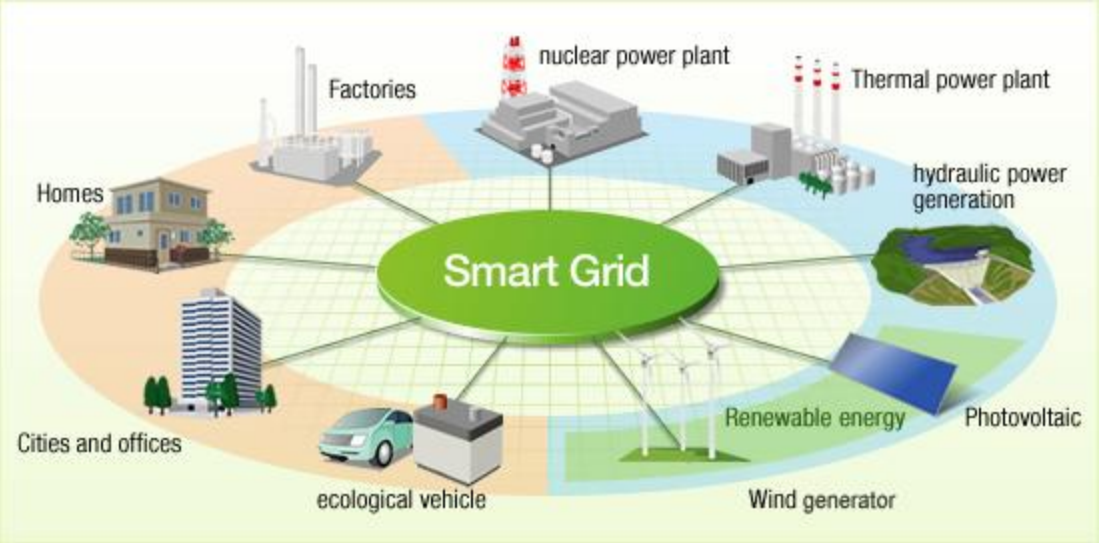
- System becomes unreliable for long distance usage.
- Demand and supply cannot be regulated easily.
- Fluctuations in load cannot be easily monitored.
- Electric power infrastructure is old and incompatible with the new technologies.
- The grid cannot support the development of renewables, which would make it less sustainable.
- More of human component in operation.

Concept of Smart-Grid

Currently we are trying to make our conventional grids equipped with better sensors and technologies such that the limitations could be decreased, the solution to this is “SMART GRID”. Smart grid is a name giving to the conventional grid which makes use of computer intelligence and networking abilities to overcome its limitations. It is not something new but still in its nascent stage where many researches are still going on to increase its usability.

It deploys various sensor at various levels so effective monitoring and control can be made possible. Some advantages of a smart grid are given below:

- Increases system reliability through new and improved sensors deployed in the system.
- Saves time and money for utility companies due to faster response time.
- Analyzes consumer load and giving them better schemes to reduce their electricity bill.
- Introduction of renewables possible into the smart-grids.
- Reduces all over cost of production.



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REFERENCES AND CITATIONS

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[3] http://burnanenergyjournal.com/the-electricity-grid-a-history/
[4] http://mentalfloss.com/article/57769/12-biggest-electrical-blackouts-history
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From Smart Grid to Smart Home

Numerous components are synchronized together to achieve the concept of smart grid. For our convenience, we divided the smart grid into two broad divisions: the consumer side and the utility side. The utility side includes all the technologies and setups required to get electricity to the consumer end. The consumer side includes all the technologies and setups at the consumer's premises which help the grid monitor and manage the load consumption.

Consumers form an important part of the smart grid as fluctuations in load at the consumer end need to be monitored to have efficient production and transmission of electricity. Consumer energy patterns can be studied to predict peak loads and different methods to avoid overloading the system and run it efficiently.

With a continuing increase in employing various forms of renewable energy sources in homes, there is a need to have a constant communication between the grid and the consumer premises. Automated reading infrastructure (AMI) helps in two-way communication.

