Operation and Planning of Power Distribution Systems

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Lecture - 35
Distribution system automation and smart grid: Part - II

So, today is the last part of this module 8, in which I will discuss the Distribution System Automation and Smart Grid. In fact, in my last lecture I introduce the concept of this automation and smart grid, and we will proceed to that to understand that what are the changes required to convert a traditional distribution networks to a smart network, ok.

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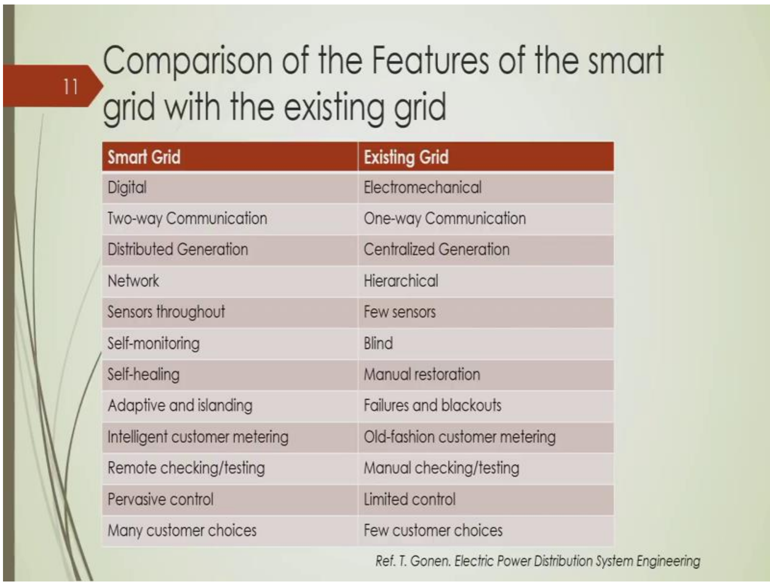

So, in my last lecture, I discussed the comparison between the smart grid and existing grid as far as the different features are concerned.

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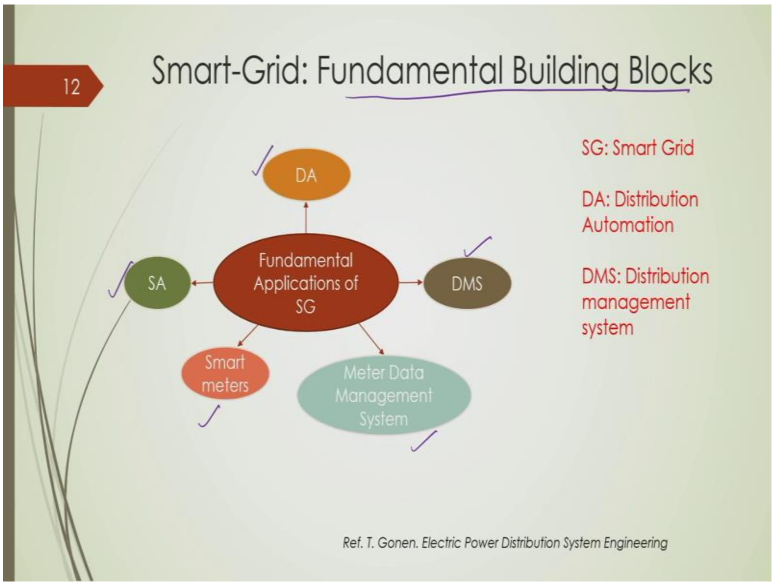

And also I discussed the different fundamental building blocks of a smart grid which include different building blocks, for example, distribution automation, substation automation, distribution management system or DMS, smart metering system, and meter data management system. So, these building blocks will try to describe in more detail in this lecture, ok.

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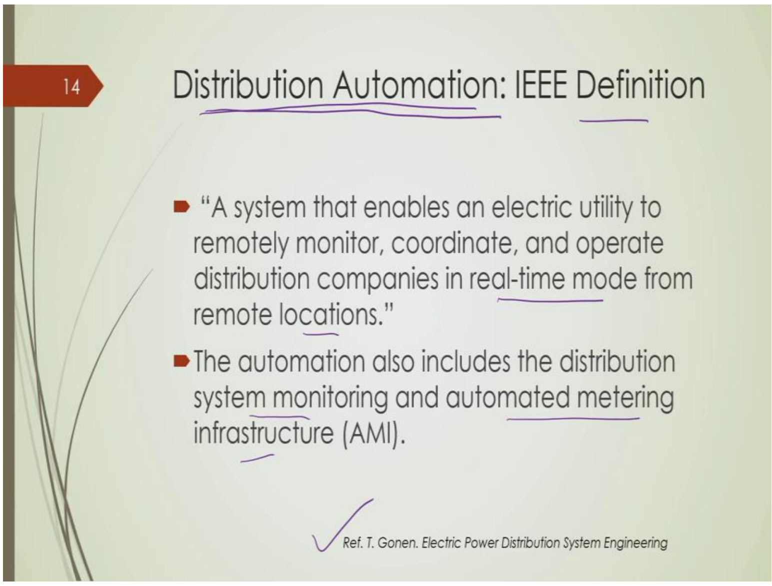

So, let us start with this distribution automation, ok. Although there is an IEEE standardized definition which is mentioned in the Gonen's book is there, but as such for this kind of system there is no formal definition. But, IEEE and its task force has probably defined it in a standardized form which says that a system that enables an electric utility to remotely monitor coordinate and operate distribution companies in real time mode from remote locations, ok.

So, that is called distribution automation. And this automation also includes distribution system monitoring and automated metering infrastructure, ok. So, this all these building blocks which we are talking about they are not isolated building block, they are basically overlapped with each other. So, they their functionalities are overlapping. Those things I will be discussing today.

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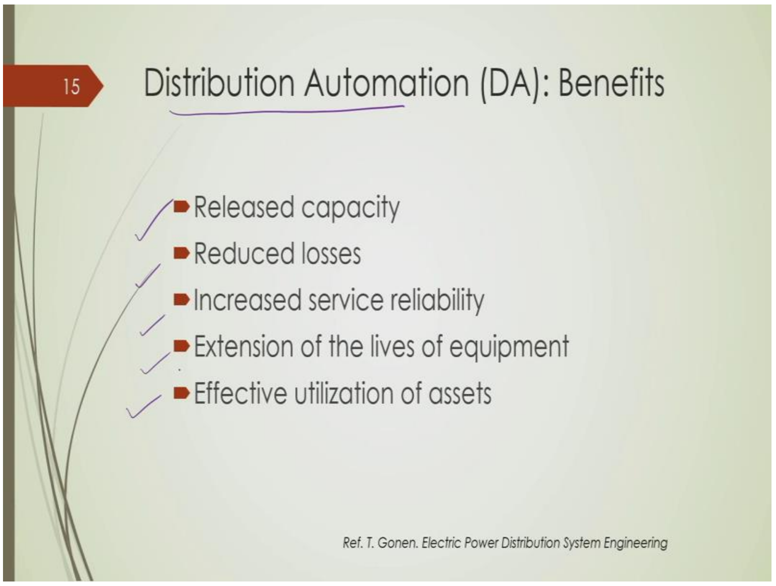

So, what are the benefits of distribution automation which the utility can get? That, it will have released capacity reduced of energy losses, improvement of reliability, extension of the lives of the equipment and effective utilizations of assets which are all these positive points for a electric utility, ok.

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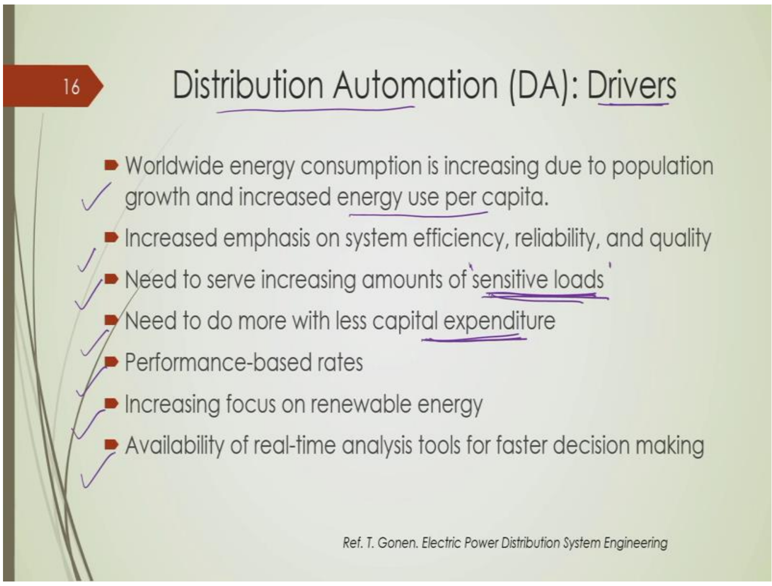

And these are the drivers which drives the need of this distribution automation, ok. One is of course, that increase in power demand worldwide, ok and also increased energy usage per capita, ok. So, it is because of the increase in per capita energy usage, the energy demand is increasing in a rapid space nowadays, ok and also the need of higher efficiency, reliability and power quality. So, previously whatever equipment the customers are using now these are completely changed, whether you are talking about the lighting equipment, whether you are talking about the air conditioning system. So, all these things are rapidly changing, ok.

