Introduction to Smart Grid

Dr. Premalata Jena
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 11
Wide Area Monitoring Systems- I

Good morning to all of you in this lecture, today we will discuss about the Wide Area Monitoring Systems in sort it is called as WAMS. As all of you know that we are just moving towards the smart grid era where this mentoring, protection control of all the equipments and are very very essential. For that purpose recently if you could see that in India we had a severe blackout in July 2012 a July 30th and 31st and we have very huge loss also and apart from that we have also different types of blackouts in our country and also throughout the globe.

So, if you could have a very good monitoring system or some control system online, then we can always prevent such huge disturbances and as a result we can save our money and also the loss which is going to occurred to our society that also we can stop. So, in that context the researchers and the technologist and also industry person and the I mean the academician together we are trying to have very good monitoring protection control system and earlier we have this SCADA system.

And now we have the same proof technology that is basically the wide area monitoring systems, throughout the globe it is just going an and still the researchers also going on how the best thing, the best technology we could have in our smart grid system; Coming to the definition of this WAMS.

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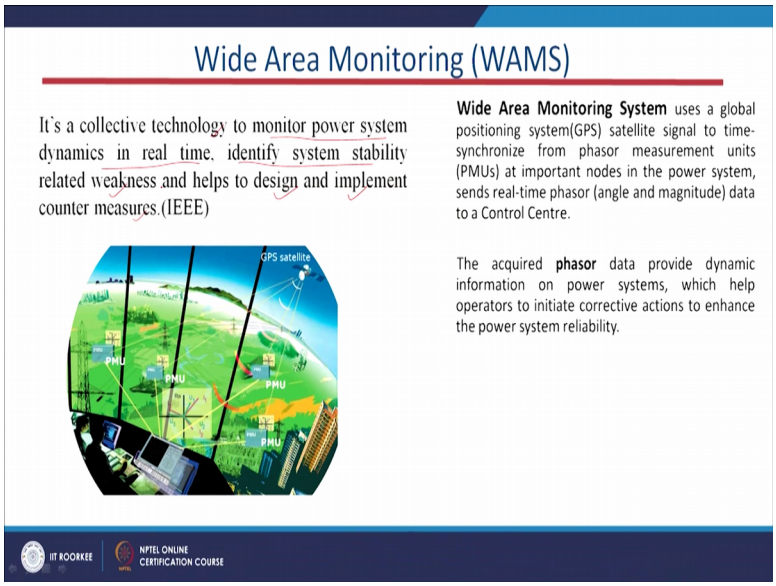

It is a collective technology to monitor power system dynamics in real time and also to identify system stability related weakness and helps to design and implement counter measures. The WAMS technology helps in identifying the weak areas or in identified the major disturbances and further, after that it can also take the corresponding control actions online basics. That is the major advantage of this wide area monitoring system, that is our WAMS and this particular WAMS is completely dependent on the global positioning system, satellite that is GPS satellite. From this satellite the WAMS technology gets the reference clock signal the reference time from signal.

And if you see further in our discussion you see that the voltage current measures or any quantity we are going to measure physical the voltage current we measure using this wide area monitoring system, they are the timestamp is very very essential and that particular time stamp is universal. That universe clock, the universal time is maintained using this GPS satellite that is our global positioning satellite signal and the heart of this WAMS technology is are Phasor Measurement Unit that is a PMU, we call it PMU.

Nowadays, also we are planning for micro PMU system, the micro PMU is basically design for more resolution systems like distribution networks and PMU targeting further transmission networks. Now, what are the goals and the benefits from this WAMS technology we are going to get or what are our goals.

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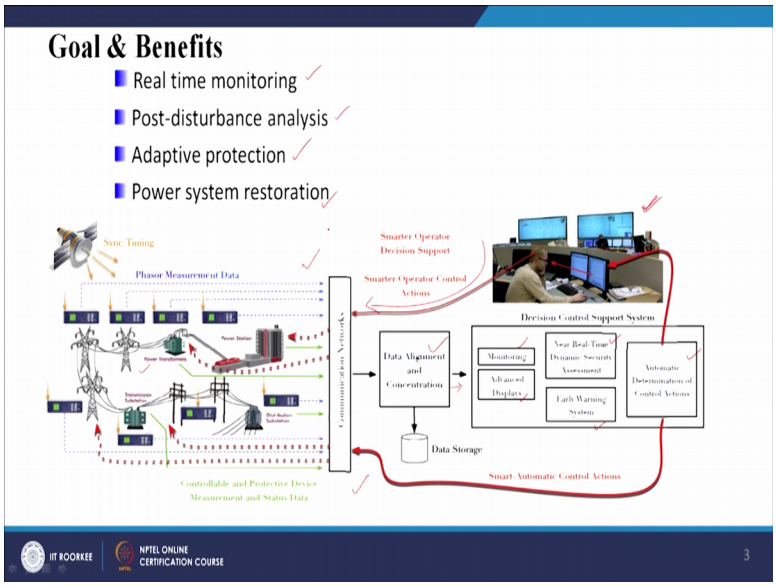

The first one is the real time monitoring and the second one is the post disturbance analysis, third one is the adaptive protection and next the power system restoration. We will discuss one by one this all these three points that what is our goal and what are corresponding benefits. If you could see this particular picture that in case of a WAMS, the PMUs are installed in the transmission networks at different substations, different critical points and from there we basically we see if the signals. May be voltage current signals and those voltage current signals are sent to this data alignment or concentration, where we will get the voltage current data from all the PMUs which are installed at different buses, in the power network or in our smart grid system.

