Introduction to Smart Grid
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Lecture – 20
Smart Grid Protection – II

Good morning to all of you, welcome to this NPTEL's lecture series on Introduction to Smart Grid. In this lecture today we will discuss on Smart Grid Protection along with that we will also discuss one, two different protection schemes which are dedicated for protection of the smart grid system.

Now, if you see nowadays we have like different disturbances; if you could remember in 2000; 12 July in India we have very large blackout. And due to that make out with the India faced lot of problem and as was the money is concerned and the economy is concerned. So, and that particular disturbance was due to the protection failure.

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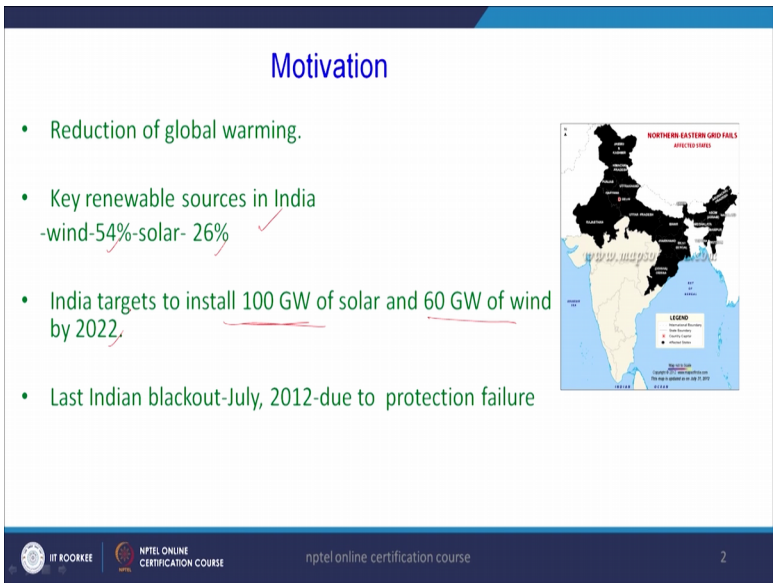

And if you could see that here another issue is coming here; the key renewable sources in India basically the wind and solar. If you could see the wind is 54 percent and the solar is around 26 percent of the total renewable generation.

And again the India is targeting to install 100 Giga watt of solar and 60 Giga watt of wind by 2022. Coming to this aspect of this particular today's lecture ah, I will just

discuss about the different protection schemes and mostly I will discuss the adaptive protection schemes for the (Refer Time: 01:58) system. And before that I will just want to define; what is this adaptive protection schemes? The adaptive protection scheme that particular protection scheme where the protection scheme will operate with the change in system condition.

It will just adapt it will change the protection philosophy or this relaying algorithms or settings of the relay, according to the system change or the according to the change in behavior of the system.

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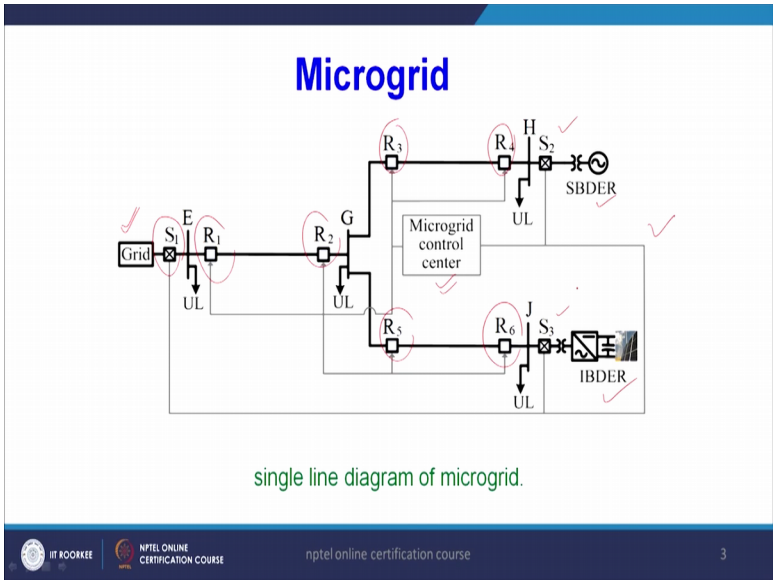

And this is say if you could see here this microgrid system; here we have this grid the main grid and here is our IBDER; that is the Inverter Based Distributed Energy Resource and here it is SBDER that is Synchronous Based Distributive Energy Resource and here this is the microgrid control centre.

