Power System Protection
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Lecture No 13
Relay Coordination with fuse

Welcome to NPTEL power system protection course so we are going with the overcurrent relaying and in this lecture we will address relay coordination with fuse.

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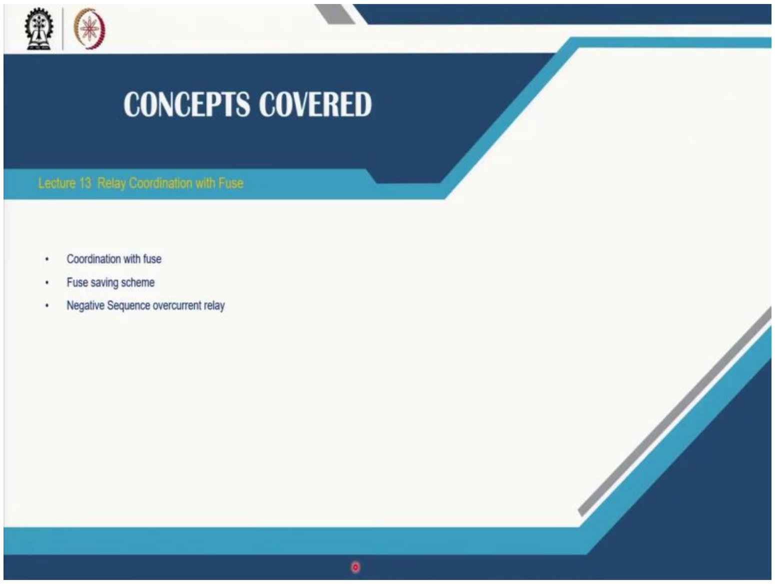

In the last lecture we have seen how relay coordination can be achieved for a distribution system application. Now, similar coordination is required for other aspects, we will see some of the perspective. Particularly coordination of relay with fuse and how fuse saving scheme can be obtain for a system and then as a final point we will see how a negative sequence overcurrent relay also can be integrated into overcurrent relaying principle.

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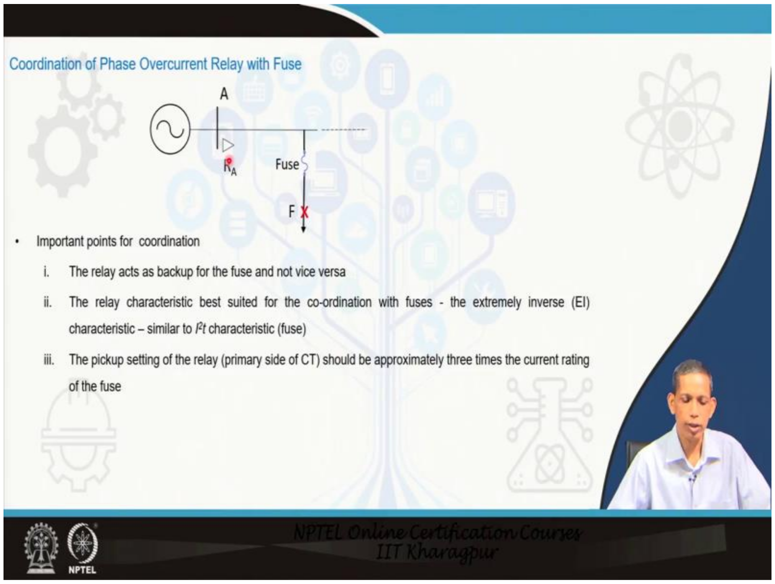

