Power System Protection
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Lecture No. 31
Adaptive Distance Relaying

Welcome to NPTEL course on power system protection; we are continuing with distance relaying. In this lecture it will be on adaptive distance relaying.

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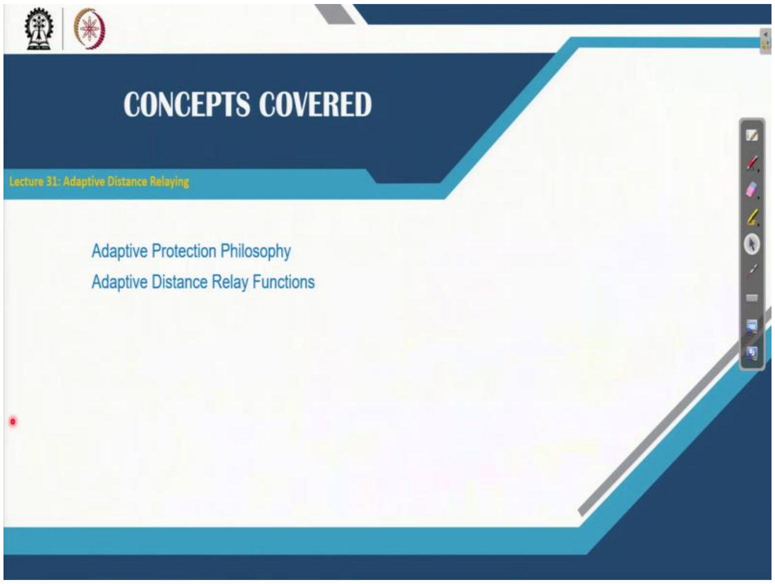

We will be covering two aspects. The usual, the philosophy of adaptive protection and how the different distance relay functions can be made adaptive.

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The philosophy of variety protection; we have discussed earlier also to have more clarity. A protection philosophy, which permits and seeks to make adjustment automatically in various protection functions, in order to make them more, attuned to prevailing system conditions. So, what you mean here that we will see through demonstration that at different system conditions, the setting requirements will be different. So, what we have learned is that we consider a fixed setting, but at times that may not be adequate.

So, therefore that the protection functions, if they can be automatically attuned to prevailing system condition; then you can achieve better performance on relaying. And will see how the distance relay can be made adaptive, remain adapts to situations.

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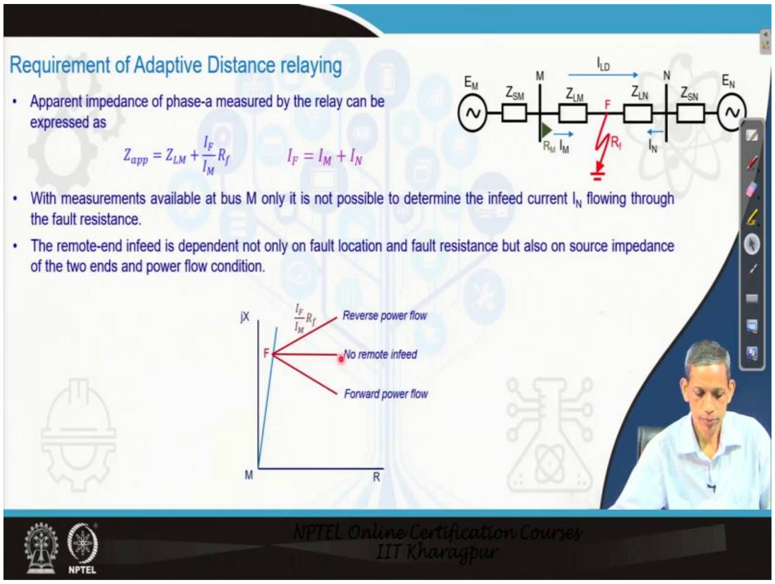

So, let us first appreciate that what are the issue with the conventional fixed setting approach; and then will see how we can achieve adaptive settings. Now, we see here that this is a two-bus interconnected system, and we have relay at R_M the distance relay we consider, a fault in the line at F with R_f. If you remember most of our derivations we started with that considering R_f to be equals to 0. Whenever R_f is to be 0, the fault point voltage becomes 0; so therefore this relay bus voltage becomes the drop in this line.

But, when R_f happens to be there and we have sources on the right hand side also; so for any fault, the corresponding current flows from this side, and also from this side. And the summation of current will be through this R_f part. But, now with presence of R_f, the fault point voltage is no more 0. And therefore we can say that this voltage the fall point voltage depends upon the current infeed from the remote side also. So, that is that in earlier most of the derivations we consider that R_f is 0; and therefore we can say that the fault point voltage becomes 0 and so on.

Now, with that scenario, if we can say that the corresponding Z_{app} becomes the positive sequence impedance, of what the line sees at for this fault, plus $\frac{I_F}{I_M} \times R_f$. So, that leads to the corresponding situation, because at this point, voltage becomes equals to $I_F \times R_F$. So, that leads to that the earlier R_f was 0, so we are getting consider position impedance up to the fault point perspective; this Z_{1LM} and so.

Now, in the presence of R_f and then infeed, which leads to such a current ratio. And where this R_f is you consider that current fault current through the fault path; that becomes I_M side and the I_N perspective, so that is the contribution. With measurements available at bus M, only it is not possible to determine the infeed current I_N. So, this we need to say that for I_F calculations, so we need this this; to have we can say that the current to say that Z_{1LM} calculations.

From the calculated Z_{app}, if we subtract this part; then only we will get the positive sequence impedance up to the fault. And then we do not know also this corresponding R_f also. So now what happens that, that creates problem; that leads to inaccuracy in the Z_{app} calculations, as compared to the, positive sequence impedance up to the fault. Now, the remote infeed depends on you consider the fault location. The remote infeed how much I_N compared to I_M that matters to us, in this ΔZ or the error tripping into this Z_{app}. That the corresponding I_N depends on the fault position, the resistance of the fault, the fault resistance in that perspective; and the corresponding source impedance of the SN.

Now, if you see a situation, so what is being observed? That if this you consider on the R-X plane; if this is the line impedance and this is the fault point here. So, in earlier case if we think about any fault resistance R_f; so we are putting simple parallel line with respect to R axis. And we say that because we are considering no infeed, no infeed no source; we are cutting a radial system and then if we add we consider that a fault resistance; then the R_f we considered was error to consider that each point we consider, we can add each point of the line. We can add R_f in a horizontal axis.

Now, however if the corresponding I_F/I_M happens to be there. So, the corresponding that depends upon that situation that the corresponding free fault load condition is flowing from M bus to N bus or N bus to M bus. So, this is forward power flow for this relay; and this is the power flow from N to M becomes reverse power flow base.

