Power Electronics and Distributed Generation
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Lecture - 8
Protection Components

Welcome to the class eight, and in the last class we were formulating the problem of coordinating and upstream, and a downstream circuit breaker. So, we will continue with that particular problem.

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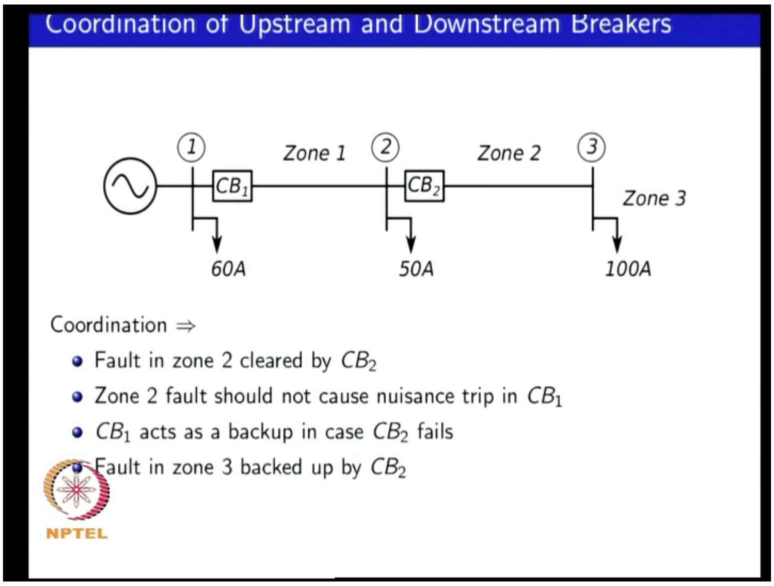

So, we had circuit breaker 1 and 2, and the question was what do you mean by coordinating these 2 breakers. So, we discussed what should be the requirement, and the points that were discussed was requiring to the requirements of the individual breakers.

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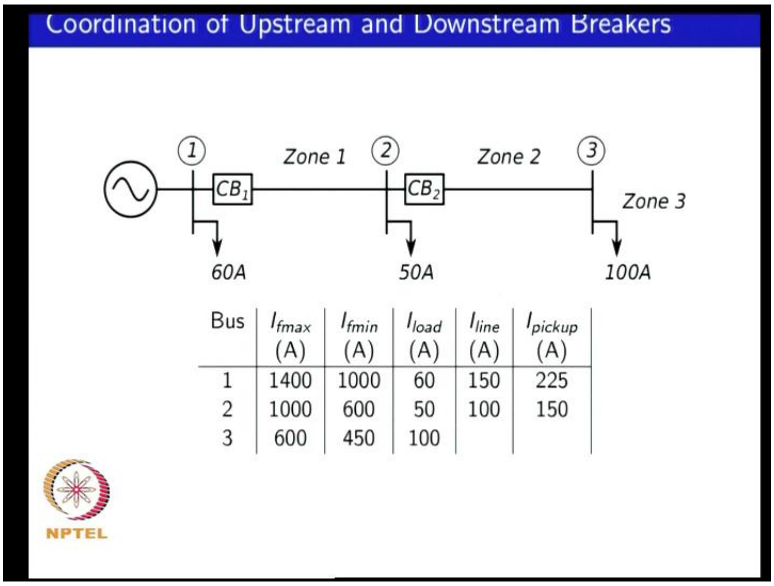

Then the next thing that you need for doing the coordination is to actually do you need to perform a fault analysis at the different zones in the bus, and identify what is the range of fault currents, that you could expect to the protective device. And what is the nominal current, and then you will decide on what would be the parameters, that you would employ for your breaker to enable the appropriate coordination. So, we started with the data regarding the circuit breakers. So, if you look at the circuit breakers.

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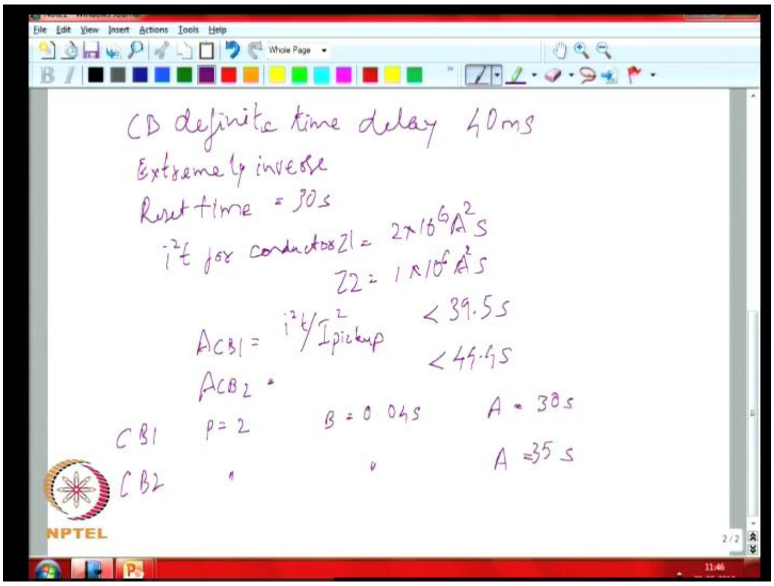

We had mentioned that the circuit breakers, definite time delay of 40 milli seconds or 2 cycles. It has extremely inverse characteristic, and reset time of 30 seconds, and we mentioned that the i square t for conductor in zone 1 is 2 into 10 to the power of 6 ampere square second, and for conductors in zone 2, it is 1 into 10 to the power of 6 ampere square second. Then you could calculate, what is the A of requirement of C B 1 and based on our previous discussion, you can relate that to the i square t divided by i pickup square; and this case, you a need an a less than 39.5 seconds for C B 1, and a for C B 2. We identify it should be less than 44.4 seconds, and then we decide to actually have breakers C B 1 and C B 2. So, it has p equal to 2, b equal to 0.04 seconds, and A is 30 seconds for C B 1, which is less than 39.5. For C B 2 your p and b is the same your A you could select it to be say 35 seconds, and 35 is less than 44. So, next we will have to look at what are the fault conditions. So, if you have a fault in zone 1, your circuit breaker 1 has to operate.