Going ahead on coordination of phase overcurrent relays with fuse, so let us take a system like this, source, substation, bus A has a relay overcurrent relay R_A and then in downstream we have several laterals and one of the laterals here which has a fuse and let us assume there is a fault here. So, the objective of any protection scheme that this fuse will be blown out immediately following the fault. At that situation if the R_A trips the breaker here then this is not desirable because all the loads connected to this feeder will be disconnected. So from that perspective we can say that we need the coordination between this fuse element and this one. Note that fuse is also an overcurrent protection and fuse follows a characteristic that depends upon the heat and heat is nothing but I^2Rt similar to I^2t kind of thing. Depending upon that the fuse has certain characteristics, melting aspect and then finally blowing out, so that leads to that the fuse characteristic and then the relay characteristics in between them is sort of a coordination. So, to have that we have some coordination rules, the relay acts as backup this relay acts backup for the fuse but not the other way means fuse should not be backing up relay. The relay characteristics best suited for coordination with fuses is the extremely inverse characteristics because it is similar to I^2t characteristic of the fuse. The pickup setting of the relay (primary side of the CT) should be approximately or around the three times of the current rating of the fuse. So, these are the guiding factors for coordinating within relay and the fuse.

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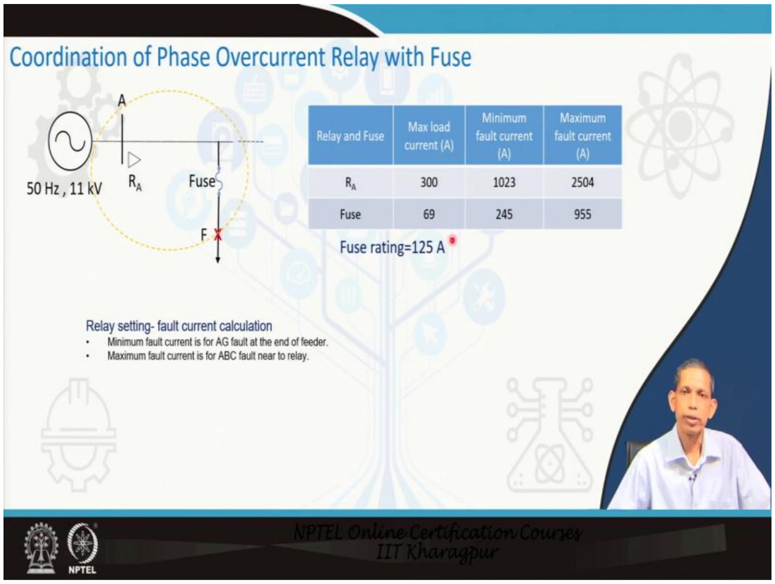

So, let us take an example to see how the corresponding phase overcurrent relay is being coordinated with fuse. So this is the system, part of that we are talking about for coordinating between one fuse and one relay. However, we can have several such fuses and relays in the system. For simple applications we are saying that the relay and fuse here, just like earlier coordination we talk about maximum load current then minimum and maximum fault current aspects. So, this are load perspective and this is obtained from the system simulation as we have already mentioned minimum fault current from the remote end line to ground fault also and then maximum fault current is a three-phase fault at the close to the particular bus where coordination is to be accomplished. So, these data sets are available including the fuse rating for the system, in this case fuse rating is 125 A. So, with this we will proceed how this coordination that the characteristic of the relay R_A can be selected based on this data for the system.

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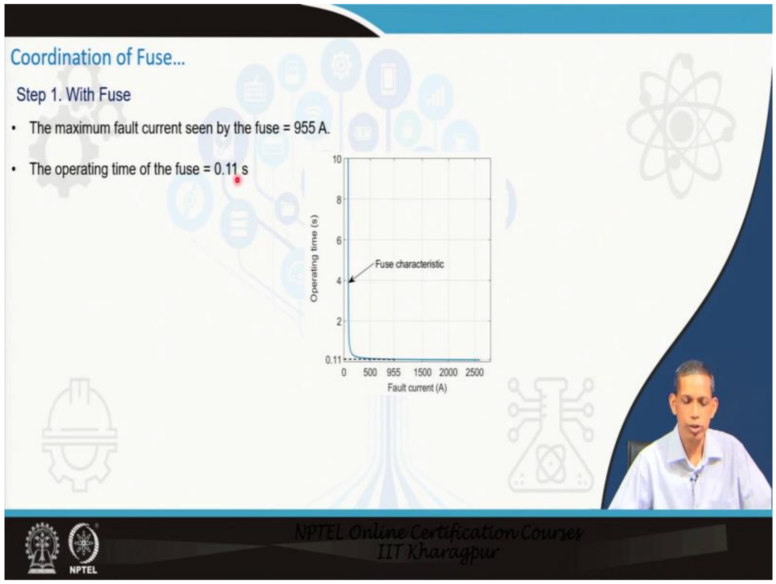