So, 3 situations we see here with R_f value in this kind of interconnected system; with no remote infeed from this side, just like radial. What we discussed? If this is your this horizontal line; now with power flowing from M bus to N bus. Then we see that we can see that the forward power flow; so this may consider that depending upon the amount of power flow and other conditions we will see. The corresponding Rf addition will not be no more horizontal; it will be trending towards downward to this horizontal line. And in case a power flowing from right to left for this you consider that the relay. Then the reverse power flow, it will be upward trend as compared to the horizontal line, which we consider for the no remote infeed.

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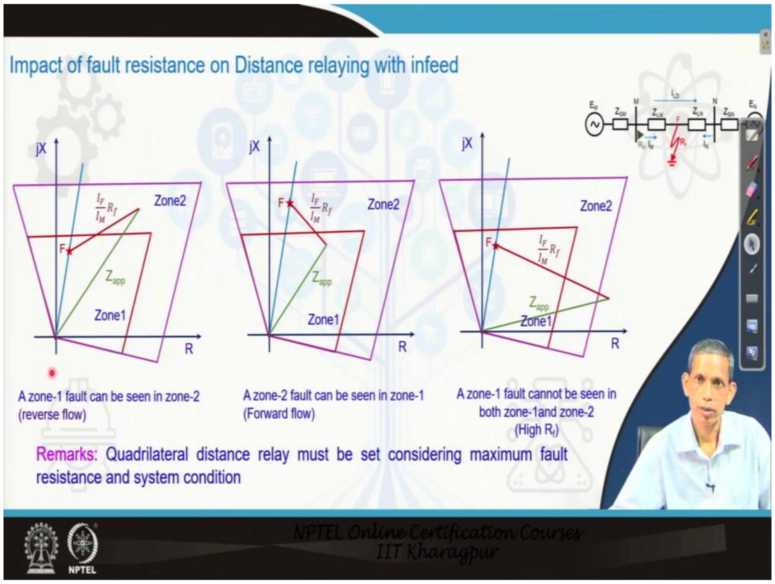

Now, let us consider that for this system; if you consider quadrilateral characteristics, in this characteristic we see here RX plane, so this is zone 1 and this is zone 2. Now, I will consider that the corresponding fault point you consider that the mark F here, in all the three figures. So, if we can say that the now for a zone 1 fault first case, zone 1 fault; and then the I_F/I_M.

So, that you consider that factor consider that will be added to this system for a given R_f value. In that case you consider that the in a reverse power flow situation, this zone1 fault maybe seen in zone2; so, this may you consider as Zapp point. So, that you consider that it means that zone 2 will be a delayed the condition decision. So, even in zone 1 for you consider that it will be observed in zone 2, and relay you consider that will be taking a decision with a delayed one; which is not desirable.

Now, take the case of second case, fault in zone 2 remote fault; and in that case consider that the let us say consider that forward power flow, as usual this direction of power flow is I mean. So, what will happen that this is you consider that zone 2 point actual one; but with the forward flow power flow directions. Then it will be downward, and zone 2 fault maybe seen in zone 1 . This will be apparent impedance seen at that time.

So, the third case with higher you consider that R_f value, what will happen that if this is a forward the direction power flow is happening and lay downward. Then even you consider that it is it is a zone 1 fault also, we see here we consider that with a large value of we can say that the R_f. If there is not taken care in the zones; it maybe observed in the zone 3 also in that case.So, therefore what happens that because we have we can say that fixed setting of R_f coverage thinking that this will be cover this much, but depending upon the power flow condition that may not be the boundary; there may not be the adequate to adjust the solutions.

So, from these 3 plots; we see we consider that that is chance that the corresponding relay may malfunction or it will be a delayed decision. Then the reason in that we say the infeed to the system, the high value of R_f and so on. And the reverse power flow or the, I_M say that forward power flow are also the governing factor, on the modulating the apparent impedance; compared to the Z_1 up to the fault point.

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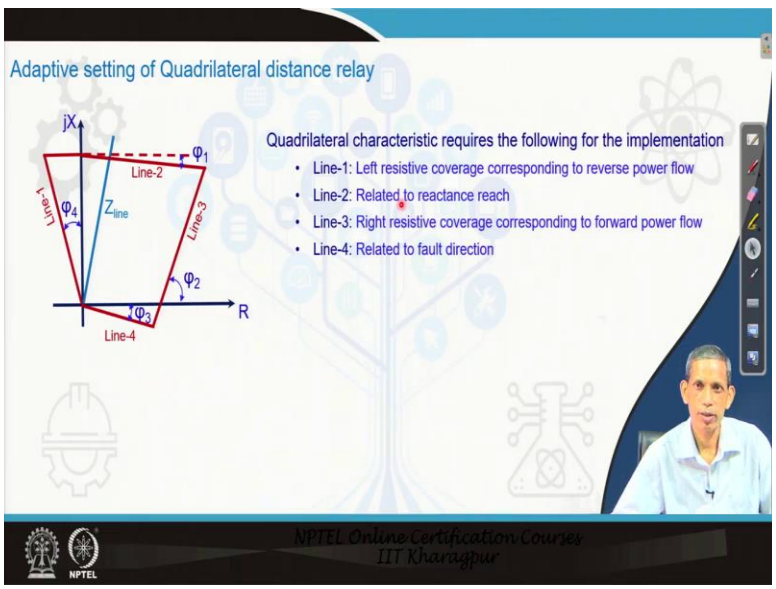

Now, that means that the fixed boundary approach is not proper; so you require to consider that some mechanism to adjust the solution for that one, to improve the performance in that respect. Only when you see the distance relay perspective, we know that the relay avails the local data; unless otherwise there is a communication system to provide more information to the relay.

Now, when you say that the, to address that as you have already pointed out in the adaptive concept, adaptive relaying concept, one approach you consider about these the changing the setting, depending upon the system condition at that moment. There are other approaches also, in the measurement process you can change the approach of the measurement process will see also. Or also not only setting perspective; you can change the corresponding characteristics also. Or, you can switchover from one characteristic to the other.

So, there are different approaches available today in different relays; to adjust the different better performing relays by adapting the different functions. So, we will see we can say that how the in the distance relay perspective, this adaptive relaying concept can be can be used, can be applied to improve the performance. Many relays today possess the different kinds of adaptive features. Now, let us say consider this quadrilateral characteristic which is being widely used in relays.

We have already seen this discussion at the starting point of the distance relay. So, these are the different the lines, so we require for the quadrilateral 4 lines: Line -1, Line-2, Line-3 and Line-4. These 4 lines are the parts of the quadrilateral characteristic, and that characteristic you have considered and then we have Z_{app} calculations, based upon the voltage and current. And based on that these two we consider that the relay decides whether to trip or not to trip.

