Power Electronics and Distributed Generation
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Lecture - 11
Islanding of distribution systems

Welcome to class eleven of the on topics in power electronics and distributed generation. In the last class, we were talking about grounding of distribution systems, and we looked at the need and the possible methods for grounding of distribution systems.

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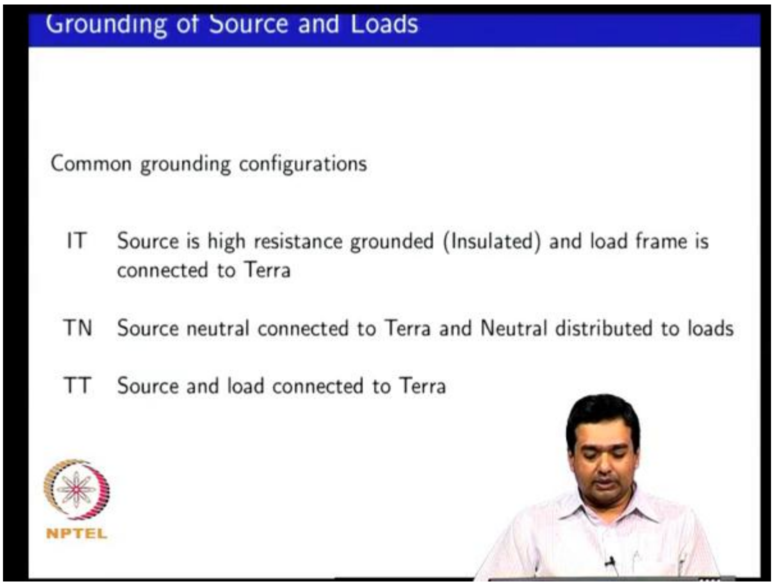

In terms of the grounding of sources, you can have a ungrounded source or a delta type of source. In this case, in terms of the actual implementation a IT type of secondary distribution grounding grounded network is similar to what would be for this type of system. The source is ungrounded, but loads frames is connected to ground. Then you can have a solid grounded system in which case the source neutral is connected, so lead to ground, the ground point which is the neutral is now distributed to loads. The TN network is a example of such a secondary distribution network grounding situation. The third scenario that we are talking about is a impedance grounded source.

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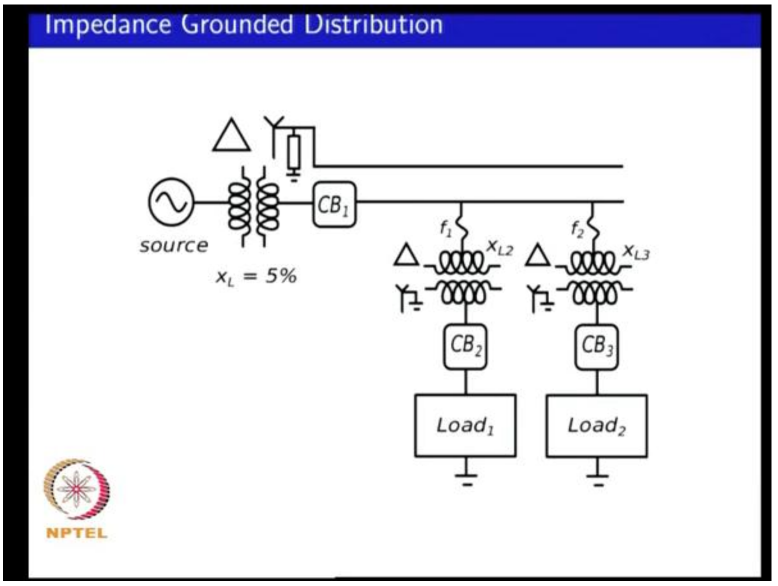

So, we are talking about having a impedance now connected between the neutral of the transformer under y side and the earth, the earth in terminal and it can be a resistance or a reactance. You can have the possibility of high impedance or low impedance grounding and we saw in the last class an example of a small value of reactance, which is connected between neutral and the ground.

We saw that in such a situation when you have a single line to ground fault, then your phase voltages is somewhere now in between that of a solidly grounded system and a ungrounded system in terms of fault current level. It is the current magnitude is high, maybe sufficient to trip a instantaneous time over current characteristics, but it is not so high. That might cause very severe arcs at the point of fault and these issues are important from the single line to ground fault perspective because the majority of faults are actually occurring on a line to ground basis. Now, we will look at a case of a high impedance to ground fault and we are looking at a case where a large value of a resistance is now added between the neutral and the ground. The objective in this particular case would be to keep your power current level quite small.

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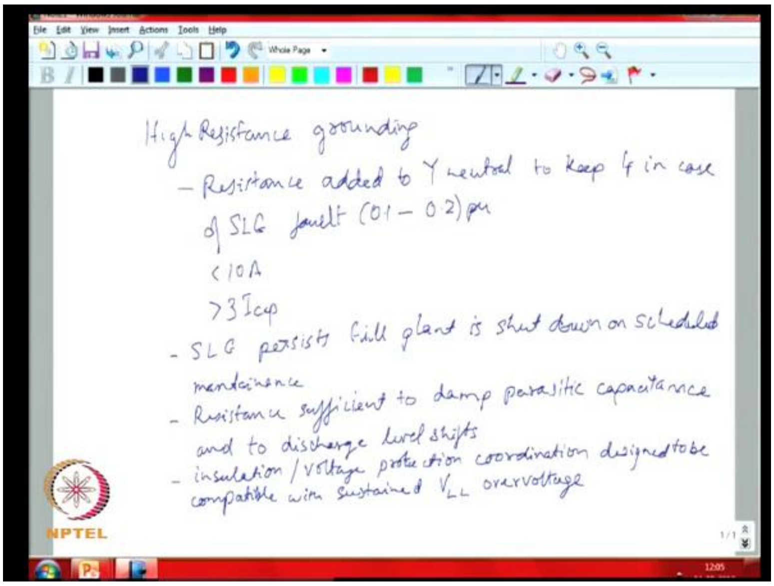

So, you are talking about high resistance grounding, so say something like say 0.1 to 0.2 per unit range. So, of the order of 10 percent typical current value is less than 10 amps typically and it cannot be extremely tiny. Another, we saw an ungrounded system if you have more physical path to ground, you would excite the parasitic capacitances of the line. So, typically you would keep the current through the resistor to be greater than I time 3 times I capacitive current, capacitive charging current through for that particular current distribution network.