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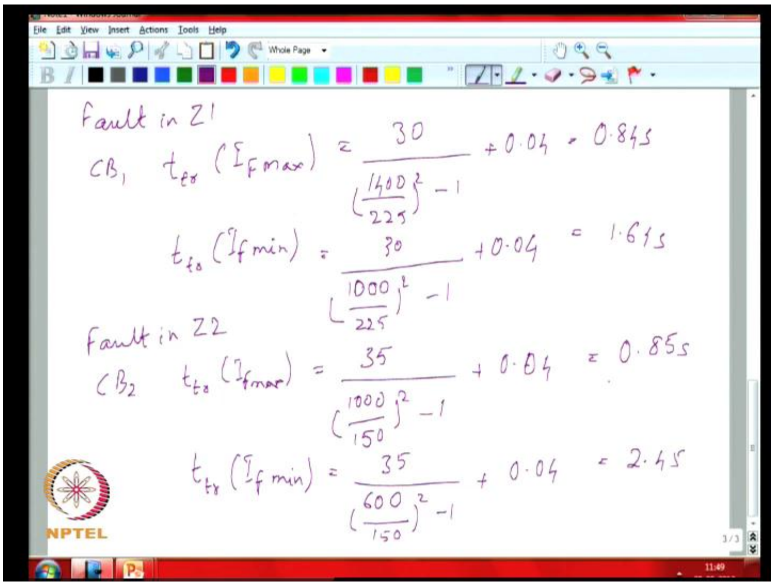

So, for circuit breaker 1, your trip time at i f max in zone 1, is now 30 divided by 1400 divided by 225 which is the pickup current for that particular breaker minus 1 plus 0.04. So, this is the 0.84 seconds. If you look at the trip time, at your i f min, you can do the calculations, it will be 1.64 seconds. The current level is 1000 amps in this case. So, it is 30 divided by. So, if this fault in zone 1, C B 1 has to operate. For fault in zone 2, essentially circuit breaker 2 has to operate. So, for circuit breaker 2 your A is 35 divided by 1000. The, pickup current for the circuit breaker 2 is 150 amps, and if you look at your trip time at i f min, the i f min is 600 amps, pickup current of 150 amps. So, at 1000 amps the circuit breaker 2 trips in 85 milli seconds, and at 600 amps, it trips in 2.4 seconds. So, the next question is, if for some reasons circuit breaker 2 does not operate, and circuit breaker 1 backs up or circuit breaker 2, then you can ask what isthat required trip duration for circuit breaker 1, during the fault range in zone 2.

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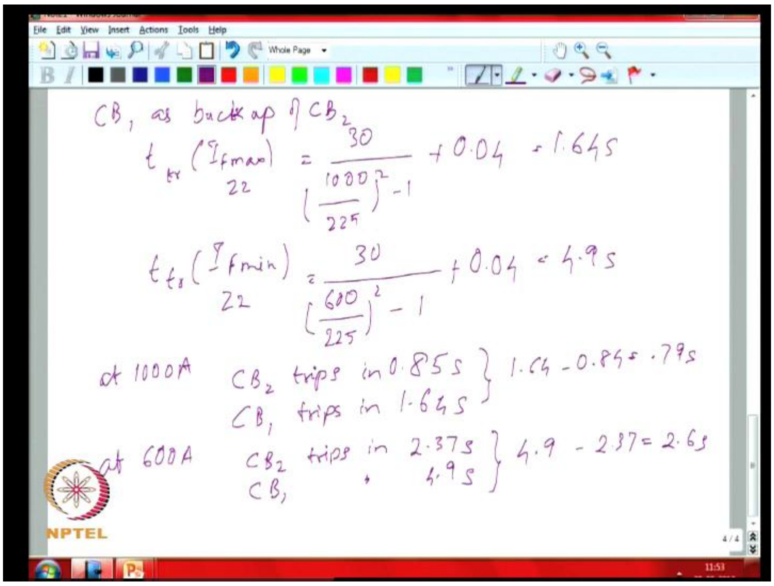

So, C B 1 in zone 2 is now 30. If you look at the minimum current level. So, if you look at, now at the 2 current levels at 1000 amps, C B 2 trips in 0.85 seconds and C B 1 trips in 1.64 seconds. So, C B 2 should; obviously, trip over here if it does not trip, then C B 1 acts at 1.64 seconds. if you look at 600 amps, C B 2 trips in 2.37, and C B 1 trips in 4.9 seconds. So, if you look at this case, you have a margin of about 1.64 minus 0.84 of 0.79 seconds, and here you have a margin of 4.9 minus 2.37 of 2.6 seconds. So, the margin is greater than 20 to 30 percent tolerances that might occur. So, you may not have new sense trip problem of; say breaker 1 for some reason operating before breaker 2, for a fault in zone 2. Then calculate what would be the i square t level, corresponding to the fault in zone 2 and breaker 2 failing to operate.

