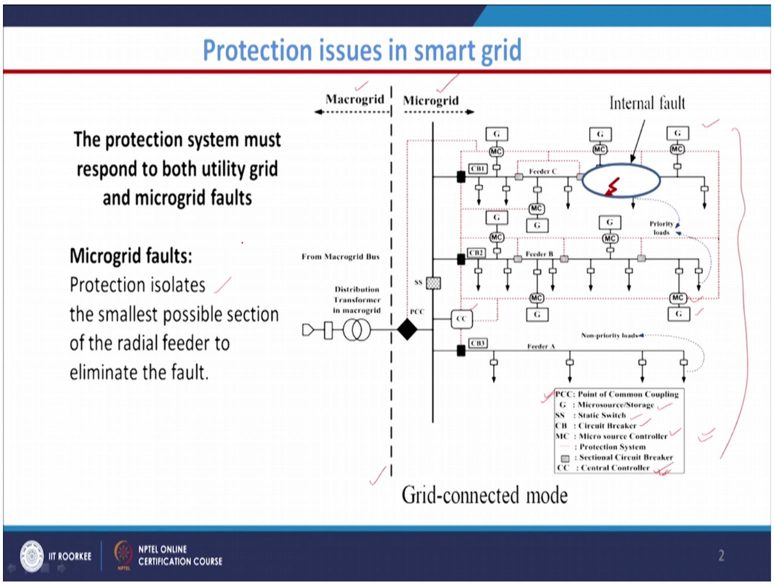
Introduction to Smart Grid
Dr. Premalata Jena
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 19
Smart Grid Protection – I

Good morning to all of you, in this lecture we will discuss about this Smart Grid Protection. In one of our lecture we discussed the relaying practice basically the digital relays are adopted for the protection of the system or power system. And as you know that this electromechanical relays are not anymore in use and we are moving towards smart systems; in that case we have to use the digital based relays. And in this lecture mostly we will focus basically issues and protection of the smart grid system.

So, what are the protection issues or difficulties are present due to the integration of renewable sources; one by one we will discuss. And after that we will go for basically the operation of the over current relay and along with that also we will discuss about this directional over current relay operation which are used for protecting this smart grid or a microgrid system.

(Refer Slide Time: 01:29)



Now, coming to this particular part of this figure you can see that we have this portion is our microgrid here it is and this portion is our macro grid.

This micro means or grid side grid system and this is our micro grid means, we have this renewable, we have batteries and we have loads. If any fault occurs let us say at this grid side I mean this microgrid side then those protection devices are going to take care for this particular fault so that this fault should not propagate to the healthy sections of the network. You see we have this symbols we have use this PCC and G is the storage and also we have Static Switch; SS, this CB stands for Circuit Baker, MC is basically the Micro source Controller and also we have this CC the Central Controller.

You know this in smart grid system we are designing as a neutral controller system and also we have local controller system. So, what will happen the protection devices will also share the data with the central control station and from there again we can take some decision which will be more accurate and reliable; for the proper a smooth operation of the micro grid system. That is what this CC the central control system dash and if you can see this CC is present here and the red dotted lines are basically the information coming from the protection part or protection infrastructure we can say. And this protection infrastructure is almost collected, this is connected to all the parts of the network this red dotted line you can see here.

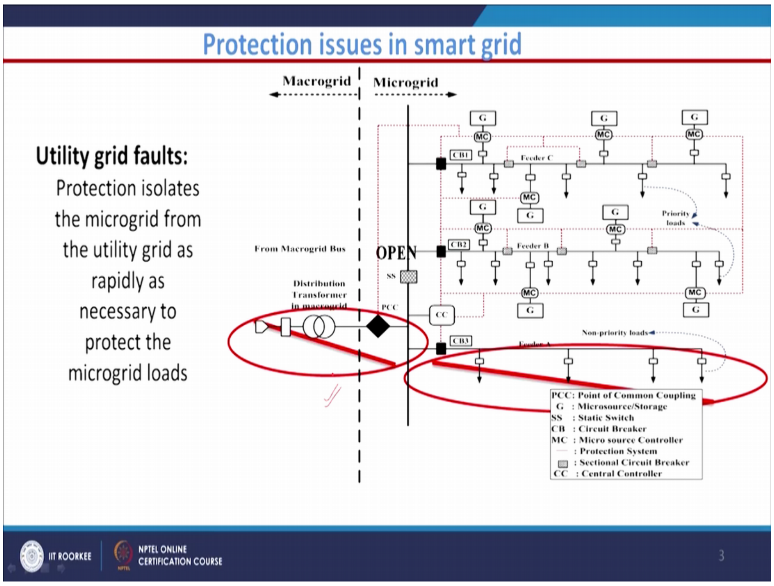
This is our this MC is basically the micro source controller; this MC is present near to our renewable energy source. And this MC also communicates with the CC and as well as this particular, you can see here the corresponding circuit baker; this is our sectional circuit baker present here the sectional circuit baker also talks to our MC.

