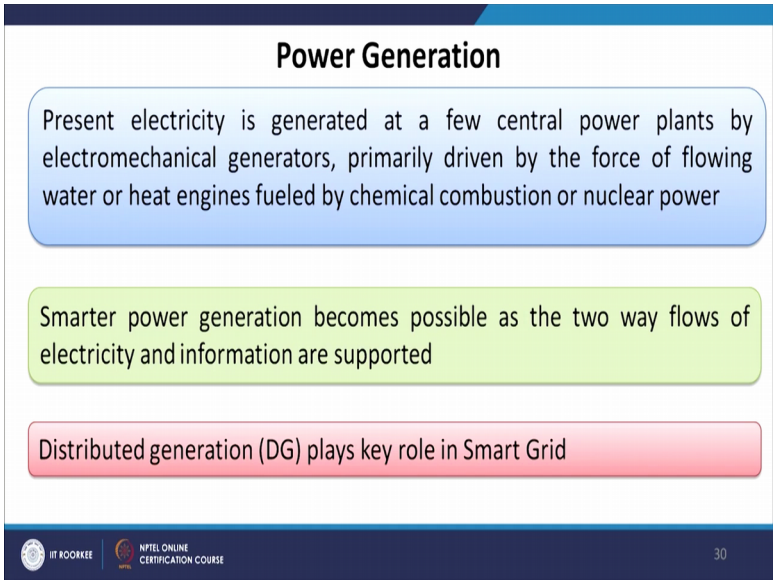
Introduction to Smart Grid
Prof. N. P. Padhy
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture - 02
Introduction to Smart Grid- II

Welcome viewers. Today, we are at lecture 2 the second part of the Introduction to Smart Grid. As we discussed during last lecture the background definition of smart grid at large and also the major components of smart grid. And, today we will get into in detail different definitions of components of smart grid and different I triple E standards and communication networks, protection mechanism, and hope today's lecture will be very useful if you have understood in detail of your first lecture.

(Refer Slide Time: 01:24)

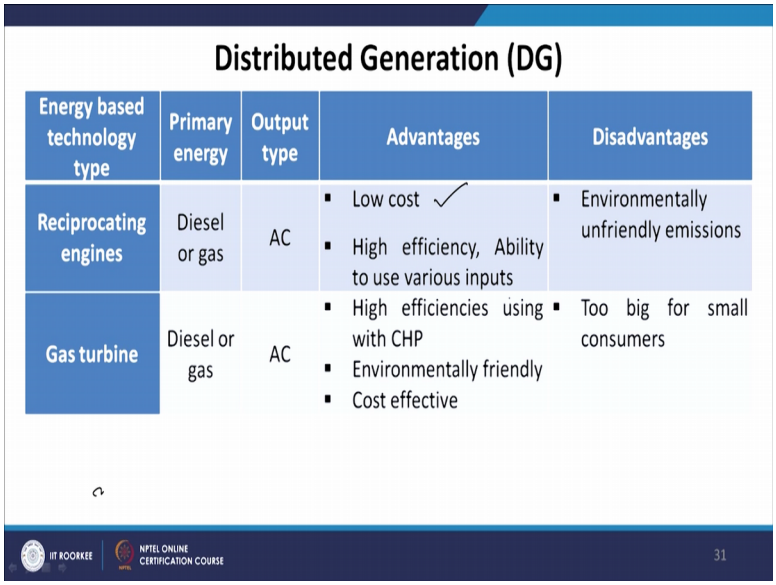


Now, first of all when we talk about power generation present electricity generated at few central power plants by electro mechanical generators, primarily driven by the force of flowing water or heat engines fueled by chemical combustion or nuclear power.

Now, perhaps we are just interested to see that in future how my power generation is going to change or take new shapes? Now, the smarter generation becomes possible as the 2 way flow of electricity and information are supported. Means currently it is mainly as far the demand driven, but if you can do both side communication, the generation is based on the expected demand and the demand drive the generation as it desires.

Now, the very important component of the smart grid power generation such as distributed generation, which can settle a play a key an major role in our smart grid.

(Refer Slide Time: 02:38)

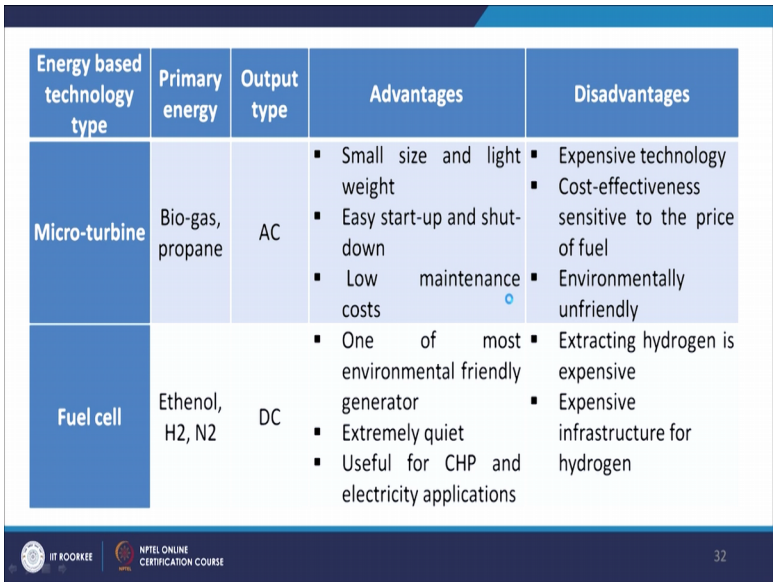


Now, there are different types of distributed generations, let us discus based on their energy based technology type primary energy, output type, advantage and disadvantage. So, this will give us an idea different type of distributed generators, as well as how they can be integrated in my smart grid and what kind of merits that we can achieve and the limitations that you have to face.

For example, the first one is reciprocating engines diesel or gas as my primary energy and the output will be of AC type, and you can see that ya the measure merits of this reciprocating engine is low cost and it is high efficiency ability to use various inputs, but the main disadvantage is environmentally unfriendly because of emissions.

Now, the gas turbine, which is again diesel or gas is my primary energy source and the output type is AC, but the measure merits are high efficiency using CHP concept environmentally friendly cost effective, but it is quite large for consumers.

(Refer Slide Time: 04:21)

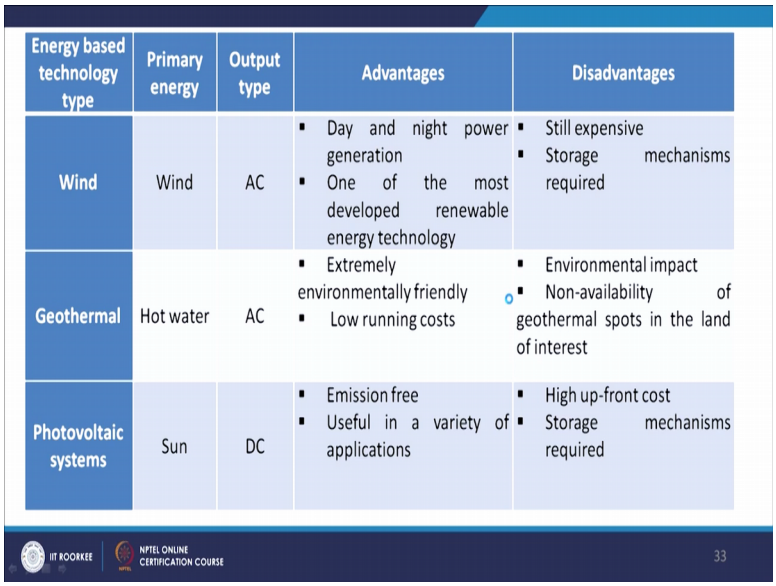


Now, then move to micro turbine concept which is either bio gas or propane the output is again AC type advantages are small size and light weight easy start up and shut down, low maintenance cost and the disadvantage is, because it is quite expensive technology, cost effectiveness to the price of the fuel is not appropriate and environmentally unfriendly.

