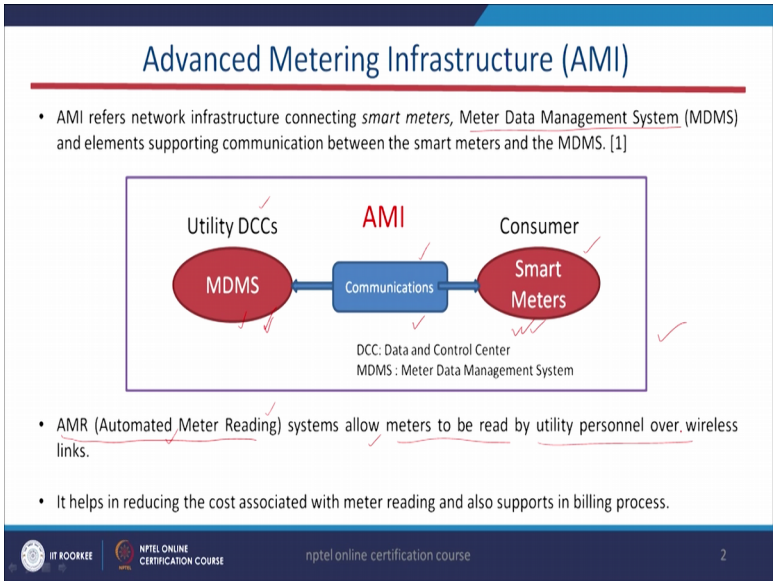
Introduction to Smart Grid
Dr. Premalata Jena
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 05
Elements and Technologies of Smart Grid System – I

Good morning to all of you. Today we will talk about the smart grid elements and technology. First in this lecture, I will discuss about the advanced metering infrastructure.

(Refer Slide Time: 00:51)



Coming to this AMI basic block diagram; you will see here that it consists of three components. The first one is the MDMS. This MDMS stands for Meter Data Management System and the second one is the smart meters which is basically a located in the consumers periphery or premises and this MDMS basically present inside the utility DCC's. And this is the data control centers which is basically present at the periphery or the premises of the utility

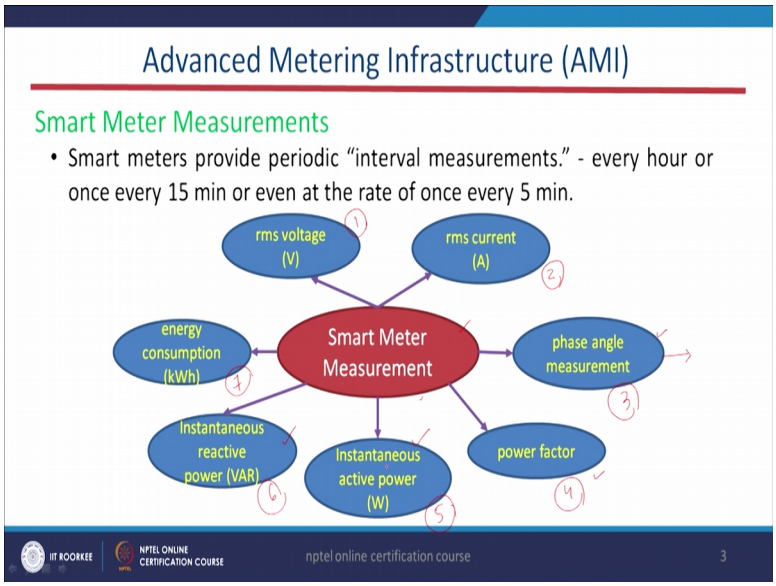
And this two components, this two blocks this MDMS and smart meters are connected with each other or they communicate to each other with help of a communication infrastructure. So, this is how this very basic block diagram works as far as the advanced metering infrastructure of the smart grid system is concerned. This is very important component or you can say technology of the smart grid system.

And apart from this AMI, we have also AMR. This AMR stands for Automated Meter Reading. What is the function of this AMR? This AMR systems allow meters to be read by utility personnel over wireless links.

What is the meaning of this? Basically inside the customer, we have the energy meters. We have the smart meters. So, those smart meters readings, we have to read; we have to collect the data from those smart meters. So, for that purpose this automated meter reading system allows; if suppose any personnel will reach near to the customer premises. So, from there itself by wireless communication, we can read the data of the meter which is basically located inside the customer premises. That is what this AMR does.

Now, also with help of this wireless communication of these smart meters to the AMR system, we can reduce the cost because it is a wireless medium. If it is wired medium, so it will demand more cost. So, that is what it helps in reducing the cost associate with the meter reading and also supports the billing process. Automatic the smart meter readings will reach to the person. That is a very great benefit, great technology or you can say great facility as far as the smart grid is concerned.

(Refer Slide Time: 04:02)



Now, the next will talk about what are the measurements we basically obtain from the smart meter. The first one is the RMS voltage and the second one is RMS current and third one is phase angle measurement. This phase angle basically we talk about the angle

between the voltage and the current of the particular network or customer network where the loads are connected. So, this phase angle also measured with help of this smart meter and the fourth one is the power factor which is very very important for us. As far as the customers are concerned, the power factor has a great meaning. So, this power factor can also be measured with help of the smart meter.