And thereby, the need of this efficient power supply, need or the reliable power supply, need of clean power supply are required, ok. And also we have many loads which are sensitive loads. Now, what do you mean by sensitive loads? I discussed in my module 1, that there are some loads which are very much voltage sensitive, ok and even very short period of time, voltage disturbance may cause total interruption of those loads, ok. You may talk about in a hospital where different kinds of life saving equipment are there. So, this can be considered as the sensitive load, ok. Similarly, our air traffic control is a kind of example of sensitive load where we cannot tolerate even a few micro-second of interruption, ok. So, similar kinds of loads are increasing nowadays. Even our computer is a sensitive load and in all of our houses we have nowadays computing facilities, ok. And data centers are also an example of sensitive loads. So, these types of sensitive voltage, sensitive loads are increasing in a rapid pace and also we need to you know reduce or minimize the capital expenditure which is our goal on power distribution system planning I discussed.

Performance based rates, this will yet to come. And also increasing this renewable energy which I discussed in my last module, this is also a driver nowadays to automate the system. And also availability of real time analysis tool for a faster decision making. So, if we want to make use of those systems we have to automate the whole process, ok.

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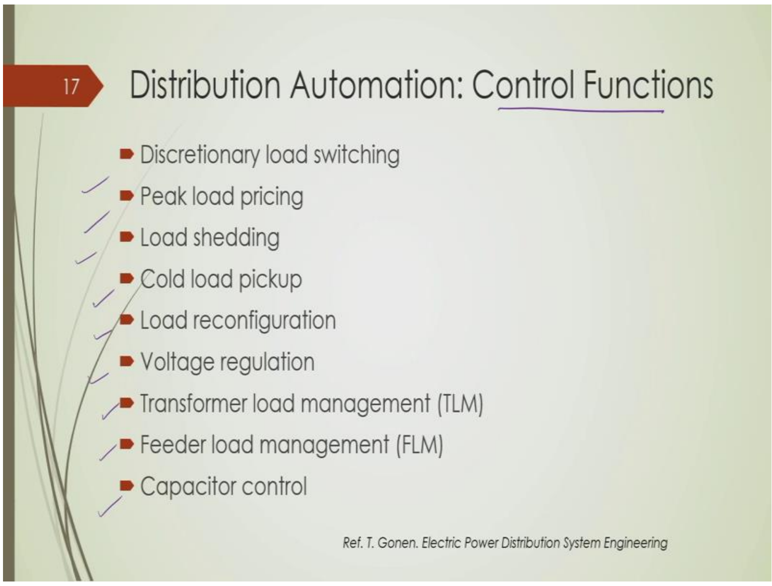

So, these are the control functionalities of distribution automation, load switching, peak load pricing, load shedding; automated load shedding of course, this cold load pickup, reconfiguration, voltage regulation, transformer load management, feeder load management, capacitor control. Those things, at this point we know many things.

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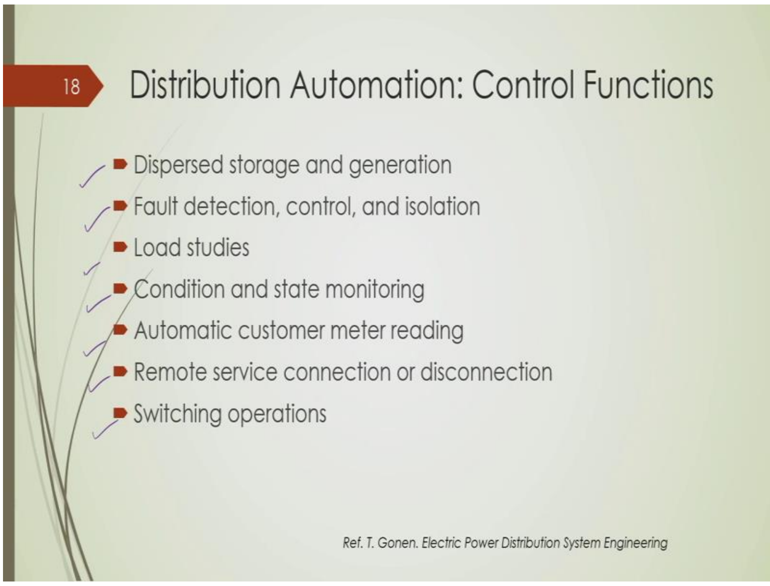

And also, this presence of storage, fault, automated fault detection, load studies, condition and state monitoring, automated meter reading, remote service connection and switching, these are the some of the functionalities of distribution automation, ok.

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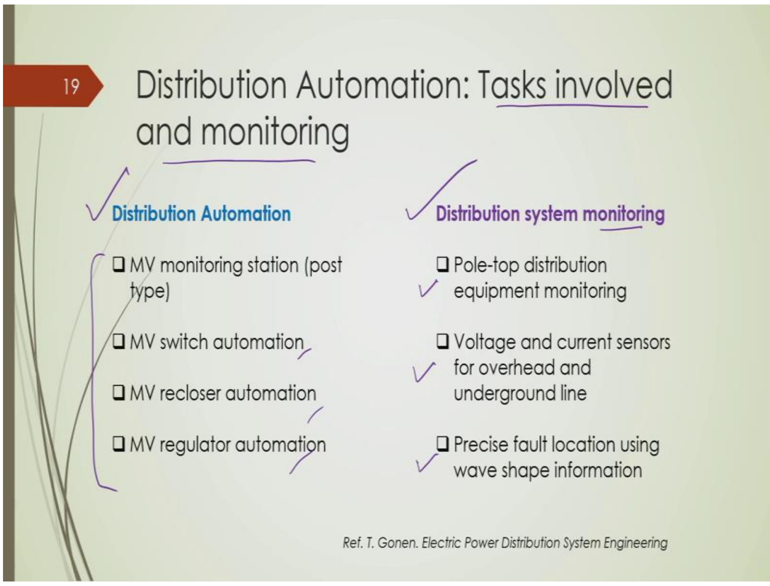

And if we can vertically divide into the whole task of distribution automation then we will be having one task as distribution automation, another is distribution system monitoring. Under distribution automation, we have this medium voltage monitoring station, switching switch operation, recloser automation and regular your regulator automation, ok. So, those which are associated with the substation those need to be automated. Similarly, in distribution system monitoring, we need to have some monitoring process in this pole top of distribution equipment, then we need many sensors to be deployed in overhead and underground distribution lines, and also we need to have a fault localization, automated fault localization and detection process, ok.

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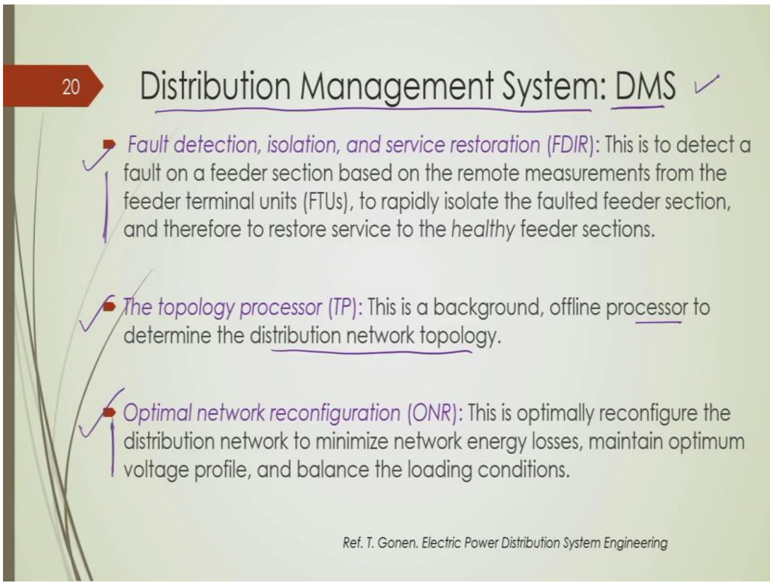

Now, next building block that I am talking about for a typical smart or typical automated distribution system operation is distribution management system and its acronym is DMS. In fact, lot of research is going on this particular aspect, ok. Now, let us see that what are the features these distribution management systems have. One is called fault detection isolation and service restoration this is an important thing in order to improve this reliability of the operation. Then, topology processor, in topology processor once this should automatically trace out the distribution network topology with the help of different sensors deployed in different part of the system. Even operator does not know anything about this topology with the help of the sensors, one can trace out that, what is the topology of the network, what is the structure of the network at present, ok.

Then, optimal network reconfiguration which I already talked about that network reconfiguration; it is an area of research in power distribution systems. And it incurs lots of benefits, ok, in terms of this power or energy loss reduction or alternatively improves the energy efficiency in terms of the service restoration and many aspects, in terms of the improvement of the reliability and many aspects. So, those things are also part of this distribution management system.