So, we are also planning see in sometime I mean in the time will come that all the devices are going to speak to each other that is what we are aiming for smart grid system. And this aim of this particular subject is basically the basic concept we are just providing here, we are trying our best to give some idea that what will be our near future system where you will see that all the components will speak to each other and finally, at the central controllable or at the local controllable, we can take our decision quickly.

And very fast decision can be also possible with our very dedicated communication infrastructure. And you can see that if any fault occurs, this protection system will try to isolate very less number of I mean sections; I mean it will just effect only the faulted section not the other healthy sections that is where the protection system MC.

Now, if you have some fault at the grid side then also we have to check this we also we have to take care for that.

(Refer Slide Time: 04:52)

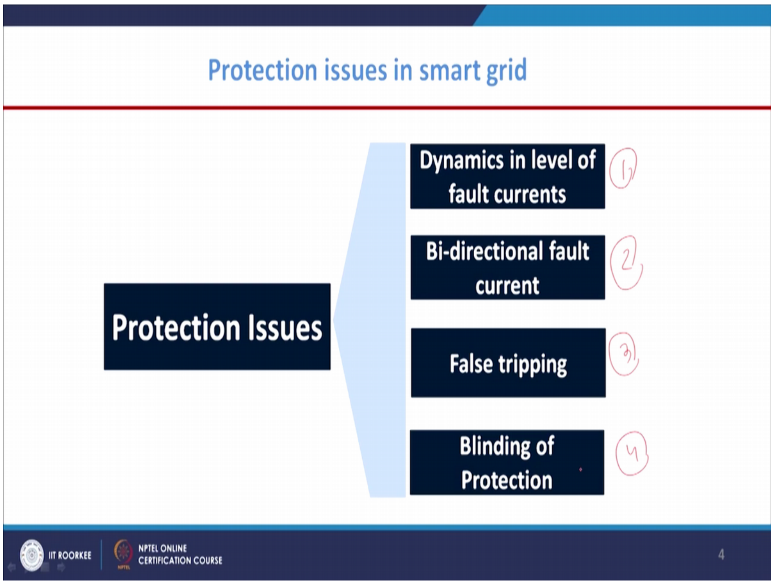


Otherwise this fault current will propagate to the microgrid parts or microgrid components like a renewable sources, like a we have battery storage we have loads you will also storage also we have in the macro grid side or the grid side, but still those components are basically very sensitive electronic devices.

So, we have to basically restrict the fault current should not I mean the fault current should not flow from the grid side to the micro grid side. That is what also another issue I mean we have to take care this utility grid fault should not propagate, fault current should not propagate to the micro grid side.

These are the issues you can see.

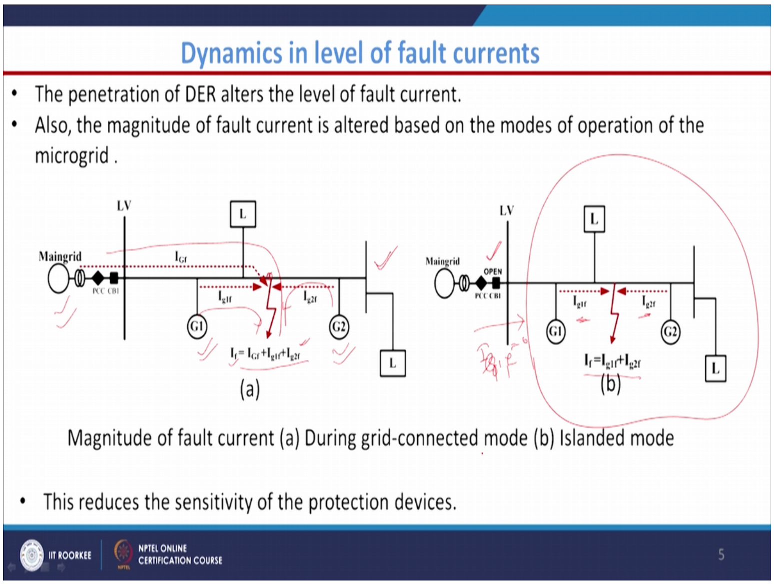
(Refer Slide Time: 05:35)



The first issue is the dynamics in level of all currents that is the first issue; we will discuss one by one the subsequent PPTs. The second one is the bi-directional fault current and third one is false tripping and the fourth one is blinding of protection.

