Digital Protection of Power System
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Lecture 29
islanding Detection

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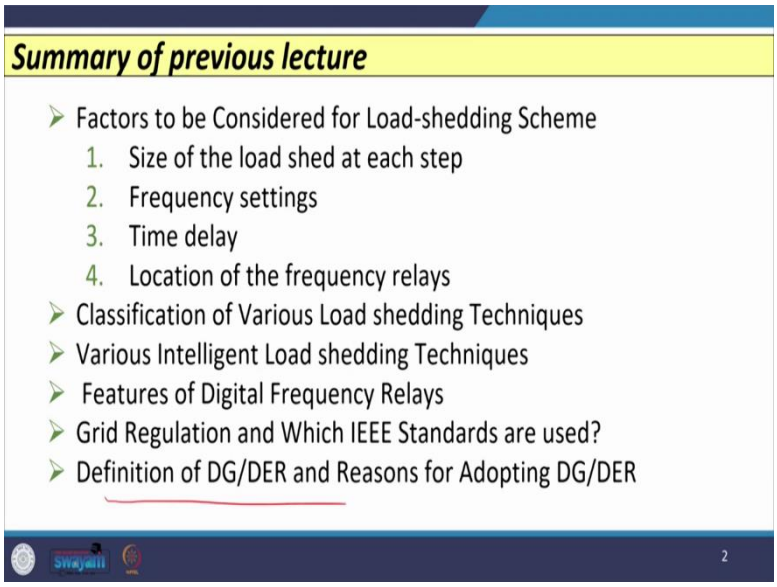

Hello friends. So, in the previous lecture, we have discussed regarding the factors to be considered for designing an intelligent load shedding scheme. And in that we have considered four important factors, the first step is the size of load to be shed at each step, then second is the frequency settings. Third is the time delay. And the four is the location of frequency relays.

After that, we have discussed the various classification of load shedding techniques. And then we have discussed the features of digital frequency relays. Finally, we have discussed the grid regulation and IEEE standards used for frequency relaying and then, we have decided or we have defined the definition of renewable energy sources that is distributed generators and distributed energy resources. And we have discussed the important reasons for adopting such DG or DER into the electrical grid or network.

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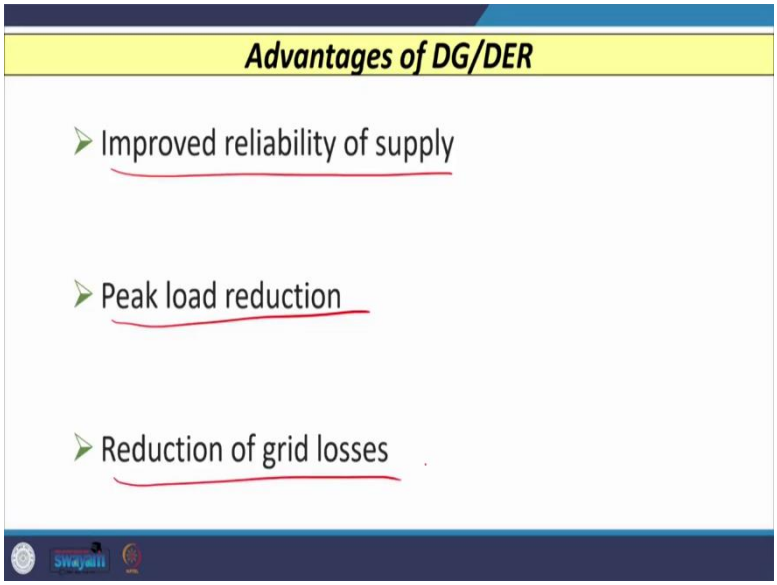

Now, there are three important advantages of DG or DER. The first advantage we have that is the improved reliability of supply, because we have some additional diversified energy option is available, so reliability of supply improves. Second is the peak load reduction because we have the DG or DER are available. So, as and when there is a huge demand of load, so during peak hours you can easily connect the DG and you can supply this peak load or load during peak hours and peak load can be reduced.

The third is the reduction of grid losses. So, we have discussed that we can connect DG or DER actually at the place where lode is situated. So, the transmission of power from generation end to the load end that will reduce and hence the losses can also be reduced.

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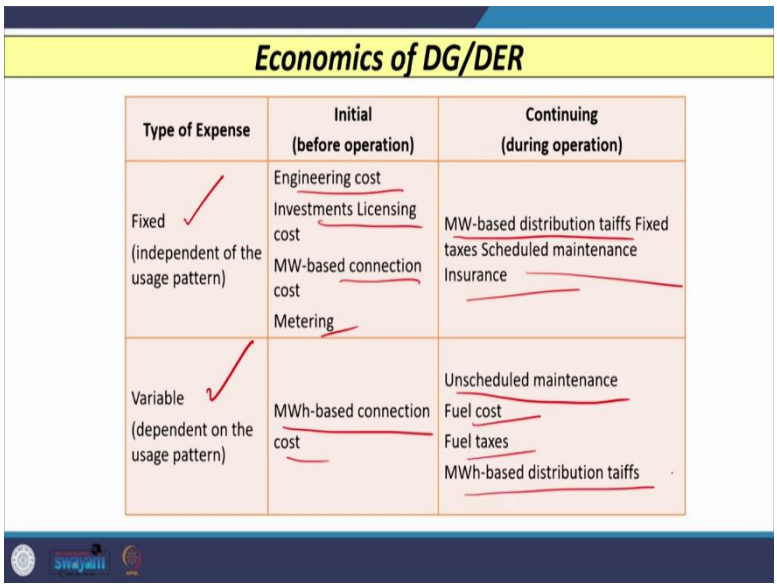

If we consider or talk about economics of DG or DER, then there are fixed costs involved and variable cost involved. And if we consider the fixed cost, then the initial cost involves engineering cost, investment licensing cost, connection cost and metering cost.

Whereas, the running costs are during operation cost that involves megawatt-based distribution tariff, fixed taxes, scheduled maintenance and insurance. Whereas, in case of variable type of expenses for DG or DER in initial condition, it involves megawatt hour-based connection cost, whereas, in case of the operation, it involves unscheduled maintenance cost, fuel cost, fuel taxes and the distribution tariff.

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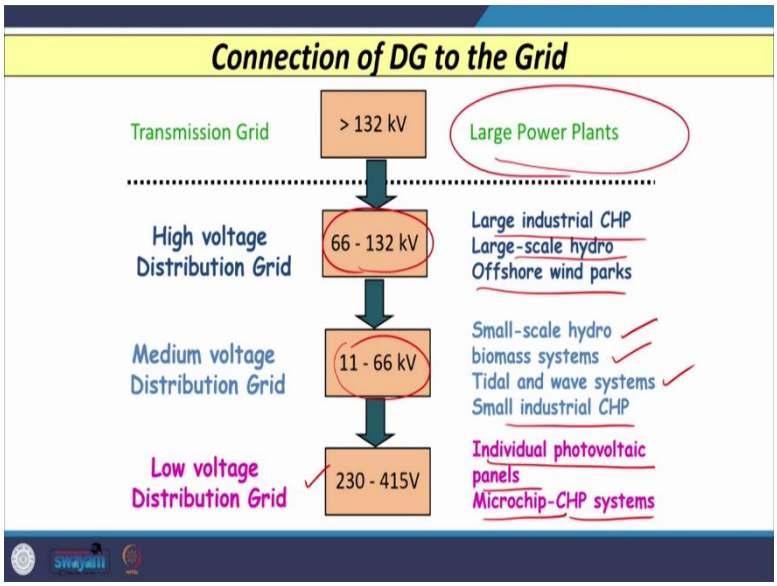

Now, the question comes at what level we are going to connect the DG or DER to the grid? So, here you can see that you can connect the DG or DER at low voltage distribution grid. And the examples are individual photovoltaic panels or you can connect microchip or combined heat and power systems. At medium voltage distribution level that is between 11 to 66 kV you can connect it all DG or DER also.

And the examples are small scale hydro power plants, biomass-based power plants, tidal and wave systems or small industrial combined heat and power plant. You can also connect DG or DER at high voltage grid that is 66 to 132 kV and the examples are large industrial combined heat and power plant, large scale hydropower plants and offshore wind parks. And you can also connect the DG or DER at transmission level when you have large let us say solar or wind parks.

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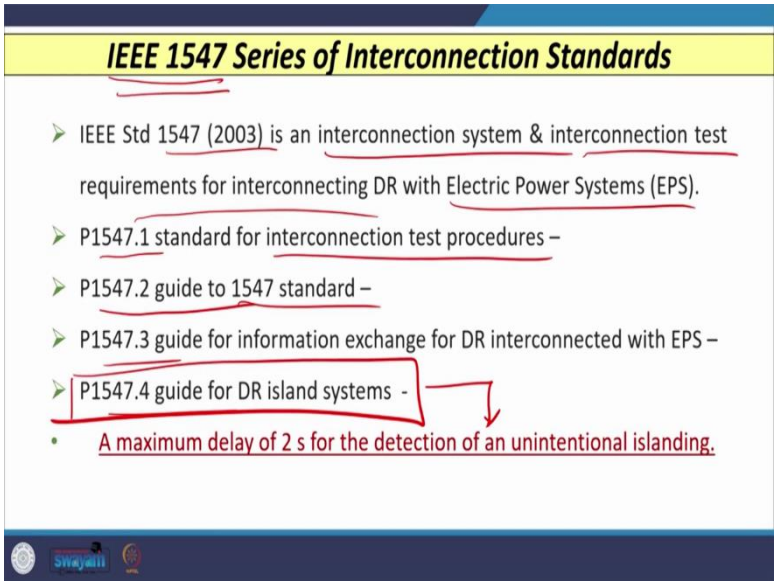

Now, before we go into the details of DG and DER, when we connect a DG or DER into the grid or network, we need to follow certain standards. So, the important standards that is IEEE 1547 series of interconnection standards. So, this standard was implemented in 2003. Later on, it was amended as several years after several years.

And this standard is meant for interconnection system and interconnection test requirement particularly when we are going to interconnect distributor generators or distributed energy resources with our conventional power system network. So, in this standard 1547.1, the interconnection test procedures are mentioned, 1547.2 is a complete guide for this standard, 1547.3 is the guide for exchange of information between the utilities and the distributed resources or distributed generators, and 1547.4 is the guide for islanding conditions or systems.

So, we will discuss more about this a this fourth one that is 1547.4, which is meant for islanding situation. In this 1547.4, it has been mentioned that a maximum delay of 2 seconds that is required or means whenever islanding condition is there or exists then we need to detect this condition before or in less than 2 seconds as per this standards.