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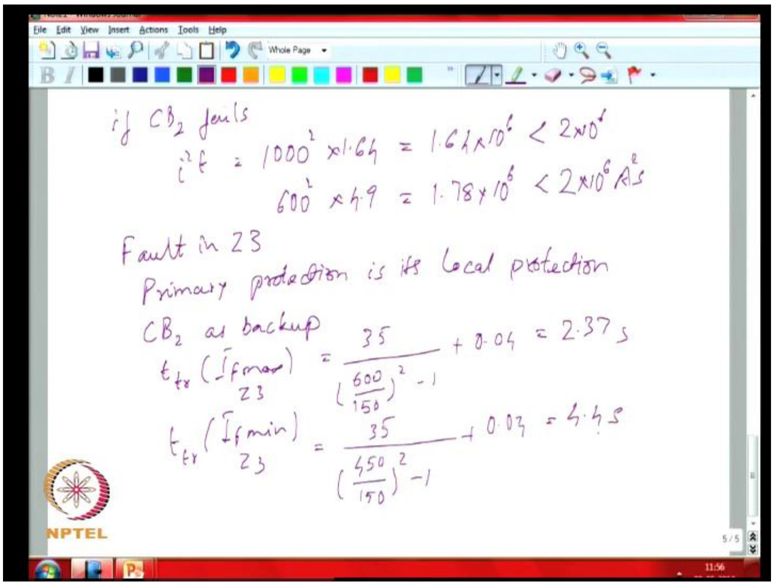

So, if C B 2 fails, your i square t is at 1000 amps. It is 1000 into 1.64, is 1.64 into 10 to the power of 6 is less than 2 into 10 to the power of 6. So, the fault does not cause damage in zone one. So, the damage does not spread to zone 1. So, if you look at the other range of current, you have 600 square into 4.9 seconds equal to 1.78, which is also less than 2 into 10 to power of 6 ampere square second. So, you might due to the failure of circuit breaker 2. You might have some damage in zone 2, but the damage does not know propagate into zone 1. So, the next thing that you would have in this particular situation, is we had identified three zones; so zone 1, zone 2, and zone 3.

What happens for a fault in zone 3. Ideally, we have not indicated what is the protective device that is used in zone 3, it could be circuit breaker, or it could be a fuse. The question is, will the breaker C B 2 act as a backup, and if it is acting as a backup what was the fault i square t that is happening in zone 2. So, if you look at fault in zone 3. The primary protection, is the local protection, and C B 2 is backup, and if you look at now your trip time, for i f max. In zone 3 you have 35 divided by, and if you look at your trip time at i f min zone 3, your current level is now 450 amps.

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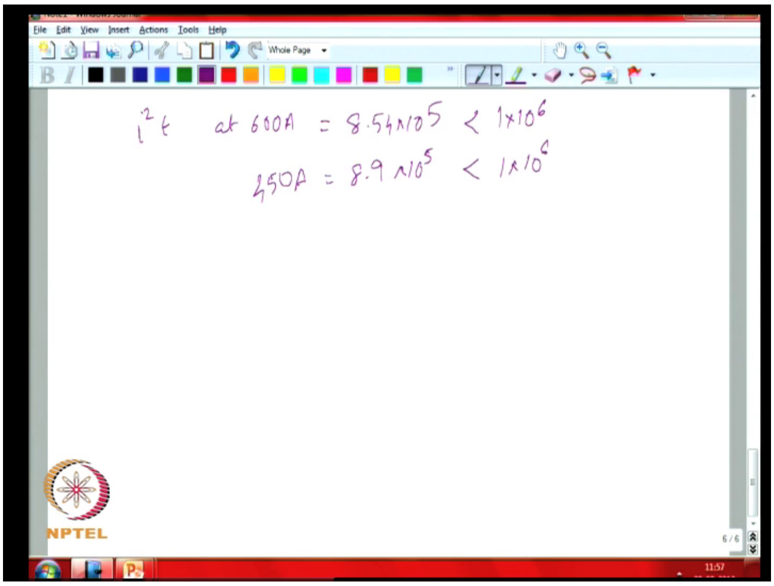

You could then calculate what your i square t level is. So, your I square t at 600 amps, that transferred to 8.54 into 10 to the power of 6, or 10 to the power of 5, which is less than 1 into 10 to the power of 6. If you look at the 450 amp level you get 8.9. So, again in case there is a failure in the protection in its local zone, then the C B 2 settings will not cause of fault to propagate into zone 2. So, there is backup protection; however, in many situations it may not be possible to apply, to obtain all the possible conditions, you might have situations, where if you look at the example that we have been looking at the fault current levels are not overlapping.

