Operation and Planning of Power Distribution Systems

Dr. Sanjib Ganguly
Department of Electronics and Electrical Engineering
Indian Institute of Technology, Guwahati

Lecture - 34
Distribution system automation and smart grid: Part - I

So, we reached in the last module of this course and this module I kept as this distribution system automation and smart-grid ok. Now, basically this module is to provide you some basic idea about what is smart grid and how could we convert an existing distribution network into a smart network, what sort of features should we add.

And, this is most important basically what are the research going on this smart grid perspective of distribution networks ok. So, this module is all about Distribution System Automation and Smart Grid ok.

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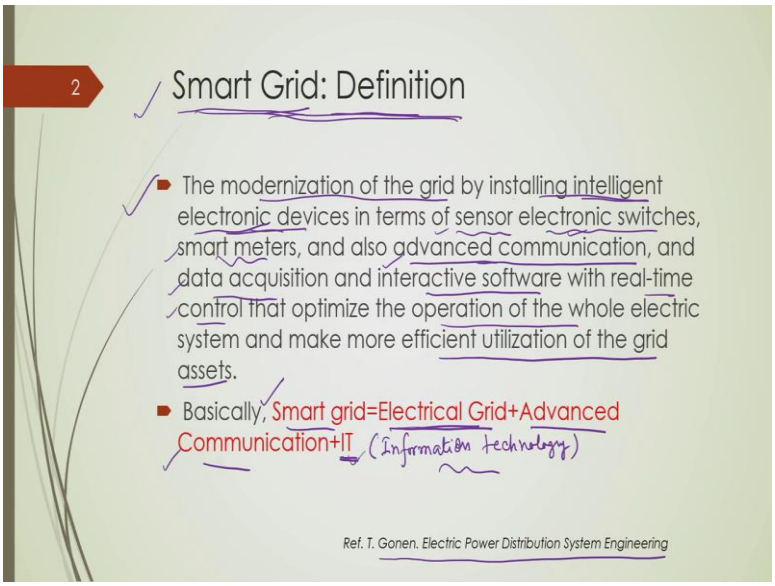

So, first of all, let me give you a basic definition of smart grid. In fact, this is such an upcoming area of research, I should not say upcoming, but it is started the initiative started at least few years ago and it is going on full swing. And, the goal is to convert our existing network into a smart network ok, with the help of some advanced technologies ok.

Now, the formal definition of smart grid you one cannot find anywhere, although there are many works related to smart grid reported and in fact, there are many journals also on this smart grid publishing papers ok. Now, I whatever I will discuss in this module, the source of my discussion is the Gonen's book ok; I mentioned at the bottom this last chapter of this Gonen's book chapter 15 ok.

So, there you can find some definitions. The first few pages, you will find some definitions and I will quote these definitions word to word here ok, I will quote this definition word to word. So, let us first give the definition of smart grid. In fact, what is electrical grid, I already discussed at the very beginning of this course. In my preamble lectures, I discussed what is electrical grid and what are the stakeholders of a typical electrical grid.

I discussed starting from the generation to transmission then sub-transmission system then distribution system and finally, to the customer. So, starting from the generation to the customers, there are many stakeholders ok and even customer is also a stakeholder for this process ok. So, I discussed what is typical electrical grid, what do we need of this interconnected power system; those things and those things I discussed and also I discuss some brief overview of Indian power grid ok.

Now, here this definition according to this Gonen's book, this smart grid is a process of modernization of the existing grid. It is not a replacement of the existing grid, but it is a modernized form of the existing grid. Now, the question is, what are the process of these modernizations we have? those things I will be discussed. Now, how do we modernize this electrical grid? We need to install some intelligent electronic devices ok. In short these are called ID, I will come to that; the basic definition, I will come to that.

So, I we can modernize the grid with the installation of intelligent electronic devices ok. And, these intelligent electronic devices include sensors, say electronic switches, smart meters etcetera ok. So, these intelligent electronic devices include these sensors, electronic switches and smart meters (Refer Time: 04:57). There are many others and also another way of modernizing the grid is to by using advanced communication system ok and data acquisition system, also with the help of this interactive software and real time control so that we can optimize the operation of whole electrical system and we can make more efficient utilization of the grid assets. All these wording are very important.

So, that is why I quoted word to word from this Gonen's book, all this wordings are very important. So, if you look at this definition, you will get several new words in which we are not somehow familiar with so far with our discussion.