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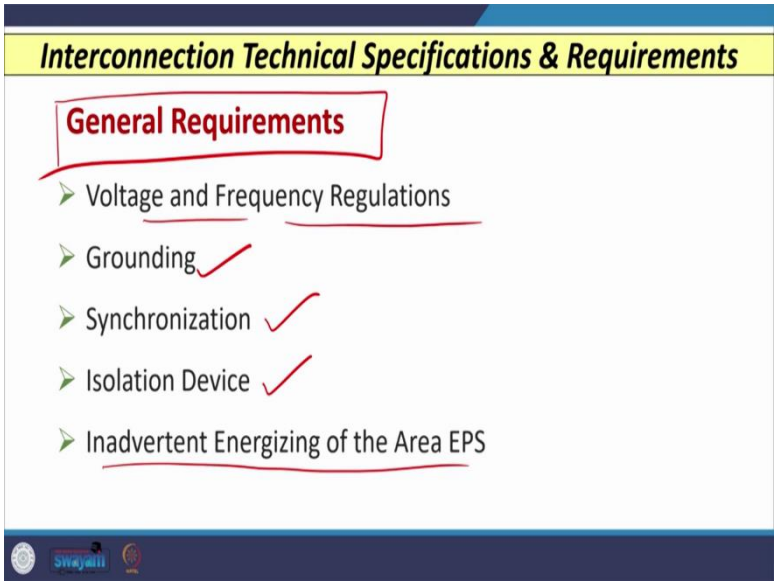

Now, when we connect or when we interconnect distributed generators or distributed energy resources with our conventional network, then there are certain general requirements we need to consider and these requirements are related to voltage and frequency regulation. So, when we connect any generators, distributed generators with the grid, then the change in voltage should be same, frequencies should be same, phase sequence should be same. So, all these things we need to consider.

The grounding connections are also important, synchronizing procedure is also play an important role, what type of isolation devices we are going to use, whether we use circuit breaker we use recloser or we use some sectionalizing switch, so that is important.

And inadvertent energizing of the certain distributed generators or distributed energy resources in the grid that also an important issue.

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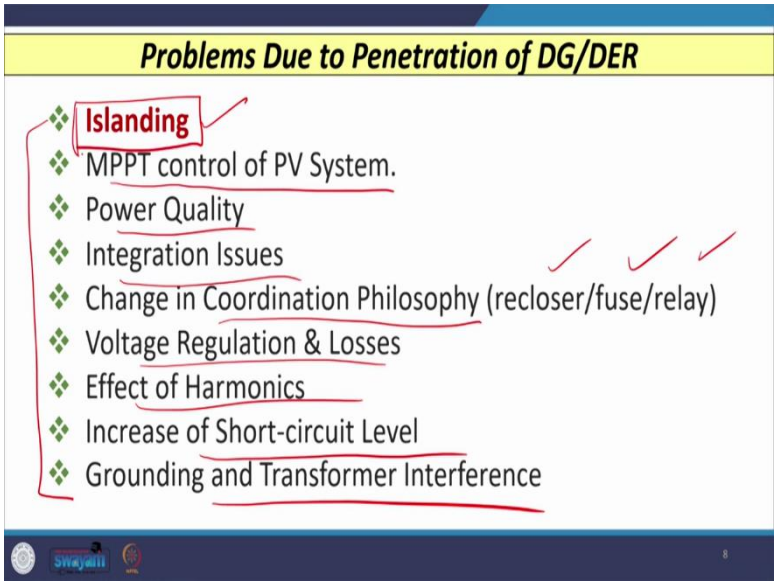

Now, when such type of distributed generators or distributed energy resources are connected or interconnected with our conventional grid, then they are going to impose several issues and challenges. These issues are islanding, maybe the maximum power point tracking control of PV system or wind system, power quality issues are there, integration issues are also there. There are issues related to coordination among various devices like recloser, fuse, relay, breakers, voltage regulation and losses are also there, harmonic effects are also observed, there has to be an increase in short circuit level.

So, we need to consider the braking and making capacity of several other devices. And grounding and transformer interference issues are also there. Now, out of all these issues, we are going to concentrate on only the first one that is the islanding.

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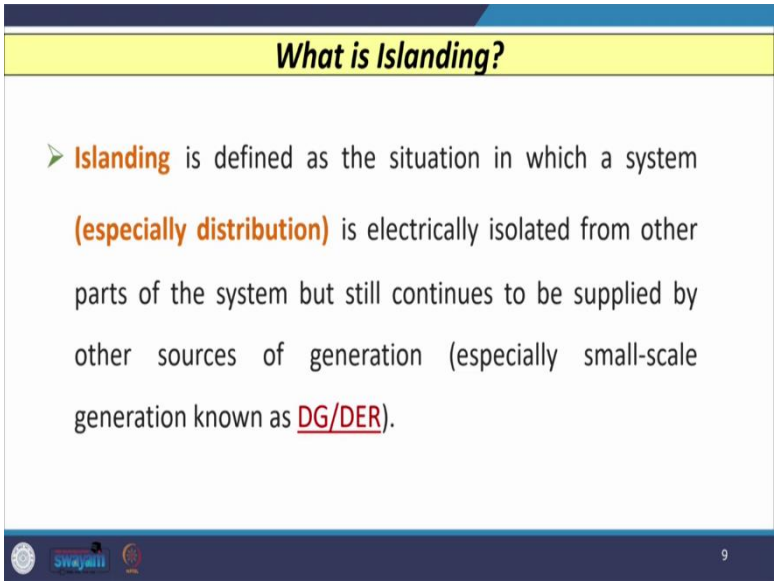

So, let us see what is an islanding condition? So, islanding is defined as the situation in which the systems special distribution system or distribution network is electrically isolated from a part of the system and this isolated system, it is still going to have the supply from local sources which we called as distributed generators or distributed energy resources.

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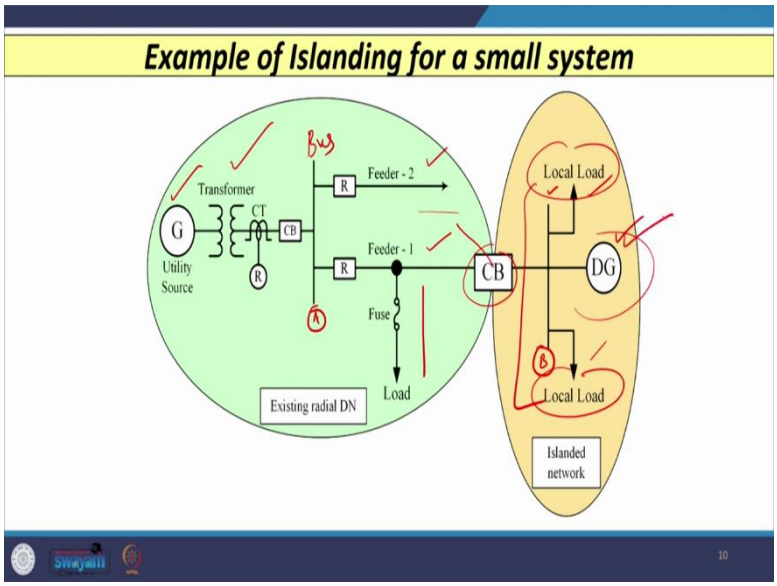

The examples of islanding for a small system. You can see that we have a utility source connected with the generators and then we have the bus and then we have several feeders like feeder 1 and feeder 2 are emanating, we have laterals also. And this feeder 1 is connected at another bus here, let us say this is bus A and this is Bus B. And on this bus B, we have connected some loads as well as we have also connected distributed generators.

Whenever this breaker is going to become open, then the island is formed and whatever these local loads are there that is supplied by these distributed generators or distributed energy resources and these are subjected to the total requirement of the load and the capacity of the DG.

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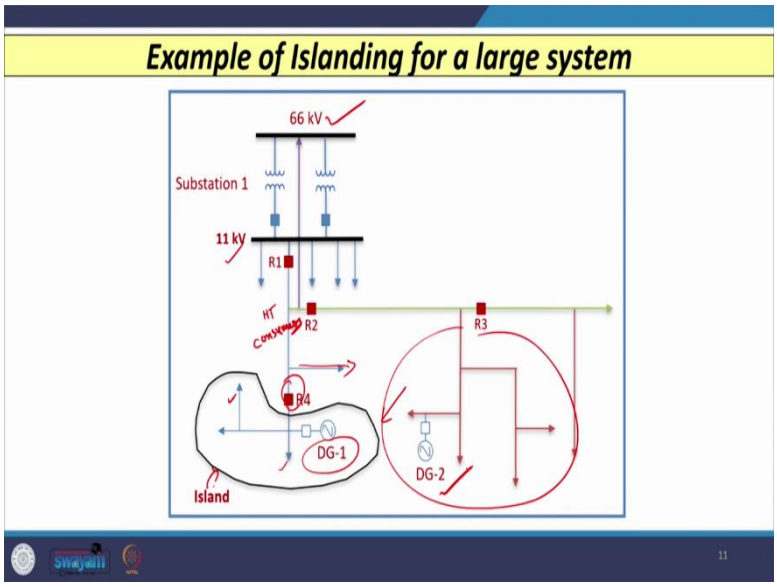

If we consider large network then you can see (as shown in above slide) we have 66 kV system, which is further step down at 11 kV. And we have 11 KV HT consumers and on one of the 11 kV HT consumers. You can see that we have the several laterals like this and at this lateral I have connected one DG, that is distributed generator 1 and by opening this switch there is a formation of an island which is known as the island. So, here you can see that these loads are supplied locally by this DG 1. Same way you can have an island somewhere here also, where several local loads are supplied by DG 2.

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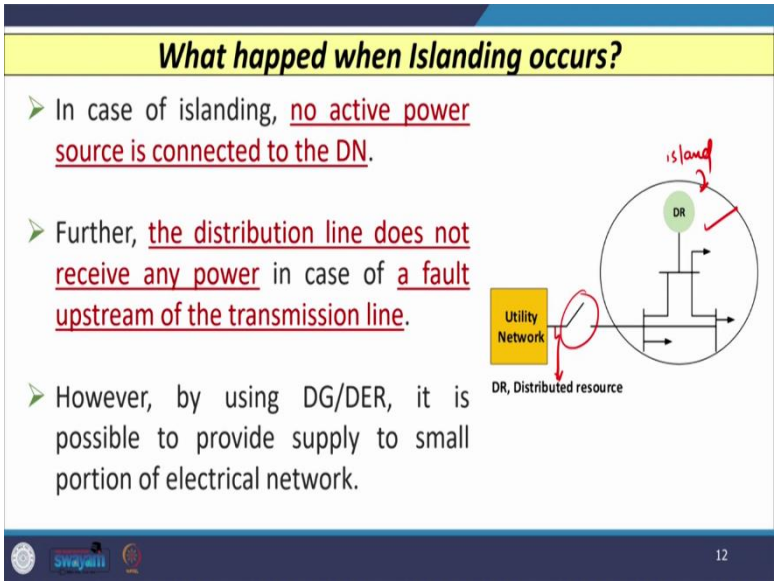

So, let us see what happens when islanding occurs? So, whenever islanding is there no active power source is connected in the distribution network. So, your grid or utility, that is going to be disconnected. So, your distribution line does not have any power in case of fault.