And from there we can monitor the voltages or current profile or power profile or the frequency of different buses, a snap shot of those buses we can always visualize by this monitoring system or section of (Refer Time: 05:22) or WAMS. And second one is the advance displace, what will happen pre predictive measures also we can display and the next part we have the near real type dynamic secrete assessment, also we have early warning system and also we have automatic determines of control actions.

So, these are the corresponding different components of the WAMS system and after this access, if after getting the voltage current information or frequency information further we can take some control actions through our operator through our operators. This is a data centre where are we are receiving the data from the PMU or these are this is our

control center from where we can control different equipments which are just installed in inside our periphery of the power network or the smart grid system. And further from this control just we will just decide some operation and those commands will be sent to the network to take proper prevention or to take proper control actions.

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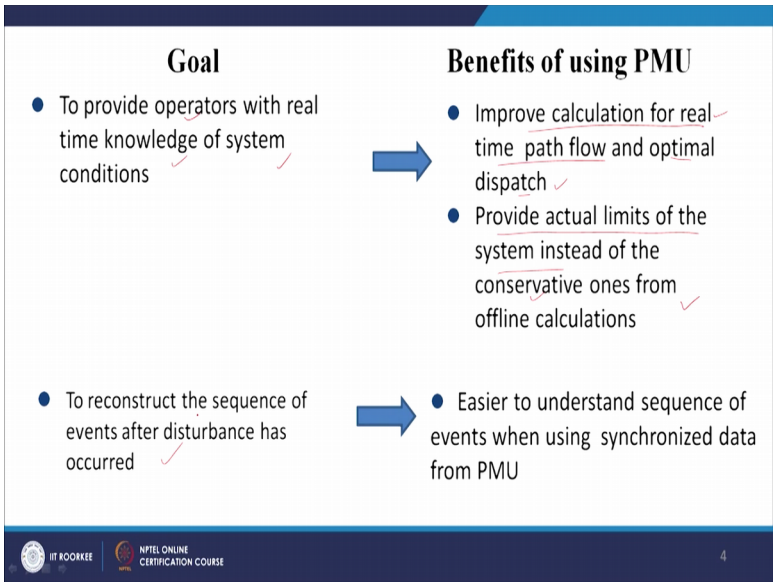

The first one is the, to provide operators with real time knowledge of the system. So, using this WAMS technology we are able to provide the real time knowledge to the operator who is sitting inside the control room that is important. Now using this information, real time information so what benefits we are going to get. The first one is improve calculation for real time path flow and optimal dispatch, if I know; what is the status of my power requirement.

So, according to my rules, regulations and real time data status we can always go for optimal power flow or optimal power flow scheduling, that is known as power scheduling, how I can schedule my power. So, that I can get optimal dispatch of the power from the stations, that is first and the real time path flow, we can see that where the power is flowing from what station to, from which station the power is flowing now to what station.

So, the power flow is always in front of us. So, we can always control the this optimal dispatch of the power. Now, it also helps in this regard like provide the actual limits of the system, instead of like conservative ones which we got from the offline studies.

Because in real state the power limit or the some in some extent some parameters may change because we have always loads on and off, may be due to some fault one line is out of service in that case the impedance is of particular line may also changed like a we have double sided lines. So, one line is out of service the overall reactance seen by the system the generator or relays will be different.

Similarly, if you some loads are out of service so the current flowing through that particular line power flowing through that may be less, in that case ah; that means, the real time information or of power or voltage or current or frequency all the information we are going to achieve from this WAMS technology; So, using that we can further take some necessary actions. So, instead of taking some offline data range or power information, current information it is always to take decisions based on the present real time data information, that is what is this provides this particular goal. Now, the second one is to construct the consequence sequence of these events after the disturbance has occurred.

So, how to reconstruct basically, if I have some black out, if I have some brown out, so how to reconstruct the system after onwards; So, that is what the second goal and through that it will be easier to understand the sequence of events using this synchronized data from PMU. How this disturbance has occurred if I have some recording online basis, if we can record the data from where the disturbance has been originated and where it is ended. So, those data, sequence is always we can record using this type of monitoring system.

