Power System Protection and Switchgear
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Lecture 19
Carrier Aided Schemes for Transmission Lines-I

Okay. So, after discussing the distance protection relay for transmission line, now let us discuss the next chapter that is Carrier Aided Scheme or Pilot Protection Scheme for transmission lines. So, we know that, because of installation of fax devices and because of the reformation that is the restructuring of power system, modern Power Systems may be transmission line also that operate very close to the stability limit. And because of that fall clearing time, that is very important.

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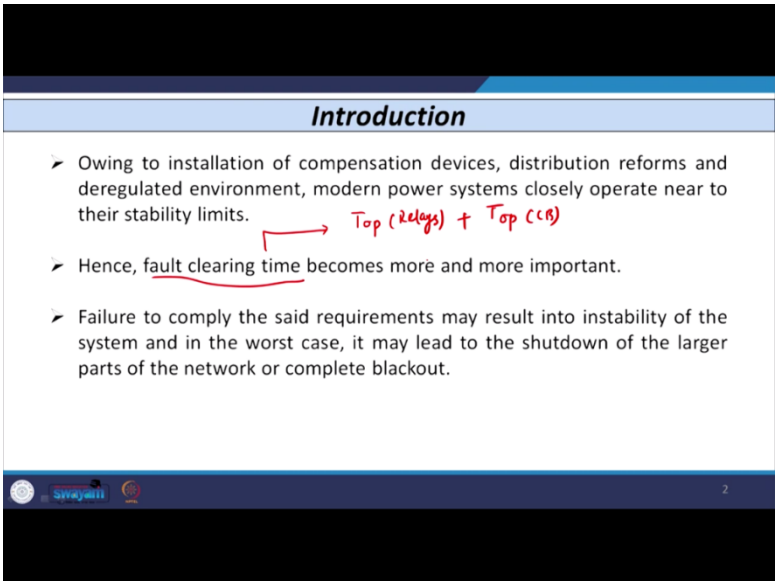

So, when I say that fault clearing time, this includes the time of operation of relays as well as the time of operation of circuit breakers. So, that is known as fault clearing time. So, this becomes very important. And if we do not need to fulfill this requirement that means if fault clearing time is not very less, then there are chances of instability of power system network. And sometimes in worst case, it will lead to partial or full blackout.

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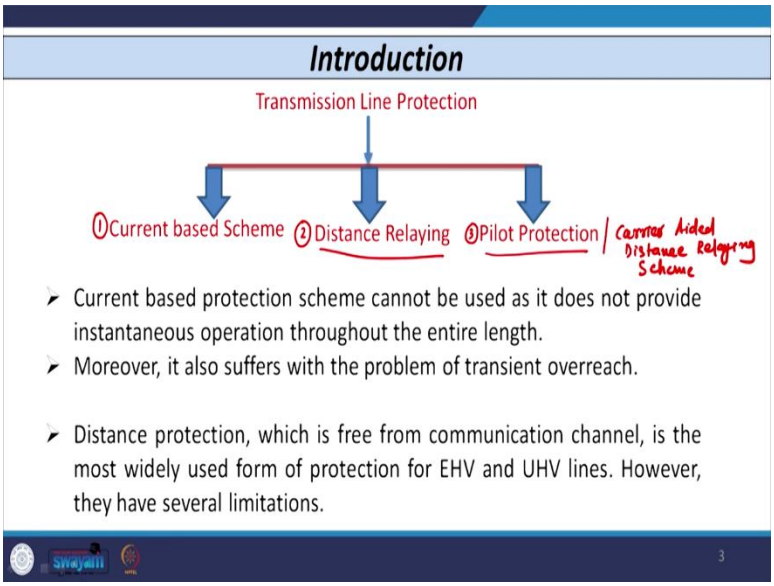

So, to protect the transmission line, as we have discussed, we can use three different types of schemes. First is known as the overcurrent relay scheme or current base scheme. The second is known as the scheme based on distance relays, and the third type of scheme that is known as the pilot protection or it is also known as the carrier added distance relaying scheme. So, now, out of these three schemes, we know that the current base schemes that cannot be used, because if we use that scheme, then we do not have the instantaneous operation throughout the line length.

Moreover, it also suffers with the problem of transient overreach and the coordination of overcurrent relays for an interconnected power system network is very difficult. So, to avoid that, the next scheme we have discussed that is the distance relaying scheme. So, distance relaying scheme does not need any communication channels.