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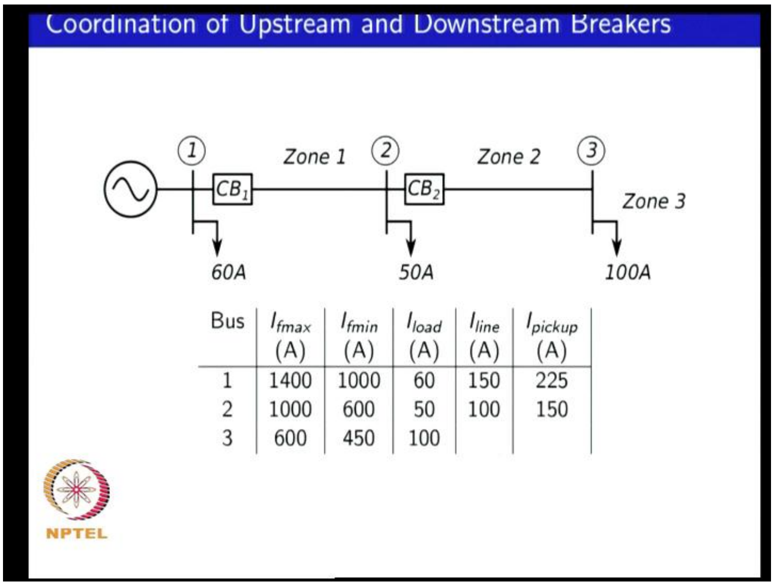

If you have overlapping ranges of fault current levels you may not be able to achieve all the conditions of your coordination requirement. Also you might have situations where your upstream source might have, impedances that are varying over a wide range. You might have transformers that are switching in and out. You might have lines that might be tripping. So, the impedances might be varying over a wide range, and over that entire range it might not be possible to achieve the full coordination. So, you might not be able to meet all these requirements, but your objective is to try and meet, as many as possible. So, the other thing that we did in this particular example is, look at individual values of fault current levels, and looked at a maximum minimum, and looked at what the trip timings are, of the breakers. Another way of looking at coordination, is to plot your trip time versus current, and see where the curve lies.

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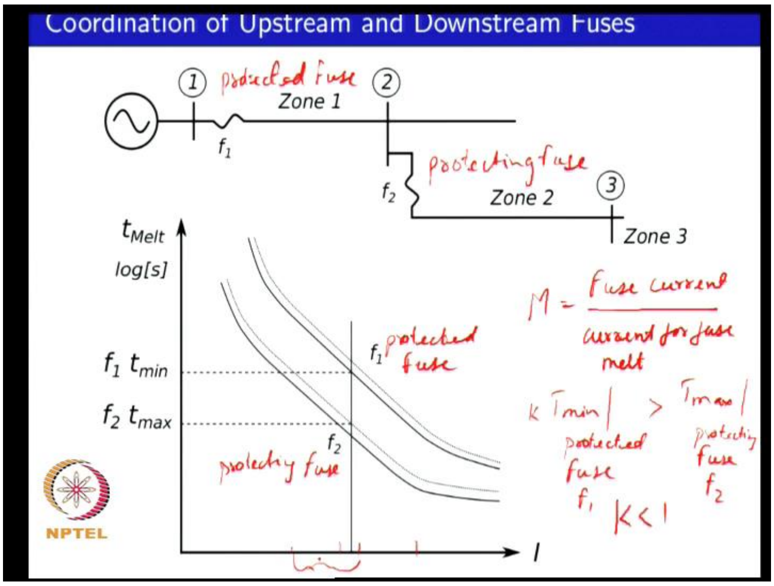

And we will look at this, say in the case of a fuse, and by looking at the position of the curve, you can get a broader feel for, is the coordination working or not. Is it possible for 1 device to trip, before the other device. So, many times software's that do the coordination calculations, can actually give, plots of time versus current coordination curves, which also give you a visual feel of, whether the coordination is happening over a range of conditions. So, in the second situation, we will look at case, where you are coordinating, say between 2 fuses; upstream and a downstream fuse. So, in case of a circuit breaker, you have that pickup current, and the actual current flowing through the protective device. In case of a fuse, you have looking at the ratio between your actual current flowing through the fuse, and the current required to melt the fuse. So, similar to what we defined for the circuit breaker. You could actually now define a ratio M, melt ratio as your actual fuse current divided by. So, as long as a current is below this melt current, the fuses not going to get damaged, once you go above that particular melt current level, you have a possibility of the fuse melting, and the time required to melt, would now depend on, your value of the current, that is flowing through the fuse .

So, in this particular case, again we can define says, zone 1 and zone 2, and we can define what it means by coordination between fuse 1 and fuse 2. For example, if you have a fault in zone 1, fuse 1 is the device which needs to operate, by coordination if you have a fault in zone 2, you want fuse 2 to melt, without damaging fuse 1. So, that is essentially the requirement for coordination between a upstream and a downstream fuse. So, you can, now define in case of a upstream and downstream fuse. If you have a fault say in zone 2, then the fuse that is actually protecting, is actually f 2.

So, f 2 by we call the protecting fuse, and f 1 is actually the protected fuse. f 1 is actually protected by f 2, and you want your protecting fuse, to be below in terms of your melt time versus current characteristics, you want it to be the curve to lie below that of the protected fuse . So, the protected fuse would typically having larger i square t, and what you want to ensure is, if you take a typical component, you would have tolerance, you would have, the minimum melt time and a maximum melt time. So, in this particular case, your solid lines might corresponds to the minimum time required for the fuse to melt, and your dotted lines might corresponds to the maximum melt time.

So, what you want to ensure is, that your some k times your t min of your protected fuse. In this case, f 1 is greater than your t max of your protecting fuse f 2, and k is a number which is less than 1. So, for fault current ranges on zone 2, you want a condition like this to be satisfied; say you could take k as say 70 percent and or 75 percent. So, you want to ensure that with some margin, you have sufficient distance between this particular point t max of f 2 and t min of f 1. So, I think that gives you a picture about what it takes actually do coordination between, upstream and a downstream fuse, and here you can see that the curve gives you a picture. So, this shows at 1 particular point, the range of current that might be experienced by f 1 might be a range somewhere like this. The range of current experienced by f 2, might be a smaller range. So, you want to make sure that, within its range this coordination is being achieved.

