Power System Protection
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Lecture 49
Protection Using Travelling Waves

Welcome to the Power System Protection course. We are continuing with Traveling Wave-based Protection.

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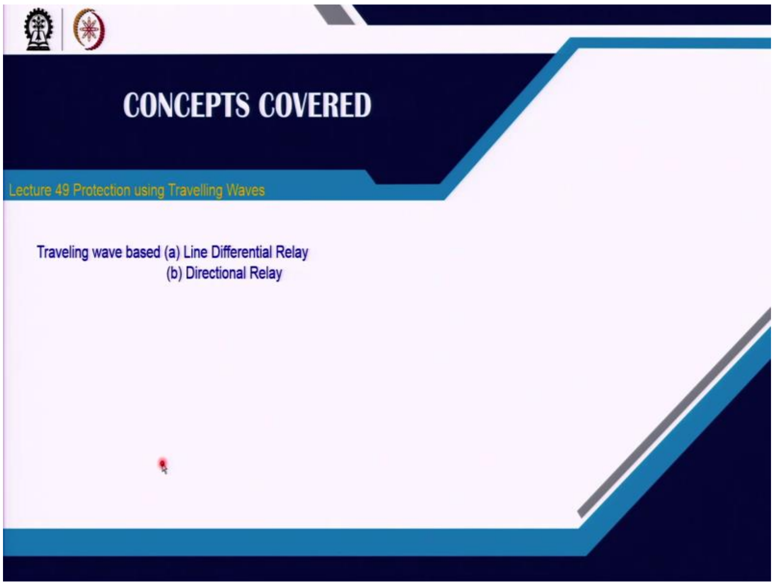

In this lecture, we will address on application of traveling waves for protection perspective. Two relay principles we will discuss: differential and directional relay for line protection. We have already seen in the earlier lecture, how to extract traveling wave and how they can be explored for possible application. In this one, we will see these two specific applications.

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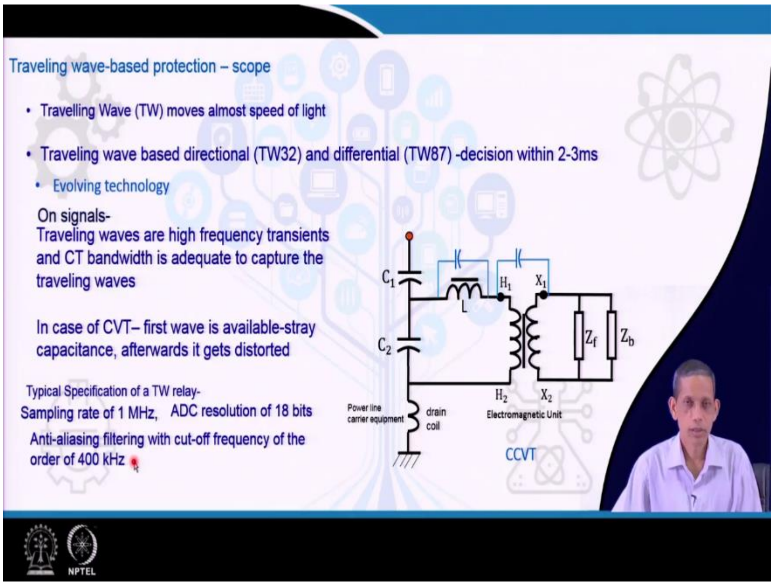

Let us come to revisit on the scope of traveling wave. So, we have already seen that the traveling wave was towards the line end to the relay location travels with almost speed of light, the γ which depends upon 1 /√ LC. These two relays are available by vendors in the market, traveling wave 32 directional relay and traveling wave 87 line differential.

At this speed perspective, they can descend within 2 to 3 ms, of course, that depends on the length of the line, and we see that. This technology is evolving even though the concept is pretty old to realize that is tougher. We have already addressed in last lecture, it is associated with high frequency components, and so sampling rate requirement is very high.

So, associated technology is also much better than the conventional 3 to 10 kHz sampling rate-based relay. This technology is moving forward, evolving, so in near future we will see more and more applications based on traveling wave principles. On signals, we have also mentioned earlier that these are high frequency transients. CT bandwidth is compatible for extracting the current based signals for possible application but on CVT, if you see the CVT, then because of the inductor, the associated voltage gets inhibit, and then we may not get the proper voltage signal of the system. However, the first wave literature suggest is available because of the stray capacitance of this inductor and the corresponding transformer associated with the electromagnet unit. So, this gives a scope to reach the corresponding relay side about the initial voltage transient. Afterwards, the voltage gets distorted and it is difficult to extract the corresponding system side transient voltage associated with the traveling wave. Some of the specifications of a traveling wave relay is that sampling rate is 1 MHz as compared to a few kHz for the conventional phasor-based relays.

The ADC, A to D converter conversion is typically of 18 bits, we require more accuracy, 12 bits or so for normal relay. anti-aliasing filter, the cut-off frequency is 400 kHz associated with the 1 MHz sampling rate.

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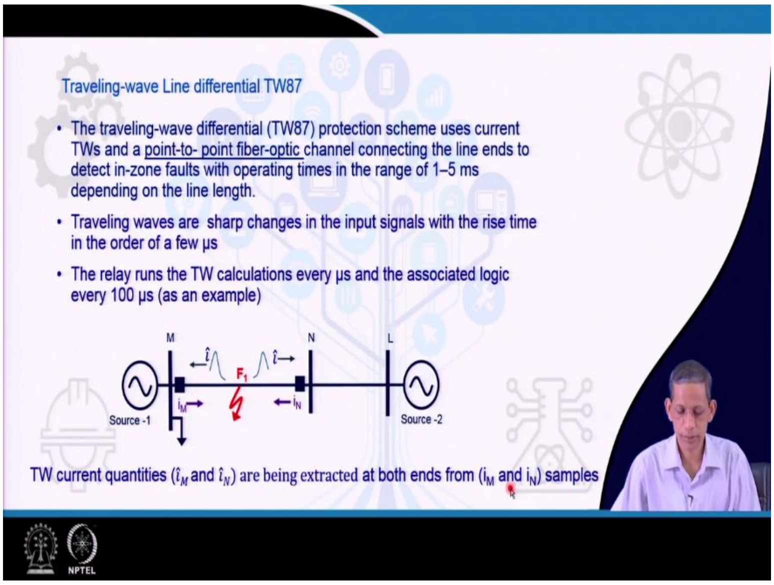

Now, let us come to these applications on the Traveling-Wave Line Differential TW87. So, conventional line differential, we have seen how both end currents can be used, both in sample domain as well as phasor domain. Similarly, we will see how current based traveling waves, can be used for differential principle for possible applications to protection. Already mentioned, such a traveling wave-based approach gives high speed of protection.

