Introduction to Smart Grid
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Lecture - 06
Elements and Technologies of Smart Grid System- II

Good morning to all of you. Today we will talk about again the second part of the Smart Grid Components and Technologies. Now we will discuss about the SCADA that is the Supervisory control and data acquisition System.

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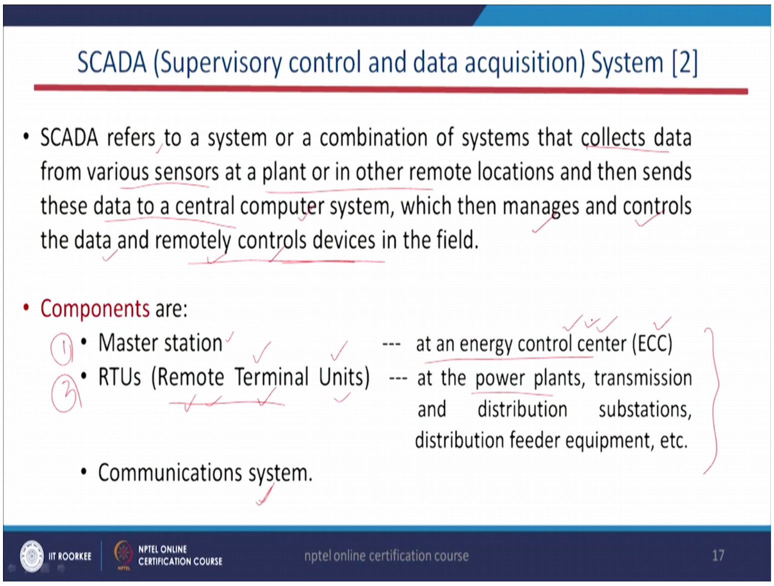

The function of this SCADA is basically to collect the data; collect data from various sensors at a plant or in other remote locations. And then sends this data to central computer system and which then manages, controls the data remotely controls devices in the field. Basically in broad sense the SCADA helps in monitoring and collecting the data from the devices; which are located inside the distribution system, may be transmission system. And those data are sent to the Central Computers System CCS.

And again by using those data further actions are taken remotely; I mean the remotely controls devices in the field; that is what the by and large the function of the SCADA. Now there are three major components which are present inside the SCADA system. The first one is the Master station and the second one is RTUs the RTU stands for Remote Terminal Unit and the third one is the communication system.

Now, this master station it is basically energy control center; the master station is also known as energy control center. And this RTUs what is the function of this RTU? Basically this RTUs play great role inside this SCADA system; this RTUs send the data to the control center from I mean this RTUs basically collects the data from all the devices which are located inside the customer premises or in the distribution system. Because we are talking about distribution automation; so those I mean the data are basically connected to the control center using this RTUs. And sometimes we call it also this RTU also known as remote tele control unit; sometimes this RTUs are also called as remote tele control units.

With help of a tele system or communication system, these units communicate the data to the control center of the SCADA system. And of course, the communication system is a very essential part of the SCADA system; without communication. So, these RTUs cannot communicate to the control center. That is why in the smart grid system one of the major components, major layers that is the communication layer.

Now, first of all we will talk about the master sessions.

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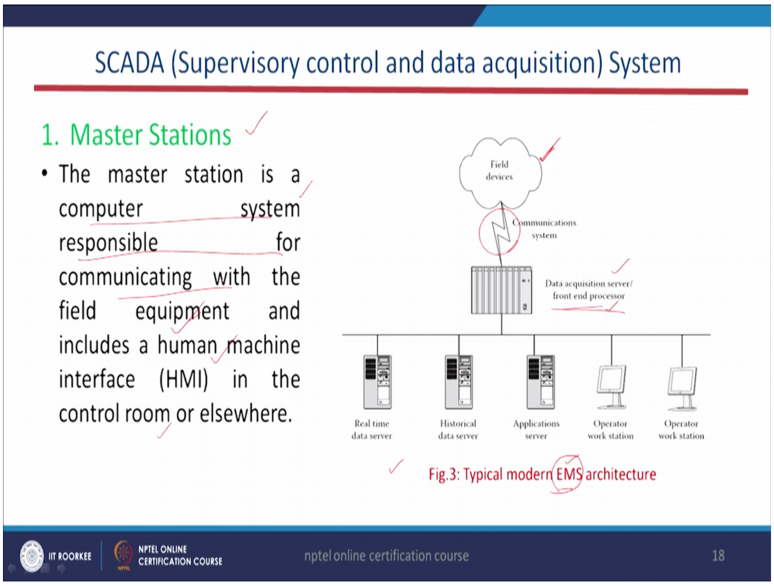

This is the typical modern EMS architecture what is this EMS? This EMS stands for Energy Management System and you could see here that we have first of all the field devices. The field devices are like you have circuit breakers, we have relays; digital relays we have this (Refer Time: 04:34). So those are the field devices.