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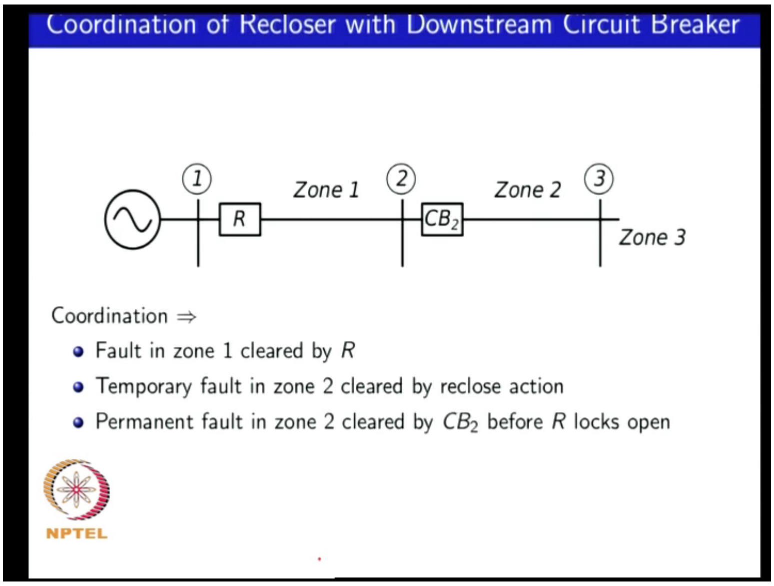

So, next we will look at the case, where you are trying to achieve coordination between say recloser and a circuit breaker. So, you have a upstream recloser, and then you have a a circuit breaker downstream. So, your recloser might be sitting at the substation, and your circuit breaker might be somewhere further down the downstream, and by a recloser it need not just be the timing of trying to stay close for some time, then opening reclosing again etcetera. The logic underlying the recloser might also have a circuit breaker characteristic. So, in addition to the reclsoer characteristic, there might be an underlying circuit breaker characteristic. So, the circuit breaker in this particular R, can be coordinated with C B 2 like what we have discussed previously.

So, now we will focus on, what the characteristic of the timing, in terms of the cycling between the open and close, of the reclosers should be, so that you can coordinate between R and C B 2. So, a first question is what you mean by coordination is this particular case. If you have a fault in zone 1; so obviously, the device that needs to protect that, is your recloser. So, R has to clears fault in zone 1. Now if you have a fault in zone 2, the question is that fault temporary or permanent. if you have a temporary fault in zone 2, then it can be cleared by a recloser by a its recloser action, but if you have a permanent fault in zone 2, you want C B 2 to open, before your recloser locks open.

So, if you have a fault in zone 2, C B 2 would open, then the next reclose cycle, your zone 1 would go back to normal operation, and it would continue with this particular breaker being open, and the section in zone 1, having its now normal power feed. So, if you look at then, what the logic in the recloser is. If the current in the recloser goes above some particular threshold value, it will open. So, once it opens, the current goes down to pseudo, it will wait for some duration, and then it will close again. So, after it recloses, it will see whether it is a current, is still going above the threshold, and then it will go through such cycles of; say n cycles. After n cycles if the current is still above the threshold, then its stays locked open. So, in terms of logic, it is a fairly simple and straight forward logic, in terms of what the recloser would do.

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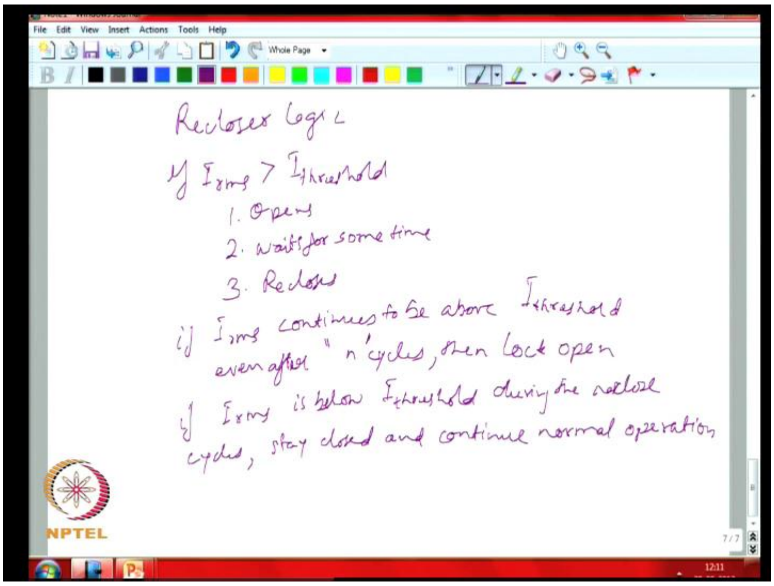

If you look at the recloser logic, if I rms through the recloser is greater than I some threshold. So, 1 it opens, it waits for some time, then it recloses, and if I rms. So, depending on what the n is, you can have 2 cycles, 3 cycles, number of cycles of the recloser. So, with this logic we will make use of the same data for; say zone 1 and zone 2, and look at an example of what can be done, when you have a upstream recloser, and a downstream circuit breaker.

