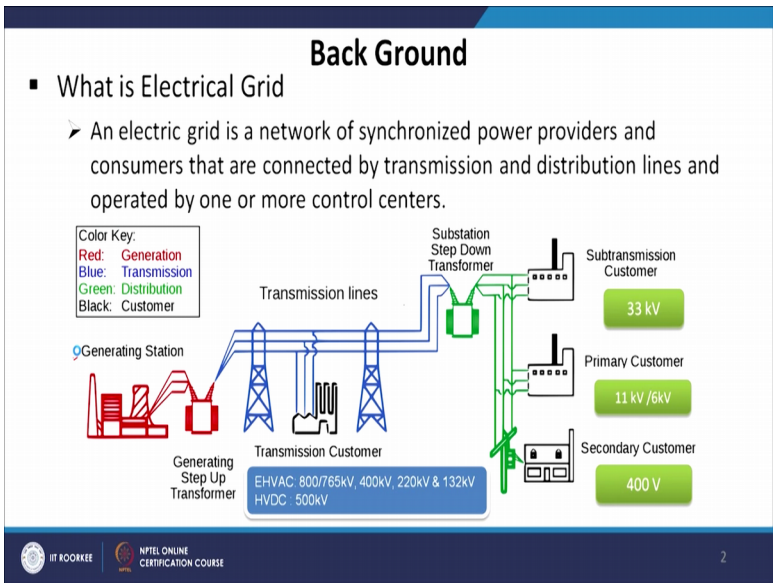
Introduction to Smart Grid
Prof. N. P. Padhy
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture - 01
Introduction to Smart Grid- I

Hello everyone. I am Professor N P Padhy from Department of Electrical Engineering Indian Institute of Technology Roorkee. We used to deliver the lecture on Introduction to Smart Grid today.

First of all let us understand what is the meaning of electrical energy grid?

(Refer Slide Time: 00:57)

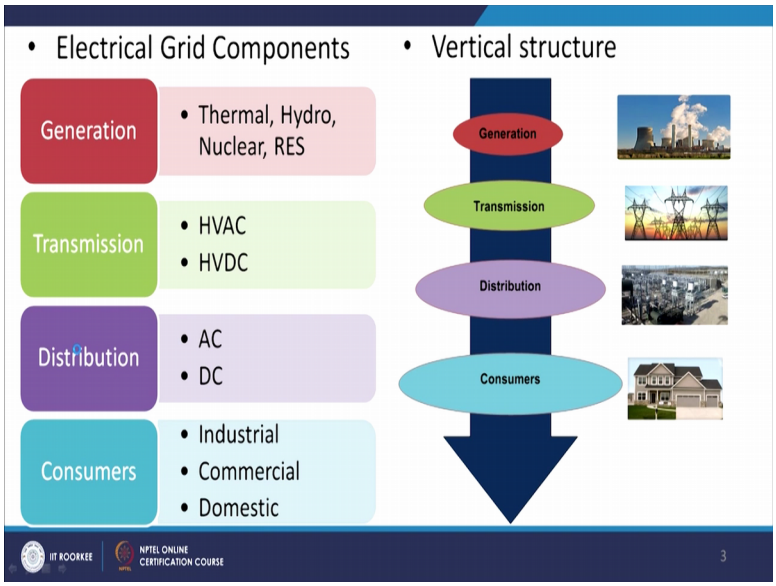


The moment we talk about electrical grid, it means electric grid is a network of synchronized power providers and consumers that are connected by transmission and distribution lines and operated by one or more control centers.

Being said that, now you can see the view of energy grid or electrical grid, we do have generation stations, transmission lines, substation step down transformers, and connected across different type of loads. The generating station which is ideally transfer it is energy through either EHP AC lines or HP DC lines.

And, the voltage rating of those EHP AC lines are either of 800 slash 765 kilo volts, 400 kilo volts, 220 kilo volts and 132 kV whereas, the commonly used HP DC lines are of 500 kilo volts. The customers especially the sub transmission customers connected it 33 Kv, primary customer set 11 kV, and secondary customers V residential are at 400 volts.

(Refer Slide Time: 02:39)

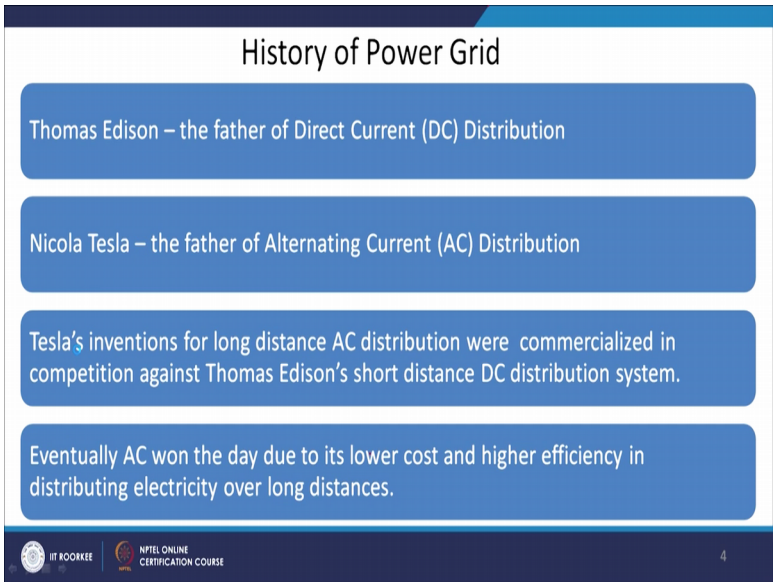


Now, the different components of electrical grid to me is generation first, which is either of thermal type, hydro type, nuclear type, and very recently renewal energy sources. Now, the transmission has being told a recently it is either of high voltage AC or high voltage DC, the distribution system mostly it is AC type, but in the recent time people start to talking about DC type too.

The consumers as we all know they are industrial types, commercial types, and residential domestic types. The electrical energy grid structure historically vertical in nature that is the energy is being produced at the generation point or generation station, then being transmitted through transmission lines, distribution lines, and reaches to the consumers, but with the new technology and the mega penetration of renewable energy at low voltage levels. May allow the energy to flow not necessarily from top to bottom, but it could be from the bottom to top to.

So, the vertical structure currently may have 2 different forms, that is energy flowing from generation to consumers and the energy may flow from consumers to generation stations to through transmission and distribution.

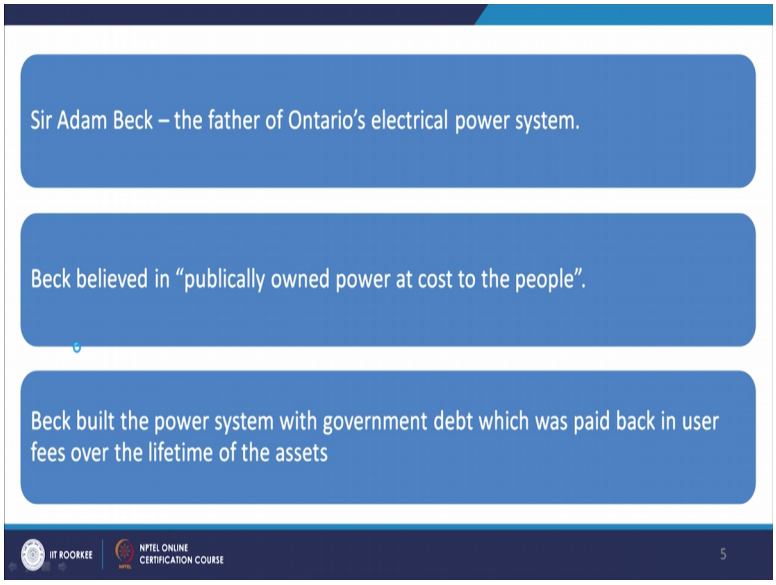
(Refer Slide Time: 04:29)



The history of power grid is quite interesting, if you look back Thomas Edison, considered to be the father of direct current distribution; who perhaps created DC technology. And, then hence Nicola Tesla again we treat him as a father of AC distribution system. Tesla invention for long distance AC distribution, were commercialized in computation against Thomas Edison's short distance DC distribution system. And, eventually AC systems or AC distribution won the day due to it is lower cost higher efficiency in distributing electricity over long distances.