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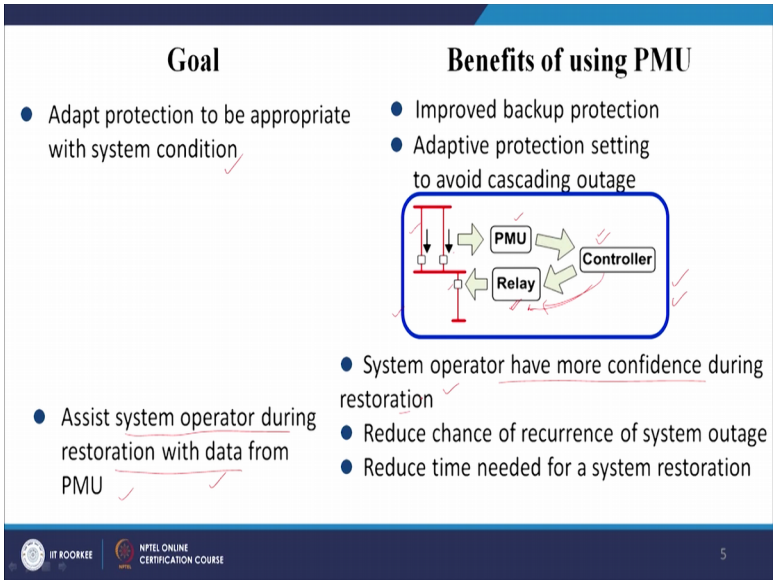

And the third one is adapt protection or adaptive protection to be appropriate with system condition, this adaptive protection means the protection is always essential for the power system where 5 percent of the total cost of the power system may dedicate for the protection of the system. Without protection, so we cannot save our equipments or lines or any a devises which are installed in the system.

So, and again we have to do adaptive protection, what is adaptive protection? It is a protection system which adapts, which takes decision according to the changed system or change system parameters or changed system quantities. If my voltage will vary a current will vary or any line parameter varies or power will vary, then accordingly my protection system will take certain decision which should be correct and accurate.

So that is; what is adaptive protections scheme and that particular adaptive protection scheme are possible using this WAMS technology. If you could see this block diagram, the very simple block diagram I have just kept here and this is a our power structure, our lines two lines which are carrying basically the power and this is our PMU which is installed, as I said the PMU is the phasor measurement unit.

And this PMU is installed in this particular, particular bus in this network and this PMU is sending the data may be the voltage current information and frequency to the control centre to the controller. Then the controller will inform to the relay to take some corrective measures and it will just open corresponding breaker where it is desired,

where it is required, that is what this PMU based adaptive protection schemes relay itself is a local device and it takes the decision based on its own the algorithm.

If we will talk about the digital relays and why they again we are just adding this PMU information, as well as the WAMS technologies concerned because to make this in relay more intelligent, more smart, more information if you can provide globally. It is a local device, religious looks takes care the voltage and current information at the bus where the relays located. But if I can take the information from other buses with help of this PMU which is the basically very good important component of this WAMS technology then that particular information, those information those data will be really helpful for the relay to takes some other actions or other some necessary actions. That is what this adaptive protection scheme.

So, using this scheme we can make our system more smart and the fourth one is, the goal is to assist system operator during the restoration with this PMU data, if suppose we have one smart grid system and we have 3, 4 micro grids which are connected to multi grid systems, multi micro grids are connected to multi grid systems. And let us say due to some to some disturbances the micro grids are disconnected from the main grid. So, again we have to restore the service, so that process is known as restoration of the service of this micro grid system or smart grid system. So, in that case we can to restore the service, we can take the help of the PMU data that is what it is mentioned here the system operator have more confidence during the restoration process.

Because the operator knows what is the status of this line, what is status of this particular slide breaker or bus whatever the equipment we have all the information are basically with the operators. So, operator can easily take the decision and reduce the chance of recurrence of system outage and also reduce the time needed for the restoration. So, within very short period of time we can just restore the system and we can just, basically the power is intact it is back to its original position, this is a small comparison between the SCADA system and the PMU.

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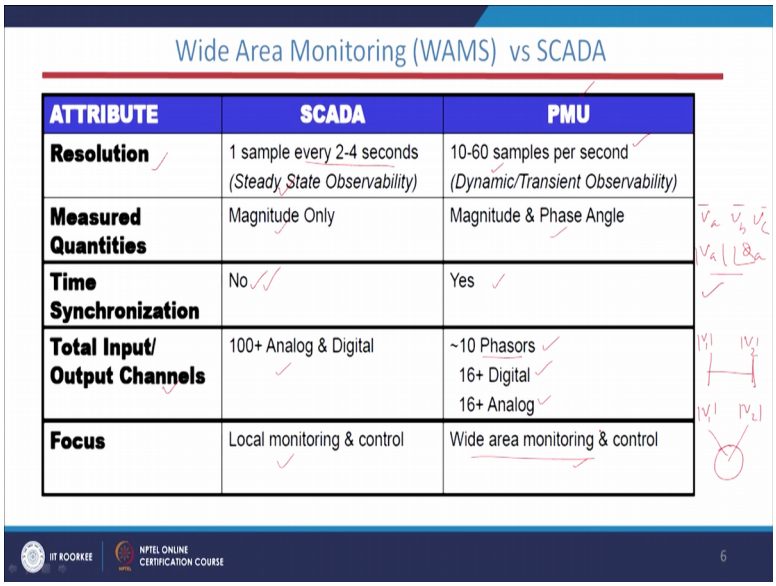

Here is the SCADA system, if you just come to the resolution part, for SCADA it is one sample every 2 to 4 seconds and that is to this observability is during the steady state only, the observability is not during the dynamic state. However, in case of PMU we have 10 to 60 samples per second and again this is basically designed for the dynamic transient observbility because if the, it is a online basis information even during the dynamic and transient condition of the system or generator transmission line loads.

