Introduction to Smart Grid
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Lecture - 04
Standards of Smart Grid System

Good morning to all of you. In this lecture will study about the transmission domain. In the previous section of the module I have discussed about the architecture of the Smart Grid System and here will continue with the transmission domain.

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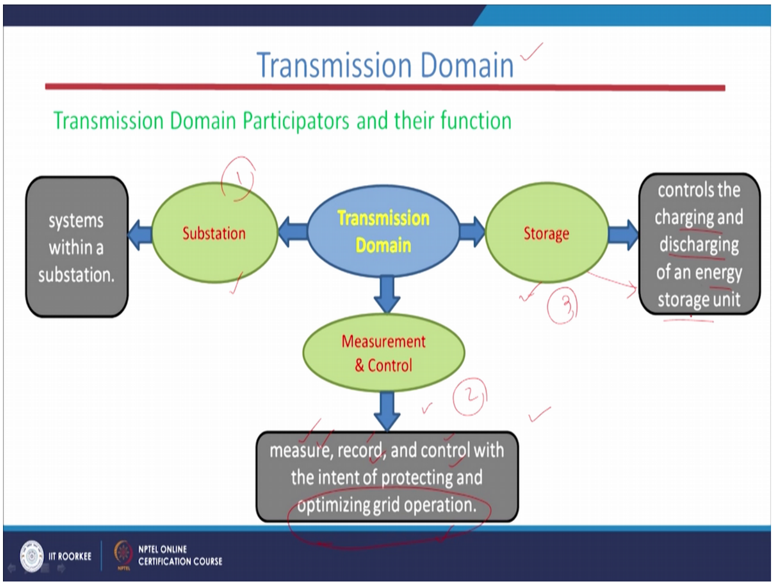

If you see this block diagram of the transmission domain we have 3 parts. The first one is substation, second one is measurement and control and the third one is the storage. What are the functions of this substation?

The substation helps basically in maintaining all the keeping all the equipment's which are used for the transmission system. We have the transformers, we have the measuring equipments, we have protecting equipments metering equipments. So, we can see inside the substation and coming to this measurement and control section of this transmission domain, it basically measure record and control with the intent of the protecting and optimizing grid operation in this case this is very very important this optimizing grid operation.

So, our main aim is to optimize the operation of the grid or optimize the operation of the smart grid. In that case, we have to have a very secured very reliable measuring system recording system and control system and of course, overly we have a very reliable and accurate protecting system inside the transmission domain.

And, coming to the storage part in the storage we have the controls the charging and discharging of an energy storage unit, this is the main function of the storage component of this transmission domain. This storage will help in charging and discharging of this energy storage unit. As, you know that in transmission system, we are transferring the energy and in between also we have storage units, which are installed to store the energy, which is going to be utilized later.

Let us say in the transmission system we are penetrating the renewable sources like solar or wind in the large scale may be more than 2 mega watt, 6 mega watt, 10 mega watt. So, in that case if our consumption is less. So, we have to store the energy. So, for that reason we have this storage facility. Now, coming to the last domain of the smart grid architecture, that is the distribution domain.

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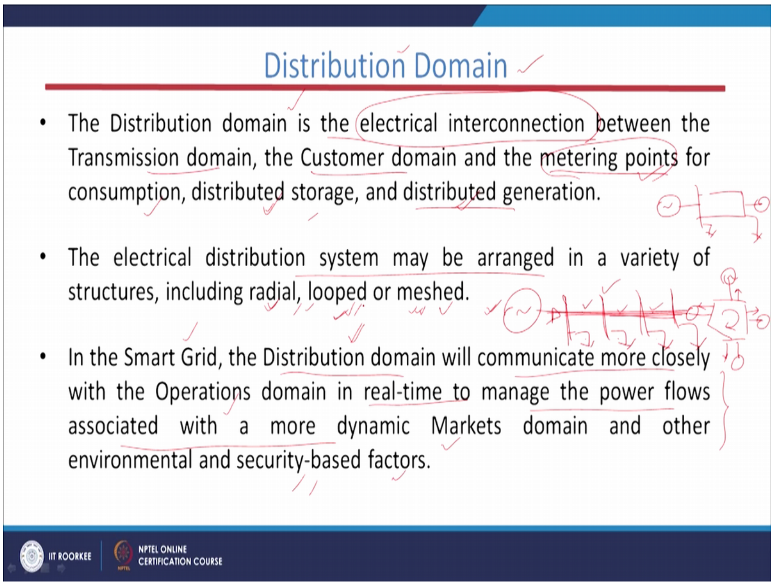

The distribution domain is basically it connects the transmission domain, and the customer domain. So, these 2 domains are connected using this distribution domain.

What is the function? What is the aim of this particular domain? I have kept here 3 points with help of which we can define we can study, what is this distribution domain?

The first one is the distribution domain is the electrical interconnection this is important this is the electrical interconnection, between the transmission domain and the customer domain. These 2 domains are interconnected with help of this distribution domain. And metering points for consumption distributed sources, storage, and distributed generation. This is also important apart from this interconnection between this transmission domain and customer domain, we have also the metering points this is very very important again. These metering points for the consumption were consuming the power; the customer is basically consuming the power, and also the metering facility for the distributed storage and also for this distributed generation.

The distributed generation is nothing our renewable sources, that is the solar system, wind system, or we have like fuel cell system, or we have small hydro systems, micro hydro systems. So, those distributed generations metering systems are also well connected with help of this distribution domain.

Now, coming to this second part the electrical distribution system may be arranged in a variety of structures including radial loped mesh even, if you could see generally our distribution system is radial in nature and also it is looped and meshed. For reliability point of view we have also this looped system and meshed system in radial system, we have only one generating station or source of supply, if this source is disconnected. So, rest of the loads are disconnected, if this is my source and these are the buses where I have loads, here my loads, these are the feeder, this is feeder 1 2 3 and these are the line sections. So, the loads this is bus 1, bus 2, bus 3, bus 4; this is line 1, line 2, line 3, these are load 1, load 2, load 3, load 4.

So, this is my source which supplies power to this loads this is known as the radial distribution system. If you have a loop circuit also, we have also a looped structure, where we have loads and the sources. We have also structure like this may be, we have different buses at different buses, we have different sources or substations and further at every bus we have loads. So, this is a loop system; that means, even if in our smart grid system we are aiming to penetrate the renewable sources or the storage systems, may be it may be radial system, it may be a looped system or it may be a meshed circuit does not matter. So, everywhere we can connect these renewable sources.

The last one is as per the smart grid is concerned this distribution domain will communicate more closely with the operation domains and that is to be in real time to manage the power flows associated with a more dynamic markets domain and all other environmental and security based factors. See I will just simplify this one then what is the meaning of this? Part the last one. It is like this our distribution domain aims to communicate very closely with the operation domain, why? Because, the you know I have discussed in the previous lecture the operation domain is the very large domain, lot many components many functions are basically the part of the operation domain.

So, in that case this distribution domain should communicate this operation domain. So, the communication media and that is in real time, not that in offline will take some data from here and there it will it should work together in real time basis to take some action on real time, not offline basis. And, why it is so, why this access is very essential because, we have to manage the power flows, associated with more dynamic markets, because nowadays the markets should be dynamic it should not be static, as we are aiming the smart grid system. So, our market should be dynamic in nature. It is dynamic means it is changing with respect to time. So, that dynamic market property or dynamic market strategy can be maintained properly, if this distributed domain will interact with the operation domain very closely.

Now, also we have another factor for what we are interested for this is the environmental and security based factors that is obvious because while we are designing something the environmental concern is must. How this environment is secured? That is very very important, it should be eco-friendly it should be environment friendly those actions those operations should be environment friendly and of course, the security based factor is also important.