In fact, this conventional field engineers who work in power distribution system, they are also not familiar because these things we have not used so far in our traditional distribution networks. So, that is why in fact, whatever I discussed up to this last module, those things somewhat familiar, those things are somewhat familiar to the practicing engineers, but this is something which is new ok. There are many things which we did not bother being an electrical engineer.

For example, with the use of advanced communication, we can make some difference ok. So, being an electrical engineer, being a power engineer we bother on power flow, but we never you know bothered on this information flow ok. And, we may not have much idea about the communication ok. So, those things are the part of this modernization process of the existing system and those things are the essential stakeholders in typical smart grid ok.

So, in smart grid what will be the additional stakeholders apart from the existing network? Because, again and again I want to emphasize the fact that this smart grid is not a completely new grid, it is a modernized form of our existing grid. Or, to be more precise, I should say that smart grid perspective of power distribution networks is a modernized form of power distribution networks with the help of many advanced technologies.

And, which are the advanced technologies? You can see over here intelligent electronic devices: IDs, which include sensors, electronic switches, smart meters etc; also this advanced communication system, data acquisition system and software and real time control ok, real time control ok. So, this makes an existing power distribution network to a modernized or so, called smart power distribution network.

So, in brief a smart grid is existing electrical grid plus advanced communication plus Information Technology: IT; IT stands for information technology. Now, you can remember my first lecture in which I discussed the history of the development of power system. So, it was started in 1890s and it is the development is still going on today. So, it

is almost you know that 130 years old technology and, it has changed a lot since its inception ok.

But, we did not talk about that what could be the use of this advancement of this communication infrastructure, because communication infrastructure also was started with basic telephone and now it is in the era of x G ok, 4 G, 5 G etc. And, there was a there is a tremendous development in the communication system. So, the one of the perspectives of this modernization of the grid is to utilize those development or those developed this communication infrastructure in order to have a better operation of the existing power network ok.

So, smart grid is basically existing grid, electrical grid plus the advanced communication infrastructure plus advanced information technology ok, alright.

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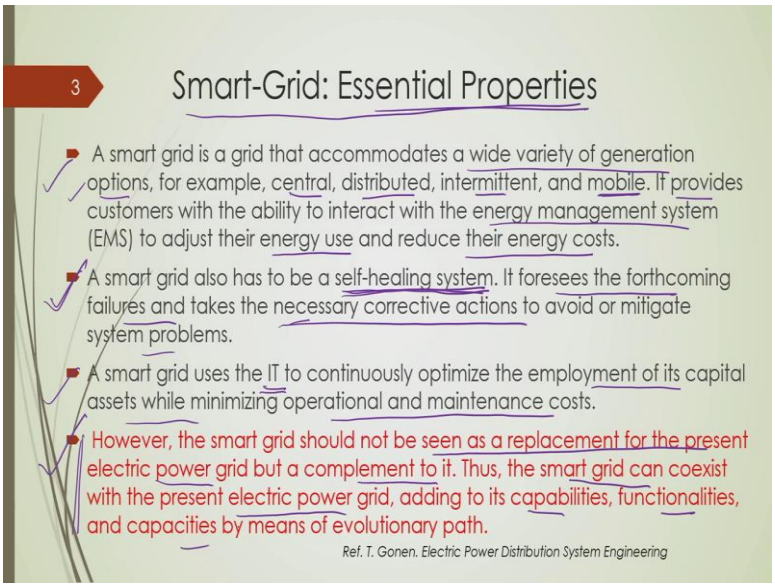

Now, there are some properties, essential properties of the smart grid which I would be discussing ok. So, it is expected that smart grid will accommodate a wide variety of generation options ok. So, far I discuss in fact, the traditional power distribution networks are of passive networks ok and the source of power is only the existing grid, that is coming from the conventional thermal power generating stations ok. And, we assume that for passive distribution network, our starting point is the substation ok.

And, this it is the substation who is basically feeding all these loads in a typical distribution network. But, in smart grid environment, it is expected that a smart grid can accommodate wide variety of the generating option which includes centralized generation which we have the existing generation, distributed generation; so, which is very important. So, distributed generation we already discussed in the last module.

And of course, it is now a there is a part of a typical distribution network and also intermittent generation that is you know already discussed some sort of renewable energy resources like solar or solar portable type or wind energy system, there basically their generation is intermittent ok.

So, those things should be part of a typical smart grid and also mobile generation unit which I have not talked about. It means that you may have mobile energy resources which are in terms of a small battery or in terms of a small generation unit ok.