So, we can always observe the what is happening inside the circuit or network, now as per as the measured quantities are concerned it will just measure the magnitude only, but in case of this WAMS due to this presence of PMUs we can measure the magnitude and phase angle of the voltages and currents of each phase. Like if you have V a and V b and V c this corresponding phases means the both the magnitude if it is V a magnitude as phase angle of this particular quantity we can always measure is in the PMU.

This is basically the phasor measurement unit, inside this PMU we have a basically and a signal processing algorithm called as DFT, Discrete Fourier Transform using that particular algorithm we can calculate the phasors of different signals like voltage signal or current signals. Now, here it was a time synchronism is concerned, so time synchronization is nil in case of SCADA. Let us say we have two buses, now a different buses here what voltage is measured at this bus location and here what voltage I have

measured, let us this is V 1 and V 2 and this two voltages are measured at different times. If I want to compare these two, I have to bring it to a common time frame.

So, that time frame is missing here, that synchronization is missing in case of SCADA, but; however, in case of PMU this synchronism means present. We can compare these two bus voltages or angles at a common time frame, that why this satellite this GPS system helps in doing that. It will just provide a common reference clock or universal clock signal to each PMU stations, the where the PMUs are installed.

So, the each PMU will receive a clock signal to the from the GPS or satellite. Now next point is the as per the total input output channels are concerned in case of SCADA we have like 100 plus analogue and digital channels and here we have 10 phasors this is important. This phasors means it includes both magnitude and as well as phase angle and also we have along with this we have 16 plus digital channels and 16 analog channels.

And focus unit is the local monitoring and control; however, here it is wide area monitoring control. The wide are monitoring means it will just control a very large network, but here it is basically the local monitoring system. What are the components of the WAMS? The first one is the PMU, the Phasor Measurement Unit.

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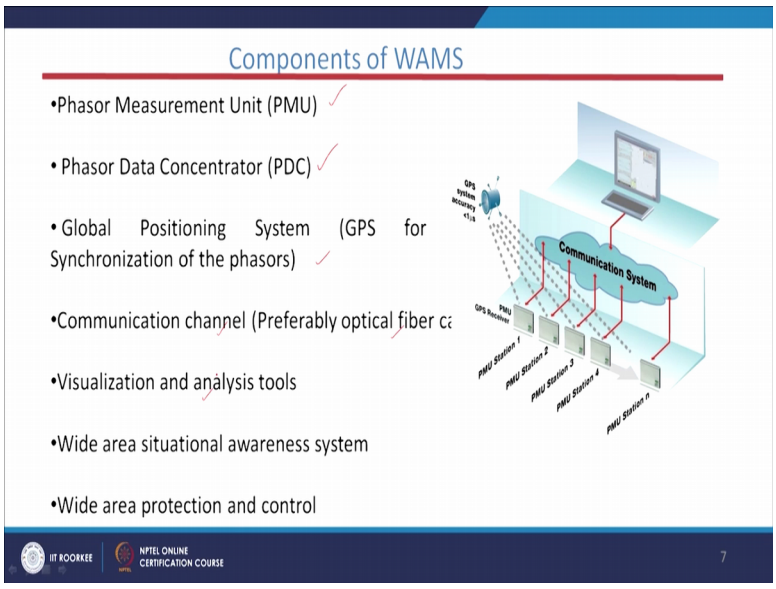

In the next class we will discuss in detail of this particular unit and the next one is the Phasor Data Concentrator, PDC we call it and third one is the GPS that is our Global

Positioning System and which is used basically for synchronization of the phasors of different buses. At particular bus we have voltage current phasors, at second bus we have different voltage current phasors. So, we have to synchronize this phasors for our further calculation or control purpose.

Now, this is the third one is the communication channel, yes without this communication this WAMS technology cannot stand. So, it is it is basically fully dependent on communication channel where we use mostly the fiber optic, preferably this fibre optic cables are basically used for communication purpose in case of WAMS technology. Next is the visualization and analysis tool, this is of course, it is necessary because after getting the data.

So, we have to keep it in certain forms so that we can visualize what is happening in our whole network and also for analysis purpose we have to analyze further how we can improve or we can control the corresponding equipments which are present in the system. And also we have wide are situation the (Refer Time: 19:37) system, this is very very important also because if beforehand we could guess that my voltage is going to be collapsed after certain time so always we can takes some decision, some prevention we can do always for that.