So, you get adequate damping for possible oscillations between your physical inductances of your components and the parasitic capacitance. So, in this particular case, because the current level is so low your single line to gone fault can continue for a long time after the fault inception. So, instead of waiting for a unanticipated point at which you need to come in and repairs you could maybe coming when everything is shut down then and going and do the repair and clear the point at which you are having the point to ground fault.

Your resistance is sufficient to damp parasitic capacitance and what you saw was you can have arcing upon the fault and arc the current to the arc will be symmetric in the positive energy. The negative half cycle is always a possibility of level shifting of your distribution feeder in case you are having a arcing fault and now your resistance provides a DC path to ground to discharge possible level shifting.

So, however in this particular case what you would see is that after you have the fault the un-faulted phase would see the conductors would see voltage line to line voltage on a conductor to ground basis. So, your installation and your over voltage protection and its co ordination need to consider the fact that you would have sustained line to line voltage possibly occurring in a on a line to line basis.

So, if you look at the IT type of distribution network that we discussed earlier it is quite close to what the higher systems grounding situation is going to be in terms of its characteristics. So, you can actually look at that as a case where the value of the resistance is made to be a really high just to look at your capacitance to prevent oscillations of your parasitic capacitance with your distribution network. So, you can think about the IT distribution secondary distribution network as a example of a this particular situation.

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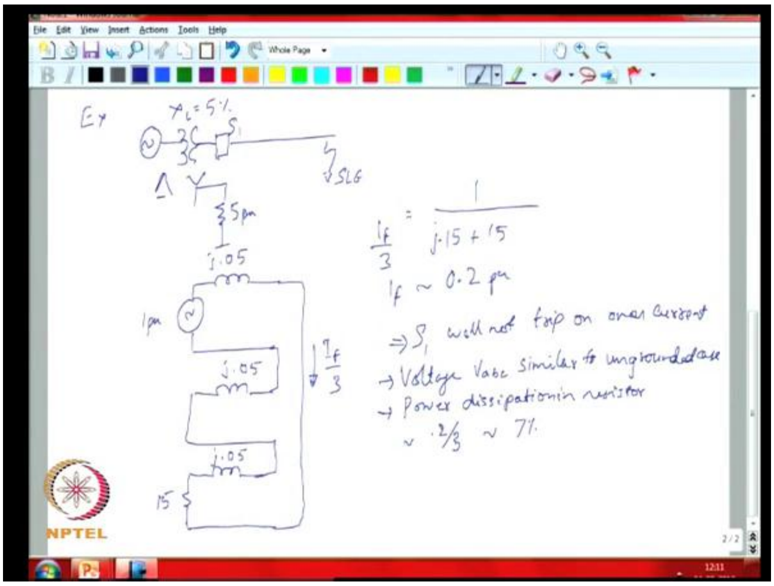

So, we will look at example of high resistance grounding, so we will look at an example where you have a source and say this is delta y and the y is connected through a resistance of a say 5 per unit. You have a circuit breaker and say the impedance X L of the transformer is say 5 percent and you have a single line to ground fault occurring somewhere down the distribution line.

So, if you look at what would be the corresponding fault current, in this case you can draw the sequence network to analyze the fault current. So, you have your source with one per unit voltage, your negative sequence network is there is a impedance j point into the power 5 and your 0 sequence network is just the combination of the reactance plus three times the grounding resistance which is 15. So, if you calculate the fault current your If is now equal to 1 by this, so your fault current is about 0.5 by 3, so your If is about 0.2 per unit.

So, you can see that with a 0.2 per unit current, you will not trip a circuit breaker because your load current itself might be 1 per unit, so you rover current trip will not function. So, if s 1 is a circuit breaker, can see that s 1 will not trip and if you look at voltages are the voltage v a b c would be similar to what we calculated in the ungrounded case. So, one way in which then you could sense that a fault has happened is by looking at your voltages.

So, if you see that your voltages on one phase have come down to 0 and the other phase voltage has gone to the other phase has gone to line to line voltage with respect to ground. Then, it means that there is a single line to ground fault somewhere on the system then the question is where that particular fault is. There is another question, but we know that there is a fault when you see the shifting voltage, you could calculate. So, you can calculate the power dissipation in the resistor because after you have a fault potentially the resistor will stay connected in the circuit for a longer duration till the planned schedule maintenance comes in.

So, you are talking in this particular case of about 0.2 divided by 3 about, 7 percent power is getting anticipated till your fault gets cleared in the grounding resistor. The other ways of doing, people have also looked at possibility of having high inductance grounding though it is not very common because you know to damp you are your l c oscillations and for damping you need the resistance. People have also looked at something called resonant grounding, where you have your inductor with your parasitic capacitance tuned.

So, it is resonant at 50 Hertz, so in that particular case, you might have some advantage that in a resonant circuit, your parallel resonant circuit your current drawn from the source in phase with your voltage. The current is drawn only into your loss in the branch that contains losses, so you have in phase voltage and current and having in phase voltage and current.