It is current based and because the associated signal with traveling wave remains for very small period of ms therefore, we see that the protection scheme has to carry out pretty fast and the decision is obviously much faster than conventional relay. So, it requires point to point fibre optic channel for application. And the decision time for in-zone faults is around 1 to 5 ms only. Whereas, in case of phasor-based approach and so, typically it is a requirement of half cycle and more. These traveling waves are sharp changes in the input signals. Whenever a fault is incepted, the traveling wave propagates towards the line ends, where through the protection arrangement such signals are being captured. Note that in last lecture, we have mentioned, these are not 50 Hz signal, these are high frequency components.

So, we have different steps to capture that information using bandpass filter and so. Also, we require that α- β transformation perspective. Now, this rise time of the signal is of the order of few µs only. The relay runs the traveling wave calculations every µs, 1 MHz sampling rate.

And the associated protection principle can be managed with every 100 µs. So, what we do here in this traveling wave-based line differential, let us say an internal fault happens to be there at F_1, so current waves will travel from both M end and N end. So here, with the CT and the A to D process, the relay will acquire the sample's value, filter out the undesired component, capture the high frequency component, and then extract the α- β or like that whatever components required, and then based on that, a differential principle can be obtained. So, with traveling wave quantities, the $\widehat{I_{(M,N)}}$ are the extracted high frequency current components, which we call as traveling wave components. And they are obtained from the sample value of i_M and i_N, and these are sampled at a very high sampling rate.

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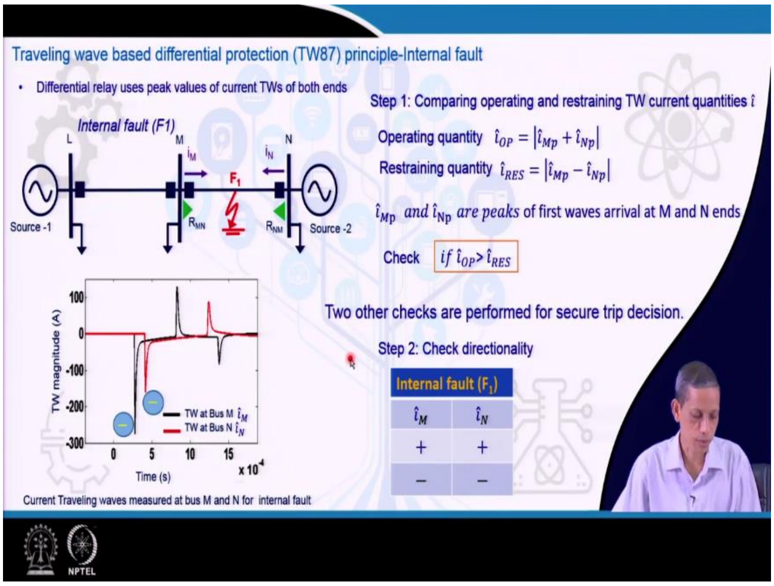

Now, let us go how this traveling wave based different protection is being applied. The differential relay uses this one of the application perspective. There are different ways you can see in future also. Differential relay uses peak values of currents of travelling waves of both sides. So, the line which we are considering this MN line and our relays are R_{MN} and R_{NM} traveling wave-based relay TW87. Now, from this sample value at this location and this location, they obtain the traveling wave components as shown here, and they extend the corresponding information through dedicated fibre optic cable. So, what they use is the peak value of the traveling waves. Now, what we do here in step 1, compare the operating and restraining traveling wave quantities. Traveling wave quantities are in mentioned in terms of i cap. So the operating quantity becomes

$$\hat{\imath}_{OP} = |\hat{\imath}_{Mp} + \hat{\imath}_{Np}|$$

And the restraining quantities is decided by

$$\hat{\imath}_{RES} = \left|\hat{\imath}_{Mp} - \hat{\imath}_{Np}\right|$$

So, what is this Mp and Np correspond, they are the peaks of the first wave. So, when the fault is incepted, the wave travels this side and this side current wave. And it, it is captured by the relay at this M end and the N end. So, if you plot these two on the same time axis, then the first wave is the black one, this one at the M end and the red one is the first wave captured at the N end. So, that is why this is traveling at bus M and travelling at bus N, red one. And then this first wave is of concern, and the subsequent waves we are not considering here.