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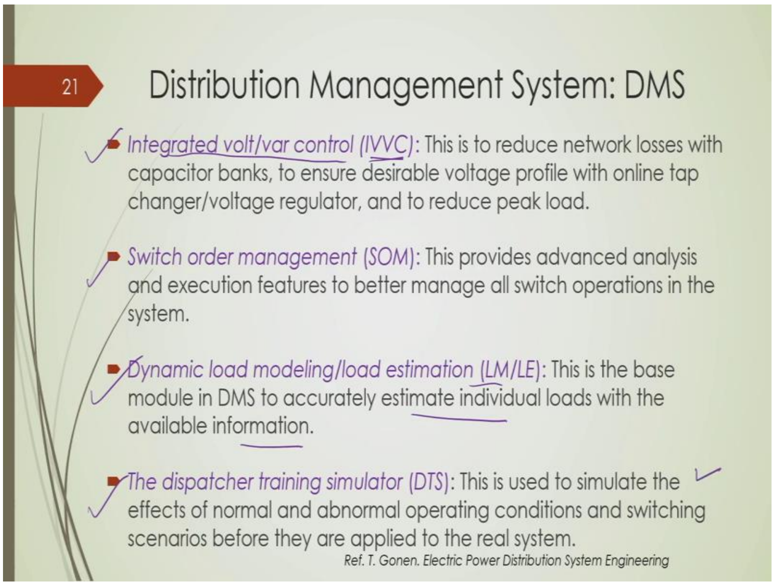

Then, next is integrated volt-var control, IVVC in sort. So, this is basically required in order to improve the voltage profile and in order to reduce the network losses as well as in order to have a better voltage regulation, ok. And, we have many sort of voltage control devices which include traditional capacitor bank to traditional on load trap changer of the transformer located in the distribution substation. And also, there are many others voltage controlling devices, voltage regulator deployed in different part of the networks, and maybe different others which I will be discussing today. And also the switch order management, this is another you know feature of DMS; Dynamic load modeling and load estimation. So, this is similar to you know this estimation of the network topology. With the help of DMS subroutine, one can also determine this or estimate the individual lodes in a particular feeder and also dispatcher training simulator. This is a simulator to simulate this performance of a network during abnormal or normal condition.

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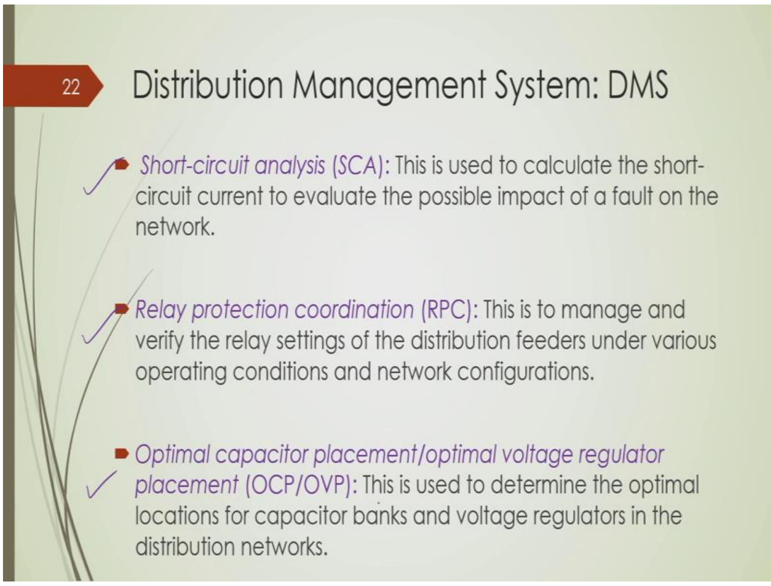

Also, it has short circuit analysis capability, this relay protection coordination system and optimal capacitor placement, ok which I was also talking talked about in module 5, ok.

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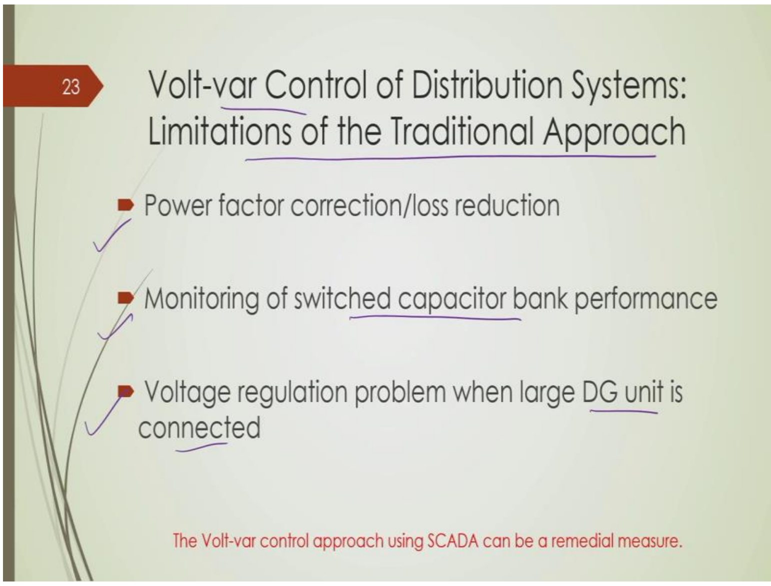

Now, these are the limitations of traditional approaches for volt-var control. What do you mean by traditional approaches? Traditional approaches are deployment of capacitor bank and traditional approaches are also make use of on-load tap changer, ok. They have some limitations. So, these limitations are: they have certain capability of loss reduction and also they have some switching problem, ok.

And this monitoring the switched capacitor bank performance is also a limitation and voltage regulation problem when large DG unit is connected. So, that is another problem when large DG connected to a network.

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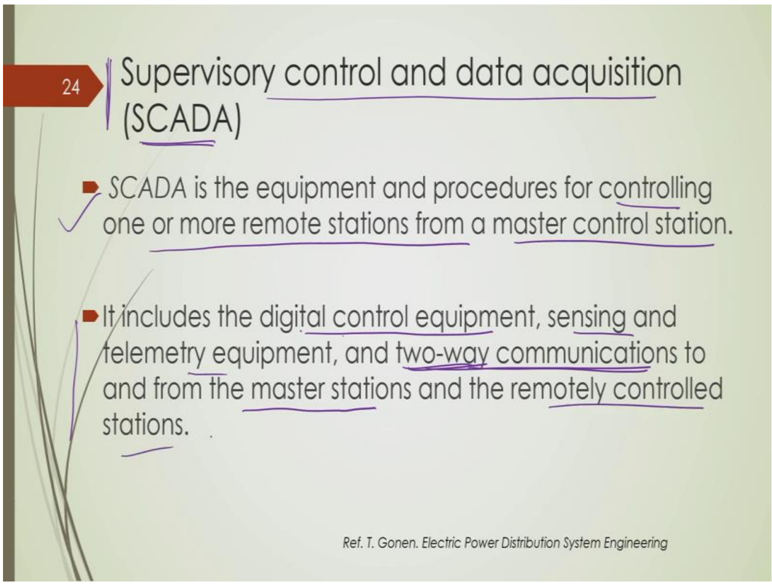

Now, for operating a distribution network in an automated environment, one of the tools the distribution network utility use is called supervisory control and data acquisition system or, in short, it is acronymic as SCADA. Now, what is SCADA? The SCADA is a equipment or procedure for controlling one or more remote stations from a master control station. This is again not formal definition, but one can understand what is SCADA. So, it is basically an equipment or it is a procedure for controlling one or more remote stations by sitting in a master stress control station which may be located few kilometers away from this demonstration, ok. So, it is a procedure to remotely control many sort of equipment of under a distribution network, ok. And this SCADA includes several things which include digital control equipment, sensors or and telemetry equipment communication, which is a backbone of this SCADA system. And here it is talking about two-way communication. How it works? I will come to that. And also, we need to have a master station and many remotely control stations, ok.

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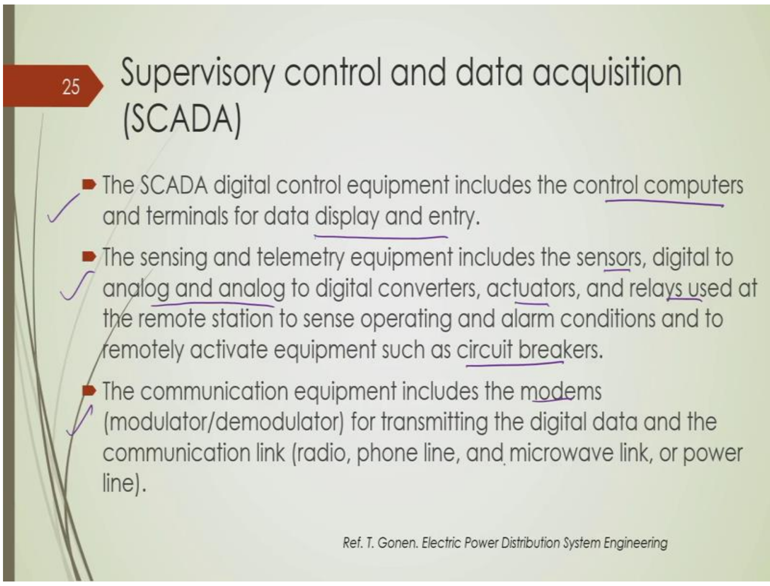

So, this, SCADA digital control equipment includes this computers and the terminals for data display and data entry. And many sort of sensing and telemetry equipment which include sensors which are deployed in different part of a network, digital to analog or analog to digital converters whenever required, actuators, relays etcetera and also which needs to operate the circuit breaker remotely, ok. Now, communication equipment includes modems, but transmitting digital data and communication link, ok.

