Digital Protection of Power System
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Lecture 28
Load Shedding and Frequency Relaying - II

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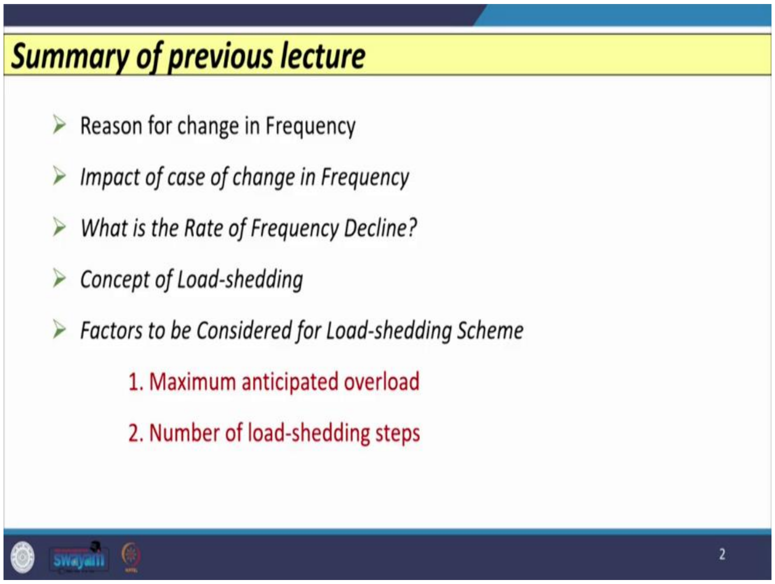

Hello friends. So, in the previous lecture, we have discussed regarding the reason for change in frequency and we have seen that impact of change of frequency. So, whenever there is a decline of frequency then what are the various impacts that also we have discussed. Then we have discussed regarding the rate of frequency decline that means, at what rate frequency reduces.

And based on that, we have seen that if we want to avoid or if we want to stop the frequency decline, then we have to go for the scheme that is known as load shedding scheme. And we have discussed in this the concept of natural load shedding, and after that we have seen that if I want to design intelligent load shedding scheme, then what are the factors to be considered?

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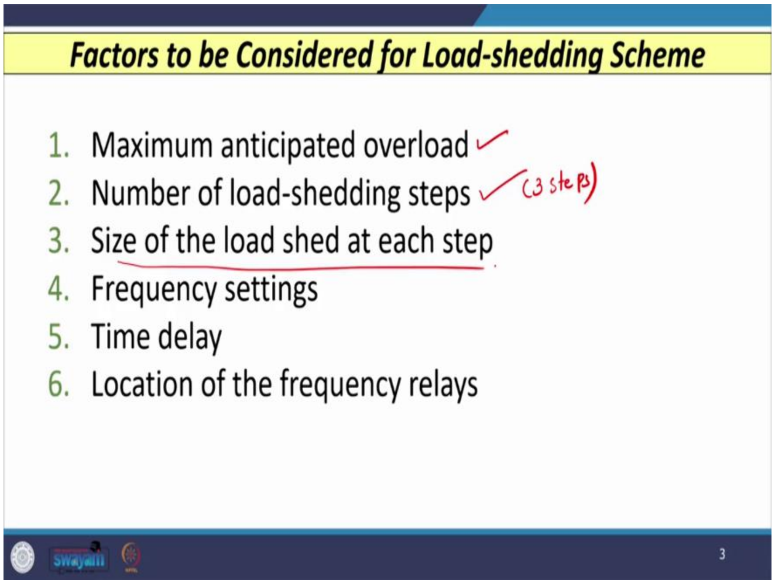

And there are 6 factors which we need to consider. And out of that, we have discussed the first two factor, the first one is the maximum anticipated overload. And second, that is the number of load shedding steps. And in this, we have seen that most of the utilities, they will use the 3 steps when any load shedding scheme that is designed. Now, the third factor which we need to consider for the design of intelligent load shedding scheme, that is the size of the load that is to be shed during each step.

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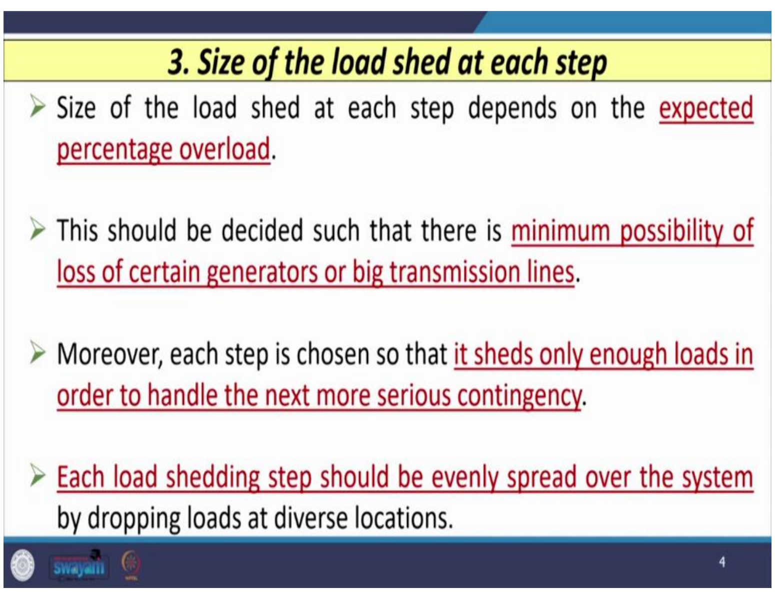

So, the size of the load that is to be shed at each step that depends on what will be the expected percentage of overload. And whenever such expected percentage of overload is there, then we have to design this shed of each load during each step in such a way that minimum possibility of loss of generations and big transmission lines are there. Moreover, when we design the or when we decide the size of load to be shed in each step, then during each step, we have to see that the load sheds only particularly when we handle the particular step.

And in each step load that should be shed in such a way that, that is capable to handle the next severe contingency, if it is there. Each load shedding step should be evenly spread, so that should not be uneven load shedding. So, this is also an important factor which we need to consider. And whenever we design the load shedding scheme, then each load shedding steps should be distributed or should be spread evenly throughout the entire distribution or transmission network.

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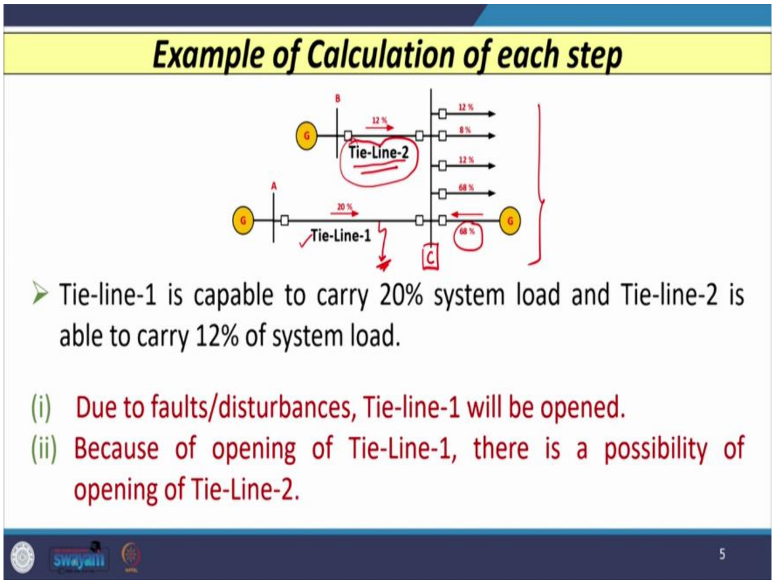

Now, to understand the calculation of each step, let us consider one example. So, here you can see (as shown in above slide) I have shown one single line diagram of a portion of a power system network which is fed by three generators. So, here we have a tie-line-1 which is connected at bus A and let us say this is bus C. And this tie-line-1 is capable to take care of 20 percent overload. The another tie-line-2 that is connected between bus B and bus C, and this tie-line is capable to take care of 12 percent overload.

And the other tie line is connected with another generator with bus C which is capable to take care of 68 percent of overload. Now, in this situation, it may be possible that because of fault, let us say on tie-line-1 or maybe some disturbances are there or some abnormal conditions are there then tie-line-1 may trip.

So, if tie-line-1 is tripped and because of this tripping it may be possible that the next consequences is the tripping of the another tie-line-2 also. So, if tie-line-1 that is tripped or if tie-line-2 that is tripped or both will trip, then we want to discuss that how the load on these feeders that is to be shed. So, our objective is to implement the load shedding scheme that will preserve the remaining system or that means the remaining loads or remaining feeders are connected to the bus C, when the tie-line-1 or tie-line-2 are lost.