So, the fuse characteristic for this 125 A is available like this now for this fuse the maximum fault current seen as in the given data is 955 A, therefore for the 955 A the corresponding time is 0.11 s that is what we obtained for the coordination business.

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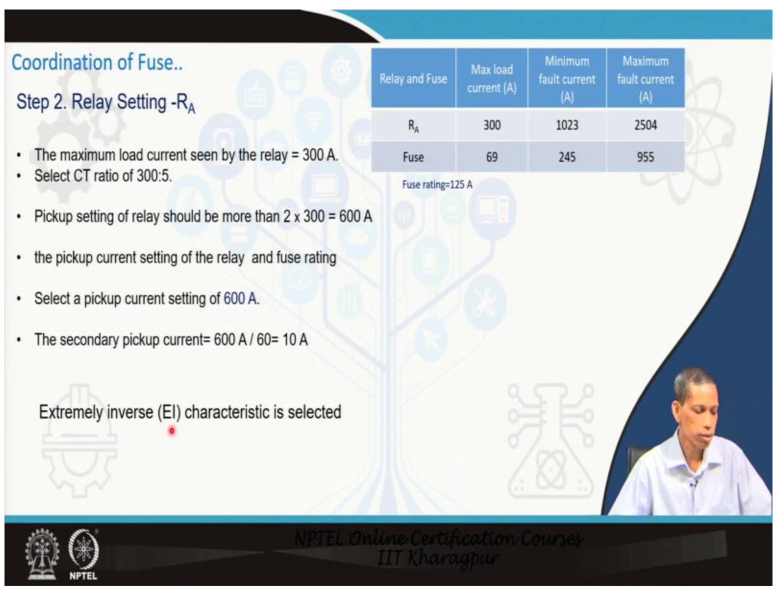

I will go to the relay perspective R_A the load of 300 A so you picked up a CT of 300: 5 you can take 300:1 also. Or suitable to that pickup setting for the relay should be twice of the full load that is around 600 A that the pickup current setting of the relay and the fuse rating based on including the fuse rating perspective, we will selected a pickup setting for the relay in the primary side to be

600 A. Therefore, we have CT ratio of 60, pickup current for the secondary happens to be 10 A. Now as I already mentioned that we pickup extremely inverse characteristics for the relay.

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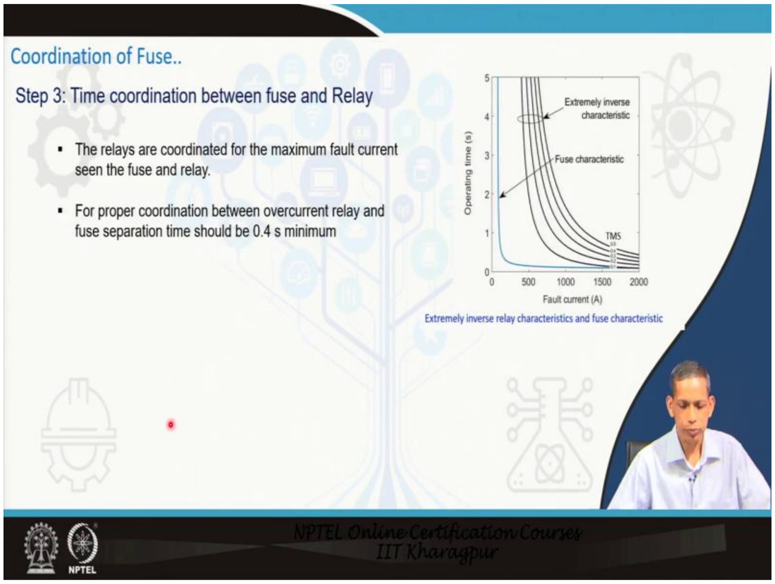