A smart grid should provide customers with the ability to interact with the energy management system which is not at all there in the present day passive distribution network. So, it is like a customer is also acting as a passive entity ok. So, it does not have any role on this power management system, only it is acted as a consumer of the energy and according to the consumption a customer used to pay.

But, there is no such role of this customer in energy management system till today it according to its operation. But, in it is expected that in smart grid environment, a customer would be also a part of the energy management system. It also participates, customer participation is another important keyword in a typical smart grid environment ok. So, that this customer can adjust their energy usage according to this requirement of the grid and it can reduce their energy cost ok.

Also, a smart grid should also have a self healing system, it is another area of research nowadays self healing system. So, it should be resilient to external disturbances or external attack which includes many entities which includes cyber physical attack, as well ok. So, if it foresees any forthcoming failures, technical failures it should take necessary corrective actions to avoid this any sort of outages ok.

So, this will improve essentially the reliability of the network ok. So, a smart grid also uses information technology ok to optimize the employment of the capital asset while

minimizing the operational and maintenance cost ok. But, you look at this the last bullet point which I have intentionally marked with red color point. It says that the smart grid should not be seen as the replacement of the present electrical power grid, but a complement to it ok, which is very important.

It is not a replacement, it is a modernized form of this existing grid. So, in fact, a smart grid can also coexist with the present electrical power grid, adding to its capabilities, functionalities and capacities by means of evolutionary path ok.

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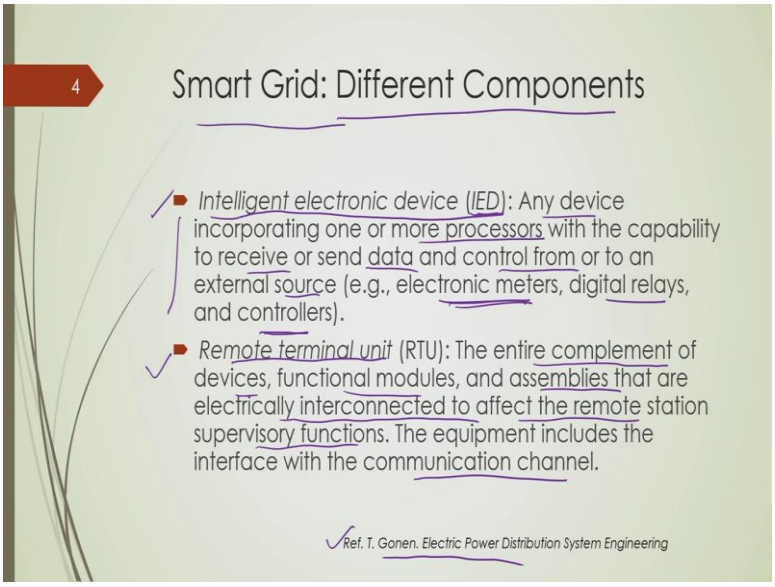

Now, we have some definitions, some typical definitions of typical components of smart grid ok and this definition as I said I took from this Turan Gonen's book chapter 15 ok. And, also I will discuss what they are actually. So, first definition is Intelligent Electronic Device: IED which I will be using many times while discussing many of the smart grid initiative or many of the smart grid projects ok.

So, what is intelligent electronic device or IED? Any device incorporating one or more processors with it so, that it can receive or send data. And, also it can control from or to an external source.

So, any device which has a processor to receive or send data and to have a controllability is called as intelligent electronic device. And, examples are electronic meter or smart meters. In fact, I will talk about in bit detail on smart meters latter part of this module

and also digital relays and controllers. So, an intelligent electronic device should be capable of sending and receiving data or in brief it can communicate with it can capable of communicating with this other devices and it can have control ability ok.

The next definition is Remote Terminal Unit: RTU, it is an entire complement of devices functional modules and assemblies that are electronically interconnected to affect the remote station supervisory functions. So, these remote terminal units are usually located in the remotely operated station or remotely operated devices ok. So, this equipment includes the interface with the communication channel.

So, there are some of the substations, small substations or some of the part of the networks which are remotely operated ok, so, which are part of this remote terminal unit.