So, I wish to conclude at the stage that though DC distribution was equally popular similar to AC distribution, but over a period of time it has being realized, that AC distribution system is more economical compared to DC distribution especially when you are transmitting through long distance.

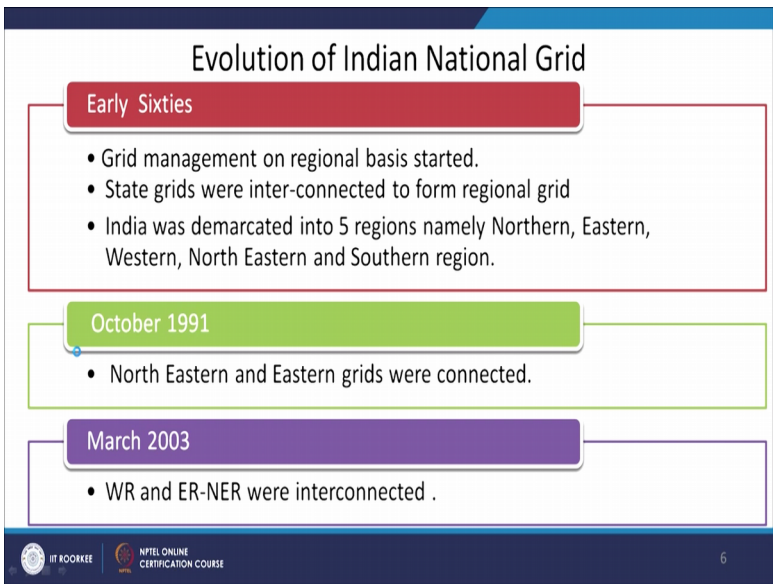
(Refer Slide Time: 05:48)



Further to add Sir Adam Beck the father of Ontario's Electrical power system beck believed in the principle that publically owned power at cost to the people. And, Beck built the power system with government debit, which was paid back in user's fees over the life time of the assets.

Now, that is how today we see the whole world is depending on AC system, which is reliable robust working well for long distance transmission, but in recent time there are 2 new things which are coming up. The first one is presence of renewable energy at all the voltage levels and the DC technology cannot be discarded completely as it was before many decades.

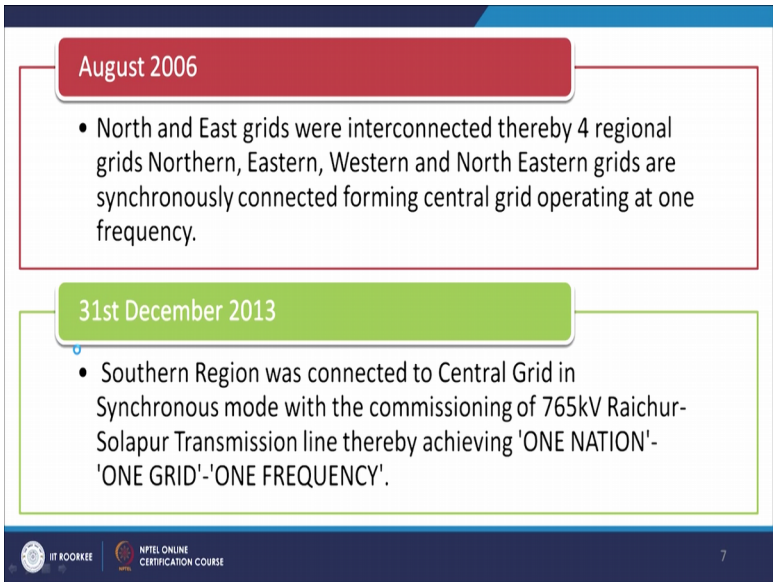
(Refer Slide Time: 06:52)



Now, looking at Indian national grid a quick glance in Early Sixties Grid management on regional basis started state grids were inter connected to form regional grid, India was demarcated into 5 regions namely Northern, Eastern, Southern, Western as well as North Eastern regions.

In October 1991 North East and Eastern Grid, where connected and during March 2003 western region and eastern region as well as north east region were inter connected.

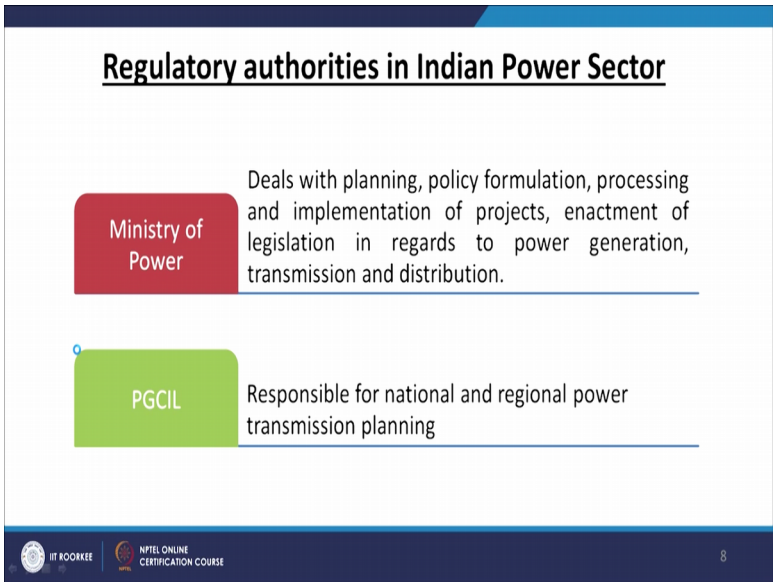
(Refer Slide Time: 07:39)



August 2006 North and East Grids were inter connected there were 4 main regional grid that is Northern, Eastern, Western and North Eastern grids are synchronously connected forming central grid operating at one frequency, considered to be great achievement during 2006.

Thirty first December 2013 Southern region was connected to central grid in synchronous mode with the commissioning of 765 kilo volt Raichur Solapur Transmission line thereby achieving ‘one nation’ ‘one grid’ ‘one frequency’. So, dear listeners I wish to conclude that the energy grid of India achieved one frequency one grid in the month of December year 2013.