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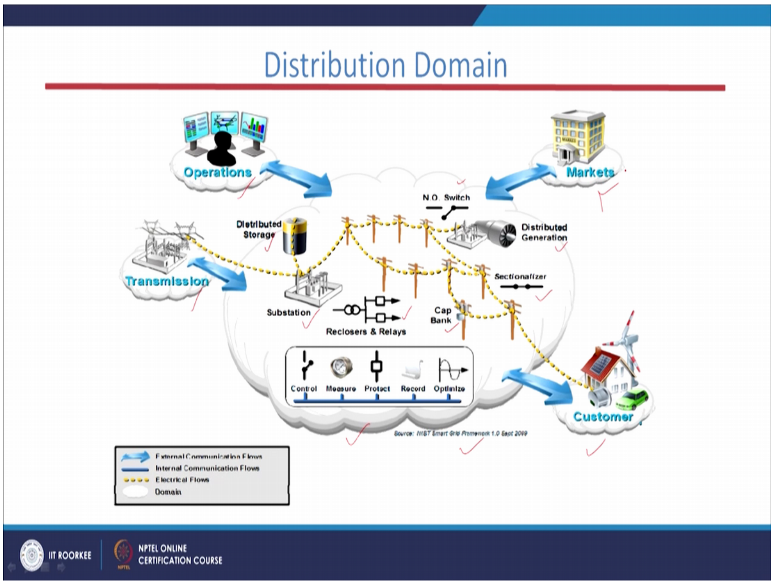

Now, these are the components of the distribution domain these are the substations, we have distributed storage, we have reclosers relays, we have capacitor banks and also we have sectionalizer, we have distributed generation, we have switches. And, if you see here apart from these components the distribution domain also interacts with the operations transmission customer and markets all these domains, for smooth operation of the smart grid system.

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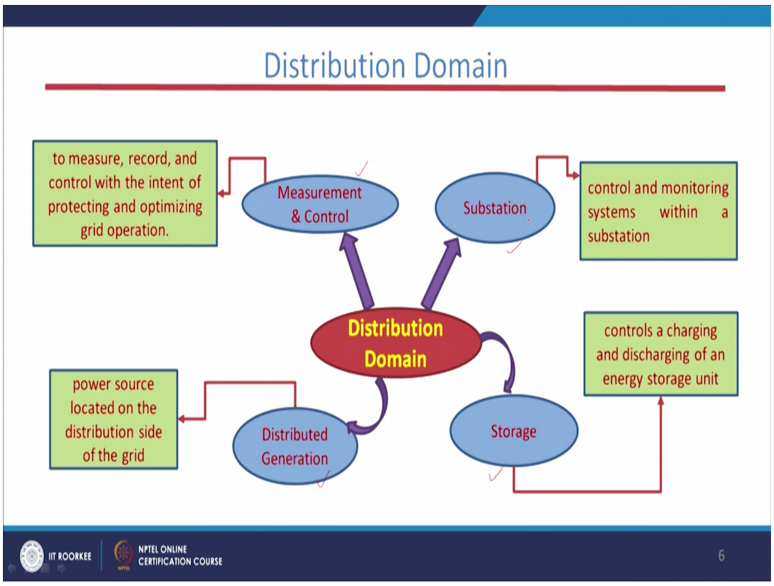

And coming to the this function of the components of the distributed domain, here you could see the measurement control, we have distributed generation and we have storage, we have substation more or less it is equivalent to the transmission domain part.

So, in this particular if you just rewind, if you remember the previous lecture and this part of this few discussions on transmission and distribution domain you could see that, the as far as the architecture of the smart grid is concerned all the domains are interlinked with each other, for smooth reliable accurate and first operation of the smart grid system. So, will now go for the next part of this lecture, that is the smart grid standards..

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We will discuss, what are the standards are maintained for the operation of the smart grid environment.

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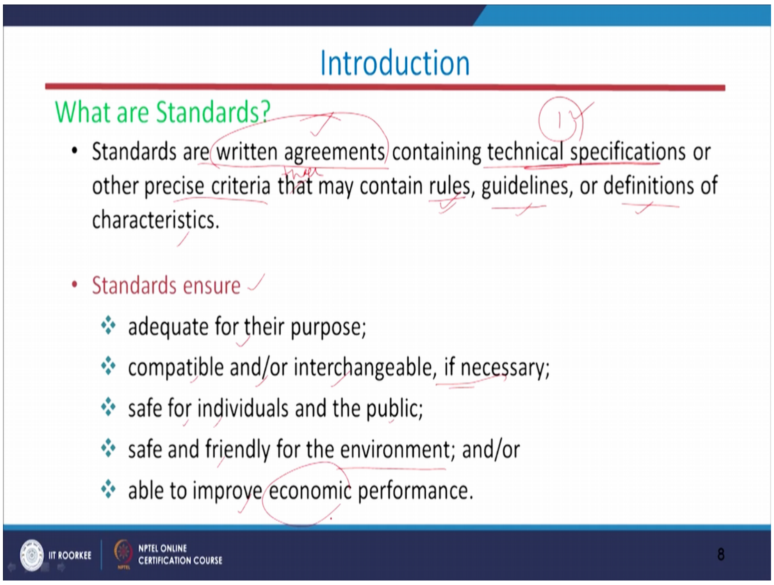

First of all I will define what is the standard? Why we are so, much interested for the standards? Without standards, what will happen? With standards, what will happen? So, the standards are basically written agreements right. So, this is a basically these are the written agreements, containing the technical specification that is first. This particular standard I mean the written agreements, contain the technical specifications or other precise criteria those criteria it should be those criteria may contain rules, guidelines, definitions of characteristics, of what? As I have mentioned here technical specifications rules, guidelines, definitions of what? If you could see the smart grid contents our existing grid or our normal grid system, loads along with that we have renewable sources also we have storage.

For every aspect apart from this we have also control elements, monitoring elements, metering elements, protecting elements. So, all the devices should have certain standardized specifications for their operation. And of course, some rules and guidelines should be maintained while connecting the solar to the distribution network or transmission network, or if you are interested to connect the wind system to restoration network, we should follow certain rules and guidelines, that is what the standard.

And of course, some definitions how the operation characteristic should be? How the curve should be? So, those are the points which will discuss.

And, what is standard ensure? How it helps? The first one is adequate for their purpose, if I am designing some standard solar panel. So, it should provide me the power at proper rating proper voltage, whatever I desire for my operation or whatever we desire in the smart grid system and should be compatible, compatible and interchangeable if necessary. This is the well understood this compatibility without compatibility the connection the operation is not possible. And of course, safe for individuals and the public if we are designing, if you are just framing some rules and regulations standards which is not safe for the public or man power or society then it is not useful.

So, we have to be also careful for this safe for individuals and the public, as a whole for the society. And, yes it should be safe and friendly for the environment that already, we have discussed everything should be environment friendly, it should not destroy the environment and able to improve economic performance. So, everything aims with one term that is economic aspect, if it is not economical. So, we are not going to advise we are not going to implement the standards the rules and regulations which are basically designed for the smart grid system.