These are the protection issues as was the micro grid is concerned; if we are in going to integrate solar based DGs or we are going to integrate wind system or we are going to integrate likes synchronous based DGs that is small hydro power plants to our distribution network; then how this protection system is going to be affected. The first one is dynamics in level of all currents.

(Refer Slide Time: 06:23)



I have taken this particular figure or system this is our main grid and this is DG 1 and this is our DG 2. Now if any fault occurs like one fault let us say is present here then this current and this I Gf, the fault current is going to be driven by this grid and also fault current will be contributed by this G 2 and also the fault current is going to be contributed by this G 1 this G 1 and G 2 are 2 renewable sources.

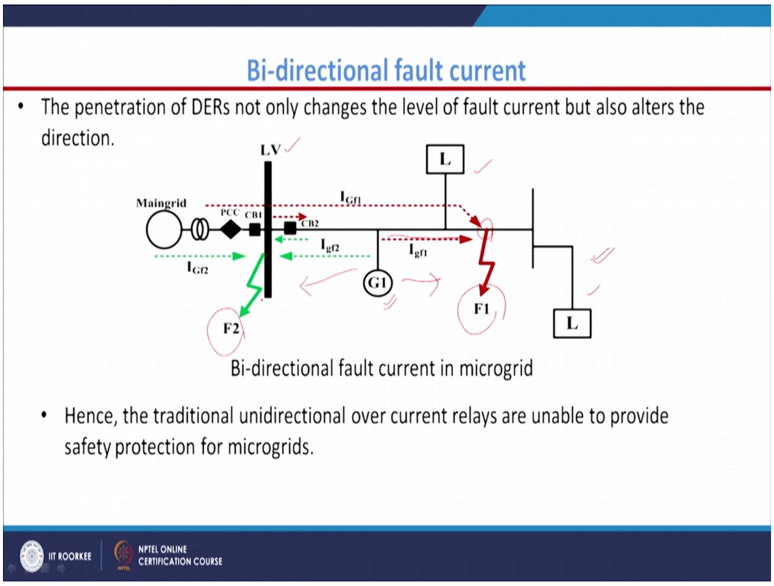
Now finally, this fault current I f is the summation of I G f plus I g 1 f plus I G 2 f. So, this is basically the one scenario when this is a grid connected mode of operation. Let us say now the grid is disconnected from the rest of the network due to the opening of the circuit baker; that means, this 2 DGs; 2 renewable sources are disconnected from the main grid in that case what will happen? So, in this case the fault can be is equal to summation of only these 2 currents, there is no question of this I G the grid current I G f; I mean this capital G this I G f is equal to 0 that is why this fault current is summation of I g 1 f plus I g 2 f.

So, the conclusion here I mean the discussion says that giving fault the fault current label during different mode of operation, this fault current level changes. And also based on the type of this particular grid integration like you have mode of operation whether the microgrid is connected to the grid or it is in islanded mode of operation or 2 DGs are present or 1 DG is present, how many loads are switched on switched off. Based on the different type of mode of operation and the network configuration the level of fault current changes and apart from that based on the type of DG integration, if you have like inverter based DG if any fault is a incepted.

Then the fault current is going to be clamped to 2 per unit of the rated current; if it is basically synchronous base DG then the fault current is going to be 5 times of the rated current. So, these are basically the concerns basically the dynamics of the fault current label changes as well the penetration of the DER is concerned or the magnitude of the fault current also changed due to this different modes of operation of the microgrid or smart grid system. So, these two are the major reasons due to which this fault current changes.

Now, we have another concern that is the bidirectional fault current.