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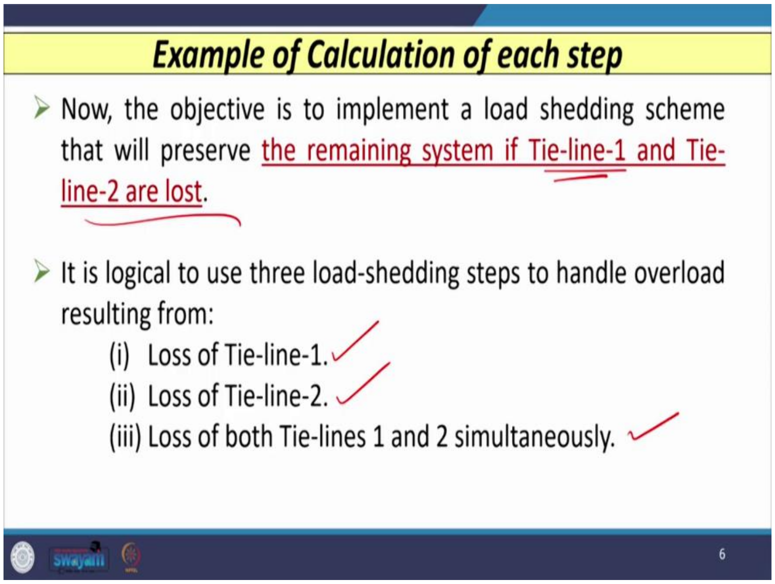

So, in this case, it is logical to use normally three load shedding steps to handle the overload resulting from either the loss of tie-line-1, the second case would be the loss of tie-line-2, and the third case that would be the loss of both tie-line-1 and tie-line-2 simultaneously.

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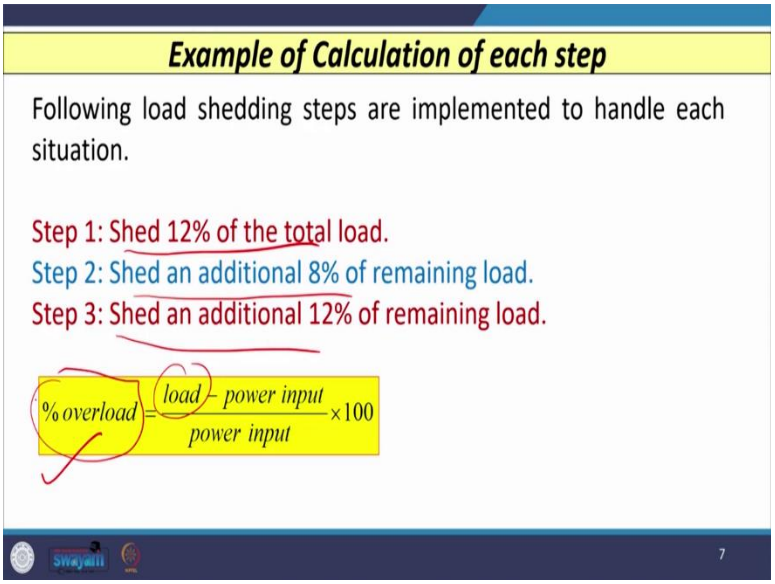

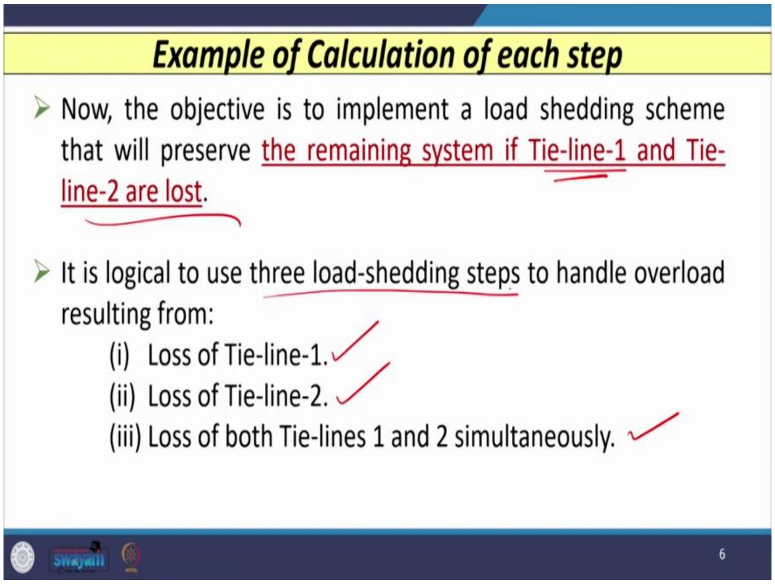

Now, when we design the load shedding scheme, then as we have seen that we will go for the three load shedding steps. So, these steps should be implemented in the following situations. So, in step 1, we have to shed 12 percent of the total load. In step 2, we have to shed the additional 8 percent of the remaining load.

And in step 3, we have to shed an additional 12 percent of the remaining load. And in each step, step 1, step 2 and step 3, we can calculate the percentage of overload that is going to occur on the network using this equation, $\%overload = \frac{load - powerinput}{poweroutput} \times 100$

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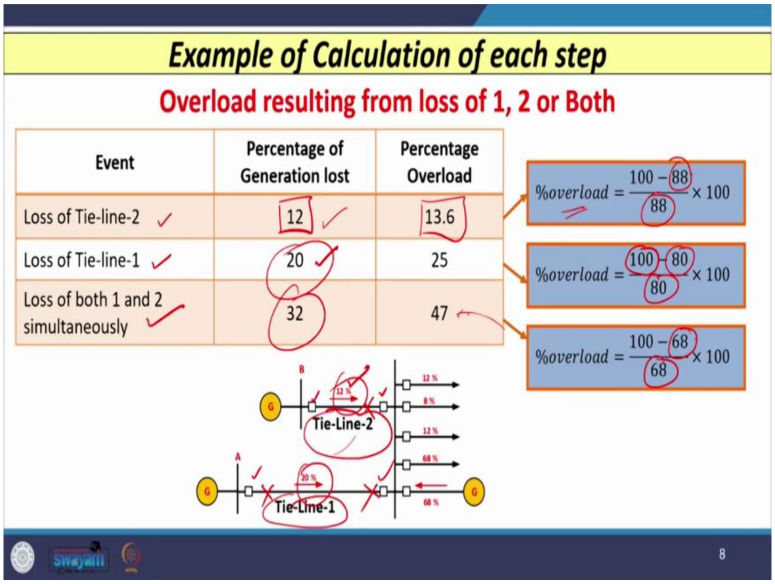

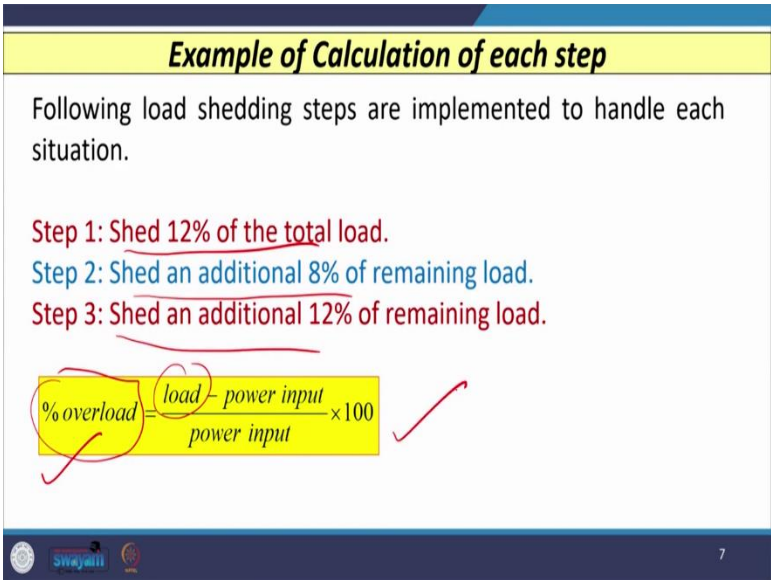

So, if I use this each and every case, let us say in case 1, there is a loss of tie-line-2. So, when there is a loss of tie-line-2 that is in this figure, this is not there, because of some reason, this breaker and this breaker both will become open. So, then there is a loss of tie-line-2. And this tie-line-2 is carrying the percentage of the load that is 12 percent. So, the generation lost that is 12 percent.

And based on that, we can calculate the percentage of overload using this equation. So, in that case, the percentage of overload that would be the load that is let us say 100 percent load is there $\%overload = \frac{100-88}{88} \times 100$. So, you will have the percentage overload that is 13.6 percent.

In this second case, when there is a loss of tie-line-1, so this is working perfectly, but tie-line-1 is lost, because of opening of these two breaker. So, as this line is carrying 20 percent overload. So, here we can see that the percentage overload that can be calculated considering the, your load is 100 percent and the remaining power input and output that would be 80 percent because 20 percent which is carried by this tie-line-1 that is lost because of opening of this line.

So, you will have the percentage over load that is 25 percent. And in the third case, when both tie-line-1 and tie-line-2 will open simultaneously, then the addition of 20 percent + 12 percent that is 32 percent that is not there. And based on that 100 - 32, so that is 68 percent $\%overload = \frac{100-68}{68} \times 100$, that will be if you put it here you will have the percentage overload value that is 47 percent.

