Introduction to Smart Grid
Dr. Premalata Jena
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture - 03
Architecture of Smart Grid System

Good morning to all of you today will start in this module the Architecture of the Smart Grid System.

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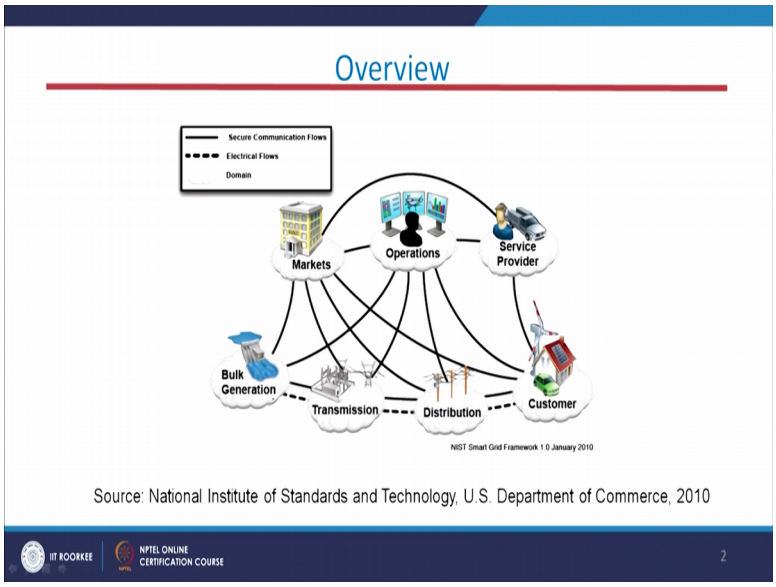

If you could see here that in smart grid system we have 7 sections or 7 parts, the first part is the bulk generation and the second one is the transmission system, third one distribution and fourth one the customer. In general the power is basically generated at the generating station and this powers basically transformed from the generation station to the customers end through the transmission distribution networks. And apart from this 4 sections we have other 3 sections if you could see here this markets operations and service provider.

And coming to the very I mean very this the basically this is the very basic block diagram of smart grid architecture or layout in this case I will start from the bulk generation.

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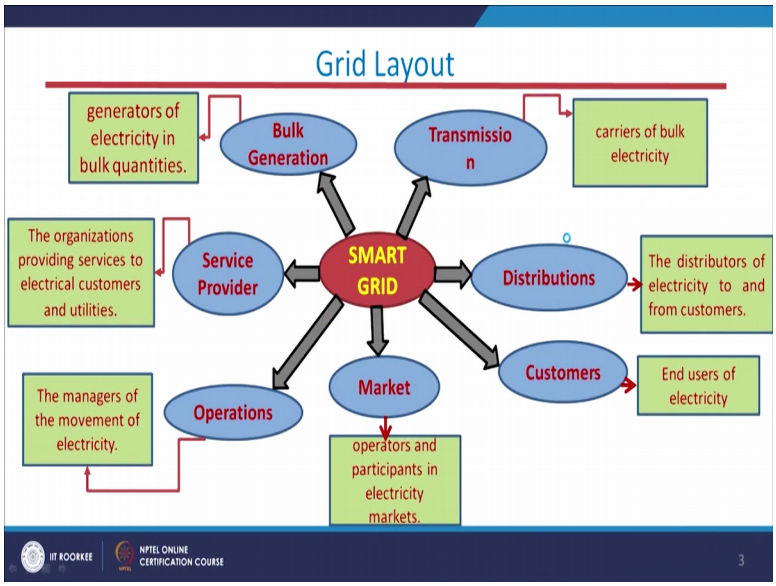

And this bulk generation basically generates the power and this generating stations are basically may be the coal based generation, may be hydro based generation and also presently we have renewable sources as far as the smart grid is concerned. In this case also we have wind generation and solar generation systems and this the major part the major role of this block bulk generation the system is to generate the electricity in bulk quantities.

And after this the generated electricity or power is transformed to the transmission network and then distribution network and then the customers. If you could see here the markets I mean already we have discussed in the first part that this generation transmission distribution and customers are the very very important part along with this we have this market operations and service provider.

As far as the service provider are concerned basically the there are certain organizations which basically provide service to the generation system, to the transmission system, to the distribution system and also to the customers. And apart from that we have also operations sectors we have also market, in the market basically the participants they basically participate for sailing a trailing of the power.

So, will discuss slowly one by one every part very quickly welcome to the first the customer domain, in the customer domain as I said the customer is the end user part which consumes the power.

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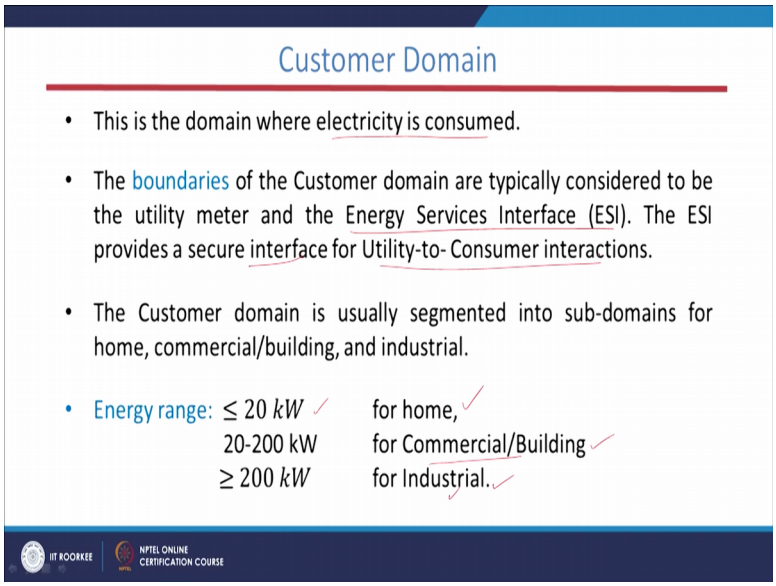

This is how this where the electricity is consumed and if you say this customers are basically of 3 types. The first one is the our home customers that is known as home or equipments where we use the power and second one is the commercial or building consumers, where the power is consumed in the commercial buildings or commercial sectors and the third one is the industrial power sectors or industrial consumers.

If you could see the power range for home type of consumers the power range is within it is less than or equal to 20 kilo watt and for your commercial buildings the power range is within 20 to 200 kilo watt. And similarly for the industrial part the power range should be greater than or equal to 200 kilo watt, this is basically the energy range based on the energy range basically classify the customers in this manner.