But however, we have also discussed the several disadvantages of distance relaying scheme, starting from the fault resistance, close-in fault, the series compensation, series compensated line or maybe the overloading condition power swing etc. So, to avoid this, the next phase of scheme that is known as Pilot Protection Scheme or Carrier Aided Distance Relaying Scheme.

So, let us discuss this scheme. Now, before we discuss, before we start discussing this pilot scheme or carrier aided distance relaying scheme, let us discuss what are the main two disadvantages of distance relaying scheme. Of course, we have discussed the very disadvantages,

but these two disadvantages are entirely different than the disadvantages we have discussed in earlier class.

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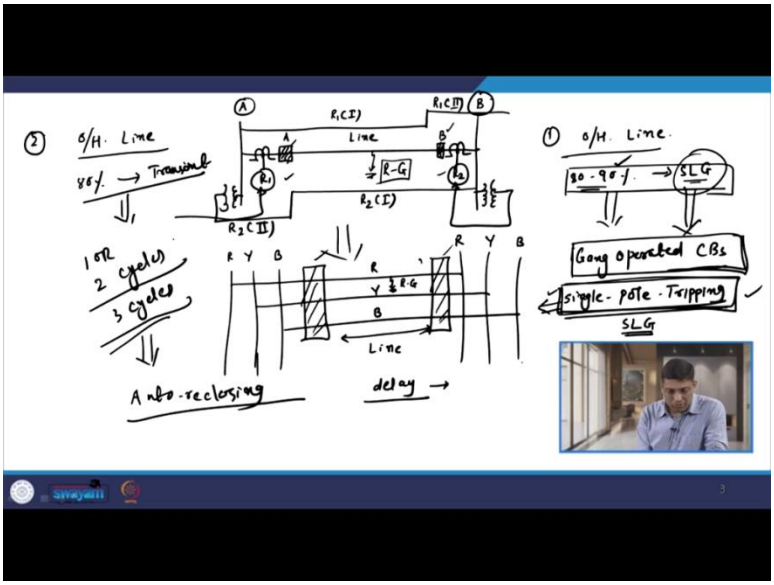

So, if I assume simple transmission line, so let us assume that we have a line connected between two bus A and B. This is a long transmission line, maybe 100, 200 kilometer long. And if I used the Relay R1, which is a distance relay. So, distance relay is used to protect this line. Similarly, the distance relay at the other end, that is bus B, let us have the other distance relay also. So this line basically is protected by the two distance relays, R1 and R2.

Now, let us assume that the first zone of relay R1 that covers 80 percent of the line length from bus A. So, this is R1 1. And the second zone then later on covered, so, this is R1 2. Same way, the first zone of R2, that covers the 80 percent, so, this is R2 one. And then, after some time delay, the second zone of R2 starts.

Now, and of course, we have a breaker connected here at bus A, let us say circuit breaker A. And we have the breaker connected at this side, let us say circuit breaker B. Now, when we consider this transmission line, which is protected by two distance relays R1 and R2, we know that, whenever fault occurs on the overhead conductors, overhead line, then we know that 80 percent to 90 percent faults are of single line to ground.

There is a I-EEE statistics and literature available. And that indicates that, out of total faults that occur on the overhead conductor, 80 to 90 percent faults are single line to ground fault. Now, whatever breaker we are using, if I just draw the three phase view diagram of this, this is bus A and this is Bus B. And we have line connected like this. So, this is your RYB and this is also the RYB. Now, whatever breaker I used somewhere here, we used the breaker here and as well as we also used the breaker here, these are the three conductors transmission line.

Now, whenever fault occurs, single-line to ground fault occurs, let us assume that the R2 ground fault occurs here, this is R2 ground fault. Now, the normal strategy that we follow in our country is that, whenever any single line to ground fault occurs, we try to open all the three poles of circuit breaker, because obviously whenever say line to ground fault occurred somewhere here, it is an interval fault.

So, relay R1 detects this fault in its first zone. So, it senses this fault. It gives signal to the breaker and breaker, circuit breaker A, so that is this breaker, all the three poles of the breaker that become open. Same way this fault, again detected by R2 in its first zone. So, it gives a signal to the breaker B, at substation B and again the three poles of this breaker that become open.