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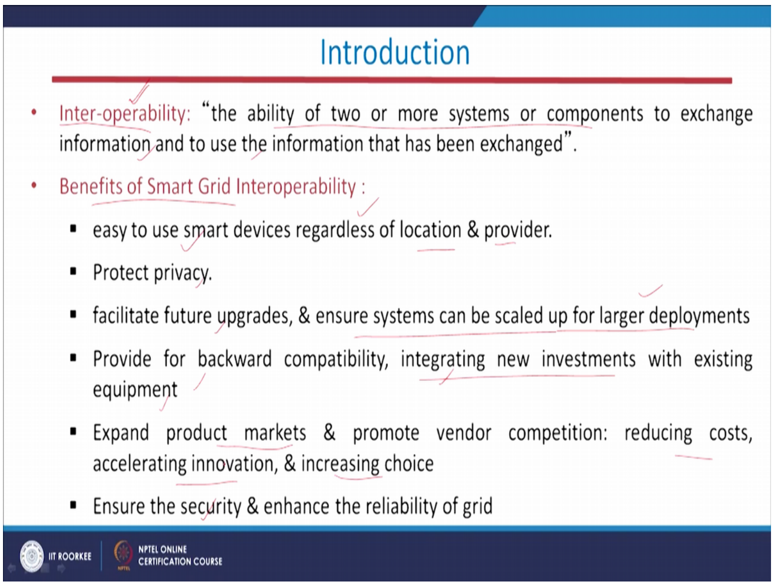

Now, one term is very important that I just want to interoperability this word is very very important. What is the meaning of this particular word? The, ability of 2 or more systems or components to exchange information and to use the information that has been exchanged, I will define the other way like in smart grid system we have different domains, we have different components in inside the domains. Like, we have renewable sources, we have storage, we have protection devices, we have control devices monitoring devices generations generating devices.

So, those devices should speak to each other they should share their data information with each other, they should help each other. So, every kind of like not a necessary I mean the communicational power. So, the data exchange is must that is what this word this particular point tells us.

Now, what are the benefits of these particular interoperability easy to use smart devices regardless of the location and the provider? See, we have a concept now it is coming of multi micro grids the micro grid means, it is the combination of different types of renewable sources storage loads, which is basically intended to for a particular operation? For what we are designing this system it should operate accordingly. So, those we have different types of may be solar based micro grid both solar wind based, we have inverter based where the micro grid, where the solar is present we call it inverter based micro grid also in some micro grid system, we have solar wind storage together.

So, we have also now the concept of multi micro grid system. So, in that case does not matter where is my micro grid micro grid one is present located, where is my micro grid 2 is located. So, we with our communication system we can communicate this 2 micro grids regardless of that is why it is written here regardless of the location and the provider who may be the I mean the owner for this particular systems.

Now, next one is it protect the privacy we have this is important we have to maintain the privacy the data should not be disclosed to the public that privacy can also be maintained. Now, it facilitate future upgrades and ensures system can be scaled up for larger deployments, that is of course, it is very very essential because if you do not know the standard rule regulation and it is operation, we cannot aim for the further scaling of my system up gradation of the system, that is what the larger deployments.

And, next one is it is provide it provides for backward compatibility integrating new investments with the existing equipment, this is also important because while we are just deciding the standards. So, we should know integrating new investments with existing equipment. And of course, the last one I mean I will say this is a the product markets, and reducing cost, accelerating innovation and increasing choice.

It is obvious because in the smart grid system we are expecting that we will satisfy the customer's choice, what the customer needs accordingly we will supply the power to them? Even according to their need time also, what time they need the power at what cost? So, everything should be automatic it is not so, easy, but we have to basically frame the control algorithms in such a manner that, we have to make we have to make the standards in such a manner that will satisfy the customers in time.

And, ensure security and enhance reliability of the grid that is also the function of this interoperability which is part of this standard. Now, the security and enhance the reliability this 2 are always essential components right.

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So, now, I will come to what are the institutions basically these are the institutions, which provide us the standards standard development organizational call it that is SDOs.

The first one is national institute of standards and technology that is that is stand for NIST. And the second one is American National Standards Institute that is ANSI. And, the third one is International Electrotechnical Commission that is IEC. And, the fourth one is Institute of Electrical and Electronics Engineers that is I triple E.

And next International Organization for Standardization, that is ISO and the last one is International Telecommunication Union ITU. This telecommunication union is very very important, because the main backbone of the smart grid system is the communication system. So, for standardizing the communication network operation we need some union. So, that union is international telecommunication union it stands ITU.

If, you see the as far as the classification is concerned the classification of the smart grid standards.

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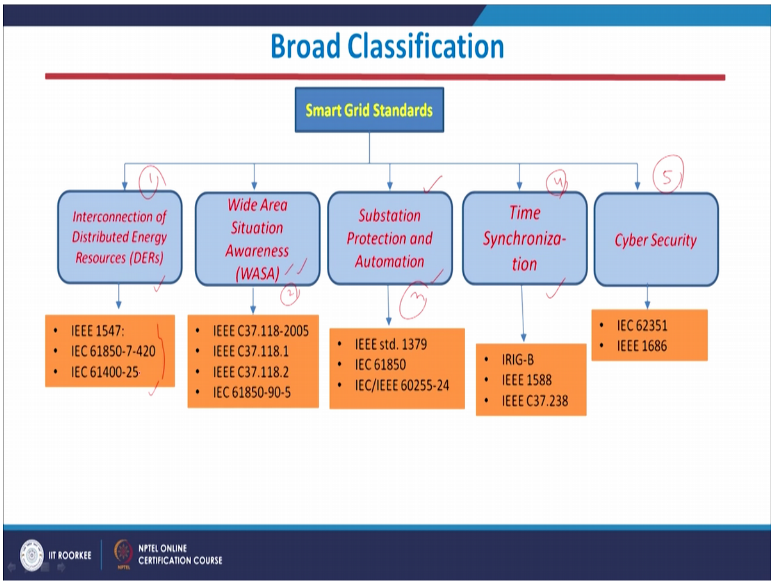

Here it is the first one is the interconnection of distributed energy resources. Some in some papers in some standards or booklet or books it is referred as distributed resources or in some case it is also written as distributed energy resources does not matter. These 2 words are equal I mean there is no difference, in my lecture I may also tell DERs and sometime DER also. So, this DER also stands for this distributed energy resources.

Now, the first one as I said is the interconnection of distributed energy resources, the second one is wide area situation awareness it is WASA. And the third one is substation protection and automation and fourth one is time synchronization and the fifth one is cyber security.

Broadly these are the broad classification of the standards of the smart grid, we have many standards, but I have kept in front of you few standards. And broadly these are the major areas where the standards are very essential, while we are connecting this (Refer Time: 23:26) to the adjusting network may be it is transmission distribution generation. So, we have to follow the standards.

Similarly, well go for wide area situation awareness. So, we have also follow the standards and yes of course, this is essential substation protection automation there also we follow some standards. Those standards are basically written here you could see here in this small box like I have written for this first one the interconnection of distributed energy resources, that is basically there are 3 lines I have written here; first one is I triple E 1 5 4 7, second one is IEC 6 1 8 5 0 7 4 2 0 and similarly others also. These are the guidelines these are standard booklet us or books where everything is written how to connect, how to operate, how to maintain the things properly in smart grid system?

Now, I will just describe the interconnection of distributed energy resources that is DERs.

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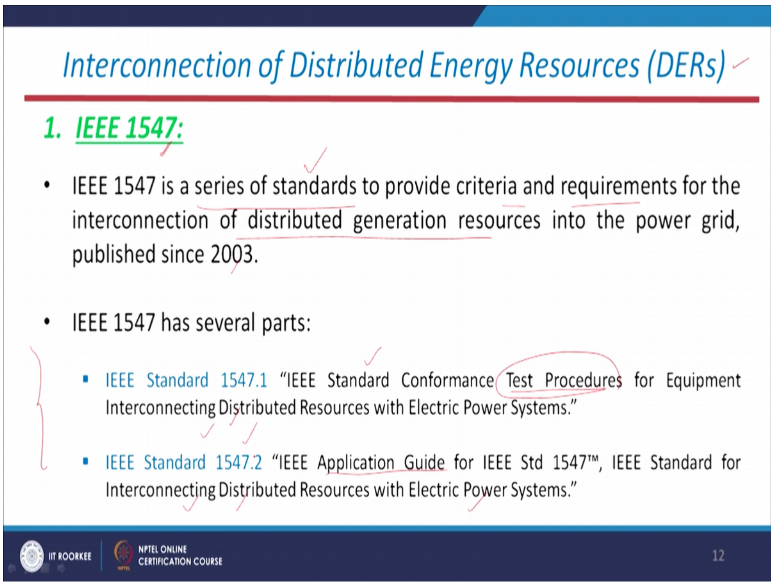

What are the terms and conditions how it should be? This I triple E 1 5 4 7 series is used for interconnection of distributed energy resources, standards are retained in this series I triple E 1 5 4 7. This is the series of standards as I said we have 1547.1 0.2 0.3 0.4. So, on is a series of standards and this standards provide the criteria or requirements for the interconnection of distributed energy resources, into the power grid and these standards are basically published in 2003.