Now, one point here I want to mention, that is the ESI which is very very important that is Energy Services Interface, what is that it provides this particular system. This particular practice it provides a secure end interface for the utility to customer interactions. This is the very very important part of the architecture of the smart grid now if you come it is a very consigned very important figure I will say where you could see all the customers together.

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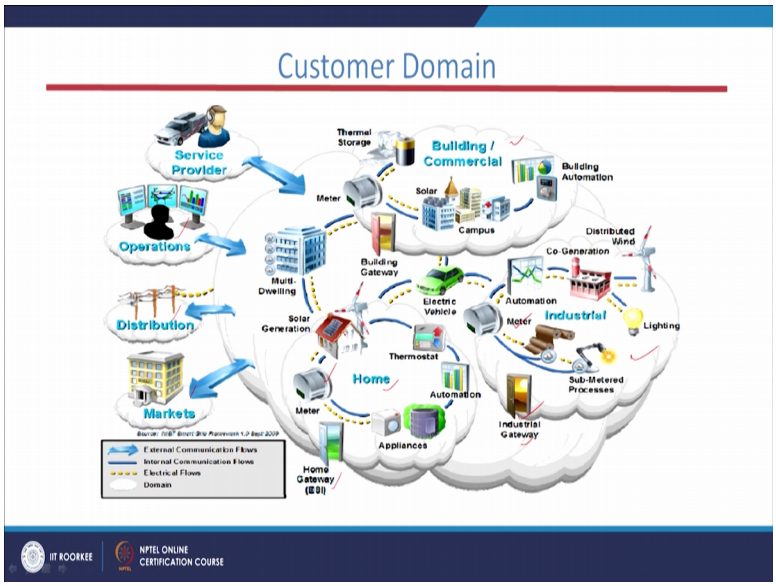

You could see this is the building, commercial part, this is the industrial part, this is the home and these are all the service operation distribution markets. What I want to say from this particular figure, it says that if you could see in every commercial I mean the customer domain may be it is commercial, it may be industrial or it may be home type of customers everywhere the common thing is the metering facility and we have a basically gateway.

You could see here industry also we have one meter and also we have industrial gateway and similarly for this home type of customers we have home gateway and also the meters and as far as the definition of the smart grid is concerned, the major block of the major part of the smart grid system is the communication system. Communication network dedicated communication system is very very essential for flow of the data from one customer end to other customer end or may be from one part of the smart grid network to the other part of the smart grid network.

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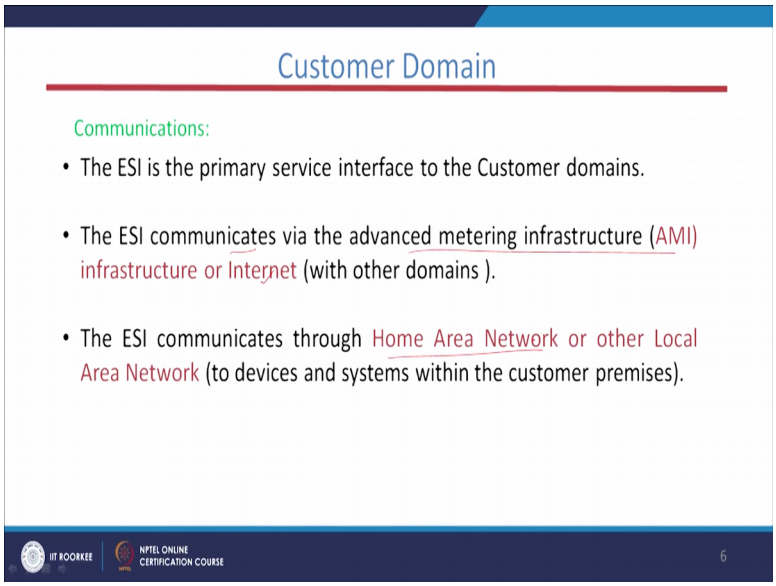

Now, as I said mentioned before 2 slides that this ESI is the primary service interface to the customer domain as far as the communication is concerned for this ESI, this is very important and I just want to mention here. This ESI communicates with the advanced metering infrastructure this is very important and this infrastructure advanced metering infrastructure is very essential part of the smart grid system and this is basically interconnected to the ESI how so, the internet so, the internet.

And another one is also very important part of the ESI communication system that is it also communicates with the devices which are present inside the system through the home area network or the local area network, which is known as HAN or LAN the HAN stands for Home Area Network and the LAN stands for Local Area Network and coming to the basic block diagram of the customer domain here it is. So, you can see as I said we have 3 types of customers broadly like we have the commercial, industrial and we have residential customers.

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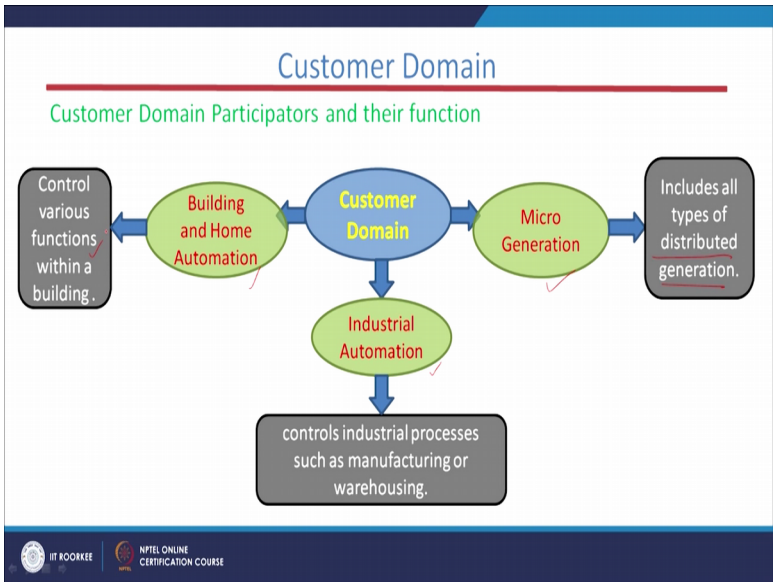

And one more thing I have just added here this is the micro generation, you could see here this micro generation is nothing this includes all the type of distributed generations that is also the part of customer domain. So, this distributed generation means we have solar system, we have wind system, we have fuel sales, also we have batteries. So, those batteries are also the part of the distributed generations we will discuss more about in the subsequent slides or may be in the subsequent modules.