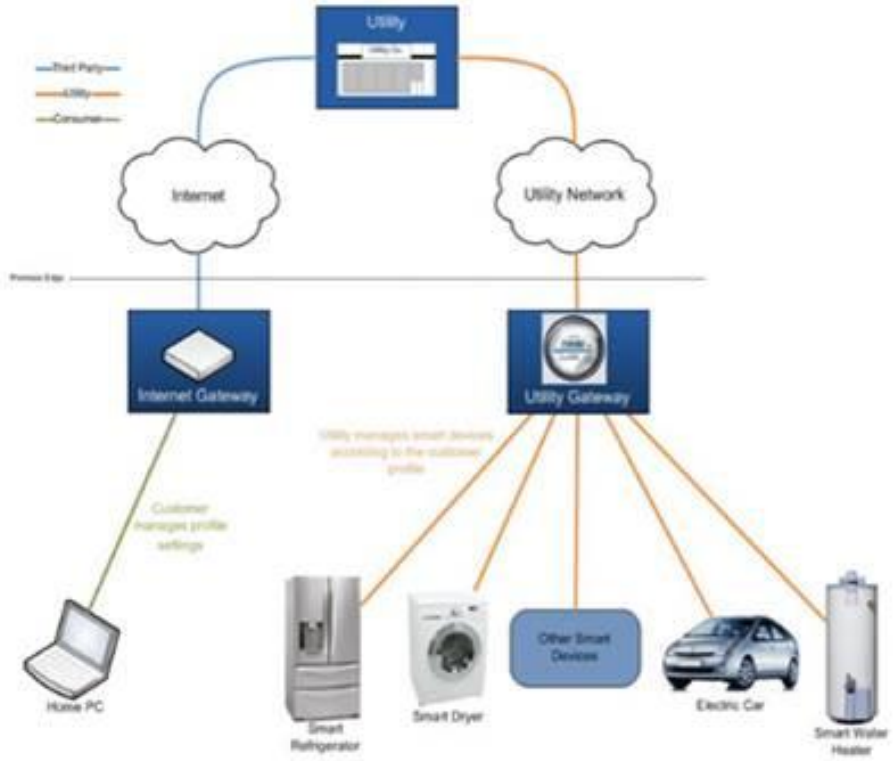
Smart homes enable us to manage electricity by giving us continuous updates. Consumers enrolled in smart pricing programs get hourly electricity usage data from their utilities. We would be building our focus more on the consumer end rather than the utility end.

There are two types of architecture that can be employed at the consumer end for monitoring and controlling:

1. Utility-controlled architecture
2. Consumer-controlled architecture

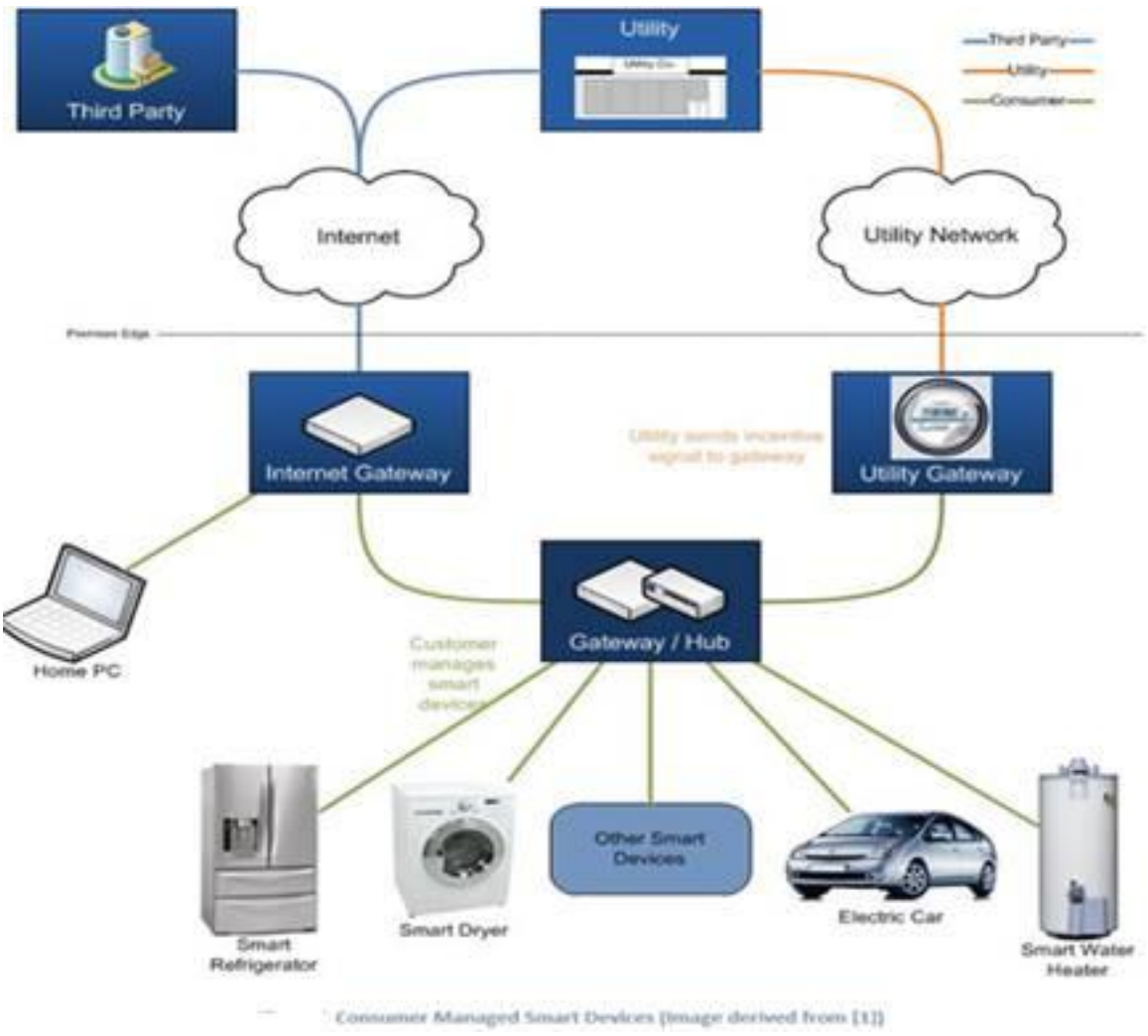
<u>Utility-Controlled Architecture</u>

In this type of setup load control can be done from the utility side. As it is apparent that consumers have a minimal role to play in this type of arrangement, most of the consumers do not like it. The following diagram represents this model.



Consumer-Controlled Architecture

In this type of architecture control is solely in the hands of consumers. This architecture is preferred; hence, we will proceed our discussion with it.



Consumer Managed Smart Devices (Image derived from [1])

Smart Homes

A smart home is a building which is equipped with special structured wiring and other communication arrangements which enable the consumer to monitor and control various devices being remote from the home itself. In a smart home one can simply operate the heating system from his/her phone even before reaching home or even see inside the refrigerator on the cell phone so that they can know what items are required to be bought. Similarly, the smart home also enables the utility to get information energy usage patterns of the consumers. The two architectures through which a utility can

communicate are explained above. The communication between the devices make it all possible. Hence we need to understand what are the different parameters which make up a smart home, namely:

- A smart meter
- Home Energy Management System (HEMS)
- Home Area Network (HAN)
- Smart Appliances

A typical smart home would require the HEMS to communicate with appliances connected to it and give the status of each appliance to the smart meter. The communication is built through HAN using several communication protocols.

Smart Meter

A smart meter is nothing but an enhanced version of a normal Automated reading meter (AMR). It enables a two-way communication between the grid and the smart home, i.e., it can send and receive messages from the grid. Through smart meter the grid is able to track electricity usage and send different pricing options, which can help the consumer to adjust their usage and reduce their electricity bill.

Two-way communication is achieved through advance metering infrastructure (AMI). There are several ways AMI can be employed by the grid that can help communicate with the smart meter. Such technologies are Power line communication, RF, and Zigbee through NAN or WAN. Some of the leading companies that manufacture smart meters are Itron, General Motors, Elster Group, and Schneider.

As we are more concerned with the consumer end, we must understand how the smart meter communicates with consumer devices. Different models use different kinds of communication protocols, but the following are most commonly used:

- WiFi
- Zigbee
- Internet Protocol
- Power line communication

Depending on which smart meter you are using, different protocols will be used. The most widely used in the U.S are Zigbee and power line communication. Different protocols need different setups in the subsequent devices so that a proper communication is obtained.

Zigbee Alliance has made a large impact in the market with smart energy profile (SEP). Many smart device companies are using this technology because of the its high interoperable nature. Some reasons why Zigbee is widely used are enlisted below:

- It is very low cost and has low energy drain
- It has a very low energy consumption, in the degrees of mW, which can increase the battery life
- It has a low latency rate
- It can be customized for specific usages
- It has high interoperability and allows easy connection with other devices

Home Energy Management System and Devices

Home energy management system and devices help in monitoring and controlling the devices. These devices can be connected to the smart meter so that close monitoring and controlling can be possible. Some of the devices and systems that can be used are stated below:

1. Lighting control system
2. Gateways
3. In-home displays
4. Energy monitors
5. Smart plugs
6. Smart thermostats

Examples of each device will be explained in depth later in time.

Home Area Network

Home area network, or HAN, enables communication and sharing of information typically for a home or office. It is dedicated to connect HEM devices and other smart meters together with means of a network connection. It also helps connecting the HEM with the smart appliance for monitoring and control purposes.

There are two ways in which HAN can be accomplished:

- Separate HAN gateway or HAN device portal
- HAN integrated in a smart meter

Separate HAN gateway or HAN device portal

In this type of setup there is a dedicated device which can form HAN and connect the smart meter with HEM and smart devices. Recent practices have begun to integrate

HAN capabilities to one of the devices so that the necessity of having a standalone device only for communication purposes can be avoided.

HAN integrated in a smart meter

In this architecture, HAN capabilities are built in the smart meter itself and do not require a separate standalone device to form the network.

HAN device portal architecture is widely used, and we would also be using a similar architecture for further explanation. Residential consumers are increasingly given a choice of power sources, and these retail suppliers of electricity may have their own demand-side management programs, complete with a recommended or required HAN solution. Consumers (and utilities) have a choice of home networks, including 6LoWPAN, FlexNet, HomePlug, LonWorks, Radio Data System (RDS), Wi-Fi, Z-Wave, and ZigBee.