That is what the pre hand alarm system or some awareness system which is very very essential nowadays and now the last one is wide area protection and control. As I said before, so the protection is a very important, I mean the smart grid system, now our system is going to be more complex due to the integration of renewable sources and also due to the integration of batteries and near future also we are planning for integration of the electric vehicles, plug in electric vehicles.

So, due to the integration of different smart devices the network. So, the of course, system is going to be more complex and the definitely our protection and control system is also going to be more challenging. So, in that case this WAMS technology will help in adopting our protection and control system according to the change condition of the network, this is the WAMS process.

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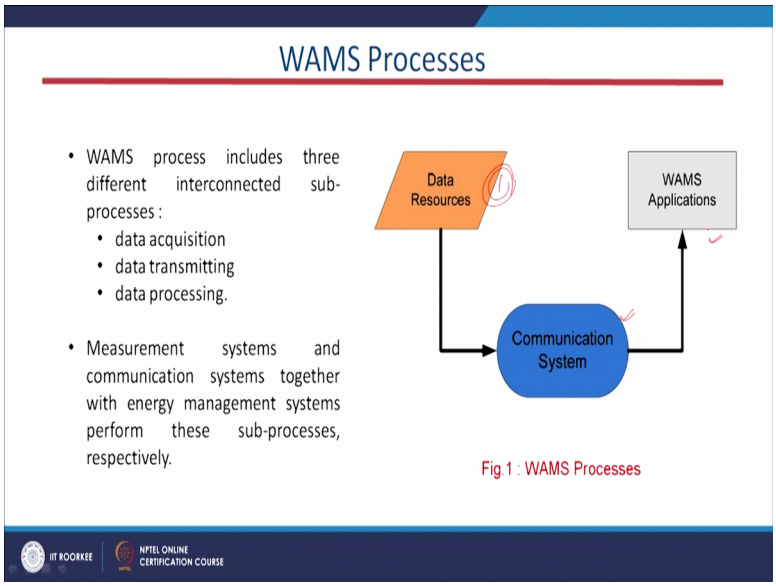

The first one is the data resources we will receive, this WAMS in WAMS technology the PMU basically send the data to the data concentrator PDC Phase Data Concentrator, there we will get the data resources and.

So, this communication system we can always apply or techniques or control signals or protection signals for further improvement of the system, first one is the data acquisition, second one is the data transmitting and then the data processing. If we will see the data resources are concerned we have two types of data, the first one is the operational data and the second one is non operational data. Let us say: what is the basic difference between these two data.

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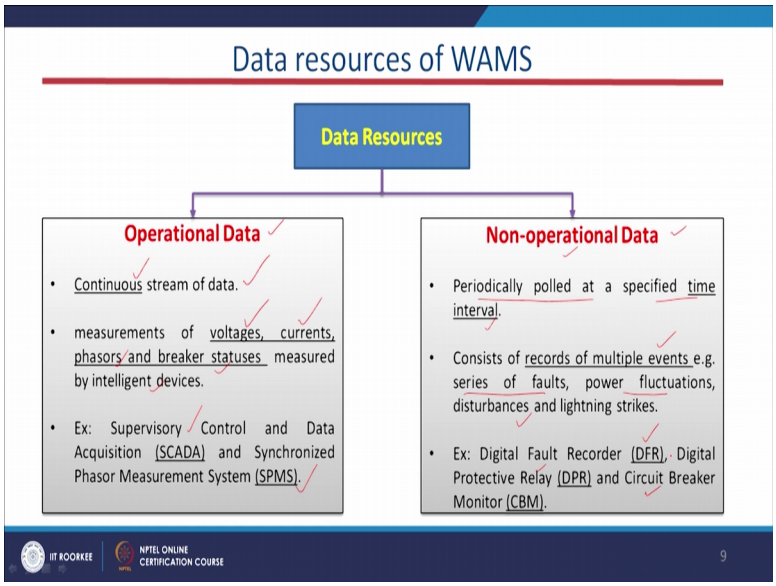

The first one is the operational data is continuous stream of data, it is a real time data it goes on it is basically measured at the end of PMU Phasor Measurement Units that is why it is very very vital component of the WAMS technology. Where we can measure the voltage current and frequency in the very bright flow like continuously we are just monitoring voltage current frequency of the system that is why it is a very continuous stream of data is possible there.

And here we measure basically the voltage, current, phasors and the breaker status and so these are basically measured by the intelligent devices. So, for example, we have this operational data, we have this SCADA system and also we have synchronized phasor measurement system, which is the part of this WAMS. Coming to this non operational data it is basically periodically plot, polled at a specified time interval.

So, this is not continuous mode of operation, if the data is not coming continuous data are not coming continuously. So, that is why it is periodically polled and it consist of records of multiple events like series of false or power fluctuations or disturbances or lightning strikes. So, this is basically the non operational data mode and here the examples like fault digital fault recorder, we have Digital Protective Relays that is DPR and we have circuit breaker monitor. So, these are the devices which provide basically this non operational data in the smart grids system.