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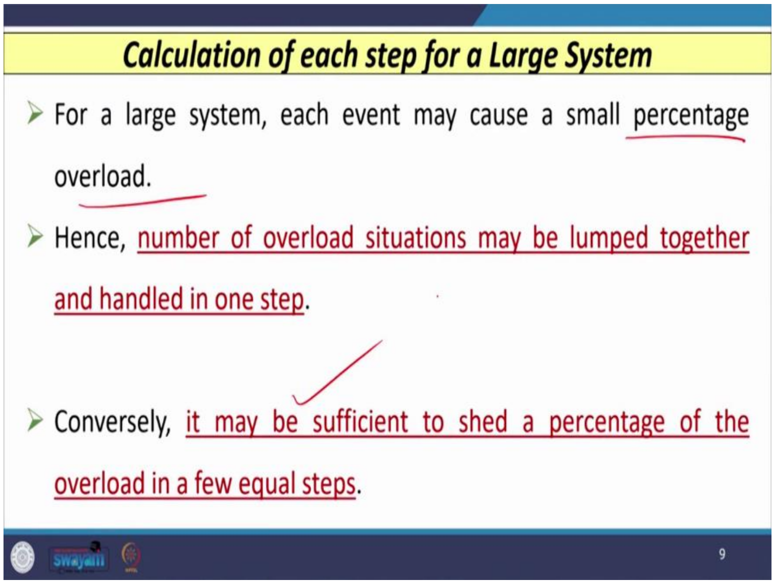

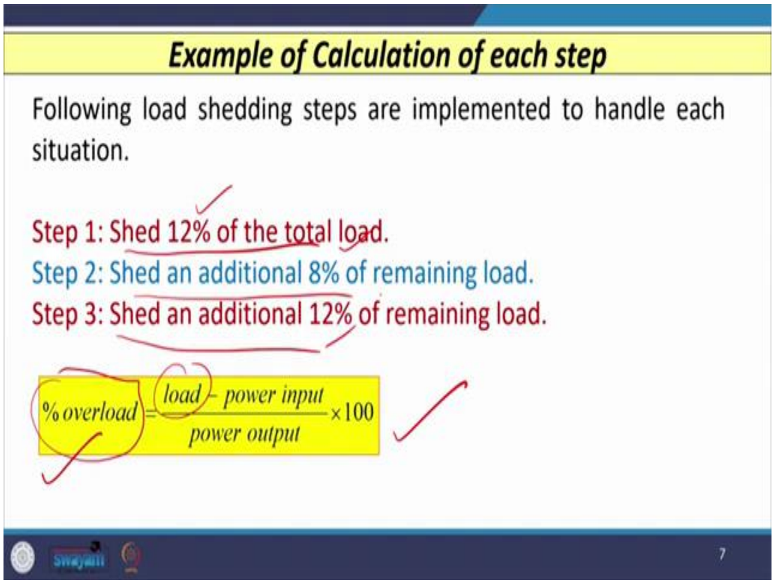

So, we can say that, if we have a large system or large network, then each event may cause a small percentage of overload, because in larger network, when any let us say overloading of one line is there, any disturbance is there, any abnormal condition is there, then the small percentage of overload that is always observed.

Hence, the number of overload situations that can be lumped together and that can be handled in a single step. On the other hand, it would be sufficient to shed a percentage of the overload in few equal steps. As in earlier case, we have considered the three steps and during each step, we have shared the load maybe 12 percent, 8 percent and 12 percent. So, that we can adopt.

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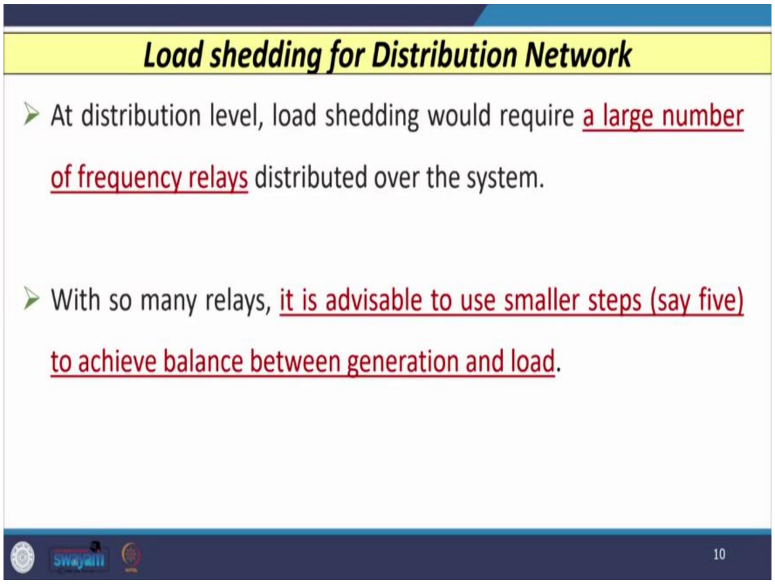

Now, when we talk about the load shedding for distribution network, then at distribution level load shedding would require large number of frequency relays. So, with so many large number of frequency relays, it is advisable to use smaller steps, let us say three steps or five steps to achieve the perfect balance between the generation and the load.

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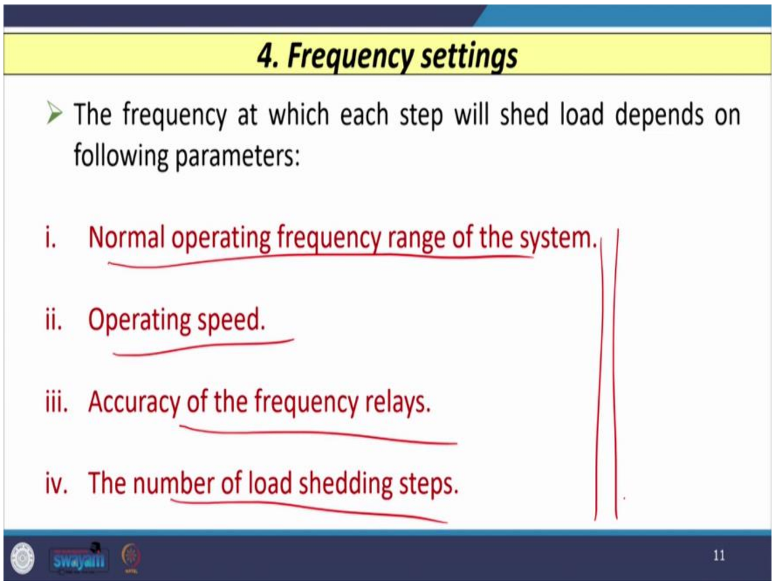

Now, the fourth factor which is going to affect the design of an intelligent load shedding technique, that is the setting of frequency. So, the frequency at which each step the load will shed that depends on several parameters. And this parameter are the normal operating frequency range of the system, what is the operating speed, what is the accuracy of frequency relays and what is the number of load shedding steps we are going to use. So, these four factors are very important, which are going to decide the frequency settings.

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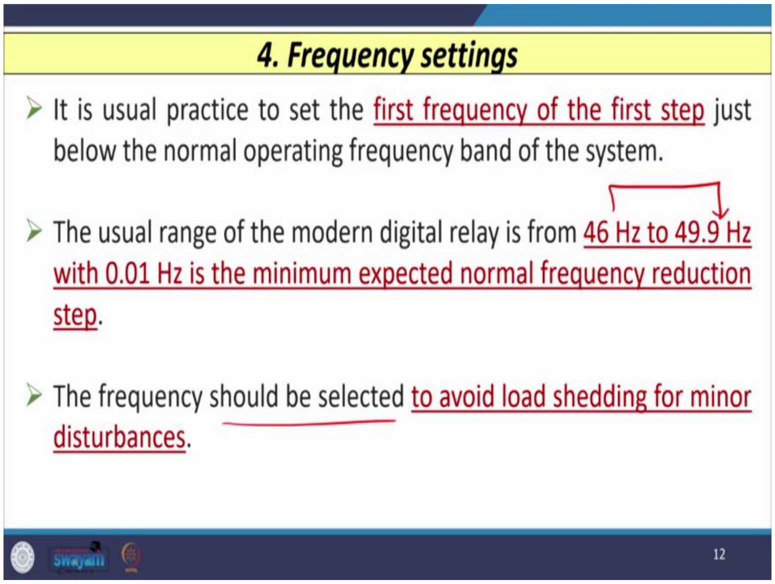

Now, it is usual practice to set the first frequency of the first step just below the normal operating frequency band of the system. The usual range of the most of the digital relays that would be from 46 Hz to 49.9 Hz with 0.01 Hz is the minimum expected normal frequency reduction step, assuming 50 Hz is the fundamental frequency.

The frequency should be selected in such a way that we can avoid load shedding for minor disturbances because in case of minor disturbances, the system itself is capable to recover or regain the original steady state condition.