The quadrilateral characteristic we can say that what we see that in the earlier discussions, it needs to we can say that should not be fixed; it should be adapt to the situations, we will have more elaborations on the later slides. So, these 4 lines what they mean here we see here to realize is we can say that the quadrilateral characteristics. Line-1 this line is beyond this we can say that this x-axis towards left, left hand side.

Left resistive power corresponds to reverse power flow; so that this is nothing but to the reverse power flow happens to be there, so, we need essentially shifting of the left boundary, we can say that to the left we can say that to the jX also. This is assuming the corresponding maximum reverse power flow, this is in general set. Line-2 related to reactance reach, so Line-2 we can say that this line tells us about that the reach of that in terms of the reactance; and that is also very important in that perspective.

Line-3 for this line, the resistive coverage corresponds to forward power flow; so for forward power flow, this Rf coverage is taken care by the Line-3. And Line-4 or tells us the direction of fault. So, for any forward fault this will this side will be there; and that what at we consider Line-4 depicts this characteristics.

So, these all the 4 lines have their own role , what we say here in that perspective and all these things. So, so from adaptive feature perspective we can say that what can be done using the local information we will see later.

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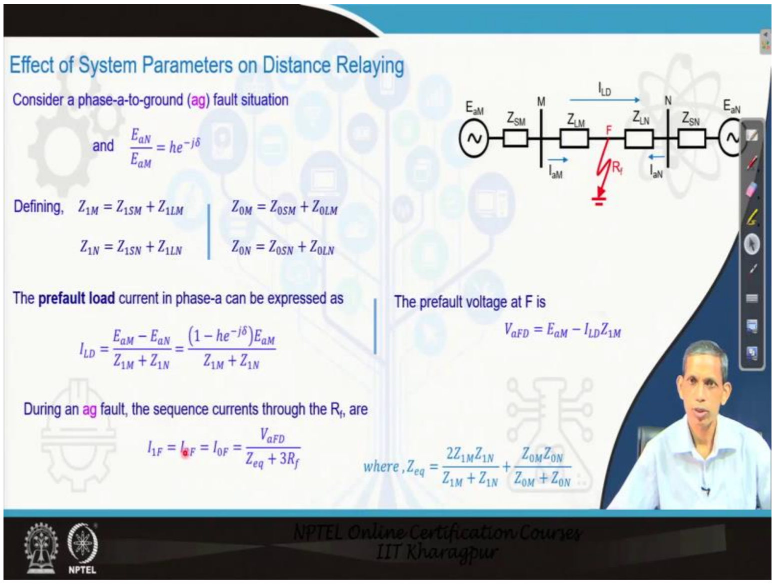

Now, let us first see how this corresponding quadrilateral characteristics is being modulated, by the different variations in this system parameters. Same two bus systems M-bus, N-bus and we have we can say that relay, we can say that at M-bus and will observe we consider the fault consider here. So, we will to make a generic we will say that we are considering now phase a to ground fault situations and here we can say that the corresponding derivation for a apparent impedance. And how this apparent impedance is being affected by you consider that this term in the different system parameters; will have the derivations in general.

Now, let us consider the internal voltage at bus, bus a source equivalent source that means equivalence upon the source; and then you can consider that the internal source at the bus N. The voltage ratio of this two phase a voltage, $\frac{E_{aN}}{E_{aM}} = he^{-j\delta}$. So, it means that you are considering here that at M the power flowing from left to right, as you see here the power flow condition. So, this M was having a positive angle with respect to N-bus.

So, that condition you can consider that we are considering this ratio; but at times you consider that power flow being from this side to this side, so in that case, δ will be negative. Now, we are defining few terms here, let us say Z_{1M} at this bus, positive sequence impedance at this bus, Z_{1SM} of this one plus Z_{1LM} up to the fault point. So, this from F you can say the source equivalent source, so this impedance we consider that it is defined at Z_{1M}.

Similarly, Z_{1N} you consider that the impedance at this part, plus this part; what is you can impedance is Z_{1N}. And similarly, Z_{0M} and Z_{0N}, so there also we consider that from this point fault point to the left hand side, we call it Z_{0M}; and fault point to the right hand side, we call it Z_{0N}. They are some of the source voltage impedance; plus the fault path impedance in the line Z. The prefault load in this condition will be nothing but this internal voltage minus this internal voltage, upon the series impedance. $I_{LD} = \frac{E_{aM} - E_{aN}}{Z_{1M} + Z_{1N}} = \frac{(1 - he^{-j\delta})E_{aM}}{Z_{1M} + Z_{1N}}$. Now, note that the prefault voltage at F now from this relation, because the current flowing from I_{LD}. $V_{aFD} = E_{aM} - I_{LD} Z_{1M}$

So, this balanced system positive before the fault, so only positive sequence diagram will be there. So, considering that you consider the V_{aFD} at the fault point voltage in phase a, will be consider that will be internal voltage in phase a, minus you consider the drop in the system. The drop in the system is Z_{1M} into prefault current. For ag fault, we know we consider that this positive sequence, negative sequence and zero sequence all sequence network will be connected in series. And because this is R_f, so there will be $3R_f$ considerations here.

So, therefore all we can say that through the fault path, the corresponding positive sequence current, negative sequence current, and zero sequence current will be same, for fault path. $I_{1F} = I_{2F} = I_{0F} = \frac{V_{aFD}}{Z_{eq} + 3R_f}$ and Z equivalent is nothing but this positive sequence equivalent seen from the R_f side. So, that leads to we can say that from F point, if we can see you can that where the corresponding $3R_f$ will be connected. So, this side and this side so they will be parallel, for both positive, for positive/negative and so also for the zero sequence component.

So therefore, the Z equivalent becomes equals to positive, negative and zero in that parallel path equivalent. But, we know you considering we have you have consider here that the positive impedance, positive sequence impedances and negative impedances are same; both for sources and lines. $Z_{eq} = \frac{2Z_{1M}Z_{1N}}{Z_{1M} + Z_{1N}} + \frac{Z_{0M}Z_{0N}}{Z_{0M} + Z_{0N}}$.

So, I told you consider that that because the corresponding sequence diagram, for zero sequence will be having two parallel paths; left and right at the F point. For that is why we consider that in equivalent impedance of this side. So, this total equivalent you consider that will be that impedance; plus $3R_f$ will be the corresponding for the Line-2 fault case will be the total impedance. And the voltage upon that impedance gives you the corresponding to the positive, negative and zero sequence current; all are same for Phase a to ground fault.