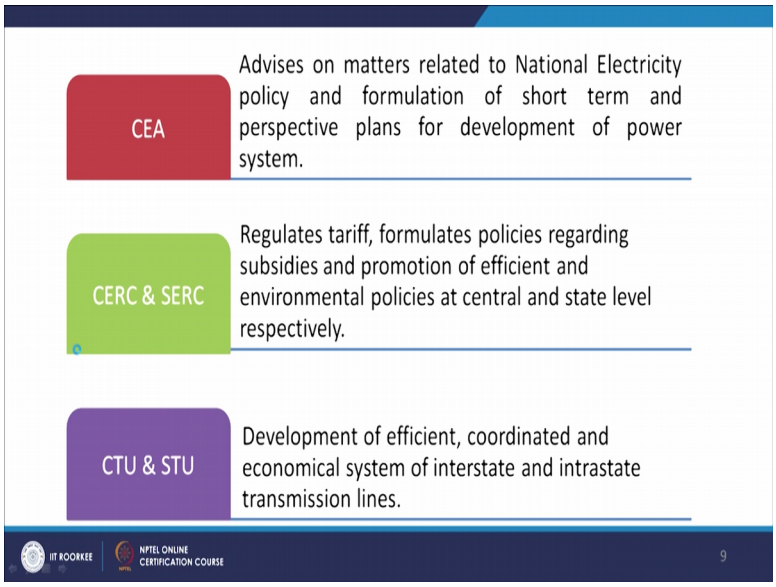
(Refer Slide Time: 08:59)



Now, look at the regulatory the authorities of Indian energy sector ministry of power, which is the major component deals with planning, policy formulation, processing and implementation of projects, enactment of legislation in regards to power generation, transmission and distribution.

Next important body which is power Grid Corporation of India limited; responsible for national and regional power transmission planning.

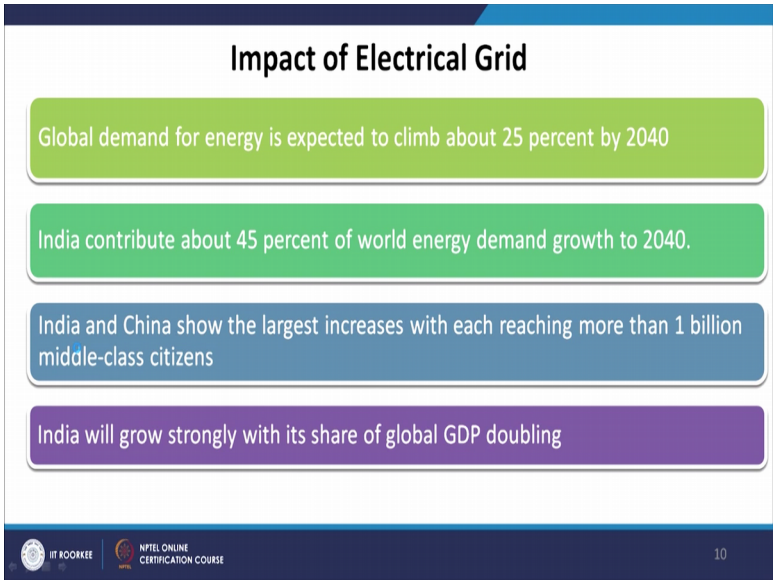
(Refer Slide Time: 09:39)



Then we move to central electricity authority advice on matters related to national electricity policy and formulation of short term and perspective plans for development of power systems. The next central electricity regulatory commission and state electricity regulatory commissions, regulates tariff formulates policies regarding subsidies and promotion of efficient and environmental policies at central and state level respectively.

Then, we move to central transmission utilities and state transmission utilities; develop efficient coordinated and economical system of interstate and intrastate transmission lines.

(Refer Slide Time: 10:35)

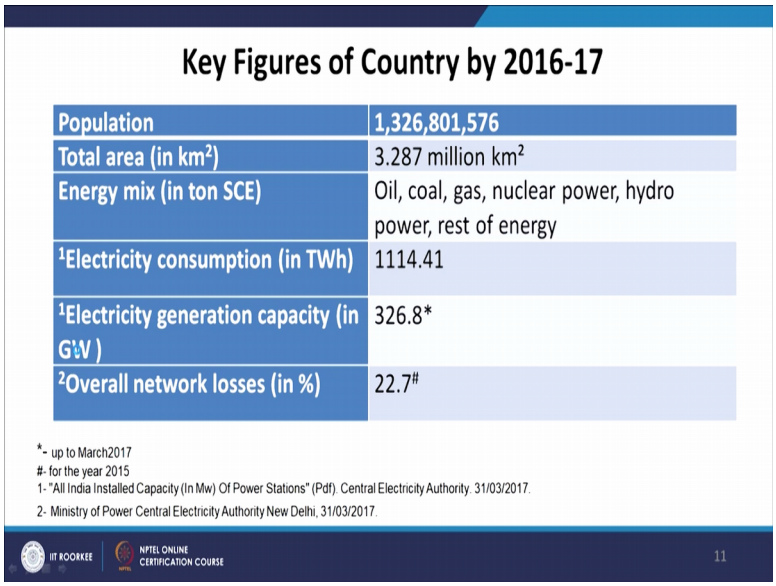


Now, if you look at the impact of electrical grid in specific global demand of energy is expected to climb about 25 percent by 20 40. It is a great hike the whole world is expected to increase their per capita energy consumption and it is great challenge in front of all of us how to achieve that 25 percent increase by 20 40 in a green clean manner.

Above and all India contributes about 45 percent of world energy demand growth in 20 40. So, being said the whole world is worried about creation of energy sources in a cleaner green manner. Whereas, the challenge on India would be for more, because out of those 25 percent increase by 20 45 45 percent increase is just by India.

India and China so, the largest increase with each reaching more than one billion middle class citizens, India will grow strongly with it is share of global GDP doubling.

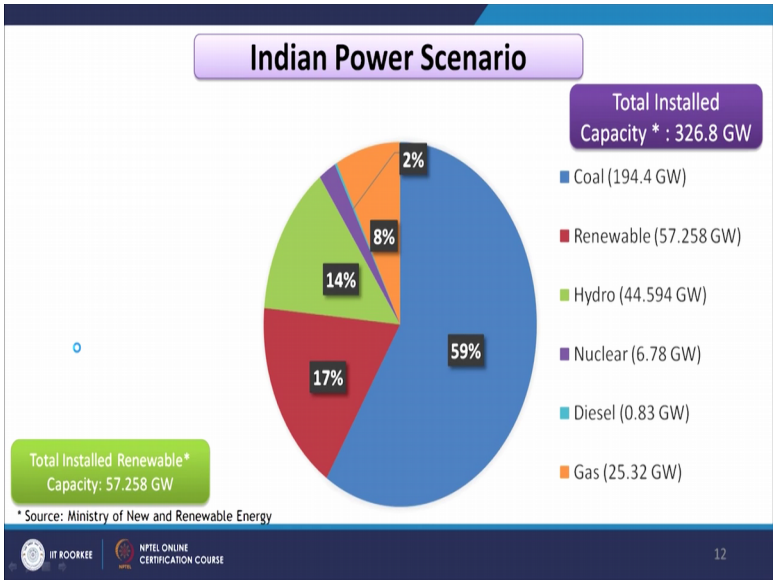
(Refer Slide Time: 12:04)



Now, if you look at the key figures of our country in 2016-17 the population is 1.32 billion, which is huge the total area that we poses is close to 3.287 million kilo meters square and the energy mix we do have energy from oil coal gas nuclear hydro and renewable. The electricity consumption it is in tera watt hour which is 1114 and whereas, electricity generation capacity as on march 2017 was 326.8 giga watt.