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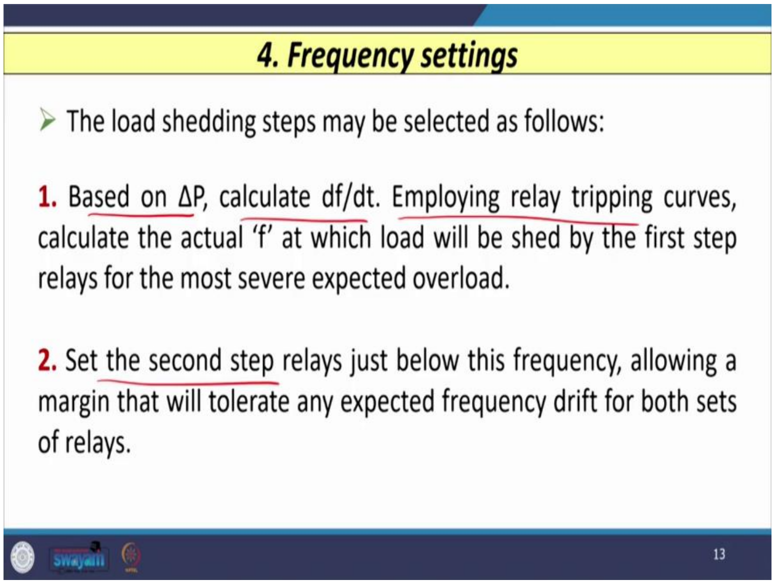

So, for frequency settings load shedding steps may be selected as follows and there are five steps which we need to follow. So, in step number 1, based on the ∆P change in active power, we have to calculate the rate of change of frequency. Once we have the df / dt, then employing the relay tripping curves, we have to calculate the actual value of frequency at which the load will be shed by the first step relays for the severe most expected overload condition.

In the second step, we have to set the second step relays that is just below the frequency which allows the margin that will tolerate any expected frequency drift for both sets of relays.

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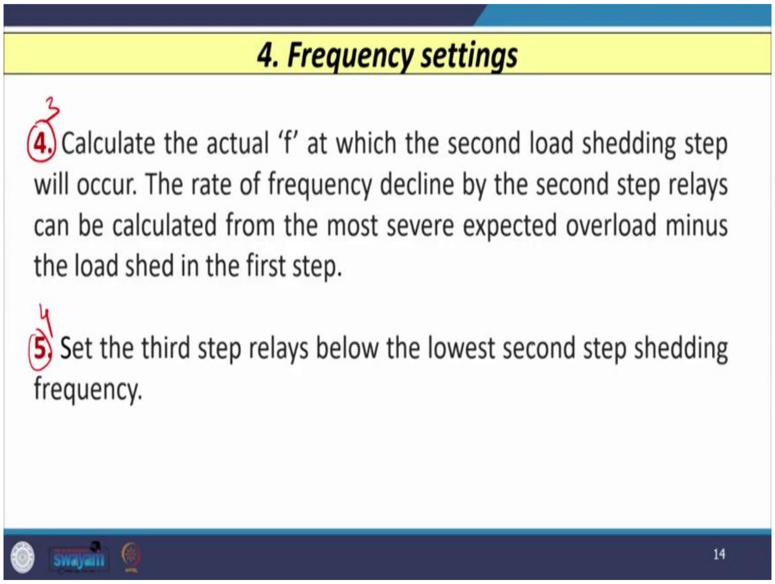

In the third step, we have to calculate the actual frequency at which the second load shedding step will occur. So, the rate of frequency declined by the second step of relays that can be easily calculated from the most severe expected overload minus the load shed during the first step. And then in the fourth step, we have to set this third step of relays below the lowest second step shedding frequency.

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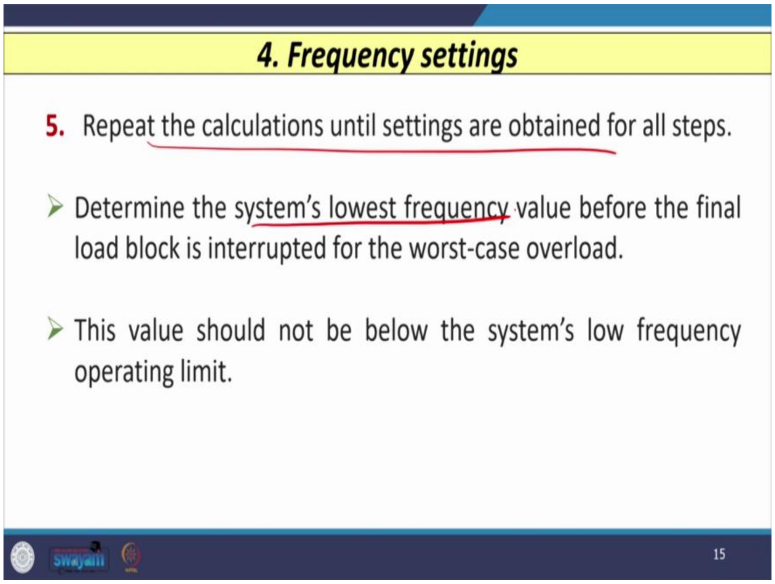

And in the fifth step, we have to repeat the calculation until the settings are obtained for all the steps which we have considered. If we have three steps, then we have to stop, if we have five step then again we have to go ahead and we have to stop at fifth step. Now, in all these situations, we have to determine the system's lowest frequency value before the final load block is interrupted for the worst-case overload and this value should be always below the system's low frequency operating limit.

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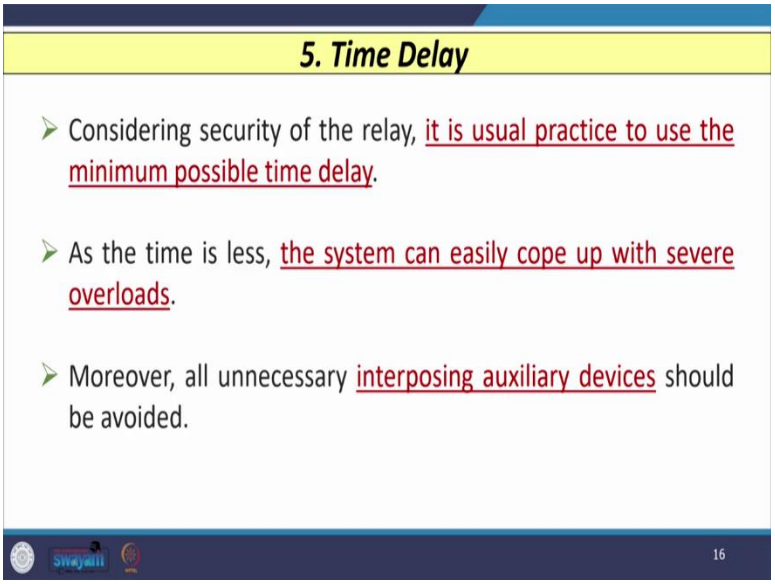

Now, the fifth factor which is going to affect the design of an intelligent load shedding technique, that is the time delay. So, it is the usual practice to use the minimum possible time delay. When the time is less the system can easily cope up with severe overloads and all necessary interposing auxiliary devices that should be avoided, so that we can have this. But however, one important condition is that time delay is needed only during specific situation.

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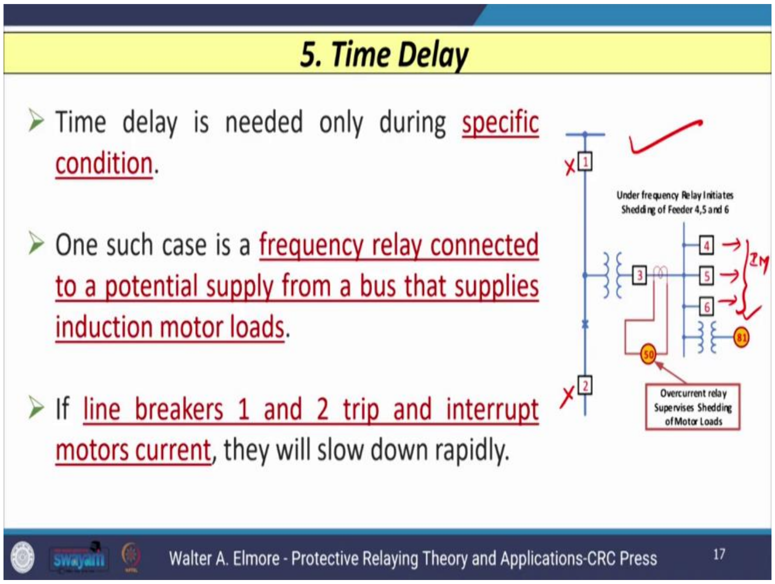

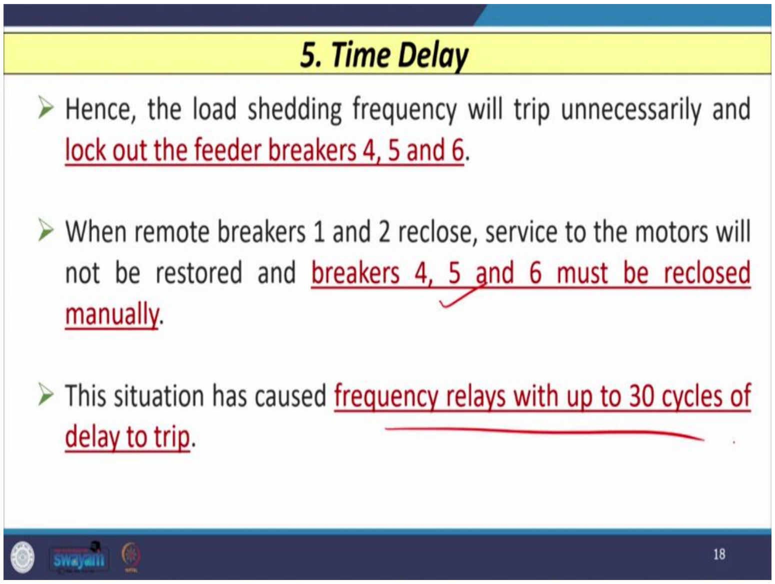

For example, one such situation we can consider using this diagram, where the frequency relay is connected. So, you can see that 81 is my frequency relay which is connected on the secondary of the PT and that is going to supply motor loads. So, here you can see that (as shown in above slide) these are the motor loads or induction motor loads are there.