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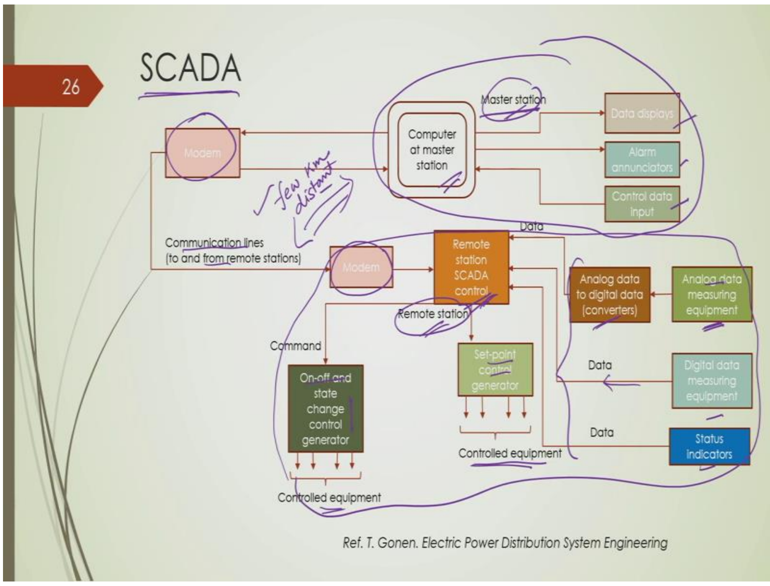

So, this is a typical, you know, schematic diagram of a SCADA system, ok. SCADA as I said, it is a backbone of automation of a distribution system, ok. Now, in this SCADA system, this part is the this part is your master station. This is the master station. And this part is basically remote station. And in between them, there are few kilometers distance. So, they are located few kilometers distant, few kilometers distant, ok.

Now, what are there in the master station? Typically, we have a computerized master station where we have displays of different data and also alarm annunciators and there is a provision to input the data, ok. And what is there in the remote station? First of all, we have different measuring and sensors, ok, in order to measure and sense the operating conditions of the different part of the network which may be the voltage sensor, current sensor etcetera, ok.

And this sensor or measuring equipment, if they are of digital they can directly feed this digital data to this remote station SCADA control part. And if they are analog data then we need to convert this analog data to digital data by using analog to digital converters, ok. So, these are the things which are basically measuring data and sensors to indicate the status and this state of the system. Apart from that, there are some controlled actions or set point control generators, whose role is to generate the desired set point to various controllable equipment. Also, there are some on and off state changer control, for example, capacitor control where we have either switch on or switch off, a typical capacitor bank, ok.

So, this you know this is a remote station and this is a master station. So, operating this remote station from this master station which may be few kilometers distance away, which may be located at few kilometers distance away is a process of SCADA. And this is what the communication link and we need modem in order to have this proper communication between the master station and all the remotely controlled stations, ok.

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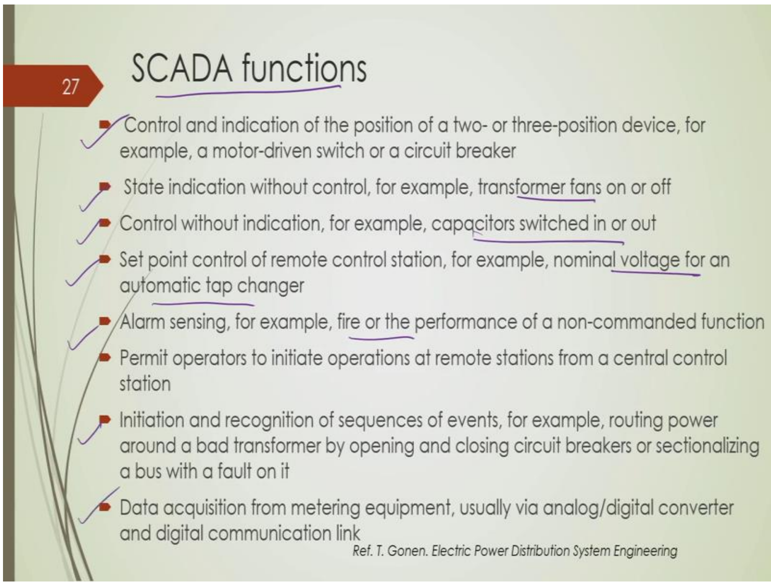

So, these are the typical functions, SCADA functions which include control and indication of various switches, state indication, for example, if we have this cooling of a transformer by using blower. So, this operation of this blower on and off can be properly indicated which is an important parameter for a distribution network operator, control without indication that is capacitor switched in and switch out; set point control which I was talking about. The includes the nominal voltage for automatic tap changer; then, alarm sensing which includes that fire and any sort of undesired parameters and then initiation and recognition of different sequences and data equation from metering equipment, ok.

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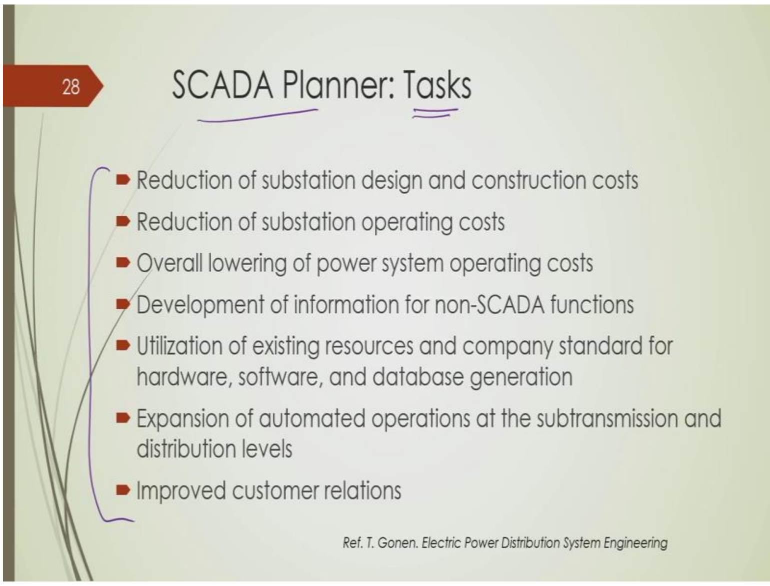

Now, being a SCADA planner, one needs to consider various task which includes the this the task where we need to reduce the substation cost design cost, we need to reduce the substation operating cost, we need to reduce the total operating cost of the whole network and we need to reduce the functionalities of non-SCADA functions. So, those are the some of the things, one need to take into consideration before deploying this SCADA.

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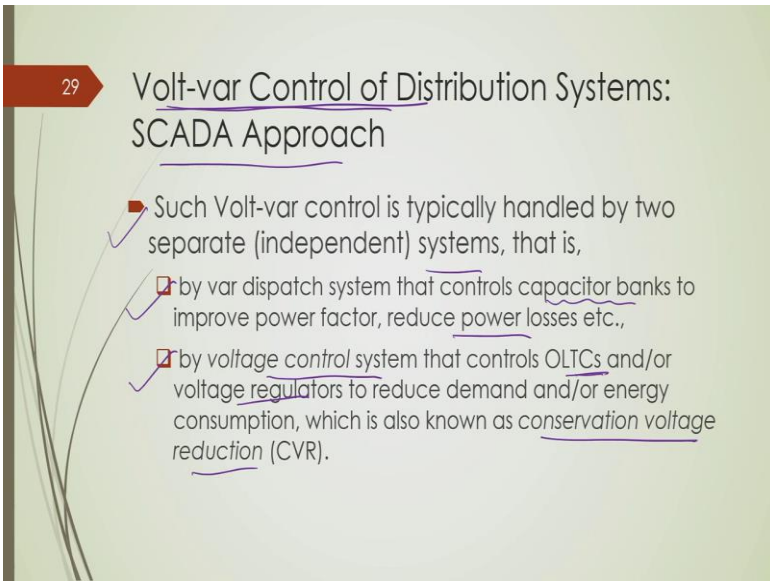

Now, there is another module or building block of this typical automated system that is called volt-var control, ok. And SCADA can be used as one of the approaches for volt-var control, ok. Now, how SCADA can be used? So, volt-var control is typically I discussed in my discussion with reactive power compensation in module 5. And this means I discussed this capacitor placement, as one of the reactive power compensators, but this is not only the reactive power compensators, there might be various other devices in order to improve the voltage.