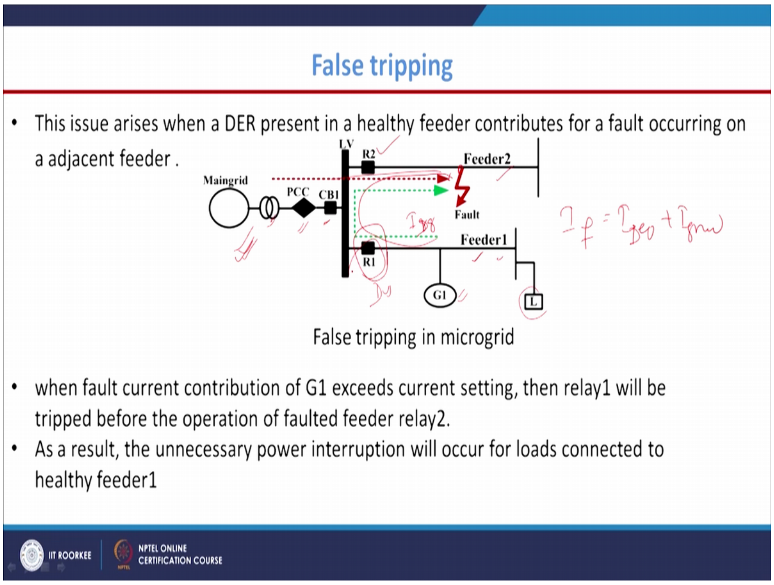
(Refer Slide Time: 09:18)



Like see this particular picture here you can see this is a low voltage bus and here we have this DG and here we have loads. And this is the fault point to this fault point the fault current if this fault is F 1; I will just designate the fault current which is contributed by this DG in left to right direction the directions is from left to right. But if this fault is at this LV bus or grid side bus, then this DG will contribute in right to left direction. That means, the direction of the fault current contributed by this particular DG differs based on the location of the fault with respect to the DG location; that means, in this case we can just memorize that in case of distribution system; mostly we use this over current relays and mesh network we use this directional over current relays.

Where the direction of the fault current is say concern and nowadays as this renewables are parented at to the distribution network; so the fault directional is changing; so that is why the only the over current relay is not sufficient, we have to also add the directional unit along with the over current unit. That is what this bidirectional fault current issues basically tells us that we have to use this over current directional over current relays, not only over current relays. Another issue is that is false tripping; so, what is this false tripping?

(Refer Slide Time: 10:57)



Here is our main grid right if you will take this example, it will be easier to understand.

So, that is why if I have taken this particular picture or figure a small micro grid system where this is our main grid and this is our PCC point of common coupling. And this is the distribution transformer and this is the circuit baker of the main grid side. Now these are 2 feeders feeder 1 and this is feeder 2; here is load recent and here is one DG connected. Now if any fault occurs like one fault is incepted in fader 2 then what will happen? This DG is going to contribute current to this fall point. At the main grid we also we will contribute some current to this fault point; so there are 2 fault components because there are 2 sources so; obviously, we have 2 fault currents.

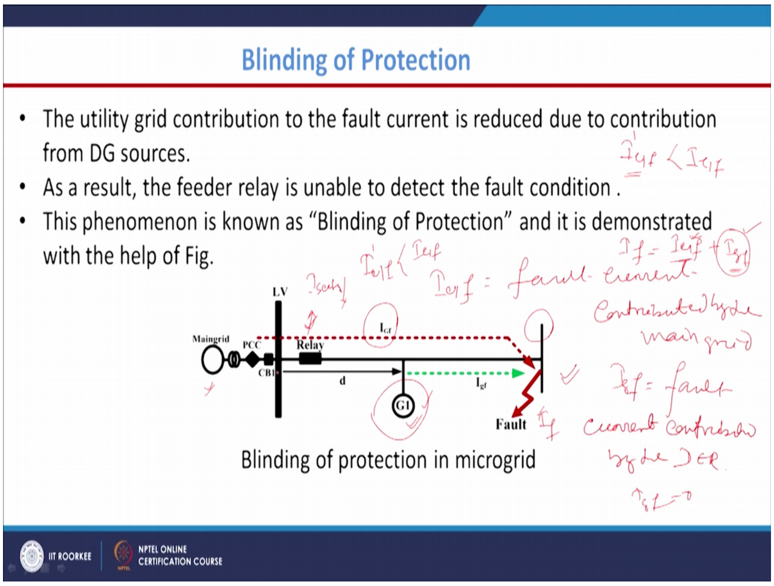
Right; so, this I f will have this I DG plus I grid 2 fault currents because the load is not going to provide any current. What will happen here? This R 1 is basically protecting this is R 1 is one relay over current relay you can say is protecting this particular feeder;

feeder 1 and this R 2 is protecting feeder 2. Now you know this is feeder 2 is basically the faulty section the feeder 1 is not the faulty section right. So, it is not necessary to disconnect feeder 1; it is necessary to disconnect this feeder 2 right.