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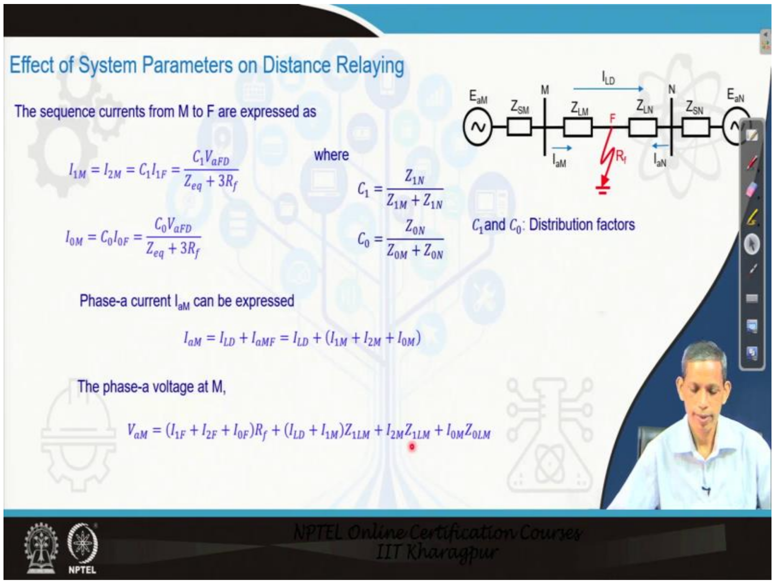

Now, moving forward, consider the corresponding current from the relay side, if we know the corresponding I_{1M} and I_{2F} and I_{0F}. So, if you know the impedance ratio; $I_{1M} = I_{2M} = C_1 I_{1F} = \frac{C_1 V_{aFD}}{Z_{eq}+3R_f}$; where $C_1 = \frac{Z_{1N}}{Z_{1M}+Z_{1N}}$. C_1 is the corresponding distribution factor from the fault current which we are trying to figure out from how much is the contribution from M side. I_{1M} is obtained by replacing I_{1F} by the voltage upon the corresponding impedance. Similarly, the zero sequence current from the M side (I_{0M}) is obtained usuing the zero sequence distribution factor C_0. $I_{0M} = C_0 I_{0F} = \frac{C_0 V_{aFD}}{Z_{eq}+3R_f}$; where $C_0 = \frac{Z_{0N}}{Z_{0M}+Z_{0N}}$. Phase-a current at I_{aM} is summation of the positive sequence, negative sequence and zero sequence current in addition to the prefault current I_{LD}. So, $I_{aM} = I_{LD} + I_{aMF} = I_{LD} + (I_{1M} + I_{2M} + I_{0M})$.

The phase-a voltage at M, $V_{aM} = (I_{1F} + I_{2F} + I_{0F})R_f + (I_{LD} + I_{1M})Z_{1LM} + I_{2M}Z_{1LM} + I_{0M}Z_{0LM}$ So, you consider here positive sequence and negative sequence impedance as to be same.

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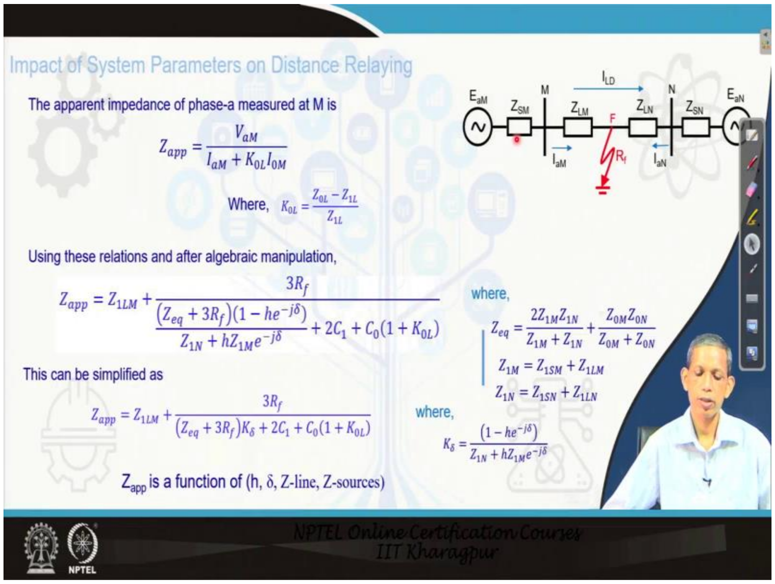

Now, moving forward, because this is phase-a to ground fault, $Z_{app} = \frac{V_{aM}}{I_{aM}+K_{0L}I_{0M}}$; where $K_{0L} = \frac{Z_{0L}-Z_{1L}}{Z_{1L}}$ is the zero sequence compositing factor. Using these relations, if you substitute what you have already derived for the voltage and the corresponding current. Then with manipulation, $Z_{app} = Z_{1LM} + \frac{3R_f}{\frac{(Z_{eq}+3R_f)(1-he^{-j\delta})}{Z_{1N}+hZ_{1M}e^{-j\delta}}+2C_1+C_0(1+K_{0L})}$ where Z_{1LM} is the positive impedance within M to F plus a ΔZ component which is a modulating component in the presence of $3R_f$. So, earlier we are talking about in our discussions that R_{f0} means this factor you can say become 0. Now, this also depends upon h and the δ. And this C_1 and C_0 are the distribution factors, depending up on this side source impedance and so; and K_0 is that zero sequence compensating factor.

So, upon simplifications we can write $Z_{app} = Z_{1LM} + \frac{3R_f}{(Z_{eq}+3R_f)K_\delta+2C_1+C_0(1+K_{0L})}$ where $K_\delta = \frac{(1-he^{-j\delta})}{Z_{1N}+hZ_{1M}e^{-j\delta}}$. And we have already defined Z equivalent, Z_{1M} and Z_{1N} in the earlier slide. So, that means that Z_{app} is a function of h, δ, Z-line, Z-sources; and also the R_f.

So, that creates problem that our usual assumption was that the Z_{app}, is a function of two we can say that the corresponding only the Z1LM and so. Now, now we can say that it is a function of Rf, also the function you consider the h and δ. h and δ are nothing but the magnitude of the corresponding voltage at the other end equivalent; and also this angle the deviation with respect to this side internal voltage. And the all the sources, impedances local, actually the remote end sources also and the line impedance.