So now from the set of curves available from the relay for extremely inverse characteristics fix into the coordination perspective. So, this operating time or the fuse is like this will coordinate so for coordination here the corresponding minimum coordination time that should be 0.4s that means there we should have minimum 0.4 s or above that.

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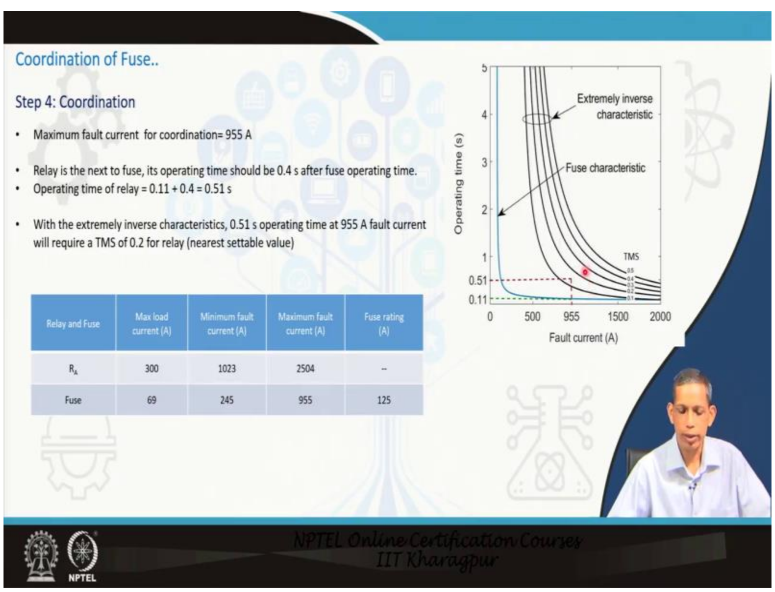

So with this we will go for the coordination that will be for the maximum current for the fuse which is 955 A. So for fuse we have already obtained 0.11 s. Therefore, if we add 0.4 s also for this same 955 A, maximum current of the fuse, the relay time should be at least 0.51 s that is

$$0.11 + 0.4 = 0.51 \text{ s}$$

then we have relay characteristic like this for the different time multiplier setting 0.1 through 0.5 that is available in this set; therefore, you picked up for the 955 A and the corresponding 0.51 s and above that is you consider a nearest settable value, that happens to be 0.2 TMS from the extremely inverse characteristics.

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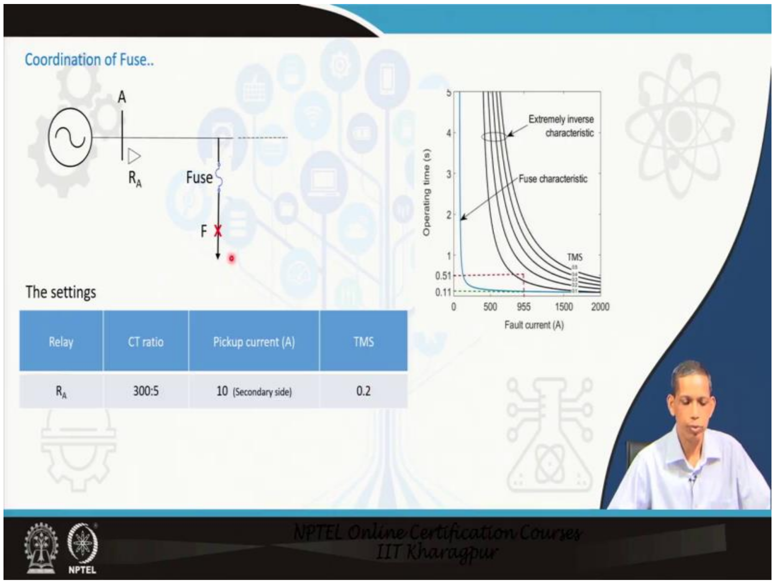