And the main role of I mean as far as the customer domain is concerned the major part is the building and home automation, we have industrial automation, we have micro generation and their corresponding functions are defined here very briefly if you will see what is the function of this building and home automation. The major function of this building and home automation is to control various functions which is happening inside a building of the smart grid.

And similarly coming to the function of industrial automation, it controls the industrial processes such as if you will see in all the industries we have different types of functions manufacturing and also ware houses. So, many things and coming to the another domain this is the second domain I will talk about that is the market domain which is very very important part again for the smart grid architecture is concerned. And here as the name suggests market means where basically we just I mean where the grid assets are bought or sold, the grid assets are bought and sold that is the main target of market domain.

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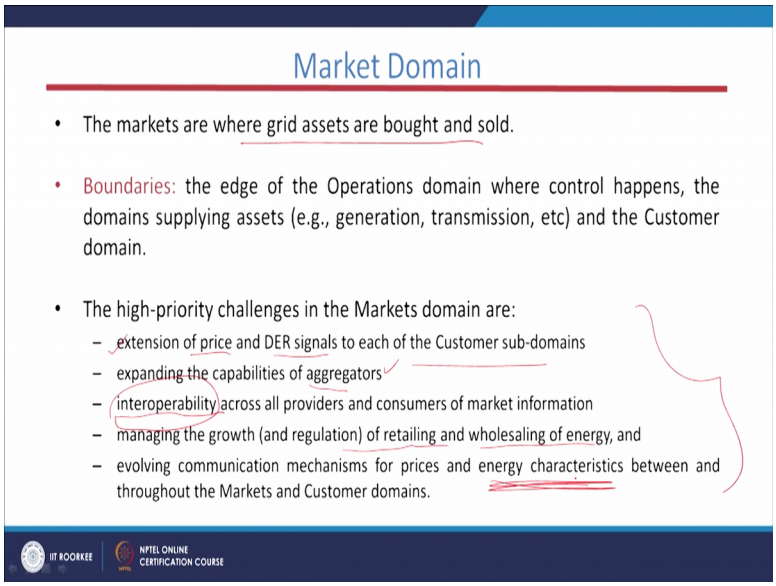

Now, if you see there are some high priority challenges as far as the market domain is concerned we have high priority challenges. What is the first challenge? The first challenge is extension of price and DER signals to each of the customer sub – domains, this is the first high priority challenge what is that; that means, we have 3 types of customers domains, customers sub domains we have also like we have commercial, we have industrial, we have residential customers. So, in that case we have to extend we have to decide the price and DER signals it should be properly judged, it should be properly monitored, it should be properly adjusted.

And the second one is very very important also that is expanding the capabilities of aggregators I will discuss more about in the subsequent part of this module I will discuss, what is aggregators. The aggregators means, which helps to participate the DER small utilities to participate in the markets of the power so, the where the power exchange takes place; So, in that case the expanding the capabilities of this aggregators that is also very very important part function challenge of the market domain as far as the smart grid is concerned.

Now, we have interoperability this is very very important, interoperability this word I will discuss in detail of my slides and I just want to say what is that actually, it means we have many devices, many equipments, present as far as the smart grid is concerned we have generation we have transmission, distribution equipments, we have customer

premises, we have different equipments present in the customer premises. So, in that case we have to will say will set in such a manner in the smart grid we have to basically they should speak to each other, every device present in the customer domain devices present in the transmission domain, distribution domain, they should speak to each other so, that is what interoperability.

Now this is how the across all providers and consumers in market information, what is happening inside the market of the smart grid the information should flow to every part of the smart grid system. Now this is the fourth one is managing the growth and regulation of retailing and wholesaling of energy, this is also important this is the one part of the challenging task as far as the market domain is concerned. Now and the last one is also part of it that is the communication mechanism for prices and energy characteristics this is also very very important, what is this energy characteristic.

The energy characteristic is between throughout the market and customer domains because the customers are the end user. So, there we have said what should be my energy characteristic, what should be the price of my energy which is going to be sold to the customers. Now I will just come very brief diagram or I can say it is a very block basic block diagram of the market domain you can see here.

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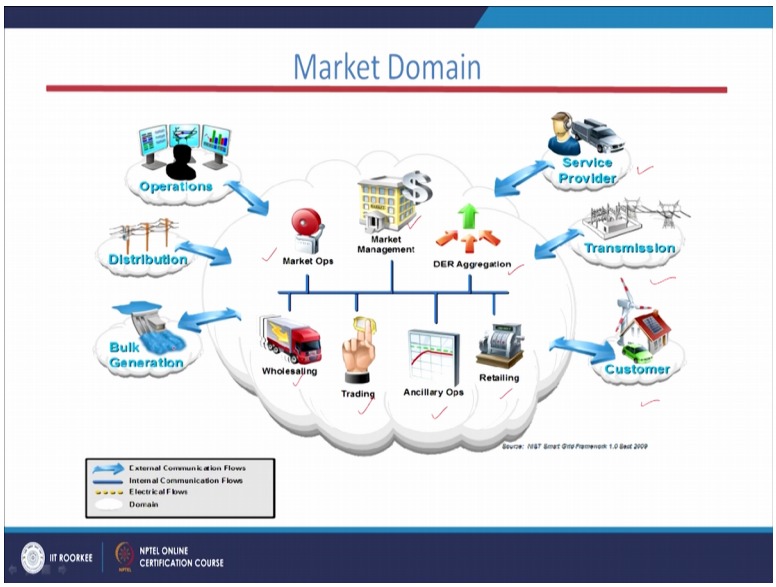

We have the sections of the parts of the market domains this is the DER aggregation and this part is market management and this is the market operation this is wholesaling

trading and ancillary services and retailing. So, these are the components of the market domain right. So, this components are going to also access our transmission, customers, service provider, generation, distribution. operations.

As I said in the smart grid system all the parts all the domains are interconnected with each other, that is very very essential which will lead to the name of smart grid, which is not available earlier which is not available earlier. So, that is why this market domain is also linked to each domain of the smart grid system this is the function of each domain in short I will just discuss that I will start from this retailing.