So, whenever there is an fault up on the upstream side of this network, then this breaker becomes open, so utility gets disconnected and that is why there is a formation of an island and that local loads are supplied by this DG or distributed energy resources or distributed resources, DER. However, by using DG or distributed energy resources, it is possible to provide supply for a small portion of the electrical network which we called as island.

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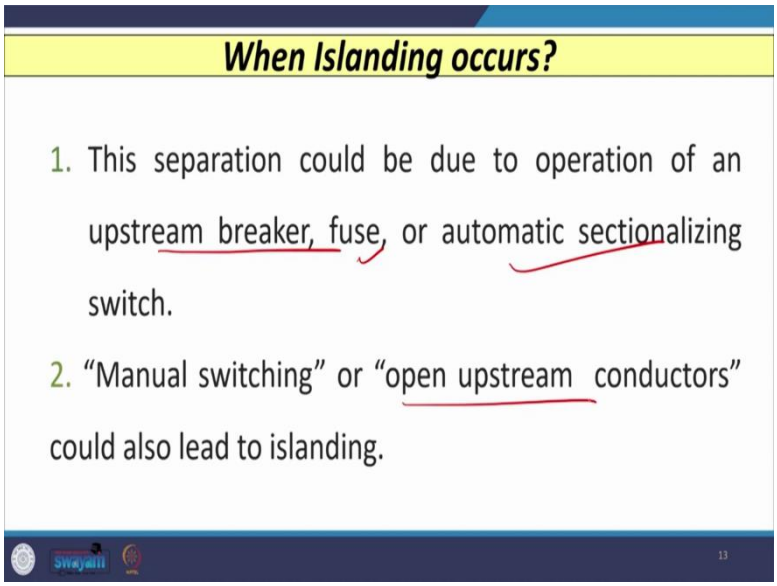

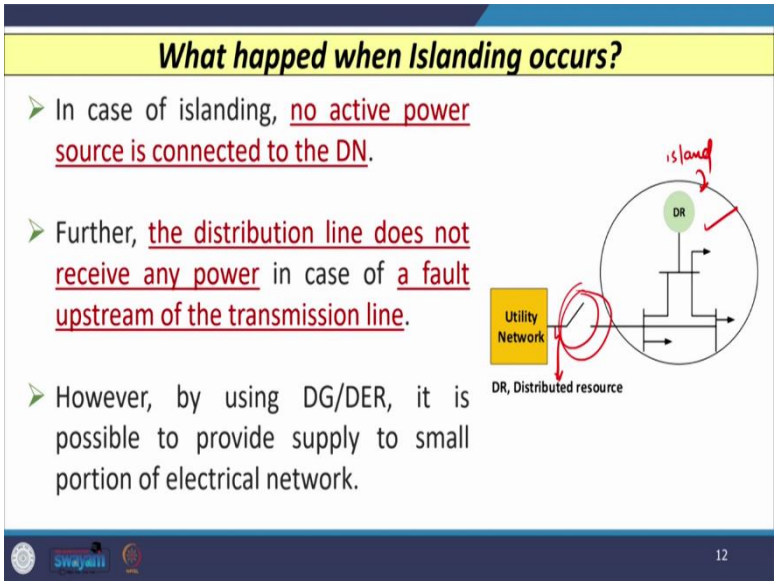

Now, let us see when islanding occurs. So, whenever there is a separation or operation because of the upstream breaker, fuse, or automatic sectionalizing switch. So, as I told you when there is an opening of this or maybe because of opening of fuse or maybe because of some sectionalizing switch, the islanding may occur. Manual switching or open upstream conductors, this can also lead to the islanding situation.

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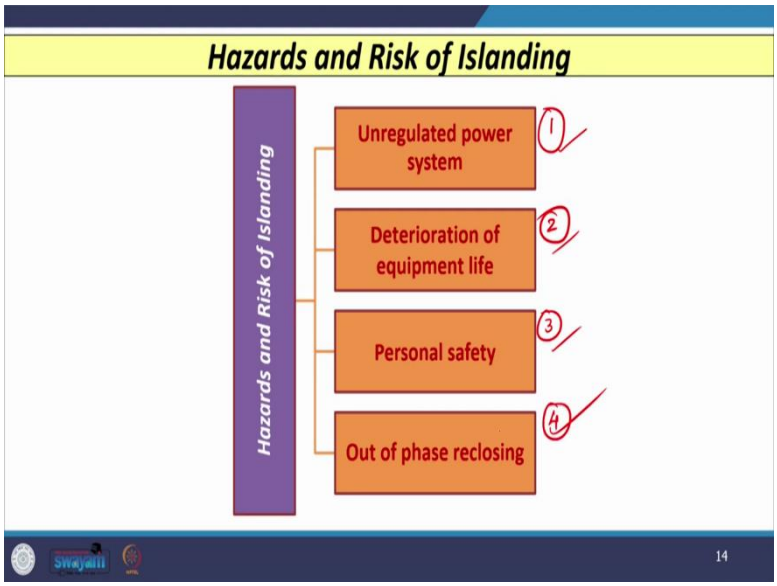

Now, the question comes let us see what are the hazards and risks of islanding. So, whenever islanding is there as I told you as per IEEE 1547.2 standards, we need to detect the islanding condition and we need to also separate it out before 2 seconds, then the question comes why we need to detect islanding and why we need to disconnect it.

So, let us consider the hazard and risk of islanding. So, whenever islanding occurs, what will happen? So, these are the four important points we need to consider. The first one is the whenever islanding is there, unregulated power system is there. Second is the, there is a possibility of deterioration of the life of the equipment connected. Third is the, personal safety issues are also there. And fourth that is the out of phase reclosing issue is also observed. Now, let us discuss each issue one by one.

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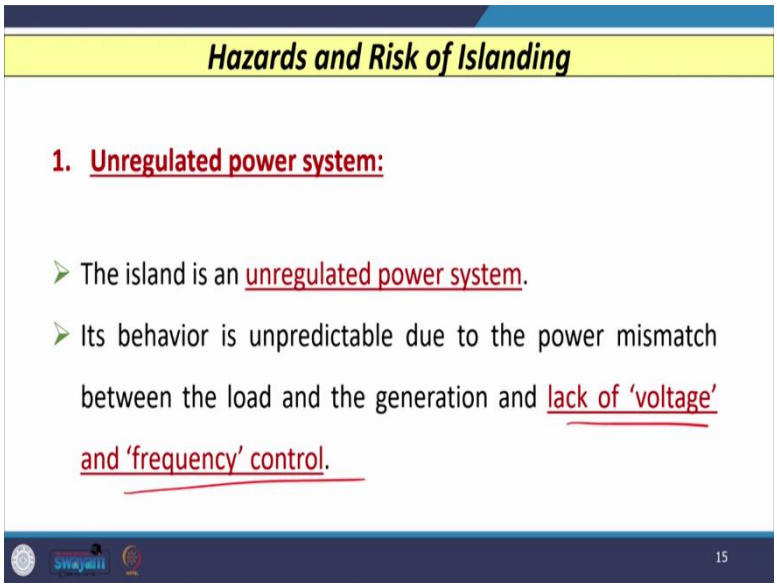

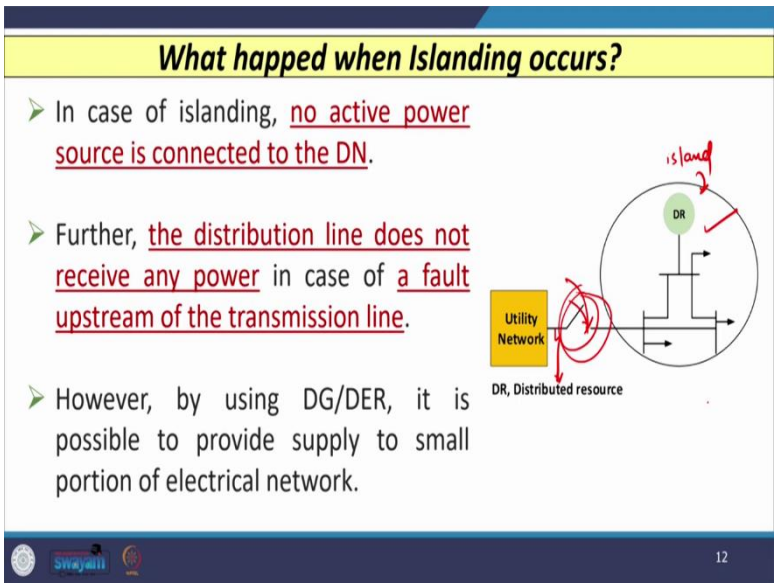

So, the first issue is the unregulated power system. So, we know that whenever island is formed, basically if I consider that this is an island, so this system is not regulated, when this switch is closed, there is no island, then the voltage and frequency of the entire network that is controlled by utility.

However, because of opening up this because of formation of an island, this system acts as an unregulated power system. Its behaviour is unpredictable due to mismatch in the generation and the load and because of the lack of voltage and lack of frequency control, because wherever an island is formed normally at the point of common coupling with the DG or DER no voltage controlled or frequency control provision exist.

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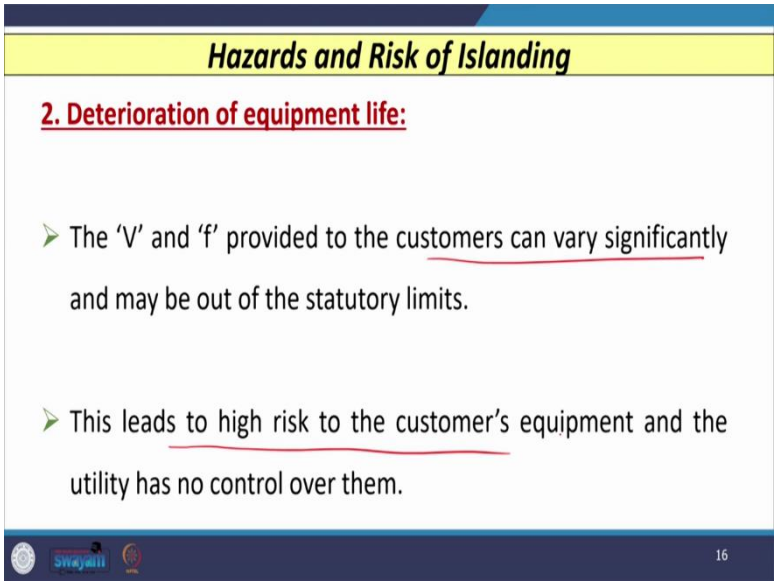

Second is the deterioration of life of the equipment. So, as I told you, V and F both are uncontrolled. So, whatever equipment are connected by the customers or consumers, they operate within certain limits of voltage and frequency. If those limits are violated, then definitely the life of this equipment, that is going to be deteriorated. So, this leads to high risks to the consumers equipment and utility has no control over this situation.