This microgrid control centre will receive the information from all the switches likes S 1 is the switch or the circuit breaker which is connecting the grid and the rest of the micro grid network. And here this was basically this R 1 and R 2; next we have R 3, we have R, 4 R 5 and R 6 and here also we have this S 2 and S 3; altogether all the relays and circuit breaker information can be sent to the main micro grid control centre. So, where will take the final decision or the that particular decision is going to be more accurate and renewable, I mean it should be very reliable for operation of the microgrid protection.

Now, I just to want to remind you in the previous lecture we discussed what are the different protection issues if the renewable resources are going to be integrated to the microgrid system? And that is why we are talking about like we have to improve the existing protection scheme, otherwise there will be failure of the relays and there will be basically on intra I mean supply to the we cannot maintain the on interpret supply to the customers. If we are going to be have without any fault the system is going to be like tripped line is going to out of service so; obviously, we will not in a position to supply power to the loads right.

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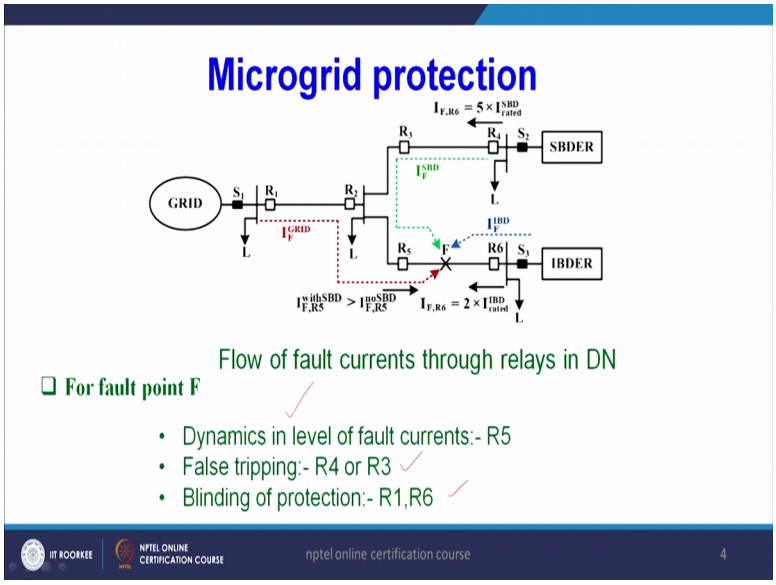

So, that is the main aim and measure issue just I want to revise here the first point is dynamics in the label of fault and the second one is false tripping and this blinding of protection. If you could see talk about this dynamics means if let us say we have different types of renewable sources like inverter based DGs like solar based. And also we have small hydropower plants where we use the syndromes based systems or machines; in that case particular if the fault will be inspected depending on the types of renewable sources the fault current label will differ.

It will just change; let us say for the inverter based DG the fault current label will be clamped to per unit of the rated current. And in case of synchronous based DERs system the fault current is going to be clamped to 5 to like may be 6, I mean 7 per unit of the rated current; it is basically more in comparison to the inverter best DGs or renewable

sources; so keeping in that mind if the fault current label changes depending on the type of renewable sources; so in that case we have to be careful and we have to take care as far as the relay algorithms are concerned.

And coming to this false tripping; earlier the system was radial in nature, the power stream form upstream to downstream like from the subtraction to the load centers. And but due to the penetration of renewable sources now the network is going to be I mean will face by directional power flow. By directional power flow means the fault directional will change and the magnitude will be changed and phase angle also will going to be changed. So, in that case we have to also take care as for as the relay algorithms are concerned relay I mean the logic which are embedded inside the digital relays those logics should be taken care.

Similarly, the blinding protection means the relay is not able to there is a fault, but the relay is not able to detect as this is a fault due to the decrease in the fault current label ah. Let me clear here that mostly in distribution level, we prefer the over current relay principle and this blinding protection is basically the issues with the over current relays. And due to this blinding protection issue the over current relay will see less amount of current for current, which may be below the setting value the I; I set. So, in that case the relay will not be able to detect the fault; so these are different issues and keeping in this mind, I mean this issues we have developed to adaptive protection schemes in subsequent classes I just want to discuss about it.