This means your voltage 0 crossing and current 0 crossing is occurring close to each other. So, you have possibility of self estimation the arcs in the fault because when the current goes to 0, even the voltage is 0. So, your arc might go away and your insulator, but it means that you have very good control of your parasitic capacitance which is not necessarily true people might switch in loads switch out loads. So, in a controlled situation, you have such possibilities, but not in general.

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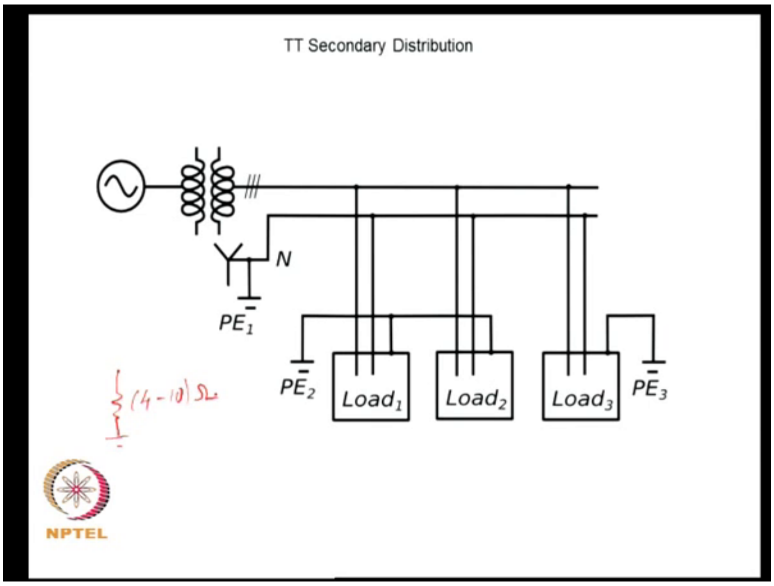

So, if you look at then the other possibility of when you look at the grounding of a the source with the load you have the t t secondary distribution network, where the first t corresponds to having a ground solid ground at your source. The second t corresponds to having grounding solid grounded electrodes at the loads, so what is shown over here is a example of a TT network. The y point is connected to power earth at the source the neutral is distributed to all the loads. So, you have three phase four wire distribution potentially, each load can have its own grounding electrode. So, in this example we have shown what we see is a load one and two has a common grounding electrode t 2 load three has another.

Its own grounding electrode might be big housing structure load 1 and load 2 load 3 might be able to be the next house. So, it could be you can have different possibilities of your TT grounding network, the one of the main thing to considering such a while analyzing such a system is that. When you have grounding electrode inserted into the earth, then you have actually the resistance earth resistance between your earthing conductor and your physical ground. So, you have what is shown over here as a connection to earth physically is actually you might have a point, you might have some contact resistance to the deep earth.

Then, you have the physical deep earth which would be considered to be at 0 potential and you look at your typical earthing resistance you try is a number which can vary common values range from 4 ohms to 10 ohms. It depends on a variety of conditions like the how much wetness is there for the soil the salinity of the soil, whether the conductor is highly crowded. It is relatively well maintained conductor or so there can be a variation in the value of resistance, but these are some of the typical numbers that people consider for the grounding resistance and if you look at the ground fault current in this particular case.

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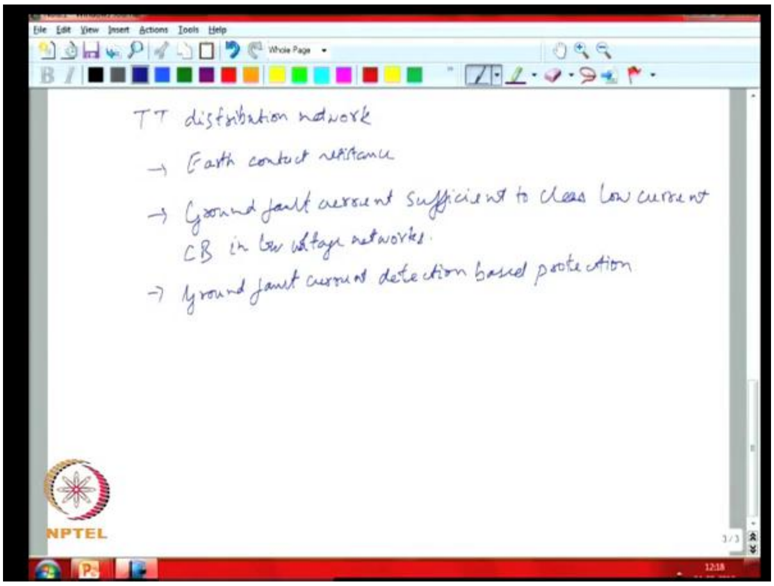

So, the first thing to consider is earthing the earth contact resistance and that may be uniform. What you would see is the level of ground fault current is might be sufficient to create to clear a low rated as circuit breakers or the circuit breakers of the order of 10 amps, but not high circuit breakers. When we say low voltage network we are talking about voltage less than 1000 volts is what people traditionally call low voltage network and we will see this in an example. We will do an example to see that the fault current level may not be large enough in a all situations and you can actually make your ground current.

You can have a ground fault current detection base protection which can be made sensitive say for example, when you are having situations where people might commonly use an electrical appliance. When there is a concern of safety you can have say areas like a kitchen bathrooms etcetera, where the ground might be wet, there is a chance of increase shock. So, you can try to set your ground fault detection current levels to be quite tight so as to ensure that people do not get shock, a severe say problem because of electric shock, so we will look at an example of a TT distribution.