Note that the traveling waves, because of the attenuation, the signal strength dies down at the subsequent stages and the relay may not be able to distinguish at this because of noise and other factors. So, it is a level, we can use the first traveling wave, and that is why I am talking about the peak value of this traveling wave. And again, we can say that the duration of this is few µs. So, every detail of this one is to compare them is also not that easy. What is being done, that one approach as mentioned here, they take the peak values and use these for the operating and restraining signal. So, i_{Mp} and i_{Np} are the peak values of this first wave at M and N end respectively. So, we obtain this $\hat{\imath}_{OP}$ and $\hat{\imath}_{RES}$ as shown here, and then check for internal fault, whether $\hat{\imath}_{OP} > \hat{\imath}_{RES}$ like we did for the differential protection. But note that these signals are available only for few µs and very quick processing aspect is done. So, to make it more secure, there are other two check at typical relay, you use. It may incorporate more also for better decision. two checks are the next step, step 2 is the directionality. For this, the direction information is extracted from the polarity of the signal. If both polarity of the signal are same, either positive-positive or negative-negative, then it ensures that the directionality is same and then it is internal. Now, when the traveling waves goes this side it is a positive current wave, and reaches here, but the relay is towards this side. See, if you remember, or in phasor domain approach or sample domain approach, what we are seeing, that for this fault, this source was feeding from this and for this same fault, this source was feeding from this. So, our relays, looking at the forward direction to the line in this manner to identify the internal fault. Therefore, here what happens, the wave propagates positive wave, propagates this wave. So, that is against the conventional direction of this. So, we consider that as the negative. Then for the side also that one becomes negative, so both are negative and negative. And if the wave is generated here, is a negative signal, then both will be positive or positive.

So, that is what we say the direction of the, at the M end and N end for the current wave originating from the fault F_1. This is the situation for internal fault, what we are discussing it for, internal fault.

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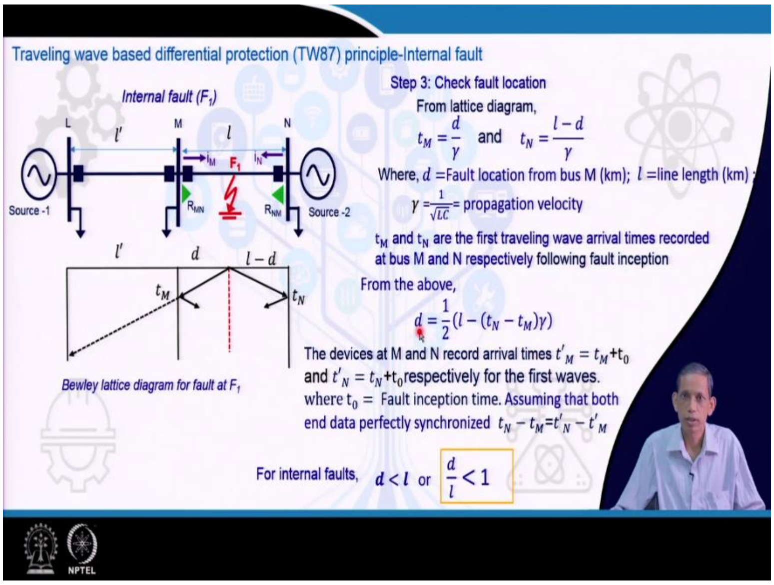

So, in the next check, the security check for differential protection using traveling wave. We have a fault location-based check. We are discussing on internal faults, so let us see this F_1 position is the internal fault within the line MN. So, whenever such a fault happens to be there, current wave will traverse left-hand side and right-hand side. So, if we see this space-time lattice diagram, then the wave traverses this path, distance of d will take a time of, let us say t_M to reach this relay location R_{MN}. And this distance (l – d) to the right to bus N, it takes let us, t_N. So, this t_M is

$$t_M = \frac{d}{\gamma}$$

. And this t_N time is

$$t_N = \frac{l-d}{\gamma}$$

So, during the fault located from bus N, this is the d distance, l is line length of the MN section, km and γ is $1/\sqrt{LC}$ the propagation velocity. Note, the t_M and t_N are the first traveling wave arriving at bus M and bus N respectively. Now, from these 2 relations, we can say that

$$d = \frac{1}{2}(l - (t_N - t_M)\gamma)$$

Now, these devices at M and N record the arrival times the recording time at R_{MN} relay is

$$t'_M = t_M + t_0$$

Where t_0 is the fault inception time. Similarly, at the N side relay the recording time is

$$t'_N = t_N + t_0$$

Now, assuming that both end data perfectly being synchronized, clocks here at R_{MN} and R_{NM} being perfectly synchronized, then

$$t_N - t_M = t'_N - t'_M$$

So, in this relation, we can obtain the recorded time at M and N end, and from there you can find t_N - t_M here, from that relations l and γ are already known from the system, therefore, d can be obtained. So, for an internal fault, the d < l or d/l <1. So, once you ensure that from this relation, using the time information at M end N end, we can compute the d and ensure that the fault is internal or not.

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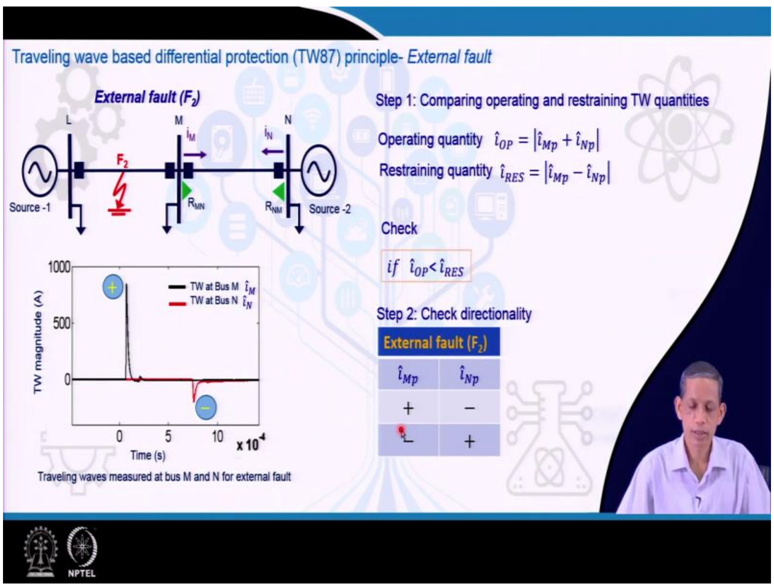

Now, let us go to the external fault case. So, for this line, external fault F_2 is there, the side or it can be the side. Let us consider for this F_2 fault and the associated traveling wave captured here from the sample value i_M and i_N. So, for differential relay we will first obtain the $\hat{i}_{OP}$ and the $\hat{i}_{RES}$ from the $\hat{i}_{Mp}$ and $\hat{i}_{Np}$, traveling wave first peak value at M and N side respectively.