Mostly I will discuss about the directional over current relaying principles because distribution network; generally we use the over current relay principle. And after that the directional relaying should be added embedded along with this over current unit. Because I will tell you in the subsequent slides that the directional relay arts the selectivity property to the over current relay principle because in this integration of renewable sources the network will see bidirectional power flow bidirectional current flow.

So, that is why if we will use the directional element along with the over current element and it will help us definitely to select the proper line the proper faulty section instead of the healthy section.

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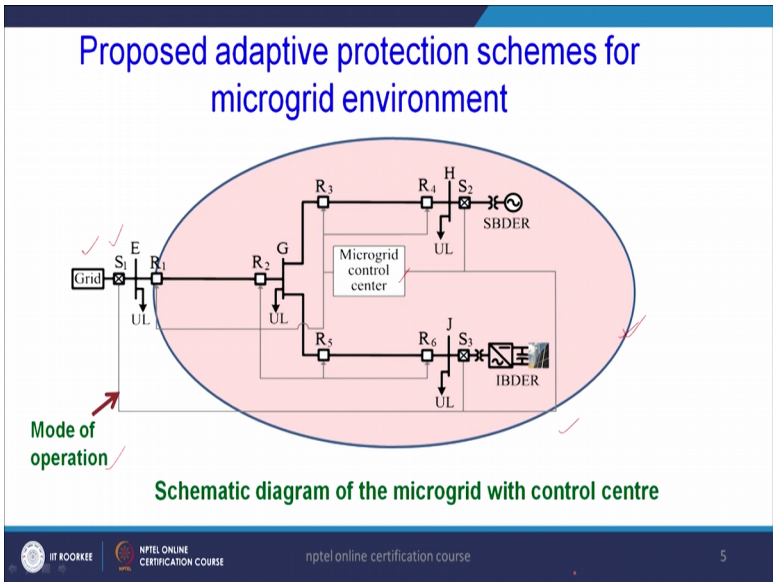

Now, we come to this particular adaptive protection scheme what we have proposed like here if you see that the earlier case, but here the main concern is that we have to know the mode of operation of the micro grid system. Because this mode of operation means whether this microgrid is islanded from the main grid or it is in connected with the micro grid system and the grid system.

This micro grid which are just highlighted whether this particular system is connected to the grid through this switch S 1 or it is disconnected from the grid that is what the islanded operation of the micro grid system. Those mode of operations basically decide the flow of the current label directions of fault current. So, that is why we are interested whether this mode of operation is grid connected or it is in islanded mode of operation right.

So, the these are the concern for I mean basically this mode of operation should be this information should be present at the micro grid control centre; along with the relay information along with the status information and those are the concern.

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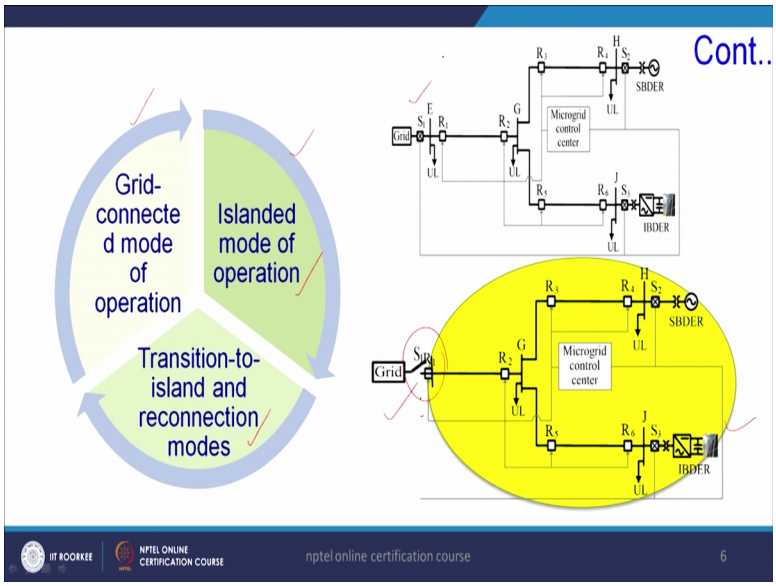

And to come to this point as I just discussed; so that we have different types of mode of operation like grid connected mode and this is the islanded mode operation and sometimes transition to island and reconnection modes.