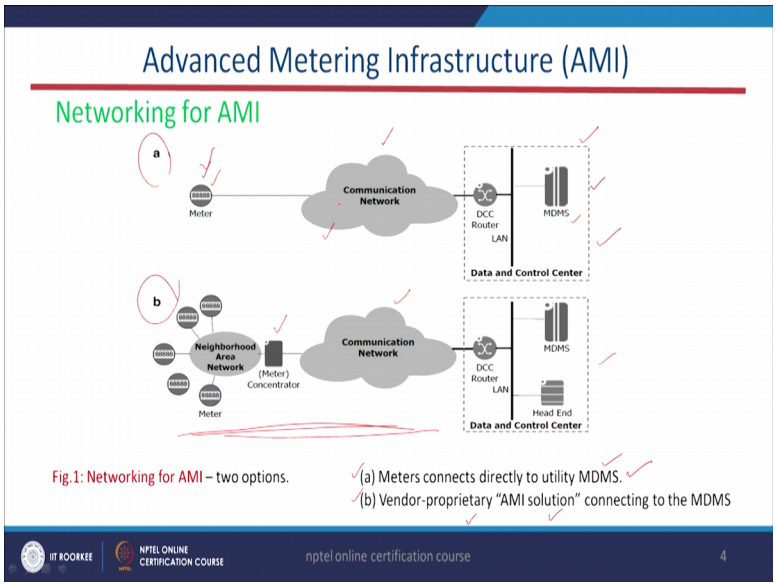
And the fifth one is the instantaneous active power; how much power is basically consumed by the customer that can also be measured using this smart meter infrastructure or smart meter device.

And the sixth one is the instantaneous power, reactive power. We have two powers basically we are talking about here; one is the instantaneous active power and the next one is instantaneous reactive power. So, these two powers we can also measure using the smart meter technology. And the last one is the energy consumption which is very very important for us; for the utility also for the consumers. So, how much power how much energy is consumed by the customer that is our target. So, that particular energy can also be measured using this smart meter that is the basically the target.

So, extra parts what we are getting here; this RMS voltage, current, phase angle power factor, this instantaneous active power, reactive power. So, those I mean the fundamental quantities or the derived quantities, we can use for further necessity. We can use for further actions; that is what the very important benefit or advantage of smart meter. We should use, we should encourage the customers. They should be trained, they should be encouraged to use smart meters inside their premises.

Now, this is the networking for AMI. We are talking about presently the advanced metering infrastructure of the smart grid system. As far as the network of AMI is concerned, you can see here; I have just taken two figures. I mean two sections basically figure a and figure b.

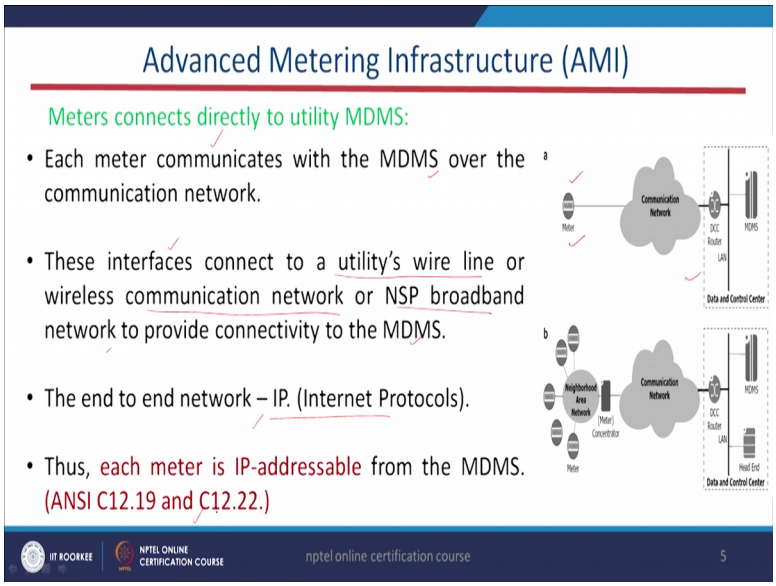
(Refer Slide Time: 06:47)



What is this figure a? The figure a tells that the meter, the smart meter is connected directly to the data control center or to the MDMS. So, which is this is the utility side and this is the customer side. This two meter basically this two devices like meters and the DMS are connected using a dedicated communication network. So, this kind of fashion of architecture or infrastructure is known as meters connect directly to the utility MDMS type. It is direct connection.

And second one is the vendor proprietary AMI solution based connection what is that? In this case if you could see here from this figure that here, there are more number of smart meters basically which are connected to the meter concentrator and again through the communication network, where connected to the MDMS of the utility section. This is this architecture this configuration is different than earlier one and will talk about more all the component what are the functions of each components.