Now, because of some reason, let us say the circuit breaker 1 and circuit breaker 2 both will trip, if these two breakers will trip, then that is going to interrupt the speed of the induction motors and their speed will drastically reduces. And because of that, your breakers number 4, 5 and 6 that will trip and that will go in lockout condition. So, after a tripping it will not be reclosed, because that will go in lockout condition.

Now, because of let us say some reason let us say circuit breaker 1 and circuit breaker 2, both will reclose, they have reclosing facility. So, reclosing attempt will be done. And after that services to the motor will not be restored, because breaker 4, 5 and 6 they will go in lockout condition. So, if I wish to restore the supply then I have to manually reclose the breaker 4, 5 and 6, this situation is going to give a rise off the time delay of the order of 30 cycles.

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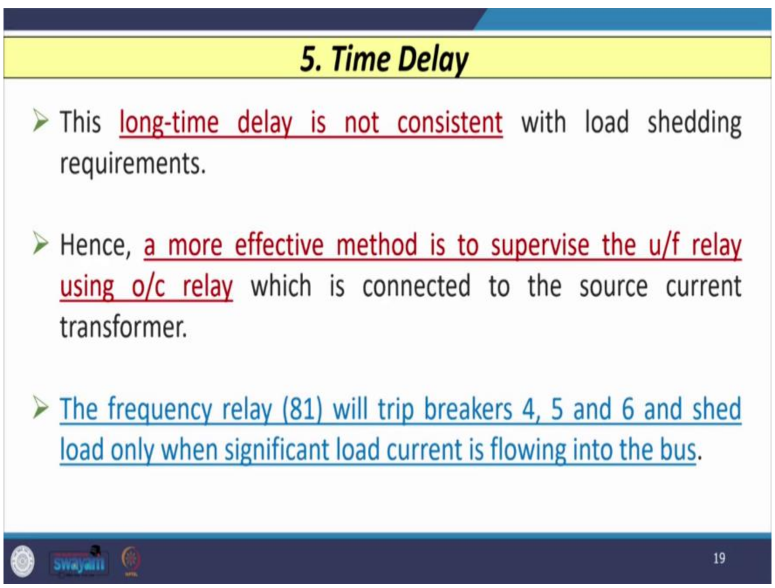

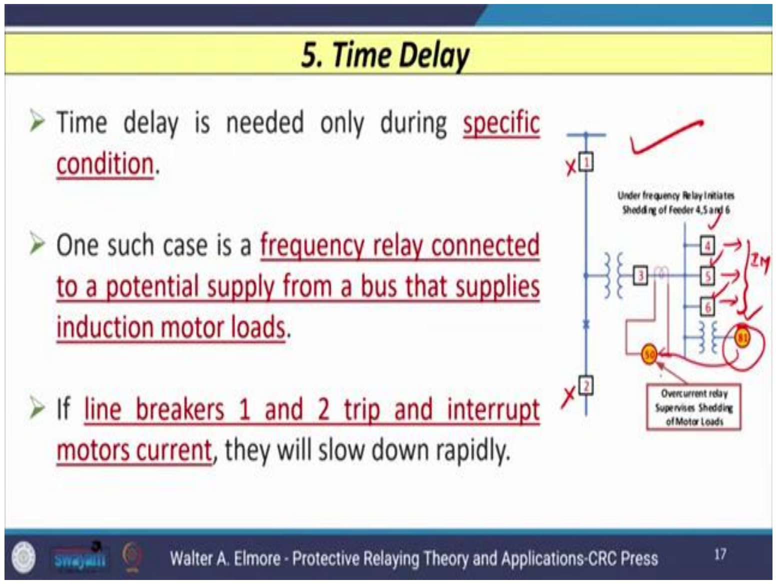

However, this long-time delay of 30 cycles that is not consistent or that is not in coordination with the load shedding requirement or load shedding requirement of the scheme. Hence, if we wish to achieve more effective method then the only option is we have to supervise this under frequency relay by overcurrent relay. So, that is why this 81 relay is all supervised with the overcurrent relay 50.

And in this case, the frequency relay 81 will trip the circuit breakers 4, 5 and 6 and shed the load only when there is a significant increase in the load current. So, both overcurrent relay and frequency relay both will be there and both will be operated then and then this scheme will be operated. So here, frequency relay is monitored by overcurrent relay.

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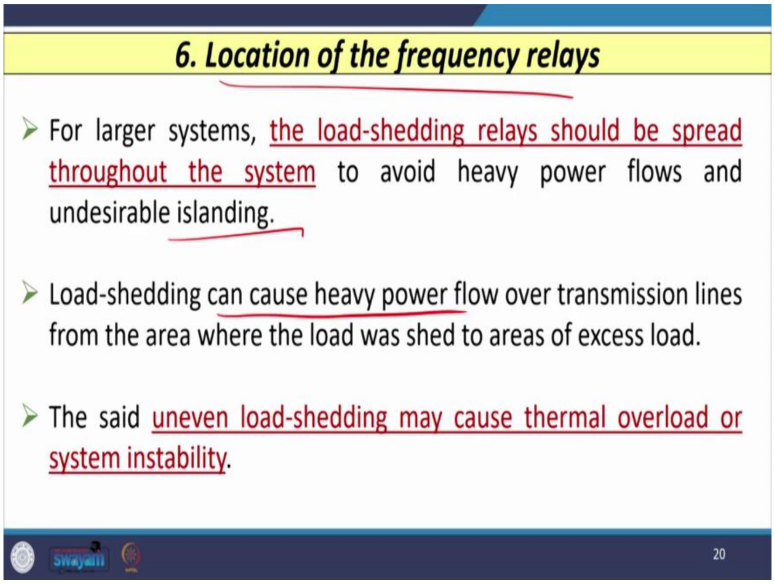

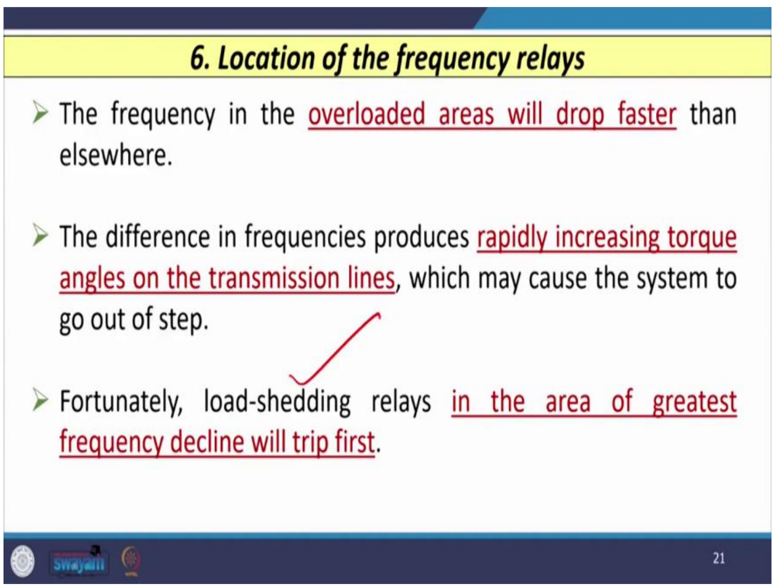

Now, the next step, which we need to consider for the design of intelligent loads shedding scheme that is the location of frequency relays. We know that for larger networks load shedding relays should be spread throughout the system to avoid heavy power flows and undesirable islanding condition, what is islanding condition? That we will discuss later on. The load shedding can cause heavy power flow over the transmission lines from the area where the load was shared to the areas of excess load.

So, they said uneven load shedding may cause the thermal overload limit and your system may become unstable in this situation. So, frequency in the overloaded areas will drop faster than the other areas those areas which are not overloaded or which are working in normal condition.

So, the difference in frequencies will definitely produce an increasing torque angle on the transmission lines, which may cause the system to go in out of step condition. However, in most of the cases, where the areas in which the greatest frequency decline is observed, in that case, load shedding relays will be operated first.

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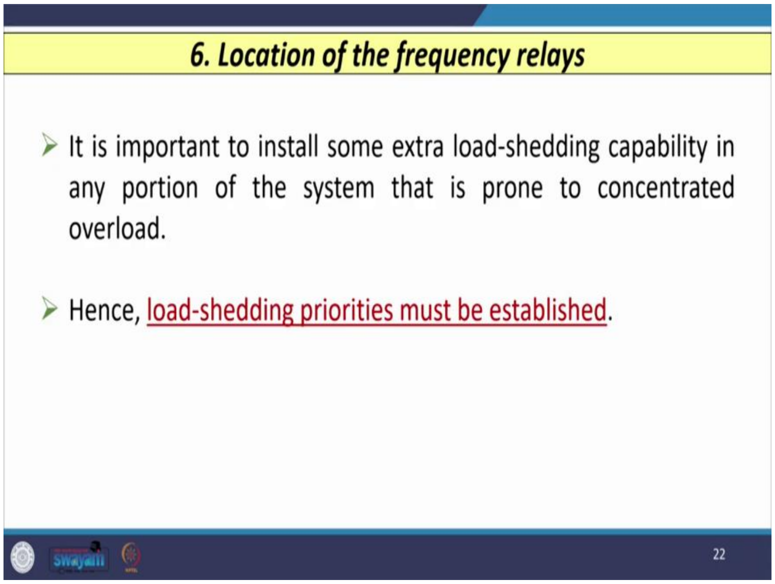

So, it is important to install some additional or extra load shedding capability in any portion of the system that is prone to the concentrated overload. Hence, load shedding priorities that need to be established when we design intelligent load shedding scheme.