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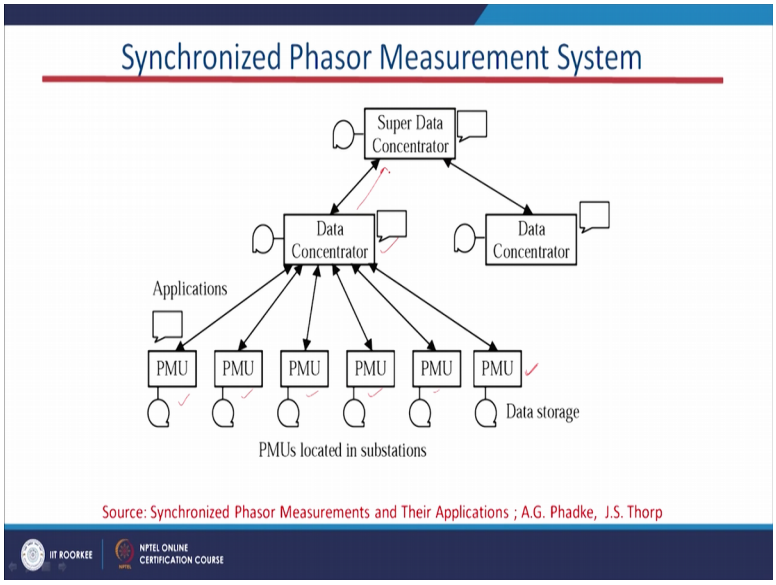

Coming to this synchronized phasor measurement system, what are the components of this synchronized phasor measurement system, the first one is the phasor measurement unit and second one is the phasor data concentrator and third one is the communication system. This is how it looks like, synchronized phasor measurement system first at different buses of the power network mostly the PMUs are located, placed optimally to save the cost. We do not like place the PMUs wherever we like, because that every bus we cannot put one PMU, we have to put the PMUs optimally.

So, after facing this PMUs at the critical point where we will have just complete observability of the system, for complete control of this voltage current frequency signals where we can measure the voltage current properly. So, after that the PMU data will reach to the data concentrator and from there it will go to the super data concentrator.

So, all the, basically this data concentrator maybe locally, so in particular area of the system will just collect the data from all the PMUs which are located inside that particular area and again also we have another area from where again we will just collect the data from all the PMUs to the next data concentrator. And from all the data concentrator we will just send to the another level of data concentrator called as super data concentrator. This is how it looks like, we have taken from this one of the IEEE power magazine.

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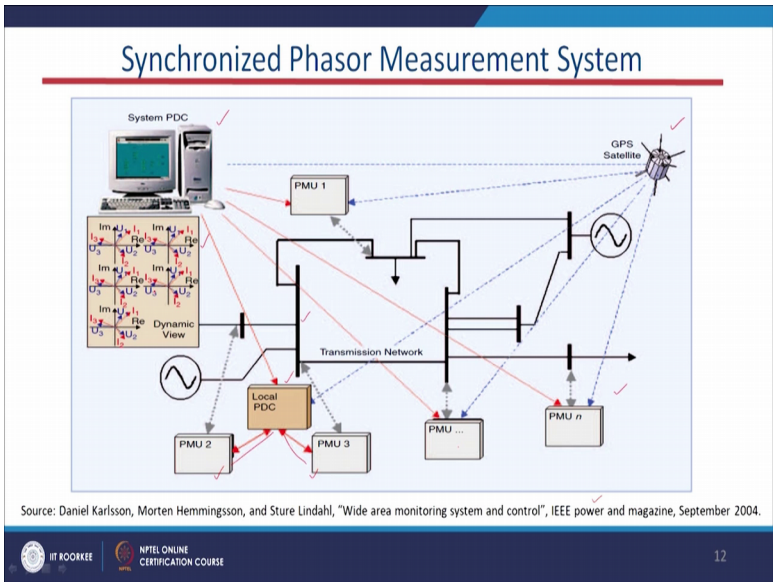

This is, let us say one bus in the power network where we have installed PMUs, PMU 2, PMU 3 and from this two PMUs this data are flowing to the local PDC. PDC means Phasor Data Concentrator and also we have like PMUs at other different buses PMU so on. Because we have just kept dotted line, let us say we have more number of buses present in this network and here also we have this GPS satellite. And due to this GPS satellite all the PMUs even including this local PDC are getting this clock signal, reference signal and it is just reaching also this system PDC and all the PMU will just reach to the system PDC, right.

So, here the symbols like phases of these voltages of every bus like U 1, U 2, U 3. So, the dynamic view of the voltage phasors in the real axis and also imaginary axis, we can visualize at this using this computer station.