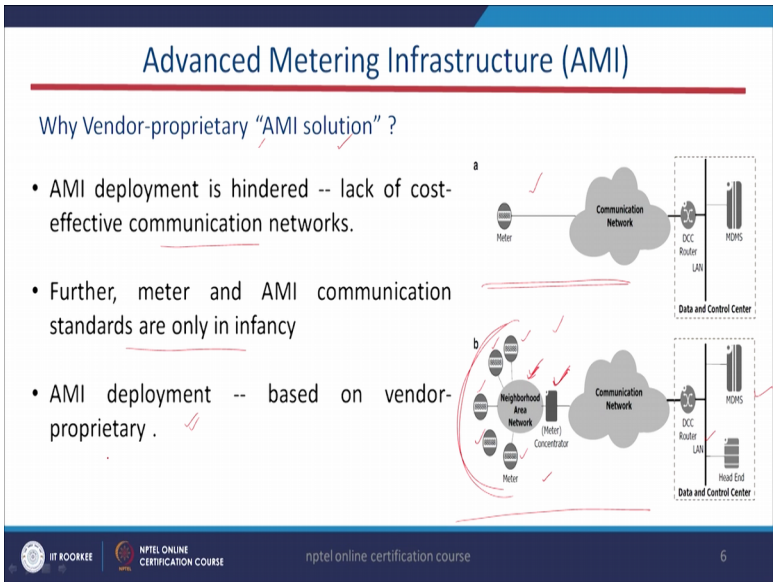
(Refer Slide Time: 08:27)



Now, it will come to the first one meters connected directly to the MDMS system. What is the function? Here that each meter communicates with MDMS over a communication network. That is the first requirement. And the second one this interfaces connect to the utilities wire line or wireless communication network or NSP broadband network to provide connectivity to this MDMS. And the third one is there may be also the communication network. It is IP type, internet protocols. So, through this type of communication system also the smart meters are also connected to the utility side.

Now see in this case each meter assigned one particular IP address and those rules are basically written in these standards, in this standards and C 12.19 and C.1222. So, these are the two standards where everything is written; that how this basical the meters are going to be connected to the utility side MDMS

(Refer Slide Time: 09:59)



Now the second solution that is the vendor preparatory AMI solution; in this case basically we have more number of vendors are associated and that is why we have more number of smart meters present. It will compare this two figures. Now this meters basically again, they are connected to the meter concentrator through a NAN network. You know this nan neighborhood area network is a network of the distribution side; the smart grid system. This NAN network, I mean the NAN neighborhood are network is a communication infrastructure. So, this communication infrastructure allows to connect the information. The output of these meters to the meter concentrator.

And again this output of this meter concentrator is sent to the MDMS or through this DCC router through a LAN. LAN means the local area network. This is also one of the communication technologies which is used in the distribution system.

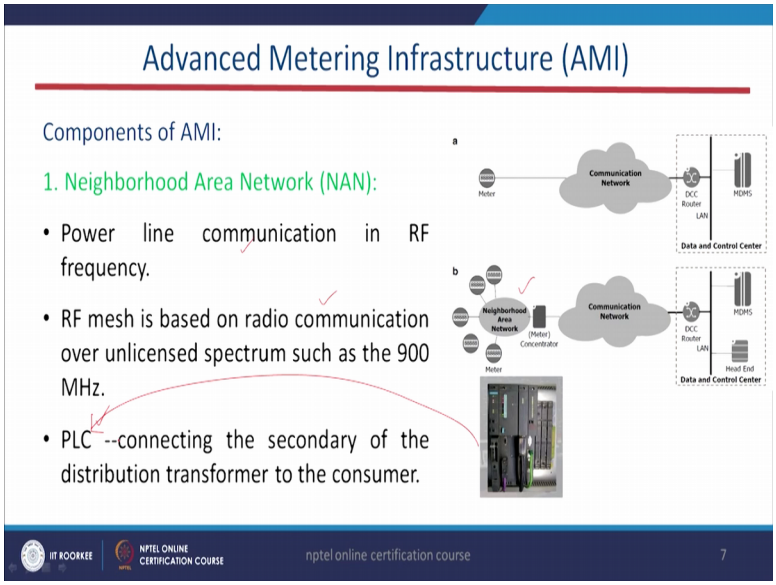
So, basically in overall if you see that what is the basic difference between these two? There is nothing; that here two things very distinguishly it is different that is first is the NAN and second one is the LAN. So, this two communication infrastructures are very essential when will go for this second type of advanced metering infrastructure. And will talk about that I will just want to mention here one thing that why this second one is essential. If you have the first one, why we are opting this the second one? What is the necessity? To be honest, this kind of structure I mean I am talking about this AMI communication standards and I am talking about this AMI deployment and basically due

to the lack of communication infrastructure and again the communication standards in the fancy stage and also in cost effective. So, for that region they might deployment is basically based on the vendor proprietary.

See this to be a list, the smart grid technology is coming up. Those technologies are in pen and paper. We have to implement in the field in your future. So, and many cases also it is implemented, but in India we are hoping very soon will see this kind of infrastructure. The smart meters are going to be installed at every corner of the house. So, that is essential because otherwise our system will not be smart. To make the system smart, we have to install the smart meters.