So, what will happen due to this fault this relay R 1 will see this I g or I D g amount of current that is also fault current you know; when there is some fault the fault current magnitude increases. Now due to that this particular fault do this particular fall is R 1 is going to trip, it is an if it is an over current relay because this fault current magnitude may exceed the threshold value I set.

So, that is why we are just if we can add one directional unit here this directional unit then we can say that no no no; there is no fault in this healthy feeder, there is better we can say there is a fault in feeder 2. So, in this process basically we can solve the protection issues that is one of the false tripping this tripping of this R 1 relay is known as false tripping.

(Refer Slide Time: 13:23)



Now, we have another issue that is a blinding protection; this blinding protection means what will what is that? In case of microgrid system let us say we are integrating many number of DGs throughout the feeder, then what will happen to the fault current label or result and fault current that is what the blinding protection says. Let us take this particular picture here we have this main grid and one DG is connected here and the main relay is located near to this substation. Now a fault is created at this bus for this particular fault the current which is contributed by this grid is I G f; this I G f is fault current fault current contributed by the grid main grid.

Now, at this I G small I g f that is the fault current fault current contributed by the DG or DER; you can write right. So, what will happen? Now initially this fault current if suppose there is no DG without the presence of DG this I g f is going to be 0 right. Because if this DG is not present so; obviously, this I f; this I f is equal to completely contributed by this grid the main grid I G f right. Now if this DG is penetrated and DG is present now this I f is equal to I G f this capital Gf plus small I g f; the current contributed by the DER or distributed energy resources.

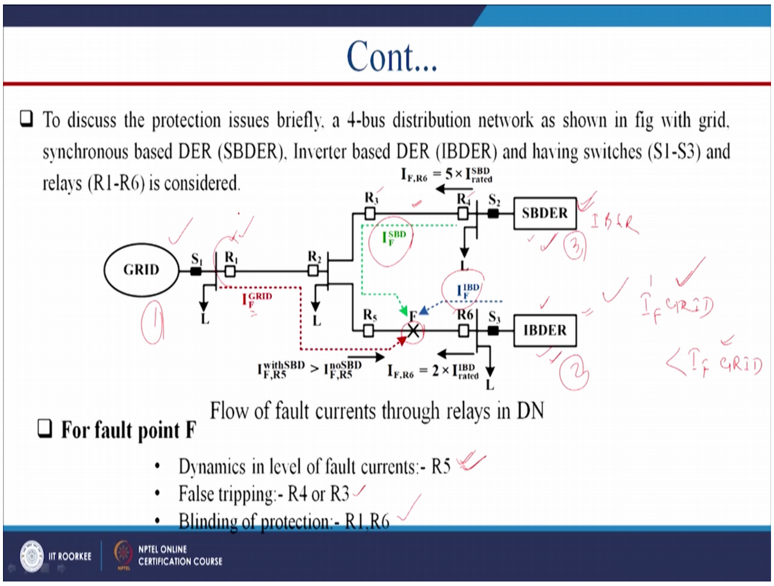
Now, if this is absent this I G based on this particular I G f the relay setting if it is an over current relay, this over current relay setting is done. The setting of this particular relay is based on this I capital Gf; the current fault current contributed by the grid system, but; however, now due to the integration or penetration of this particular renewable source what will happen, this I g this small I g f is going to be contributed to the fault point. So, as a result this I g will be less if you know this fault current will remain constant even if we integrate 2 3 number of DGs.

So, to meet this particular I f this I G this is let us say I G dash after connecting this DG is this magnitude is reduced in comparison to your I G f. If you can just write this I G f dash this is the grid is contributed the fault current after the connection of the DG. And this magnitude the fault current magnitude is less than this I g f. This I G f is the current contributed without the connection of the distributed energy resources. Now this is if this is the case; if this current contributed by this grid side due to the integration of this DG is basically decreasing that is why; that means, the fault current is falling below the set value of the over current relay and then the relay is not going to respond.