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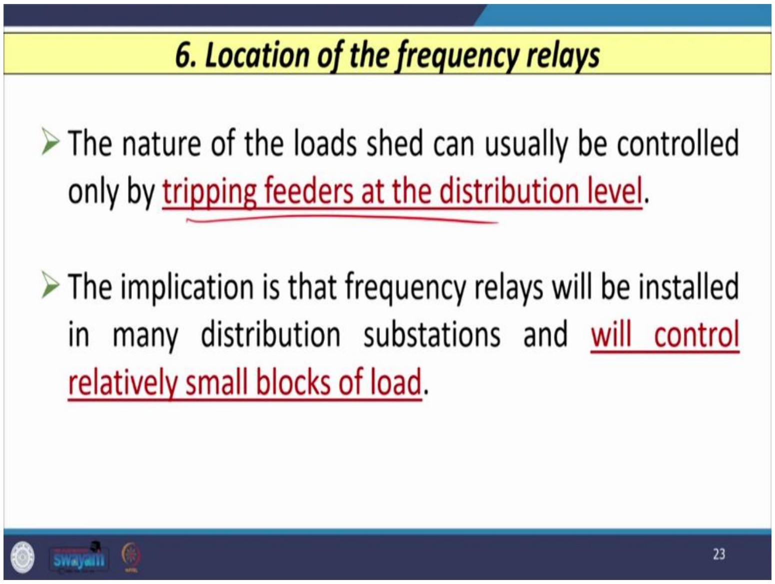

And we know that when we apply such type of scheme at distribution level, then the tripping feeders at distribution level that should be controlled when the nature of load that should be shed.

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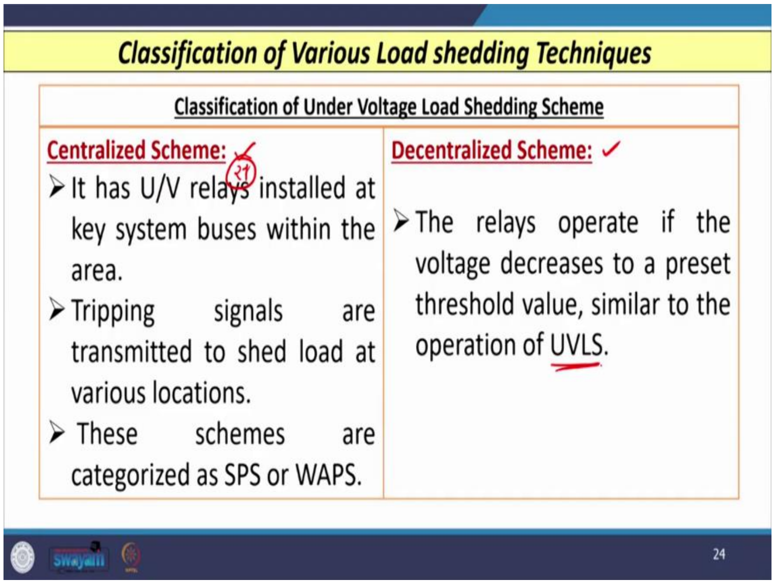

Now, let us see what are the classification of various load shedding techniques. So, the first type of classification of the load shedding technique that is one is centralized scheme and other one is the decentralized schemes. So, centralized scheme has under voltage relay that is 27 relay is there that is installed at key buses within the area or network. And tripping commands are initiated or transmitted to shed the load at various locations.

And these schemes are categorized as SPS or WAPS type of schemes. Whereas, in case of decentralized scheme, the relays operate if the voltage decreases to a pre-set threshold value. And these schemes, we can say that is similar to the undervolted load shedding scheme, which is very conventional.

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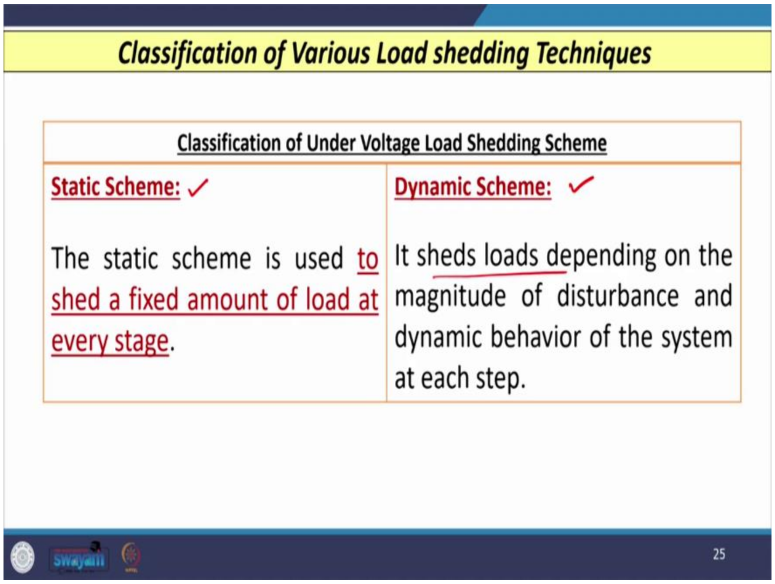

The second type of classification is based on static scheme and dynamic scheme. So, the static scheme is used to shed a fixed amount of load at every stage. So, you cannot change the load amount you have to shed the load that is fixed. Whereas, in case of dynamic scheme it sheds the load depending on the magnitude of disturbance and the dynamic behaviour of the system at each step. So, this is a difference between static and dynamic scheme.

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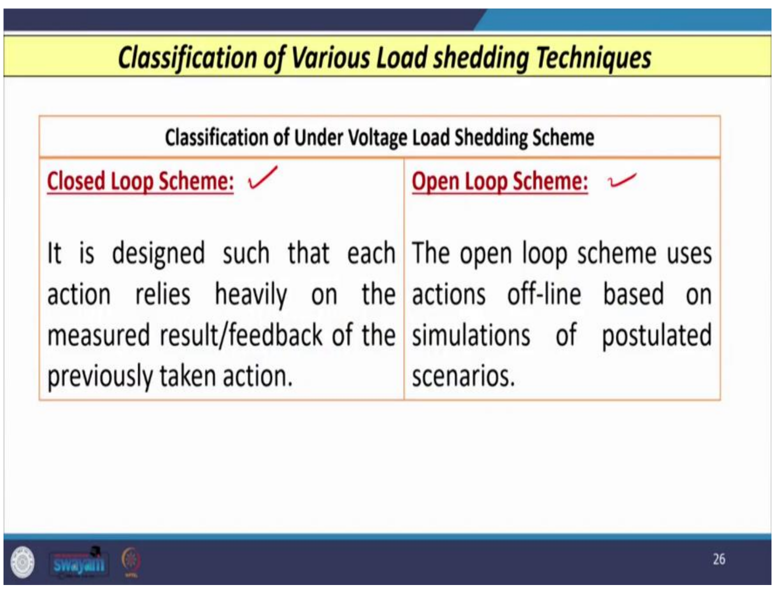

The next type of classification is the closed loop type of scheme and the second is the open loop type of scheme. So, closed loop type of scheme is designed in such a way that it relies heavily on the measured result/feedback of the previous action taken. So, whatever previous action that is to be taken based on that your next action that will be decided. Whereas, in case of open loop scheme, this scheme uses actions offline based on the simulations of the postulated scenarios.

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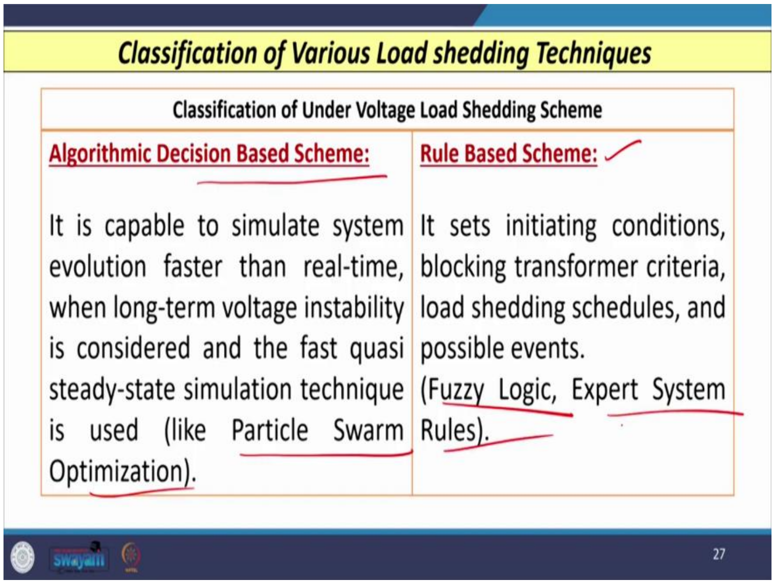

The next type of classification is the algorithm decision-based scheme and the other one is the rule-based scheme. So, algorithm decision-based scheme is capable to simulate system evaluation faster than real time when long term voltage instability is considered. And the fast quasi steady state simulation technique is used like particle swarm optimization technique.