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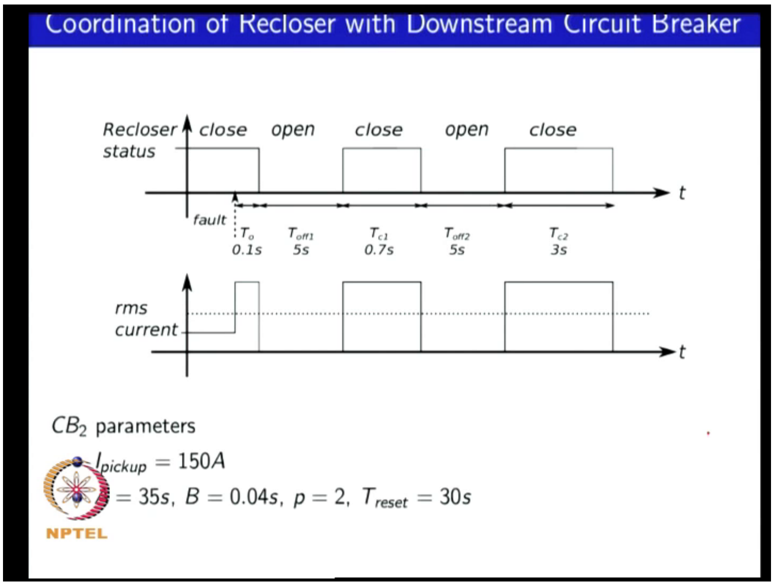

So, we will look at the example, where say the recloser. If you say you have a fault happening at some particular point of time, for a short duration the current level goes high. The duration t naught we are taken as point 1 seconds, then it opens for a duration of 5 seconds. Then it recloses, it recloses now for 0.7 seconds. If the current level stays high again for in this duration, it opens again for 5 seconds.

So, after 5 seconds it try reclosing a second time, and there it stays close for 3 seconds, if the current is continuing to be above your threshold level, even at the end of this particular 3 seconds, then it would not lock open. if the current say came down, at some point of time before this 3 seconds ended, then essentially the recloser would go back to normal operation, because it would not lock open, it would go back to the normal conditions, so that is the essentially of the logic. So, we will take these as the numbers in our example for the recloser. For circuit breaker 2 will use the same parameters, as we had in our C B, circuit breaker to circuit breaker coordination example. And will look at the situation when you have faults in zone 2. So, what is shown over here, is an example of fault in zone 1. It tried a permanent fault in zone 1, it tried 2 reclose cycles, and it just locked open and the end of it. So, the current came down to 0 and stayed 0 at the end of such a situation.

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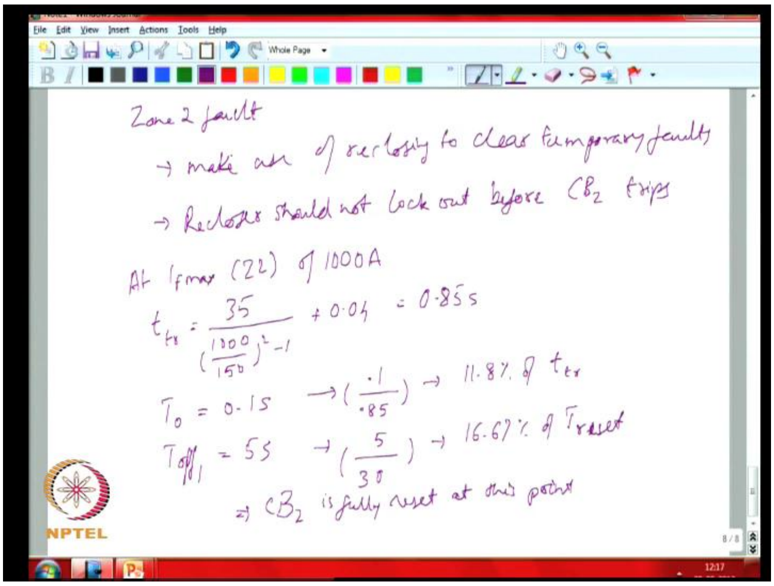

So, if you look at zone 2 fault, what your objective is, make use of reclosing to clear temporary faults, and recloser. So, will look at, what happens in this particular situation, when you have fault current, in the maximum and minimum current in that particular range, in this particular example. So, at 1000 amps which is the maximum fault current level in zone 2, you have your trip time of a circuit breaker, is 0.85 seconds. A

nd if you look at, now your t naught duration, of 0.1 seconds, then this corresponds to the breaker advancing by 0.1 divided by 0.85, which corresponds to 11.8 percent of your trip time for the circuit breaker. So, it is about 11.8 percent to trip at that particular condition, and then you have actually the first of duration t of 1 of 5 seconds, and the 5 seconds in terms of their overall reset time for the circuit breaker, which is 30 seconds. It means that it is resetting by 16.67 percent of t reset. So; obviously, it is not going below 0, its now resets back to 0. So, at the end of your cycle over here, at this particular point, your circuit breaker 2, is actually now fully reset, by the fault current level it went up to 11.8 percent, it came down to 0, it is fully reset at this particular point, of your operation of the recloser.