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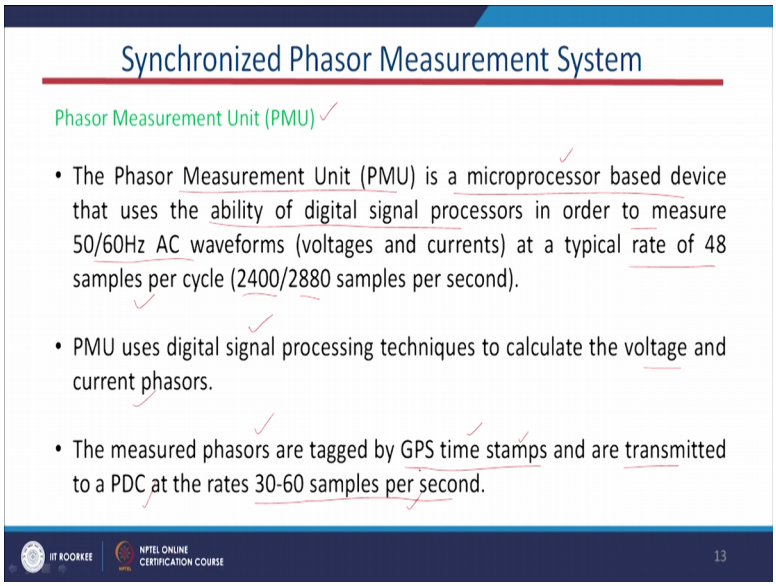

Now, we will discuss more about this PMU in our subsequent classes and I will just say this phasor measurement unit is a microprocessor based device. Also in some cases also we are using nowadays this trying to have this APJ based processor or DSP based processor. And it uses that used the ability of digital signal processor inside it we can just have different types of algorithms, signal processing techniques which will help us to calculate the phasors of the voltage and current. And also if you can just make it more comfortable like the, if you can improve the algorithm it can also provide harmonics of the voltage current signals.

Now, in order to measure 50 to 60 AC, 50 to 60 hertz AC waveforms of the voltage and current at typical rate of 48 samples per second; So, it basically measures the voltage currents at sampling data of 48 samples per cycle or 2400 or 2800 samples per second. And this PMU uses basically digital signal processing technique to calculate the voltage and current phasors, already we have discuss about it that we use one discrete fourier transform technique which uses the one phasor estimation.

Basically it is a phasor estimation technique due to that the voltage current phasors are estimated inside the PMU system, the processor of the PMU basically estimates the phasors of the voltage and current and the measured phasors are tagged by GPS stamps, GPS time stamps. At what time this particular voltage and current phasors are estimated using this PMU device that time stamp will be also there along with the voltage current

phasor and transmitted to the PDC at what rate? At the rate of 60 to, 30 to 60 samples per second. So, at this rate the data are transferred to the PDC the phasor data concentrator, now this after this PMU the next component of this synchronized phasor measurement system is the PDC.

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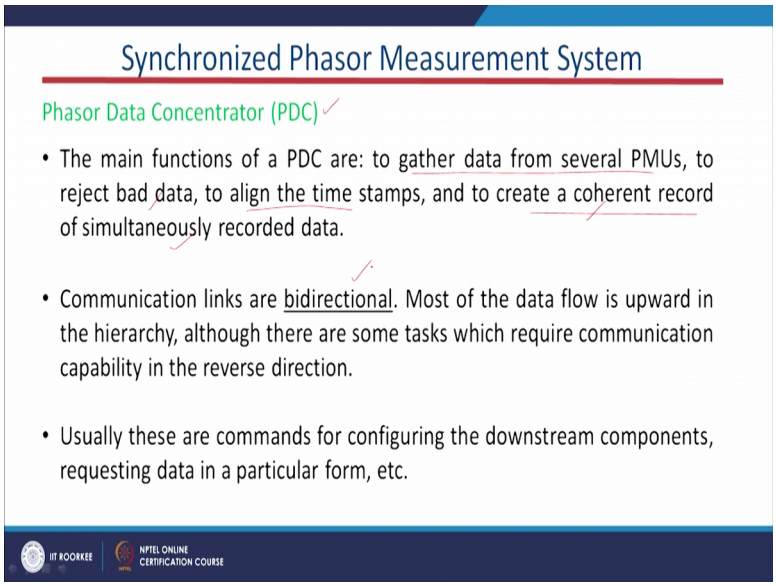

This is the main function of this PDC are to gather data from several PMUs, PDC will receive the voltage current phasor information along with the frequency also from the PMUs, to reject the bad data. If some bad data is present then this PDC will reject and this align with the time stamps and to create a coherent record of simultaneously recorded data, this is important.

Because nowadays we have one research field is big data analysis, at particular PDC or super PDC we have lot many informations, information available. So, in that case how to handle this data, that is also one question nowadays. Lot many voltage signals, current signals, frequency signals from all the buses we are receiving at the PDC level. So, how to handle this data that is also one big question and how to process it further also that is also important.

So, we have to create more more and more techniques and very strong techniques and so that we can rearrange the coherent, record simultaneously recorded data for our further process. And the communication links are basically bidirectional, mostly in the data

flows from the PMU to the PDC and some sometimes the PDC also says speaks to the, PDC speaks to the PMU also.