Then moving to fuel cell ethanol H 2 N 2, the output is DC. The major advantage that you could see is one of the most environmental friendly generator as well as extremely quite no noise useful for CHP and electricity applications, but the major disadvantage is extracting hydrogen is quite expensive, expensive infrastructure for hydrogen is required.

Now, the very commonly used distributed generation in today's world is wind, the primary input is naturally which is wind, and the output type is AC.

(Refer Slide Time: 05:46)

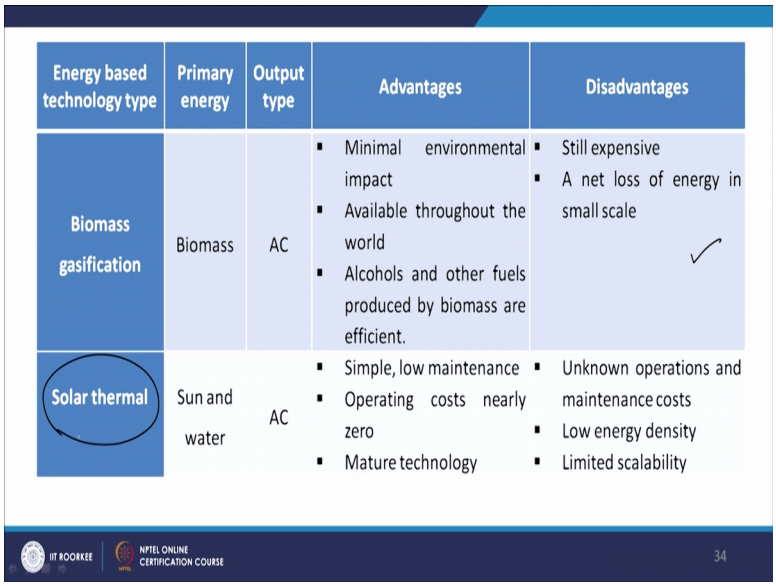


The merits are day and night power generation, one of the most developed renewable energy technology. Disadvantage, we is quite expensive and we need to have a storage mechanism and it may have effect since serious effect especially due to the climate disasters.

Now, next is geothermal a hot water is my primary energy source the output is AC, the merits are extremely environmentally friendly, low running cost whereas, the disadvantages are environmental impact non availability of geothermal spots in the land of interest. Now, the next one once again one of the most important distributed generation energy source in current scenario, which is photovoitaic system.

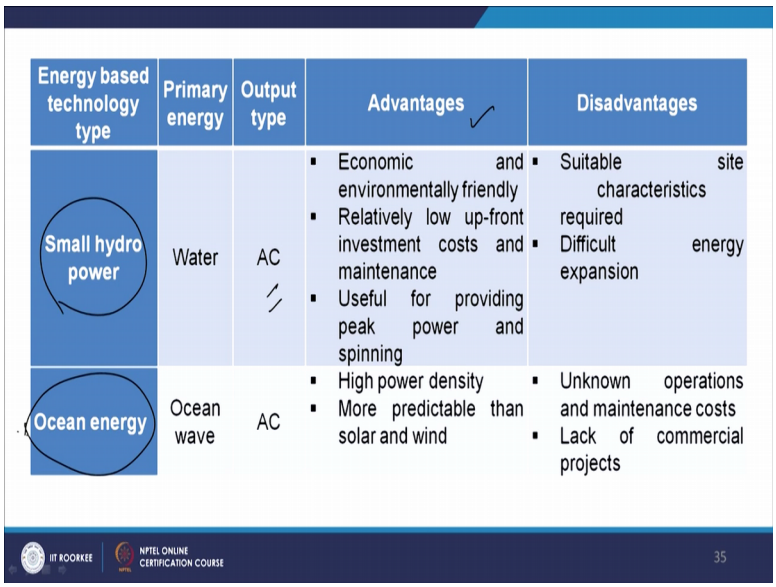
The primary energy source is our sun, the output type is DC the major advantage is emission free as well as useful in a variety of applications, but the disadvantage is high upfront cost though it is keep on reducing over a period of time, but still it is expensive storage mechanism is required as well as one of the very important requirement we need to have lot of land for their installations.

(Refer Slide Time: 07:25)



Now, the biomass gasification the primary energy source is biomass, the output type is AC the advantages are minimal environmental impact available throughout the world alcohols and other fuels produced by biomass are efficient. The disadvantage is it is expensive and net loss of energy in a small scale. Now, the solar thermal the next one is let us concentrate on solar thermal sun and water the output type is as simple low maintenance operating cost nearly 0 mature technology, and the disadvantages are unknown operations and maintenance cost, low energy density and limited scalability.

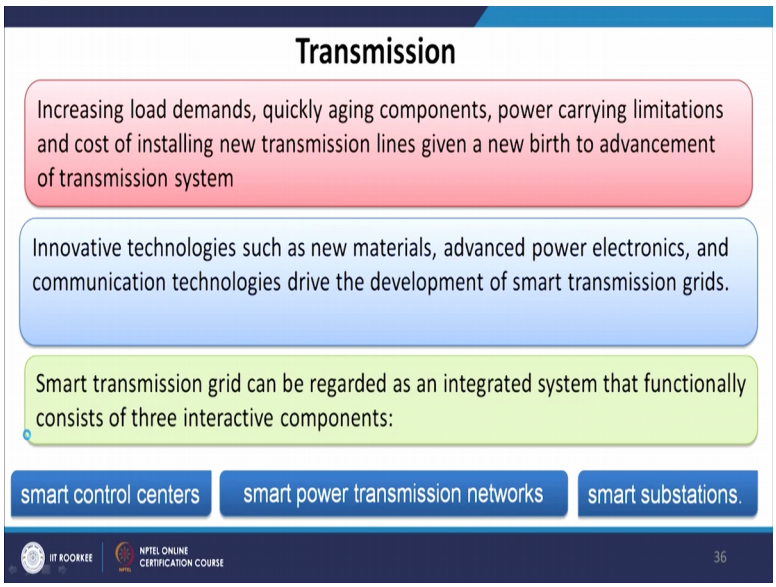
(Refer Slide Time: 08:30)



Now, the next one is a small hydro power the primary energy is water the output is AC. The very major advantage that you could see is economic and environmentally friendly, relatively low up-front in investment cost and maintenance, useful for providing peak power and spinning, but the disadvantages are suitable site characteristic required difficult energy expansion and in case of ocean energy though it is not very common, but this upcoming technology where the input primary energy will be of the ocean waves, and the output will be of AC type. High power density is one of the major merit more predictable than solar and wind, but unfortunately it has unknown operation and maintenance cost and measuredly lack of commercial projects.

Now, similar to power generation we have seen for conventional generation and in specific smart power generation in the form of distributed generation. Now, let us concentrate how my transmission network looks like and what are the components within transmission system.

(Refer Slide Time: 10:08)



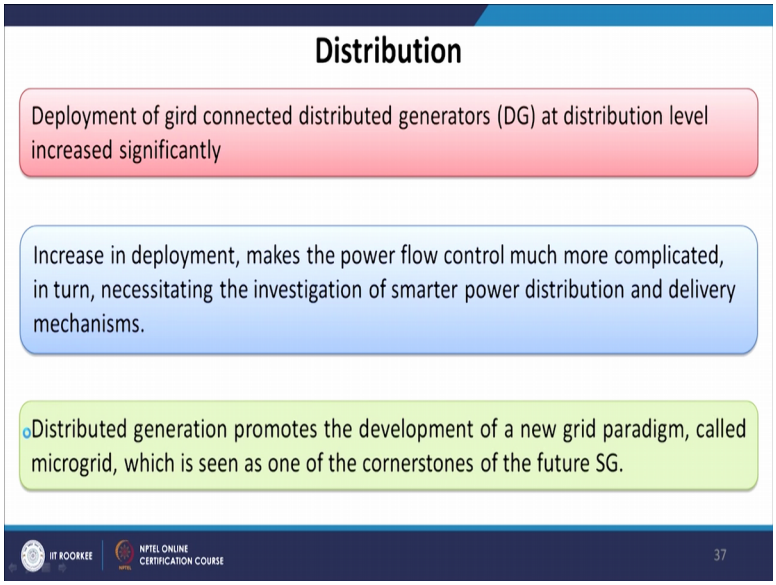
Now, the transmission defines as based on the increasing loads demands, quickly aging components, power carrying limitations and cost of installing new transmission lines given a new birth to advancement of transmission system.