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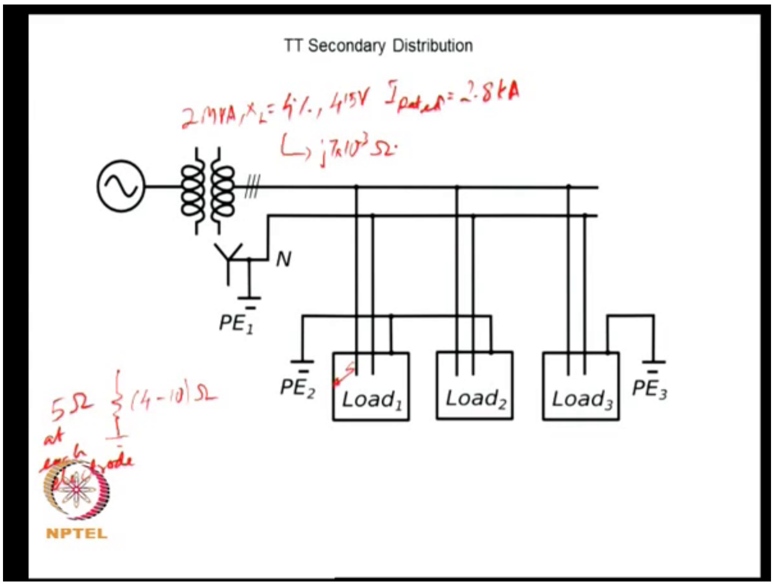

We are looking at say we will look an example where say you have A 2 mVA source two mA transformer and say your leakage inductance is say 4 percent and the secondary network is of 415 volts. We will assume your resistance to earth is 5 ohms at each electrode, so if you are looking at a 2 m VA per 15 volts network. You are talking about i rated, which is 2 mVA divided by 415 divided by root 3, so you have about 2.8 kilo amps.

So, these are thick multi conductor cables that might be connected in such a situation and we will look at an example where you have a single line to ground fault in load 1. So, you have fault in load one and you if you look at your transformer reactance the 4 percent reactance.

In this particular case corresponds to 7 milli ohms, 7 into 10 to the power ohms is the reactance of the transformer. Then, we could look at what is the resulting fault current in a situation such as this, so we can draw the sequence net work to figure out the fault current.

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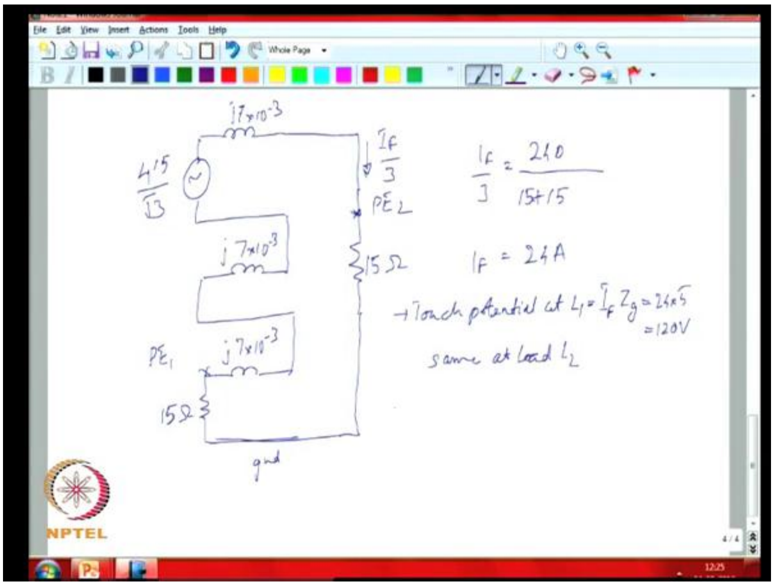

So, you have your positive sequence network 415 by root 3 is the voltage, your reactance is j 7 into 10 to the power of minus 3, your 0 sequence is then if you look at your source on the source side. You have the resistance between your grounding electrode and deep earth, which is 5 ohms, so that acts now as a effective grounding resistance of 15 ohms in a zero sequence network.

Then, your fault has occurred on in load 1 and you also have now a electrode at load one which is also having a resistance of 5 ohms between the electrode and deep earth so that can be treated as the resistance. So, you could think of this point as p e 2 and this point as p e 1 and this point as your deep earth or your physical maybe zero voltage point.

Then, you can look at your fault current and I f B by 3 is now two forty volts divided by fifteen plus fifteen because the seven milli ohms is quite negligible compared to your 15 ohms. So, your fault current level is about twenty four amps, so you can clearly see that 24 amps is a tiny percentage of your 2800 amps rating of your main circuit. So, obviously you will not see a over current tripping, but the of your main breaker which is carrying your full current.

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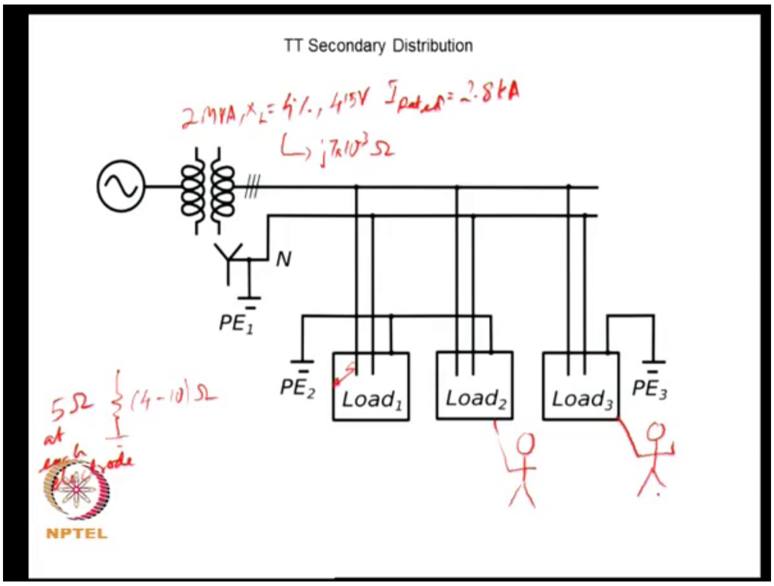