And these devices will communicate to the data acquisition server front end processor through this communication system. Now, the question comes that what is this data acquisition server or the front end processor. This is how this is basically a master station is a computer system responsible for communicating with the field equipment and includes human machine interface in the control room or elsewhere.

That is what the master stations; it is basically system computer and it has also this HMI that is the Human Machine Interface technology. And it communicates and basically this master station or the computer system; it communicates with the field equipments that is important. So, all the field equipments data will be sent to the master station.

Now, these master stations have five components.

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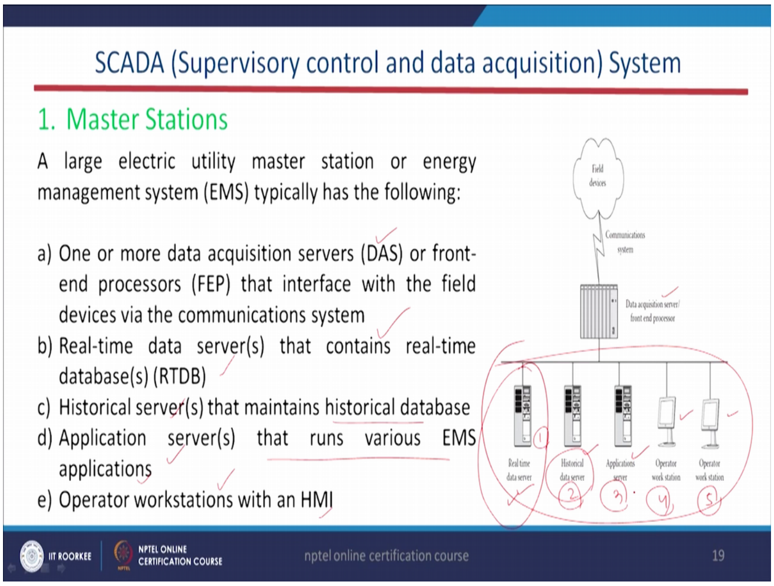

One is a real time data server, second one is the historical data server and the third one is the applications server, fourth one is number of operator works station and the fifth one is operator works station. Now, what are the functions of those stations? The first one is basically this DAS front end processor basically that particular processor interfaces with the field devices and the communication system. We have already discussed that is the front end processor.

And the second one is the real time data server this one; this real time data servers that server basically contains the real time data base. Real time means the voltage and current measurements at a particular bus; basically it will be measured in real time with respect to time the instantaneous voltage current values. So, those real time data are basically stored or managed inside this particular real time data server and this is next one is historical server. The historical server maintains the historical data base; so before 1 day, before 1 week or before 1 month or 1 year. So, what are the profiles of the voltage and current data? What are the statistics of the voltage current at that particular unit at that particular bus or devices? I mean those data are basically managed using this historical data server.

The next one is the application servers the application server that runs various EMS applications. After accusing or gathering the data from the different devices, so we have to go for the application part. The application part means we have to take some actions; let us say I got some relay information, the relative signal or some (Refer Time: 08:16) information. So, I have to take some further action; so, that action is basically is considered the application part.

So, that application is basically managed by this application server. And we have also operator work stations with an HMI that is very important that the operators are basically present inside the SCADA unit or system to operate all the functions which are going inside the SCADA system.

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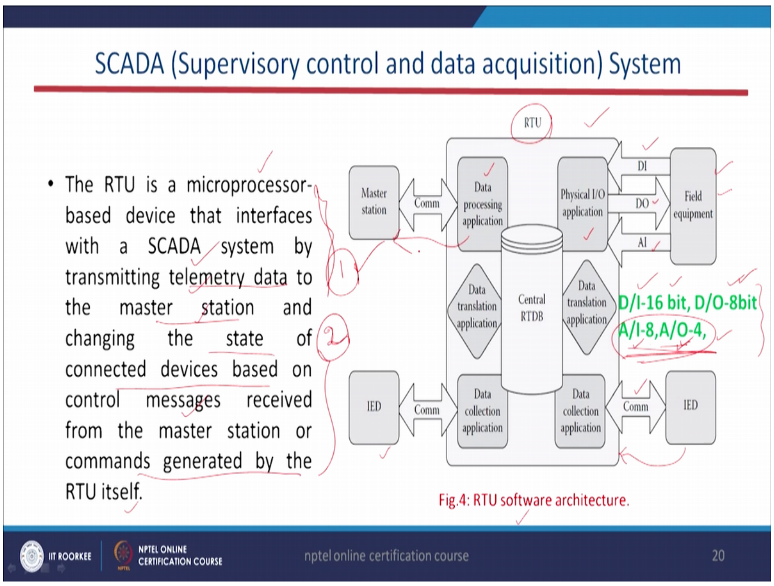

Now, we have another part that is RTU; another element of this SCADA system that is real I mean the RTU is basically here, if you could see here in the previous slide I have just descried here that the remote terminal units.