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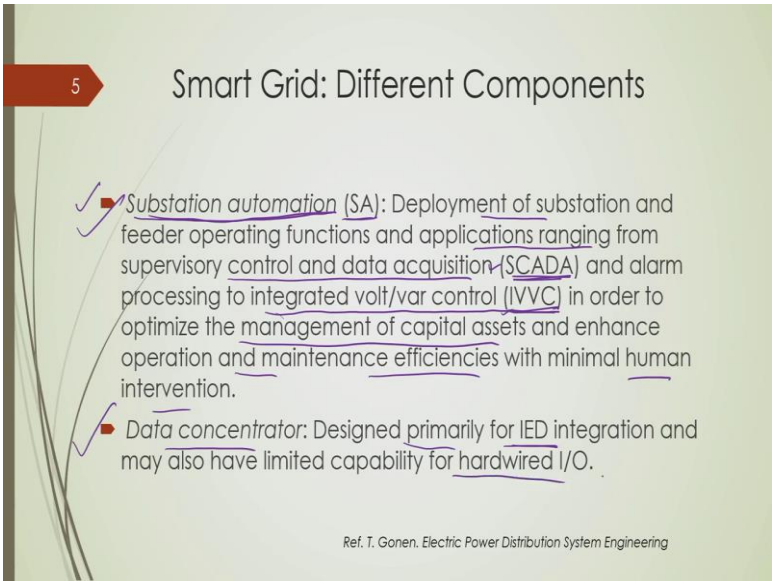

The second I mean third definition which is very important and it is also an important building block of a smart grid initiative of power distribution systems, that is substation automation or in acronym is SA: Substation automation. In fact, I will also discuss this particular entity in more detail in the latter part of this lecture. So, what is substation automation? This is deployment of a substation and feeder operating function and applications ranging from supervisory control and data acquisition.

So, this is another, you know, key word, SCADA: Supervisory Control and Data Acquisition system which is used for various purposes in a typical distribution substation

if you visit. And, also it is there is another important aspect that is integrated volt var control, this is another key word. So, this SCADA, IVVC, I will discuss in more detail in the latter part of the lecture, but these are the part of this part of the process of substation automation.

So, a substation automation needs this supervisory control data acquisition system, also it needs integrated volt-var control ok so that it can optimize the management of capital asset and enhance the operation and maintenance efficiencies with minimum minimal human intervention ok. So in fact, automation stands for minimal human intervention that one can understand ok. Next definition is data concentrator.

So, as we are talking about in fact, you know this smart grid, it is a such a you know power distribution network where there are bidirectional flows of power or energy and information ok which one should understand very clearly. So, in fact, the traditional distribution network, passive distribution network, we have seen that power or energy flows unidirectionally, because most of our distribution networks are operated as radial.

So, power flow becomes unidirectional ok, but with the inception of distributed generation in it, we no longer have this unidirectional flow of power. So, we have bidirectional flow of power. Now, with the use of this smart grid initiative we will have bidirectional flow of not only power energy, but also information; because we have many communication systems by using which we can receive and send various types of data.

Now, what types of data we will be intending to send or receive those things, I will discuss latter part of this lecture ok. So, data concentrator is basically designed for these IEDs: Intelligent Electronic Devices and also have limited capability for hardware I O ok.

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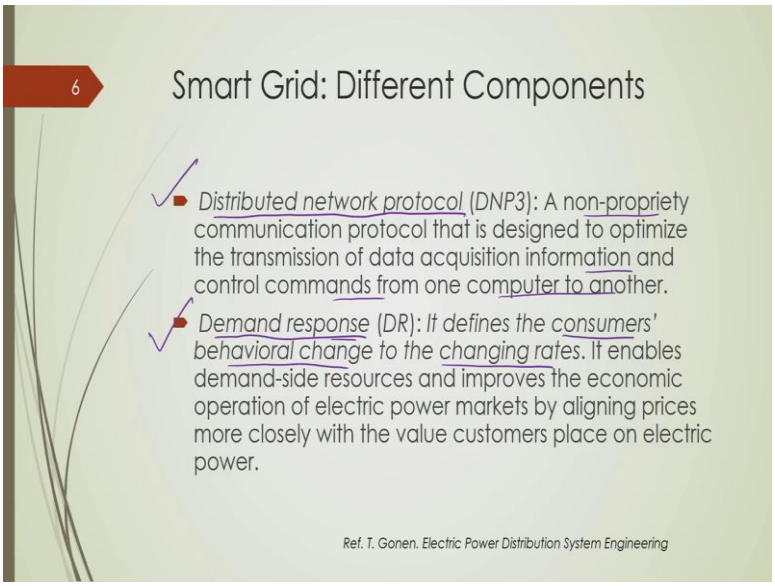

Now, since we are talking about this communication system, so, we will be having some protocol, communication protocol. And, there is a Distributed Network Protocol: DNP which is definition is non-proprietary communication protocol that is designed to optimize the transmission of data acquisition information and control commands from one computer to another computer.