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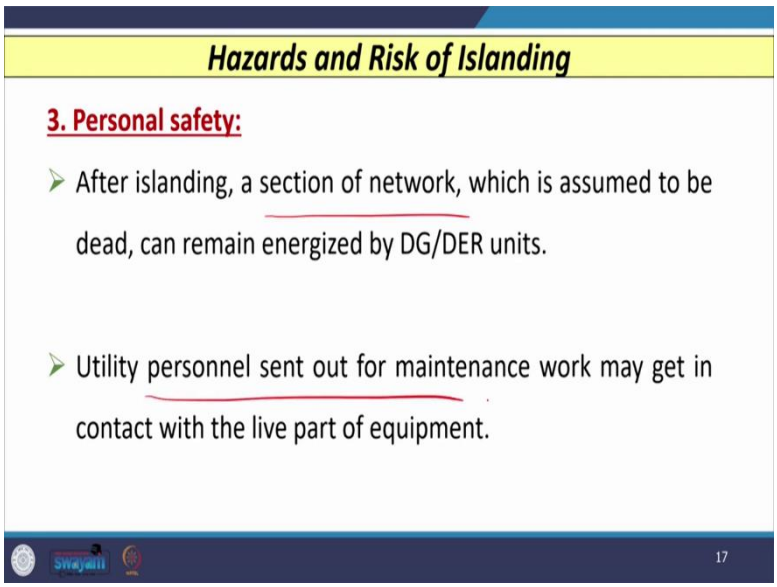

The third important issue is the personal safety. So, after islanding wherever island is formed, because of opening of the breaker and utility gets disconnected the section of network which we called as islanding and that network is fed, means local loads are provided power or supply by the distributed generators or distributed energy resources.

So, this part is remained energized for a local system. So, if you send any personnel, for the maintenance work, then he may come in contact with the live part of the equipment and he may get an electric shock.

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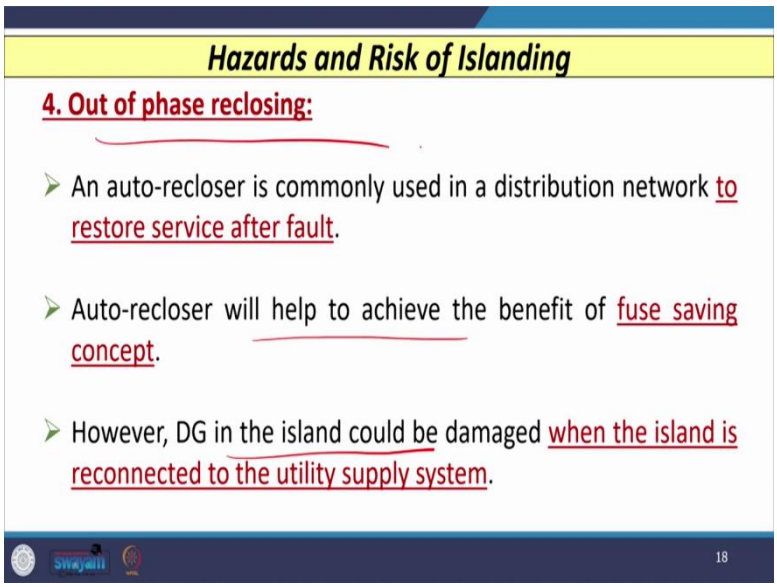

The fourth important issue is the out of phase reclosing. Now, we know that the auto reclosers are widely used in distribution network and the remain reason is we want to restore the service

after the occurrence of temporary faults because whenever fault occurs, we know that 80 to 90 percent faults are transient in nature or temporary in nature and we do not want to operate the breaker and remain there in open condition till the manual intervention is there.

So, in temporary or transient faults, we want to reclose the breaker immediately after 300 milliseconds. And we know that if we do that, then that will restore the service of the supply immediately after the occurrence of transient or temporary fault. So, auto recloser will help to achieve the fuse saving concept.

So, we have discussed earlier, that when we consider the auto recloser that means whatever breaker has an auto reclosing facility or reclosing facility and if we have the fuse, then the characteristic of recloser and fuse both are coordinated with each other and for any temporary fault recloser in fast mode should operate first whereas fuse will operate later on. And this is known as fuse saving concept.

And we have also discussed that when DGs are connected this coordination may last. However, DG in the island, that could be damaged when the island is reconnected to the utility of the system or network. Now, the question is whenever an island is formed, and whenever you want to use the reclosing concept, so we know that island is formed and we want to reclose the circuit from the island and network back to the grid. Then because of this out of phase reclosing phenomena your system may damaged.

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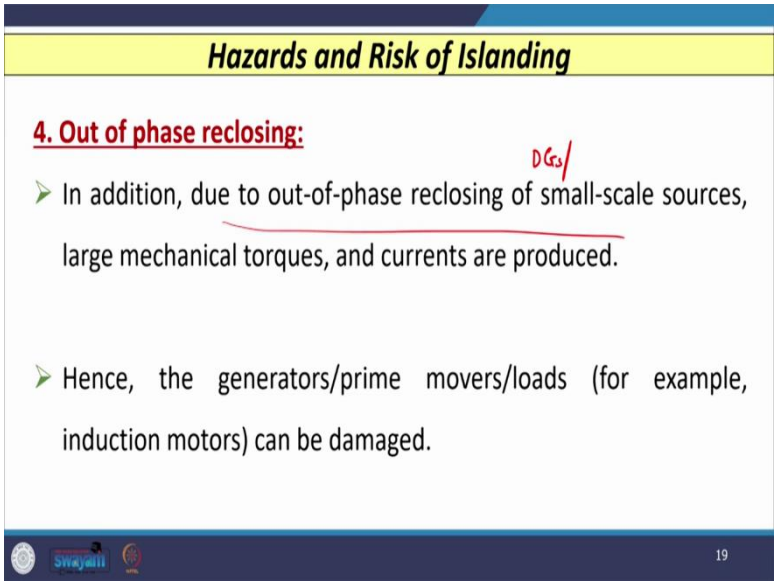

Let us see how? We know that the due to out of phase reclosing of small-scale resources that is DER or distributed generators, there are chances of the production of the mechanical

torques and heavy currents are induced and because of that, your generators maybe your loads, for example induction motors they may get damaged.

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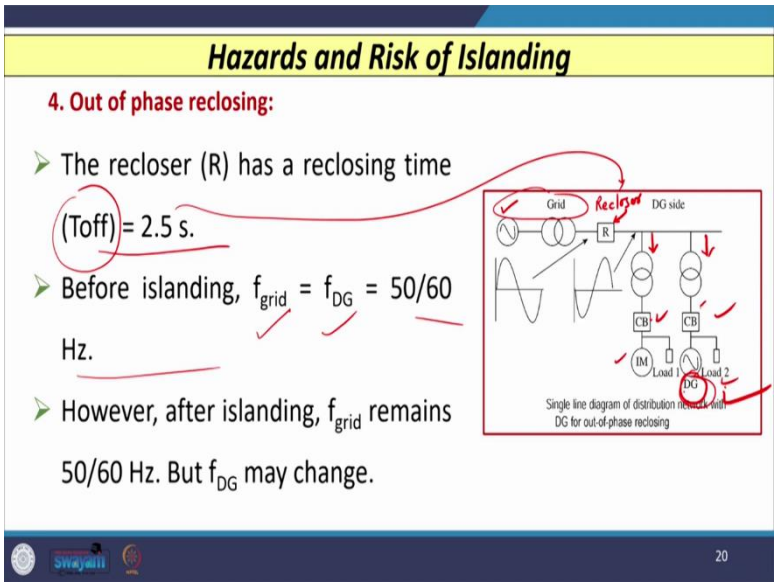

Let us see how this is possible. So, to understand this, let us consider (as shown in above slide) one network where we have a grid. So, we have a generator which is connected to the transformer. I am calling this as grid and then we have a recloser. So, circuit breaker with a reclosing facility. So, this is a recloser. And then these are the feeders where you have some laterals connected here with the transformers, you have breakers and then you have the loads are connected like induction motors, and we have also connected one DG at this point.

Now, when we use the recloser in case of distribution network, this recloser has some reclosing time as per the standards. So, let us consider that this recloser has a reclosing time of 2.5 seconds. So, I am denoting this reclosing time of this recloser as T_{off} that is equal to 2.5 seconds. Now, before any island, we know that the grid frequency that is f_{grid}, that is same as this frequency of the DG and both let us say they have 50 Hz.

Now, whenever island is going to form because opening of this breaker or recloser island is going to form and the local loads are supplied by these distributed generators. However, whenever the island is formed grid frequency remains same as 50 Hz or 60 Hz, but the frequency of DG that may change because this islanded system is not regulated.