You could actually calculate what your touch potential is say if a person is over here and the person say if he touches load 2 because you now have a current flowing through power earth 2. You have a resistance between your earth and there is a contact resistance the frame of load 1 and load 2 will get elevated when you have a single line to ground fault and you could calculate what that particular voltage is.

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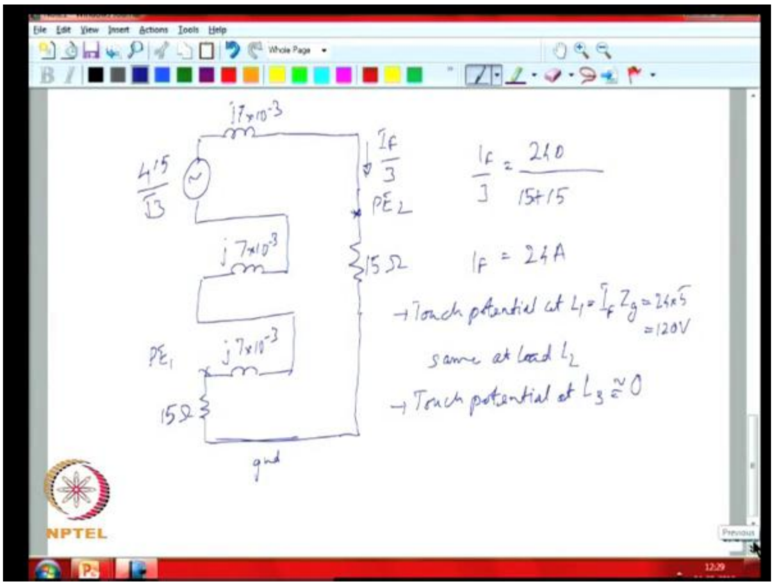

If you look at this sequence network that is essentially corresponding to the p e 2, so touch potential at load 1, so with 120 volts, you will definitely feel a shock if you actually touch a cabinet at the particular voltage level. Similar same thing at load 2 if you look at load l 3. So, if you have a person now standing over here and touching load 3 with respect to power earth three then there is no current flowing in power earth 3, so with that particular location the person will not get a shock.

So, the all the loads to connect it parallel, which has its own independent earth you do not see elevated touch potential, but within the particular load it might be a house or something like that you would see elevated touch potentials. So, you have seen the situation where you have some old aged wiring in a house and suddenly you and touch different equipment and get a shock because at in that particular establishment. You might have now elevated touch potential for your equipment, so it is important to insure that quality of your wiring etcetera is good.

Otherwise, you end up having problems of possible shocks when you are touching equipment and within common ground load, which has its common ground through which the current is actually flowing in. You can see that just a over current fault might be sufficient to clear maybe 24 amps maybe sufficient to clear 10 amps circuit breaker, but definitely it will not clear a 30 amps circuit breaker, it will not clear a 100 amps circuit breaker. So, in a situation where you are having high rated loads, you cannot just depend on over current to give a protection.

You would need a protection from ground fault current detection and if you have something like 24 amps flowing through a circuit, which is designed to carry maybe a 20 amps or 30 amps, it means that your conductors would get hot. So, there is actually a potential for eventually having electrical fires, so you have to ensure that the fault gets cleared or continuous over current that is flowing through the network can actually lead to a possible fires and there is something that one would need to avoid. Also, if there maybe some bad practices where instead of putting your actual fuse someone might just have a physical conductor strand of copper can use as a fuse and in such situations.

You go and touch the fuse the fuse blog will be very hot because it is carrying a high current, but not sufficient you actually interrupt the circuit and things are running hot because there is a fault somewhere in the system, which you cannot identify. For small facilities, I mean for small establishment homes etcetera where your loads are typically ten amps or less. This would be a TRD network that would be low cost because a number of conductors that are need to passed around is quite small and is adequate for protection of smaller establishments, so at this point with.

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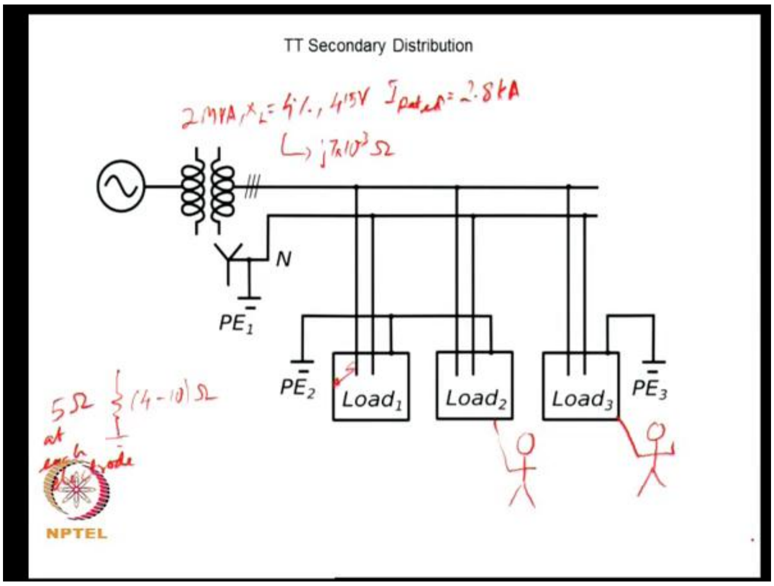

This background on what can happen what type of possibilities are there in distribution system sand what can happen due to say core grounding or the issues in that are there when you have a common type of faults. You can actually then look at the situation as a of what would happen when you add a distributed generator source into such a network which has its own grounding characteristic. So, we looked at again the I T grounding that is type of grounding mechanism where you might have high priority for continuity of service.