So, for external fault, we see here that this $\hat{\imath}_{Mp}$ this first peak at the M end, the black one is M end and the red one is N end. You see here, this is positive and this is negative, so this plus this will be less as compared to this minus this. So, when we make this minus this, that will be added and when we make this plus this that will be lesser. Therefore, $\hat{\imath}_{OP} < \hat{\imath}_{RES}$ for external fault case as evident from the wave also.

And for the security check perspective as you did for the internal fault case, so for external fault case, what we see here, that the positive peak for this case and the other line negative. So, they will be naught of same sign, they will be of opposite sign. And this +- or -+ for M end and N end, and the other way. So, what we see here, that for this fault, if this current wave is a positive one propagates this way, for this case, this will be along this one. So, if this will be positive, for this one, it will be against this one compare to conventional direction. Therefore, this will be negative. So, this will be positive and negative. And if the corresponding wave is negative wave, then this will be negative here and positive here, so negative, positive here. Therefore, the direction of conclusion can be obtained from the value of the first peak of the traveling wave obtained at the two locations, and that indicates about the external fault situation. For internal fault, we see both polarities are same.

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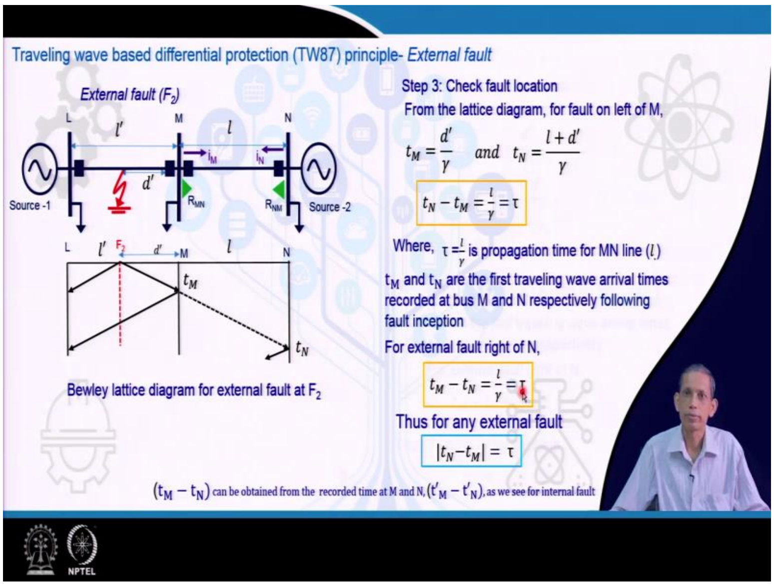

Similar to the internal fault, for external fault also, we could have this security check based on, the fault location. Now, it is a case of external fault and how the corresponding location is related to the differential protection. So, for this protection of the line section MN, this fault is an external fault F_2. And in this case, the distance of this fault from bus M is d'. So, whenever the corresponding traveling wave reaches at bus M from this location, then the corresponding time associated with that becomes t_M and it becomes

$$t_M = \frac{d'}{\gamma}$$

Now, the travelling wave traverses through this line MN and reaches N at t_N which is given by

$$t_N = \frac{l + d'}{\gamma}$$

So the time difference between t_N and t_M becomes

$$t_N - t_M = \frac{l}{\gamma} = \tau$$

Where γ is the velocity of propagation for line section ML and MN to be same and τ is the propagation time for the line section MN by the wave. Note again, like the internal fault case t_M and t_N are the first time traveling wave arrival at bus M and N respectively. For external fault beyond line section, beyond the bus and to the right, we can similarly say that from that the corresponding fault inception will be there and reach at N first, and then goes to bus M. So we can conclude fault for right of this N will be close to t_M - t_N, it will be equals to l/γ and that equals to again τ. So, in general, we say that for external fault left of M or right of N will be equals to

$$|t_N - t_M| = \tau$$

Similar to the internal fault case, we have a third check, the security check on external fault, which we find here that t_N - t_M equals to τ. But these t_N and t_M like the earlier can be computed from the recorded time by the R_{MN} and the R_{NM} relay following the fault inceptions at t_0 and that equals to the recorded time will be $t'_N - t'_M$will be t_N - t_M. From the recording time and using the relations

$$t_N - t_M = t'_N - t'_M = \gamma$$

It ensures that the fault is external beyond the lines section MN.

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Summary for a trip decision, when to trip for any internal fault in the line MN, trip at this, the $\hat{\imath}_{OP} > \hat{\imath}_{RES}$, if not, so, then it is a external fault. Both end traveling wave polarities should be same, this is check, first check, both end traveling wave polarities should be same, either '++' or '--'. And the third check is $|t_N - t_M| \neq \tau$. If it is satisfy probably it is an external fault. And then we check as already mentioned for internal fault, if this is not so, then d < l or d/l <1. So, with these, we can say that the traveling wave based can take a correct decision based on these three checks.

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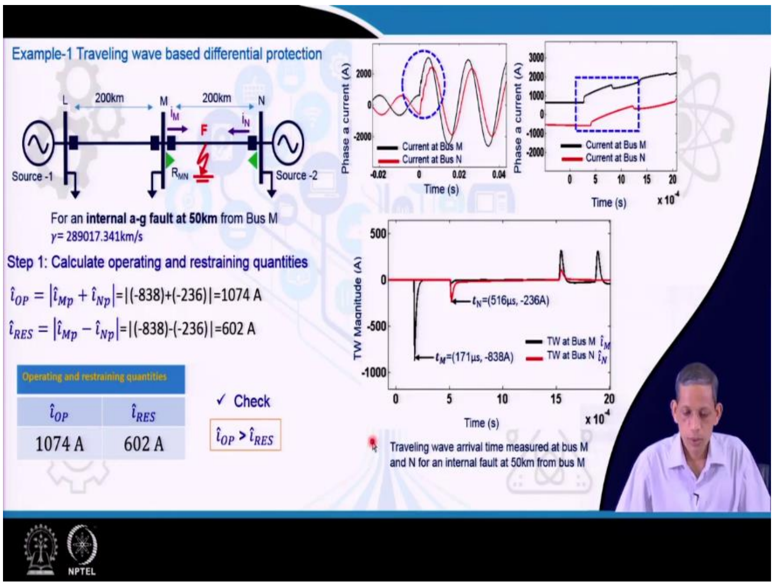

Let us see example, first example on traveling wave based differential protection. So, this is an internal fault case, 50 km from bus N for this 200-km line. Now, in this case, we see the γ given, that based on the LC parameter considered for this one transient simulation package using this phase-*a* current at both the ends M end and N end.