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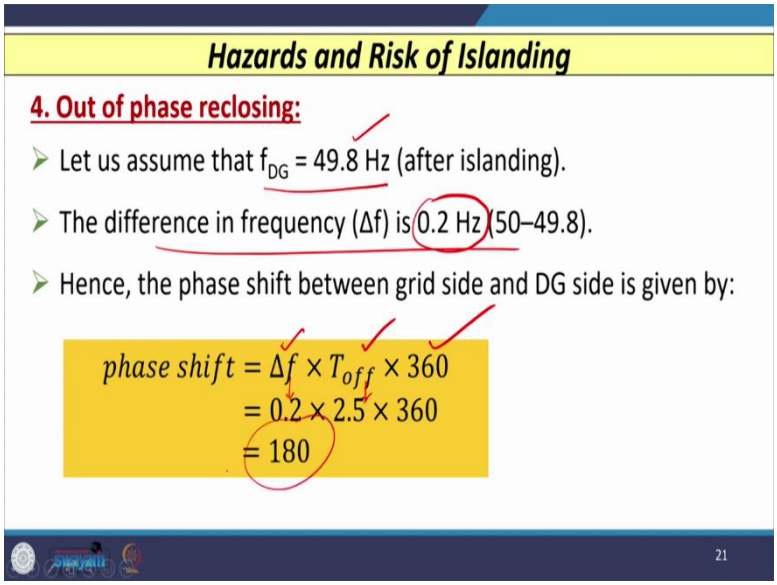

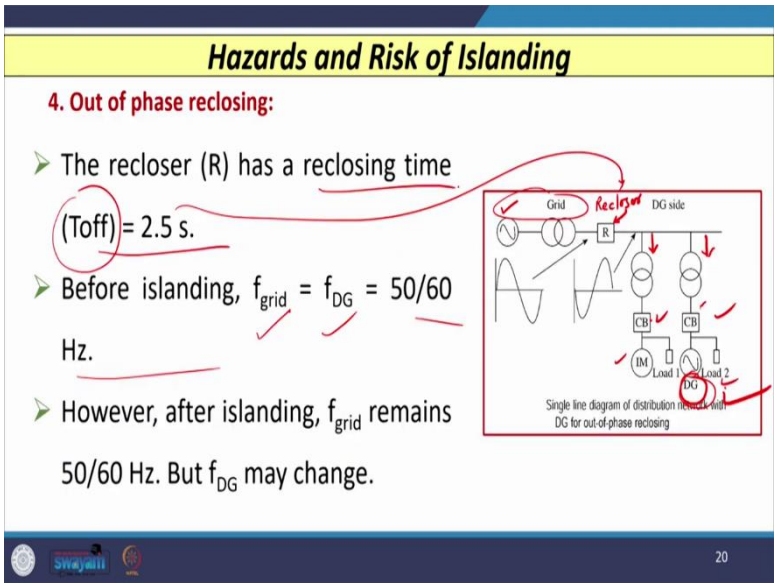

So, if we assume that let us say after an islanding phenomenon, the frequency of DG side islanded part that becomes 49.8 Hz from the 50 Hz. So, the difference in frequency that is Δf is 50 - 49.8 Hz. So, that is 0.2 Hz. Hence, if I calculate the phase shift between the grid side and the DG side, then that is given by the equation phase shift is equal to Δf multiplied by the reclosing time of the recloser for distribution network which we have considered as 2.5 seconds and multiply by 360. So, we will have delta f 0.2, T_{off} that is 2.5. So, we will have a phase shift of 180˚.

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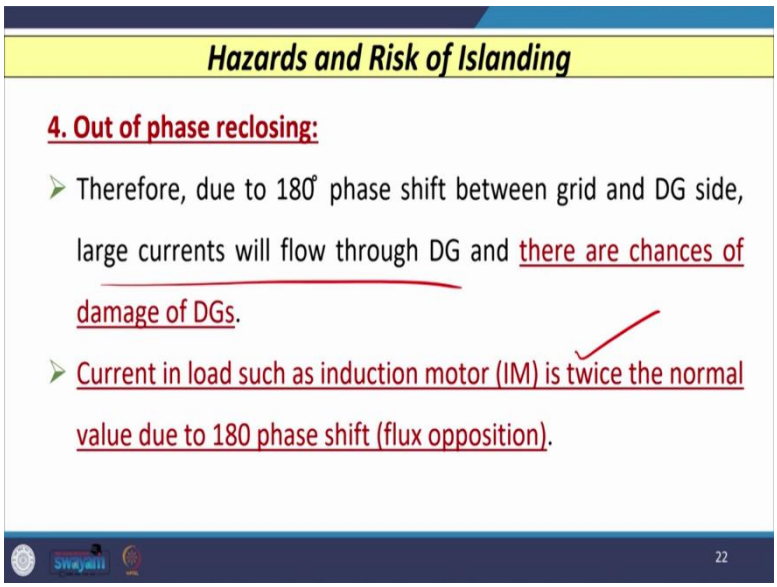

So, that means, due to 180˚phase shift between the grid side and DG side, if you are going to reclose the circuit after an islanding or after the occurrence of an islanding, then large currents are going to flow through the DG and there are chances of damage of these distributed generators. Moreover, currents in load say for example, in induction motors, that becomes almost doubled than the normal value because of this 180˚phase shift because of the flux opposition. So, this loads or induction motors they can be damaged.

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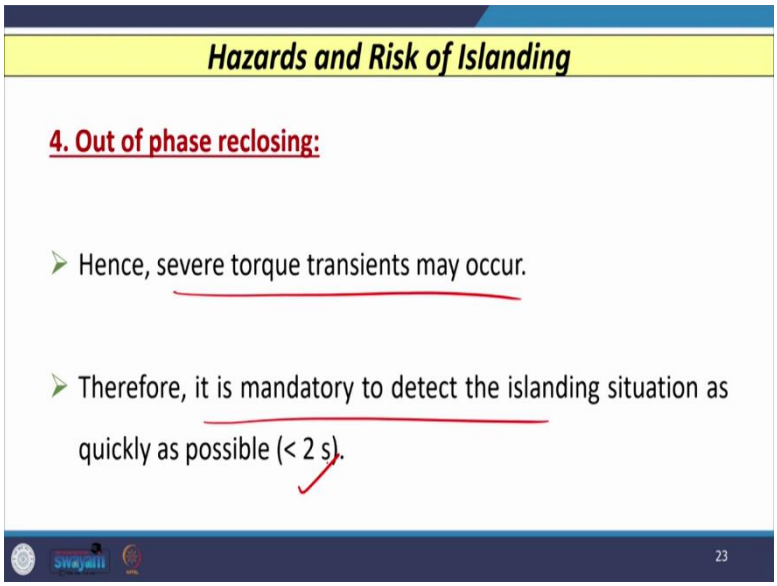

Hence, severe torque transients are going to develop. And hence, it is mandatory to detect the islanding situation as quickly as possible and as per 1547.4 standard, it has to be detected before 2 seconds.

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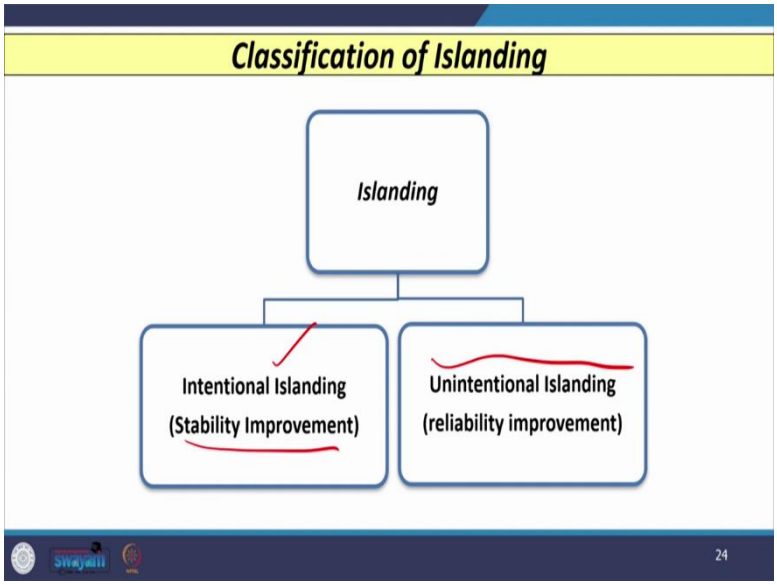

So, let us see what are the techniques to detect the islanding situation? So, we have normally two types of technique before we discuss how to detect the islanding condition and what are the different techniques, let us see first how we can classify the islanding? So, there are two ways of the islanding, how islanding is going to occur.

The first is the intentional islanding, and normally intentional islanding is carried out in most of the developed countries to achieve stability improvement. In our countries, the type of islanding which we are going to deal that is known as unintentional islanding and that is basically carried out for reliability improvement. So, there is a difference in the intentional islanding and unintentional islanding.

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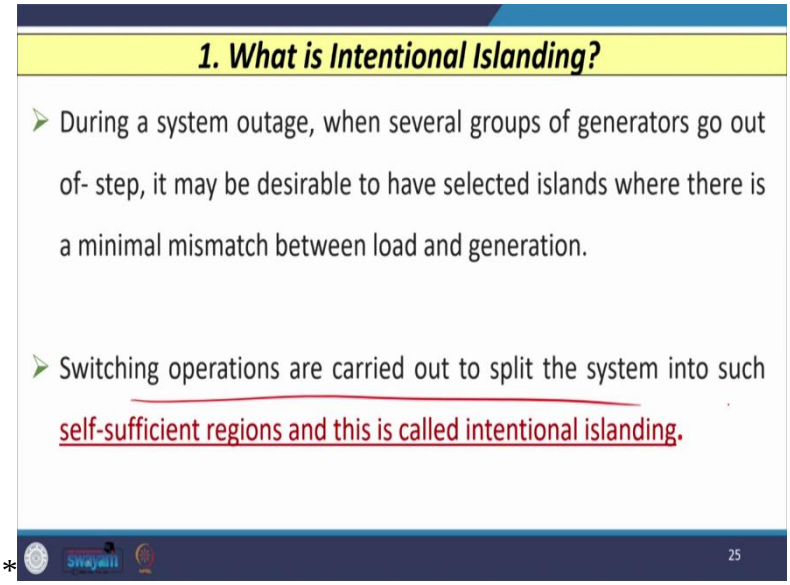

So, during the system outage, when several groups of generators go out of step, then it may be desirable to have selected islands when there is a minimal mismatch between the load and generator. So, switching operations are carried out to split the system into several such self-sufficient regions, which we called as intentional islanded regions. And this is basically done for stability improvements. So, that rest of the system that can be saved.

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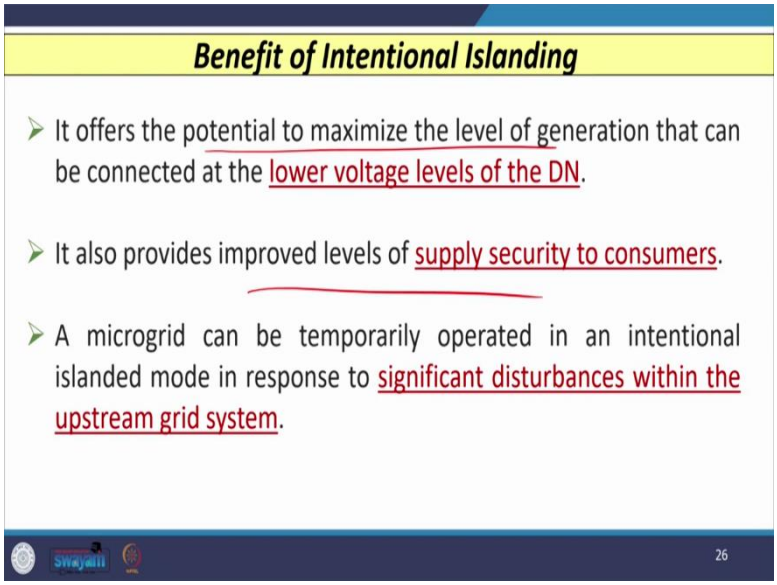

And as you know that benefits of intentional islanding, so that it offers the potential to maximize the level of generation that can be connected at the low voltage level of the distribution network. It also provides improved levels of supply security to the consumers. And that is why normally when we have a micro grid, then that can be temporary operated in an islanded mode in response to the significant disturbances in the upgrade system or network.