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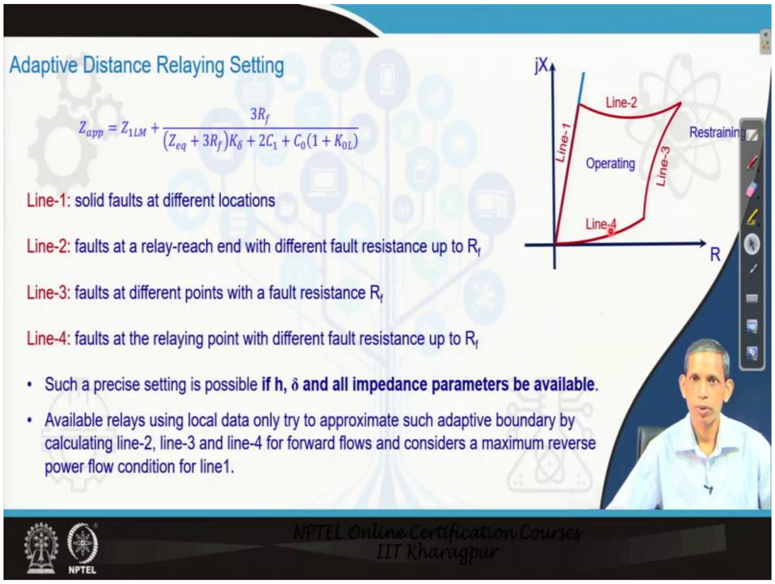

So, this you consider from this perspective if we again revisit the corresponding 4 lines which we are earlier talking about in terms of directions, in terms of reverse power flow; in terms of the forward power flow, in terms of the reactance series and so for these 4 lines. So, Line-1 is solid faults at different location, no R_f, this straight line. Line-2 falls at a relay-reach end with different fault resistance up to R_f; so at the relay-reach, you can get this , go on increasing the R_f value, for a given operating condition.

Faults at different points with a fault resistance R_f, and then such a precise setting a fault, a relaying point with different fault resistance. You see that fault at the relaying point, local point and only change upon on changing the Rf. So, these are the variations for the 4 lines, by which you can trace out the given relation like this.

Such a precise setting for a given condition for this one; depends upon these 4 boundaries. Then whenever a fault current what happens to the line, that the fault point will fall inside this one; so, that is what expected. So, that is why these 4 lines stated with respect to this equation.

Now, as regard to that if we like to can say that have this equations to create the required boundary; then you require essentially h, δ and all impedances in this one. And also how much

R_f coverage we like to do for this case. So, that means that the, it is not only the local parameters; it also the remote bus parameters, source impedance and the corresponding voltage magnitude and angle with respect to this. The voltage magnitude and angle is indicative of the corresponding load flow, current and so that maybe in some perspective.

But, however we consider the relay uses local data; assuming that if it is does not have the data from the remote end. Then what you see here, in general the Line-2, Line-3 and Line-4 are the for the forward power flow. And consider a maximum the reverse power fault current conditions, to the Line-1. In earlier we discussed that the Line-1 gone by the reverse power flow, so expecting maximum reverse power flow; the line was in being set.

And Line-2, Line-3 and Line-4 are set in terms of this forward power flow conditions at that time. So, we know what is the corresponding load condition the I_{LD} for the forward path perspective, and accordingly this boundary is being set.

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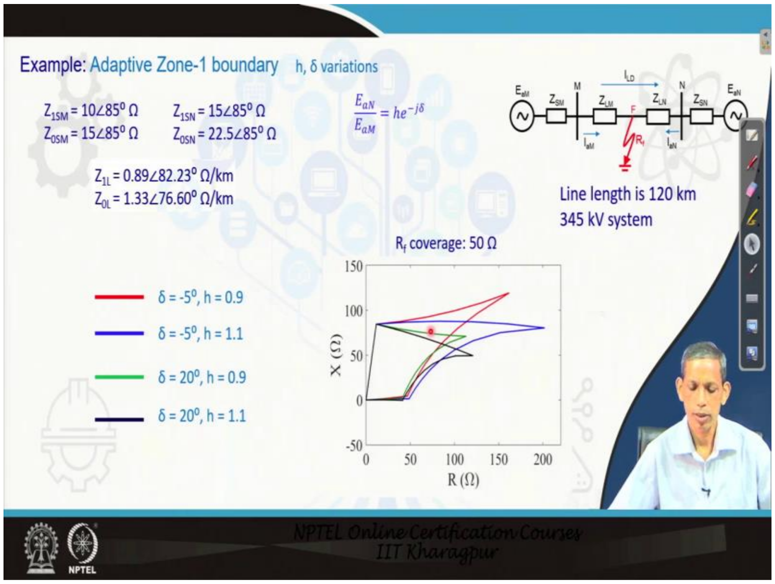

Now, let us consider that take a two-bus systems, 345 kV systems, 120 kilometer length; and we will try to understand how how the parameters of the system affects the boundary of the quadrilateral characteristics. So, we know $\frac{E_{aN}}{E_{aM}} = he^{-j\delta}$; and we have we can say that h and δ variations here first case. The other system parameters maybe same.

So, we consider this side source to giving 10 and 15 positive and zero sequence impedance. This way also we have positive sequence impedance equals to negative sequence impedance. The remote side positive sequence impedance and negative sequence impedance $15\angle 85^0\Omega$ and zero sequence is 22.5∠85° **Ω**. And then line impedance, zero sequence impedance and the positive and negative are same. So, we have consider in terms of this and then we checked what happens to the boundary, the characteristics.

So, we have 4 variations we have taken; one is the corresponding δ = -5°, h = 0.9; δ = -5°, h = 1.1; δ = 20°, h = 0.9; and δ = 20°, h = 1.1. So, δ positive means consider that power is flowing from this to this forward power flow; and δ negative you can consider that power flow is from the reverse. So, for reverse power flow, two conditions red and blue; and the forward power condition green and consider black.

Now, from here if you clearly see that with respect to horizontal axis on the R axis; the green and blue that is you consider for the power flow forward power flow. They are bending in the downwards side, and red and blue you consider that they are in the upward side for the reverse power flow cases. In addition to that what you from this result you noticed for this R_f 50 ohm coverage only, that there is a variation you consider that in the impedance boundary, for angle positive angle to negative angle and also on the same magnitude ratio also; point end and point 1, red and the blue; so, you consider that there is variation in area you can say in terms of that. So, now from this conclude that the system conditions h and δ variations only; also modulate the corresponding boundary significantly. So, in terms of that if the boundaries not set in accordance with that; you may have to compromise performance of the distance relay.

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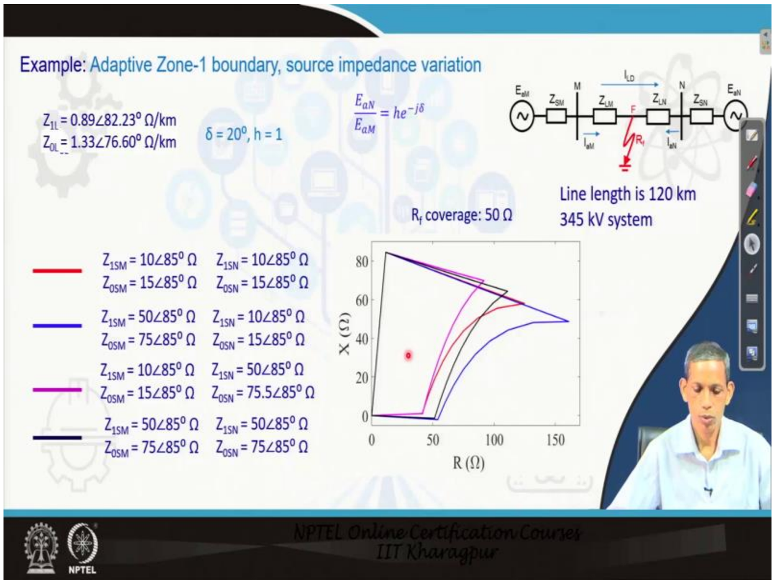

There is another example here same system, same R_f value of coverage of 50 ohm maximum; and then we see here taken a fixed $\delta=20^O$ forward power flowing, h=1, magnitude ratio same. And now what we have derived you consider that the source impedance variation. So, we have varied consider the local source impedance magnitude, and remote source magnitude. First case the red one you consider that both are have the same strength, this side and that side.