Innovative technologies such as new material, advanced power electronics, and communication technologies drive the development of smart transmission grids. Now, according to us smart transmission grid can be regarded as an integrated system that

functionally consist of 3 interactive components, and let us see what are those 3 components makes my transmission system, smarter smart control centers, smart power transmission networks, and finally, smart substations.

So, up gradation of the existing transmission system by installing or establishing smart control centers, smart power transmission networks, as well as smart substations can make my transmission system region ably smart. Similarly, now let us understand what is distribution system? And, how we can achieve smart distribution system?

(Refer Slide Time: 11:40)



Deployment of grid connected distributed generators at distribution level increased significantly. Increase in deployment, makes the power flow control much more complicated in turn necessitating the investigation of smarter power distribution and delivery mechanism.

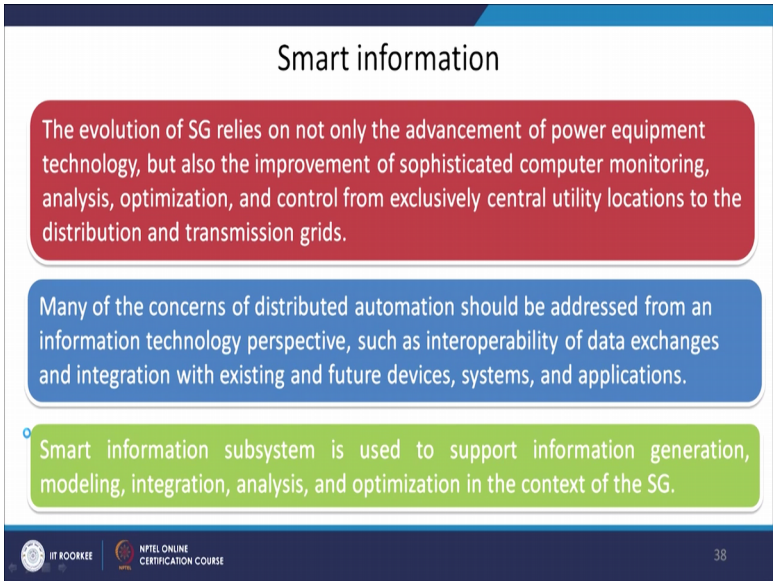
Now, distributed generation promotes the development of a new grid paradigm called microgrid, which is seen as one of the corner stones of the future smart grid within distribution. Now, will have to create a smarter distribution system at different voltage level so, called smart grid considered to be the major important corner stone of the future grid.

So, dear listeners I wish to emphasis at this point of time the major challenge on smart grid against the conventional grid would be focused at each and every level starting from

generation transmission and distribution. But the major focus will be at distribution level because the distribution level need to be made absolutely smarter for achieving, reliable, economic energy for the customers to achieve that we need to have smart information.

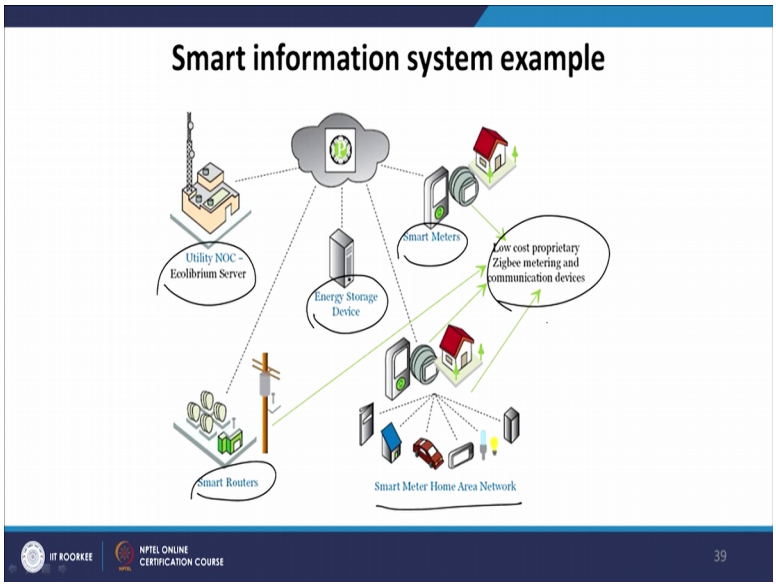
Now, what is smart information the evolution of smart grid Relies not only the advancement of power equipment technology, but also the improvement of sophisticated computer monitoring analysis, optimization, and control from exclusively central utility locations to the distribution and transmission grid.

(Refer Slide Time: 13:39)



Now, many of the concerns of the distributed automation should be addressed from an information technology perspective, such as interoperability of data exchanges and integration with existing and future devices, systems, and their applications. Smart information subsystem is used to support information generation, modeling, integration, analysis, and optimization in the contest of the smart grid.

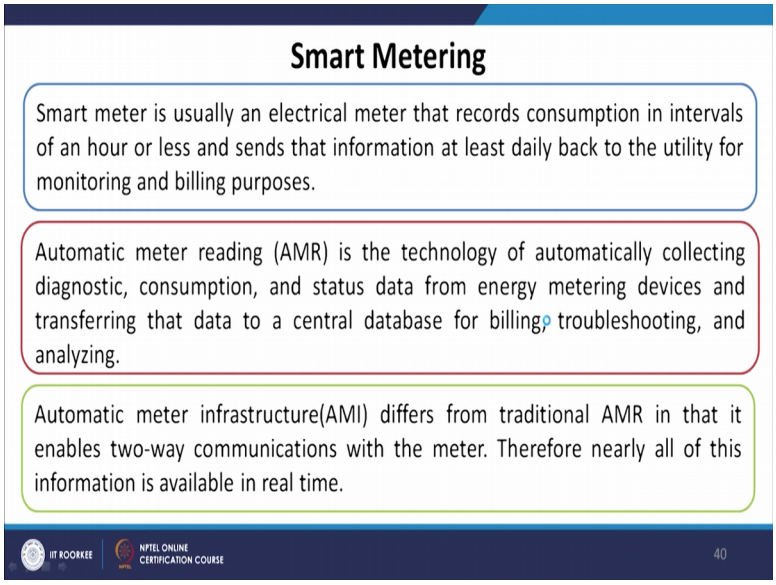
(Refer Slide Time: 14:35)



Now, if you look at smart information system example. Now, first of all this is the utility and we do have energy storage devices in place, and then we have the smart meters and then the smart routers are placed and the smart meter home area network is through low cost Zigbee metering communication devices are placed for the exchange of information within smart grid.

Now, one of the major concern that a distributed system can be made smarter only if the data's at different nodes will be made available in distance through a Wi-Fi mechanism and for that we need to have smart meters in place, smart meter is usually an electrical meter itself, that records conception in intervals of an hour or less even at 5 minutes interval, 15 minutes interval, half hour interval, as far the requirement that information at least daily back to the utility the information is being recorded and then transmitted to the utility for monitoring and billing process.