Whereas rule-based scheme sets, initiating conditions, blocking transformer criteria in load shedding schedules and possible events and the best example of rule-based schemes that is fuzzy logic base scheme and expert system-based scheme. These are the examples of this type of scheme.

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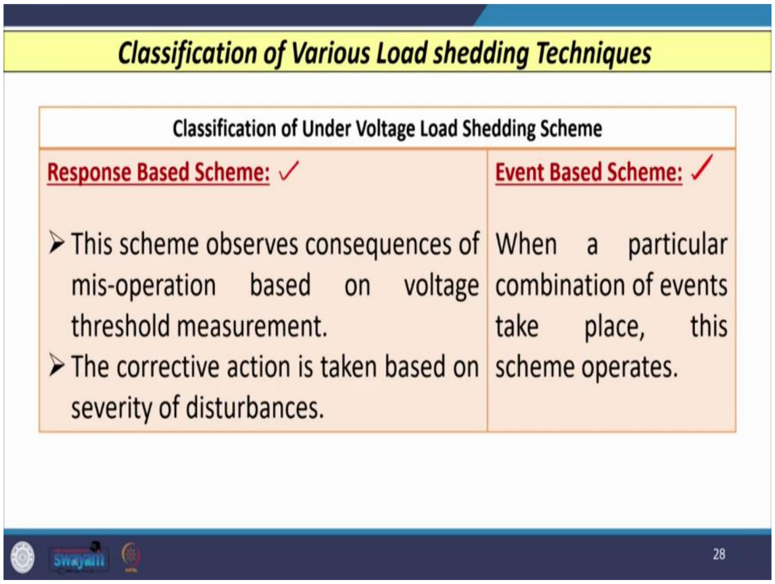

The next type of category or classification of load shedding technique, that is the response-based scheme and the event-based scheme. So, in response-based scheme this scheme observes consequences of mis-operation or mal-operation based on voltage threshold measurement. And the corrective action is taken based on the severity of disturbances. Whereas, in case of event-based scheme a particular combination of events when takes place, then this type of scheme operates.

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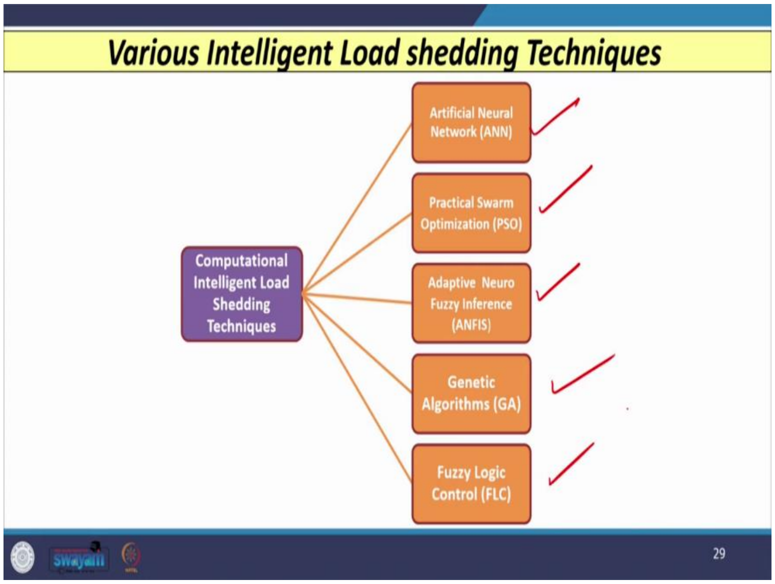

Moreover, you can have various intelligent load shedding technique based on artificial neural network, you have the technique based on particle swarm optimization, you may have the technique based on adaptive neuro fuzzy interference, you may have the technique based on genetic algorithms and you may have the technique based on fuzzy logic control. So, all these techniques are based on pattern recognition-based techniques.

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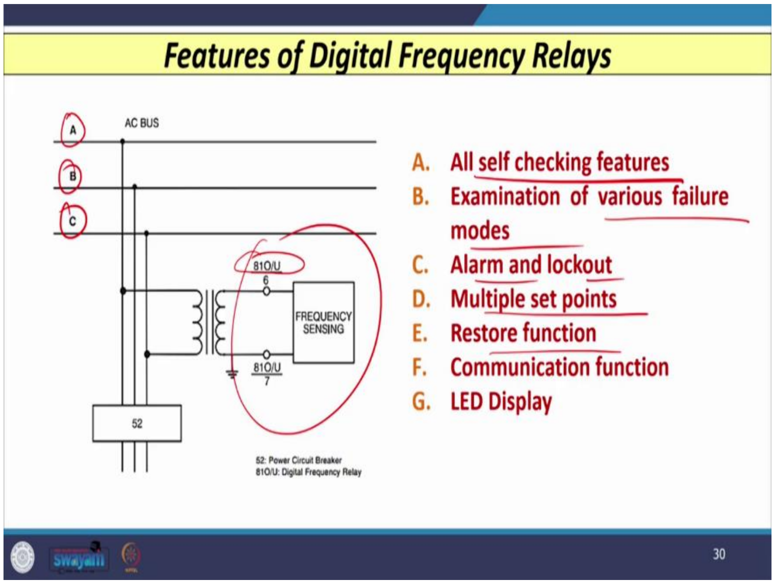

Now, with this let us see what are the features of digital frequency relays? So, here you can see (as shown in above slide) I have shown the three conductors A, B, C. And when you have the frequency relay, as I told you, it comes with 81 number and you have 81 over frequency unit. So, you have the frequency sensing that is to be carried out from the secondary of PT and digital frequency relay which is used by most of the utilities all have all self-checking features.

This relays are capable to examine various failure modes, they have the facility of alarm, lockout, multiple set points, restore functions, and additionally they also have communication capabilities.

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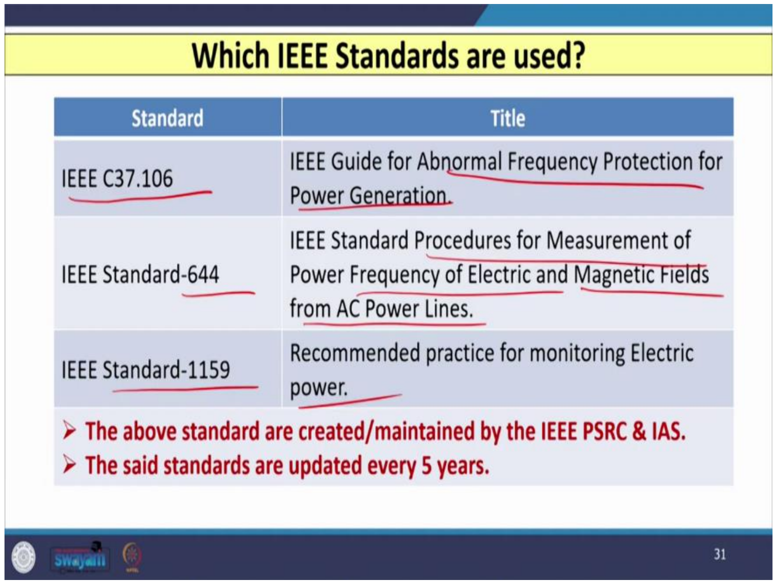

Now, for all this we need to follow some IEEE standards. So, for that IEEE C37.106 standard is there for abnormal frequency protection for power generation. The other standard is IEEE standard 644, and this is meant for the procedures for measurement of power frequency of electric and magnetic fields for AC power lines. And the another standard IEEE 1159, this is recommended practice for monitoring electric power. So, these three standards are mainly used when we are dealing with the load shedding and frequency relaying.

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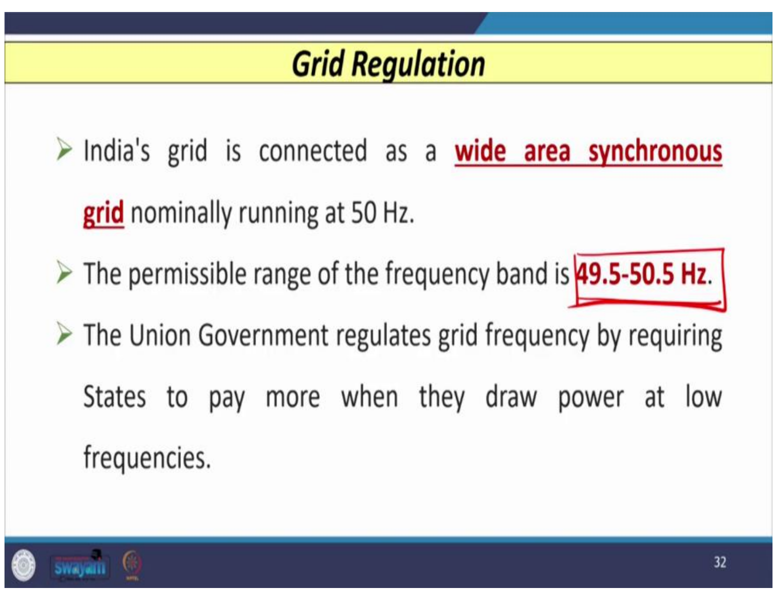

Now, the important aspect is the grid regulation. So, we know that our Indian grid or network is connected to a wide area synchronous grid which is normally running at 50 Hz. In other countries the fundamental or base frequency is 60 Hz. The permissible range of frequency for 50 Hz fundamental frequency is 49.5 Hz to 50.5 Hz.