And if you see the pdf files of I triple E 1 5 4 7 standards are available in the I triple E website, you can also download and you can see lot many information, you will get from there, but briefly I will discuss here few things. This starts the first one 1547.1 it is the standard I triple E standard, which provides the test procedures. It provides the test procedures for equipment interconnecting these DERs to the electric system. What are the test procedures? We should maintain before connecting the equipments of I mean, which will see the equipment which connects, the DER to the, I mean to the power network. So, those test procedures should be followed before connecting the DERs to the distribution network or transmission network.

And the 1547.2 it describes this is basically the application guide and it provides the interconnecting distributed resources with electric power systems. How, these electric distributed resources should be connected with our existing power systems? Those rules regulations are written in this 1547.2.

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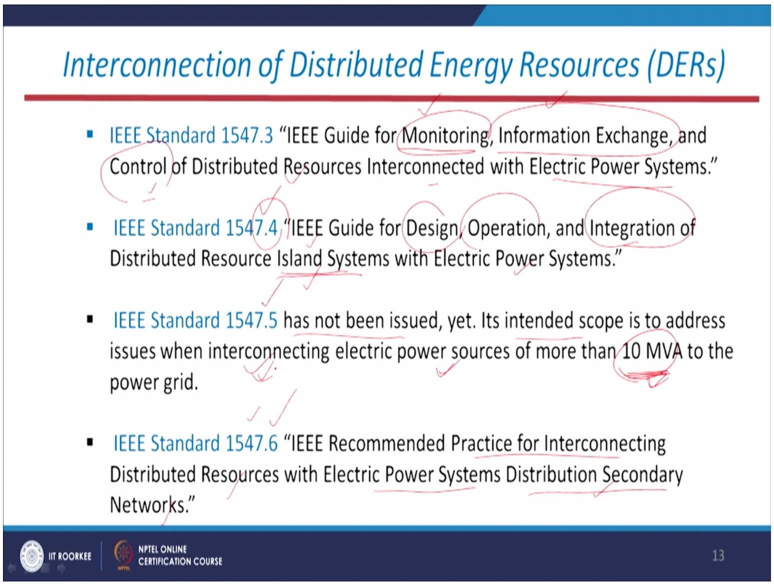

And similarly our next series that is 1547.3, it provides the information about the monitoring information exchange and control of this DERs interconnected with electric power system. The 3 things one is monitoring information exchange and the control aspects of the distributed resources or DERs, which are basically going to be connected to the adjusting system.

And, the fourth one the fourth series tells about the design, operation, integration of DERs Island systems, here one more point has come extra, I mean it is new basically; Island means the island system means the distributed energy resources, which are disconnected from the main grid. Those DERs or those micro grid systems are called as Island systems.

Because, you know in a smart grid system we have micro grids micro grid is a part of the smart grid system, this micro grid is basically connected to the main grid if the main grid is absent. So, in that context I mean during that period the micro grid is basically islanded for the main grid, that is what the Island system with electric power system disconnected it from the main grid. So, those design operation and integration of distributed resources island systems are discussed in our fourth standard.

Now, the fifth one has not been issued it is basically under process. And, it is intended scope is what it is to address the issues with interconnecting electric power sources more than 10 MVA, this is the target of this particular standard. The fifth series that is our I triple E standard 1547.5 it aims to provide the interconnecting rules, where the electric power sources are more than 10 MVA those rules are under process.

And the sixth one is basically recommended practices for interconnecting the distributed resources with electric power systems, with distribution secondary networks, we have primary network, we have secondary network. With the secondary network how to connect the DERs so; those rules are basically described in 1547.6.

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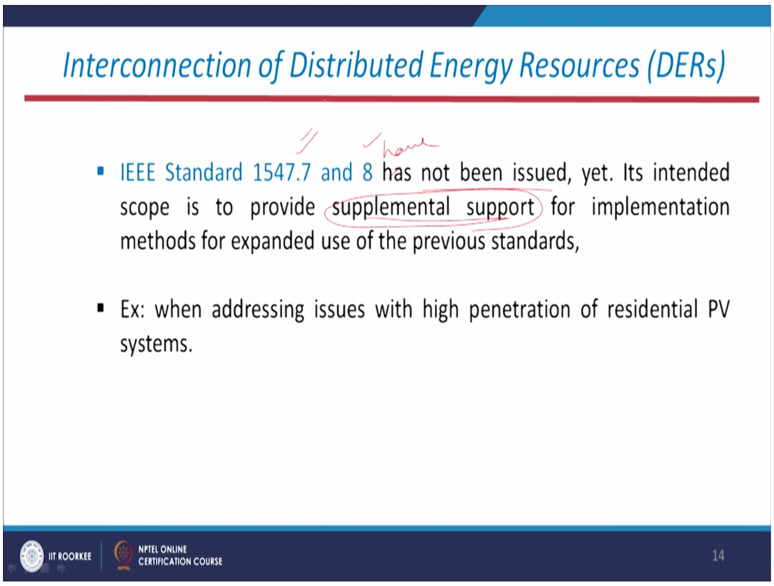

And, similarly we have 7th 8th series and the 7th and eighth series have not have been issued yet. So, it is intended with basically provide the supplemental support, the supplemental support is basically expected from this 7th and 8th.

Now, so, these are the few rules I mean the standards of I triple E standard 1 5 4 7 series.

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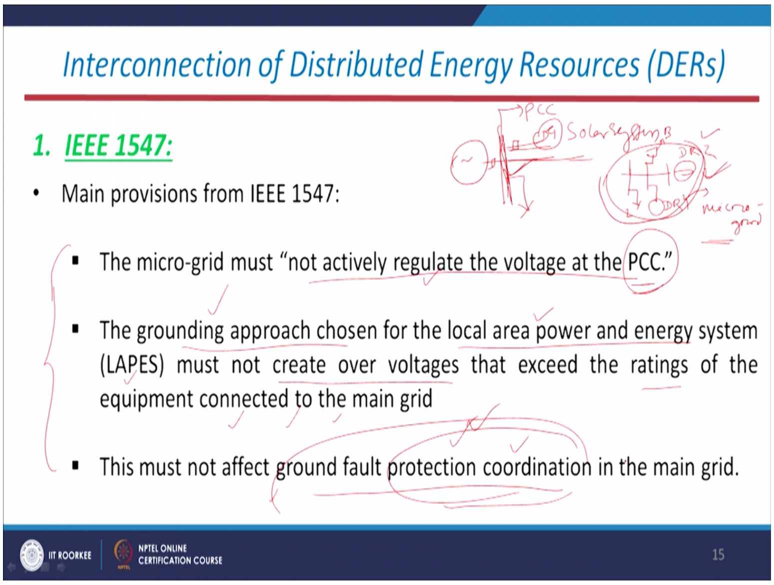

Now, I will just tell very important points these are the important points as far as the 1547 is concerned. The first one is the micro grid must not actively regulate the voltage at the PCC. What is the meaning of this? I will just draw a very simple diagram, if this is my grid. And here is my few loads and at this point I will connect one solar system solar system so, this DG or DER, which is connected to this particular grid.