And that process needs a total proper coordination of various devices which will be participated in this voltage control and that process is called volt-var control, ok. And this control is handled by two separate systems, independent system, one is var dispatch system to improve which are used to improve the power factor and to reduce power losses, for example, this capacitor bank. And there are some systems which are used for voltage control, ok for example, this OLTC; OLTC stands for on load tap changer, ok, and or voltage regulator. These are used to improve the voltage or in order to regulate the voltage of the network. And also there is a process called conservation voltage reduction; this is used to purposefully reduce the demand for some of the loads when you know that the voltage variation is very wide, ok.

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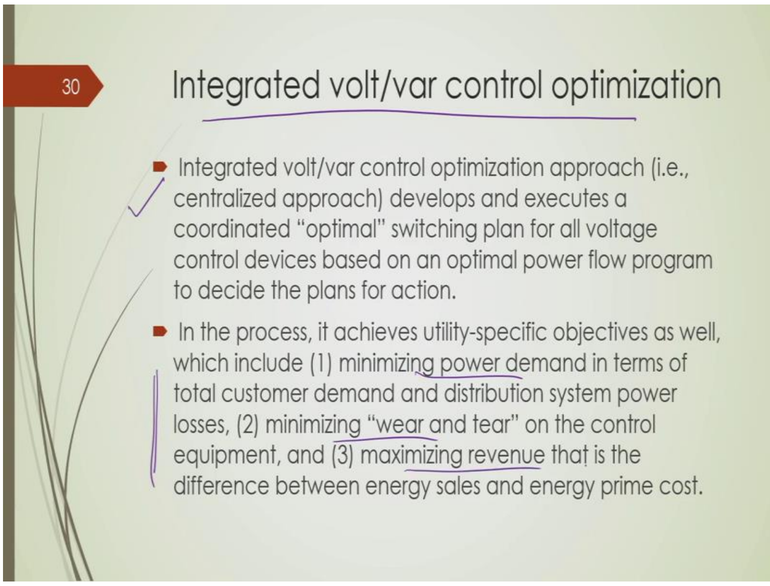

But this integrated volt-var control optimization is another domain of research, ok which requires devising an appropriate approach to control or to determine the optimal coordination of the many such kind of volt-var, many such kind of systems which is used for this volt-var improvement, ok. So, there are some of the utility specific objectives, one is minimizing this power demand in terms of total customer demand and distribution system power losses, minimizing wear and tear in the control equipment, and maximizing the revenue. Those things I discuss; some of the things I already discussed.

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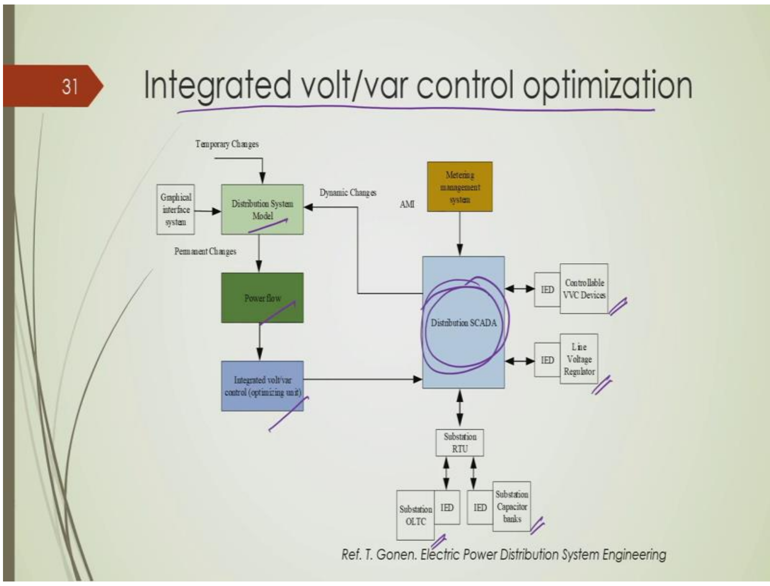

So, this is a schematic of integrated volt-var control optimization, ok. So, if you look at, so this is our distribution SCADA, ok and which is connected to many sort of volt-var system which include substation OLTC on tap changer, substation capacitor banks, line voltage regulator, controllable volt-var control devices, ok. And their set point is decided by sitting in this, you know master station, ok. And in order to decide the set point, we need to have, you need to get the data of different sort of states of the system which we can get from this distribution system model by using power flow approach and by using different type of optimization approach, ok.

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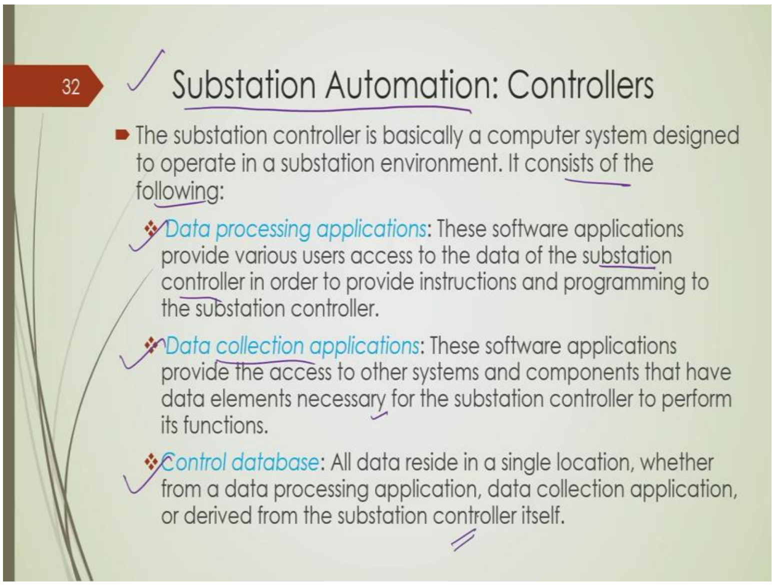

Now, next building block for automated distribution system operation is called substation automations, ok. Substation automation consists of the following attributes, one is called data processing application, one is called data collection application, another is called control database.

In data processing application, this software application provides various users access of data the substation controller, ok. So, we have various data collected from the sensors with the use of this SCADA system, this data need to be appropriately processed, ok. And this processing happens to be task of a substation controller, ok.

So, data collection application, this is another software application which is used to access other system and component data. And also, there is a control database, ok.

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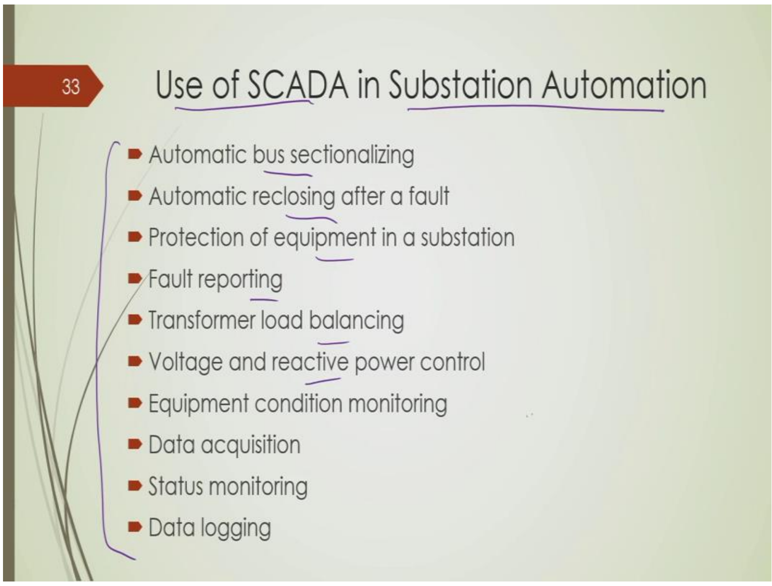

Now, use of SCADA in substation automation: so, as I said SCADA is a backbone of automated distribution system operation and it is useful for substation automation as well. So, we can do many things by using the SCADA system which includes automated bus sectionalizing, automatic reclosing after a fault, fault reporting, protection, transformer load balancing, voltage and reactive power control etc., ok.