So, in a situation where you place greater priority for continuity of service you might put a a i t type of network whereas, if you are you feel that it is to interrupt the loads, but your fire is fire protection is something which is extremely important. Then, you need to ensure that you have high current levels to ensure clearing of faults, so a t n type of network will ensure that there is high fault current and it would clear the breakers within a short time frame.

So, you do not have possibility of long lingering over currents and T T network is a balance, you do not have the situation where one fault will cause evaluated touch potential at multiple loads. Especially when they have independent grounding options and it is also sufficient when you are establishing of drawing lower levels of current. In case it is drawing higher current levels of current, you could look at additional options of actually measuring the ground fault current level and actually tripping your breakers.

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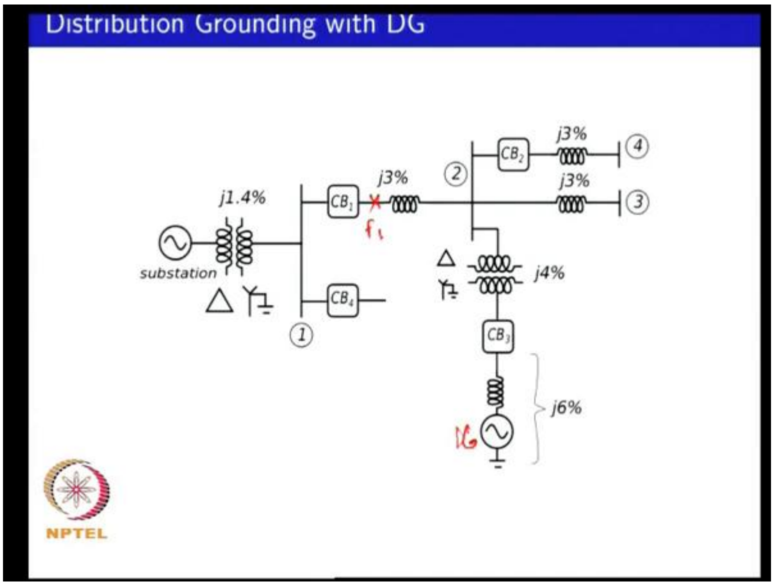

So, we will look at now an example where you have a distribution network and we will look at the same distribution network that we studied when we looked at the issue of co-ordination, where we had some initial fault current levels that the system was carrying. Then, we added the DG and we wanted to see what would happen to the fault current level so we will look at the same network, where you had a traditional the old network which is say solidly grounded. Then, you want to add DG to this setup and you want to see what the possible situations are.

So, when you have a fault and the fault that we would consider is say a fault of 1 just close to circuit breaker one. So, to analyze this fault situation we will assume that the single line to ground solid fault is occurring at f 1. So, to analyze this particular situation we will now again have to draw the sequence networks.

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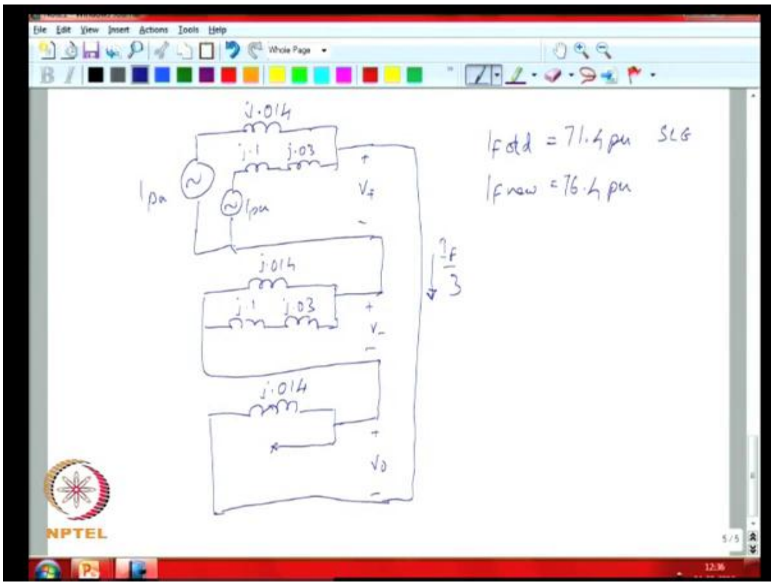

So, you have the situation where you now have possible the possibility of the contribution from your main source which is a grid and now the DG. So, your positive sequence network would consist of say j, so this reactance corresponds to the source reactance and then you have the DG. This is also 1 per unit voltage and you have the reactance of the DG plus the interconnection j 0.1 and the feeder reactance which we took as j point 0.3, so these are positive sequence network. If you look at you are a 0 sequence, your negative sequence network and if you look at your zero sequence network on the source side. You have now a solid grounded network on your DG side you now see the delta side of the transformer, which means that is open.