So, will see the further, what is the; what are the benefits? What are the advantages of installing the smart meter inside our home or inside any customers, I mean any type of consumers; may be residential, may be commercial, maybe it is kind of industrial. So, this is how this two infrastructure I have described here.

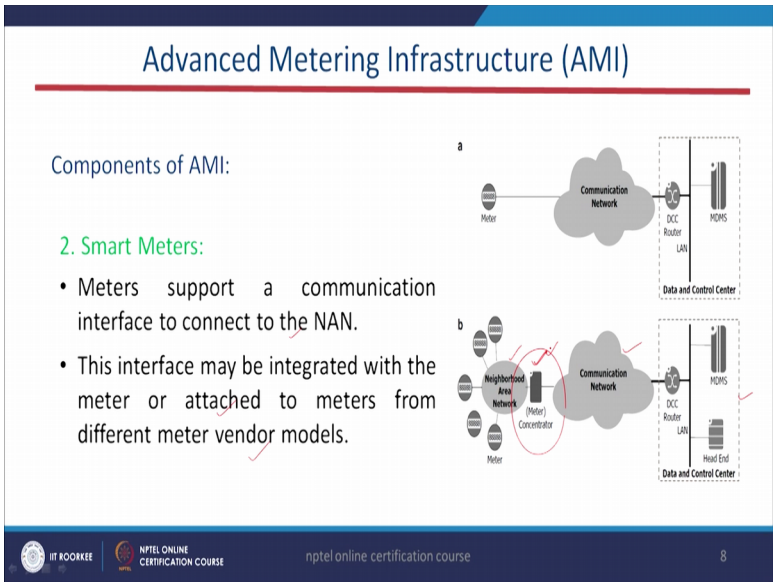
(Refer Slide Time: 13:25)



Now, I will come the function of this NAN. This NAN is basically it is a communication infrastructure and it may be a power line communication type or it may be radio communication type or it may also PLC the PLC stands for Programmable Logic Controller ok. So, it looks like this. The PLC looks like this programmable logic controllers are basically used mostly in industries to control the machineries. The operations of the machines and here also we can use the PLC concept by connecting the

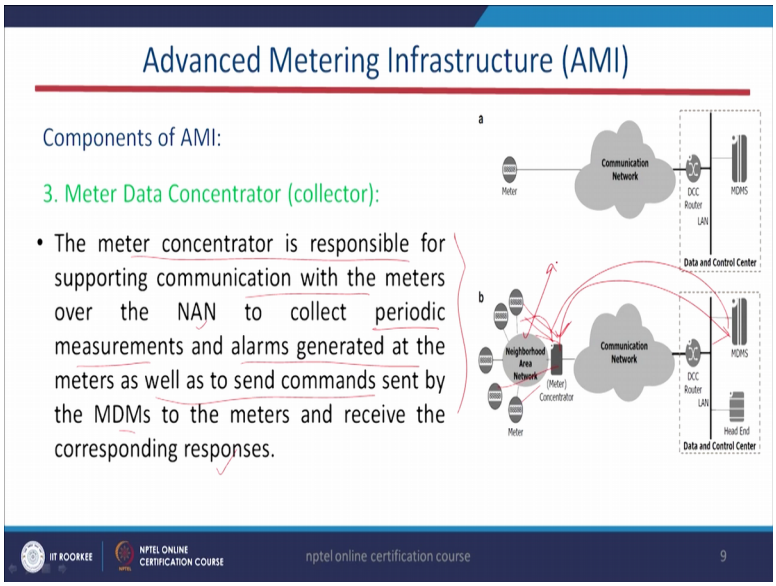
secondary of the distribution transformer to the consumer. So, basically it is a kind of wired or wireless communication system. So, this NAN helps in connecting by connecting the smart meters to the utility section through this meter concentrator and communication network.

(Refer Slide Time: 14:31)



And the next one is the smart meter. What is the smart meter function? The meter support a communication interface to connect this NAN and this interface may be integrated with meter, attached to the meters from the different vendor models. So, this is also important and this smart meter concentrate on, what it happens? What we do here; smart meter and this is the smart meter concentrator? This concentrator helps in connecting this NAN information through this communication network to the utility side. That is the function of this meter concentrator.