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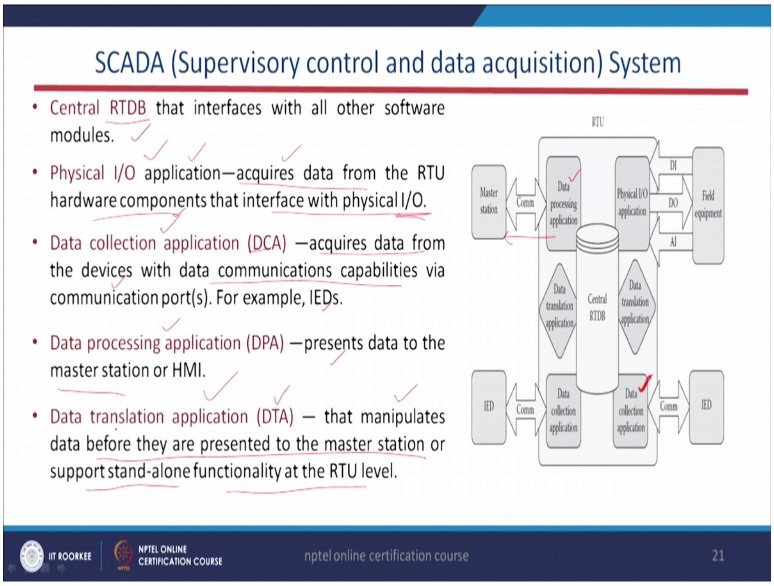

So, this remote terminal unit; what is the function of this? The main function of this is together the data from the field equipments and it will send to the master station. And before going in further the detail functions; what is this RTU? This RTU is basically, it is a microprocessor based device and that interfaces with the SCADA system by this transmitting the telemetric data to the master station.

So, basically it the function of this RTU is it is a microprocessor device and then it interfaces with the SCADA system by transmitting this telemetric data to the master station. This is the main function this is the part of this RTU and changing the state of connected devices next part this is the first part this is the first part. What is the second part? The second function of this RTU?

As far as the function is concerned the first one is it will just collect the data or information from the devices which are located inside the distribution network and it will send to the master station. And the second one is it will just collect those data that is not sufficient.

The other function is here it is the changing state of connected devices based on control messages received from the master station and commands generated by the RTU itself. It will also receive a signal from the master station; the master station will generate some signals and those signals will be also sent to the RTU.

And again RTU will itself also can generate some signal. The RTU after receiving the signal from the master station, it will generate a signal by itself and those signals are sent to the corresponding devices. So, what kind of work we need? What kind of control actions we need; so accordingly the actions will be taken care. And here if you see the as far as the input output section of this RTU is concerned; in single a RTU we have 16 bit digital input, 8 bit digital output and 8 bit analog input and 4 bit analog output; this is analog input, this is the analog output.

So, these are the basically the specification of the digital and analog inputs and outputs; we have the 16, 8 and 8 here and 4. That means to this particular RTU we can provide 16 bit digital inputs. And similarly we can get from the RTU as 8 bit digital output. And similarly we can apply 8 bit analog inputs to the RTU and we will also get from the RTU, 8 bit analog output.

So, these are the digital input and output specifications as per the data size is concerned. And this is the software architecture if you see this is the how this field equipment is present from this field equipment with help of this D I; DI stands for Digital Input and DO; Digital Output and this A I stands for Analog Input.

So, with help of these ports analog and digital ports the data from this field equipment are basically sent to the physical input output application; part of this RTU software. This is the architecture of the RTU software and again we have also here IED that is the Intelligent Electronic Device, this IED also will communicate with this SCADA collection application part; with the help of this communication infrastructure and here also same thing.

Now, after getting this data; this data part that is the data application part, processing application part will communicate to the master station. It is a basically flow of data from the field equipments to the master station with help of this RTU and the communication infrastructure.

Now, these are the in this particular slide we will discuss about the function of all the components which are associated within the RTU of the smart grid system or the SCADA system. The first one is we have central RTDB the real time database; we have this RTDB stands for Real Time Data Base.

And because we are accusing, we are accusing the name suggests SCADA means Supervisory Control and Data Acquisition system. So, we are accusing the data, we are collecting the data inside this RTU system from the field devices or field components or we have many senses which are installed near to the devices. Those sensors will sense the current or voltage or power factor or frequency, then it will sent to the corresponding RTU and RTU will send to the main control center.

So, as far this physical IO application is concerned; what is the function of this? It acquires the data from the RTU hardware components; hardware component means in RTU we have in physically, we have the analog channels analog input output channels. We have digital input output channels. So, these are the hardware components of the RTU.