The very challenging component is overall network losses it is regionably high which is expected to be far lower than what is being mentioned currently it is 22.7 percent which is extremely higher end. So, we need to try our level best to make sure the energy does not move along distance and it is efficiently being utilized so, that the loss can be dropped on by few percentages in near future. And certainly the smart grid we are talking going to talk in detail end of the lecture today will certain help us accepted that the distribution losses will drop further.

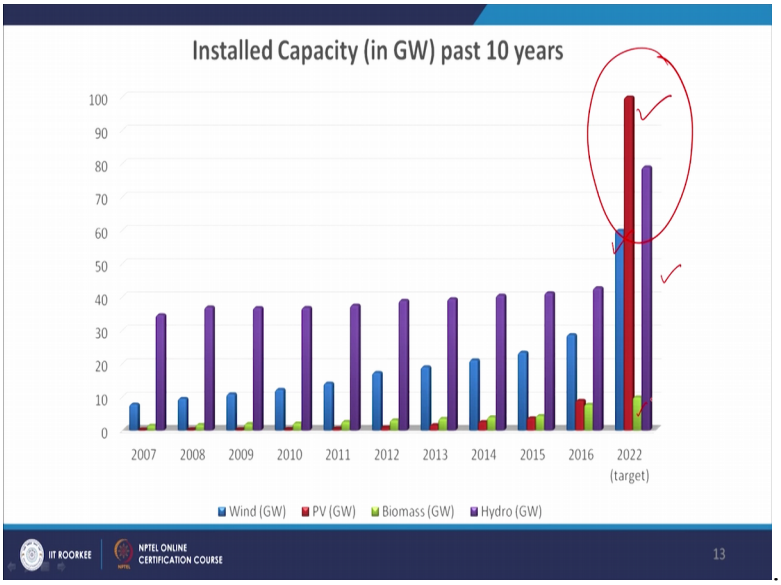
(Refer Slide Time: 13:53)



If, you see the Indian power sector the energy shared we do have the measures share from coal, which is as high as 59 percent and then we do have renewable which had a wonderful stack of 17 percent followed by hydro, which is 14 percent and then we have nuclear and diesel are of single digit and gas is of double digit percentage contribution respectively.

. But, I am very keen to mention something very specific here that the renewable energy contribution in India is close to 57 giga watt and that is a close to 17 percent of the total energy mix. And, it is a good idea and we will keep on increasing those renewable contributions in future to achieve the low carbon foot prints, in this country and contribute to the global challenge in achieving green energy in future.

(Refer Slide Time: 14:57)

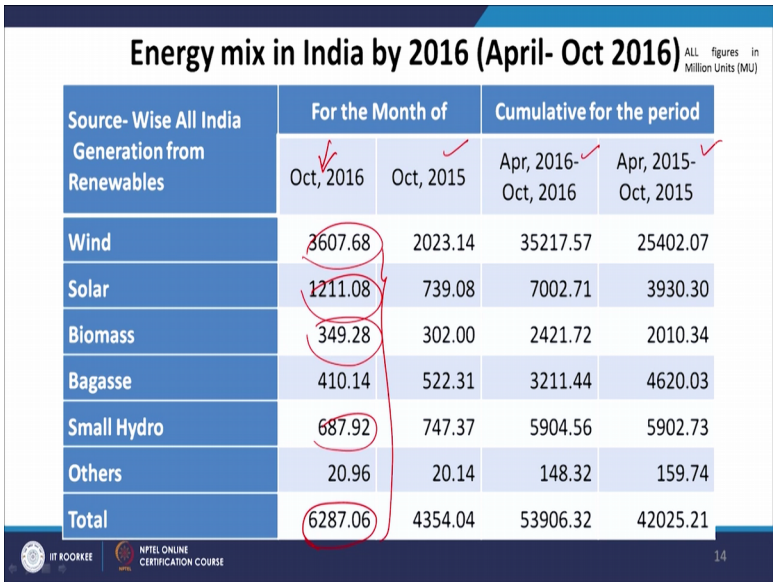


Now, if you look at the current status in this country the installed capacity, over last 10 years, you can see that the wind energy installation is keep on increasing the PVS also keep on increasing, the biomass is also keep on increasing, and the hydro is keep on increasing. So, today we can easily see the hydro which is very close to 40 giga watt and my wind which is very close to 28 giga watt, and my PV which is very close to 88 giga watt and my biomass, which is close to 6 giga watt.

But, one interesting scenario that we all can see here, when you come back to the year 20 20 now we can see that the PV installation will go as close to a 98 to 100 giga watt which is a say great challenge and followed by the wind which is close to 60 giga watt and then the hydro may go up to 78 giga watt and then the biomass may be close to 10 giga watt. So, in 20 22 may be another 4 to 5 years from now we are going to add as high as 200 and 50 giga watt renewables in this system.

So, we need smarter technology to accommodate those renewables for stable operation of the energy grid.

(Refer Slide Time: 16:34)



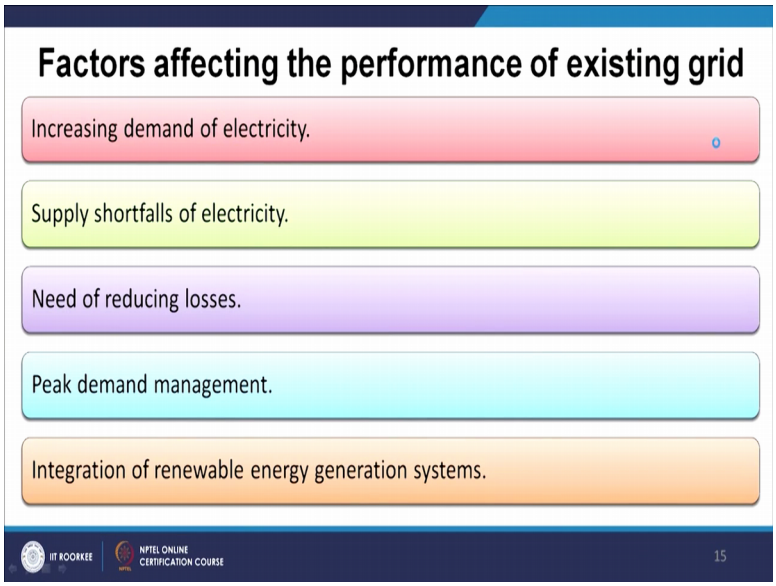
Source- Wise All India Generation from Renewables	For the Month of		Cumulative for the period	
	Oct, 2016	Oct, 2015	Apr, 2016- Oct, 2016	Apr, 2015- Oct, 2015
Wind	3607.68	2023.14	35217.57	25402.07
Solar	1211.08	739.08	7002.71	3930.30
Biomass	349.28	302.00	2421.72	2010.34
Bagasse	410.14	522.31	3211.44	4620.03
Small Hydro	687.92	747.37	5904.56	5902.73
Others	20.96	20.14	148.32	159.74
Total	6287.06	4354.04	53906.32	42025.21

Now, if you look at the energy mix this is what the report says, I mean in the October 2016 if you take the one of the data, in the first column we can see that the total mix the energy mix is 6287 for the month of October itself and it has combinations the energy coming from wind, solar, biomass and small hydro and others.

So, this gives me an idea how the energy mix from especially renewable sources on a particular months we can see the pattern in which how it is being generated we can see for October 2015 and then this is completely April 2016 to October 2016, which is a 6 months period and as well as for 2015. So, region ably we are at good position with respect to renewable power generation and their mix as well as the energy production.