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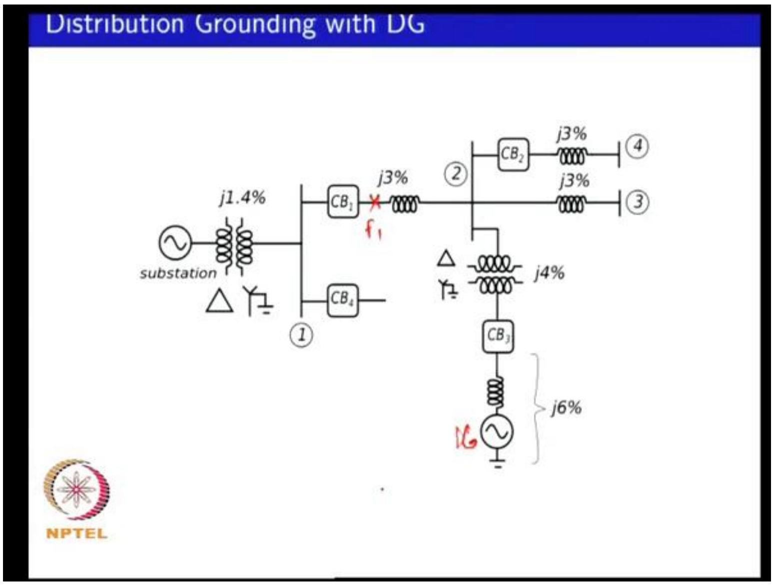

So, if you look at the example, so the zero sequence corresponding to this transformer would be a open circuit because it is delta on the on the on the this high voltage side as here you have a possible path for 0 sequence current. So, you could then calculate what the fault current would be, so I will give you the numbers your if old what I mean by I f old is that the fault current there is no DG.

So, assuming that in this particular branch was not there in this particular branch was not there you would be able to calculate i f old. So, that was 70.14 per unit for a single line to ground fault a solid single line to ground fault. Then, I f new is the fault current that you have when the DG is connected, so that corresponds to this particular figure, which is drawn over here and that was that is sent to 6.4 per unit.

So, if you look at this particular situation, you see a increased fault current level at the point of fault and you can have your breakers operating in response to the fault because you have a solid grounding. Over here, you will see a higher current over here which might say a trip circuit breaker one. So, we will look at a situation that can potentially arise if the current, the way it branches out because the impedance at strain is quite small compared to the impedance back towards the DG. The current is such that it trips say circuit breaker one before circuit breaker three.

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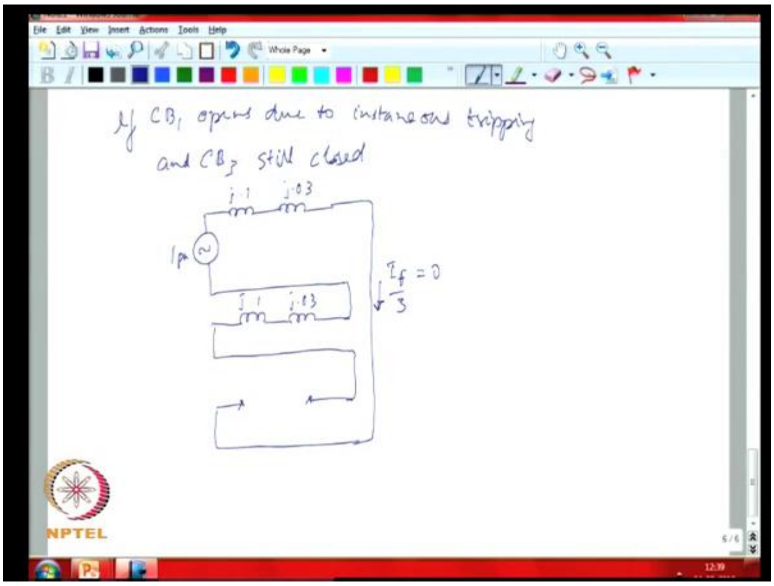

Then, we will end up with now a new situation where then the new sequence network would be A and your series sequence in this new scenario is essentially A, open circuit, so your I f, your fault current level is actually 0. So, as soon as your circuit breaker one opens you fault will fault current would go away which means that. Now, you will potentially energize the feeder from the DG side and there is no fault current. So, if the DG is capable of support supplying your power real power to the feeder corresponding to the level of demand of the feeder, then you can continue in that situation for a very long time.

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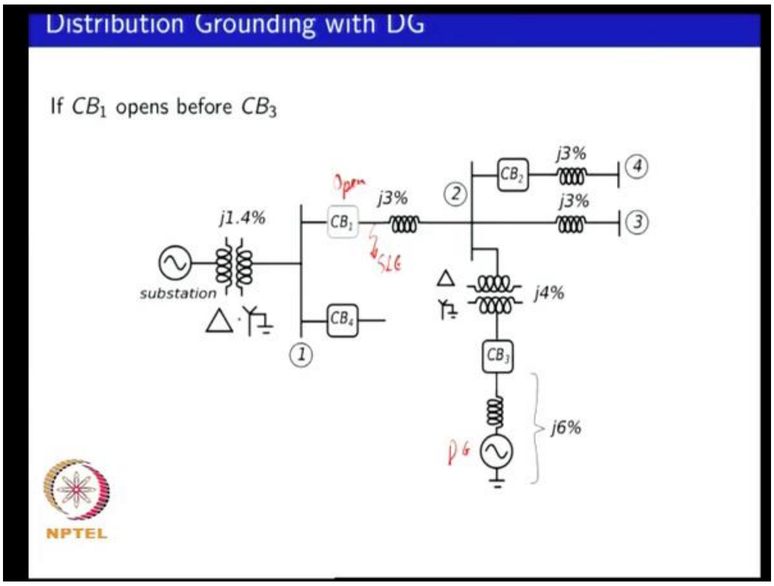

So, the situation over here is say your CB 1 open and CB 3 is still closed, it means that even though you have a single line to ground fault, you will not actually have any fault current because your system has now become a delta, delta ungrounded system. Originally, it was a y grounded system when circuit breaker one opened it has now become a delta type of source, which means that if CB if your DG over here is capable of supporting the loads on this particular feeder. You too continue to operate for a long duration of time, so if this is actually A can lead to any problems and you say for example, because you where originally solid grounding your source you might assume that you are not going to have a phase to ground voltage of a that is going to be large. Now, because you are having in a delta connected source, it means that now you are conductor to ground voltage can potentially go to root 3 times what is now the nominal. So, we will see higher over voltage and system were not designed to actually experience over voltage of 70 percent etcetera, so you can have damaged to a components.