Then next definition is demand response which is somewhat known to you, because I discuss demand response in the module 1, last part of this module 1 to be more precise where I discuss various types of demand response activities ok. So, basically it defines as the consumers' behavioral change to the changing rates ok and it is only possible if you have a time varying energy pricing. So, then the consumers would be interested to change its consumption process in view of this energy usage ok and, thereby, you can have several of programs successful which include peak saving, which include valley filling etc.

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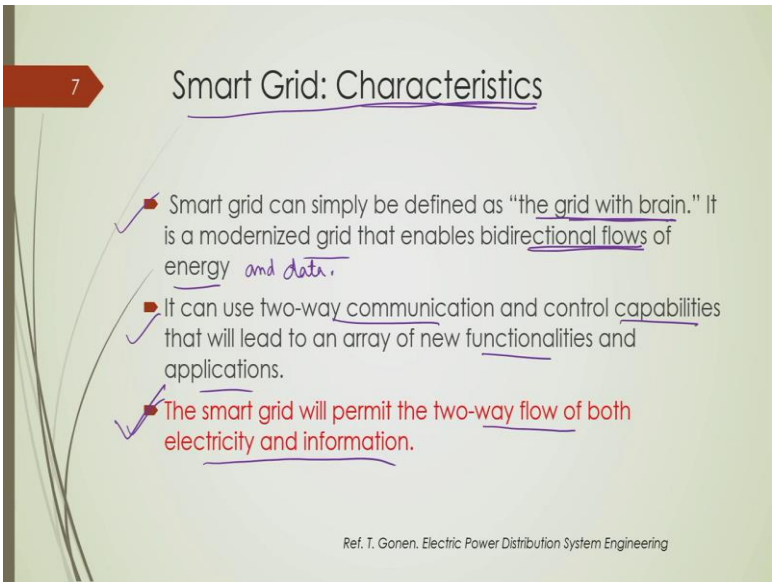

So, this demand response is already taught. Now, let me talk about some characteristics, instant characteristics of smart typical, smart grid ok. So, a smart grid is implied to a grid with brain; a grid with brain because it is automated because, we have several advanced, we use several advanced communication and information technologies ok. So, it is a modernized grid that enables bidirectional flows of energy as well as data; so, energy as well as and data ok. So, this is very important. So, a smart grid is a power grid, where you have bidirectional flow of power or energy and data ok. So, it uses two way communication or bidirectional communication and controllabilities that will lead to new functionalities and applications. So, communication and controllability are the inherent part of a smart grid initiative ok. So, smart grid will permit two-way flow of both electricity and information which I was trying to emphasize ok, which is the main message that one should understand. So, a smart grid, a typical smart grid means it enables the bidirectional flow of power and data or information.

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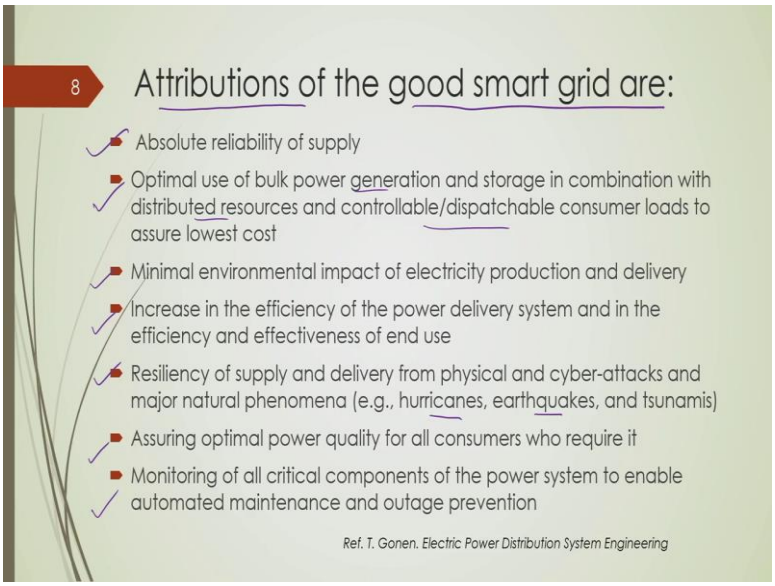