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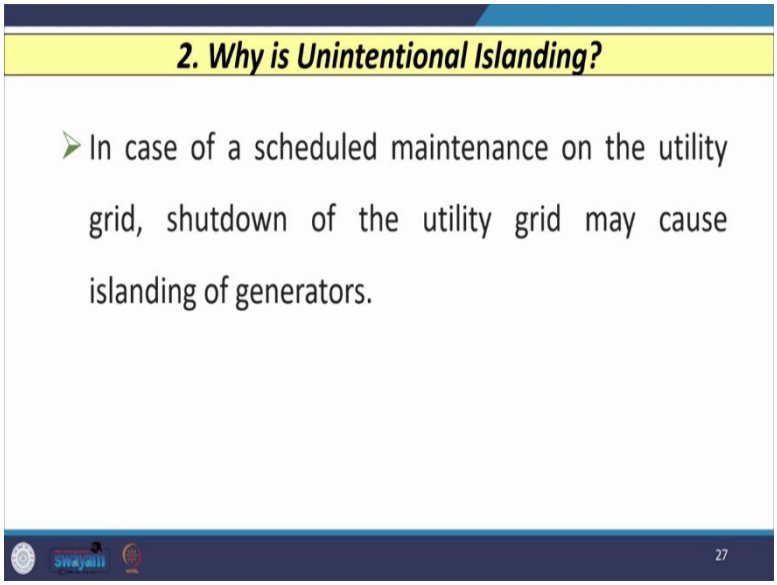

In case of scheduled maintenance as I told you, the shutdown of utility grid may cause the islanding of generators and that is why the unintentional islanding takes place.

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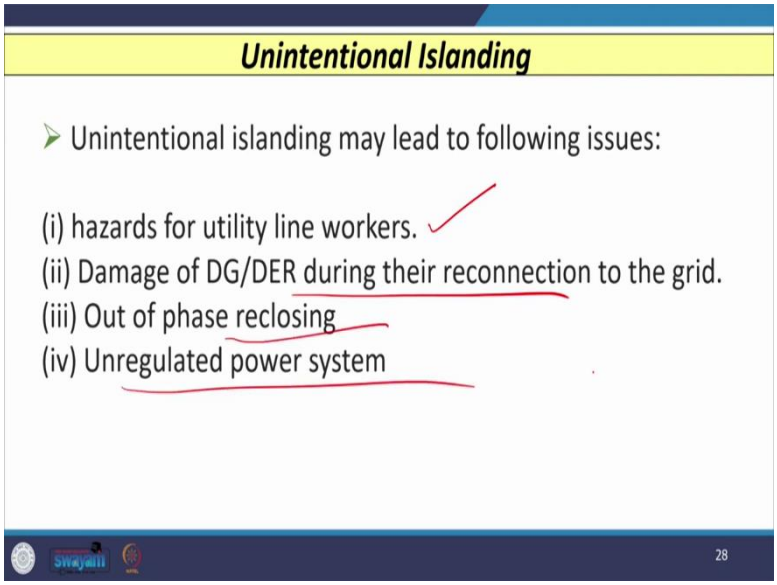

But as we have discussed in case of unintentional islanding, we have the issues like hazard to the utility or main persons, maybe damage of the distributed generators are there because of reconnection of the grid or maybe load, out of phase reclosing is there, an unregulated power supply system is there.

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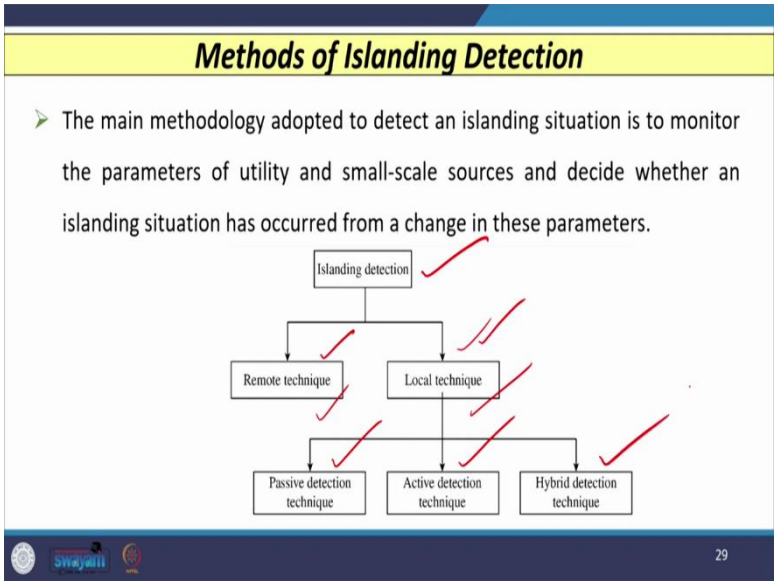

So, in a nutshell, we can say that we have to detect the islanding situation and we have to detect before 2 second. So, we need to use certain techniques. So, let us see what are the various techniques, that are used in case of islanding situation. So, for islanding detection, mainly two techniques are used, the first technique is known as remote techniques. And the second technique is known as local techniques.

As the name suggests, remote techniques that means, it needs communication device or medium to acquire or to get the data from various buses, that is why the name given remote techniques. Whereas, the local technique is the technique which takes the or which acquires the data from the local bus.

And based on those data, this technique will take certain decisions. Local technique can be further classified as the passive detection technique, active detection technique and hybrid detection technique. So, let us see each and every technique one by one. So, let us start with the remote technique.

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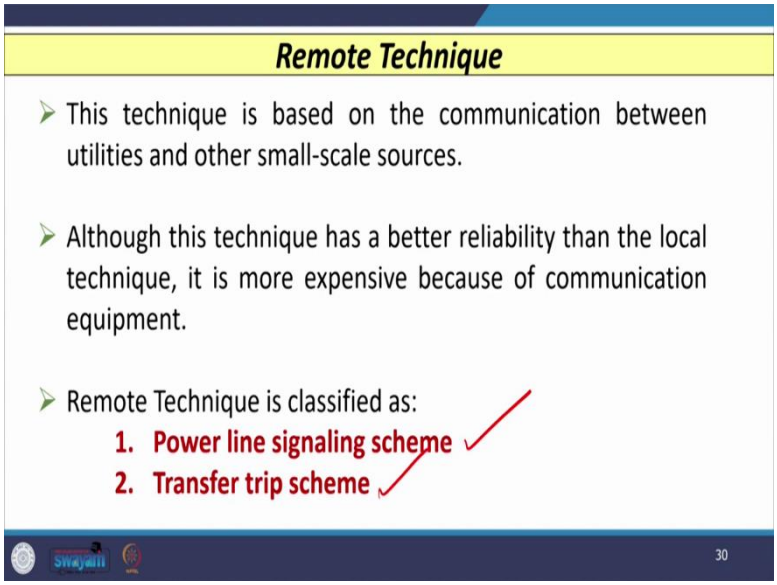

So, if we consider the remote technique, then as I told you this technique is based on the communication between the utilities and the small-scale distributed energy resources, which we have installed or connected at the point of common coupling. Although this technique has a better reliability, because we are having data from several locations, then the local technique, but this technique is more expensive, because of the requirement of several communication equipment.

Remote technique that can be further classified as power line signaling scheme and the second is the transfer trip scheme. So, let us discuss first the power line signaling scheme.

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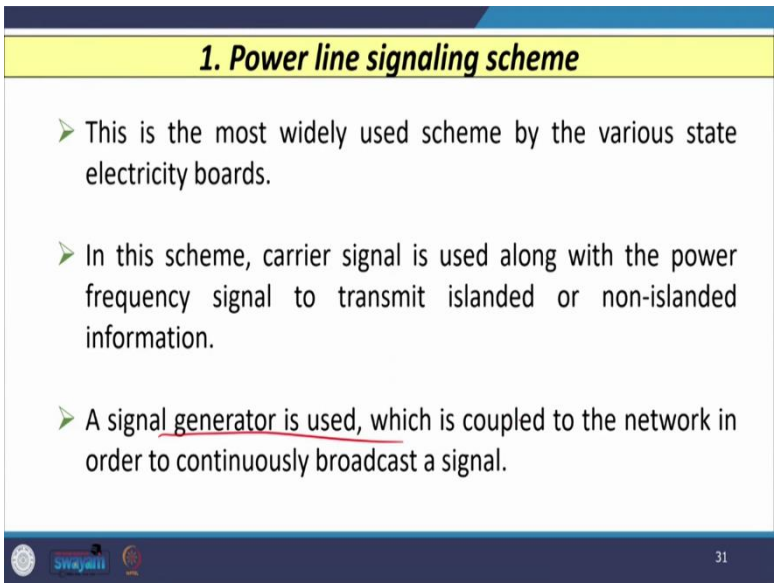

So, power lines signaling scheme is the most widely used scheme by utilities. So, in this scheme carrier signal is used along with the power frequency signal or fundamental frequency signal to transmit the islanded or non-islanded information. So, here in this case in most of the substations, a signal generator is used which is coupled to the network in order to continuously broadcast a particular signal, whether the islanded signal or maybe non-islanded information.

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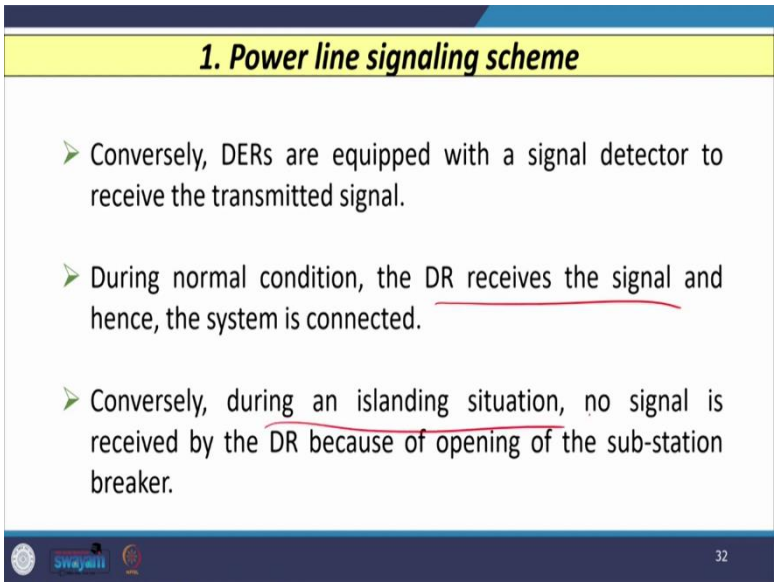

Conversely, when distributed energy resources are equipped with a signal detector to receive the transmitted signal. So, during normal condition when there is no island nothing is there, distributed energy resources receives the signal and hence system is connected.