Relay	CT ratio	Pickup current (A)	TMS
R_A	300:5	10 (Secondary side)	0.2

So finally, we say that the coordination between this fuse and this R_A for the system as per the data available, the relay R_A should have a CT ratio of 300: 5, pickup current of the secondary level is 10 A, and at primary level it is 600 A and the time multiplier setting for the extremely inverse characteristic is 0.2. So this is the coordination between the phase relay and the fuse as we have seen for this example.

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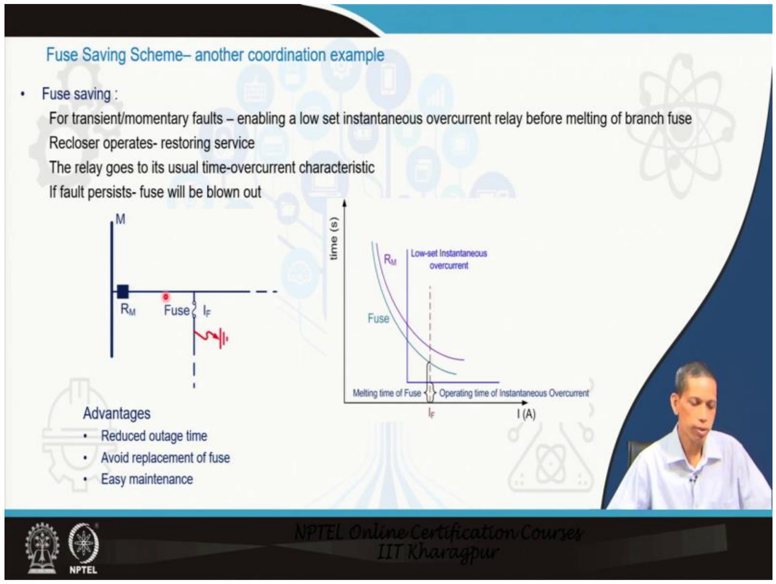

Now, we will go further on how this coordination can also be applicable for this fuse saving scheme. So, let us first appreciate what is fuse saving business and then how the coordination is being applied in that perspective we will see as an example. Now, what happens most of the faults in overhead lines as we have already discussed earlier are transitory or momentary in nature, they come and vanish of their own. Therefore, consider this system, here this is a lateral where we have a fuse, if a momentary fault happens to be here then there is a chance that the fuse will be blown out, but being that is momentary is not desirable because unnecessary fuse blown out would be there and then the crew people will come from some places for maintenance of this, so the restoration will take time which becomes an interruption perspective, not desirable from the customer point of view. So, to avoid that what is being done assuming that most of the faults are transitory in nature in the system. This relay solves the issue using a different characteristic and that is what we call the fuse saving scheme. Now, we will see in this perspective what is being done that this relay uses first an instantaneous characteristic which acts very fast and with that the recloser operates before the fuse is been blown out and the service is again restored if the fault still persists, then this fuse will be blown out because after the fast instantaneous characteristic the relay goes to its usual time current characteristic. So, now let us from the characteristic we can see here if this is the fuse characteristics and this the relay characteristic as usual, which we see earlier in the coordination perspective. Now what we do that we add another relay characteristic which is the instantaneous overcurrent. So, by this way what will happen suppose your fault happens to be there in this lateral which is been taken care by the fuse. So, this instantaneous characteristic takes for that fault current this much of time therefore the relay at here will open the breaker here, before the fuse starts melting. So, this fuse operating time is higher than the time taken by the relay of instantaneous characteristic and then the breaker will open before the fuse starts melting. After certain interval the breaker will be reclosed considering the fault during momentary and thereby this service can be restore automatically. So, it means that if the fault is transitory or momentary the fuse will not be blown out. So, we save the fuse and also there is no need for the crew people to go for that repairment. However, if the fault is a permanent fault the objective that this fuse must be blown out before this relay otherwise whole system will be hampered. So, in that sense after the first event the recloser operates once or twice, the relay characteristic switches from this characteristic to this one and if the fault persist here the fuse will be blown out and this objective of protection system satisfy in case a fault happens to be here, first the instantaneous will be operate and open this one and reclose and because this is not fuse issue. Therefore, fault will be seen by this afterwards characteristic and then the relay R_M will successfully intervene for the fault at this point also. So, this is what in general we see that we have advantages in this scheme that it reduces the time outage for the laterals, avoid replacement of fuse in most of the cases because of the transitory nature of fault, easy for maintenance people also because we may not sending crew people for this purpose. So, this is called fuse saving schemes, many utilities use such scheme for the better management of the distribution system.