After island in this microgrid, we have to also reconnect to the main grid that is what the transition that is transition to island and grid connection modes. If you see that islanded already we have discussed in one of I mean one, two lectures that if this particular switch is the disconnected from the grid, then this particular micro grid system is islanded and if it is connected that is the grid connected mode.

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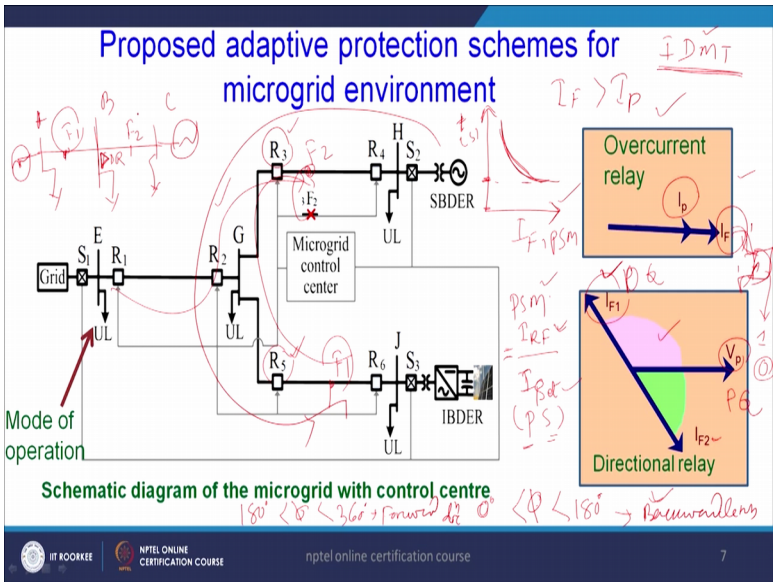

Now, as I discussed that in this lecture I will focus the different schemes basically that is the over current relay principle and also the directional relay principle. Coming to this over current relay principle; the principle of operation of this over current relay is if this is I p is my set value I set and this I F this I F is the fault current which is basically measured by the over current relay then if this I F this I F is greater than I p.

So, relay has to take decision and of course, different types of over current relay principles, but in general we use IDMT; this IDMT best over current relay. This IDMT stands for Inverse Definite Minimum Time over current relaying principle; this characteristic is like this IDMT characteristic along this x axis and y axis this is y axis. So, this; so y axis we generally take the time of operation of the relay and along this x axis, we took this current fall current or sometimes also be took this PSM.

This PSM is nothing plug setting multiplier that is the relay current I relay fault current divided by the I set. This ratio this plug setting multiplier is nothing that the ratio of the fault current which is seen by this relay to the I set that I set is nothing, we call it plug setting; this PS stands for Plug Setting. And this PSM stands for Plug Setting Multiplier.

Now, this characteristics as I said this is IDMT characteristics Inverse Definite Minimum Time characteristic; if my current fault current magnitude increases the time of operation this time of operation second the decreases; that is why this is known as inverse. And why it is definite minimum time? Because this particular characteristics will not touch

the 0 axis x axis; it will maintain certain time. So, that is why this particular time which is maintained above with only the renewable going to operate.

So, that minimum time is maintained so that is why this name is inverse definite minimum time type of over current relay. Also we have different like very inverse characteristics based over current relay principle or only this extremely inverse type of over current relay principles, but general in industry you prefer this IDMT type of over current relaying principle. And after that by this time of operation is calculated and we maintain this TMS that is the time multiplier settings which is the time for operation of the relay with respect to the time dial setting; what time we are marinating. As if like this PSM we also maintain the TMS that is the time multiply setting of the relay.

Now, the very simple (Refer Time: 12:31) over current relay operates if the calculated fault current is greater than my setting current, then the relay is going to react. But the point here is as I said form the beginning that if we have a microgrid system, where this bidirectional fault current is going to be seen by the over current relay. So, it may happen that some over current relays like which are.