Now, what are the attributions we have for a in a good smart grid? It should be absolute reliability, it should be absolute reliable, so, absolute reliability of the supply which we have already talked about. So, by with this smart grid initiative, the goal is to have almost 100 percent reliability ok, more than 99.99 percent reliability of power or reliability or less than 0.01 percent of power interruption ok; also, optimal use of several types of generation which may be conventional generation, distributed generation, controllable or dispatchable consumers load. So, this is already discussed, minimal environmental impact of electricity protection and delivery. This is possible if you have more sort of renewable energy generation units, such as, solar portable type or wind energy or other type of renewable energy systems into a network and, also higher efficiency, resiliency which is very important against any sort of physical or cyber-attacks ok. Also, it should be resilient to natural calamities like hurricanes, earthquakes, tsunamis etc. So, assuming optimal power quality, similar to this reliability one should expect a good quality of power so, that needs to be provided in a smart grid initiative and also monitoring all critical components of power system to enable automated maintenance and outage prevention ok.

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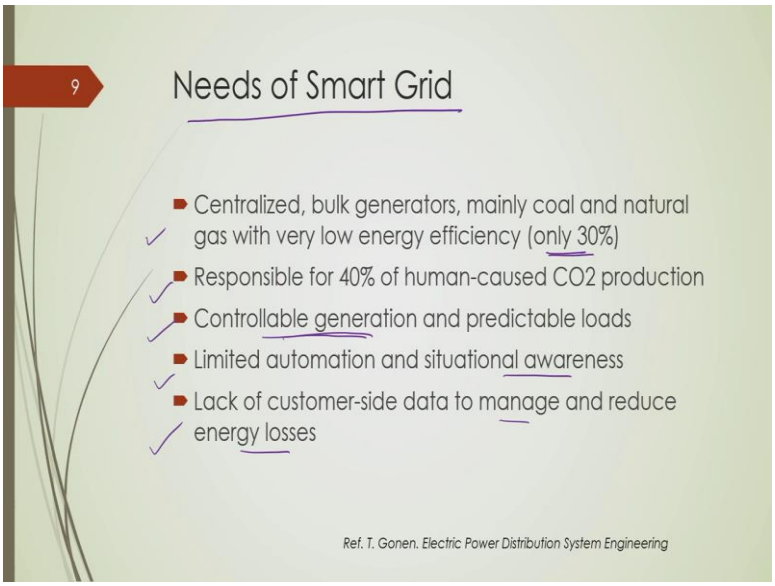

Now, what are the needs of this smart grid? Some of the needs are well known that we basically know that centralized power generation units use conventional type of fuels like coal and gases which we are trying to reduce ok. And, they are also having lower efficiency, lower energy efficiency ok. But, they are responsible for most of the greenhouse gas emission, carbon dioxide emission. So, we need to cut short ok.

As well as, we have to go for other forms of energy so that this energy demand can be fulfilled because there are two things, two contradictory things here. One is customers' demand which is increasing year by year. So, one utility has always a challenge to meet the increased demand with this available generation, another part is we have to cut short this because, till today we mostly rely on this conventional type of generation.

So, it is also a challenge to reduce such kind of generation by integrating more sort of renewable energy resources ok. Also controllable generation and predictable load, controllable generation is of course, a challengeable thing because again renewable energy we are talking about their generation is not controllable ok. So, how to utilize them in a better way that is also a factor and limited automation and situational awareness was there so far in an existing power grid. And, lack of customer side data to manage and reduce energy losses and another important thing which is not mentioned over here that is to increase the customer participation in the power management process ok. So, this is another need of a developing this smart grid.

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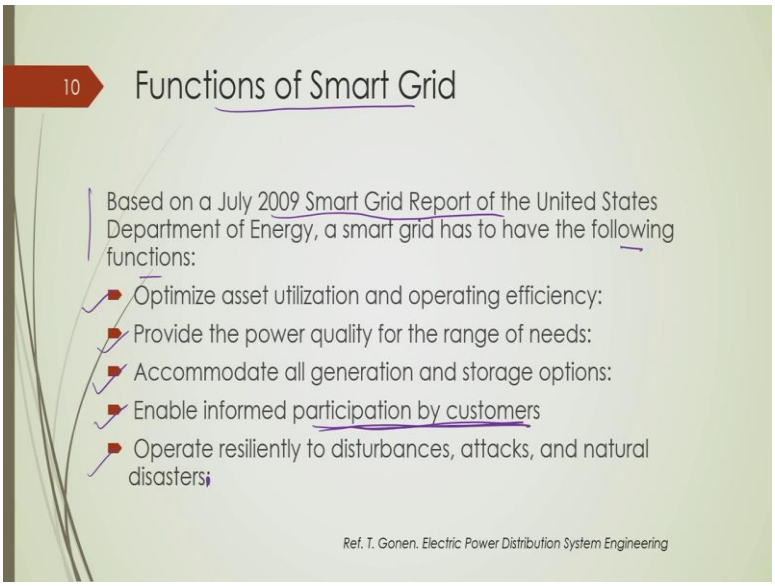