So, this bus is known as the PCC, PCC. This PCC stands for point of common coupling this PCC stands for point of common coupling, it refers or it states that the bus where the connection point where the DG is connected to the grid or DG and the grid both are interconnected that is known as PCC.

Basically, what this standard says this micro grid we have micro grid means we have different DGs DG 1, we have also DG 2, we have different loads. So, this small micro grid system we have also storage. So, those equipments I mean together is called as micro grid system this is my DR 1 and this is my DR 2, this is DR 1, this is DR 2, it may be a solar system it may be a wind system and this is my battery storage and this is my load. So, those equipments together consists micro grid we call it micro grid. So, this micro grid should not regulate the voltage at the PCC, this is very important this is one of the important guidelines of I triple E 1 5 4 7 series.

And, the next one is the grounding approach should be chosen in such a manner that the local area power energy system, that stands for LAPES must not create over voltages. And, which is going to exceed the ratings of the equipment connected to the main grid, this is also another vital rule for the interconnection of the DERs to the existing system.

What is that? Again I will just explain I want to explain that we have to maintain the grounding approach, because basically we have star connected loads star connected sources. So, we have to choose in the star connected system the grounding system in such a manner that, those grounding systems should not affect local area or energy system. Local area power energy system means the small micro grids itself may act as a local area power energy system. Locally how much power and energy we are getting from the DERs or batteries. It should not create must not create over voltages, that may exceed the rating of the equipment connected to the main grid so; that means, of the main grid we have inside the main grid we have many equipments.

So, we should choose in such a manner the grounding system of the local area and energy system. So, that it should not create any over voltage, over voltage means the voltage may increase the rated values of the equipments of those equipments, which are installed inside the main grid that is also one of the important standard for this particular interconnection of the DERs of the smart grid system.

Now, this must not affect the ground fault protection coordination. In one of our lecture series we will also concentrate on this protection coordination or ground fault protection coordination will discuss. Basically, in the ground system also we basically we connect the protection devices. So, those devices should be coordinated with each other properly, if any disturbance is going to be inserted inside the smart grid system. That is what is this the meaning of this particular word this I mean this sentence, that this must not affect the ground fault protection coordination in the main grid system.

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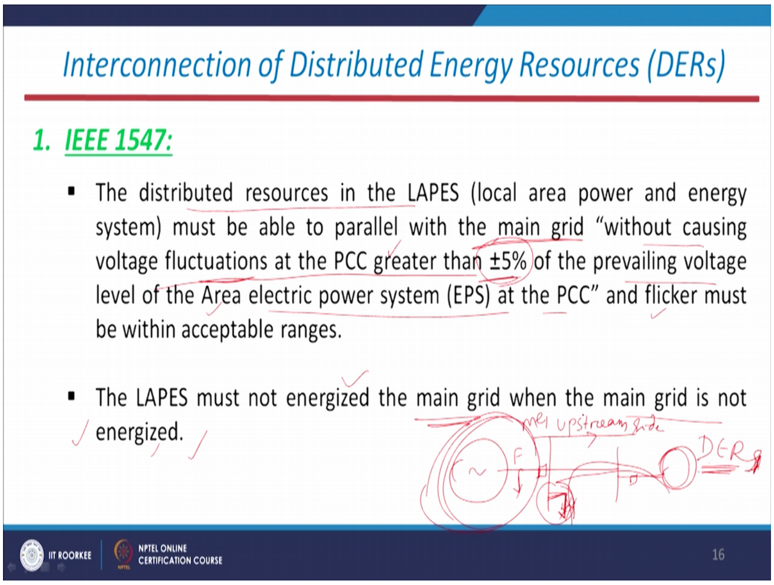

And, this is also another point I just want to mention that, we have to this distributed energy resources in the local area power energy system that is LAPES must be able to able to parallel with the main grid, it should operate properly with the main grid, without causing voltage fluctuations at the PCC; greater than plus minus 5 percent. So, will connect the DERs may be the solar system or wind system to the existing grid in such a manner that this voltage fluctuation at the PCC bus should not exceed plus minus 5 percent on the rated value, or of the nominal value that is what the one of the standard for this I triple E 1 5 4 series 4 7 series.

And, the prevailing voltage level of the area electric power system at the PCC. And, the flicker must be within the acceptable limit flicker is basically one of the power quality issues, we have voltage sag swell flicker voltage interruption. So, this flicker is one of it. So, will connect those DERs in such a manner that it should not create any flickering at the PCC bus and also the voltage fluctuations should not exceed plus minus 5 percent of the nominal value, at the PCC bus. As, we have discussed the PCC means the bus where the DERs are interconnected or connected to the main grid PCC is a connection point.

Now, the last one is also important that is the LAPES is local area power electric system energy system must not energized the main grid when the main grid is not in function or it is not energized. Let us say due to some upstream fault the main grid is out of service upstream fault means, if this is my grid and this is these are some loads and here 1 DER 1 DER is connected 1 DER DERs means distributed energy resources.

So, 1 DER is connected to the main grid due to some fault at this terminal at the grid side main grid side this is my main grid. So, this main grid may be disconnected from my rest of the network this as we expect the main grid is supplying power if the power flow is like this. So, we may call it upstream site this is my upstream site the power is flowing from left to right the left side is upstream and the right side is the downstream.

So, in this case if any fault occurs one fault is inserted on the grid side. So, the grid is going to be disconnected from the rest of the network, otherwise the fault current will also penetrate it will propagate to the rest of the network and it will damage the equipments. So, that is why when it is disconnected the main grid is disconnected then the rest of the micro grid system, which are in operation should not energize the main grid. Otherwise, let us say this, what will happen, what is the consequence if it will happen?

So, what will happen if these are the loads of the grid side? So, if let us say this grid is out of service and this loads are if this particular micro grid this particular DER will supply power to the, this load the people who are working here. So, they will get some shock because they know that the grid is off, but; however, due to the DER power availability the power will flow to this the current will flow to this load to these loads.

So, that is what the thing? So, that is what the last one the LAPES must not energize the main grid when the main grid is not energized.

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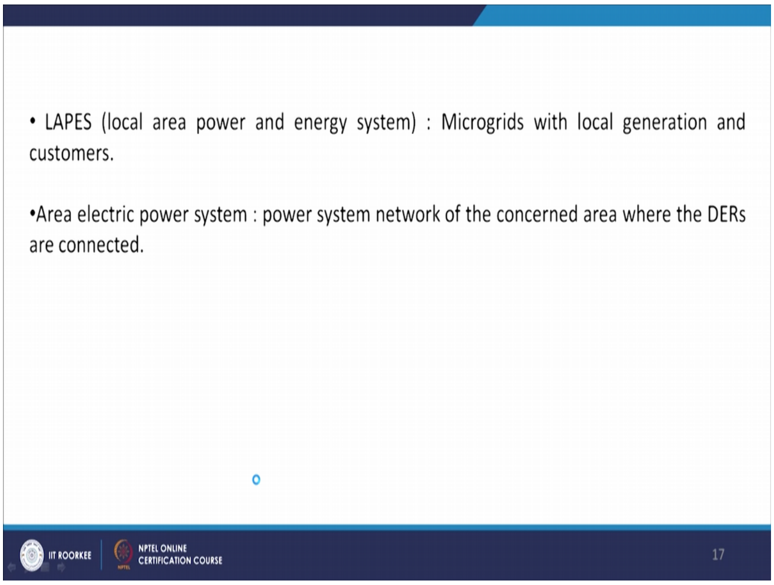

This is how the definition I have kept what is LAPES and what is this area electric power system?