So, this particular physical IO application acquires data from the RTU; hardware components and that interface with the physical IO, physical input output this IO stands for Input Output. And the data collection application part that is DCA; here it is the Data Collection Application part. In this section, you can see here inside the architecture of this software architecture of the RTU. It acquires data from these devices with the data communication capabilities or where the communication ports with help of the IEDs; IEDs means the Intelligent Electronic Devices; this one this is the function of this data collection application. These are all softwares basically these are the software parts of the RTU.

Now, we have data processing application unit that is DPA; this DPA presents the data to be to the master station or HMI, here it is data processing application. Basically this data are sent to the master station. Now, we have data translation application part that is DTA what is the function of this? It manipulates the data before they are presented to the master station or support standalone functionality at the RTU level. So, it manipulates, it estimates or recalculate or reframe the data structure before it is sending to the master station for further control actions.

So, that is what the last one that is the data translation application part of this RTU system.

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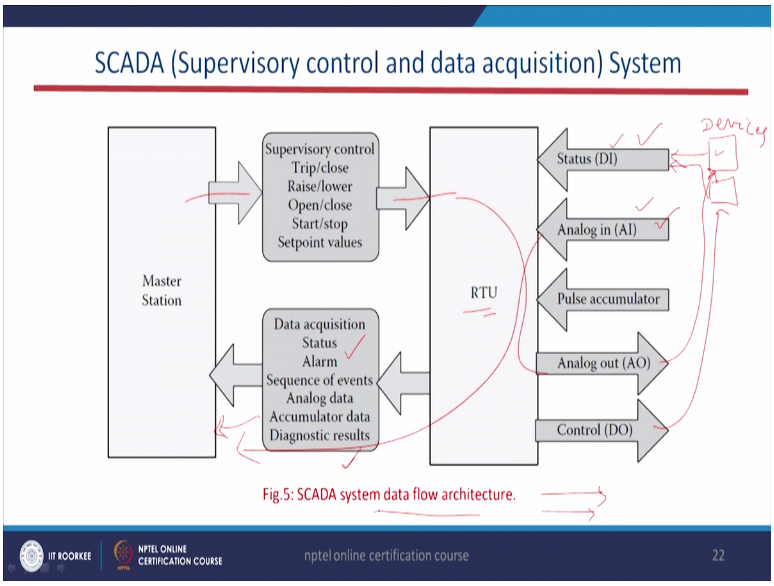

Now, this is the SCADA; system data flow architecture as I said that in case of a SCADA system we have RTU that is the real I mean Remote Terminal Unit or we call it also remote tele control unit, where it will just connect the data from the I mean from the different devices in the distribution system to the control center; main control center of the SCADA system.

Now, this is the flow of data you could see here this DI stands for the digital input and this is the analog input this. This arrow mark says that the data is coming from the devices, this is the device may be one or two. These devices are installed throughout the feeder of the distribution system.

And these devices will send the data to the RTU; so these digital input or analog input ports, these ports are available within this RTU. Now, similarly after this data which is which are reaching to this RTU section, those data are sent to the data acquisition system. And this data acquisition status alarm whatever the things we have diagnostic results everything will send to the master station.

So, these are the I mean the first round of flow of data from the remote devices through this RTU to the master station. And the second one this is a basically bidirectional power flow this I mean it is not a power flow; it is a basically data flow.

The data flow is bidirectional here and next one is this master station will also send the data or information through this supervisory control section. And it will send to the RTU then the RTU. RTU will react to the corresponding devices through this analog out or control outputs right. So, these are the two way data flow one is from the field devices to the master station and other one is from master station to the devices.

So, this is the basically will basic blog diagram of the SCADA system data flow architecture.

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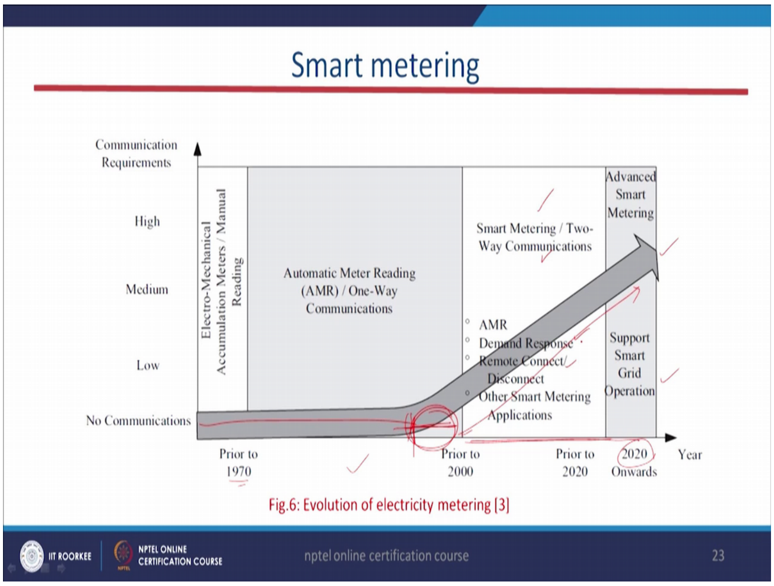

Now, in this context I will just talk about the smart metering part. So, as per the SCADA is concerned what we have learnt? The SCADA helps in monitoring and data accusing and controlling the devices which are located inside the distribution system.