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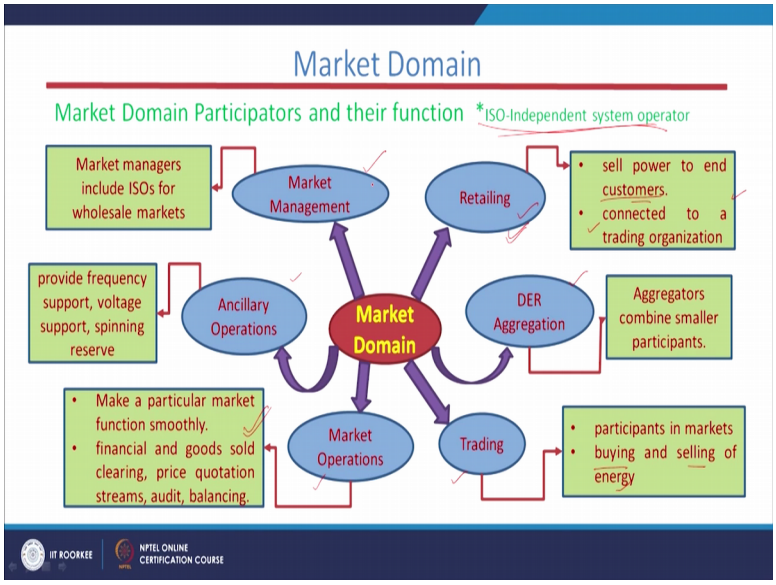

Retailing means here in this retailing section of the market domain will sell power to the end consumers where selling the power to the end consumers are this consumers will basically consume the power. So, this retailing part helps to do that and also connected to the trading organization this is also second function of this retailing part or retailing component of the market domain and the second one is the DER aggregation already we have discussed this word what is aggregation.

The aggregation nothing the aggregators combines small participants in the market to sell their power to the I mean to the energy market to participate in the energy market that is what DER aggregation and next is a trading in case of trading we have this it is a very important part of this market domain where we go for buying and selling of the energy that is very essential part of our market domain.

Now, of course, this market operation is also important that what is the function of this market operation, the market operation basically function very smoothly and basically the financial and goods, which are used in this smart grid environment. What are the financial documents, financial affairs or the goods, which has sold inside the smart grid environment or system and also the price quotation stream audit balancing.

So, these are all the part of this is the major part of the market operations and we have ancillary operation in the ancillary operations sometimes also we have to support the frequency and the voltage and the spinning reserve of smart grid system. So, this ancillary operation ready to supply those support that is the frequency voltage and spinning reserve support.

And coming to this market management because every system has should have some management system. So, this market management is also there to manage the ISOs you could see here this ISO means the independent system operator, this market management block or this component of the market domain helps to manage the ISOs for the wholesale markets. So, these are very brief the functions of the market domain.

Now, I will come to the third part third part of the as far as the architecture of the smart grid is concerned that is service provider domain. In this case as the name suggest service we have to provide service to all the components all the sectors all the things which are involved inside this smart grid environment that service that service provider, I will just define in very short it supports the business process the first part I will just name it.

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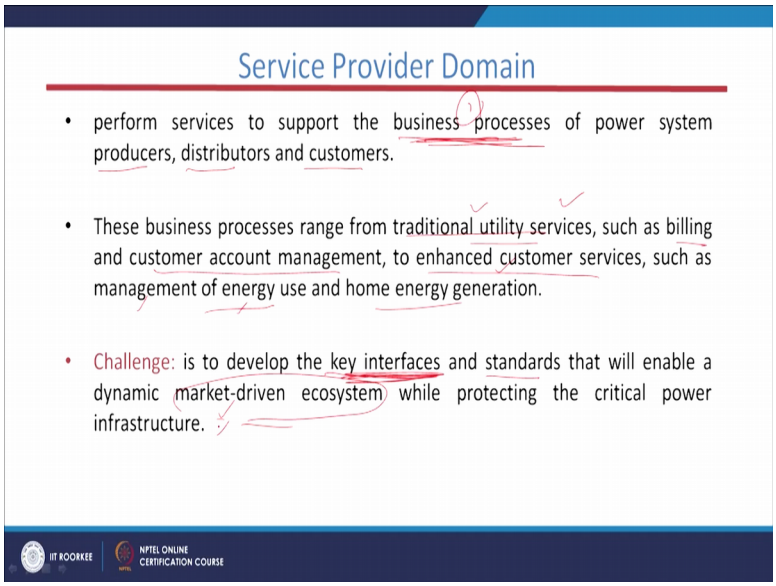

It supports the business processes of power system producer the producer means it may be the generation it may be equipment producer anybody. So, we have to provide this service provider domain will provide the business processes and distributors and customers yes of course, because as I said the power network as the basic building blocks that is the generation distribution and the customer consumption that is the customer is the last end part of the electric network.

So, the service provider domain will help in processing the business of this 3 domains and coming to another point which is basically involved in the service provider domain that is the business processes range from tradition utility services. This is important the tradition utility services such as the billing and we have customer account management, we have enhanced customer services such as management of use and home energy generation.

See these words are very very important every word as a meaning like if you see that as I said here the traditional utility services such as billing, billing of the customer, and customer account management or this enhanced customer services or management of energy used how much energy is used inside a customer home as far as residual customers are concerned. So, those information basically should be maintained by this service provider domain and coming to the challenge what is the challenge for this particular domain.

That it is very difficult to develop the key interfaces, this interfaces and standards that will enable a dynamic market driven ecosystem this is very very this ecosystem market driven ecosystem is our target, without market driven ecosystem so, there is no I mean existence whatever the service provider domain provides to us.

So, we have to see that first whether the things which are provided by the service provider system which is ecosystem (Refer Time: 19:45) economical reliable or not is it user friendly to the environment or not and while protecting the critical power infrastructure the critical power infrastructure should be intact, it should not be affected. Now, this is how this definition goes as far as the service provider domain is concerned and coming to this part.

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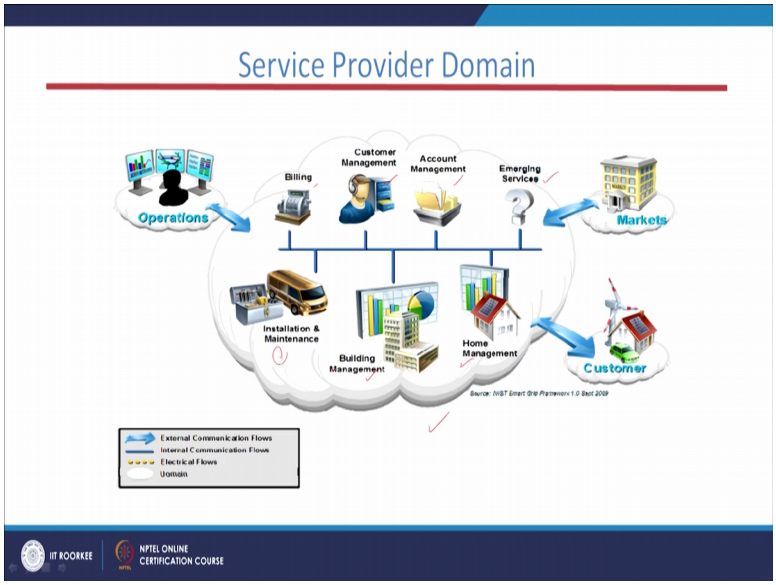

The very basic block diagram of this service provider domain, what are the components of this particular domain; The first component I will just start from here installation and maintenance, then the second one is the building management, third one is home management and the fourth one is emerging service and the next one is account management, custom management, and finally, we have billing system.