Now, these are functions of smart grid according to this 2009 Smart Grid Report of US Department of Energy. A smart grid should have following functions: One is optimizing asset utilization and operating efficiency, providing power quality for the range of the needs, accommodate all type of generation and storage options; enable informed participation of the customers which I was talking about in my last slide ok and to operate resiliently to disturbances attack and natural disaster. So, these are the things, one need to understand. These are the functionalities the smart grids should have or these are the functionalities expected from a typical smart meter.

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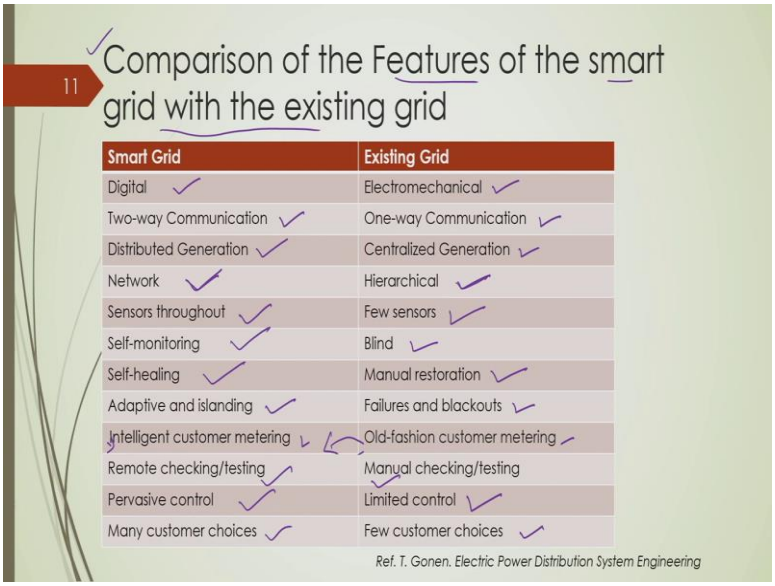

Now, here we will compare the features of the smart grid and existing grid ok. So, existing grid, if you call it as electromechanical, then smart grid operation would be fully digital; ok, fully digital. So, in existing grid, we have one way communication ok. Sometimes there is no communication at all, but in smart grid there should have a bidirectional communication or two-way communication ok.

And, existing grid mostly depends upon the centralized generation of the conventional type of the generation systems like coal fired energy generation system or natural gas fired energy generation system. But, smart grid should have more sort of distributed generation which mostly focused on renewable energy generation system like solar, photovoltaic or wind.

So, existing grid operates as a hierarchical process. I also discuss this in very detail starting from the generation then transmission then sub-transmission then primary distribution and then it reaches to the distribution transformer and finally, it reaches to the customer via distribution via secondary distribution network. But, this smart grid itself acts as a self-sufficient network ok.

So, in hierarchical system, you can see the power is fed from one hierarchical part to another hard hierarchical part from starting from the generation to transmission and then transmission to sub-transmission. But, here with the smart grid initiative, since a typical distribution network will have more sort of distributed energy resources, they did not operate it as a hierarchical process ok. So, in existing grid we have few sensors and in particularly in distribution networks we have very few sensors, very very few in fact, negligibly small amount of sensors.

But a smart grid needs sensors throughout. So, that whole operation should be observable. So, existing grid if you call it as a blind and smart grid should be self monitoring, that feature should have been there. If existing grid needs manual restorations due to a fault or any sort of disturbances then smart grid should have a self healing capability.

So, if existing grid suffers from failures and blackouts, smart grid should have islanding process. This islanding is something like when we have a self-sufficient distribution generation or distributed generation based distribution network, it can isolate from the grid if there is a major grid disturbances ok.

And it can operate to this local load so that load will never or customer will never get affected from this any sort of grid disturbances ok. So, existing grid is having old fashion customer metering, but smart grid should have intelligent customer metering. In fact, meters are to be replaced and this process has been initiated.