(Refer Slide Time: 15:13)

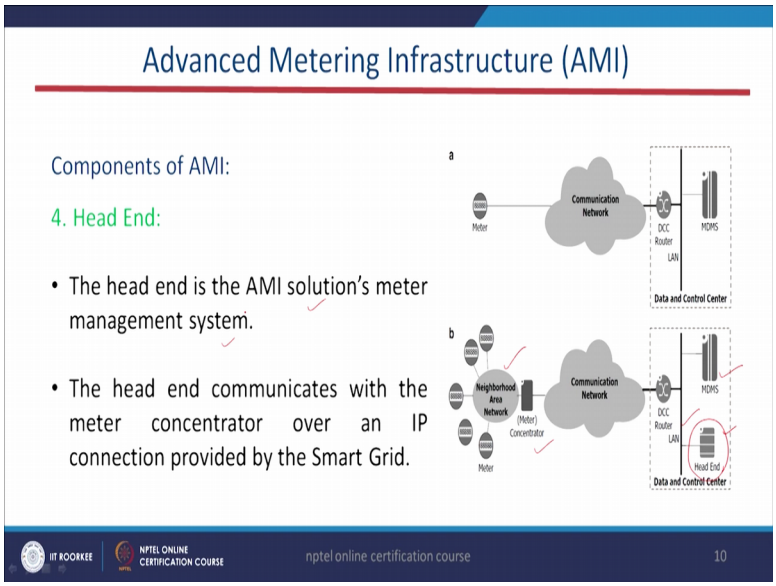


That is what I have just described in the previous slide and this is what written here. This meter concentrator is responsible for supporting the communication with the meters over the NAN to collect periodic measurements. This is important. It may be within 5 minutes 10 minutes. So, that periodic measurements and alarms generated at the meters as well as to send the commands or send the DMS to the meters and receive corresponding responses. I want to explain further, this point.

What is the function of this meter concentrator? Basically first of all this meter concentrator will collect the information from the smart meters through this LAN section. This NAN section and again this meter will send the data to the MDMS and also the reverse side. What is the reverse side? This MDMS will send the information or data, whatever the things we need in the operation of the smart grid system. So, this will send the meter concentrator. Again this meter concentrator will react I mean, it will just send I mean it will just convey the message to the smart meter through this NAN communication infrastructure. So, this is a two way communication.

The two way communication means the smart meters will speak to the MDMS system and the MDMS system will also talk to the smart meters is two way communication infrastructures. And coming to the, what is the function of head end you could see here, it is written head end.

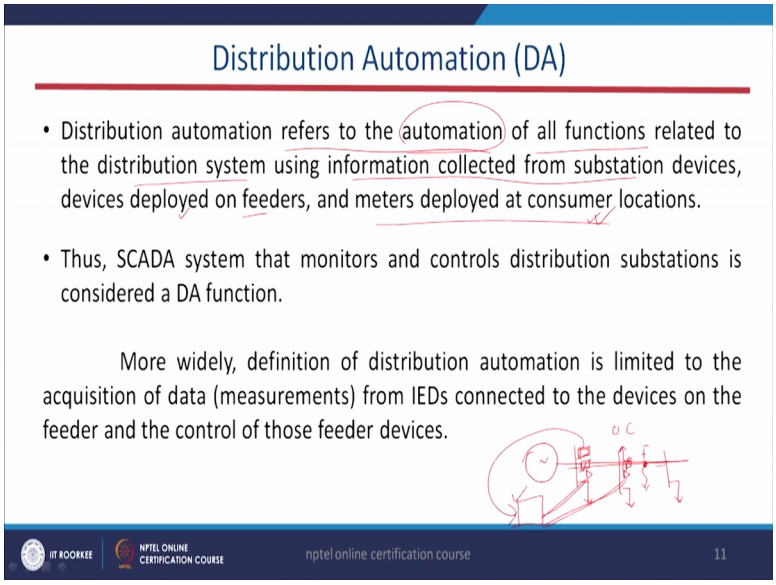
(Refer Slide Time: 17:04)



We already discussed, what is MDMS? What is this LAN and what is this meter concentrator and what is this NAN and the smart meters? So, another element or device, that is head end. This head end is AMI solutions meter management system. It manages the AMI solutions meter; whatever the data or information we exchange between the smart meter and this utility MDMS. So, those exchange I mean the data exchange should be managed properly. So, this data head basically does that ok

Now, the head end communicates with the meter concentrator over an IP connection provided by the smart grid. Basically some through this IP structure best communication system. This head end communicates with your meter concentrator.

(Refer Slide Time: 18:29)



Now will come to the second technology and where also will talk about some components right so, the smart grid system that is our distribution automation system. So, as all of you know that the name itself suggest what? It is a basically automation system. The distribution system is basically automated as far as the operation is concerned; as far as the control is concerned, as far as the monitoring is concerned. It should be automatic in nature that is what this distribution automation.

So, this distribution automation refers the automation of all functions related to the distribution system. This automation is important. I sing information collected from substation devices, deployed on feeders meters, deployed at customer location. It is very easy I mean the concept is very easy. What is it? That this distribution automation system allows to collect the data or information from the census which are basically located or devices which are located at the consumer locations. And this basically consumers location data are sent to a central computer center will talk about later that system. And this center I mean computational system will receive all the data all the information from the I mean the devices or censes which are installed rather consumer premises or consumer locations.

And then by getting those data, by obtaining those data are the center place, so we can do our desired work. We can do any, we can take any action we like we can do any offline study, we can do any online study, we can do online actions also. For example, we have one feeder. The feeder is basically it is a if you could see that if it is a substation and we have let us say 4buses and this is a feeder and these are the loads. If any fault is incepted,

let us one line to ground fault is incepted and this section of the feeder, then particularly we have relays protective relays to protect every section.