So, these are the essential components of the service provider domain in a smart grid system and you remember this all this components of the service provider domain, this components, this sections also will speak to our markets customers and operations through very dedicated communication system by exchanging the data between them.

Now, this is how the functions of each components of the service provider domain I mean the functions of each components outlined in this particular PPT you could see here I will start again the installation management part this is the first part.

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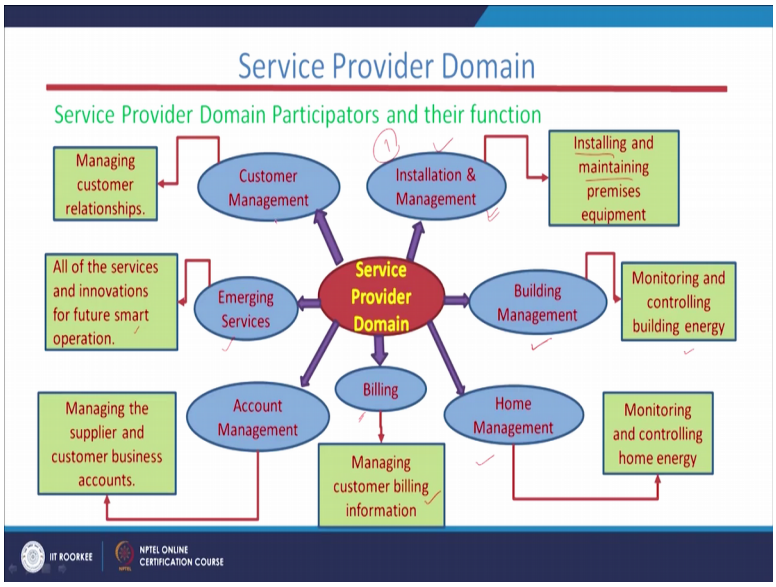

So, here what is the function of this in brief, it helps in installing, maintaining premises equipment that is what the function of this installation management component of the service provider domain. And similarly I should not read all you can see here this building management, in this building management section we have the monitoring and control of all the building energy, that facility we should have how the building equipment can be monitored and controlled time to time that is the function that is the part of, of this building management section.

And similarly the home management and we have very important part is the billing part because as far as the service provider is concerned that the main part is building we have to manage the building; I mean the billing of the customers information, the customer information should be properly accessed the bill should be prepared at the proper time that is very important.

Now, we have emerging services, the emerging services basically we have all the services and innovations of the smart grid operation future, smart grid operations what innovation we can do, further to have a very reliable and accurate operation of the smart grid very dependable and secure operation of the smart grid. So, that part is basically

emerging services what are recent trends, what are recent technology is evolved with help of those technologies we can basically make our smart grid more accurate, more reliable, more I mean secure in operation.

And the last one is the customer management, where this customer management section maintains the relationship between the customers, how the customer's relationship will be maintained properly in a fare manner. Now the operation domain that is the next domain of smart grid architecture that is the operation of the smart grid system I will say this particular domain is the very huge.

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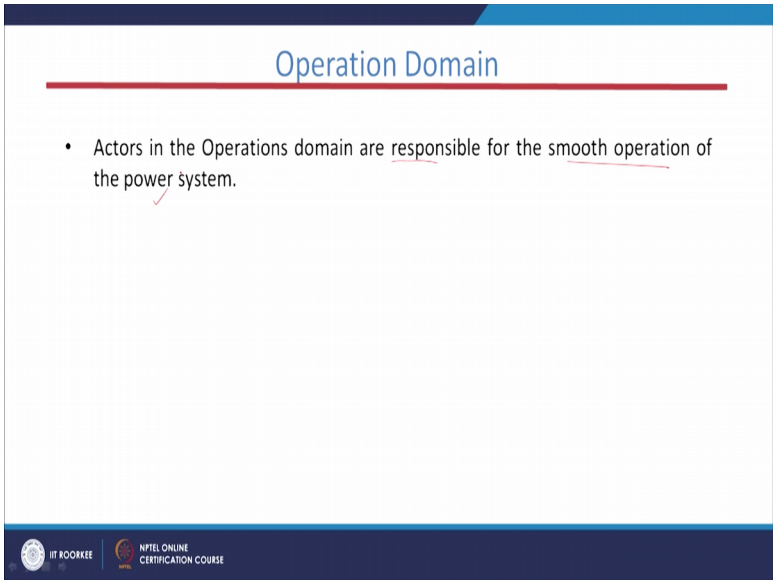

It will compare to other domains like customer domain or operation domain or that is your market domain. So, this operation domain is very very important and is very huge and is large it is a large scale domain well. It helps in basically it is responsible for smooth operation of the power system nothing else our main target of this operation domain is to maintain, to operate, to monitor, to control, the smart grid in a very secure and dependable and reliable manner that is what this aim of this operation domain.

And if you come here this operation domain components as we have discussed in the previous few slides that exactly the same manner I want to say here that what are the components of the operation domain.