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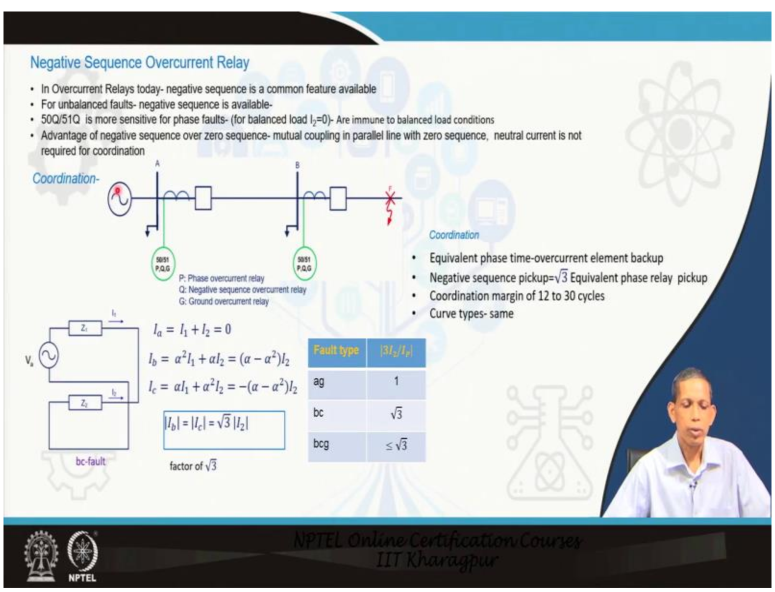

Now, we will go to another perspective of overcurrent relaying principle. So, we have earlier learned that how sequence components can be computed and we have mentioned there that sequence component are also useful in relay decision process. Many overcurrent relays today are having the features of negative sequence overcurrent principle, so we will see how that can be applied and how that has been beneficial in this slide.

We know that for all unbalanced faults negative sequence component is available, because we also know that for balanced case whether it is fault, balanced fault or balanced loading then negative sequence current component is zero. Therefore, in overcurrent instantaneous or time overcurrent 50Q or 51Q the Q stands for negative sequence 50Q or 51Q means overcurrent negative sequence can be employed for unbalanced fault because negative sequence components are available during those periods. These are such an approach has an advantage as you know that normal operation time the system remains balanced so negative sequence component will be zero or small amount. In case of an unbalanced fault negative sequence components becomes significant like we notice for ground relays, the zero sequence component becomes significant when there is a ground fault. Therefore we claim that ground relays are more sensitive than phase relays similar situation happens to be for unbalanced fault where the negative sequence component is more sensitive than phase relays. So this negative sequence relays are also immune to balanced load condition during balanced condition no negative sequence current. So even the load grows also it will not be tripping unlike case of a phase relays or so. The advantage of negative sequence over zero sequence is that in case of a parallel line the mutual coupling of zero sequence component may dominate whereas there is no mutual link for the issue for the negative sequence components and that raise to one of the advantages.