And note that our focus will be only this portion, where the transient is being initiated, this portion, because that is this surge being injected to the system and that is our traveling wave. And this is few 1- 2 ms only for this, our observation should focus on. Now, if we expand this portion, then the black one is M end and the red one is N end. And you see this is almost dc. So, we are talking about this portion only.

This whole sinusoidal one from which we capture the fundamental using the phasor and so, in the earlier discussion on conventional relays. But now our focus is only this surge, this change. If you see this change, that is our concern point. So, that first, we can say here that here, and for the N end, you can say that this. So, this leads to our conclusion, and we extract from this portion, the high frequency components this is positive, this is a negative and also the red one is negative and our focus is for the difference relay, the first peaks at M end and N end, black and the red respectively. So, the first peak gives us often at 171 ms as recorded, and that is -838 A, and this one is - 236 A. So, we will calculate from this as step 1 for the difference relay principle operating current, edition of the first two peaks. So, the operating current is

$$\hat{\imath}_{OP} = \left|\hat{\imath}_{Mp} + \hat{\imath}_{Np}\right| = |(-838)+(-236)| = 1074 \text{ A}$$

And the restraining current becomes

$$\hat{\imath}_{RES} = \left|\hat{\imath}_{Mp} - \hat{\imath}_{Np}\right| = |(-838)-(-236)| = 602 \text{ A}$$

So, it clearly, the $\hat{\imath}_{OP} > \hat{\imath}_{RES}$. So, this trick satisfy the case of internal fault. And this of course is in agreement with the simulation situation.

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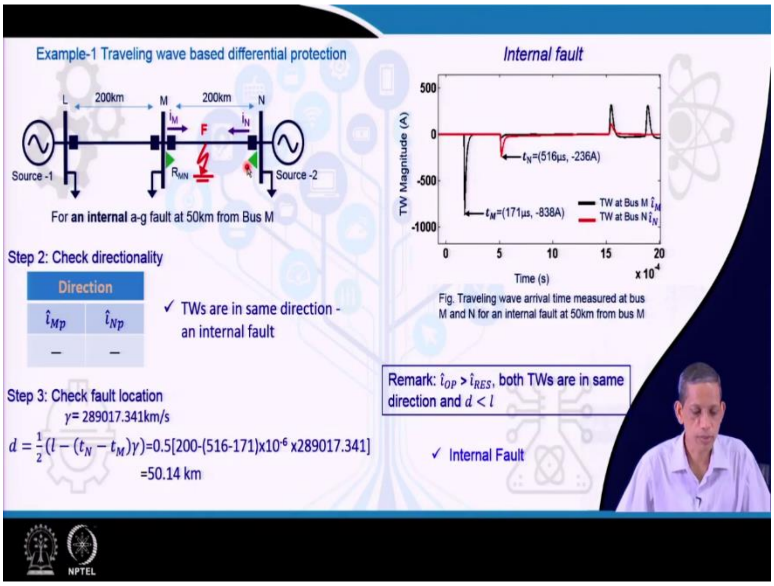

Now, we will go to the first check on that directionality to support the corresponding thing for a secured decision, directionality. We see both waves are positive and positive or negative and negative, that was the requirement. So here, you see that both first waves are negative polarity and that is what we say. And we have already explained that for both the polarities, so this is also in agreement with the internal fault situation.

The third check is on fault location. It is given γ= 289017.341km/s. Therefore the fault location d calculated as

$$d = \frac{1}{2}(l - (t_N - t_M)\gamma)=0.5[200-(516-171)\times 10^{-6} \times 289017.341]=50.14 \text{ km}$$

This calculation gives us 50.14 km. So, from this M end, and that is less than 200 km. So, the second check also in agreement with the internal fault. So the conclusion is that $\hat{\imath}_{OP} > \hat{\imath}_{RES}$, that we have seen, differential agreement. And for security check, we say the direction is same both negative-negative polarities. And also d < l. So, it ensures that this is an internal fault. And we have seen related to this case also for phase-a to ground fault at 50 km from this. So, this calculation check obtained from the two relay locations using the traveling waves ensures for that the TW87 functions correctly for this case.

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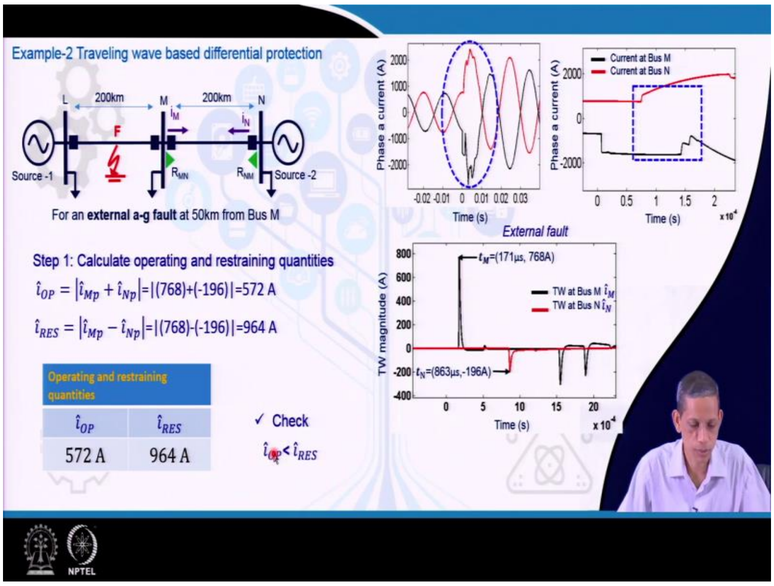