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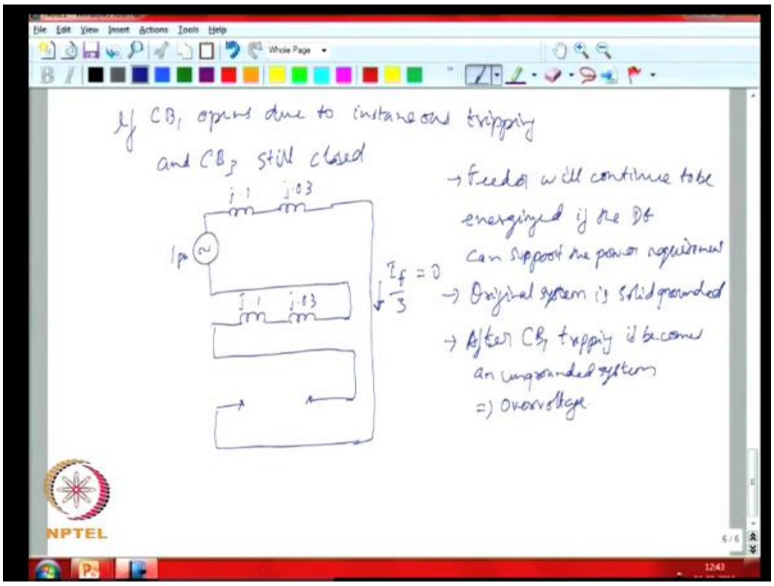

If the DG can support the power requirement and maintain the voltage, you will continue to energize the feeder and original system is solid grounded, whereas after tripping, there is a possibility of over voltage. So, what it means is that your DG circuit breaker has to take as soon as your upstream breaker trips and the upstream breaker might trip for reason other than for fault. For some reason, if the breaker is open say CB 1 is open, then now what you have is the possibility of the grounding of the system changing from one strategy to another strategy is to have one particular strategy. It is difficult to have system, which are changing the grounding strategy being changed when your breakers open.

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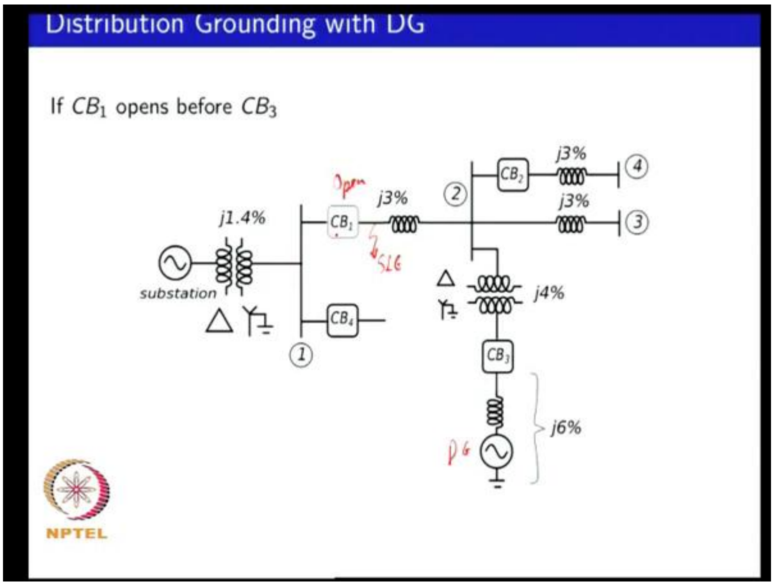

So, again if you look at this particular requirement what it means is that for any reason if any fault happens in the system or if circuit breaker one opens the DG has to be disconnected quite rapidly which is similar to the conclusion that we saw. In the other example, when we looked at the protection co ordination, which means that you have to make your CB 3 trip potentially not just for a fault condition, but also for any reason if CB 1 opens, you need to actually open CB 3. Your grounding strategy would not be consistent. Now if you want to make CB 3 that sensitive it will become prone to a lot of nuisance trips, so being able to meet such a requirement is actually quite challenging.

The situation where CB 1 opens and CB 3 is closed is a what people refer to as a situation of an unintentional island what you have done is you have disconnected from the main grid. You are actually operating your balance of your feeder as a island which is disconnected from your main grid. So, this unintentional island has many consequences safety problems liability problems etcetera.

It is important then that your DG system is not just able to detect a fault, but actually now you need to generalize and be able to detect a situation where your system your distribution system at potentially have an unintentional islanding situation. What we will do is in the next class we will discuss this islanding issue more closely because it is a important consideration for distributed generation sources and have not just unintentional balance.

You also have intentional islands, we will look at why you people do have intentional islands primarily from power quality perspective you may want to disconnect from the grid when the grid power quality is poor. So, islanding is a important consideration especially when your operating a distributed generation system source and you can have different situations of islanding and we will discuss that in the next class.

Thank you.