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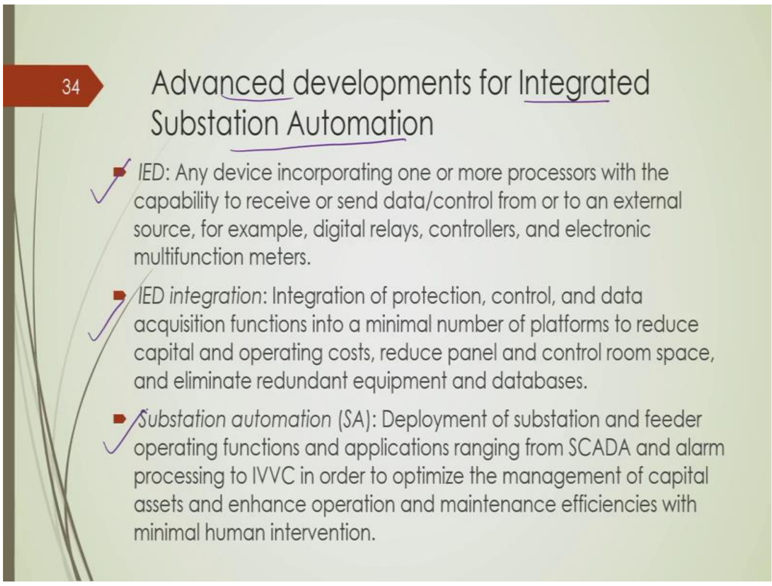

Now, in advance development of integrated substation automation, we have IED. The concept of IED is already discussed in my last lecture. It is a system having some processor which can receive or send data, which can communicate data, ok. So, this IED, there are many research going on development of this IED and its integration in order to have a better substation automations, ok.

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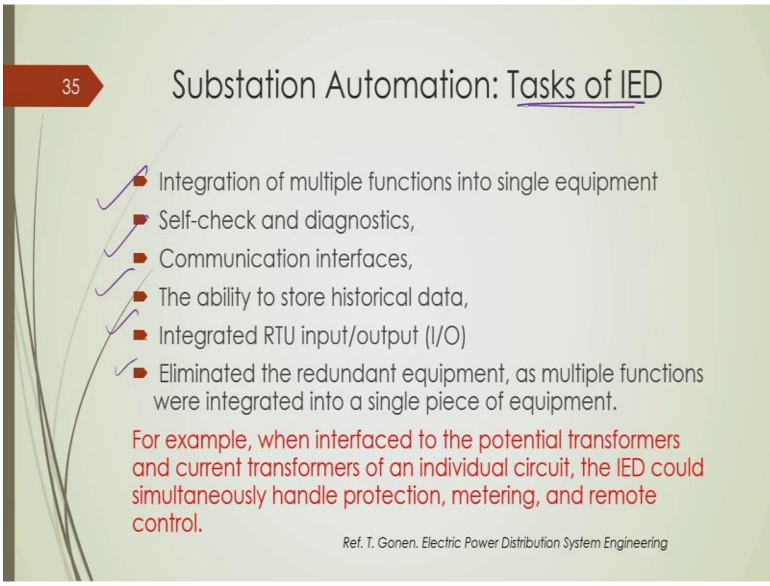

And what are the tasks of IEDs, we have in a substation automation process? There are multiple tasks which include integration of multiple functions into a single equipment, self check and diagnostic or self-healing process, this communication interface ability to store historical data and there are many others, ok.

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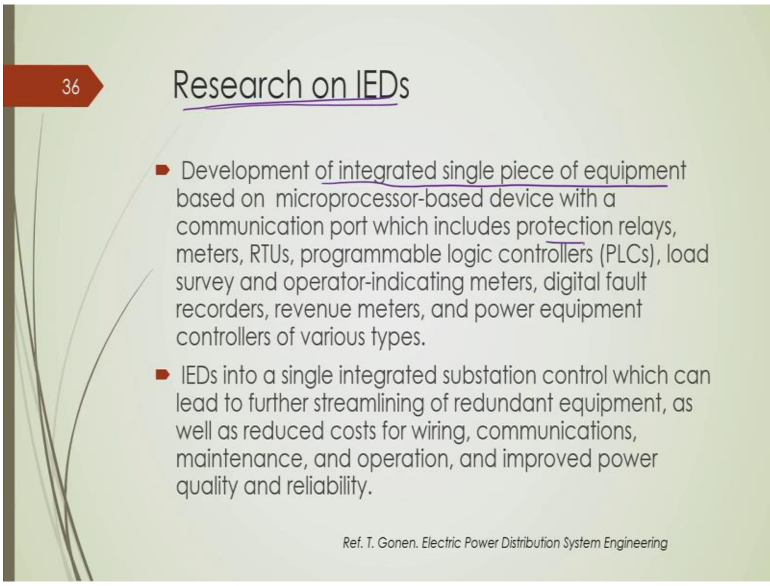

As I said, there are many research papers reported last few years on the development of IEDs which are basically aimed at development of integrated single piece of equipment. Of course, it is microprocessor based device in order to have various you know properties which include protection, which include metering, which include load management etcetera, ok.

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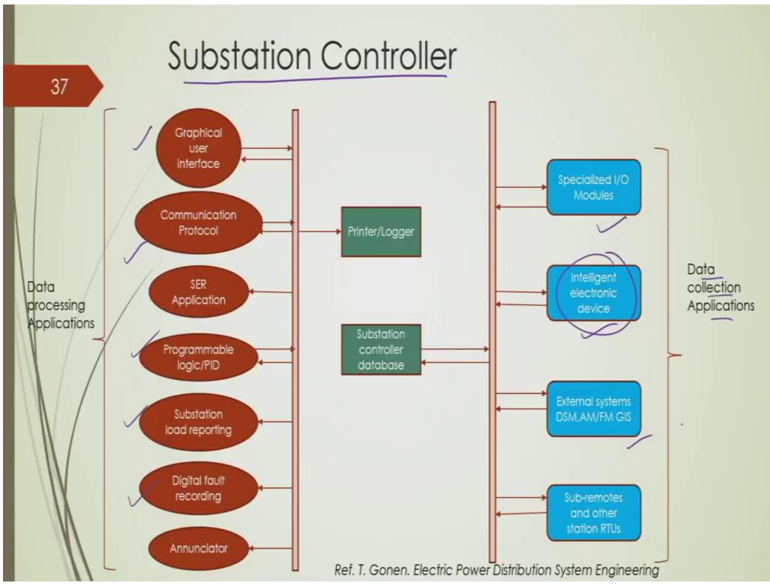

So, this is a typical, you know, schematic part substation controller. There are many things connected with this which include graphical user interface, communication protocol, substation load reporting, programmable logic, digital fault recording, etc. And also, there are some data collection applications, for example, input output modules, intelligent electronic device, IED I was talking about, and many others.

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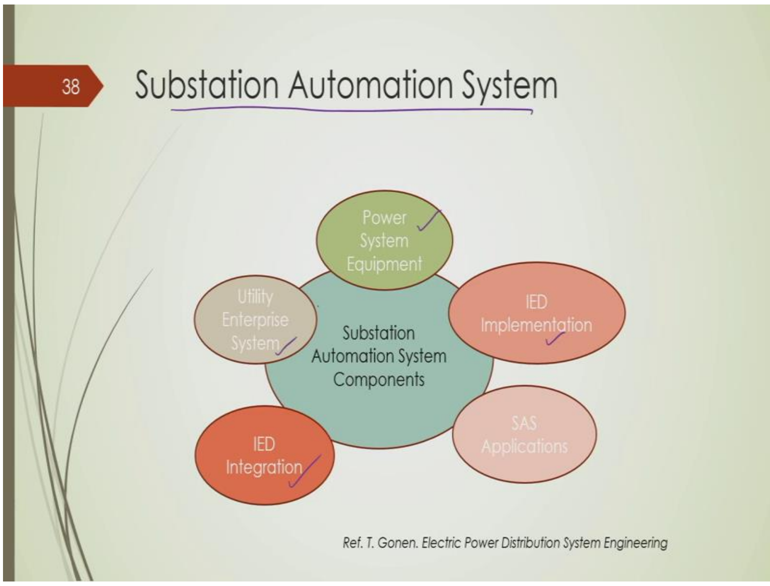

So, this is a schematic of substation automation system which includes different power system equipment, IED implementation, IED integration, and utility enterprise system.

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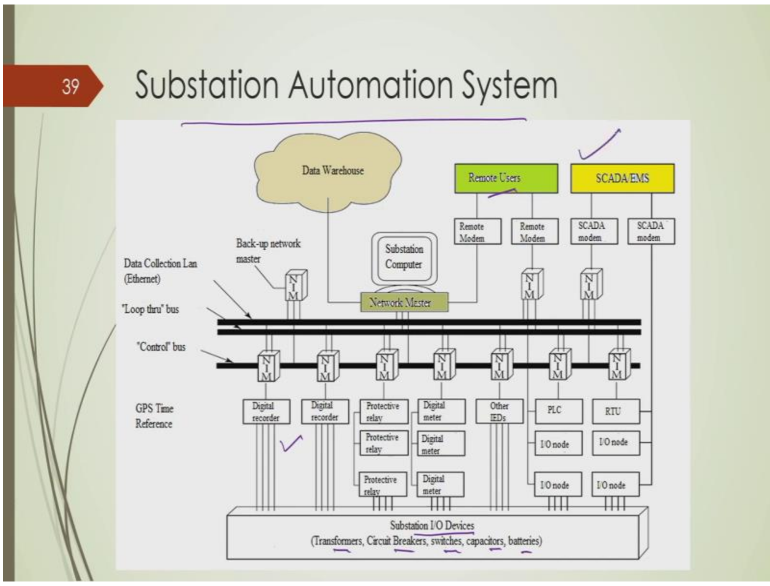

And this is another schematic for this substation automation system. You can see here this I also took from this Gonen book, where we have different users which are connected to this two control buses. And in this one control buses, we have this different substation input output devices which may be of different substation stakeholder equipment, like transformer, circuit breaker, switches, capacitors, batteries etc., and how they are you know connected and operated with the help of this SCADA system.