Now, what are the major factors affecting the performance of the existing grid? Now, as we all seen that we are keep on putting a generations over year, because the demand is keep on increasing the expectations from the public is keep on increasing the per capita energy consumption is keep on increasing, and hence the one of the major factor that puts us in risk today is increase in huge increase in demand of electricity, supply shortfalls of electricity means there is a energy gap between what we produce and what we expected to deliver.

(Refer Slide Time: 18:08)



So, they too do not match exactly and perhaps the energy production is slightly less compared to the energy expected during peak hours.

The, the need for reducing loses one of the major factor as you send we are at very close to 22 percent of distribution loss that need to be reduced, peak demand management; means today a especially during peak hours we experience peak shortage of close to 4 to 5 percent and that need to be reduced by putting maximum generations. And one thing I like to highlight here when you like to reduce the peak energy gap by putting energy sources it is very difficult to go for huge nuclear or hydro or thermal power plants that may take actually 6 to 10 years' time from now.

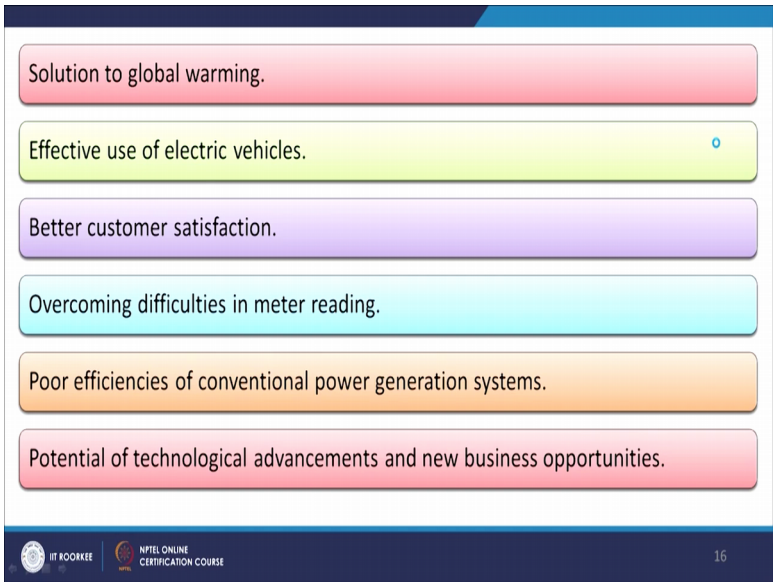
So, very quickly you cannot meet out your peaks shortage. So, the only one way I could see at this point is that putting renewable energy sources, as maximum as possible in our country, that lead to achieve excess generation install capacity and may reduce the gap between peak energy requirement and the energy available at that time period.

Now, integration of renewable energy generation system so, as I mentioned we have to go for renewable energy to meet the peak energies peak demand management, but to do that we need to have technology, which can perhaps integrate safely and for reliable operation of those sources connected at different voltage level.

So, integration of renewable energy generation system also do poses challenge. Now, solution to global warming we all have to contribute effective use of electric vehicles currently they are randomly being manufactured and especially the electric vehicle in India, it is most electrical rikshaws and the charging discharging pattern are never being technical and they need to be organized. So, that the charging can be done during off peak period and discharging is not possible bit at least the charging can be respected, but in next 5 years' time from now the electrical vehicles may contribute for discharging during peak hours.

Now, better customer satisfaction quality power or energy, overcoming difficulties in meter reading so, currently we have all manual reading that can be made automated and poor efficiency of conventional power generation systems.

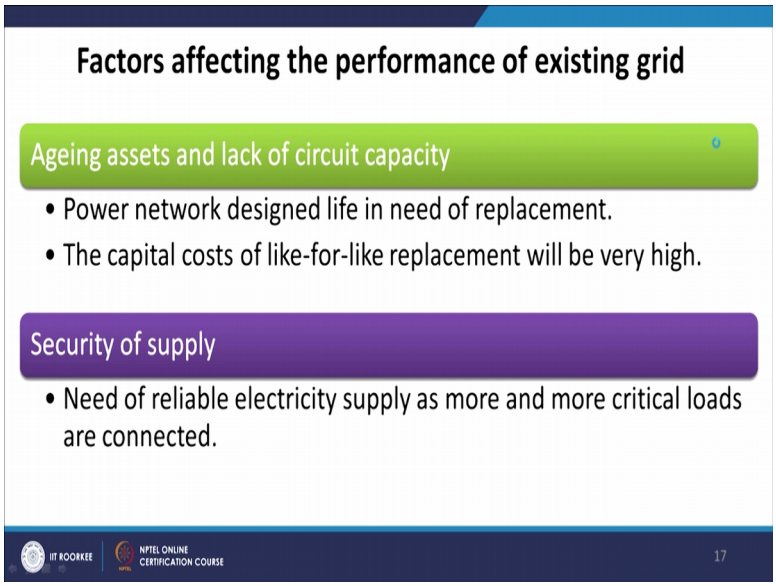
(Refer Slide Time: 21:05)



Most of the thermal power plants today are getting old, aged, and their efficiencies are coming down day by day. Potential of technological advancement in new business opportunities, aging assets and lack of circuit capacity most of the assets in this country are 40 to 50 years old, they required quick replacements and power network design life is need of replacement, which is a biggest challenge.

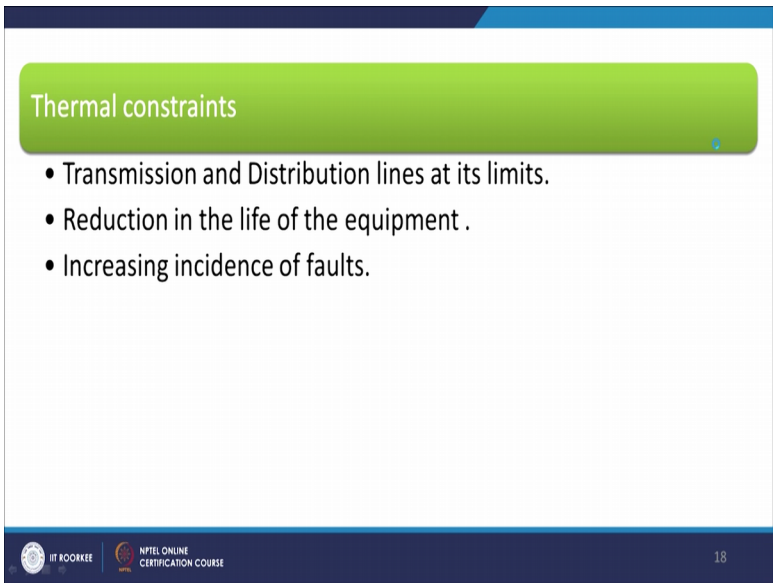
The capital cost of like for like replacement will be very very high.

(Refer Slide Time: 21:40)



Security of supply need reliable electricity supply as more and more critical loads are connected.