Now, we will come to another component or I will tell it is a very important technology of the smart grid system that is smart metering. So, this smart metering if you will see this particular evolution of the electricity metering graph; here prior to 1970s, this smart metering concept was 0, no communication first of all no communication of two almost around 1995. So, this period is basically we have started the smart metering technology.

So, after 2000 the smart metering concept has been increased. So, last that means, the last 2 decades we have this smart grid concept. Now if you see and what is the aim of this 2020; the aim is we should have and advanced metering smart metering facility within the smart grid environment; this is how this charts says, this particular graph says.

And what about within this 2000 to 20; 20 to 20 these are the things smart metering, two way communications we have demand response, we have remote connect disconnect facility. So, these are basically the technologies which are involved inside the distribution system and which we call it as a smart distribution system.

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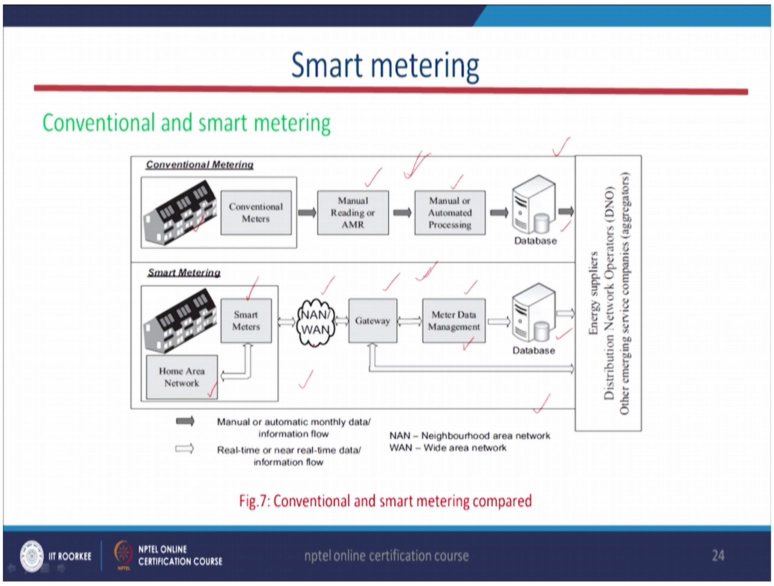

Now, this is the basic building block of the smart metering system. The first one is the convection smart metering structure and the second one is the recent smart metering infrastructure. What is the difference between these two? What is the difference between this conventional metering structure and the recent new smart metering structure? Now, in this convectional metering we do not have this NAN or WAN structure communication infrastructure. You could see here is the let us say this is the residential building, we have convectional meters next we have manual reading.

And next we have manual or automated processing then we have the database, but now it will come to this new smart metering structure. We have home area network, we have NAN that is we have already discussed Neighborhood Area Network; WAN, Wide Area

Network, we have the gate way and we have the meter data management and then we have the database.

Now, if you could see that these smart meters are the main block I mean the center place I mean center equipment as far as the smart metering of the smart grid is concerned. And apart from that we have also a very dedicated communication infrastructure for the distribution system. That is those are this home area network we have NAN or WAN. So, those communication structures allow us to use these smart metering structures or we can easily implement this smart metering concept. That is the basic difference between this conventional and present smart metering architecture.

Now, if we see what are the components present inside the smart meter.

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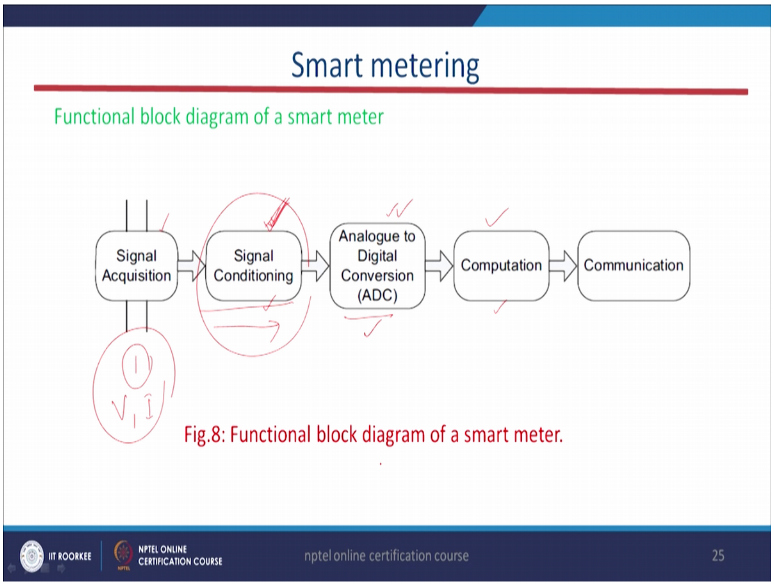

The first is we have to accuse the signal may be it is a voltage signal or it may be a current signal. After that we will go for the second stage that is known as the signal conditioning.