(Refer Slide Time: 16:20)

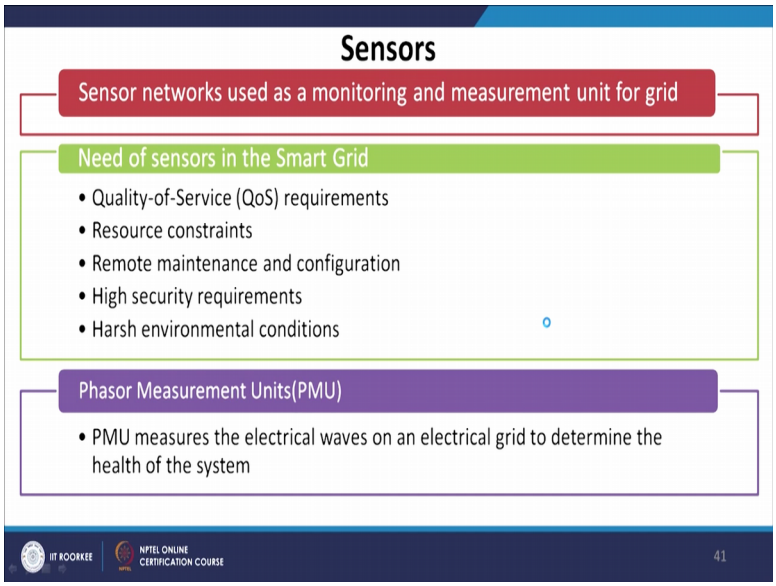


Automatic meter reading very commonly known as AMR system is the technology of automatically collecting diagnostics, consumptions, and status data from energy meters and transferring that data to a central database for billing, troubleshooting, and analyzing.

So, smart meter do play an important role in sending all the information of grid to the utility. So, that different trouble shooting analysis can be per formed for a given time. Automatic meter infrastructure that is so, called AMI differs from tradition AMR in that it enables two-way communication with the meters. Therefore, nearly all of this information is available in real time. So, AMR is certainly a helping instrument for smart grid infrastructure, but the smart grid infrastructure or the automatic infrastructure AMI do have 2 way communication therefore, nearly all this information is available to the utility in real time.

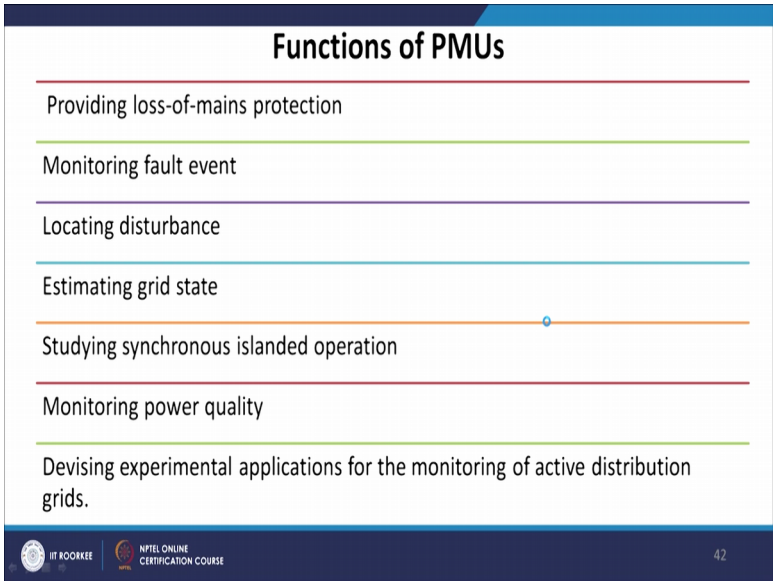
Now, let us now move to the second important component of my smart grid that is censors.

(Refer Slide Time: 17:52)



Censor networks used as a monitoring and measuring a unit for grid need of sensor in the smart grid is mainly; because of it is quality of service, resource constraints, remote maintenance and configurations, high security requirements, harsh environmental conditions. Now, one more important point here I like to emphasize that we need to have phasor measurement units that is PMUs PMU mainly measures the electrical waves of an electrical grid to determine the health of the system.

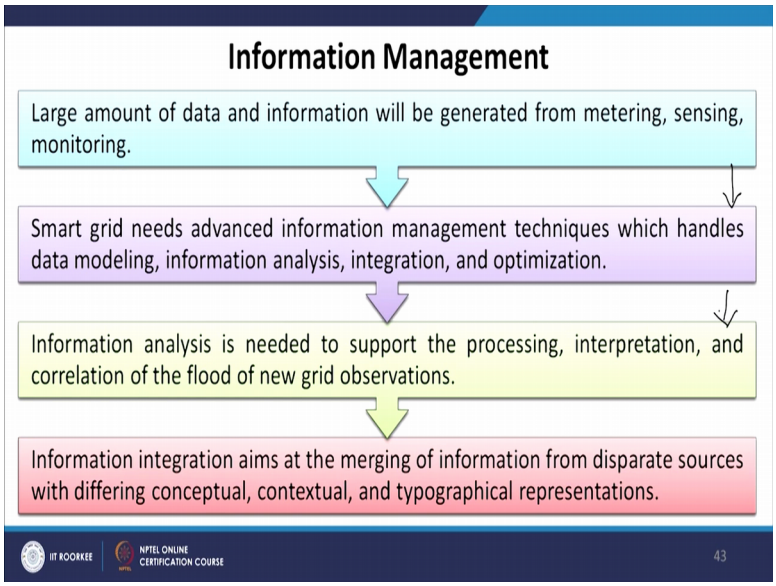
(Refer Slide Time: 18:42)



The major functions of PMUs is mainly provide loss of.

The major functions of PMUs is mainly provide loss of mains protection monitoring fault event, locating disturbances, estimating grid state, studying synchronous islanded operation, monitoring power quality, devising experimental setup fir applications for the monitoring of the active distribution grids.

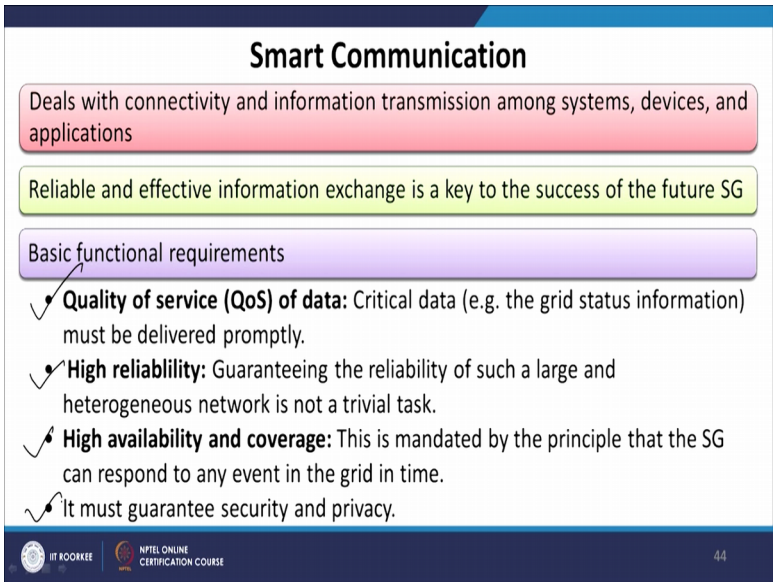
(Refer Slide Time: 19:18)



Now, and hence we have to manage the information, the information management is being carried out through, different steps large amount of data and information will be generated from metering, sensing, and monitoring, through different equipment and devices and those will be passed through smart grid, that needs advanced information management technique, which handles data modeling, information analysis, and integration, and optimization.