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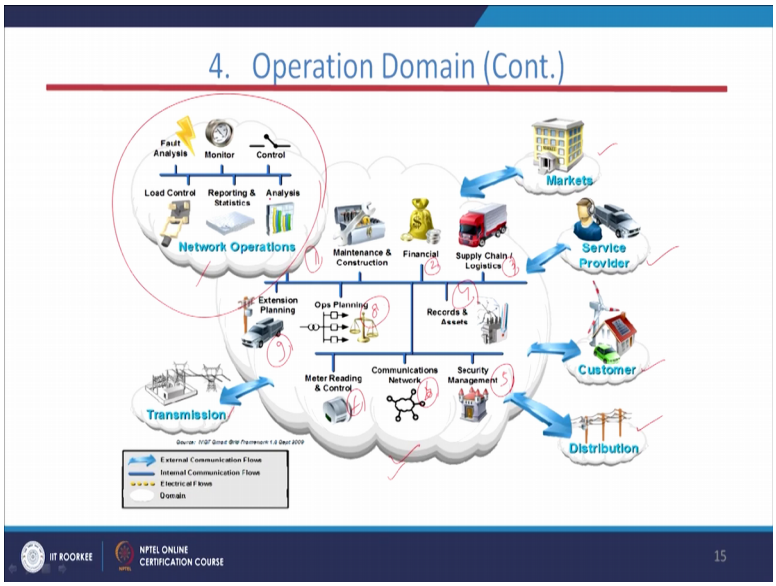

In the operation domain I will start from here. first one is maintenance and construction and the second one is the financial part and the third one is supply chain logistics. And yes we have records fourth one records and assets and the fifth one is security management and sixth one is communication networks seventh one is meter reading and control and yes the last two is operation planning this is 8 and ninth one is the extension planning.

So, again I just want to say share with you that all this components of the operation domain communicate with other part of our smart grid system, that is markets service provider customers distribution, we have transmission yes. Here the network operations this is very very important, this part is very very important, this network operations very very important that is where we have I mean how to operate the network very smoothly, without any disturbance, without any hindrance, without any problem.

Because our aim is to basically flow the power allow the power to flow from the generation station to the customers that is our aim that we are designing we are desiring the smart grid in this manner we aspect that power should not be interrupted at any time and the quality of power should be maintained to the customers that is how the aim of the smart grid. And of course, there are lot many I mean functions of the smart grid in general this is the statement, this is our aim and yes of course, with efficiently and economically without disturbing our environmental issues, our environmental things

should be I mean maintained properly. So, that is how this operation aims and all the components help for proper functioning of the operation domain.

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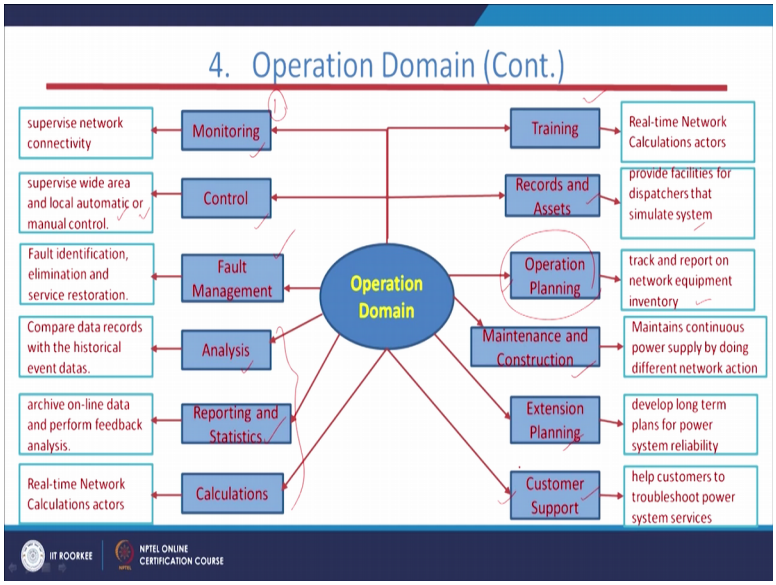

And you could see here it is a very big chart and I will try to summarize nicely and easily I mean it is a very simplified manner, if you will come to this monitoring part of the operation domain. In the subsequent modules we will learn how to monitor the smart grid system using phasor measurement unit or wide area measurement systems. Those are the equipments yes in recently in there are lot of projects are also running on this monitoring system of the smart grid and earlier we basically used the SCADA system will also discussed in the module of components of the smart grid.

So, those equipments like SCADA or PMU or VAMS. So, those components or equipments provide the monitoring aspect. In the monitoring system basically supervise the network connectivity how this network is basically connected with each other, how the power is flowing, how the frequency is maintained, how the voltage is maintained. So, those aspects are going to be basically supervised using this monitoring component monitoring section of the operation domain.

Now, we have of course, after the monitoring we have control, how to control those equipments or the generating stations or the distribution networks or it may be transmission network or it may be storage device you can name anything in the smart grid network how to control those equipments. So, the control section will take care of

this that is what it is written here, supervise wide area and local automatic or manual control to be make it clear that in the smart grid era we are not any more dependent on manual control, rather we are going to be dependent completely on this automatic control system.

And the third one is the fault management component, this fault component I mean fault management system basically it helps in identifying the fault which is being inserted in the smart grid system and also it helps in elimination and further the service restoration. You can see the fault is very it is invertible, it can come to at any time you cannot basically control the fault. It will not provide any basically some notice that I am going to I mean to be present I am going to present at this time and this day it is very uncertain. So, the fault is basically the, I mean the main part the main major disturbance which is expected in the smart grid system.

Those major disturbances should be taken care, it should be detected, it should be maintained, it should be repaired, and again the service to the customer should be restored. Now the analysis; obviously, because whatever we are doing, the very important part is we have to analyze the system operation, control, monitoring, fault, detection, every part should be analyzed properly, whether it is proper according to the standard, according to our desire, what for what this equipment is designed to operate whether it is perfect. So, those analysis is basically those analysis are must in the smart grid system and reporting statistics calculations are part of this analysis.

Now, coming to this part the training, real time network calculation actors training we need and also the records assets it provides the facility for dispatches that simulate the system this records and assets and this is the another part that is the operation planning. This section basically provides the track and report on network equipment inventory, that is the function of this operation planning. What kind of planning further, we can do what planning is necessary further yes of course, what smart grid layout is presently operating.

So, that we cannot change, but from the analysis from the operation analysis from the record analysis or data analysis what further extra things we can embed to this particular smart grid network for further smooth operation. Yes, I always say I say one sentence that our target is the smooth operation of the smart grid system, all these components are basically designed for that purpose for smooth operation the smart grid system.

Now, the 3 sections left out that is the maintenance construction and extension planning and customer support I will discuss about the last one this is the customer support is very very important, because we should help to the customers for troubleshoot power system services. Because the customers are the main part of the smart grid system, if we have generation we have transmission we have distribution, but there is no customer so, there is no use of the power. The customer should be satisfied first if any trouble at any time comes to the customers then we have to rectify it through our automatic process or we have to reach to them through our man power so, that is what this customer support part.