So, irrespective of whether it is single line to ground fault or double line to ground fault, whenever any fault occurs on the line, all the three poles of these two circuit breakers that become open and that will clear the fault. So, irrespective of the single line to ground fault, we open all the three poles. Now, this is because we are utilizing, in our country, we are utilizing the gang-operated circuit breakers. So, it is known as gang operated circuit breakers.

The gang operated circuit breaker means all the three poles of the breaker that become open simultaneously irrespective of type of fault. Now, this is against the requirement, because if R2 ground fault occurs, then we need to open only R-pole of the breaker, the remaining two poles Y pole and B pole of the breakers, that remain in closed condition.

And if we do this, then that is known as single pole tripping, that is known as single pole tripping. And this type of philosophy that is widely used nowadays, because if fault, and it is only used to basically for single line to ground fault only, SLG faults only, because 80 to 90 percent faults are single line to ground fault.

So, if we want to utilize, means this this type of philosophy that is known as single pole tripping, then distance relay is not capable to work sufficiently if we want to utilize this philosophy. So, we have to use some other philosophy or we have to modify the conventional philosophy of distance relaying scheme, so that we can utilize the single pole tripping facility. So, that is the one thing.

The second thing is that if I consider the second problem of distance relay is then we note that if I consider again overhead line or conductors, then whatever faults occur on conductor, on this overhead conductor, again 80 percent faults are transient in nature. So, the meaning of transient in nature means this type of fault may die down after maybe one or two cycles or maybe three cycles, it depends on the type of faults.

So, if such faults which are transient in nature and if they died out after maybe two-three cycles, then there is no need to trip the circuit breaker, because now, so what they are utilizing again? They are utilizing the another philosophy that is known as Auto Reclosing. So, what is Auto Reclosing? That means, again let us consider the same example, say R2 ground fault occurs. So, both relay R1 and R2 detect this fault and gives signal to the circuit breaker, respective breaker at substation A and B and both breakers will operate.

Now, in case of RG fault, if suppose the breaker become open and after some time delay, after opening up the breaker, some time delay. If we again reclosed the breaker, both the breakers from bus A and bus B, then if these faults are transient in nature, then, again it will automatically die down. So, again, whenever we reclose it after, first reclosing attempt, such type of fault that is not persist in the system and our system becomes stable. So, there is no need for any other types of service like the maintenance and other services are not required, because fault that is already cleared.

Of course, whenever fault is not clear, if fault still, it is a permanent fault, not transient, then again we need to open it and that is a part of reclosing that we will discuss later on when we discuss the Auto Reclosing and Synchronizing Chapter after this chapter. So that means, if I wish to achieve Auto Reclosing feature, then distance relay again is not capable, so we need to use again the some other philosophy or we need to modify the conventional distance relaying

philosophy. So, that we can utilize the auto reclosing feature itself in the distance relay, conventional distance relay. Same way if we want to utilize single pole tripping, then also, we need to again either modify or we need to go for some other type of relaying scheme.

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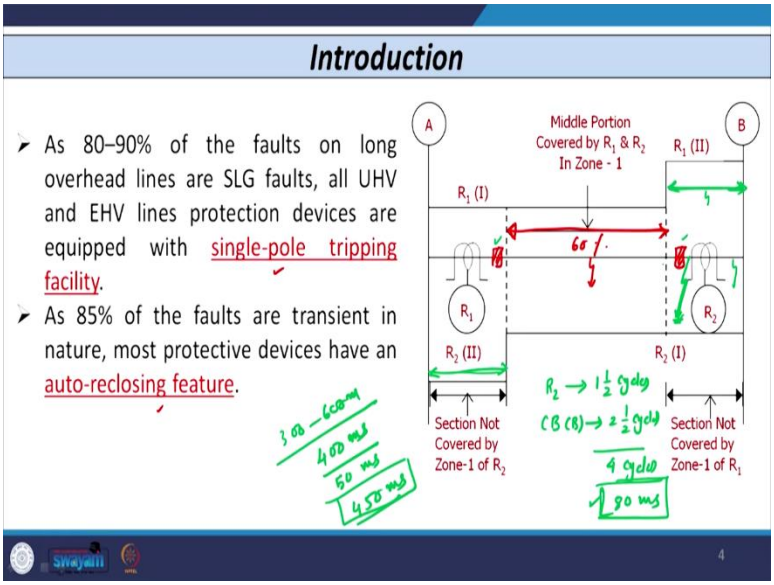

So, these two are the major disadvantage of distance relaying scheme, that is single pole tripping and the auto reclosing feature. Even you can see on this figure, any fault occurs on this same figure, I have shown here. Then only if fault occurs in this region, there and then, this fault, any fault that occurs in this region, then this fault that is shown or that is, that falls under the first zone of relay R1 and R2.