And whenever any state government or any state level dispatch center is there, then the Central Government or Union Government has given some regulation such that whenever any state will draw a power at low frequency, then that state has to pay some additional money or penalty, because this range is very important.

And nowadays it is equally very important, because when we consider or when we want to restrict the frequency within 49.5 Hz and 50.5 Hz, then we know that nowadays the penetration of renewable energy sources are increasing day by day. So, now government is encouraging the responses or the penetration or inclusion of solar based generators or maybe some wind-based generators or fuel cell-based generators or maybe some other renewable energy sources-based generators.

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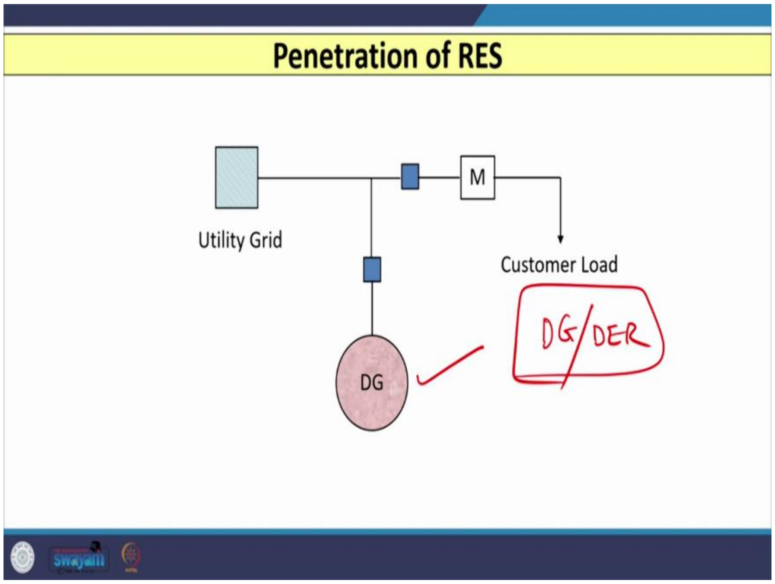

So, when we have such type of generators, these generators are known as distributed generators DG or sometimes they are also known as distributed energy resources. So, when we have such type of DG or distributed energy resources and when this type of resources are penetrated or connected in the distribution or sub transmission or transmission network, then they will impose certain challenges. And this challenges we need to discuss in this lecture.

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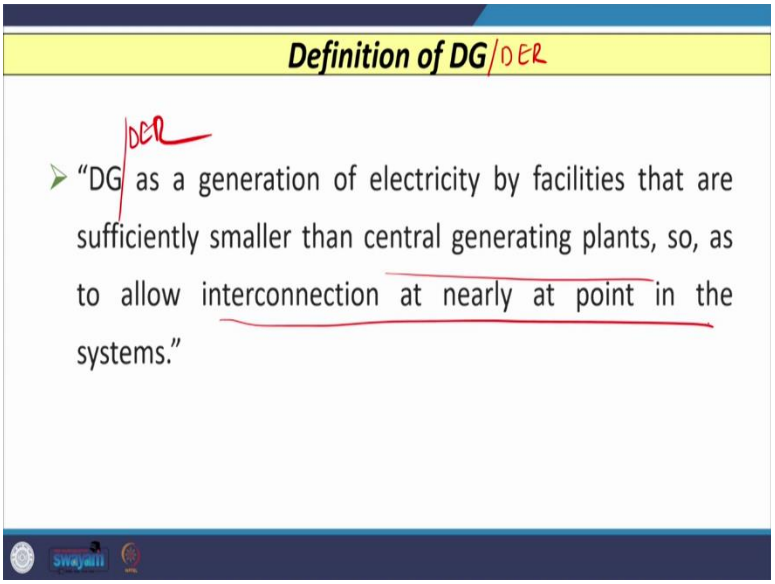

So, let us first discuss how we define the distributed generator or distributed energy resources. So, DG or distributed energy resources is defined as a generation of electricity by facilities that are sufficiently smaller than central generating plants so as to allow interconnection at nearly point in the system. And this point, where you are going to connect the generators, either grid that is known as point of common coupling PCC.

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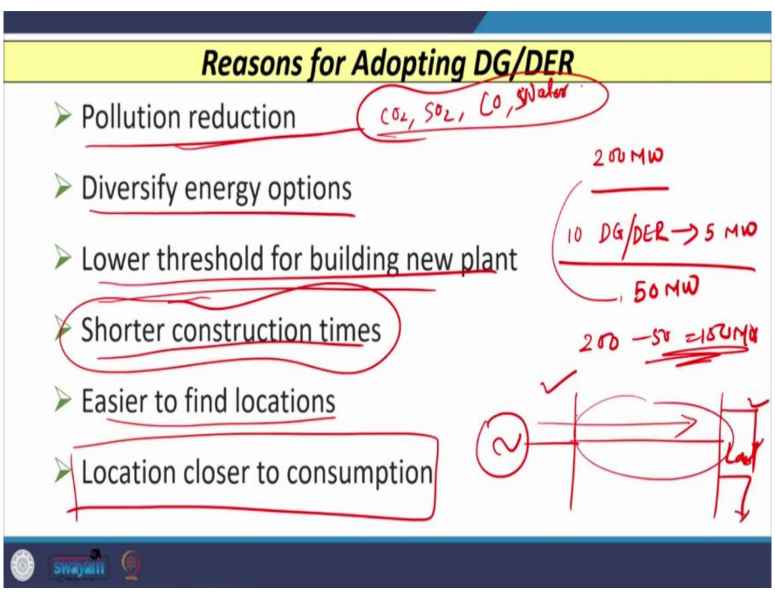

So, there are certain reasons that why we need to adopt the distributor generators or distributed energy resources. So, the first advantage or reason that is the reduction in pollution, because all these DG or DER they are renewable energy sources. So, obviously there is no production of greenhouse gases that is the CO2, SO2, carbon monoxide, then you have water vapor and so on. So, all these gases which are known as greenhouse gases, they are not there, when we connect the distributed generators or renewable energy sources-based generators.

We do have the diversified energy options, so if grid is not available, then we have this DG or DER available at particular point and depending upon the capacity of DG or DER, they can supply the load locally for a certain area or some important critical loads. So, diversified energy options are available and we should not be totally depend on the grid supply.

The third advantage or the reason for adopting the DG or DER is the lower threshold for building new power plant. The reason is if I wish to develop a new central power plant, and let us say its capacity is 200 megawatt. And now, I am adopting or I am connecting several DGs, let us say I have connected 10 distributed generators or distributed energy resources, each having a capacity of let us say 5 megawatt, so the total capacity of this that is 50 megawatt.

So, now whenever I want to build a new power plant, depending upon my load requirement, I have to build the capacity of new power plant that is not 200 megawatt, but it is 200 minus 50, that is 150 megawatt. So, this threshold of building a new power plant that can be reduced. Further, we have shorter construction times, if I want to connect the DG with let us say capacity of 500 kVA or 1 MBA or 1 megawatt.

Then in this case, the construction time is very shorter compared to the construction time required for building a large or central power plant. Easier to find location, we can easily find the locations there is no need of acquisition of a big area or land that is required in case of building a central or big power plants. So, this is also not there, this can be avoided if we adopt DG or distributed energy resources.

And the most important point is that we can connect the DG or distributed energy resources, particularly at a location where our loads are situated. So, let us say if my big power plant generating power plant is here, and then I have a long transmission line and my loads are situated here, then in this case, we have to transmit the power from this point to this point, where the actually load is situated.

So, in this case, transmission line losses are there. However, if we add up DG or DER, we can connect several DGs or DER here where actually the load is situated, then the power to be transmitted that can be reduced and hence the transmission line losses that can be also reduced. So, these are the main important reasons why government is encouraging the penetration or the connection of distributed energy resources or distributed generators, which are basically renewable energy sources-based generators at the distribution level, sub transmission level and transmission level.

So, in this lecture, we have discussed regarding the four important factors which need to be considered, when we design an intelligent load shedding scheme. After that, we have discussed the features of digital frequency relays. And we have also discussed the various ways of classification of load shedding techniques.

And then we have discussed the grid regulation. And in that we have seen that the grid regulation is very strict. The range of frequency is also very strict between 49.5 Hz to 50.5 Hz, in Indian system where 50 Hz is the fundamental frequency. And this can be violated, because now government is encouraging renewable energy sources-based generation and which we call it as distributed generators or distributed energy resources.

And then we have discussed the several important reasons, why we need to adopt or the distributed generators or distributed energy resources or its connection at distribution level, sub-transmission level and transmission level. So, we will further discuss more about this in the next class. Thank you.