Neutral current is not required for coordination, zero sequence require, zero sequence component is being, can be computed from the three phases I_a, I_b, I_c or you required the neutral connections by a neutral CT. if you have neutral CT then coordination becomes easy for the zero sequence component but such requirement is not there for the negative sequence component. So negative sequence component can be useful for phase relay specifically and also can act backup for zero sequence based relay that is ground relays. Now see how these relays can be coordinated and how this can be applied to the system, so we will have a glance on this. So these are two buses and we have one relay set with circuit breaker here and set of relay here for this circuit breaker here, so we need a coordination between these two so this is downstream. So, this relay is to fix first and then this relay is to be coordinated with this because this relay at this one should backup this relay. You see here this *P*, *Q*, *G* here; *P* for phase, *Q* for negative sequence and *G* for ground so at each point we have *P* and *G* as already mentioned earlier *P* for phase relays and then ground relays are the usual components. Now you are ready, you can say that *Q* also the negative sequence component for the 50 or 51 overcurrent principles. Now what we say here some of the situation, let us say this is a *bc* fault then for the phase relay we can have the sequence component for the equivalent network from bus A to onwards, so phase *a* voltage and then we have the Z_1 the equivalent impedance from this part and Z_2 the equivalent impedance of negative sequence path and they are in anti-parallel so I_1 positive sequence current and I_2 the negative sequence current. For this *bc* fault and in phase *a*, we can write down as

$$I_a = I_1 + I_2 = 0$$

Yes for *bc* fault I_a current will be zero, subsequently fault component of current in phase b and phase c can be obtained from

$$I_b = \alpha^2 I_1 + \alpha I_2 = (\alpha - \alpha^2) I_2$$

$$I_c = \alpha I_1 + \alpha^2 I_2 = -(\alpha - \alpha^2) I_2$$

That we have learned from the sequence component analysis. Therefore, from these two relations we say that the corresponding magnitude of I_b and I_c to I_2 are related by

$$|I_b| = |I_c| = \sqrt{3}|I_2|$$

This √3 coming from the $(\alpha - \alpha^2)$ term. So there is a factor of √3 to negative sequence component and for phase to phase fault the phase current has relation of √3 this factor should be useful in the coordination of negative sequence relay perspective. Note that the negative sequence relay has to be coordinated to the relay at this end also and that is for the phase relays. So for coordination what you have to see that the equivalent phase time overcurrent element backup. So we have because we are backing up this relay will be backup up to consider this one, so we will concern about that the phase relays at this point, that is what we are talking about. Negative sequence pickup equals to √3 times equivalent phase relay pickup. You see for *bc* fault we talk about this √3 factor for *bcg* fault its comes out to be less than equals to √3 and for *ag* fault this $3I_2/I_p$ comes out to be 1 where I_p is the phase current and I_2 the negative sequence component overcurrent. So you can see this happens to be this. In overall from this perspective the corresponding relation for negative sequence pickup becomes equals to √3 time equivalent phase relay pickup so whatever phase current I_b I_c or I_a will be there √3 times that will be the negative sequence pickup current that is $3I_2$. The coordination margin as usual, again comes out to be 12 to 30 cycles just like in phase overcurrent coordination which we have seen earlier and the curve types same as the phase relays has been used, here similar curves will be there in this perspective. So we see that negative relays sensitive than the phase relays, that is what today many overcurrent relaying principles in cooperate negative sequence relays also.

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So, overall in this overcurrent relaying part we see that the overcurrent relay is very much useful for distribution system protections but this overcurrent relay principle also is being applicable to transformer generator, motor, busbar and all. The fundamental thing is that for any short circuit the current becomes high usually the fault distance is small so that is the basic principle which is being actual, technological development process used today also for different application transformer, generator, motor busbar and so many other application. In case of in many such applications either the overcurrent principle is used as primary or as backup again these overcurrent principles instantaneous, time grading and all varieties of characteristics are being employed for successful protection scheme in power system, thank you.