Example 2 is on second situation and that is an external fault case. So, we have fault on the line, towards the left of M and between M and L. This created at 50 km from this M bus. And the corresponding signal obtained for phase-*a* is given. Then if we expand this, again we are getting like this. So, this is our focus, this change which you observed for the first change in this case. Now, coming to this, we see here the corresponding wave, at the M end, it becomes positive because it is going from this side, as already explained. And for this N end, this becomes negative. And that is what we observe, the positive peak and the corresponding negative peak. So, the first 2 are opposite sign. So, that sign also says that they are not internal, they are external.

Now, the operating and restraining current for this condition is given by

$$\hat{\imath}_{OP} = |\hat{\imath}_{Mp} + \hat{\imath}_{Np}| = |(768)+(-196)| = 572 \text{ A}$$

$$\hat{\imath}_{RES} = |\hat{\imath}_{Mp} - \hat{\imath}_{Np}| = |(768)-(-196)| = 964 \text{ A}$$

We see that $\hat{\imath}_{RES} > \hat{\imath}_{OP}$. And that clearly says that, it fails in the first principle of differential principle.

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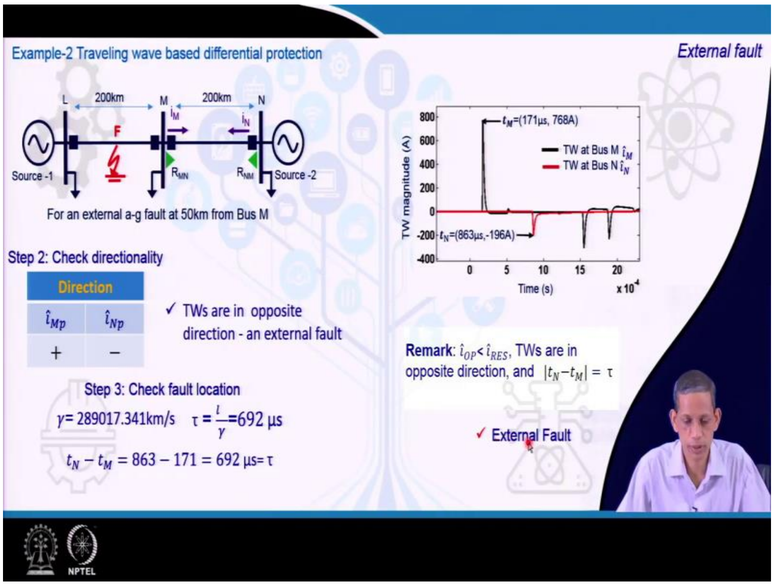

The other checks are to confirm it, to confirm that external fault case. We see the polarity, positive and negative. And that we see that the directions are if opposite sign. So, that means that this is external. And the subsequent check for distance calculation given γ= 289017.341km/s. Therefore, $\tau = \frac{l}{\gamma}$=692 µs and $t_N - t_M = 863 - 171 = 692$ µs= τ. So, in conclusion, we say $\hat{\imath}_{OP} < \hat{\imath}_{RES}$, polarities of the travelling waves are in opposite direction. Fault location is equal to line length or the time difference $|t_N - t_M|$ is γ. So, this clearly you can say is an external fault case.

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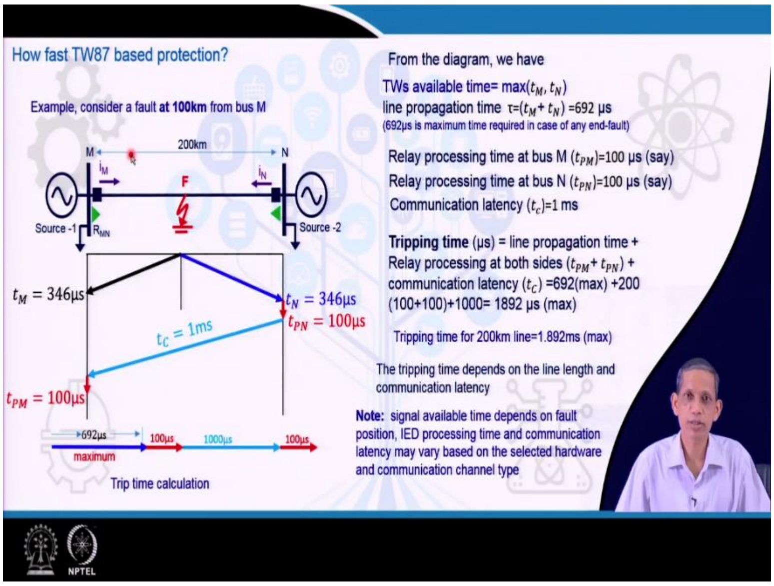

So, we see that how traveling wave principle can be applied to differential, differential, line differential protection applications. Now, this speed perspective, how fast TW87 based protection? Now, let us, in this slide, we will try to see that what will be the time frame on decision perspective, because we are mentioning about only few ms only, 200-km line, same one. And then the traveling wave, fault happens to be somewhere midway, and it travels this side exactly at 100 km, so that is why it takes 346 ms this side, microsecond and 346 µs from this side. Once it reaches this end, let us say, our all calculations are based on M end at this purpose, similar calculation is there at N end also. So, at this point, it takes 100 µs to process this signal, and then sends to the fibre optic cable in a time of 1ms, this is the communication time, 1 µs, t_c for communication time, t_{PN} for the processing time at the N end. And then we require further M end processing time of 100 µs, already mentioned in our diagram also that 1, corresponding traveling time which every µs it captures the signal, but every 100 µs or so, it process the corresponding principle.