So, positive and zero sequence, you can mention same; so this red part. So, both you consider same, we see it here at the boundary; and this for forward power flow. So, that is why it is downward the direction this part. Next case, higher value we can see that local impedance, source impedance; and smaller value of the remote impedance. So, we have very strong source this side and lesser strength source in the local side. So, that means that you consider that we see here now blue one is consider this. We see here as compared to the red one first, both having same strength and better strength.

Now, with a lesser strength with local side, the corresponding boundary changes in terms of the blue. Third case we say the local one is stronger than the remote one; then we have consider that this boundary and that different than the red one. And now consider the final case both the both are having higher impedances, strength is lower; so that becomes is this the black one. So, that means that so we conclude from here that the source depending upon the source impedance is also corresponding tree boundary. So, the black we can say that better performing relay, then it should also address is the corresponding source impedances, also from both ends.

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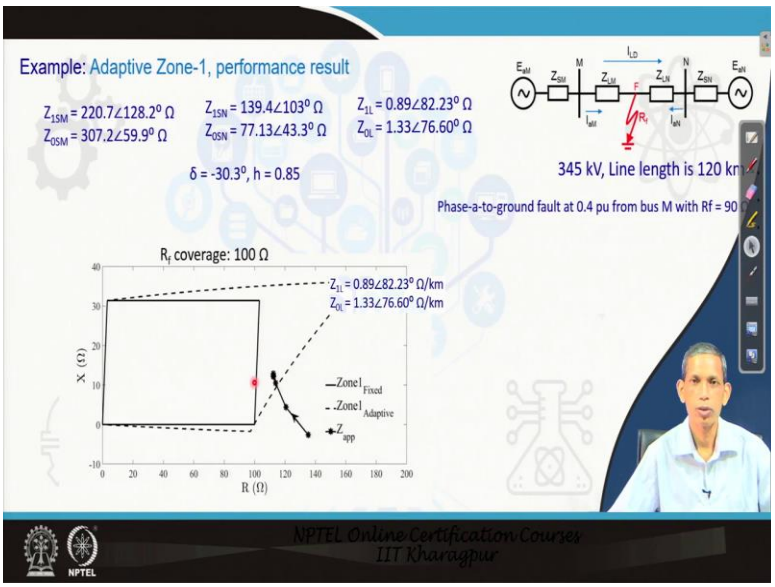

Now, we will test a performance how the distance relay will perform for zone 1. So, we have we can see that same 345kV, 120 kilometer systems; so we have a R_f 100 ohm coverage. So, we have a zone 1 setting, so this is the fix setting of zone 1, this boundary. Now, what happens here here the fault is created; you can say this is a coverage of 100 ohm. So, phase-a-to-ground fall at 40 percent from the distance from this M; and then R_f consider that 100 ohm is 90 ohm consider that consider for this point. Phase-a-to-ground fault is created, and then you found that the corresponding trajectory and the final settle at this point which is outside the fixed boundary, even though it has covered 100 ohm. Now, at this point the corresponding δ is -30^O reverse power flow; and h is at .85 to reverse condition. So, that sees the situation demands that the corresponding boundary is upward; so if we have this information and do the corresponding adaptive things, which is the correct boundary. Then we can see that this we can see that is also in zone 1 at boundary which is the adapted to the situation.

So, the conclusion from this result is that if we can adapt the boundary, knowing the corresponding parameters at the found in the desired apparent function; as the δ, and these source impedances, and the line impedance. If we have that information and arrive at the boundary correctly, then your relay will perform in better way; that is what you can conclude from this fault in zone 1.

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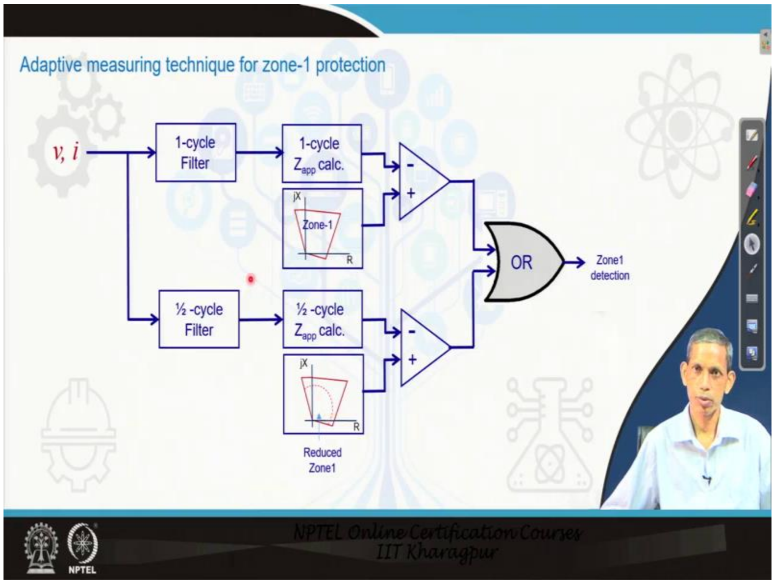

Now, there are other ways also as I mentioned that to adapt to consider it protections, protection philosophy ways . The second one what will talk about in the adaptive measuring technique; in the measurement process will make it adaptive for distance relay and see you can consider this is also being used, in numerical available relays. So, voltage and current input, so there are two things we will be run; that the distance relay many if you go to higher and higher voltage, it requires first decision, particularly when it happens in zone 1 fault; because it is close to that bus. The fault should be clear as fast as possible, with that philosophy what is being done that instead of taking one cycle of DFT, we can take half cycle of DFT. But, we know that half cycle DFT is a compromising in accuracy, you remember. Then so what is being done that for the half cycle

DFT, because it accuracies not that higher; so we reduce the corresponding setting of the distance relay.