So, let us say this is the fault where basically if that particular fault is present here, here this fault is here; this fault due to this fault this particular relay R 5 if we will see some amount of current which is going to be contributed by this particular a IDBR or also this grid is also going to contribute some current. And in that case we have to take care; like what are the current directions and what is the magnitude of the fault current.

Like say let us say here is one fault let us say this is F 1 and this particular synchronous based DG will supply some fault current to this fault point. Now, this relay R 5 will see some fault current angle as this R 3 will also see the same amount of current same amount of fault current. So, what will happen? This is R 3 will trip unnecessarily due to this fault F 1 which is not desirable. And so these are the different issues and we have to basically solve using different principles, but here we are proposed that the directional element may be added along with the over current relay principle.

So, that this directional relay will say that what is the direction of the fault? As the name suggest that the direction of the fault will be decided very clearly so that we should not disconnect any healthy sections of the microgrid environment; we have only disconnect the faulty sections. And that is why this directional relay is preferable in case of

distribution network, where the renewables are basically penetrated along with the over current relaying principles.

And we have to use together like over current relay and directional relay will be like a on operation of AND if the both the decisions this is the AND circuit basically. And this and circuit inputs to this particular and circuit will be from the over current relay and also the input to this the AND circuit will be from the directional relay.

So, if this 2 inputs like 1 1; then the final trip signal will be 1; if any one or the relay basically the output of the any one of the relay is 0; then the output is going to be 0 that is and operation AND to make it more reliable more accurate the final decision; so we can add together the decision of the 2 relays can be added together. Coming to this directional relay principle how this particular relay operates?.

We generally take this voltage the prefer voltage or this is basically the nominal voltage at the different buses like DG busses or the grid terminals or the load terminal wherever we kept the relays. So, this VP is the polarizing voltage and why this we prefer this voltage as a polarizing quantity? Because the during the fault situation the voltage mining should may increase or decreasing depending of the situation of the network, but the phase angle does not change much.

It may change may be 1 degree 0.5 degrees, but; however, at the same time during the fault the fault current magnitude as well as the face angle changes. So, that is why it is more preferable to take voltage as the polarizing quantity and this current as the operating quantity. For the directional relay anyway we need to quantities one is the polarizing quantity other one is the actuating quantity or operating quantity. And how it operates? It will take the angle between the 2 quantities this is I may polarizing quantity PQ and this currents like IF 1, IF 2 this 2 currents in front of the relay and behind the relay these are the operating quantity OQ.

This OQ stands for Operating Quantity and this PQ stands for the Polarizing Quantity; now if this angle between this say current and the voltage is lying within 0 to 180 degree. If this angle 5 basically lies between 0 to 180 degree, then this particular fault is going to be declared; it is basically behind this relay in this backward this is backward direction of the relay let me draw one figure here. So, that the things will be more clear that if you have a system like this here one source and here and DG which is connected this is my

grid and let us say we have a load point here some loads and here some loads. And this directional relays located at this bus this is bus A, this is bus B, this is bus C if this is my fault F 1 and this is my fault f 2.

So, due to this fault F 1 the current which is contributed by to this relay is I F 1 here and due to this fault F 2; the current component which is seen by this relay is I F 2. So, it is by the 2 fault components will lie in this direction and if what will be the angle between these 2 for fault F 1? The angle between this V p and IF 1 for fault F 1 position and that will lie between 0 degree to 180 degree. If it is so this relay will declared as if the fault this is my directional relay and this directional relay will declare that fault is behind this relay it is not in front of the relay.

But if this phi is between 180 degree to 360 degree, then the fault is declared to be in the forward direction forward direction; that means, it is in the in front of the relay this is F 2. So, this is the basic principle of operation of the directional relay nowadays we have different techniques to declare whether the fault is in front of the relay or in the backward direction of the relay; lot of techniques many techniques are now available.

We see fundamental technique which is also still used in industry and there are also demerits of this particular technique. If there will be voltage collapse then it will be difficult to decide whether the fault is in front of the relay or behind the relay. Now as I said that different techniques are available for coordination approach.