Relay is not blind it will it cannot see the fault which is incepted in front of it. So, this property is known as blinding of protection; again I am repeating that due to the integration of this DG to meet this fault current this grid side will grid side source; will provide with supply some current. And that current magnitude is less than the current magnitude which is due to the without integration of the renewable sources and as a result this fault current may fall below the setting value of the over current relay and this property of the relay is known as blinding.

Now, the relay cannot declare whether there is some fault in front of it; this property is a very I mean important issue as for as the smart grid or a microgrid protection is concerned. Now we will I will take this particular picture.

(Refer Slide Time: 17:47)



And what are the concerns are issues we have discussed previously we will just give one example through this particular figure. This is our grid and this is one relay R 1 this is relay R 2, R 3, R 4, R 5, R 6; we are assuming here that all the relays are over current relays. And this is one synchronous based DG and this is inverter based DG this SB stands for Synchronous Based DER means distributed energy resource and this IBDER means Inverter Based Distributed Energy Resource.

Now, let us say we have created one fault here at the point F right; now the fault current will be driven from all these 3 sources, this is source 1, that is my grid and this is source 2, that is my inverter based DER and this is my source 3 that is synchronous based DER. The 3 sources will contribute to the fall point the fall current is going to rush to the fall point.

Now, when this fall current will come you know this previously we have discussed that synchronous based DER is equal provides 5 times the rated current and the inverter based DER provides 2 times 2 per unit; that means, 2 times of the rated current. And it clamps due to the presence of the electronic parts like as if it is this particular it clamps 2 2 per unit.

Otherwise that is was for the safety purpose of the inverter it is a property of the inverter it clamps this current to lower level right. So, in, but in case of this SBDER we do not have any inverters right, that is basically synchronous machine only. So, what will happen? This more that the current which is contributed by this is SBDER is more than this IBDER and that is what this IFSBD is a current contributed by the synchronous based DER and this I F IBD is the current contributed by the inverter based DG. Now, if you will see due to this what are the issues are coming up? Let us see the first issue the dynamics in level of all current is seen in relay 5; R 5, this R 5 we will see huge amount of current that is 5 times of the rated current.

So, that is what this if this relay is not properly set or we have to keep proper setting so, that the relay will basically you should clip properly that is a first. Let us see if previously we have his IBDER type system then the; obviously, this is fault current which is going to be contributed and the see in the fault current which is seen by this R 5 will be 2 times of this I fault; I rated right.

So, in this case we have to basically change the settings time to time and this kind of system is known as adaptive setting up the over current relay. Now coming to the second point this false tripping is seen by this R 4 and R 3; R 4 is here and R 3 is here. Because you know this fault is present here whereas, this section this line is say healthy line, healthy section.

However due to the contribution of this fault current this R 4 and R 3 made if it is not directional in nature. That is why I discussed in the previous section that this is known as false tripping though there is no fault in this section, but the current magnitude is higher which may exceed the setting value of this 2 relays; R 3 and R 4. So, therefore this 2 relays should be embedded with directional unit along with the over current unit; this 2 relay should be directional over current relay.

Now the third one is the blinding protection the relay R 1 and R 6 will see the blinding protection this is our R 1 and this is our R 6. Why this R 1 will see the blinding protection? Because due to the integration of the DGs, the fault current will be also contributed by these 2 sources along with this grid system; let us say previously if will assume that this 2 this is 2 renewable sources are not present.

So, what will happen? The fault current only it is going to be contribute by this grid that is I F grid. Now let us say due to the integration of this 2 DGs; the fault current t is going to be contributed I mean the fault current is summation of this 3; that is your I F grid, IF IBD and IFSBD right. So, due to this the contribution of this fault current I F grid that is that will reduce is less than this I F grid.

If this is particular the fault current you can say that which integration of DER and this is without integration of DER and that is why this relay R 1 current will be reduced it make fall below the setting value of the relay R 1 and this is known as the blinding protection issue of the smart grid system. So, today in this class we will just summarize that we have discussed the protection issues of the smart grid system. The first one we discussed the dynamics in the fault current that is change in fault current due to the penetration of different types of DERs. And also this dynamic of the fault current depends on the mode of operations; whether the grid is micro grid is operated in grid connected mode or it is in islanded mode of operation.

Now, next we discussed that due to this integration of the renewable; the fault current direction may change right, that the bidirectional power flow will be there. And the third one we are discuss the false tripping issues and the fourth one blinding on the protection.

Thank you so much.