So, if it is suppose over current relay. Over current relay means if the current the set current I mean the relay will see the current is beyond the set value of the current the relay will react. It will just trip. It will give a trip signal to the circuit breaker. This is the circuit breaker. This is also one circuit breaker. The circuit breaker basically opens the section.

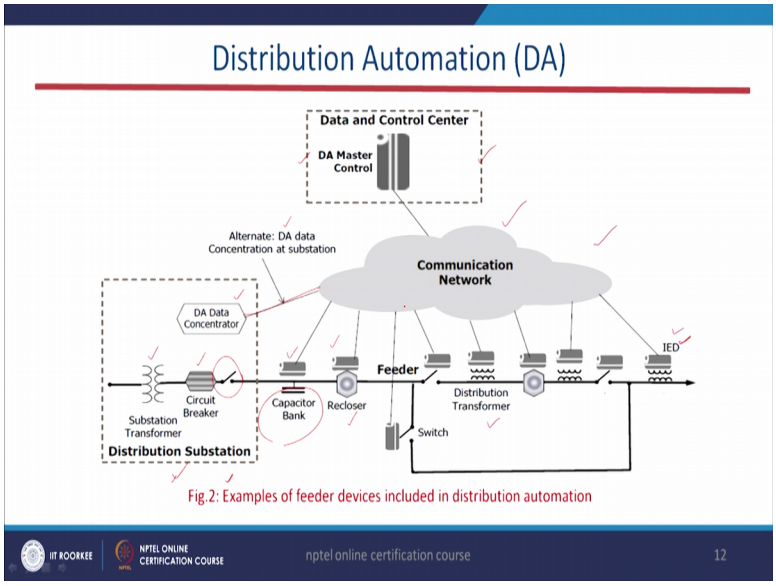
So, if any fault is incepted in the section, relay will receive the current. So, the secondary of the city current transformer and it will send a trip command to this circuit breaker and the circuit breaker will try to open that particular section so; that means, those relay information should reach to our central unit; either from the relay or may be the circuit breaker has one device will talk about the intelligent electronic devices. Those electronic devices are installed near to the circuit breaker and the circuit breaker status will be same to the central controller to take some decision. Whether this circuit breaker is going to open or not? I mean from the remote place, I mean the circuit breakers feeders are far away from the central place. The central place is the place where we have to take some action by gathering the information from the relays from cities from pts. So, it depends see that is that is what the meaning of smart grid.

In this smart grid era, we with availability of very advanced infrastructure of the communication system and very high computational technologies signal processing technologies, we can do anything. Yes of course, that should be cost effective, that should be very economic. So, to have a very I mean smart operation very automated operation, we can design our technology for the smart grid system. So, that is for this the SCADA system is one. Within this distribution automation, the SCADA system is one which helps in monitoring and accusing the data and further controlling the equipment's which are basically placed in the feeders, throughout the feeders. Basically the circuit breaker are the isolators, the reclosers. We have (Refer Time: 23:35) the many components.

So that is what this SCADA systems as I said that monitors controls the distributions substations and is considered as a DA function. This SCADA system is treated as DA function. DA means the Distribution Automation Function.

Now more widely in broadly you, how to define this in more widely? The definition distribution of automation is limited to the acquisition of data. It will accuse, it will collect the data from all the senses which are located throughout the feeder or deployed on feeders or deployed at consumers location. So, this basically the distribution of automation is limited to the acquisition of data measurements from IEDs. This IEDs stands for Intelligent Electronic Devices basically which are connected to the devices on the feeder and control of those feeder devices will see more about this the infrastructure, I have kept in further slides. Will talk about what is this IED and what is this? Where it is connected and how it functions?

(Refer Slide Time: 25:13)