Whereas, on the other hand, during islanding situation, no signal is received by the distributed energy resources or distributed generators, because of opening of the substation breaker. So, this is the situation, how they are going to discriminate islanding situation with several non-islanding events.

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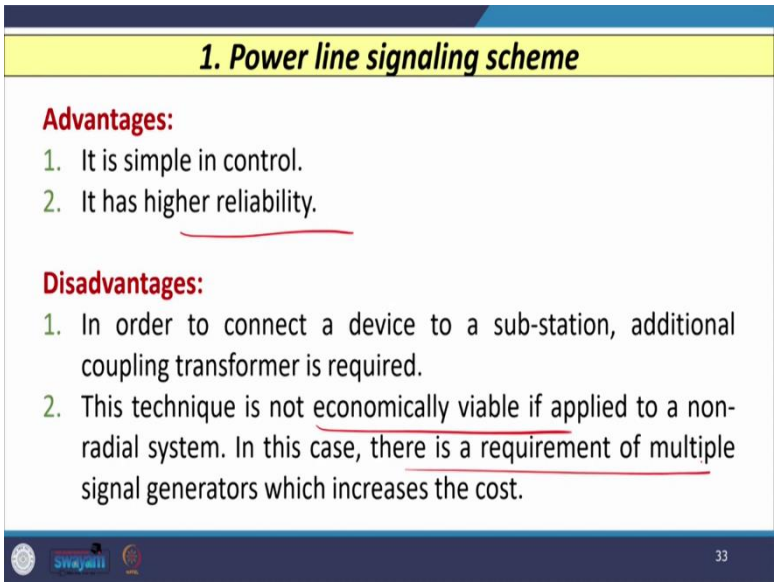

Now, let us see what are the advantages and disadvantages of power line signaling scheme. So, the first advantage is that this scheme is very simple in control and it has higher reliability compared to the other techniques. However, this has certain limitations also. In order to connect a device to a substation, additional coupling transformer is required if we wish to implement power line signaling scheme.

This technique is also not economically viable to a particularly to a system which is non radial in nature. Why? Because in this case, there is a requirement of multiple signal generators which increases overall cost of the system.

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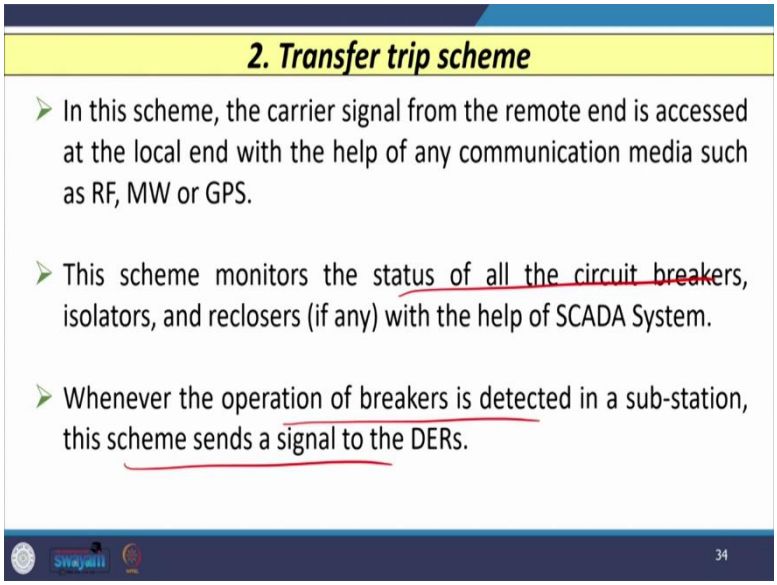

The second category of scheme that is used in remote detection technique, that is transfer trip scheme. So, in this scheme, the carrier signal from the remote end is assessed at the local end with the help of any communication medium such as radio frequency or microwave frequency signal or GPS.

So, this scheme monitors the status of all the circuit breakers, isolators, and recloser if any with the help of supervisory control and data acquisition system. So, whenever operation of breakers is detected in a particular substation, then this scheme sends a signal to the distributed energy resources or distributed generators.

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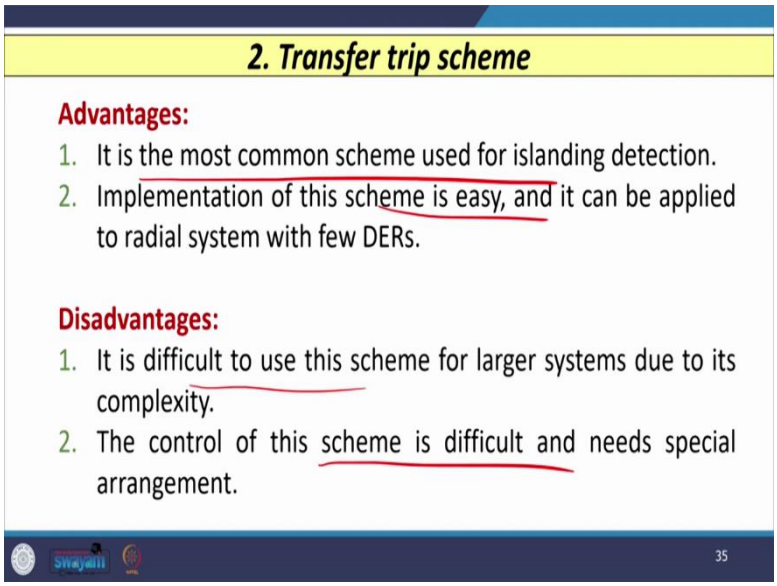

Let us see what are the advantages and disadvantages of transfer trip scheme. So, this scheme is the most common scheme used for islanding detection and implementation of this scheme is easy and it can be applied to radial system containing few distributed generators. However, for this scheme it is very difficult to use this scheme for larger systems due to complexity and control of the scheme is difficult and need some special arrangement.

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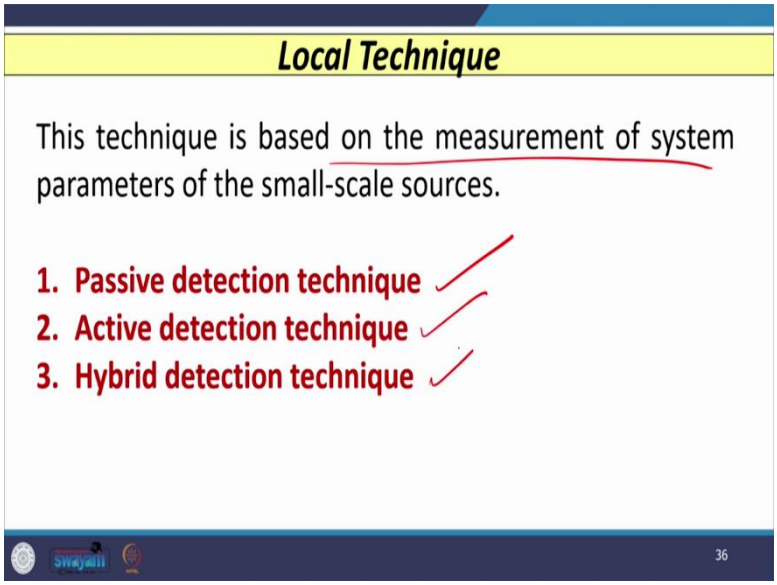

That is why the major disadvantage of remote based islanding detection scheme is the requirement of several additional equipment, let us say communication equipment and devices. So, some times when such type of cost barrier is there, then local technique that can be used.

So, this technique is based on measurement of parameters at point of common coupling or maybe at small scale resources at distributed generators or maybe DER level and these techniques are categorized as passive detection technique, active detection technique and hybrid detection technique. So, let us start with the passive detection technique.

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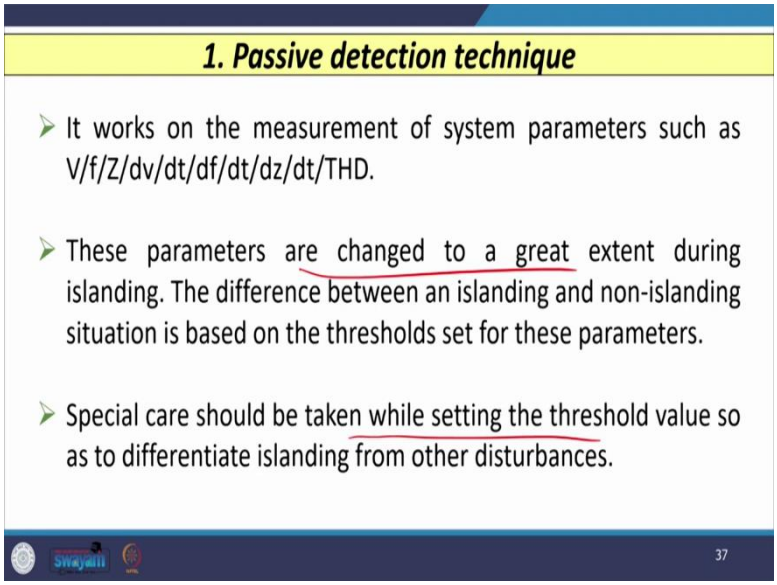

So, passive detection technique works on the principle of measurement of several parameters such as voltage, frequency, impedance, let us say rate of change of voltage, rate of change of frequency, rate of change of impedance, harmonic distortion and so on. So, any such type of parameter that can be used and based on that certain decision that is to be taken. So, these parameters are changed to a greater extent during islanding condition.

So, the difference between the islanding and non islanding situation that can be assessed by comparing these parameters with predetermined threshold value. Special care should be required while setting the threshold value. So, that there should not be any nuisance tripping when there is no islanding situation exist.