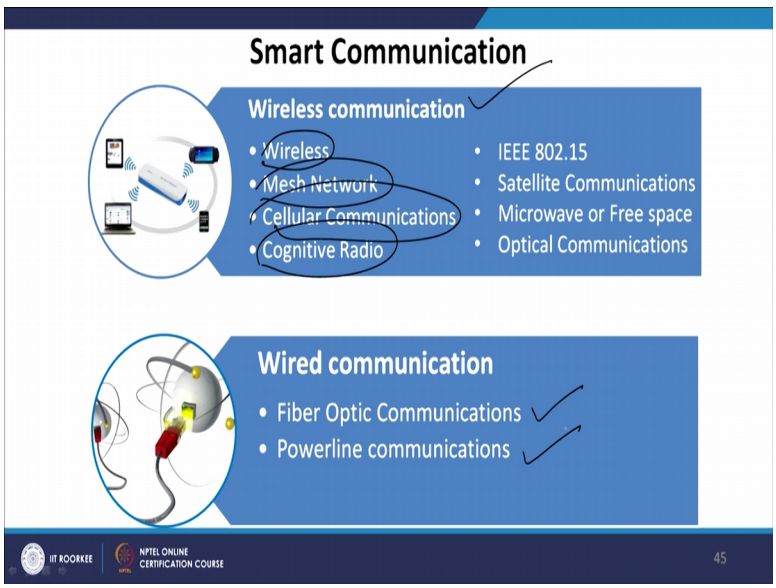
So, all the data there being transmitted to the second level and further we can say that the information analysis is needed to support the processing interpretations and correlation of the flood of new grid observations. And finally, information integration aims at the merging of information from disparate sources with different conceptual contextual and typographical representations.

(Refer Slide Time: 20:26)



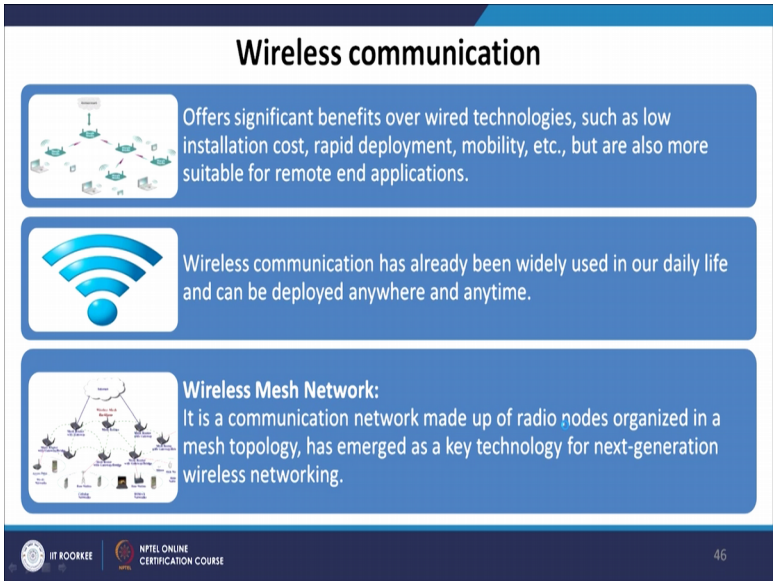
Now, let us move to smart communication, it deals with the connectivity and information transmission among systems, devices, and applications. Reliable and effective information exchange is a key to the success of the future smart grid. Basic functional requirements; now we need to have quality of service of data critical data example grid status information must be delivered promptly; it has to have high reliability. Guaranteeing the reliability of such a large and heterogeneous network is not a trivial task. High availability and coverage; this is mandated by the principle that the smart grid can respond to any event in the grid in time, it must guarantee security and privacy.

(Refer Slide Time: 21:42)



Smart communication we can see one of the major smart communication is wireless communication, it has wireless mesh network, cellular communications, cognitive radio, and these wireless communication is quite important for successful operation of a smart grid. Now, when we talk about wired communication they could be either fiber optic communications or it could be power line communications.

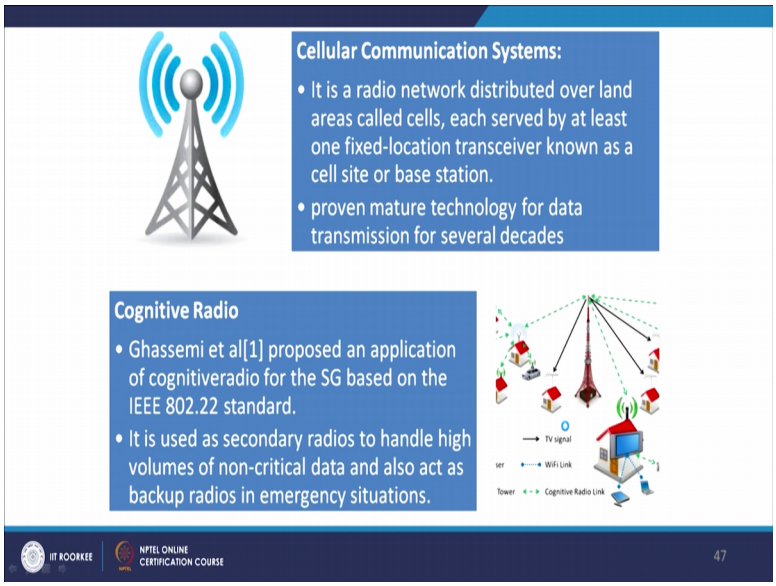
(Refer Slide Time: 22:36)



So, this 2 type of communications are being commonly used and in case of wireless communication that offers significant benefit over wired technology, such as low installation cost repeat deployment mobility, etc can be achieved, but are also more suitable for remote applications.

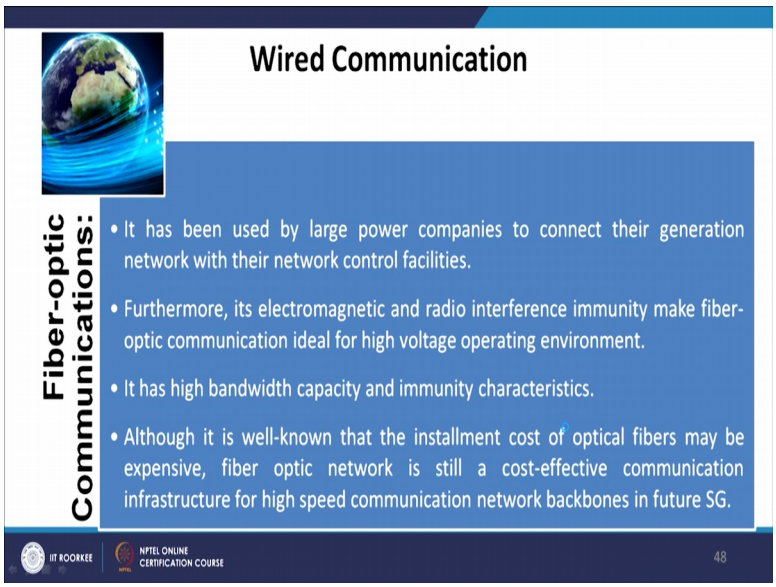
Now, let us say that wireless communication is a still an important infrastructure, but wireless communication has already been widely used in our daily life and can be deployed anywhere anytime. So, this is not a new technology, but we should take advantage of this existing wireless technology and incorporate within our energy grid to make it smarter. Wireless mesh network, it is a communication network made up of radio nodes organized in a mesh topology has emerged as a key technology for next generation wireless networking.

(Refer Slide Time: 23:44)



Now, what do you understand by cellular communication system? It is a radio network distributed over land areas called cells each served by at least one fixed location transceiver known as cell site or base station. It has proven mature technology for data transmission for several decades. Now, let us discuss cognitive radio this has been proposed for smart grid based on I triple E 802.22 standard, it is used as secondary radio to handle high volumes of non-critical data and also act as backup radios in emerging or emergency situations.