So, to apply the principle it takes 100 µs time of thing. So, this is the processing N end and M end. So, in total if we see the time frame of calculations, we see, this traveling time to this end, you can, some of this end, traveling time to this end plus this and plus this and plus this. So again, this time t_M - t_N or t_N - t_M is required.

So, if the fault happens to be, let us say, at this close to M bus N, then the traveling time from this to this will be almost that of the length line, that is τ. So, that is the maximum time, it will require to reach here, then plus this and then plus this and then plus this. So, this is what you can say that, maximum, it will take 692 ms to reach here to the N end, and then this 100 and then this 1000, there is 1 ms communication time, and then the local 100 µs. So, this is the maximum time which the relay may take for decisions. So, that is why we say here, traveling waves available time, so the traveling wave reaches at max(t_M, t_N), so that is you can say that we are talking about here. And then the similar calculation will be done at the N end also, so it will be received from the side to this side. And both the ends' relay should trip the corresponding breaker. So, that is why we are talking about the max(t_M, t_N) in a traveling wave proceed. But maximum, say that in a timeframe, what the relay is expected to decide will be τ, the propagation time, which happens to be 692 µs, that depends on l/ γ. For the relay processing time at bus M, its t_{PM} is 100, processing for N end side is 100 µs, communication latency is 1 ms that is 1000 µs. So, tripping time expected to is line propagation time, this is what the maximum we are considering in this case just for a typical value. Relay processing time at both ends will be

$(t_{PM}+t_{PN})$ + Communication latency (t_C) =692(max) +200 (100+100) +1000= 1892 μs (max). Why maximum? Because you are talking about τ here. But the expected, it may take less time dependent upon the maximum of t_M or t_N in this side or that side. So, the tripping time depends on the line length and the communication latency and the corresponding fault position and so. In general, signal available time depends on fault position, the IED processing time and communication latency may vary based on the selected hardware, communication channel and so. So, that we see, here, this less than 2 ms depending on the line 200 km and so. And if the line length is larger, it take, it may take 4 ms to 5 ms kind of thing expected. That shows that how fast is the TW87.

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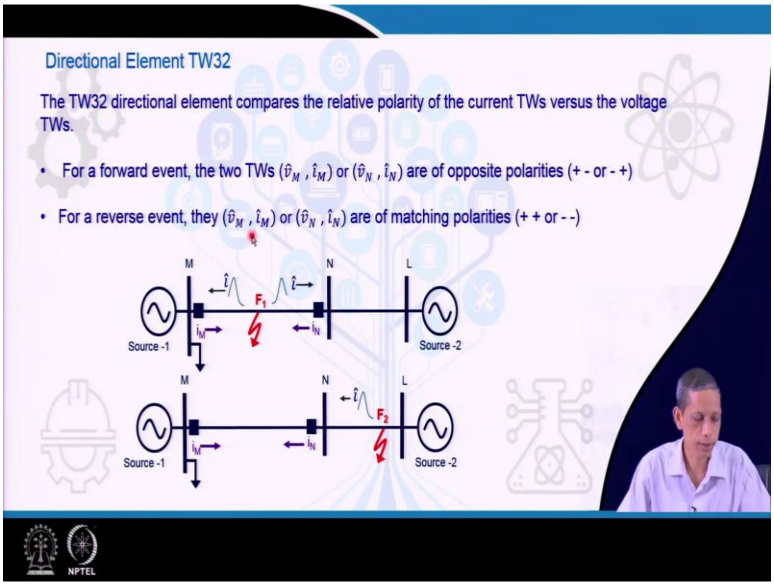

Directional Element TW32 in a similar perspective, this considers both voltage and current signals. So, for forward event, the 2 traveling wave $\hat{v}M$ and $\hat{\imath}_M$ or $\hat{v}N$ and $\hat{\imath}_N$ at both locations. So, these are individual location, we will check the direction, forward or reverse, just like any directional relay. Are opposite, the forward event are opposite polarity, plus minus or minus plus for forward thing. Forward means, this relay looks forward to the side and this relay looks forward to this one. So, $\hat{v}M$ and $\hat{\imath}_M$ will be of opposite sign, and for reverse event $\hat{v}M$ and $\hat{\imath}_M$will be of same sign. Now, let us see as already mentioned for an internal fault case, the current wave propagates this way and this way. So, at this point, this wave will be seen as a negative value and this wave will also be seen as negative value. But the associated voltage will be positive, current is positive, voltage will be also positive. So, voltage will be seen as positive here. Current due to reaction will be seen as negative, but voltage will be positive, so that is why positive and negative combination here. Similarly, voltage here also positive, current negative, so positive negative. For this fault, the current goes like this, so at this point, this corresponding current becomes positive, voltage also positive. And at this point, current is negative and voltage is positive. So, we see here, for this case, the fault is reverse and for this case fault is forward. So, forward fault, forward fault, the corresponding $\hat{v}_M$and $\hat{\imath}_M$ for this one will be positive and negative. The corresponding $\hat{v}_M$ and $\hat{\imath}_M$ at this point will be positive and negative. And $\hat{v}_N$ and $\hat{\imath}_N$ will be both positive. So, this, the corresponding, this fault is a forward fault for $\hat{\imath}_M$ side and reverse fault for $\hat{\imath}_N$ side. So, $\hat{\imath}_M$ will, see, this case positive negative. And for this case, one will see positive-positive. But that is the results and you can say that, that our conclusion is, that for forward event, polarity will be opposite one, voltage current. And for reverse event, it will be both positive-positive and negative-negative.