(Refer Slide Time: 21:55)

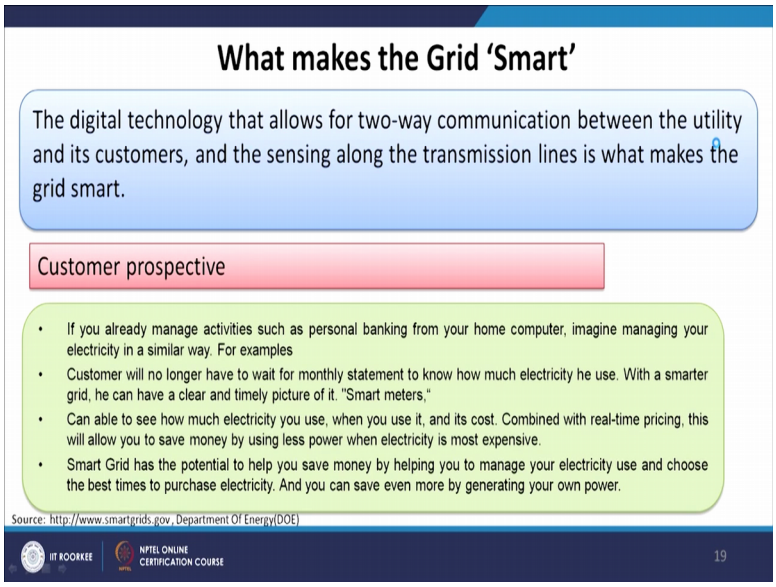


Thermal constraint transmission and distribution lines at it is limit most of the lines are consisted or over loaded, reduction in the life of the equipment, increasing incidence of faults we experience frequent fault to different corridors given extreme loading conditions.

Operational constraints voltage and frequency limits uncertainty of renewable sources. And, now coming back to so, this is what the whole history behind the conventional energy grid, the current status, challenges, that energy grid poses today, and what we are aiming in next 5 years that is 20 21, what kind of energy growth we are expecting, what type of sources, especially the integration of renewable energy. As well as in 20 40 we have to had add actually huge amount of energy sources across different energy mix starting from thermal, nuclear, hydro, renewable, all segments the energy installation has to grow though the majority may be from renewable energy sources.

But, what do we understand because this is anyway grid. So, the question is are we currently operating an energy grid, which is not smart enough or what do you understand by smart grid or what makes a grid smart?

(Refer Slide Time: 23:42)



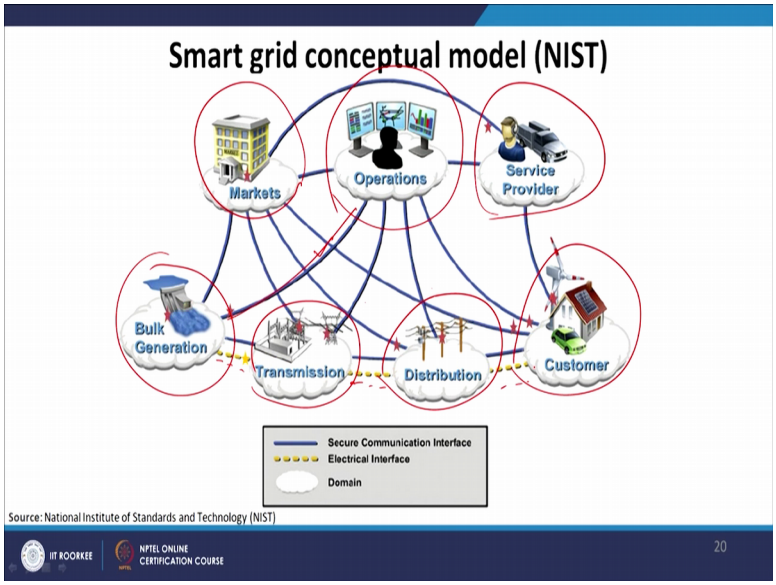
The digital technology that allows for 2 way communication; 2 way communication between the utility and it is customers and the sensing along the transmission lines is what makes the grid smart?

According to customer perspective, if you already manage activities such as personal banking from your home computer imagine managing your electricity in a similar way for example; customers will no longer have to wait for monthly statement to know how much electricity he or she used. With the smarter grid he can have a clear and timely picture of it through smart meters. Can able to see how much electricity you use when

you use it and it is cost means combined with real time pricing this will allow you to save money by using less power when electricity is most expensive. Means you can organize your consumption pattern based on the energy cost time of used energy cost so, that your monthly energy bill can be made minimum as possible.

Smart grid has the potential to help you save money by helping you to manage your electricity and choose the best times to purchase electricity and you can save even more by generating your own power by putting roof top solar.

(Refer Slide Time: 25:32)



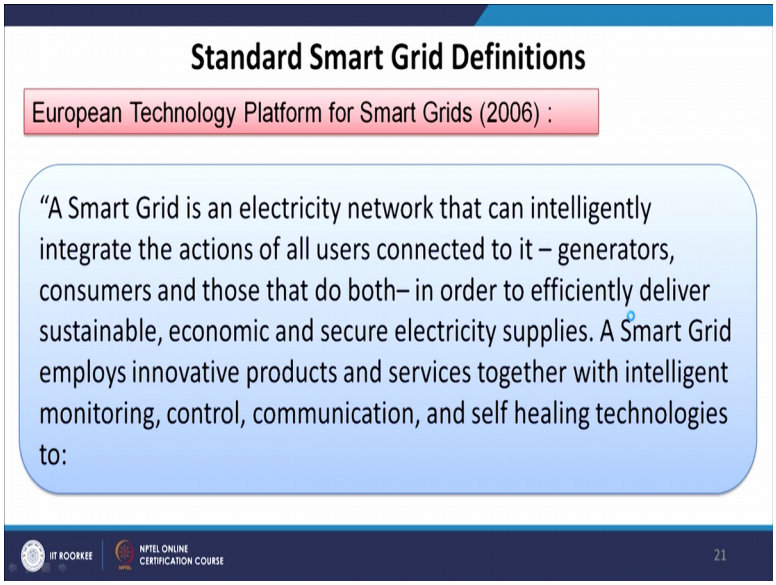
Now, the NIST National Institute of Standards and Technology provides you the pictorial view of how the smart grid conceptually works? Now, we can see there is bulk generation and we have transmission, then distribution, and customers.

Now, we can say this is my operating center and we do have energy market and we do have service providers. Now, the very interesting part that the thick lines you could see which is between operation to bulk generation, transmission, distribution, customers, the secure communication interface. And whereas, these are all the dotted lines the yellow dotted lines source the electrical interface and this clouds are nothing, but my domains.

So, this is how the smart grid conceptually works taking care of electrical energy flow interface as well as communication interface. So, this energy and communication interface together perhaps conceptualize the smart grid operation. Now, let us understand

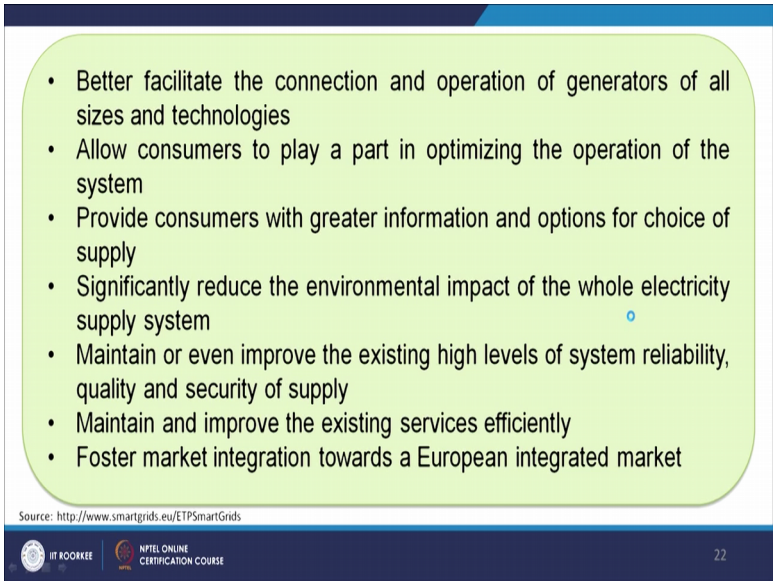
the standards of different standards of smart grid definition. Now, the first one European technology platform for smart grid in 2006 defines.