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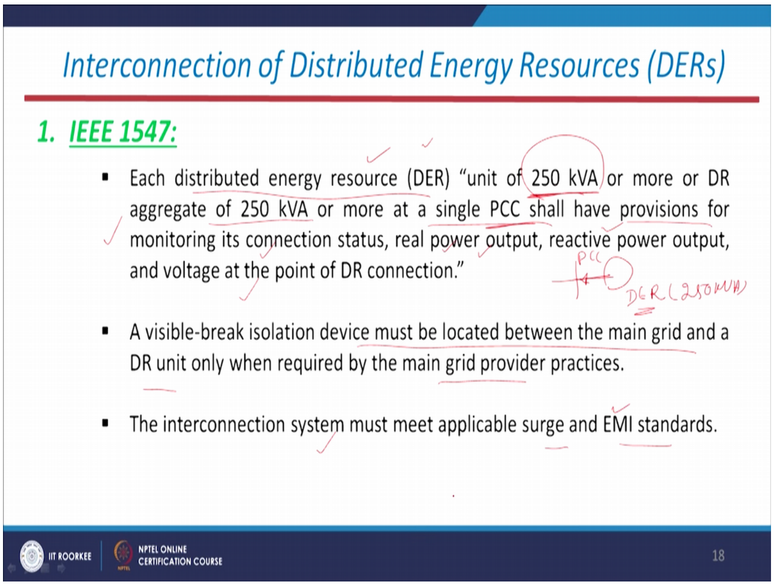

This is another point here another standard rule you can say that each distributed energy resources, resource or DER unit of 250 kVA this is the rating of this DER or more or the DR aggregate of 250 kVA or more at a single PCC cell have provisions for monitoring it is connection status. This rule says that if at certain PCC we are connecting the DER and the rating of this DR is 250 kVA. So, in that case this DR should have I mean the single

PCC cell have provisions for monitoring, it is connection status real power output reactive power output voltage at the DR connection.

This DR should have that information of how to record? How to store? How to monitor? How to basically store? The status of these quantities like we have voltage, we have frequency, we have output power reactive, we have active power all those factors I mean the quantities this DRS should have that facility.

And, next the visible break isolation device must be located between the main grid and the DR unit when connected, when it is required by the main grid provider some connecting device should be present between the DER and main grid system that is also very important. The interconnection system meet should meet the applicable surge and EMI standards, electromagnetic interference standards.

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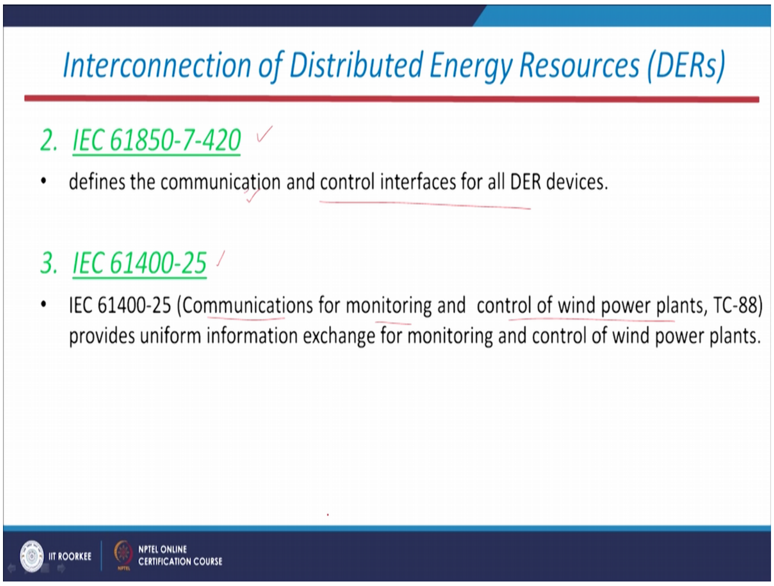

So, these are few other things apart from this 1547 series I triple E 1 5 4 7 series the pdfs are available in the I triple E website, we can have a look because lot many standards are lying many rules many regulations are there. So, we have to be within I mean few things we have we have discussed which are very very important.

And here few things I just want to discuss that is IEC 61850 7 420, it defines the communication and controlling interference for all the DER devices. It is basically communication protocol packets or standards or rules and regulations. How to communicate? How to interface? All the DER devices through the communication medium to the main grid that is what written in this IEC 6 1 8 5 0 module.

And, this next one this IEC 6 1 4 double 0 2 5, it helps what is the information it contains the communications for monitoring and control of wind power plants, because in a smart grid system we have wind power plants we have solar power plants and also we have fuel cells we have batteries. So, those equipments are basically upcoming equipment upcoming generation or storage systems. So, how to control, how to communicate, how to monitor? So, those rules should be defined within some standards, I mean the standards are released for that purpose that is TC 8 8, which provides information exchange for monitoring and control of wind power plants.

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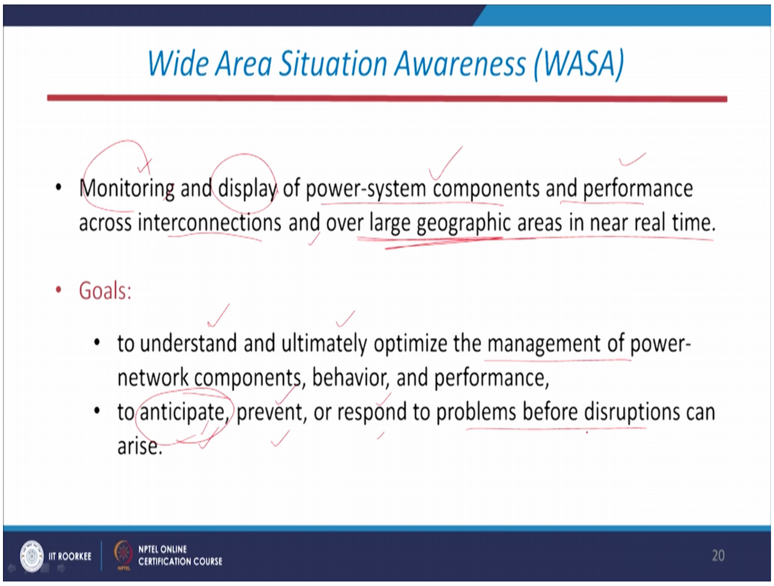

So, first part of the standard is over here that is our how to connect the DER to the adjusting network and here will discuss about the wide area situation awareness that is WASA.

The aim of this particular standard is to monitor and display of power system components and performance I will say 3 things here important one is from monitoring aspect, one is display of power components and the performance. Where the this equipments DERs connected to the existing system and across the interconnections over large geographic areas in near real time. See these large geographic areas this is also important, because our system is very large geographically it is distributed everywhere.

We have northern grid we have southern grid we have eastern grid we have western grid northern eastern grid. So, this 5 grids and it will tell about what is single grid may be it is northern grid. So, we have to monitor all the generating stations, all the distribution systems, all the transmission, all the loads. So, all the renewable sources so; that means, it is a very large network where aiming to monitor it is operation behavior and the performance.

So, for that case also we have certain rules and regulations, guidelines, and which is going to be followed and the goal of this particular module or standards to understand all ultimately optimize the management power network components, behavior, and performance, and to participate to prevent, respond to problems before disruptions can arise this is very very important.

To anticipate and also prevent or respond the problems, before disruptions can arise if you could remember there is a blackout in India in 2012 July 30 31st, one of the line which is basically connecting to Bina to Gwalior 400 kv line. So, one distance relay was mal operated June 3 distance relay was mal operated. So, due to that line was out of service as a result other lines are overloaded. And subsequently there was cascading failures of lines and this system basically, that condition was called as blackout system the power supply was not available power supply was not there in the northern grid north east grid even the eastern grid also.

That means the 3 grids under blackout. So, if you could have a very good standards, very good equipments, with help of which we can monitor the system accurately may be this kind of this type of major disturbances, we can check, we can prevent or if you can just anticipant I mean we can anticipate beforehand this is going to happen. So, that case we can take some actions. So, that this kind of major disturbances should not happen again and again, that is what the meaning of this wide area situation awareness system should anticipant and prevent and respond the problems and before the disruptions can arise that is what the meaning.