Why this signal conditioning is required? What is that name; I mean what is the meaning of signal conditioning? Before passing this acquised signal or this is the signal we are just processing inside the smart meter; to the next block that is your analog to digital conversion block; we have to take care of this signal.

Conditioning means we have to make it perfect as whereas, this D; ADC requires; what is the requirement for this ADC. Because if you could see in the power network the signals are not purely sinusoidal; first of all the signals are not purely sinusoidal. It is not having only the fundamental frequency component that is 50 hertz; the signal may have other frequency components harmonics.

So, in that sense we have to basically remove the high frequency components and harmonics. And sometimes also we have aliasing effect inside the signal, aliasing effect means sometimes very high frequency signal components will behave as a fundamental signal component. So, those basically the difficulties which are present on desired signals which are present inside the fundamental frequency component of the voltage current those signal should be removed.

We should only we should allow only the fundamental 50 hertz voltage and current signal to the next block; that is what the signal conditioning. We may have this low pass filters, we have aliasing filters; so, which will just basically remove the high frequency components and maybe on desired frequency components.

And for that we have to maintain this Nyquist criteria that is basically a basically this Nyquist criteria is basic tails, the frequency of this particular sampling frequency of the signal should be two times of the higher frequencies signal I mean the frequency content of the signal.

So those components, I mean this condition signal conditioning we will discuss more in the protection or relying part. And for this smart metering part I will tell you that this signal conditioning block takes care how nicely a very it will ensure that this it will just allow the fundamental voltage component to this ADC. And after that we will go to the computation block where the computation will be there and this computation is basically done by a processor.

And the processor will help in computing whatever the components or subsequent derived components we need from the voltage current signals. And then it will communicate to for further action.

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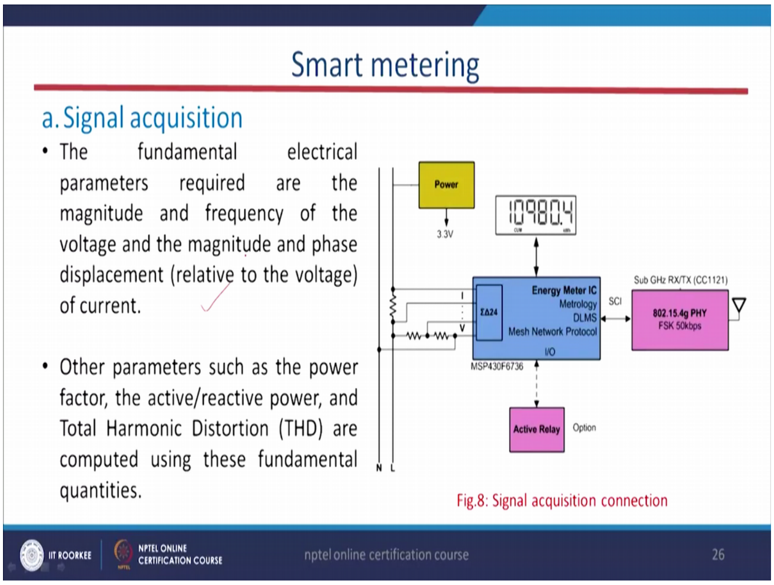

Now, this signal acquisition already we have discussed that the signal acquisition basically accuse collect the voltage current signals and then it further process to the ADC part.

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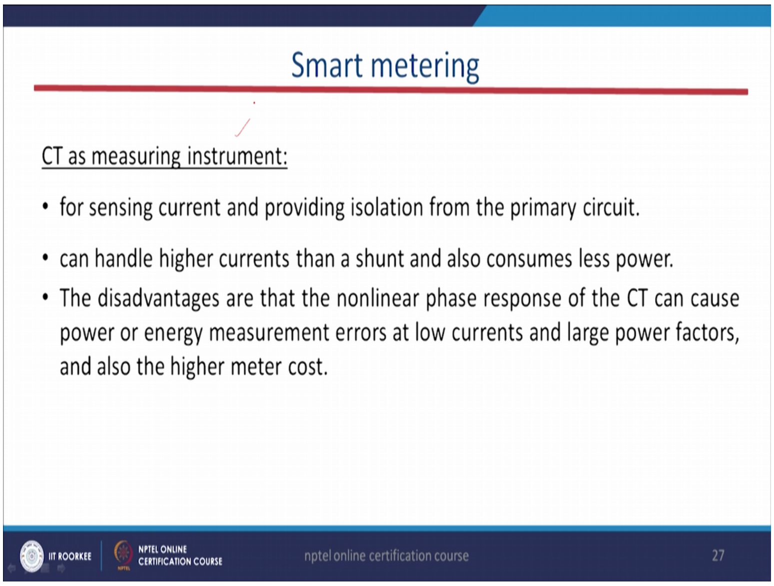