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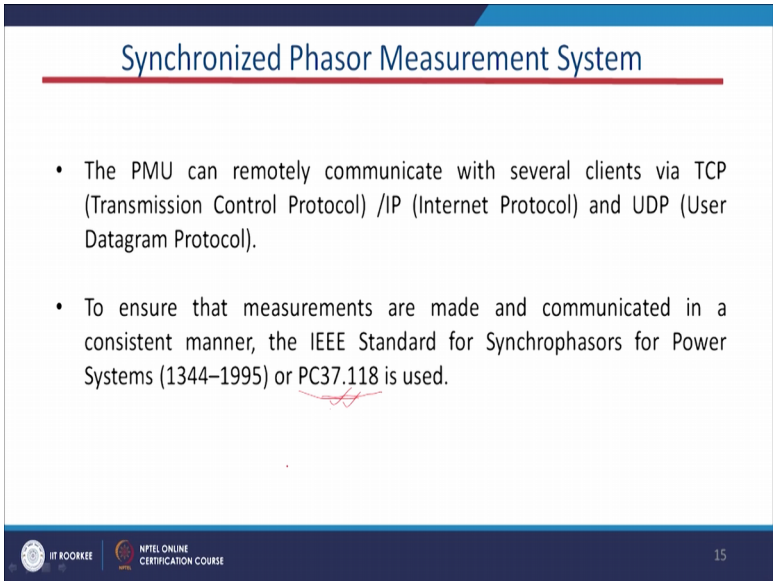

And the standard which is maintained for this PMU or synchrophasor measurement system that is basically the PC 37.118, this standard of IEEE is used to specify all the requirements or guidelines for the maintaining this PMU inside the wide area monitoring system. This is one of the synchronized phasorment system, the communication between this PDC and PMU.

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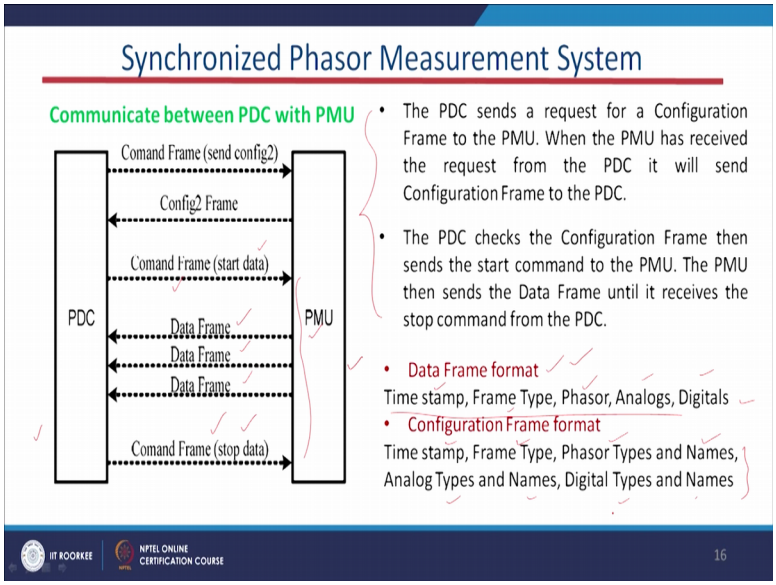

Here if you could see that the first one is let us say this my PDC and this my PMU, how this two speaks to each other, this two devices how they speak to each other. The first of all this PDC will send one command, here it is written command frame and here it will be written start of data, as if this PDC will tell to the PMU that you stain the data, you start the data. So, what will happen?

So, this PMU will starts sending the data frame to the PDC that is the first operation and the second one, this data will be sent to the PDC from the PMU, unless until this PMU receives that stop data command from the PDC. Here it is the command frame that is stop data if this command basically it is received by this PMU this PMU will stop sending data to the PDC, that is what the first phase of operation.

Now, this is what we have just written here data frame format, this is the operational part just I have discussed that was this PDC will just send one command to the PMU that send the data. So, after that this PMUs will send data to the PDC and again the PDC will send another command to stop data, the PMU has to stop the data flow.

Now, what is the data frame that is the format of the data frame that is also important it has the time stamp and also it has frame type, the phasor voltage current phasor analog or digital. So, this information should be at ago and it should be present and that particular data it is going to be send to the PDC level and sometimes also we have timestamp, time frame type, phasor types and names, analog types, names and digital types and names these are the basically the data frame format.

In this format the PMU will just send the data to the PDC, PMU sends the data to the PDC level. So, today we will just keep here, in this particular lecture we have started with the wide area monitoring system of a smart grid system. Now, the first we have just defined what is this WAMS and further just we have seen what are our goals and benefits as was the WAMS technologies concerned. And next we move to the components of the wide area monitoring system and also we have discussed the synchronized measurement system and the difference between this SCADA and WAMS technology we have seen, that SCADA has not that ability to monitor the wide area systems.

Rather, it will just monitor locally whereas, this WAMS technology can monitor in a wider, I mean range of the system easily and also it can inform us the angle status of the voltage current along with this frequency information. And further also if you can verify

like improve the technology always we can calculate the harmonics of the system, voltage and current signals. And further also we have seen the architecture of this PMU and PDC system and again here also we have discussed that how this PMU speaks to the PDC that is Phasor Data Concentration system.

Thank you.