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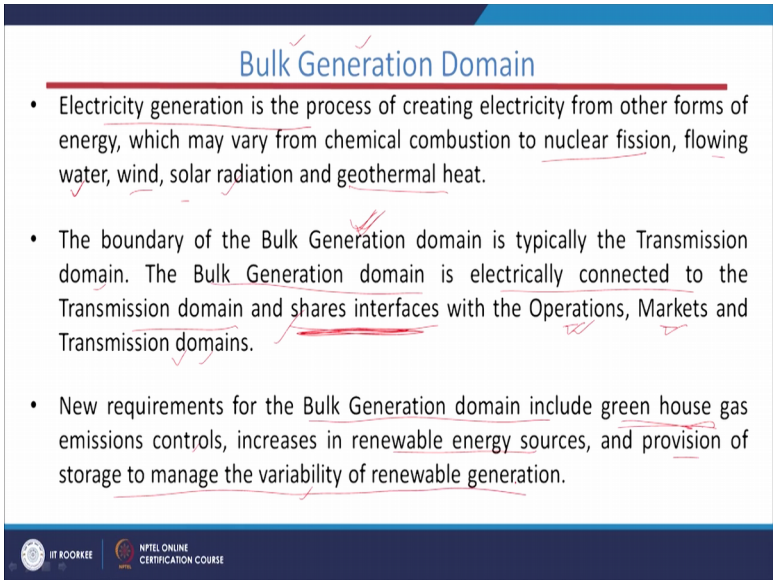

Now, I will just come to the another domain of this smart grid architecture that is the bulk generation domain and as the name suggests the bulk generation domain helps in generating the power. We have in our country we have a hydro based power stations, we have coal based power generations, we have also nuclear power based generations, also we have very quickly rapidly we are moving towards renewable power generations that is very very essential in today's as a today's market is concerned, today's age is concerned.

So, we have to be fully dependent on renewable energy as quick as possible the lot many issues are coming off like we have carbon dioxide emission target, we have to limit the carbon dioxide emission within certain limit that limit we should not cross, that because our main generation is from coal that is around 60 percent. So, we have to be very

careful we have to generate we have to generate the power from the renewable source more like wind or solar or fuel cell so, mainly our target is solar and wind systems.

So, what is this domain function, how this basically the bulk generation domain helps in the smart grid system, this is the I have just written 3 parts I have divided the function of this bulk generation domain into 3 parts. The first one is the electricity generation is the process of creating electricity from one form to other form as I said it may be nuclear fusion, flowing of water ,means it is a hydro based generation, wind, solar or geo thermal already we have discussed.

So, these are the sources from where will get the power and what is the function then the boundary of this bulk generation, this bulk generation domain is typical that transmission domain it will just send the power to the transmission domain. This bulk generation domain is electrically connected to the transmission domain and shares interfaces with operation market and transmission domains will discuss about this transmission domains after this.

So, this basically this bulk generation domain interacts with the operations, the markets and the transmission domains, it shares inter interfaces this is very very important this, this one it has a connectivity basically between this particular operations markets and transmission domains. Now, I will come to the last one what is the new requirement for this, there is this is obvious it is also happening before also because the bulk generation domain should interact with the transmission domain.

It should also interact with the service domain, it should also interact with the market domain, for it is smooth operation what is the new thing happening in this domain as far as the smart grid is concerned. The main requirement for this bulk generation domain include the green house emissions control which is very very important as I said before few minutes our in our country our full demand our full power generation where aiming from the coal 7 percent from the renewable sources.

How quickly we can make this 7 percent to 70 percent hopefully in year future we can make it hundred percent if possible that should be our target that should be our effort. So, this bulk generation domain will help us to reduce I mean how quickly this green house gas emission control should be there how this carbon dioxide emission should be controlled, it should be reduced unless until we use renewables in a huge manner as per

the percentage the of the renewable energy is not going to be increased we are nowhere we are not going to reduce the carbon dioxide emission anymore and also it helps in increases in the renewable sources that is what our discussion and the provision of storage to manage the variability of renewable generation.

The last one is also important, now a days we have lot many projects are basically happening between US - India, UK - India to have very good technology for the storage purpose because if will have generation from the renewables. So, how quickly, how nicely, how easily, efficiently we can store the energy inside a storage system that is also one of the major thrust area so, these are the things functions of the bulk generation.

Now, coming to this block diagram of this bulk generation domain already we have discussed more or less.

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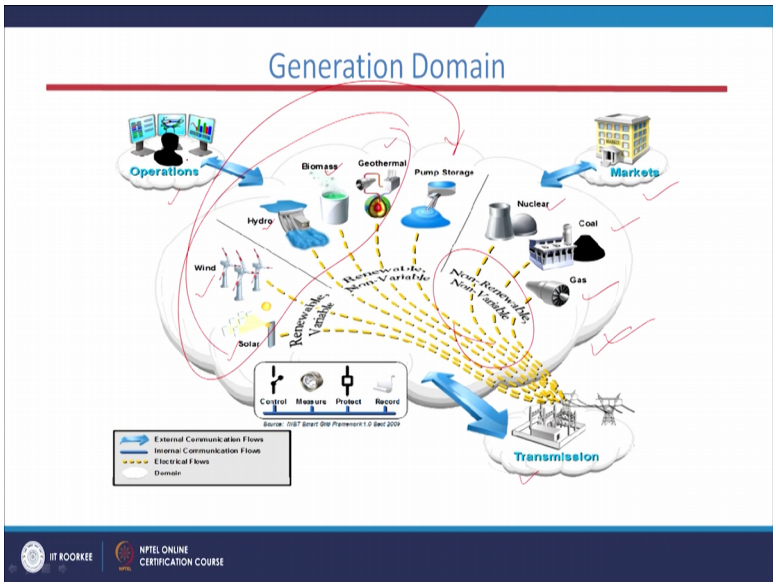

And I will say I just said we have renewable sources like solar, wind, hydro, biomass, geothermal. So, these are all renewable sources which are also part of this generation domain, along with this we have also like if it is a very sunny day and my load requirement is very less where to go where this energy which is produced from the solar we have to store. So, we have to store using this particular pump storage the pump storage basically storage part of the network, where we can store the energy again when it is required we can use it also we have different storage I mean parts I our system.

Now, what is this we have gas coal and nuclear best these are all non renewable, non variable energy sources which are also part of this generation domain and remember this generation domain also speaks with transmission markets and operations. Already we have discussed these are also components of the architecture as far the architecture of the smart grid is concerned there is your operation their markets and your transmission. So, this generations domain also speaks to this three domains, one is the operation domain, market domain and the transmission domain and this is how the functions of the components of the bulk generation system one is the control, major, protect, record and asset management.