If any fault occurs in the remaining 20 percent of the line, say for example, if any fault occurs in this region, or either in this region. If suppose for example, if fault occurs in this region, somewhere here, then R2 detects this fault in its first zone, but R1 detects this same fault in its second zone. Same way, any fault occurs in this region, then again, the R1 detects this type of fault in its first zone, whereas R2 detects the same fault in its second zone.

So, for any fault in this region remaining 20 percent and this side 20 percent then, only either any one of the relays that will operate. So, what is the problem? The problem is if suppose any fault occurs somewhere here, in this region, say this 60 percent from the midpoint of the line, 30 percent on each side, then both this relay will detect this fault in its first zone and it gives signal

to the breaker, which is situated here and both breakers become open simultaneously. But in case of fault in either of this 20 percent region, that means if fault occurs in this region or in this region, then one of the breaker may give delayed operation.

For example, suppose if fault occurs somewhere here, then what will happen? R2 relay detects this fault instantaneously, so R2 relay detects its faults let us say in one and half cycle. It give signal to the breaker, this breaker. So, the breaker at substation B that operates and let us say it operates in two and half cycles and the circuit that gets disconnected from this side, substation B side. So, the total time that is four cycles, right, that is 80 millisecond.

But if I consider from substation A for the same fault that is here, then relay R1 detects this fault in its second zone. So, second zone timing is as I told you 300 to 600 milliseconds, let us average take the average value. So, it detects this fault in 400 milliseconds. So, this relay detects in 400 milliseconds and give signal to this breaker.

So that this breaker trips, let us say again in two and half cycle, so let us say 50 milliseconds. So, the total opening time of this breaker that is 450 millisecond or 0.45 seconds compared to the breaker situated at substation B, which open in 80 milliseconds. So, again simultaneous opening up the breakers on each side that is not possible, that is possible only and only if the fault is in 60 percent region of the transmission line. If fault occurs in remaining 20 percent, then this simultaneous opening of the breaker that is not possible. So, this is the biggest disadvantage of distance relaying scheme. So, if we want to avoid this, rectify this problem, then we need to go for a pilot relaying scheme or carrier aided distance relaying scheme.

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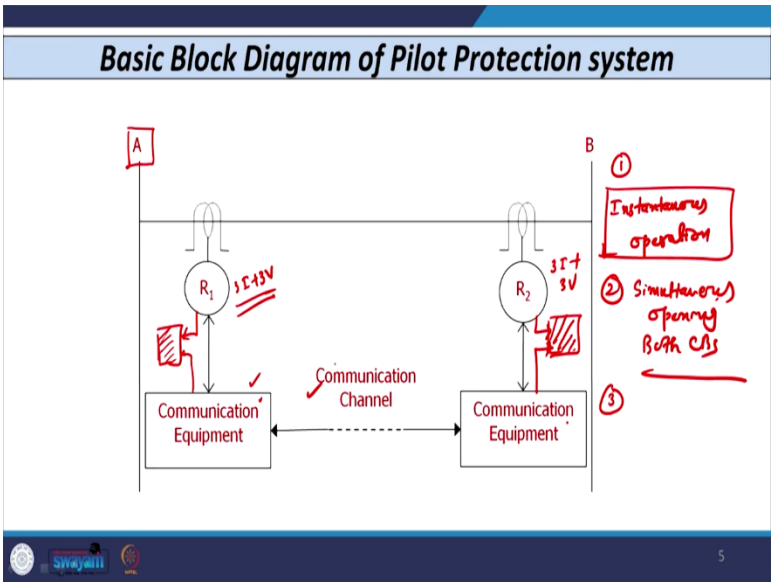

So, let us see what is the pilot protection scheme. So, if I consider the pilot protection scheme, then in pilot protection scheme, here I have shown the basic block diagram. So, the relay R1 located at bus A takes the signal so, may be three current and three voltage that is taken by this relay. And this signals that is converted into digital form, or maybe you can use analog signal also and that signal is given to the communication equipment.