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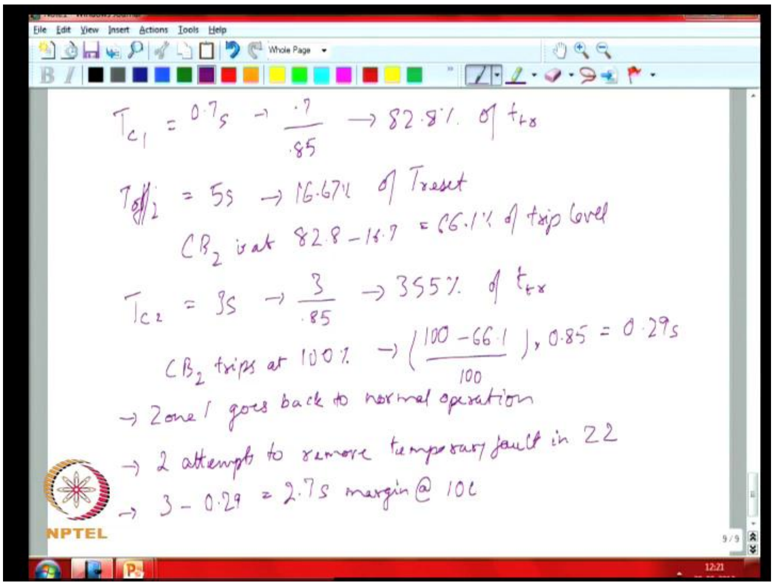

So, if you look at your next action, if you look at your closed duration 1; T c 1 of 0.7 seconds. So, that corresponds to 0.7 by 0.85 of your circuit breaker. So, it is actually about 82.8 percent of your trip time. So, in this particular case advanced to 82.8 percent, then if you look at your second open duration T off 2, of 5seconds, it is now 16.67 percent. So, if you look at your circuit breaker. So, at the end of your second T off duration. So, at this particular point over here, you are now about 66 percent of your trip level in a circuit breaker.

Now if you look at your close duration 3, of 3 seconds 3 seconds divided by 0.85 is 355 percent, so obviously, it has stubbed before the 3 seconds has ended. So, your actual trip time for a circuit breaker, it corresponds to 100. So, it did not require 3 seconds, it tripped in point 3 seconds in the second reclose cycle. So, at this particular condition, essentially zone 1 goes back to normal operation, because the current level returned back to the condition of the nominal loading of that particular zone, and what the recloser did was, it made 2 attempts to clear a temporary fault in zone 2, and because it was permanent, it trip the breaker before the recloser locked open. And if you look at the margin you have 3 seconds minus 0.29 seconds, you have 2.7 seconds of margin, at 1000 amps current level. So, next you could actually look at, what happens at the lower current level, because you look at across the whole range.

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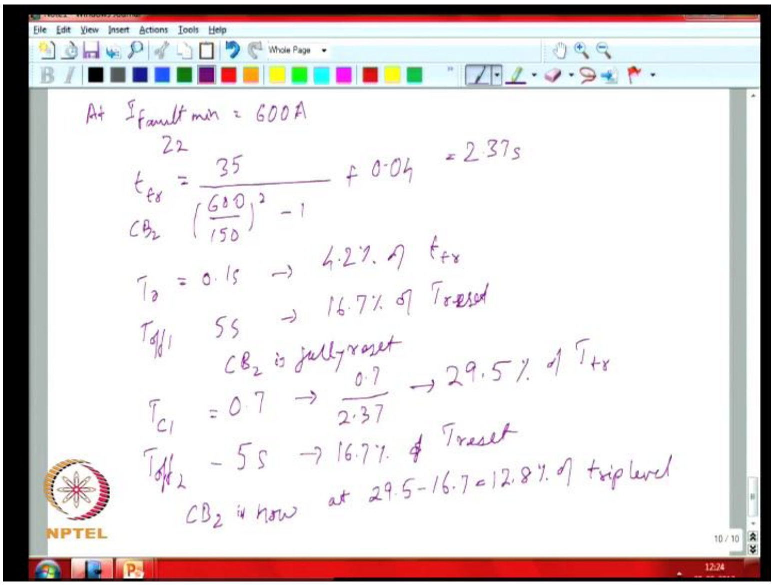

So, if you look at the current level of 600 amps, your trip time is of the breaker. So, you know your reduce current level at the minimum current level. So, if you look at, now your t naught in this case of 0.1 second, this corresponds to four point 2 percent of t t r. if you look at at off 1, of 5 seconds, it is 16.7 percent of t reset. So, again the breakers fully reset, at this particular point. if you look at, now your reclose duration a T C 1 of 0.7 second; that corresponds to about 29 percent of your trip time, and if you look at your t off 2, of 5 seconds, which is 16 percent, your circuit breaker 2 at this particular point. So, if you look at the point over here, at the reduced fault current level, it is about 12.8 percent into tripping. So, that is the situation of the circuit breaker, at that particular point of time. So, if you look at then the next duration of reclosing which is for 3 seconds.