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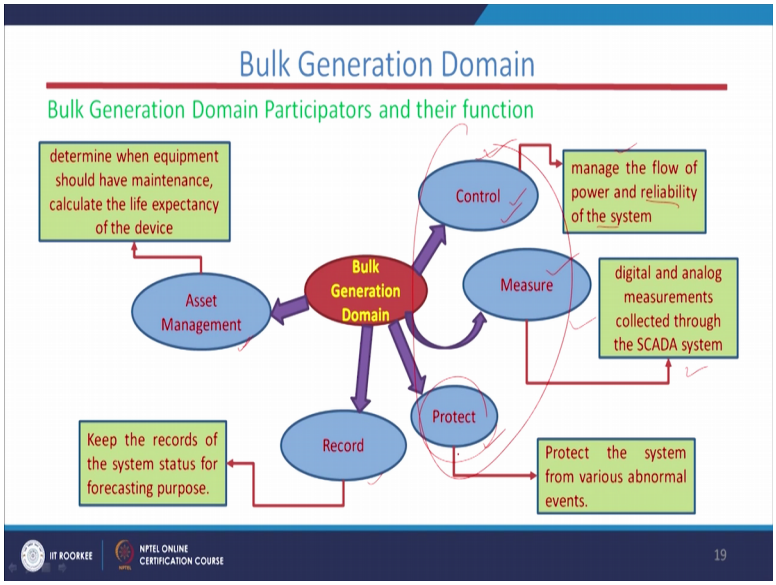

I will just emphasize this 3 record is obvious record is obvious because whatever we are doing we have to record, we have to store the data for our future analysis or may be for present analysis and also we are storing the data for online challenging task, online message we have to take some decision those data also will help us. And similar the asset management, but of course, the major part is the control measure and protect. So, these 3 parts are very very important in the bulk generation domain we have to measure the data all the quantities the basic quantities voltage current and further the derived quantities frequency and power.

So, we have to basically measure those data using be some now a days we are using the VAMS technology and also the SCADA systems are also used till this date. So, we have

to basically make it more I mean accurate more faster and VAMS is one of it. So, with help of those equipments will measure will store we can money transfer the things the data power flow or voltage or current or frequent information.

Now, as far as the control is part is concerned we have to manage the flow power and the reliability of the system this is also important because as you know without reliable operation, without any proper flow of the power, there is no question of standing of the power network it will collapse. The power flow should be maintained properly the generated power should be equal to power demanded, that is must to make the frequency constant 50 hertz the power generation should match to the demand if you many mismatch is there. So, there will be fluctuation in the frequency. So, we have to be very careful.

So, that can be done this by using this control system and yes of course, the last one is the protect the protection part is also we very very important without helmet we cannot play cricket we should not because some protection is very very essential for our body. So, similarly for all the equipments which are installed in the generation system on the smart grid it should be protected. So, protect the system from various abnormal events, coming to the another domain, that is the transmission domain of the smart grid system.

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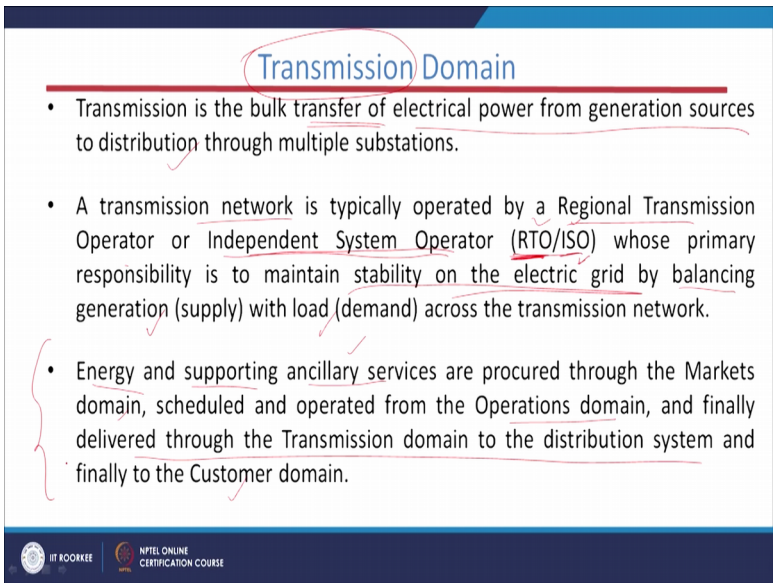

It is very clear as the name suggest it transmits the bilk power, which is generated at the generating station to the customer end through the distribution lines, that is what the

transmission domain functions it transfer. It transfers electrical power from generation sources to the distribution through multiple sub stations of course, because if you will see our generating station voltage within 20 to 23 kV it is going to be step down to 400 kV, again the 400 kV is going to step down to 230 kV, further 132 kV, then 66 kV, then 11 kV, then 440 volt at the customer end.

So, this steps which are maintained from generation to the customer end so, basically transmission helps in transferring the energy from one generating station to the customer end. Of course, through different sub stations, not exactly we are not transferring the power at 400 kV from the generating station to the customers we have to scale down the voltage then the power will reach to the customer end.

Now, this transmission network is typically operated by two things one is the regional transmission operator that is known as RTO and or it is also known as independent system operator, that is it stands for ISO Independent System Operator whose primary responsibility is to maintain the stability in the electric grid. How the stability will be maintained? It is going to be maintained by balancing the generation and the load, if this two are balanced if your generation is matching to our load the system will be stable frequency will be stable and the voltage will be stable. So, then only we can say the system is stable that is what these two sections like RTO or ISO that these two names you can see here basically it helps to maintain that.

Now, this another part is energy and support ancillary services, the ancillary services already we have discussed in the generation part, that the frequency support, voltage support, spinning reserve and are procured through the markets domain in the market domains. We have this ancillary services which are available, they can also procure from there and schedule and operated from the operations domain and finally, delivered to the transmission domain to the distribution and the customer domain.

You could see here I just want to say as far as the functions are concerned domains are also different. But however, at the end of it you could see here all the domains are interconnected with each other without help of one domain other domain is layout layman blind. So, without the help of transmission domain generation domain is layman without the distribution domain transmission domain is useless so; that means all the domains are interconnected with each other they help each other.

So, today will stop here so, in this particular module we have studied the architecture of the smart grid system. And the corresponding components of this architecture are first one, we have discussed about operation, generation, market and transmission. These are the major domains of the smart grid system and further in the new next slide our next module will discuss about the standards of the smart grid system.

Thank you all.