(Refer Slide Time: 24:49)

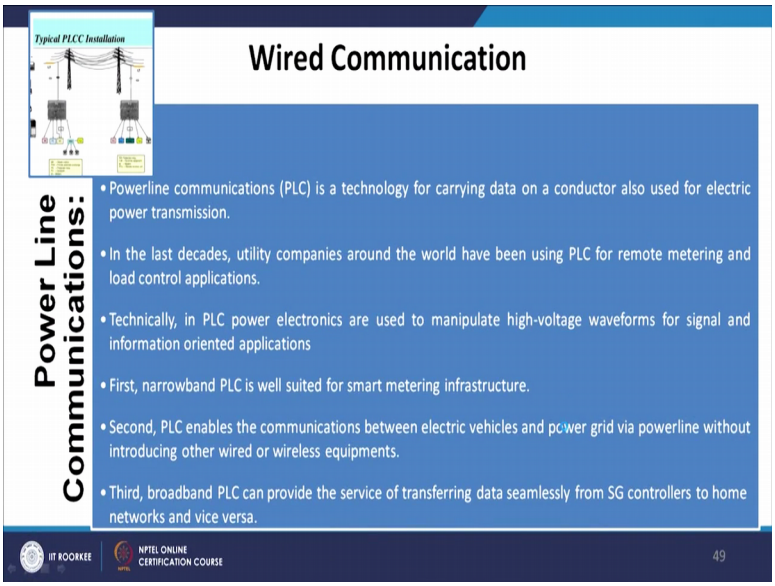


Wired communication certainly it is fiber optic communication; it has being used by large power companies to connect their generation network with their network control facilities. Furthermore, it is electromagnetic and radio interference immunity make fiber optic communication ideal for high voltage operating environment. It has high bandwidth capacity and immunity characteristics. Although it is well known that the installment cost of optical fibers may be expensive, fiber optic network is still a cost effective communication infrastructure for high speed communication network which is the backbone of the futures smart grid.

I mean I mean you must have listen to my past lectures all the time it has being told that existing grid will be made smarter by communication establishment through 2 way transformation information transformation in any form so; that means, the information can be exchanged only through a better communication media, and we understand that the fiber optic communication can certainly be an asset for the future smart grid technology.

Now, we perhaps along with fiber optics we do use power line communications which is a very old technology.

(Refer Slide Time: 26:20)

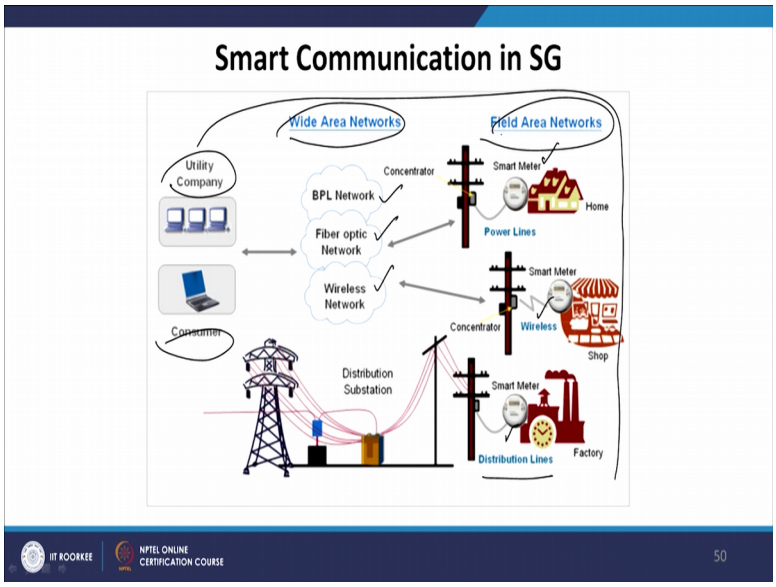


Power line communication that is PLC is a technology for carrying data on a conductor also used for electric power transmission. In the last decade utility companies around the world have been using PLC for remote metering and load control applications.

Technically, in PLC power electronics are used to manipulate high voltage wave forms for signal and information oriented applications. So, even though it is being a wide communication technology, but first narrowband PLC is well suited for smart metering infrastructure very important.

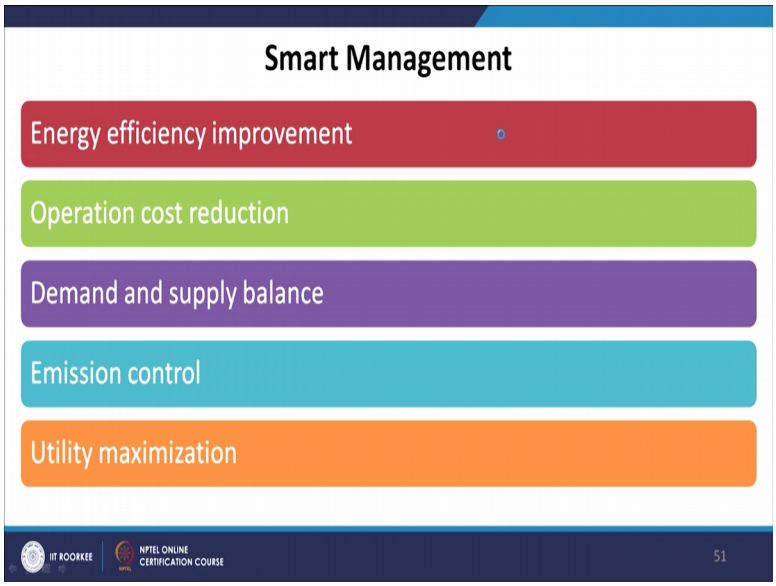
Dear listeners, smart metering infrastructure is well suited for the wired communication based on PLC and certainly we look forward to a huge PLC infrastructure for our future smart grids. One more important point the second one is PLC enables the communications between electric vehicles and power grid via power line without introducing other wired or wireless equipment's. Third broadband PLC can provide the service of transferring data seamlessly from smart grid controller to home networks and vice versa.

(Refer Slide Time: 28:01)



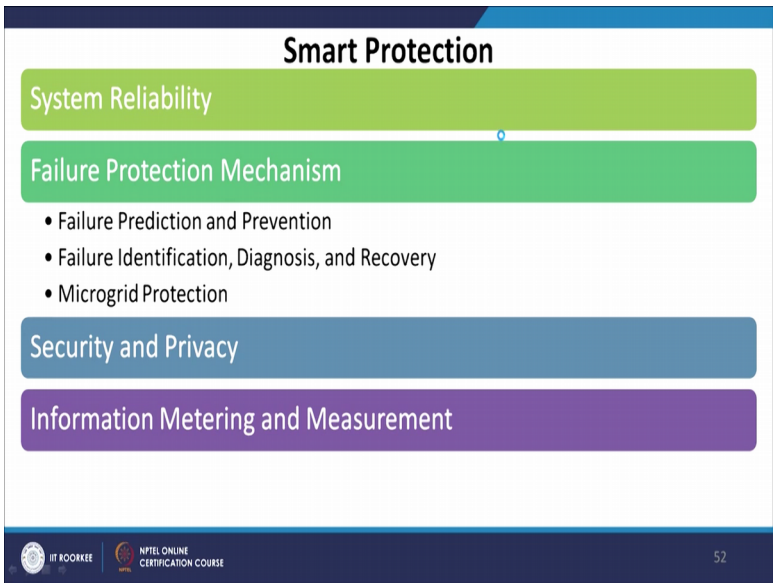
Now, the smart communication in a smart grid let us see this is the utility company and the consumer, through wide area networks it could be BPL could be fiber optic could be wireless network, and then we do have the field area networks for my smart meters and the smart meters can be installed in my power lines, this my distribution lines and the whole utility can connect to my homes shop and factory through smart meter data using field area networks as well as wide area network. So, that means the communication between the users and the source can be, can use communication as a platform for their interaction to make the grid smarter.