And CT as measuring instrument you could see that in a smart meters we basically a use also CT; the Current Transformers which is basically acts as a measuring instrument. You know why this measuring instrument name is written here? We may have also metering CTs; so this CT will act as a measuring instrument and it will sense the current which is flowing through the feeder and it will scale down to secondary through the secondary winding up the CT and that particular secondary current is basically connected to the our respective smart meters.

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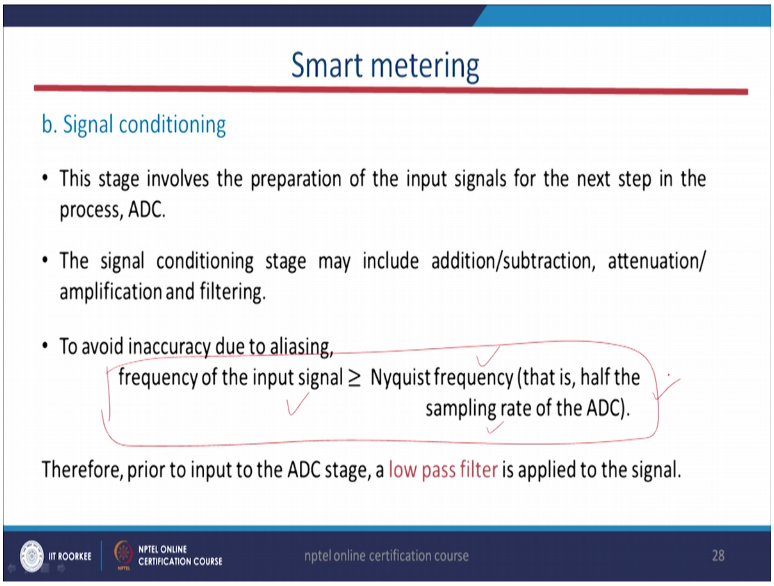

And signal conditioning as I said that this the Nyquist criteria we have here the frequency of the input signal. So, it will be greater than equal to the Nyquist frequency that is the half of the sampling rate of the ADC. These criteria we have to maintain while processing this signal from one block I mean to the ADC section.

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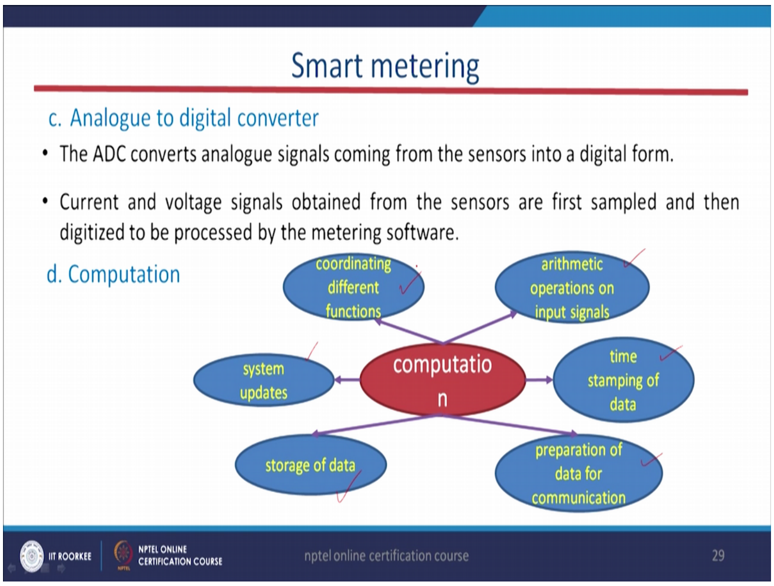

So, these are the measurements which are basically done by these smart meters, the first one basically a it will just arithmetic operations on input signals; may be the time stamping of the data. And we have operation of the data for communication, storage of the data, system updates and coordinating different functions.

So, these are the smart metering a functions or computation you can say it is a computation inside the processor the smart meter can do different computations, different required parts I mean the estimations. So, see this is not the end of the task of the smart meters the it depends on our own logic or algorithm what is which is running inside the process of the smart meter; which quantities which derived quantities or parameters we need for our further action from the smart meters.