(Refer Slide Time: 27:20)



"A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it-generators, consumers and those that do both-in order to efficiently deliver sustainable, economic and secure electricity supply. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to it.

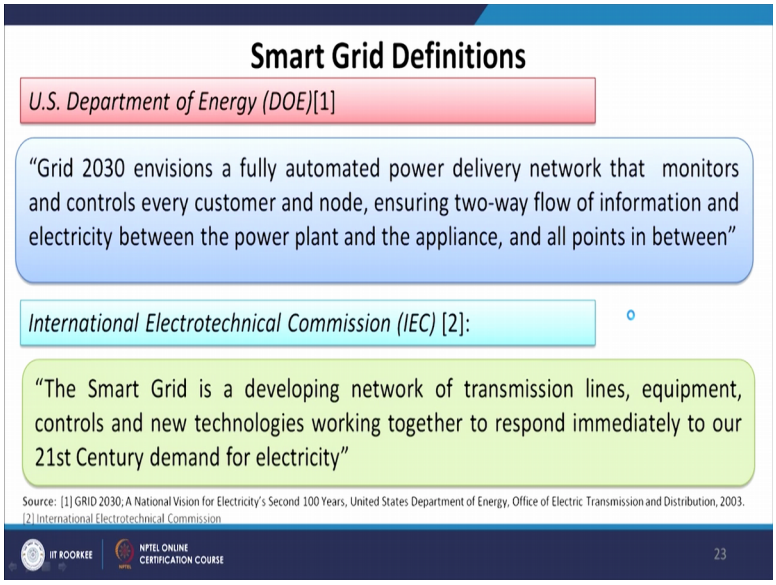
(Refer Slide Time: 28:08)



It is mainly to better facilitate the connection and operation of generators of all sizes and technologies, allow consumers to play a part in optimizing the operation of the system, provide consumers with greater information and option for choice of supply, significantly reduce the environmental impact of the whole electricity supply system, maintain or even improve the existing high level of system reliability, quality and security of supply. Maintain and improve the existing service efficiently, foster market integration towards modern energy systems.

Now, let us finally, understand the definition of smart grid in precise way.

(Refer Slide Time: 29:12)



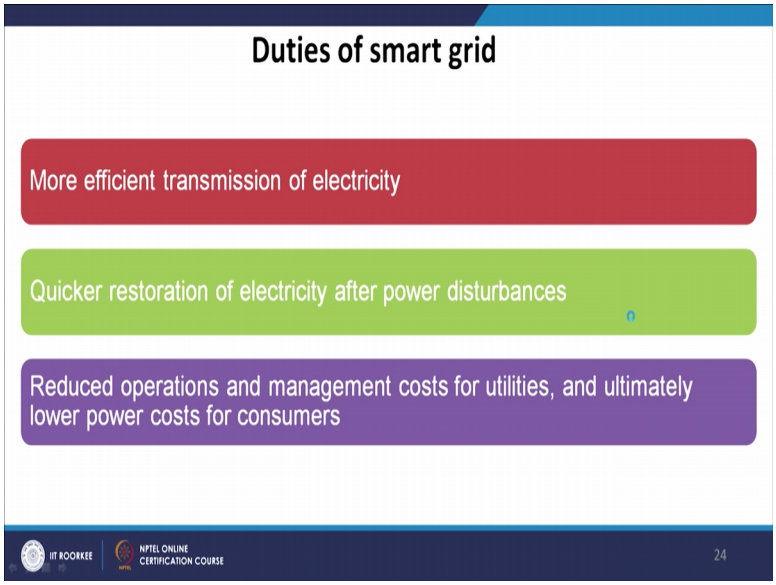
Now, us department of energy DOE, defines smart grid in the following manner; "Grid 2030 envisions fully automated power delivery network that monitors and controls every customer and node, ensuring two-way flow of information and electricity between the power plant and the appliance, and all point in between".

This is what the definition of smart grid by DOE. Now based on international electro technical commission IEC; "The smart grid is a developing network of transmission lines, equipment, control, and new technologies working together to respond immediately to our 21st century demand for electricity".

Dear listeners the smart grid definition vary, but as a whole the outcome of each definition remains same, the main intention here is to establish a strong communication 2

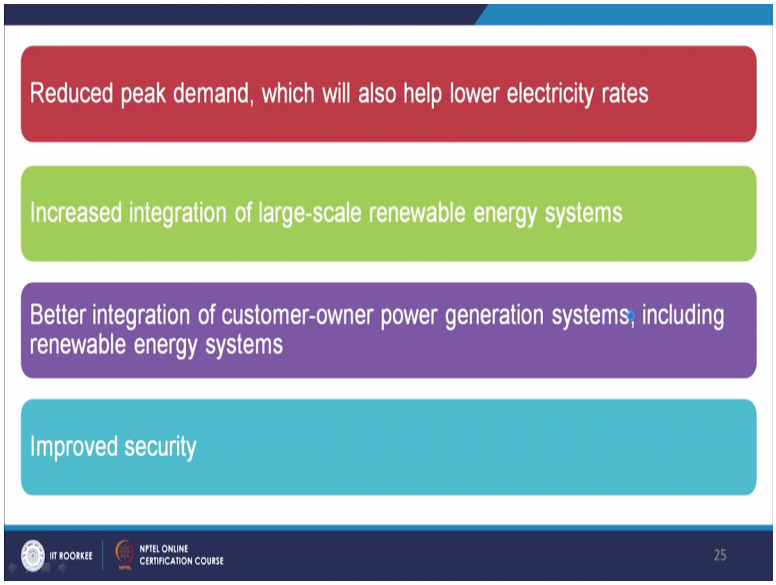
way communication or 2 way flow information, between the power plant and appliances as to be established to make your grid smarter.

(Refer Slide Time: 30:47)



Now, the major duties of smart grid is more efficient transmission of electricity quicker restoration of electricity of after the power disturbances, reduced operation and management cost for utilities and ultimately lower power cost for consumers.