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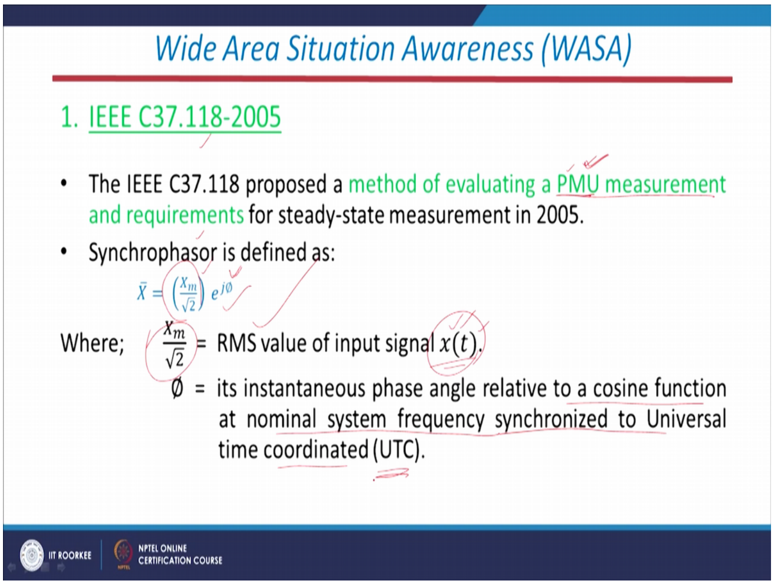

Here there are some standards the standard name is.

Here there are some standards the standard name is I triple E C 37.118 and this standard basically has been framed in the year 2005 and this is basically designed for PMU measurement. This word stands for the PMU stands for phasor measurement unit, phasor measurement unit basically it is a part of the wide area measurement system it is an it is an equipment, which measures the sequence components of voltage and current and as well as it measures the frequency, will discuss in our equipment part and monitoring part of the smart grid system will discuss in more detail about this PMU, what is that PUM?

What is the function of the PMU? And for this PMU measurement also we have some standards, basically this PMU provides all the information voltage current frequency information. So, that is why the standards are basically meant for these PMU measurements.

And, in some terms this PMU is also known as synchrophasor because the PMU operation is basically in synchronization with the universal time clock. So, that is why this is known as also this is also known as synchrophasor. If, you just see this expression there is x bar is equal to x m upon root 2 into e to the power j phi where this x m by root 2 is RMS value of the input signal, this input signal x t may be a voltage signal or it may be a current signal, which is basically the time dependent x t is a function of t.

And, this x t is basically the instantaneous signal, if I want to write this x t in phasor domain. So, I will write x bar is equal to x m by root 2 this is the RMS value and this is the phase angle value this is the magnitude part and this is the angle part. So, it is what it is written here x m by root 2 is the RMS value and phi is it is instantaneous phase angle relative to a cosine function.

See, when we talk about the phase angle we should have a certain reference point. And in this case the reference point is to a cosine function at nominal frequency system frequency synchronized to the universal time coordinated. This UTC is basically the major part of the PMU system or WAMS wide area measurement system, that is the reference point with respect to that the angle phase angle of the voltage and current basically calculated or estimated inside the PMU.

In this section will see that that is I triple E C 37.118 which tells about the TVE.

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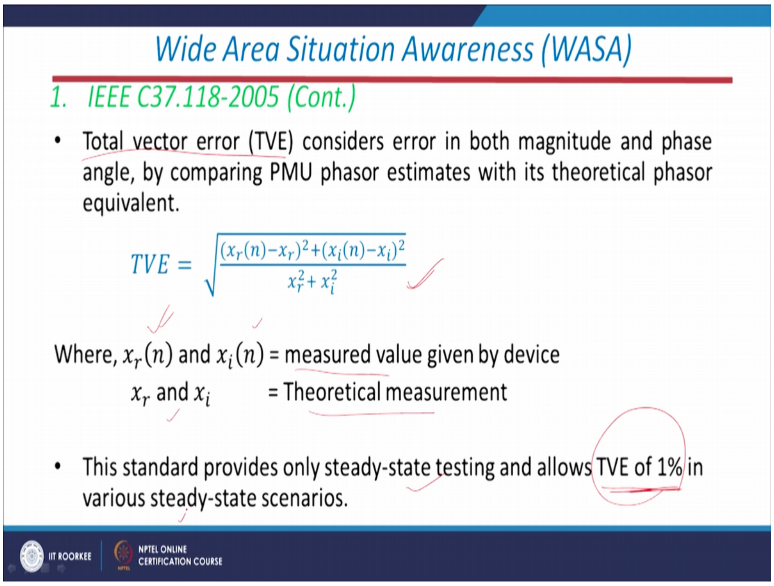

The TVE stands for total vector error this is TVE see every device has some error when the device operates some error is there. So, we should have some standards for that what should be the range of those errors I mean it should not exceed certain label sub figures should be defined for that so, that in PMU also we have some error and that is total vector error.

The mathematical expression for this TVE is like this x r n minus x r whole square plus x i n minus x i square divided by x r square by x i. What is this x i x r and x i n x r n stands i mean this x r n basically the measured value by the device x i n, and this x r and x i are the theoretical measurement. Now, this standard provides a steady state testing and which allows this TVEs within 1 percent remember this TVE is allowed upto 1 percent and that to in steady state scenario this is not in transit phase it is in steady state phase.

And, similarly we have another part that is I triple E C 37.118.

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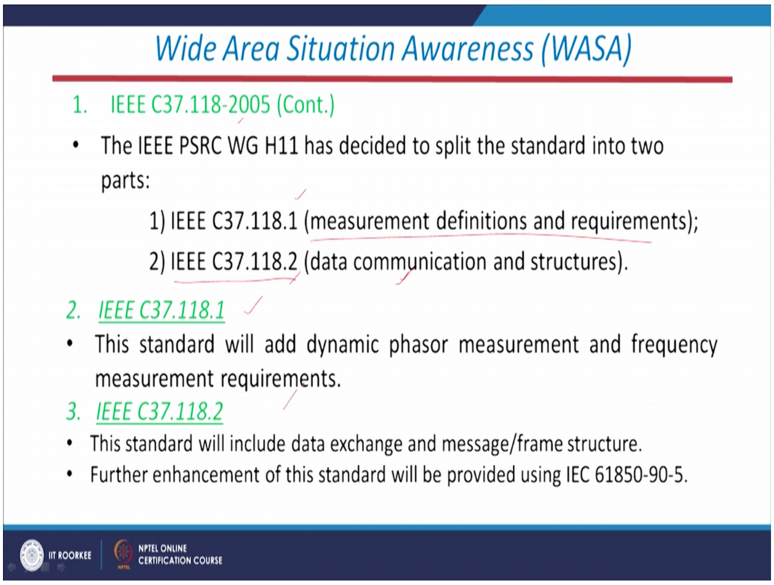

And, basically this particular is splited into 2 parts 118.1 118.2 that is the measurement definitions the first one tells about the measurement definitions and requirements, and the second one tells about the data communication and structures. You know the PMU measures the voltage and current and also inside the PMU the sequence components phasors of voltage all are computed inside or estimated inside the PMU. And to transfer those data I mean the phases or may be sequence components or voltage and current to different other devices or stations we the PMU needs the communication infrastructure.

So, those data communication structure should be defined. So, this I triple E C 37.118.2 helps for that, and we have that is what I have just written here?