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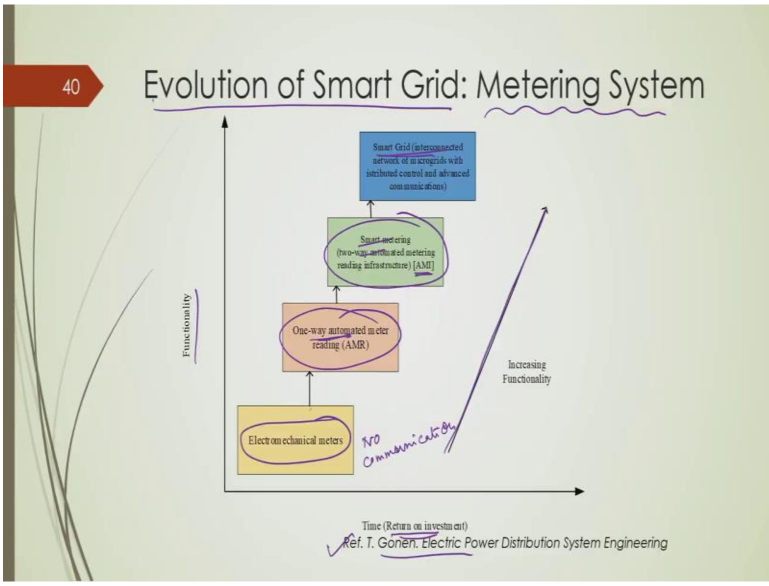

Now, another domain of this smart grid research is automated metering system. So, we have basically electro-mechanical meters previously, ok. And this would be changed to one-way automated meter reading, ok. This makes, you know, collection of data much easier than the manual collection of the recorded data, ok.

Then, the next phase is smart metering where we have two-way automated metering, meter reading infrastructure, ok. And automated meter reading infrastructure is called AMI, it is acronymic as AMI, which is another mode of advancement. So, here there is no communication. Here, there is no communication. Here, we have one-way communication; here we have bi-directional communication. And then, after deploying so, we can move forward to the domain of this smart grid. So, if you look at this characteristic, this is again I took from this Gonen book, you can see the functionality will increase from one step to another step and so as the return on the investment, ok, so, maybe that deployment of this smart grid would be much costlier than the traditional operation of the power network, but it may result in higher return in future, ok.

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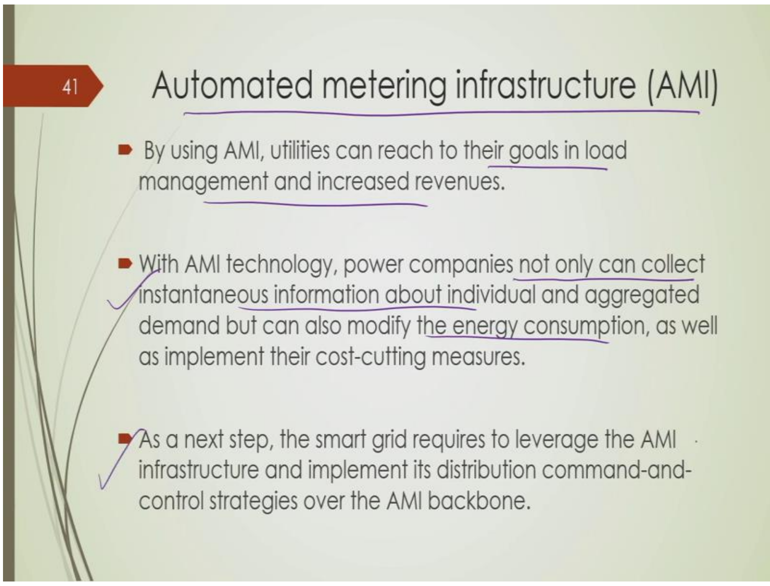

So, this automated metering infrastructure or AMI is another domain of this research in smart grid of power system, higher utilities can reach to their goals of the load management and increased revenues, ok. So in fact, in module 1, I was talking about different load management system, ok and this is only possible if we have this automated metering infrastructure, ok. So, with AMI technology, power companies not only will collect the instantaneous information of individual and aggregated demand, but also can modify the energy consumption, ok. So, these things, I discussed and that modification will have a multiple benefits. It can result in peak shaving, it can result in valley filling, it can result in many other aspects, ok. So, a smart grid requires an automated metering infrastructure.

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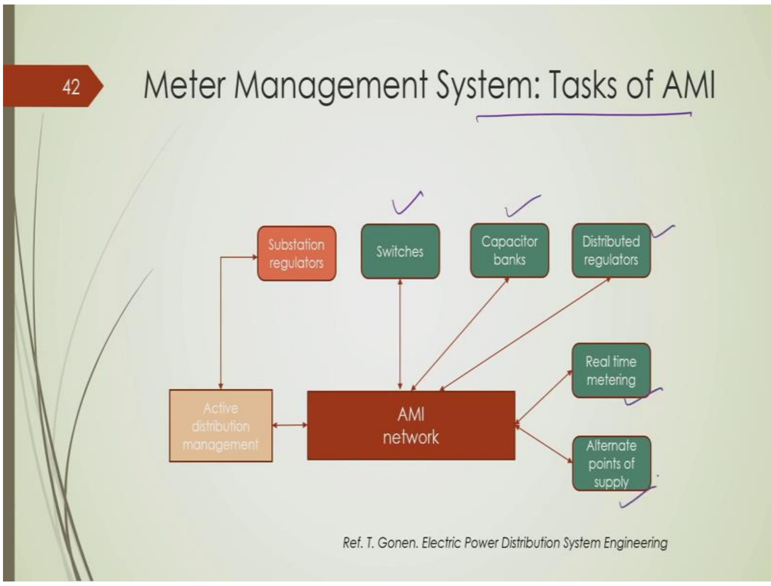

And these are the typical tasks of automated metering infrastructure network. It needs to be connected with operation of the switches, capacitor banks, distributed regulators, real time metering and alternating point of supply, ok.

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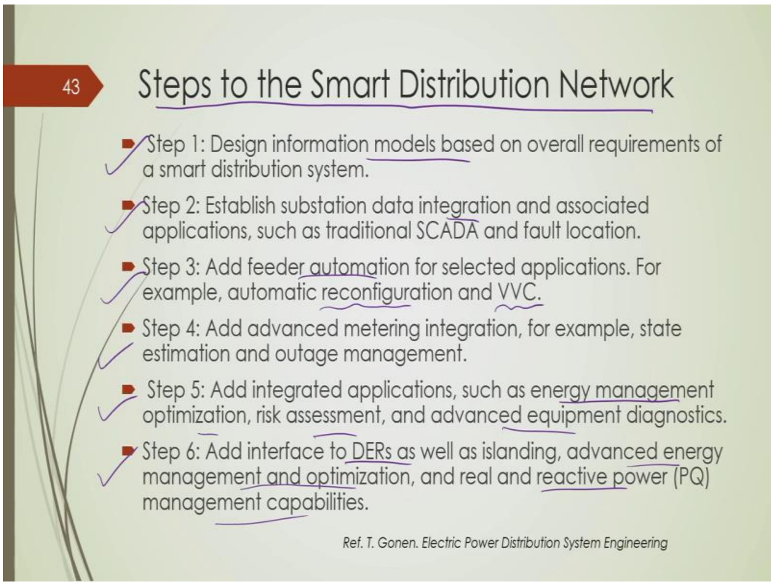

Now, finally, we have arrived at different/some of the steps to move forward from the present day distribution network to a more advanced or automated or smart power distribution network. The first step is to design information model based on overall requirement of a smart distribution system. Then, second step is to establish substation data integration and associated application. Step three is feeder automate automations for selected applications which includes that automatic reconfiguration and volt-var control. The next step is advanced metering integration. The next step is having energy management optimization, risk assessment, advanced equipment diagnostics. And final step is to interface the DER and the advanced energy management and optimization and real and reactive power management capabilities. So, step by step, a network needs to be converted to a smart grid. As already I mentioned that a smart grid is not a replacement of the grid. It is basically upgradation of a grid, and in fact, it can be selectively done based upon the investment ability of a utility.