So, depending upon the corresponding and for the full cycle, we have the complete 80 percent, let us say of the zone 1, the reach is being said that 80 percent of the line. This is the whole zone 1 which is normally we do fix point. But, what is being done here? Now we have a reduced you can say area, for the half cycle perspective. So, you have a reduced area because we know that half cycle is here compromise in terms of accuracy.

So, that gives us consider that as scope that you can consider that you can make the corresponding decision process faster. So, what is being done? We have we consider that both in parallel with the data availability; so one is being calculated in one cycle DFT and other is being half cycle DFT. And using that you can consider that we calculate the Z_{app} to proper relation, we can say that for the types of voltage and source, direction features and all.

And using that we have a reduced boundary, and using the reduced boundary; whether the corresponding point falls inside this not will check. And then you compare that in the comparator and then you pass on to the forward. Similarly, in the parallel the corresponding one cycle is being done; and then the corresponding information is pass on to this one. And anyone picks up the corresponding fault, it is an OR circuit, will be consider as a decision process. So, point you consider that if the half cycle DFT picks up consider that the fault in its zone 1 or even you can consider that the one cycle DFT also picks up, it will be there.

So, what will happen initially if the fault you consider is very close to the relay; and falls inside this one smaller boundary. Then this will pick faster, then the one cycle the DFT; and that it will oscillate you can consider with decision process. So, that is you consider the gain will be in terms of speed of operation, and finally when it works to this region cannot think; both will be consider that will be able to determine the fault in the perspective.

And in the fault towards the reach ; then this will be pick, it will not be able to pick because the boundary is reduced. Note that this is a useful for for zone 1 protection; zone 2 and zone 3 protection are delayed protections. So, therefore this approach will be not beneficial to those slower form of protection.

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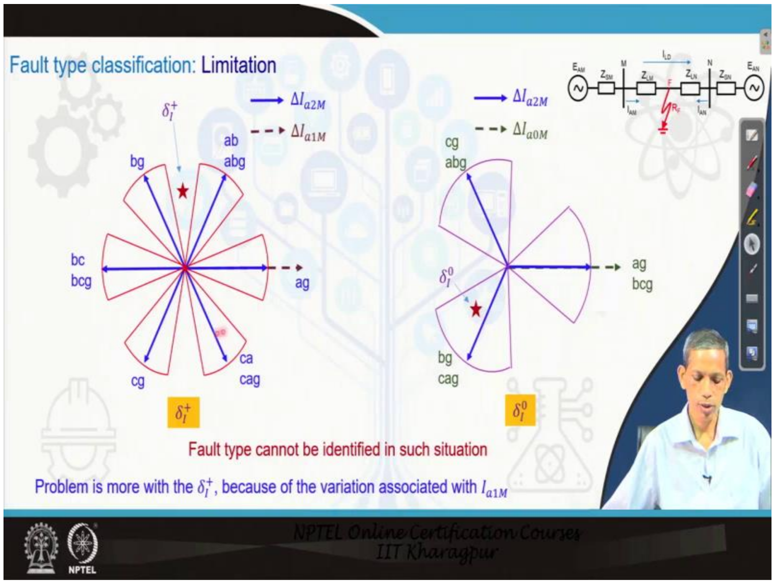

Other we can say that applications on adaptive philosophy to distance relay is fault classification. Now, let us we can say that first see what is the problem, what we have the already learned that earlier; and how we can make it adaptive. So, same system two bus system and we now can say that the protection philosophy based on the current information. We can have we can say that the corresponding fault classification; and we say we can say that the δ current is super imposed component of current.

Positive sequence current is a reference for phase-a and then what is the position of negative sequence current; that decides that which type of fault it is. So, if we take the directions, the negative sequence current, with respect to this the positive sequence current, super imposed current, then we can say that this maybe ab or abg. Now, on the top of the zero sequence ΔI_{a0}; so we can say that it take the zero sequence for the current reference δ_{a0}, with the super imposed current. And what are the corresponding negative sequence components with respect to that; if we take this position, we can say.

Now, ab and abg is see here the corresponding abg faults here; so for abg fault if you find here also the position confirm from ΔI_{a0}. Then this is abg, otherwise it will be ab fault perspective. Because this said the zero sequence component is available only for the ground fault involved cases. So, using this two we can say that δ_i^+ and δ_i^0; we say that fault classification can be achieved.

Now, what is done being done if we see here, the angle between consider this reference line and this reference line and this phasor is having 60^{O}. So, all having symmetrically 60^{O}, 60^{O} each, so that is what we saw in terms of that; and in this case we consider that this angle between this blue line becomes 120^{O}. Now, what is being done that we do to the uncertainty in the measurements and errors, and other perspective and all these things, we make 15^{O} kind of thing both these sides, and you consider that keep some margin in between these two in this two types of fault and we consider that operate the corresponding system very accurately. Now, what happens that in some of the cases, it is being observed it will two different measurement errors or the fault resistance and so and so; which makes that erroneous process. The corresponding point may fall you may consider fault within the two areas. What I mean to say that if that you consider a point in noticing in terms of that; and here it is being confirmed this is you can consider that it is either bg or cag, then we can say that we have a scope what to improve upon that.

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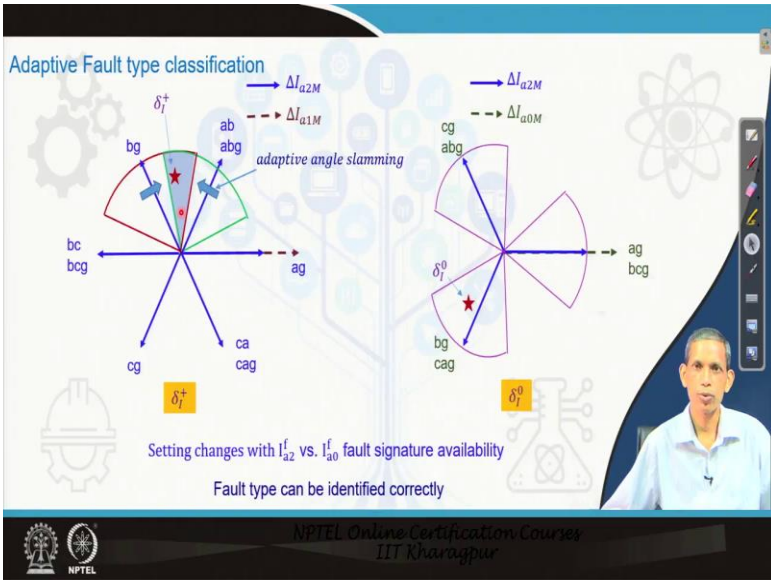

So, what is being done in the adaptive fault classification? Now this point you consider that outside the usual boundary setting of the 15^{O} kind of thing. But, here you noticed that you consider that either it is a class bg and cag. Now, it means that it is bg and cag; but we see here this point this bg or cg is closed by, and we can say that here you can say no more cag in this region. So, what is being done in that case it can extend the corresponding region, from 15^{O} to 30^{O} or more than that also.