(Refer Slide Time: 29:21)



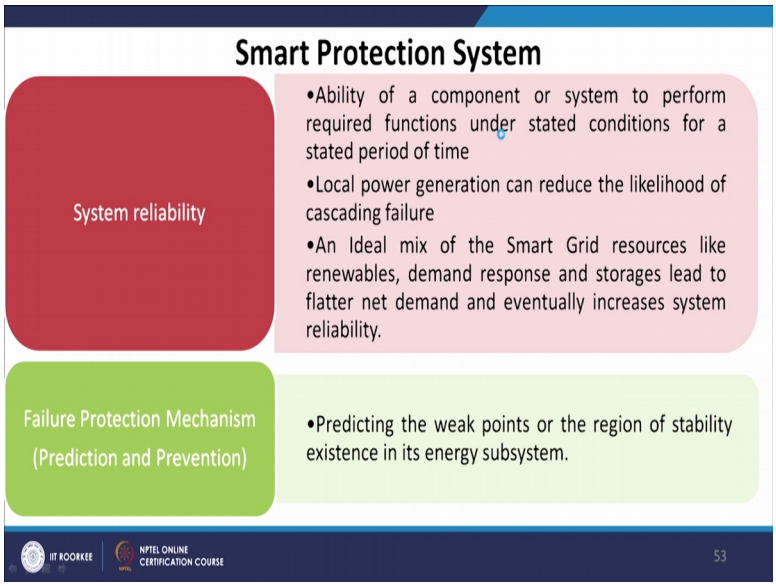
Smart management is mainly to increase the efficiency of energy operation cost reduction, demand and supply balance, emission control, utility maximization.

(Refer Slide Time: 29:31)



And one more component is your smart protection, to achieve system reliability. Failure protection mechanism; mainly to failure prediction and prevention, failure identification, diagnosis and recovery, microgrid protection, security and privacy, security and privacy also equally important in smart infrastructures information metering and measurement privacy and smart metering security in monitoring and measurement.

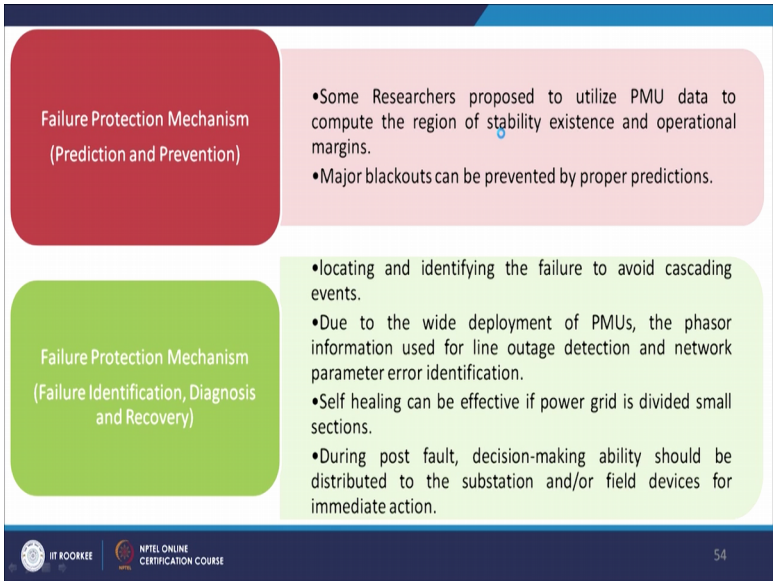
(Refer Slide Time: 30:14)



Smart protection system achieves system reliability that is ability of a component or system to perform required functions under stated conditions for a stated period of time. Local power generation can reduce the likelihood of cascading failure an ideal mix of the smart grid resources like renewable demand response and storage lead to flatter net demand and eventually increase system reliability.

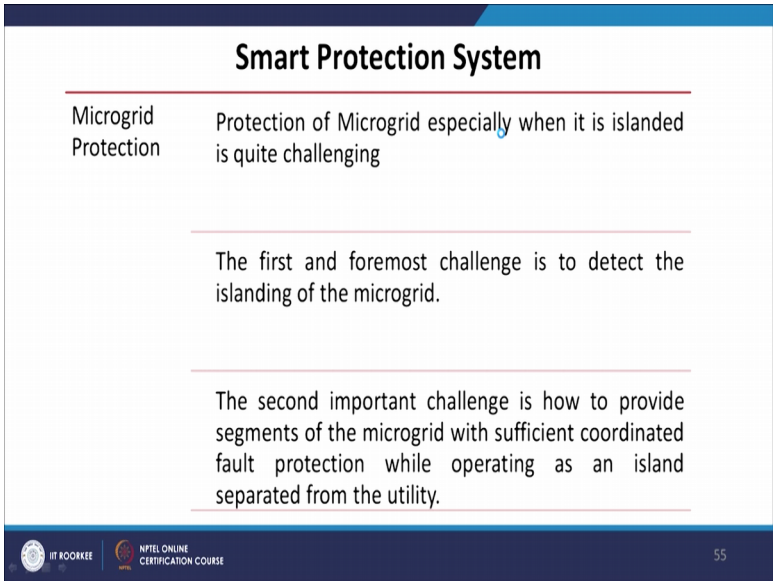
Failure protection mechanism that is prediction and prevention predicting the weak points or the region of stability existence in it is energy subsystem.

(Refer Slide Time: 31:12)



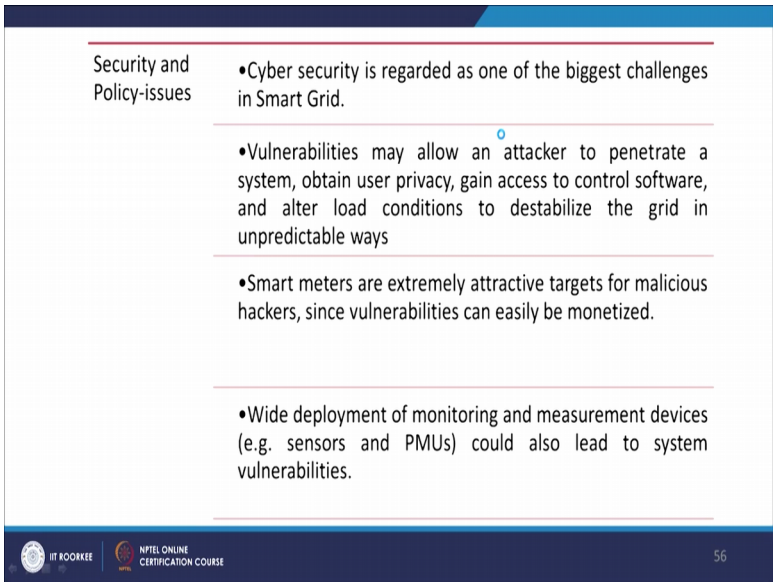
Some researchers proposed to utilize PMU data to compute the region of stability existence and operational margins, major blackouts can be prevented by proper predictions. Failure protection mechanism locating and identifying the failure to avoid cascading events, due to the wide deployment of PMUs the phasor information used for line outage detection and network parameter error identification, self-healing can be effective if power grid is divided into small section, during post fault decision making ability should be distributed to the substation and or field device for immediate action.

(Refer Slide Time: 32:08)



Then, we have different schemes of protection we have micro grid protection that is protection of microgrid especially when it is islanded is quite challenging. The first and foremost challenge is to detect the islanding of the microgrid. The second important challenge is how to provide segments of the microgrid with sufficient coordinated fault protection while operating as an island separated from the utility, which is one of the very very important during fault condition how we can operate the grid in an islanded mode? Cyber security is regarded as one of the biggest challenge in smart grid.

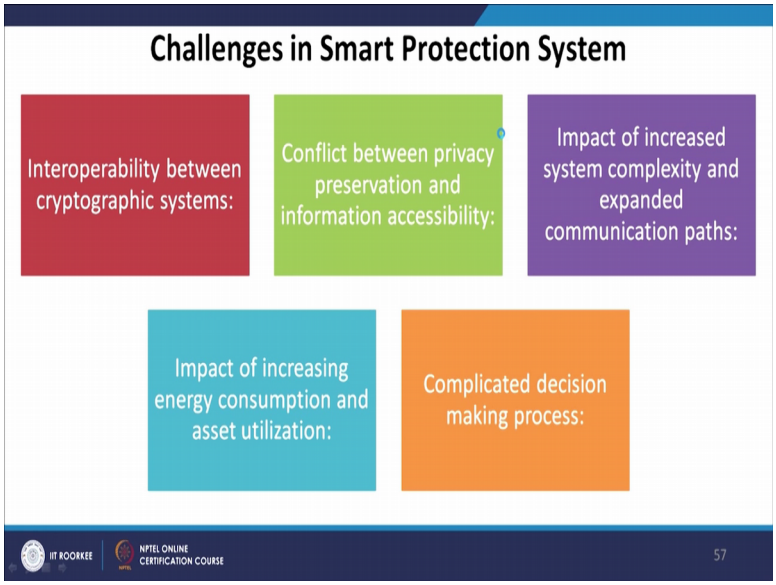
(Refer Slide Time: 32:59)



Vulnerability may allow an attacker to penetrate a system obtain user privacy, gain access to control software, and alter load conditions to destabilize the grid in unpredictable way. Though smart grid though it seems to be the future we have to incorporate robust cyber security mechanism to make your grid safer.