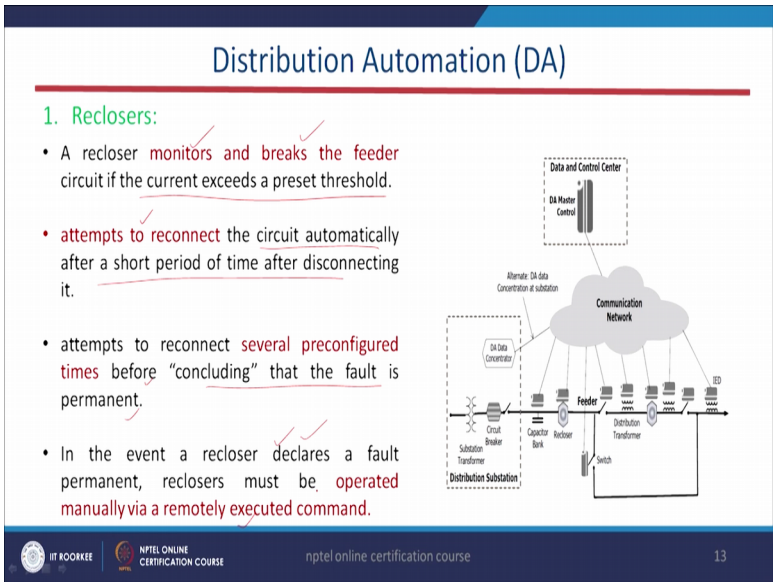


This is how the architecture or the layout of distribution automation system. Here you could see this is my distribution substation and this is our transformer, this is the circuit breaker and this is one switch. And we have the capacitor bank basically. The capacitor bank is used inside the distribution system to improve basically the correct the power factor and sometimes also to improve the voltage profile. The capacitor basically provides the leading current and it injects the reactive powers to the circuit. So, that is why sometimes, we use also the not sometimes very frequently the capacitor banks are used inside the distribution system and we have also reclosers and we have distribution transformer. This is the substation transformer. The distribution transformer basically steps down the voltage to 400 to 44 volt level. If this is a 11 kv substation, so we have to step down to 440 volt.

And these are the I just said, one term there. How this IED is connected? How does this IED connected to the system? This IED is present near to the distribution transformer or near to the switch or near to the recloser or near to the capacitor bank. It will collect the data from those devices. So, these are the devices which are basically present inside distribution system. This is our, this whole system is our distribution system and this is your distribution substation from where will get the power to the subsequent sections; I mean this is our feeder. This is one feeder.

Now; that means, that every components or devices are basically I mean every device is assisted with one IED, IED that is intelligent electronic device. Now basically this IED will communicate through this communication network to the data and control center. This is basically the master control center of the distribution or automation system that stands for DBA master control. And also we have another section here that DA data concentrator that is alternate distribution automation, data concentrator at the substation label. So, that also will speak to the master center through this communication network.

(Refer Slide Time: 27:52)



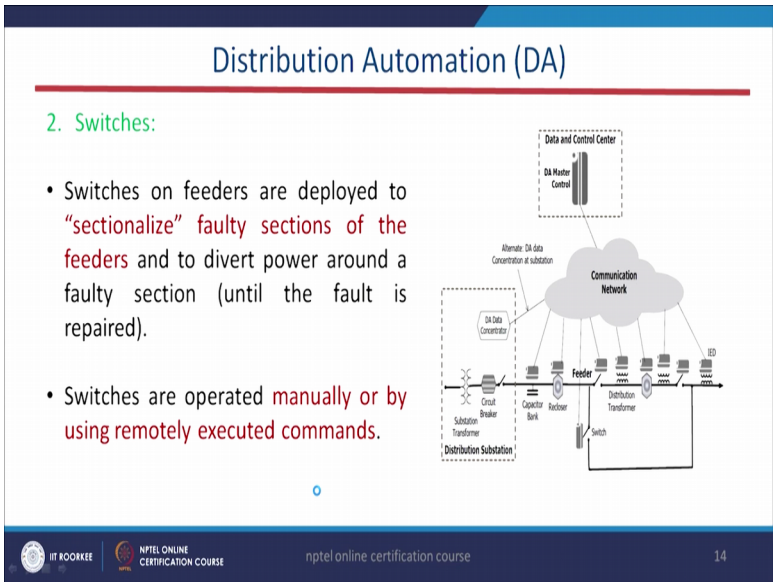
Now, basically the recloser is one of the component, one of the component components of the smart grid system and what is the function of it? Basically it monitors and breaks the feeder, if suddenly the current magnitude exceeds the set value or certain threshold value or it exceeds the predefined value.

Now this recloser monitors and breaks the feeder current, if the current exceeds a preset threshold and remember a in power system, the faults are basically temporary in nature. The tree will touch to the lines. Again it will go away due to the wind. The tree will come again. It will touch again it will go back. So, due to this I mean the fault may not be a permanent fault. It may be temporary fault. In that case the recloser will again open the line, again close the line; connect, reconnect I mean open reconnect. So, that it takes some attempt attempts to reconnect the circuit automatically after short period of time after disconnecting it. It takes some time, again it reconnects. It will I mean several predefined times, it will do and it will conclude before concluding that the fault is permanent.

Now, in the event of recloser declares a fault permanent. Then reclosers must be operated manually or remotely executed command. So, here the comes the distribution automation. If this recloser declares the fault is permanent, then the recloser must be operated from the remote station from this master control center of the distribution automation system. That is what the smart grid demands. It should not be manually, everything should be in automatic process.

Now, we have electronic switches also in smart grid system where we have electronic devices present. It will it can receive, it may be small processor is present inside it and that processor will receive the signal and it will do the desired work; that is what the electronic switches static switches and those switches basically helps in sectionalizing faulty sections of the feeders.