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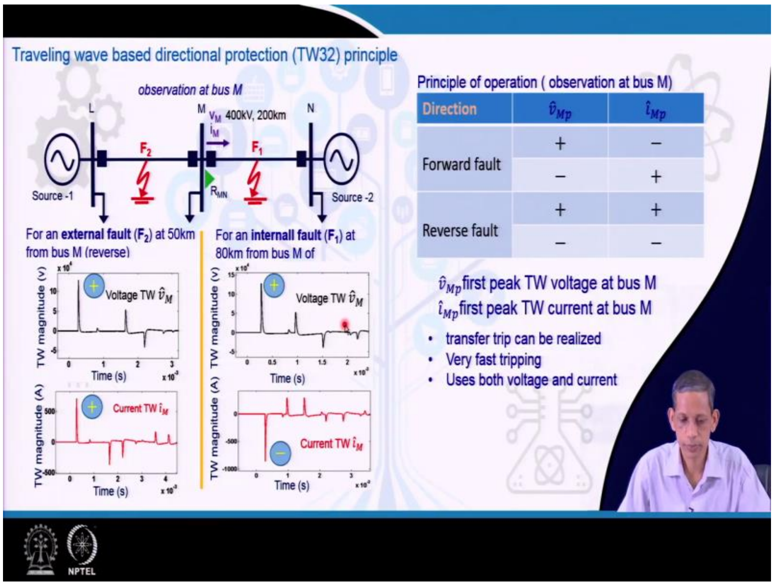

Let us see how we can see through examples. So, this is the case 400 kV 200 km, same one what we see for the differential protection to situation. First let us pay, external fault F_2. For this external fault F_2, as already mentioned, the traveling wave propagates host towards this side, relay captures $\hat{\imath}_M$, and then $\hat{\imath}_N$, this side also will capture. We have only considered $\hat{\imath}_M$ for clarity.

For this F_2, the corresponding voltage will be positive and current is also positive. This is going like this. So, current will also see positive voltage also positive, both positive and positive. So, that is what we say that positive and positive for, this is for reverse fault. F_1 is a forward fault, internal fault. You see here, the voltage wave is positive and current is negative. But for this fault, current travels this way, voltage travels at this way. So, it is in opposite direction to the current direction, so the negative voltage will be positive. The conclusion is that the principle of traveling wave based directional relay for forward fault this side voltage positive, current negative. And if voltage is negative, associated current will be negative. And then from this side, this will be positive. For reverse fault like F_2, we see here, both are positive and the voltage and currents with the negative sign travel, so this will be negative, so also this will be negative. So, same polarity means of the first wave, it means that these are reverse fault, opposite polarity means forward fault, this is for the first peak. Transfer trip can be realized, we can transfer the corresponding information trip like we did for this distance relay applications PUTT, POTT, DUTT, and so. Very fast tripping can be obtained with dedicated communication system using just local end voltage and current. So, we know the limitation of voltage signal and however if the first wave is available.

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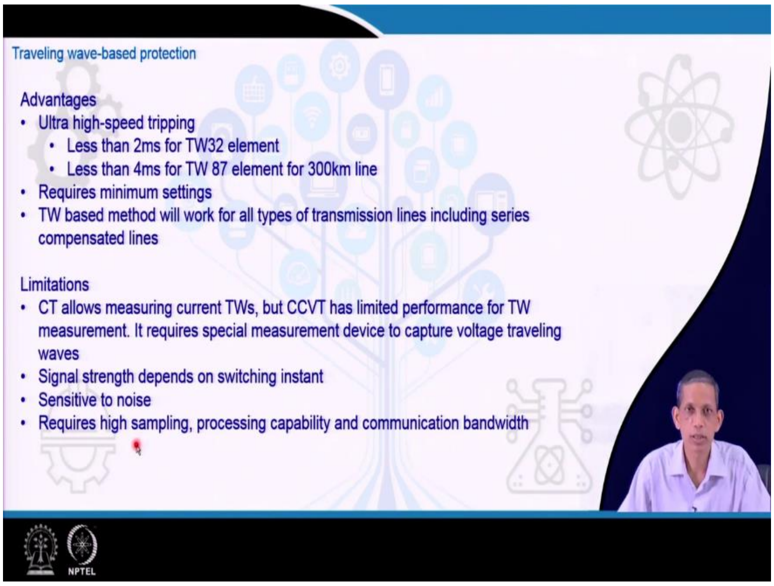

So, in overall, we see that the advantages of high-speed tripping using the traveling wave approach less than 2 ms for TW32 directional relaying, less than 4 ms for TW87 because the relay signal has to reach the other end and process in times their origin, both, both end signals. But here, TW32 requires only one end signal, both voltage and current, here it requires only current signal. Unlike distance relay, differential relay and directional relay, you see, in case of conventional phasor-based approach, it requires very minimum settings. Traveling wave-based method will work for all types of transmission line including series compensated line. For series compensation the corresponding associated reactance $X_c = 1/\omega C$, as ω is the high frequency of this transient wave in the range of 1 MHz or so, this X_c becomes pretty small. Therefore, the corresponding series compensated part will be seen as a sorted series path. Thus, no reflection or no deflection from there. And that results in that traveling based approach, which we discuss about differential direction principle will not be affected by the presence of series compensation even at the middle of the line or so. But the limitation of the traveling wave, CT allows measuring currents in the required range of frequency. But CCVT has limitations in terms of performance of traveling wave measurement, it requires a special measurement device to capture voltage traveling waves if we required the subsequent waves with sufficient signal strength depends upon the switching instant. Then that is a question sensitive to noise requires high sampling capability and communication bandwidth.

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So, overall remark for the traveling wave approach, high speed protection is achievable. We saw two applications, differential and directional. We saw also that how the distance of fault can be calculated that is explored. Traveling wave differential scheme incorporates a built-in fault identification logic based on traveling waves to support single-pole tripping applications also. More applications today being envisaged. Relays with integrated approach are available, traveling wave, phasor, time domain and so. In case of traveling wave, signal is not available because of the issue with low signal strength for certain switching instant. Then that should incorporate also phasor. And there are other reasons to support, that including time domain based approach on the sample values. So, this technology is evolving and more promising techniques and principles are expected in near future. Thank you.