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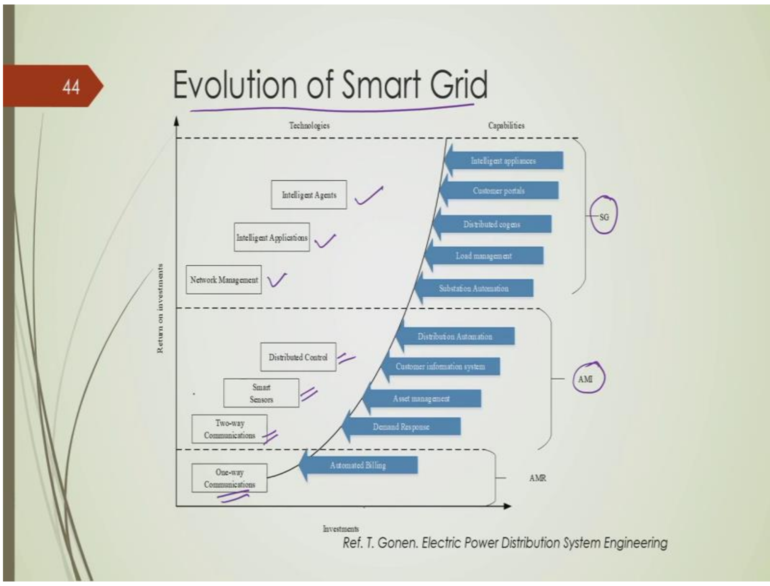

So, this is a figure which gives you again similar kind of advancement starting from this one-way communication to two-way communication deployment of smart sensor and distributed control. This is possible by using AMI, automated metering infrastructure. And next step ahead is basically smart grid which needs network management intelligent application and intelligent agents, ok. And of course, their functionalities will also increase, so as the investment and return on the investment, ok.

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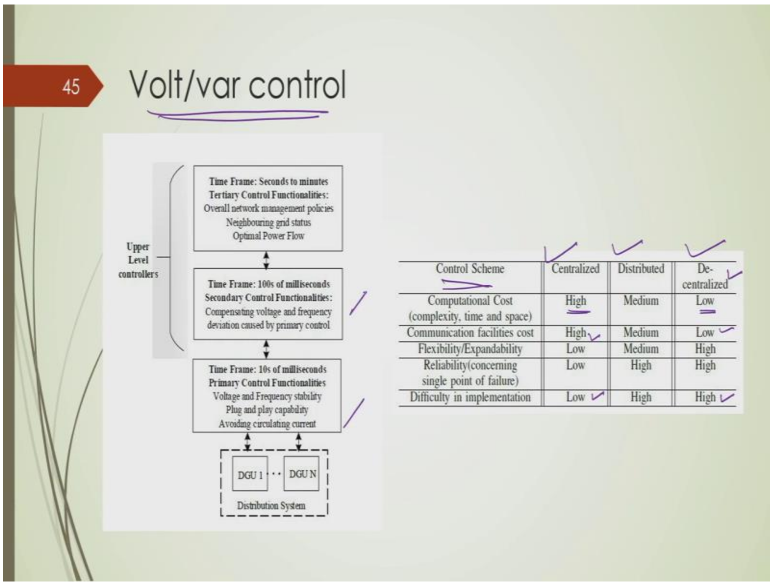

So, this is a typical flowchart of volt-var control. Basically, if you do this literature review on automated volt-var control you can get a lot of papers reported last few years. We have different control schemes, as well which include centralized control, distributed control, decentralized control, ok. And they are having some advantages, disadvantages. For example, this computation in centralized control is very high whereas, decentralized control is very low, ok. Communication facilities need is high in centralized control, low in decentralized control and so and so. So, difficult in implementation in centralized is low, but decentralized is high.

In fact, centralized control is basically with the deployment of SCADA, one can make decision from the master stations. We can decide the set point and then they can effectively transmit to the remote stations. Whereas, in decentralized control the control operation of the individual equipment would be decided at the individual equipment point of point without transmitting to the centralized point, ok. So, this needs some sort of you know upper level controllers.

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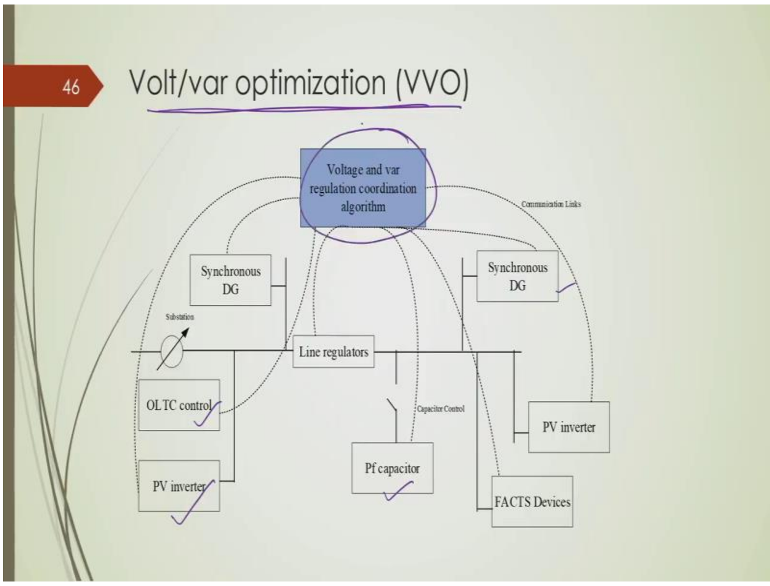

And also, in the next phase of this volt-var control with the deployment of DER in particular, we have many stakeholders for participating in volt-var control. Not only we have this capacitor or that OLTC control, but we have many other stakeholders which include the inverters that we use in the photovoltaic system. Also, if we have any sort of synchronous distributed generation system.

So, they can also participate in automated volt-var control. And, to have a effective coordination, we need a specific approach and based on that there are several research going on.

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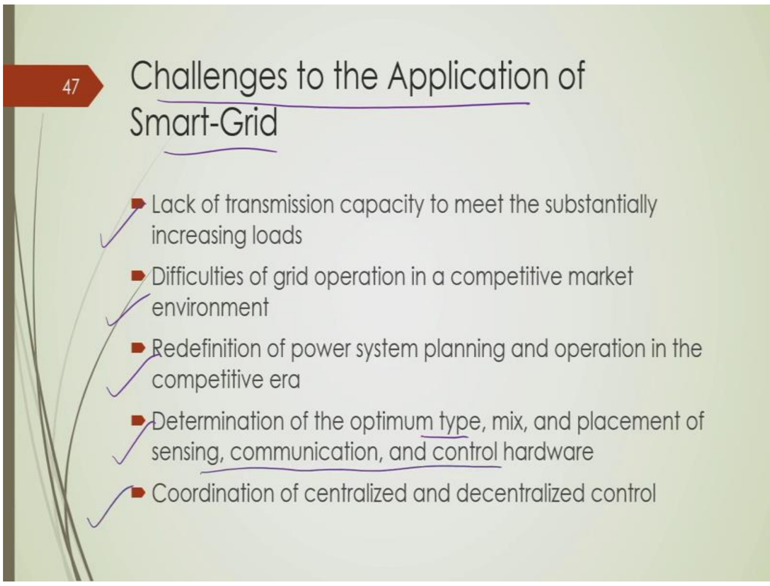

These are the some of the challenges for the application of smart grid. One is lack of transmission capacity, difficulties in grid operation in a competitive market, power system redefinition of power system planning, determination of optimum mix of the different sensing, communication, and control hardware, and coordination of centralized and decentralized control.

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So, these are the some of the areas in which research is going on the smart grid in order to make the distribution networks or power networks to a smart grid. One area is of infrastructure point of view which includes to deploy proper infrastructure, proper communication infrastructure, information integration security, ok. And also another is application and technology point of view with the help of new technologies, new applications etc., ok.

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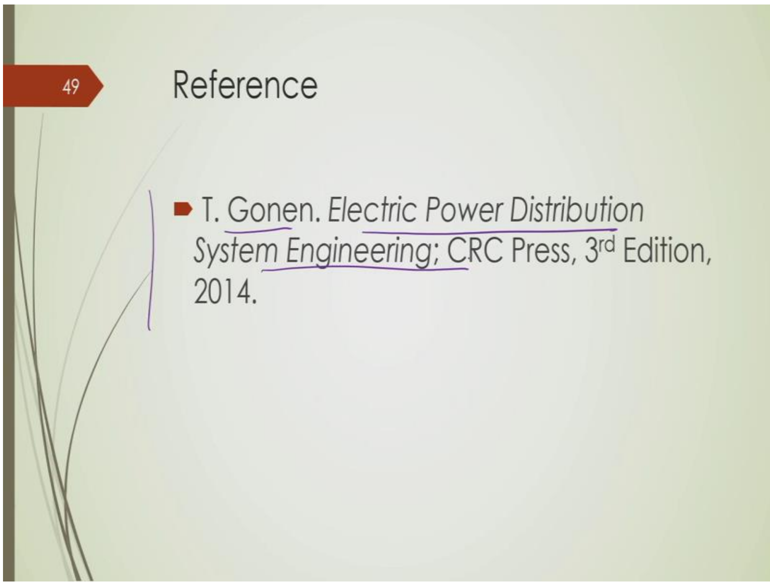

So, all these you know related data and the approaches I take from this Turan Gonen's book that is Electric Power Distribution System Engineering, ok.

So, with this I will stop this course.

Thank you very much for attending this course, once again.