And communication equipment utilizing the communication channel physical pilot or channel, it transmit the signal at this point. The communication equipment available at substation B receives the signal from substation A and then again it gives that signal to relay R2 or maybe some other block. Maybe you can utilize both the signal R2 and the signal received from other end.

So, you have some block here. That block will utilize the signal from R2 and the again signals available from other substations. Same way, relay R2 also takes the signal three, current three voltage and again it gives after converting in digital form if required, then that will give to the communication equipment and then communication equipment using channel transmit here and where it receives, it is again given to the same block, which receives two signals input, one is from relay R1 and another is from the signal which is received from other substation. And based as this block may be let us call its summing block.

This block has both the signals, signals from local end as well as signals from other end. So, based on this, you can take the decision, whether the fault is internal or external. And so, using this philosophy, you can have the instantaneous operation, instantaneous operation throughout the entire line, that is not possible in case of earlier philosophy, that is overcurrent relaying scheme and distance relaying scheme.

So, that is the one of the biggest advantages of pilot protection scheme. And second, you can have the simultaneous opening of both the breakers, both circuit breakers, that is also possible using this, because the signal from other end is available on each side. So, you can have this also. And plus, you can have the auto reclosing feature is also included. You can have the single pole tripping facility, that is also you can utilize. So, these all are the advantages of the pilot protection scheme. Now, let us discuss what are the communication equipment and communication channel, that is used in pilot protection scheme.

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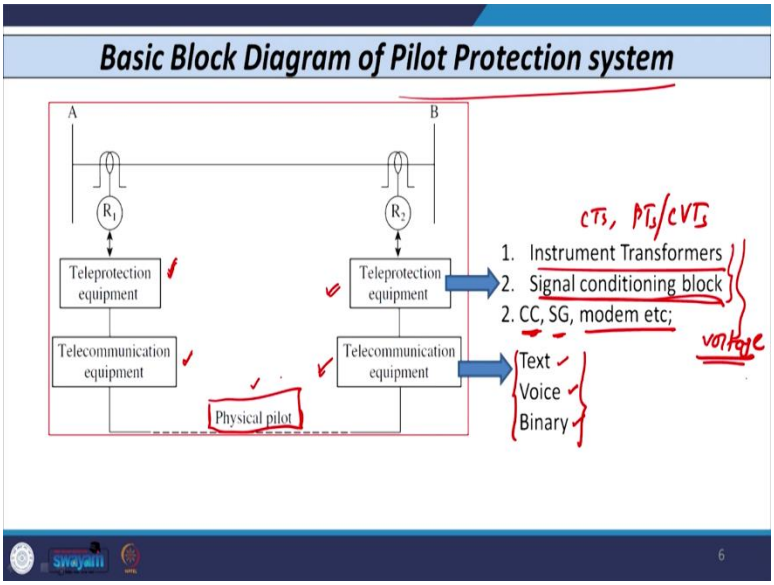

So, if I just see in the diagram, in the pilot protection scheme, there are two basically communication equipment that is divided in two parts, one is tele protection equipment and another is telecommunication equipment on both the sides. So, similarly here also tele protection and telecommunication equipment. And you have the physical pilot that is the some medium to transmit the signal from each side.

Now the tele protection equipment that contains your instrument transformers. So, that is your CTs and PTs are there or maybe CVTs are there. It also contains the signal conditioning block. So, maybe any type of filtering block is there, isolation transformer is there, maybe some logic multiplexer, all that sampling and whole circuit, all that available in signal conditioning block.

It also contains the coupling capacitors, means if I want to achieve along with protection if I want to achieve monitoring and signaling also, along with tele protection, if I want to achieve tele-signalling and telemetering, then, we can use coupling capacitor. We can use power gap, modem also. So, all these devices are available in the tele protection equipment.

In the telecommunication equipment, you have the device, which converts all these signals. Basically these signals are in voltage form. So, all these signals, you can convert either in text. If you want to transmit the signal using the physical pilot through text, you can convert it into voice. If you want to transmit the signal through voice or you can convert the signal in binary form if you want to transmit it in binary form. So, these two devices are very important as far as the pilot protection scheme is concerned. So, now, again what is the physical pilot? So, let us discuss what is the different types of physical pilot that is available.