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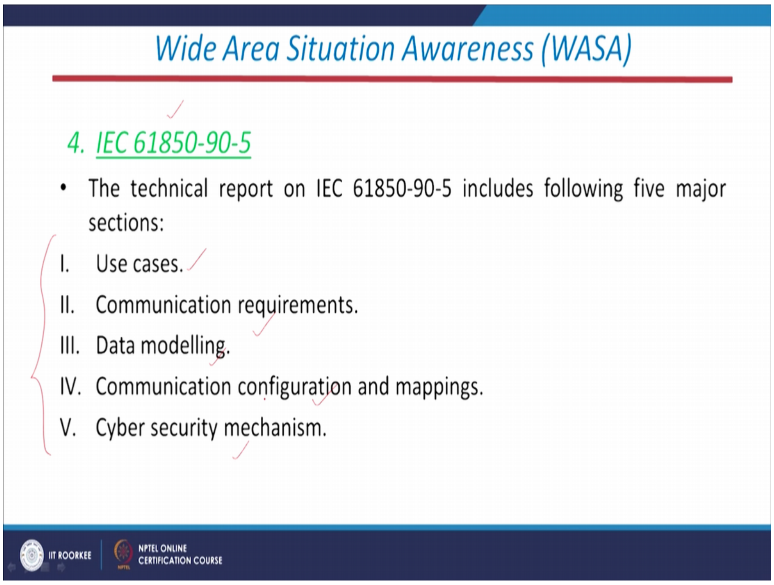

And, another one is this IEC 6 1 8 5 0 that is basically it includes this 5 things. Use cases and communication requirements data modeling and this communication configuration mapping and cyber security mechanism. Those ratings and those data what should be the data the bandwidth what should be the frequency range? So, those informations are available in this pdf file. And this is the third one that is the protection and automation.

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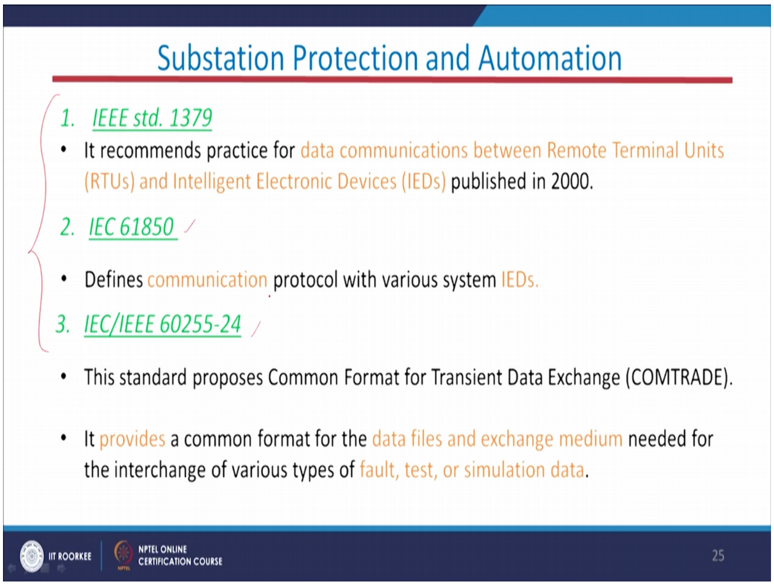

And here I will just quickly tell that 3 3 modules, 3 standard modules are used the first one is I triple E standard 1 3 7 9 and second one is IEC 6 1 8 5 0 and third one is IEC 6 0 2 5 5 2 4.

So, basically all these modules are designed for substation protection and automation all the standards rules and regulations are mentioned in this particular. All these standards and it is written very clearly how to protect, how to do the automatic operation of the substation? And the last 2 I will just quickly compile that is the time synchronization.

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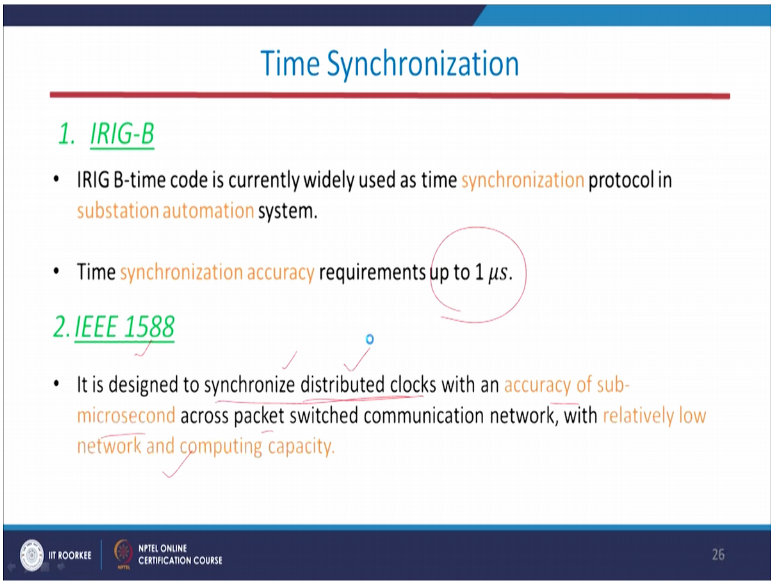

The time synchronization requirement is upto one micro second and this I triple E 1588 is designed to synchronize distributed clocks with a accuracy of sub micro seconds, across packet switched communication network with relatively low network and commuting capacity.

So, our target I mean in standards basically the target is to have the more data will transfer will be transferred with I mean smoothly and yes with a synchronization, the synchronized synchronize the distributed clocks this is very very important.

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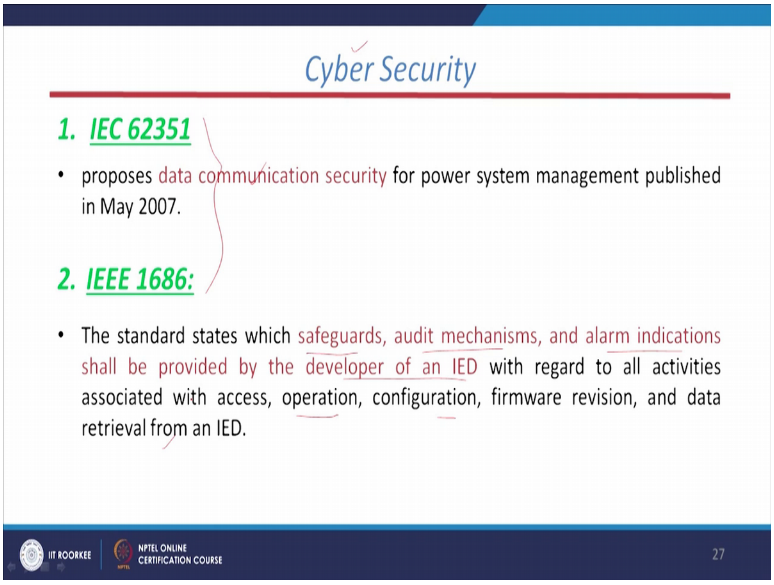

And, this IEC is part of the cyber security this is my last standard and this 2 these IEC and 6 2 3 5 1 and I triple E 1 6 8 6 this 2 are dedicated for designing the first one will design the data communication security. And the second one provides the safe guard audit mechanism alarm indication, and which is shall be developed for the developer of IED with regard to all the activities associated with operation configuration and data retrieval from 1 IED.

IED means Intelligent Electronic Devices. So, those devices are present in the smart grid system. So, how to retrieve the data how to record the data what should be the communication rate. So, those information we can get from this 2 standards.

So, this is all about as per the standards of the micro grid or smart grid I mean are concerned. So, here in this module we have discussed about the few parts, which are left from the architecture of the smart grid those are the transmission domain and distribution domain we have clearly distinguished, what are those? And next we have discussed the standards like from the, I triple E standards and also IEC standards, which are dedicated for the making the rules and regulations of the smart grid system.

Thank you all.