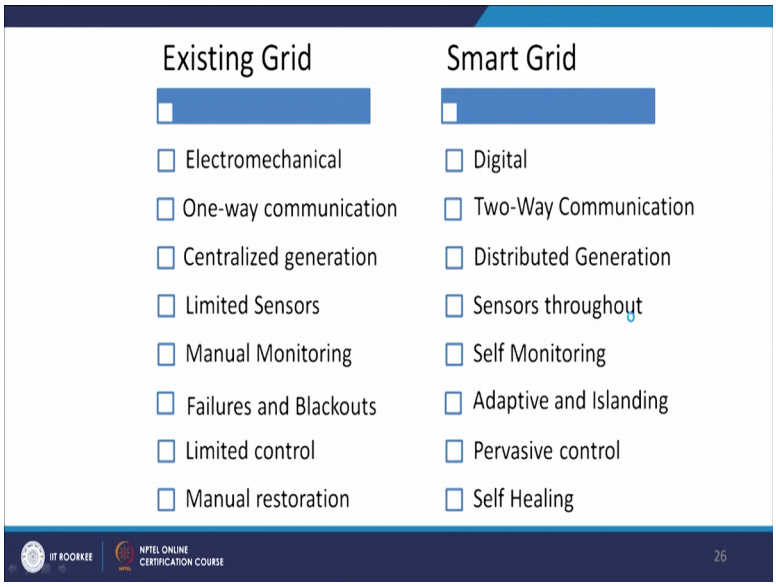
(Refer Slide Time: 31:09)



Reduced peak demand, which will also help lower electricity rates, increased integration of large scale renewable energy systems, better integration of customer owned power

generation system, including renewable energy system, improved security and if you now come to a region able conclusion to compare how the existing grid look like and how do we see the future smart grid will look like.

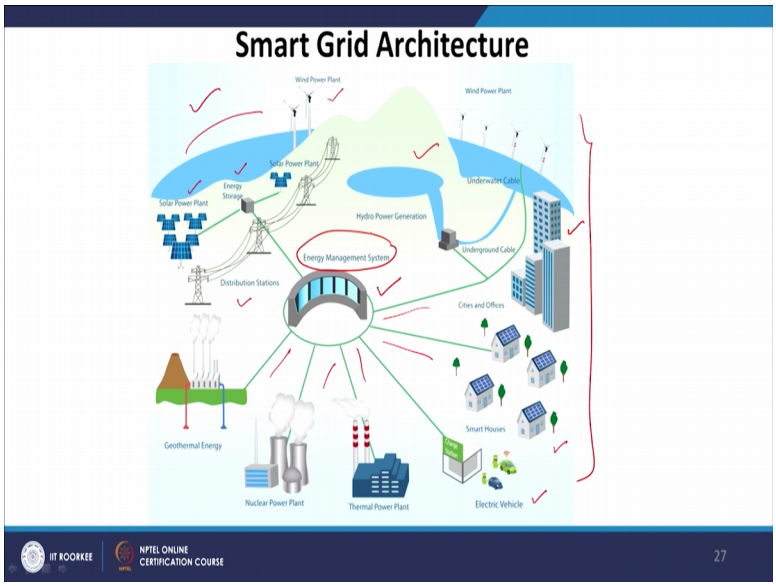
(Refer Slide Time: 31:46)



Now, the existing grid it is completely electro mechanical and partially digital, where smart grid is a expected to be completely digital, existing grid do have one way communication and the smart grid may have 2 way communication, existing grid has centralized generation, smart grid will have distributed generation, existing grid has limited sensors, and smart grid will have sensors throughout. Existing grid is of manual monitoring and smart grid will be self-monitoring, existing grid will be may come across failures and blackouts, but smart grid will convert them into adaptive and islanding mode of operation, existing grid will have limited control mechanism and the smart grid will have pervasive control mechanism. And existing grid achieve manual restoration and smart grid is expected to have self-healing mechanism.

Now, finally, let us have a look to the smart grid architecture. Now, in the smart grid architecture will have the main energy management system.

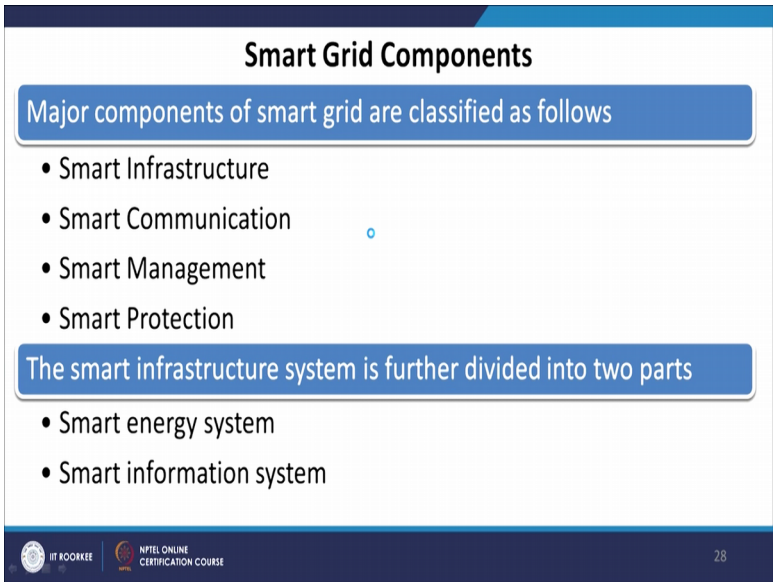
(Refer Slide Time: 32:59)



Now, we could see the distribution stations taking power, from solar, energy storage, and we could also see the wind power plant, they all constitute renewable energy sources and then we can experience hydro power generation and through underground cable they can be inter connected to the same energy management systems. The energy from thermal, nuclear, other source of energy and these are all our smart houses. So, we expect the smart grid architecture will wonderfully connect all residences electric, vehicles, cities with renewable energy sources through an efficient energy management system.

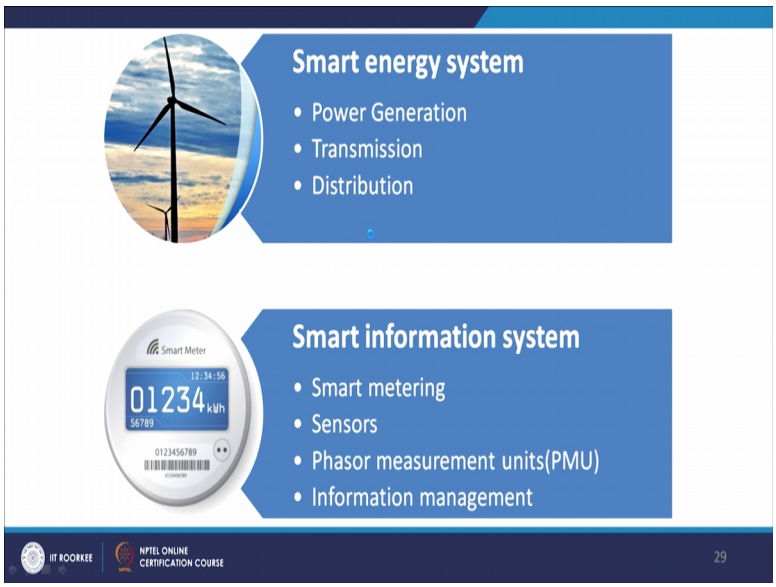
So, this is what we expect the smart grid of the future will look like and so, called smart grid architecture of the future. Now, the smart grid components are of major components of smart grid are classified as follows, will have smart infrastructure, smart communication, smart management, as well as smart protection systems.

(Refer Slide Time: 34:25)



Now the smart infrastructure system is further divided into 2 parts smart energy system and smart information systems.

(Refer Slide Time: 34:48)



The smart energy system will be of power generation type, transmission type, and distribution type whereas; smart information system will have smart metering's, sensors phasor measurement units as well as information management.

Now, with this we stop at our first lecture today and in the next lecture we will continue with the introduction to smart grid by understanding the detail components, and their characteristics applications of smart grid in detail during next class.

Thank you.