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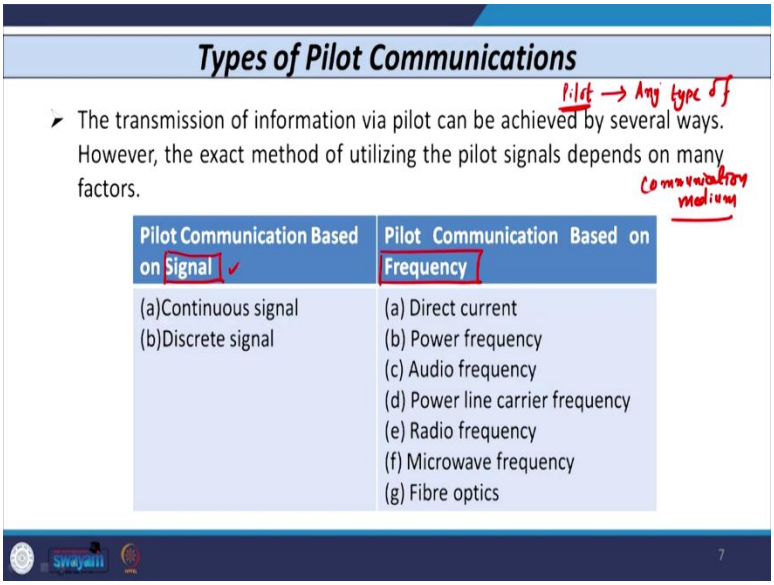

So, if I consider the medium, basically when I say the pilot, pilot as far as pilot protection scheme is concerned, means any type of communication medium So, that means any type of

communication medium. So, that is nothing but your a pilot, so whenever I say pilot, that means any type of communication medium you can use for transmission of the data or signals from one bus to the other bus and from other bus to the one side. So, either from A to B or B to A.

So, now let us see what are the different types of this pilot or communication medium available or utilized by the utility. When I consider the transmission of signal using this pilot, there are several ways. And basically it is divided in two parts, the pilot communication based on signal that is one thing and the pilot communication based on the frequency. So, there are two ways, you can communicate using by transmitting certain signals or you can communicate utilizing different value of frequencies, right different bandwidth of frequencies and then you can transmit the signal. So, let us discuss first how we can transmit the signal or pilot communication is carried out based on signal.

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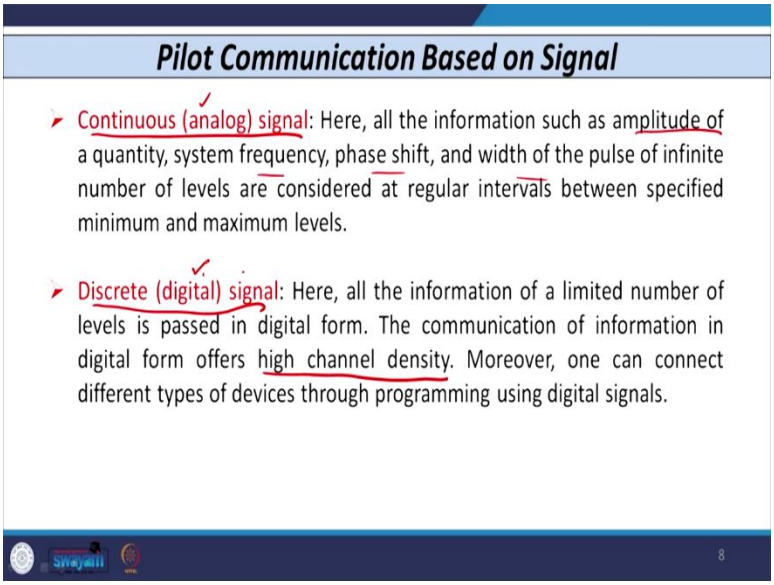

So, when I consider the signal, there are again two parts. One is, we send analog signal. So, in analog signal case, we transmit the amplitude of quantity. For example, if we have a signal, we use its amplitude, we use its frequency phase shift and several width of infinite number of pulses we transmit and that is at regular interval and again we need to again transmit this values in some range. So, maybe minimum and maximum level and we transmit all these values, frequency, phase shift, width, amplitude in analog from one side to the other side. So, that type of signal that is known as continuous signal or analog signal.

The other way which nowadays used that is known as discrete or digital signal. So, in discrete or digital signal, we convert the analog signal into the digital form. And then, we transmit in the form of limited number of levels, that is given. The main advantage of this is that, the high canal density. So, if I transmit the signal in digital or discrete form, then, the channel density increases. The other advantage is you can connect different types of devices through programming when you use such type of discrete signals.