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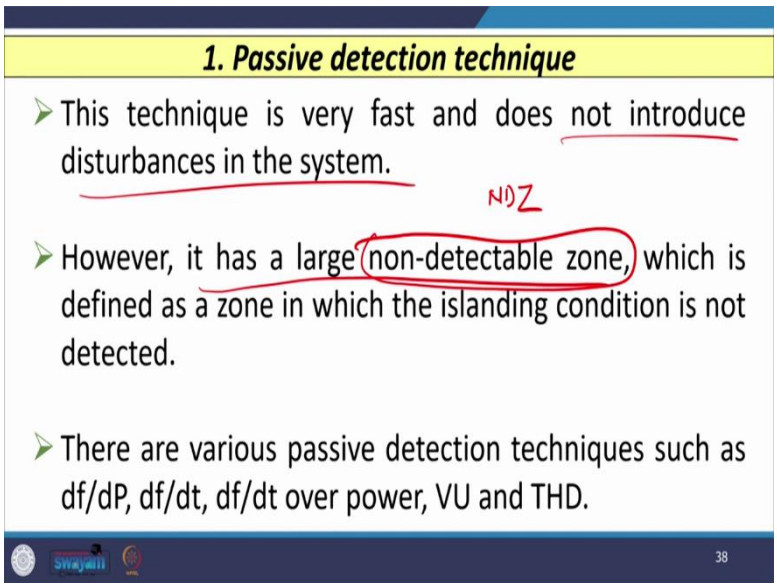

This technique is very fast and it does not introduce disturbances in the system like other active detection techniques. However, the main disadvantage of this technique is it has a large non detection zone, which is sometimes also denoted as NDZ. So, what is non-detection zone? So, non-detection zone is defined as a zone in which islanding condition is not at all detected by this passive islanding detection technique.

Therefore, various islanding detection technique that can be used as I told you maybe the rate of change of frequency with power rate of change of frequency, over power, maybe voltage unbalance, then harmonic distortion and so on.

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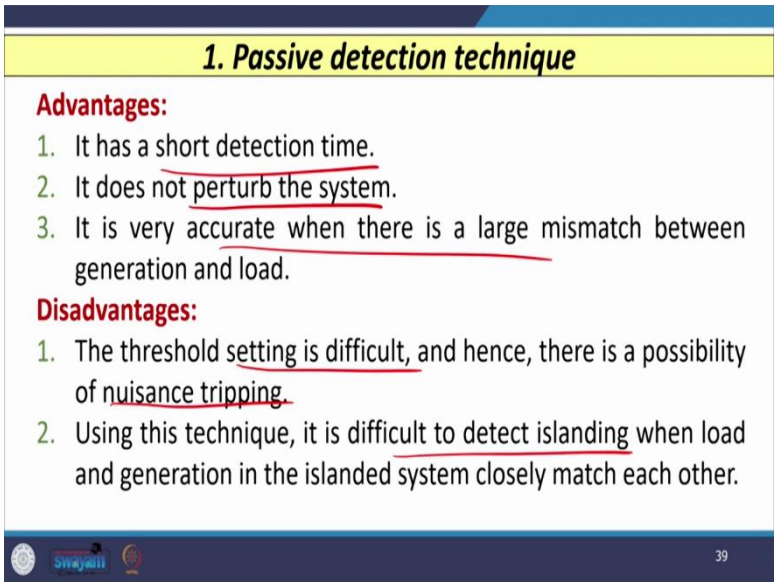

Now, let us see what are the advantages and disadvantages of passive detection technique. So, this technique has a short detection time, it does not backprop the system and it is very accurate when there is a large mismatch between the generation and the load. However, when we use passive detection technique threshold setting is very difficult and hence there is a possibility of nuisance tripping actually when there is no such islanding condition exists this type of scheme may mal operate.

Using this technique, it is also difficult to detect islanding when load and generation in the islanded system is closely matches with each other. And this type of condition is known as perfect power balance situation.

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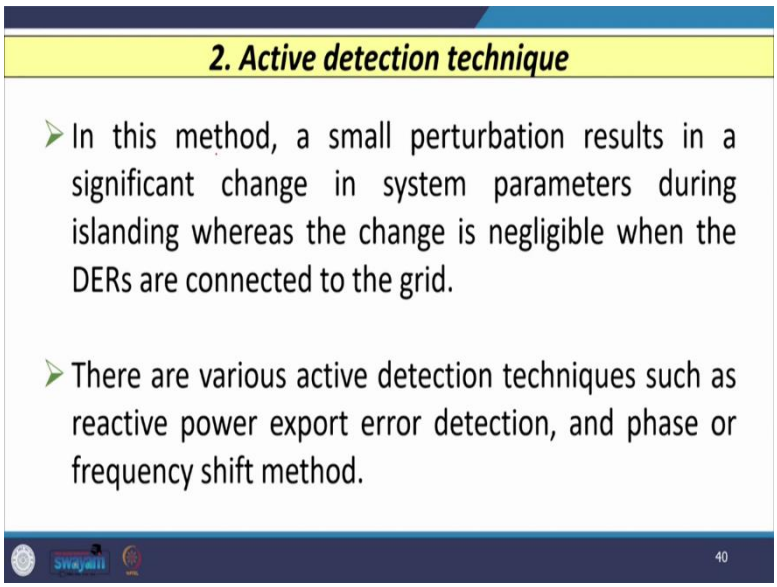

So, the second type of technique that is known as the active detection technique. So, in this method a small perturbation results in a significant change in the system parameters during islanding. Whereas, this type of change is negligible when the distributed energy resources or distributed generators are connected with the grid. So, various islanding active detection techniques, such as reactive power, export error detection and phase or frequency shift based techniques are available or come under the category of active detection technique.

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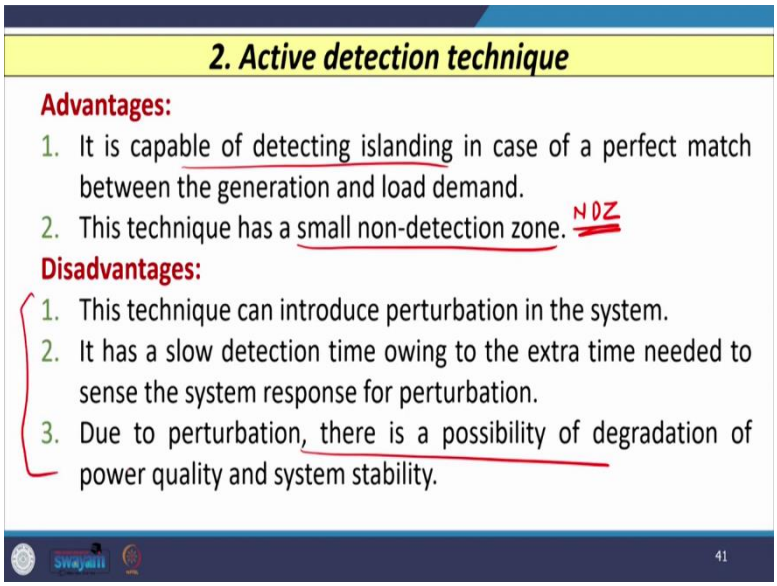

Let us see what are the advantages and disadvantages of active detection technique. So, active detection technique is capable of detecting islanding in case of perfect power balance

situation when there is a perfect match between the generation and the load demand. This technique has a small non-detection zone.

However, this technique may introduce perturbation in the system, it has a slow detection time owing to the extra time needed to sense the system response for perturbation. And due to this perturbation also there is a possibility of degradation of power quality and system stability. So, these are the limitations of active detection technique.

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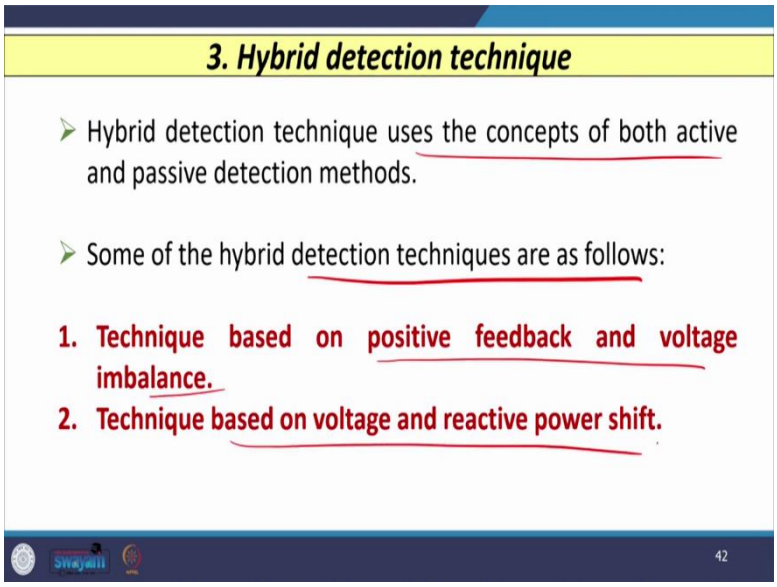

So, the third technique came after the active and passive detection technique, which is a combination of both active and passive detection technique that is known as hybrid islanding detection technique. So, hybrid islanding detection technique utilizes the concept of both active and passive methods. Some of the hybrid islanding detection techniques are techniques based on positive feedback and voltage imbalance. And the technique based on voltage and reactive power shift.

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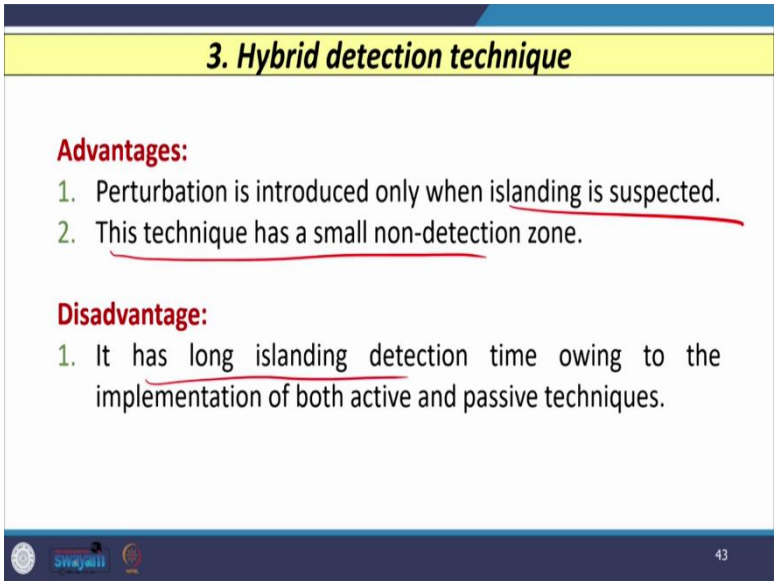

So, the advantages of hybrid islanding detection technique is that the perturbation is introduced only when islanding is suspected. Otherwise, when islanding is not there such type of perturbation is not introduced like in active detection technique. So, this technique has a small non-detection zone. So, this is also an important advantage.

However, this type of islanding detection technique has a long islanding detection time owing to the implementation of both active and passive concept. So, that is why this type of scheme is not used and in most of the cases, either passive islanding detection technique or maybe remote islanding detection technique that is used.

So, in this lecture, we started our discussion with the what is the islanding concept and what are the hazards of the islanding and we have discussed four important issues and then we have seen that the difference between the intentional islanding and unintentional islanding and then we have discussed different methods for the detection of the islanding condition and we have seen that islanding has to be detected before 2 second as per IEEE 1547.2 standards. Thank you.