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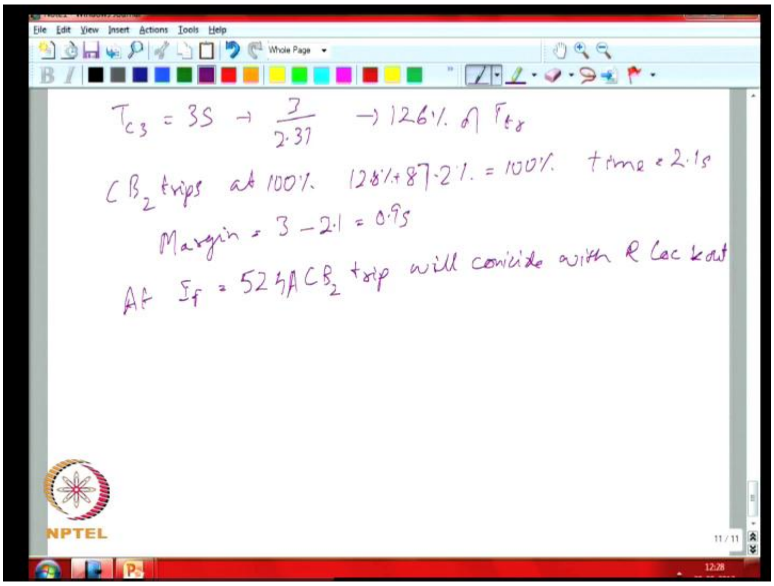

So, if you look at T C 3 equal to 3 seconds. So, this corresponds to 3 divided by 2.37 or 126 percent of trip time. So, again the circuit breaker is going to trip, when it reaches 100 percent. So, it is going to trip definitely before, the 3 second duration that you have. So, your actual tripping. So, if you look at, you had 12.8 percent from your first reclose cycle. So, what remains in your second reclose cycle, is actually 87.2, which is hundred percent. So, if you look at the corresponding time, you get of 2 point 1 seconds, would be that time required for your breaker to trip. So, the margin that you have, in this particular case is 3 seconds minus 2.1 or about 0.9 seconds of margin at the lower current level. So, you can see that the margin is reducing, as the current level becomes lower and lower. So, that very low current levels, your breaker needs more and more time to trip.

So, at some levels there is a possibility that, you might actually cause a lock out before your breaker operates. So, one thing you could do is, you could actually decide and what your threshold level for your recloser needs to be. So, if you look at your fault current in your zone 2, or further downstream if you have fault in zone 3 etcetera, your current level can come down below 600 amps. So, there is a possibility that at some reduce current level, your recloser might actually lock open, before the downstream device acts. So, 1 thing you could do is, you could verify now to calculations at I f of a 524 amps, your C B 2 trip will coincide with R lock out.

So, if your current level is above; say for 124 amps, then your C B 2 will trip, before the recloser operates, locks out. So, if you set your threshold current level for your recloser to be higher than 524 amps, then the recloser would not operate at a reduce current level, and ensuring that you do not have new sense trips and upstream, because of reduced or current levels, that are occurring downstream. Though in typical protection coordination practice, you would typically designed upstream protection, before you decide on what you would do in downstream some of the situations. You will have to look at the entire situation, to decide on whatshould be the settings. So, that you do not have new sense trips.

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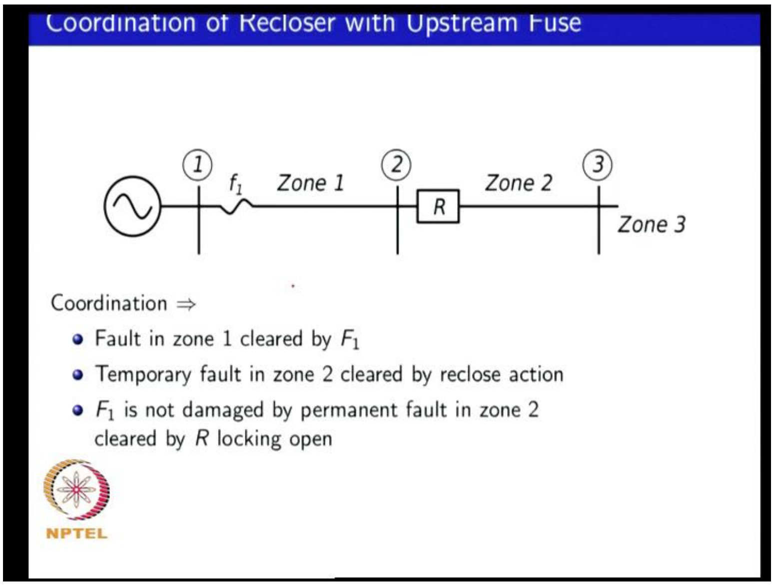

So, another situation that you can potentially have is. Then looking at a situation where say you have recloser, which is sitting in downstream, and a fuse or a circuit breaker which is upstream. So, will look at next example where, you have a upstream fuse and a downstream recloser. It could be; say a backup protection fuse, operating with a downstream recloser, and then the question is, how do you then determine the coordination settings. So, what does it mean for a coordination to be done in this particular case.

So obviously, in this case, again if you have a fault in zone 1, it has to be cleared by fuse f 1. If you have a temporary fault in zone 2, your recloser should clear the temporary fault by reclose action. if you have a permanent fault in zone 2, then your fuse f 1 should not get damaged, which means that your recloser should lock open, before fuse f 1 gets damaged. in the previous example, your recloser should not get locked open, before your circuit downstream circuit breaker or operates. in this case you want your recloser to lock open before your upstream fuse gets melted.

So, when you look at this particular example in greater detail in the next class. And the main idea behind, looking at these situations in distribution system, is that now if you are doing coordination of your protective devices in some particular manner. now if you add say (( )) to one of these buzzers, what would be the new situation, what would be the new fault current level, what would be the changes that you would need in the system, when you introduce the newer distribution generation device. And this is something that we will continue with, in the discussion in the next class we will look at the example of the upstream fuse and a downstream recloser.

Thank you.