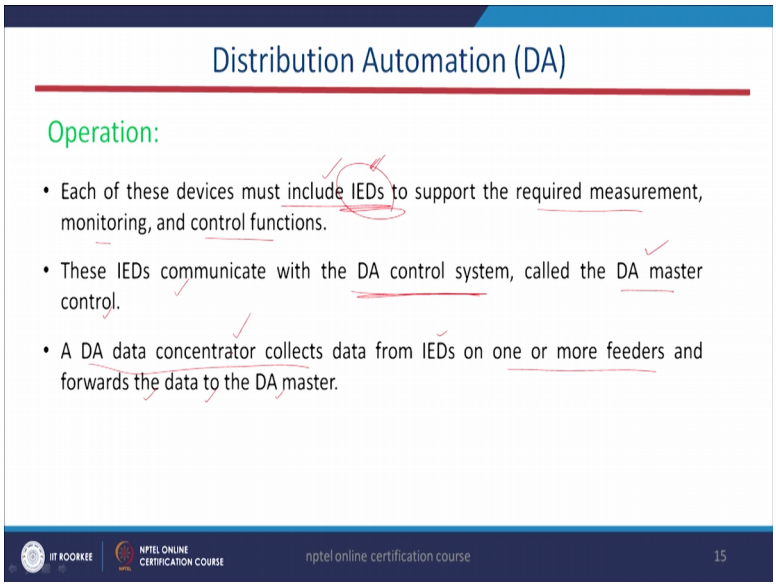
(Refer Slide Time: 30:27)



Let us say in some part of the feeder we have some fault. So, what will happen? This switches will help in isolating or sectionalizing that particular faulty section from the healthy section. So, that is what the function of this switches. So, that we can save few of our loads which are connected to the healthy section and also we should not allow the fault current to propagate to the healthy sections, otherwise the I mean the devices will see huge amount of current; I mean the current is very high during the fault conditions. So, those I mean the fault current should not propagate to the healthy sections.

And the switches are operated manually and again or remotely executed. Again as I said before this reclosers case, similarly we should expect in smart grid system, our technology should be so fast and so automatic. We should operate this switches also automatically.

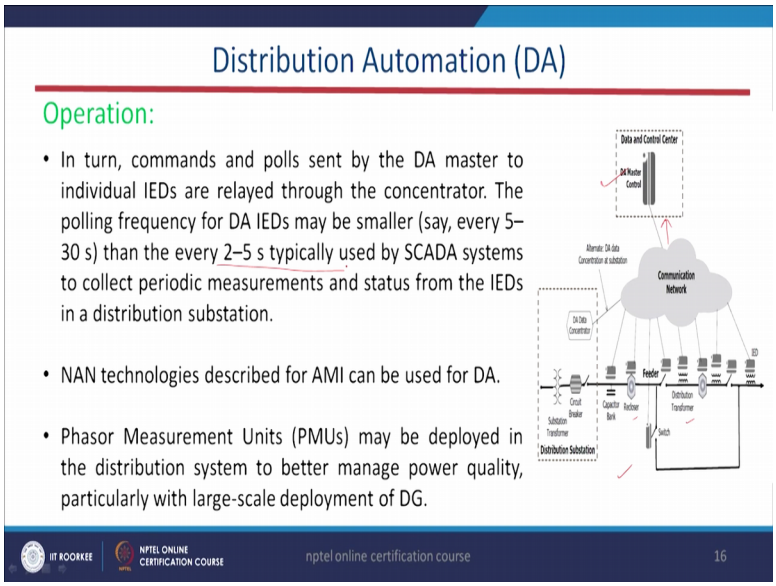
(Refer Slide Time: 31:44)



Now this is how this few points I have written how this distribution automation operates. Each of this devices must include IEDs. Without IEDs, we cannot make the system distribution I mean the automatic. Why? Because this intelligent electronic devices will basically gather the information from the corresponding devices like circuit breakers, reclosers or switches or we have distribution transformers. So, from those devices IEDs will try to collect the data and this IEDs will send those data to the center computer center main center and support the required measurements monitoring and control functions.

Now these IEDs communicate with the DA control system that is what I call and this is known as DA master control center. The information from the IEDs will be sent to the DA master control center. Now this DA data concentrator collects data from IEDs. One or more feeders and forwards data to the DA master. What is the function of this DA data concentrator? This data concentrator collects data from IEDs and it will send to the feeders ok; I mean one or more feeders and forwards the data to the DA master, control center.

(Refer Slide Time: 33:19)



That is how the infrastructure already we have discussed. Here these are the devices like we have capacitors, we have recloser, we have distribution transformer, we have all these equipments and switches. So, this IEDs will send a data to this DA master control center. This is the DA master control center.

So, basically this data sent 2 to 5 seconds as for the SCADA systems are used and you know the in future also, we are planning this PMU technology. PMU technology PMU means Phasor Measurement Units and those devices are very accurate and in near future we are also planning to deploy I mean to place PMUs for collecting the data and to have a very good monitoring and control system. And also we are planning this NAN technologies for this AMI, which is used for the AMI. We have discussed during our AMI part. So, those I mean technologies can also be used for DA.

So, today will just keep our lecture here and if you just come to the conclusion. We have started with the components and technologies of the smart grid system and I started with a advanced metering infrastructure and then we have started with like distribution automation system. There we could see that how we can make the smart grid more smarter with help of this technologies ok.

Thank you.