So, existing grid is having manual checking or testing smart grid is having remote checking, existing grid is having limited control capabilities whereas, smart grid which have fully control capabilities. And, also few customer choices and in fact, existing grid we do not have much choices as being a customer, but in smart grid we have many choices ok; that is what our expectation of this smart grid initiative ok.

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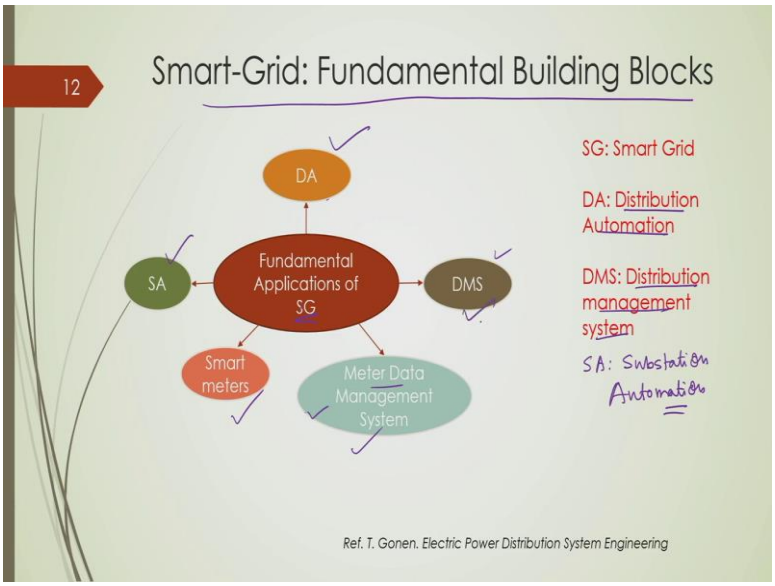

So, these are the building blocks of a typical smart grid and I will be discussing all these blocks in one by one in detail in more detail. So, this DA stands for Distribution Automation ok, this DMS stands Distribution Management System; then meter data or automated metering infrastructure which I will be discussing, smart meters and this meter data management system those I will be discussing.

And, this SA stands for Substation Automation; substation automation which I will again discuss in a bit detail in the next part of this lecture ok. So, these are the typical building blocks of a smart grid system which include distribution automation, substation automation, distribution management system. Distribution management system is having

multiple functionalities which I will be discussing ok and automated metering infrastructure.

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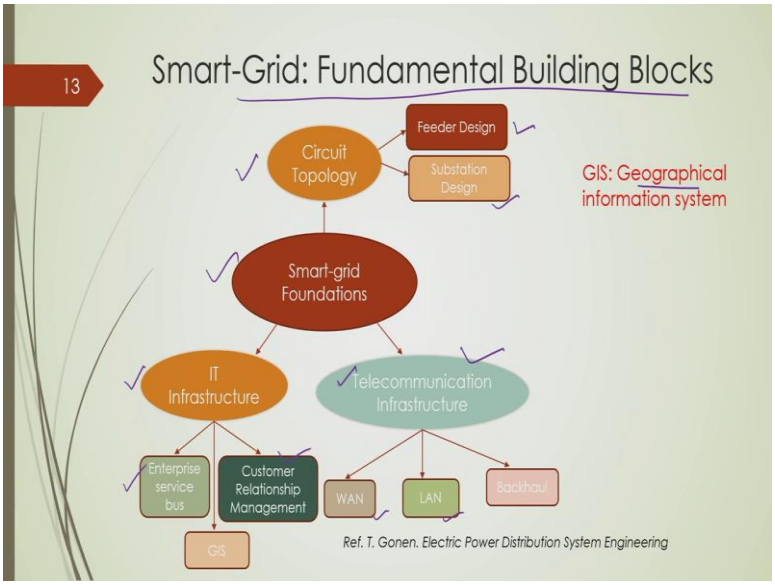

So, these are the some of the fundamental building blocks and it is you know this whole operation is broken into some four different parts. One is circuit topology; what sort of advancement we require in circuit topology. We need to have advanced feeder design, substations design. Also what sort of other smart grid functions we require; one is inclusion of IT infrastructure, Information Technology infrastructure; another is telecommunication infrastructure.

Under this IT infrastructure, we have the use of geographical information system, we have the use of enterprise service bus, we have the use of customer relationship management. Under this communication infrastructure, we have different types of this communication which is wide area network, local area network and many others ok. So, these are the different building blocks of a typical smart grid ok and some of these blocks, I will we discuss in more detail in the next part of this lecture ok.

So, I will stop today at this point and I will discuss in more detail in the next part of the lecture.

Thank you.