You can also have overlapping and with that point falls in that region for that one; and also being reconfirmed. From this ΔI_{a0} then you say that a class belongs to that. So, if there is scope confirmation form the both the perspective, then you can extend the region of you consider that this portion; and make the decision that on the fault type more correctly. So, that is why you can setting changes with a negative sequence and the zero sequence, significant value available in that perspective.

And you can at that the corresponding region. in accordance with that, if you have information from this side also. So, this keeps a better performing fault classification technique; so this not being only for distance relay, it is also auto reclosing purposes also. And this is being used in available relays.

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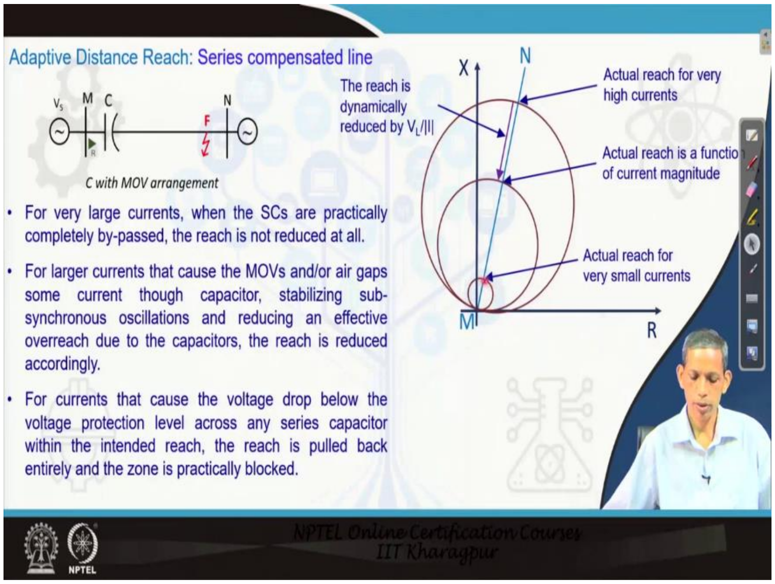

There is another application we will see, on which we have already seen a series compensating perspective. If you remember series compensation has MOV, air gape and so operations. So, whenever fault happens to be they are very severe fault; then the current becomes very large through the capacitor; voltage across the capacitor becomes very large. And damage the capacitor so the MOV operates; and after sometime we consider the air gap may also operate to bypass the corresponding capacitor from the protection of its own perspective.

So, with that what you have already done you consider that you can remember , if the capacitor is not there in the circuit, without the capacitor only line. So, if this let us say zone 1 setting.

And in the capacitor is fully there, compensation level high compensation level; then setting can be this, very small region. Sometimes it maybe so small that you do not consider that the whole zone 1 you know just bypass the kind of things. That now what happens that in the intermediate portions, current may flow, some current may flow in the capacitor; because the air gape does not operate than in the MOV.

In the MOV we can say that only MOV is there; so MOV we can say that becomes a resistive circuit. So, there is chance some current there maybe flowing through the capacitor; so, that is our the intermediate value of the current. So, that means that with the required intermediate or we can say that value of the characteristics in the ampere of that. So, what is being done that in the adaptive philosophy, depending upon the current; the some of the relays they provide in this feature adaptive feature. Depending upon on the current level, the reach of the current relay is setting of the boundary is being changed in accordance with the level of current in the circuit.

And that clearly say that if the current is very high, so it means that the the MOV and this functional, we have this boundary. The current is very low that MOV air gap is not operate then require this boundary; if the current is intermediate, we can shift the corresponding boundary in the in between these two extreme and all. And that is why we consider the philosophy do and that we have learned in our earlier discussion in series combination that line also.

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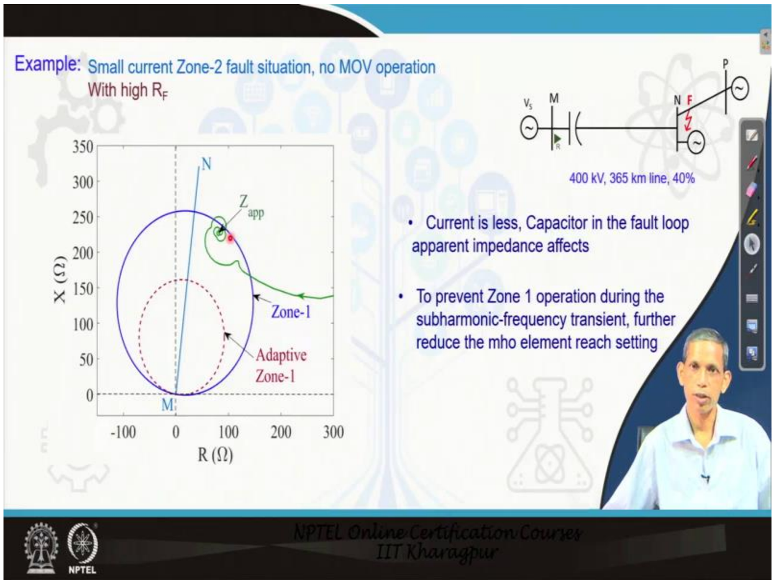

An example, we have seen a fault in the zone 2 other line we consider that from this series compensator line. And what is being done the current is less; so there is some current in the through the capacitor also. And that is why what happens that this the zone 1; you consider that is setting for the line without the compensation. Fault is outside you consider that the line, but still is observing inside this boundary.

Now, what happens we do if we allow this from the current level; and adapt the corresponding boundary. So, the adaptive boundary should be at this position for this fault; and this will be the boundary. Then this point is beyond; it means that we will say that you know this is not zone 1, this is zone 2. And that is we can say that the strength of adaptive, we can say that setting here using the current information at local point. That if we do the adaptive setting, then the performance of the relay can be improve; this is our series compensator line.

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So, in general we say that adaptive philosophy it enhances the protection performance of the distance relay. And we have numerous approaches to accomplish this adaptive relaying concept. One we say we can say that how to adapt the relays setting, the quadrilateral setting or the similar in most setting. The other one we are talk about in terms of the measurement process, you can do also. Third we can say that we saw about in the perspective of impedance that we can we can do in terms of these situations we can say that the uncertainties in the sensors and all these things will see later on.

So, what is being done that if you see the classifications; which change the setting from you can go from setting from the current to voltage also, if it is required. You consider that we have already notice in our all classification perspective in earlier also. So, point is that there are different perspective approaches to accomplish the adaptive setting. And this is a valuable in many relay in different ways, particularly in distance relay which you are addressing. And we say that there are further developments going on in that perspective also. So, this is what on adaptive relaying concept to distance relay. Thank you.