So, nowadays whenever we want to transmit the signal or data from one side to the other, we always use or we always transmit the signal in digital or discrete form. We usually never transmit in the analog form. So, we use this only in the digital form.

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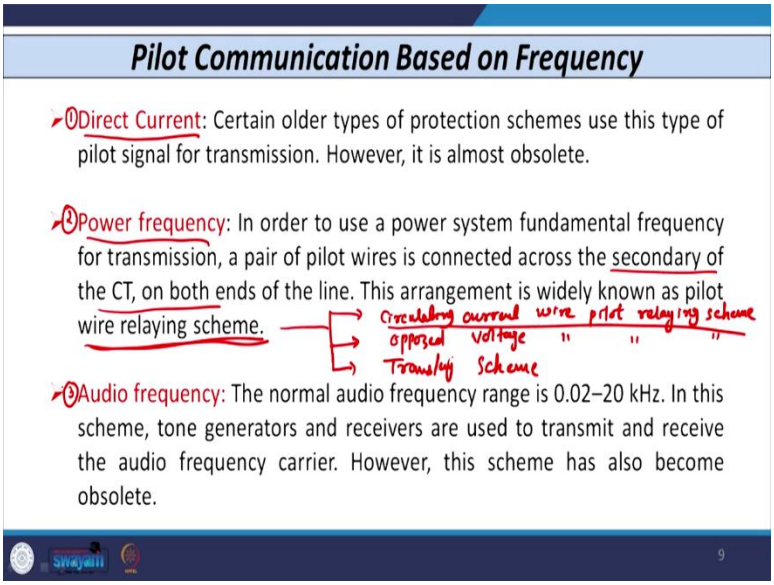

Now, let us discuss how the pilot communication is carried out based on the frequency. So, when we use the frequency, let us see what are the different frequency, how the utility that is transmitting the signal from one end to the other end. So, the first part is based on the direct current.

So, this this type of method was used earlier and nowadays it is not used. So, we start with again the second one that is based on power frequency. So, in order to use this fundamental frequency for transmission of signal from one end to the other end, we have to use multiple or pair of pilot

wires. So, basically the secondary of CT you have not one, but you have two connections. So, one is going for the relaying purpose, the other will go for the communication purpose.

So, from both the ends, you have to use the CT secondary, multiple two CT secondaries, two signals from CT secondary at both the ends and then you can transmit it. This type of basically scheme is known as wire pilot relaying scheme. So, we will discuss again the wire pilot relaying scheme that is divided in three parts.

One is known as circulating current, circulating current wire pilot relaying scheme. The second is known as the opposed voltage wire pilot relaying scheme and third that is known as the Translay type scheme. This scheme is again divided in three parts. But anyway, if we just understand the concept of circulating current wire pilot relaying scheme, the working of other two scheme remains almost similar, that is there.

Now, the third type of communication that is through audio frequency. So, when we use the audio frequency, the normal frequency range of the when we transmit the signal through audio, its range is 0.02 to 20 kilohertz. And usually in earlier cases, they used several generators known as the tone generators and receivers to transmit and receive the signal, that is basically our audio frequency carrier signal, that you have to install at each and every bus and then you can transmit the signal, transmit the data and then accordingly your relay or the protective device can take the appropriate decision. However, this type of scheme that is again not used, because there are several disadvantages. And this type of scheme now become obsolete.

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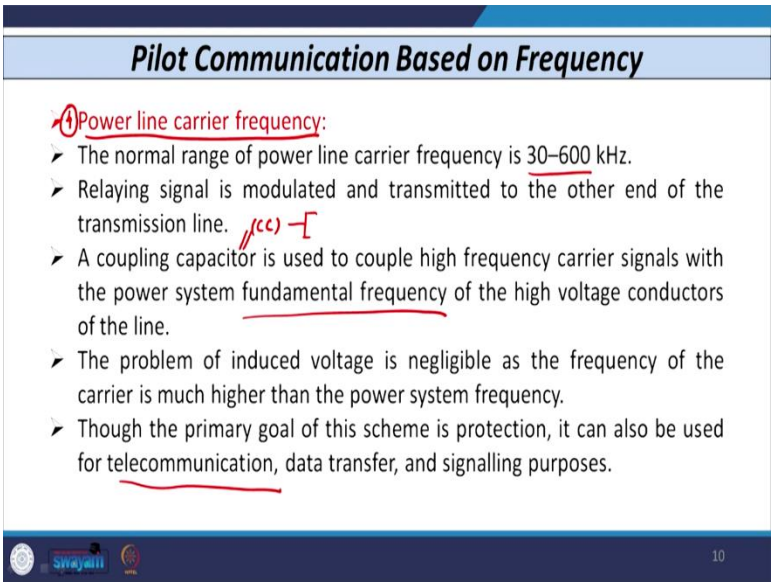