So, everything is possible using the processor action; once you will get the voltage current information inside the smart meter. So, we can calculate the current power, power factor frequency; so, all these are basically the further requirement for further control or further monitoring. So, everything is possible from this smart meter data. And if you will see in the processor we use basically the volatile memory.

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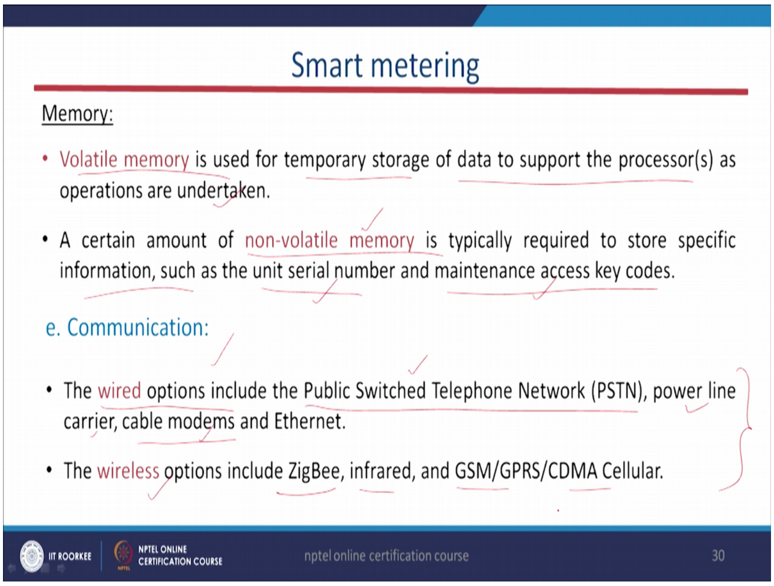

And this memory is used for temper use of the data to support the processor as operations are undertaken. And certain type of nonvolatile memory is also required to store specific informations such as unit serial number or maintenance access key codes; these two are important.

This units real number and maintenance access key codes; if some certain time the utilities or anybody even the customers they meet the information of the smart meters. So, the smart meter can communicate to them even now a days also the technologies are coming of to the smart grid environment, where the smart meter also can speak to our mobile phone also.

So, these are very advanced technologies are coming up and we are a discussing few of them and we can also go through many books and papers therefore, journals where much more very in a bigger form these technologies are coming up. And coming to this communication part of this smart metering section we have the wired options which include the publics switch telephone network PSTN; this is important this kind of communication system we use.

And also we have power line carrier communication infrastructure and also we have cable, modems and Ethernet. So, these are the communication infrastructure we use inside the smart metering system. And wireless options include ZigBee and infrared and GSM and CDMA Cellular. So, these are the basically the communication infrastructures which support the smart metering system.

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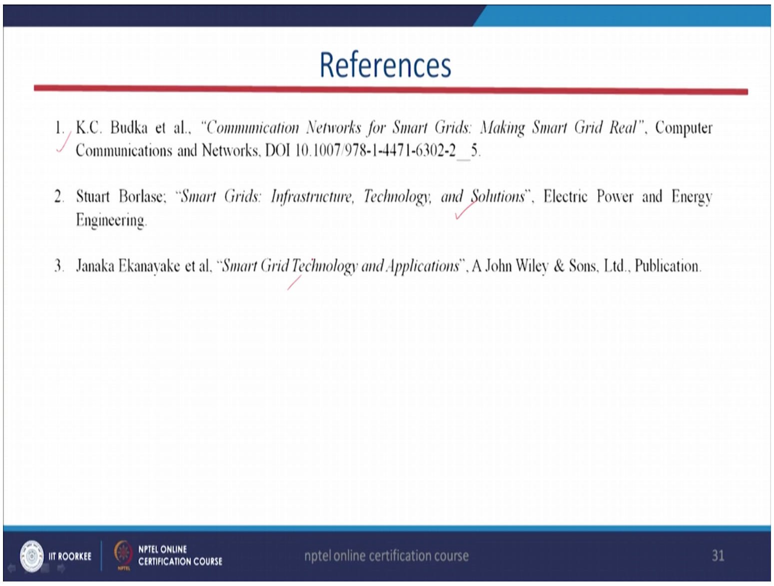

So, these are the references we can follow, you can see this references this is the first one is the book very good book on Communication Networks for Smart Grid and the second one is Smart Grids Infrastructure Technology and Solutions and the third one is Smart Grid Technology Applications; you can follow these three books.

So, we will come to the conclusion that in this lecture; we have discussed about the SCADA system and next we have discussed about the smart metering system. And in the smart metering system we have discussed how easily we can using this smart processors and data acquisition systems ADCs. We can easily calculate the desired I mean quantities or may be derived quantities or parameters for our further control actions inside a smart grid system.

Thank you all.