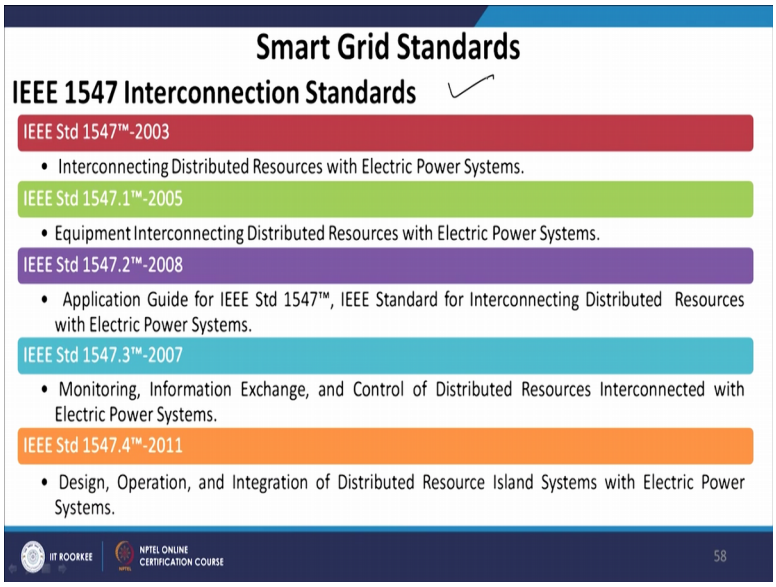
Smart meters are extremely attractive targets for malicious hackers, since vulnerability can easily be monetized. Why deployment of monitoring and measurement devices could also lead to system vulnerability.

(Refer Slide Time: 33:56)



The major challenges in smart protection system is specially in specific interoperability between cryptographic systems; conflict between privacy preservation and information accessibility; impact of increased system complexity and expanded communication paths; impact of increasing energy consumption and asset utilization complicated decision making process; and with this background now researchers establish few standards to establish smart grid infrastructure.

(Refer Slide Time: 34:47)

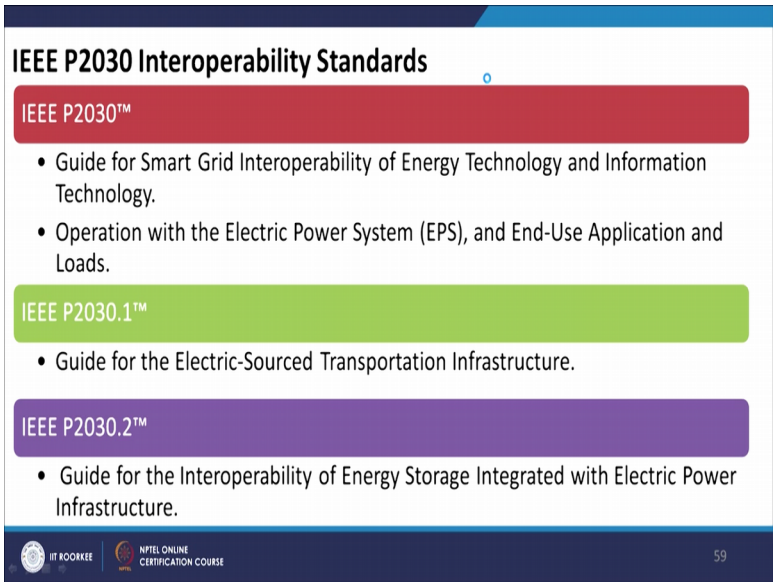


And, let us now discuss some of the very very important I triple E standards; we do have the first one which is very important that is I triple E 1547 interconnection standards.

I triple E 1547 in 2003 takes care of inter connecting distributed sources with electric power system, what are the standards that need to be maintained for inter connecting distributed energy resources with any adjusting power systems. Next one is I triple E standard 1547 version 1 in 2005, it deals with equipment interconnecting distributed resources with electric power system. Then, we move to the second version 1547, I triple E standard in 2008, that talks about application guide for I triple E standard 1547 I triple E standard for inter connecting distributed resources with electric power systems.

The third version in 2007 monitoring information exchange and control of distributed resources interconnected with electric power system, then we had fourth version in 2011, design operation and integration of distributed resources island systems with electric power system.

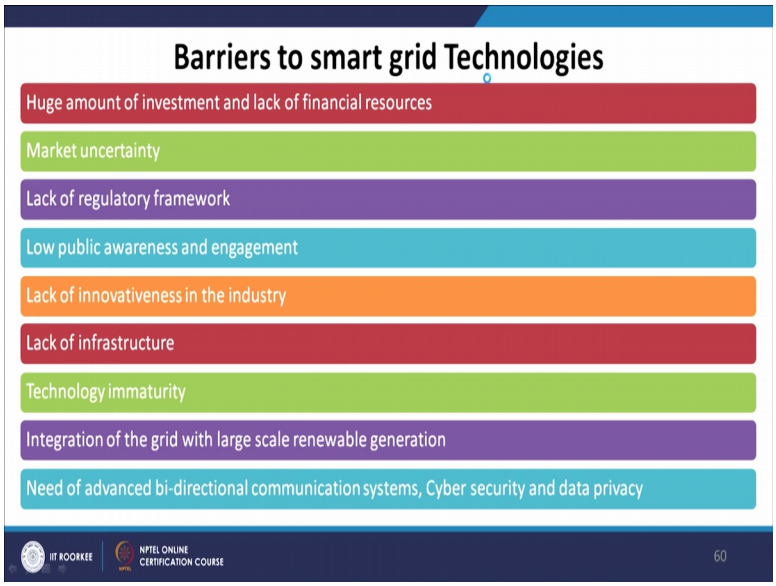
(Refer Slide Time: 36:29)



I triple E P 2030 Interoperability Standards I triple E P 2030 guide for smart grid interoperability of energy technology and information technology, operation with electric power system and end use applications and loads.

I triple E P 20 30 version one guide for the electric source transportation infrastructure, I triple E P 20 32 guide for the interoperability of energy storage integrated with electric power infrastructure, but though the I triple E standard suggest recommendations for smart grid development with different standards there are few barrier for smart grid technologies to one of the major barrier.

(Refer Slide Time: 37:34)



Huge amount of investment and lack of financial resources because we need to really invest to much to make your grid smarter.

Market uncertainty we do not know how the market is moving, lack of regulatory frameworks none of the very strong established framework is in place today, low public awareness and engagement for example, the day to day public life they are not mature enough to understand are they operating at the peak hour or the off peak hour, how they can contribute to green energy? How they can reduce the energy demand during peak hours? So, for all these concerns we need to have extremely awareness programs first of all to educate all the public those use energy in a regular basis.

Lack of innovativeness in the industry, industry has to be more innovative lack of infrastructure, technology immaturity, integration of the grid with large scale renewable generation, that is the biggest challenge when we put lot of renewable energy sources in the existing system, which is not being designed to incorporate excess renewable energy we have to have grid challenges, need of advanced bi-directional communication systems, cyber security and data privacy very very important.

Dear listeners, we end with our introduction lecture 2 and when we meet next class will get into details of smart grid modeling and technical aspects of smart grid.

Thank you.