So, the fourth type of scheme that is known as the powerline carrier frequency scheme. So, in powerline carrier frequency scheme, what is done is the normally we have the fundamental frequency component signal. Along with that, we again generate a very high frequency signal, that is known as high frequency carrier signal. And then, we superimpose both these signals, fundamental frequency component and high frequency carrier signal. And then, we transmit the signal from one end to the other end.

So, the normal range of powerline carrier frequency that is from 330 to 600 kilohertz. And whenever you use this type of scheme, first, you have to use some modulate modulator is also used at each end. So, the signal is modulated and then transmitted to the other end. The coupling capacitor also you need to use.

So, this is basically known as the coupling capacitor, that you which couples or which sometimes separates the fundamental frequency with the high carrier frequency. And this type of device, there are two things we have to use, we will discuss later on, because, depending upon the application, we have to use the coupling capacitor. So, main function of this coupling capacitor provides low frequency part to the high frequency carrier signals or your carrier signals that is available to the coupling capacitor.

So, when we use the coupling capacitor, that have used to couple the high frequency carrier signals with our fundamental power frequency signal. Now, there are certain problems. If I use such type of scheme, the main problem is the induced voltage. Of course, that is very negligible. But this type of problem is there in actual field, because when any other line is passing or other conductor is there, then there are chances of induced voltage on the other or parallel conductor.

So, that we need to take care when we use such type of scheme. Of course, if I use this scheme, then we can use this along with the tele protection. We can use this scheme for other application also like telecommunication, data transfer and some signaling purpose also. Communication purpose also we can use such type of scheme, that is known as powerline carrier frequency.

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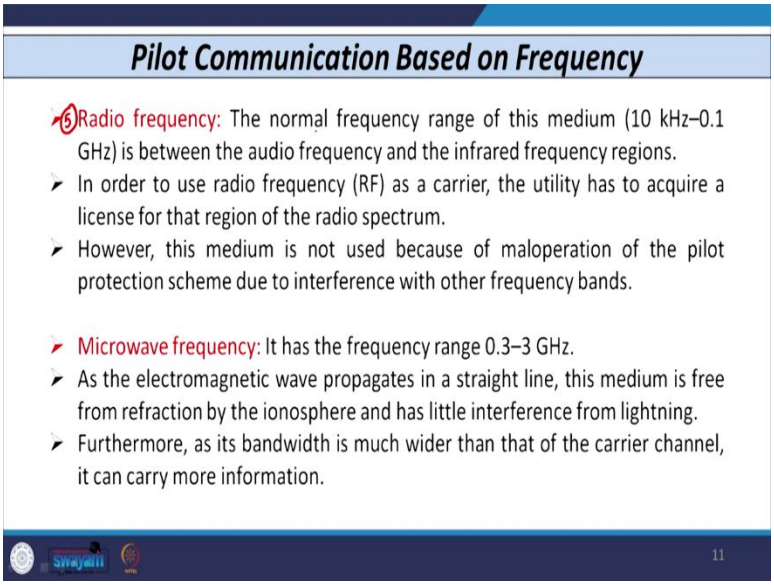

The next type of scheme that is known as the fifth one, that is based on the radio frequency. So, the radio frequency type of scheme, as I told you in earlier case, that is powerline carrier frequency we generate the high frequency carrier itself in the substation. And then, we superimpose with the fundamental frequency and then transmit, whereas here in radio frequency, the concept is entirely different.

Okay. So, we started our discussion with the what are the main problems in distance relaying scheme and we have discussed the concept of auto reclosing and the single pole tripping. Then we started our discussion with pilot protection scheme and then we discussed the pilot protection

scheme can be used based on the signal we transmit or based on the frequency. So, I stop here we will continue in the next class. Thank you.