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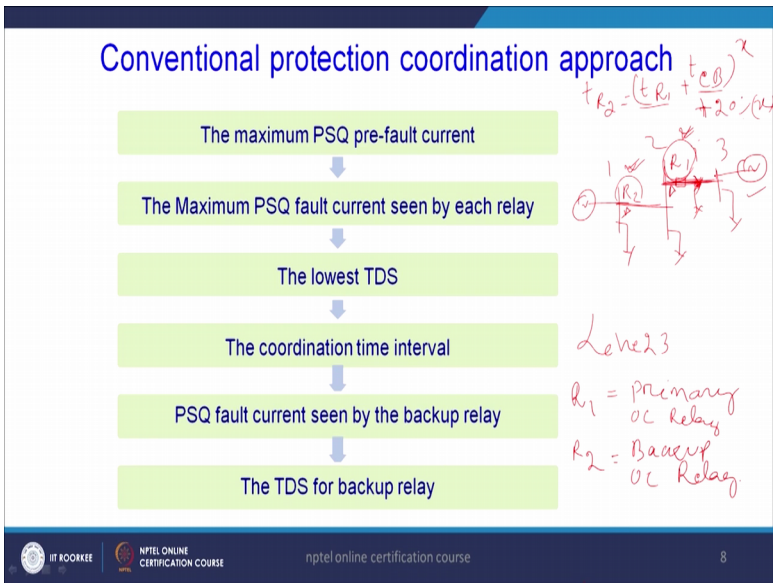

The coordination is nothing; let us say this is one source grid system and here we have one bus and one load here also one load and here another feeder or line, here also we have some loads; earlier the line was structure was like radial in network.

Let us say this particular line is protected by some relay R 1 and this line is also protected by another relay R 2. Now for protecting this line one 2 3 this line 1 2 3 this is line 2 3 this is my line 2 3 to protect this line this R 1 is called as prime (Refer Time: 20:06). So, if any fault occurs here at this point; then this particular fault is going to be cleared first by this relay R 1. And that is why this R 1 is called as primary relay; if this fault is not cleared by this R 1 then this is going to be cleared by this R 2 and this R 2 is known as backup relay.

So, here I just want to mention R 1 is the primary; primary over current relay and this R 2 is nothing that is the back up over current relay. Now what is the point; what is this primary and back up again we will discuss, now this as I said if any fault is going to be incepted in line 2 3; this relay R 1 should react as quick as possible and the time of operation may be within 0.2, 0.1 depending on its TMS and plug settings right. Because as I said that every over current relay has it's a plug setting plug setting multiplier corresponding to the fault current and also TMS.

This space and TMS are fixed; now depending on their plug setting and TMS this relay will just find some fault current IF and based on the calculation of the IDMT characteristic equation, it will calculate the time of operation which is required to trip for the relay. Now if this particular relay R 1 fails then only this R 2 which is the backup relay will operate.

And remember this R 1 operates first then this R 2 will operate inlet within a time gap of 0.3 to 0.5 second. And this 0.3 to 0.5 second basically this is a timing it is not designed like that it is a time corporation which is required for operation of the breaker which is present here for the line 2 3.

In this relay is failing; so it will take some time quickly after before the relay R 1 this R 2 is not going to operate or if R 1 is failing. So, very quickly it will not operate it will wait for 0.3 to 0.5 second and then this R 2 will react; that is the operational time for the backup relay. And that is why this time for operation t R 2 is equal to t of R 1 time of

operation of relay R 1 plus the circuit breaker time operation t circuit breaker; how much time is taken by the circuit breaker plus if it is treated as x some tolerance over suit time.

If I designs particular relay for particular time of operation, it may not operate due to different transient different tissues. So, there is some over suit time of operation and that time of operation maybe sometimes 20 percent of time of operation this 2; that is a time of operation of the relay R 1 and the time of operation of the circuit breaker.

That is 20 percent of x; I just wrote this to as x and that will be my back of relay time of operation. This is the time of operation between this primary and the back of this particular metrology, this particular of way of operation is known as coordination between the primary relay and the backup relay. So, this coordination is very very important while we are discussing protection of the distribution network using the over current relaying principle. And as I said that if a this is a (Refer Time: 23:47) network, but if you are going to penetrate some renewable sources likes let us say at bus 3; we are added some renewable source DERs.

So, what will happen? In that case this relay R 1 will not see if any fault will occur here; in that case this relay R 1 will see some different current; that means, the setting of the relays basically going to be changed may be for R 1 and R 2. So, today this much we will discuss in the next class.

Thank you so much.