Power System Protection and Switchgear
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Lecture 06
Current Based Relaying Scheme - I

So today we are going to discuss in this lecture, the current based relaying scheme which is applicable to transmission line as well as distribution feeders. So, the overcurrent protection of transmission lines is the cheapest and simplest type of scheme used for the protection of lines as well as feeders. When we say that the name itself suggest the overcurrent indicates that the relay operates and its contact that closes when the current exceeds the pre determined value that is known as pickup or the plug setting.

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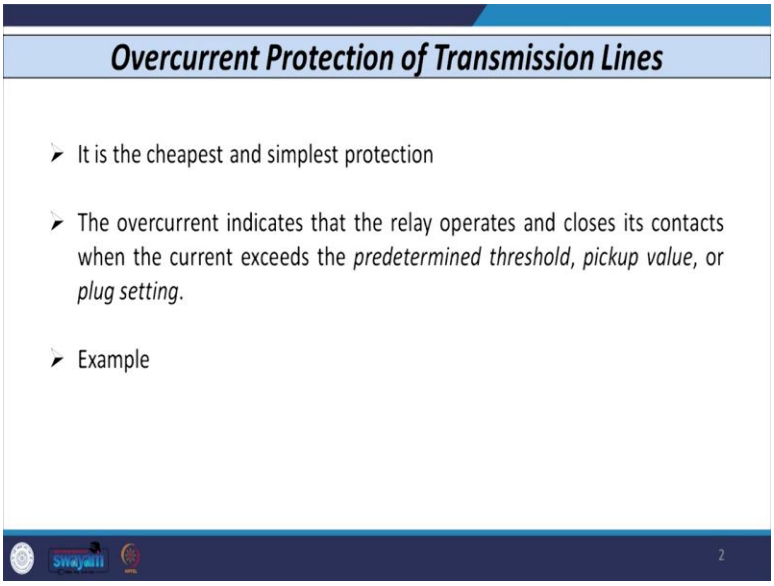

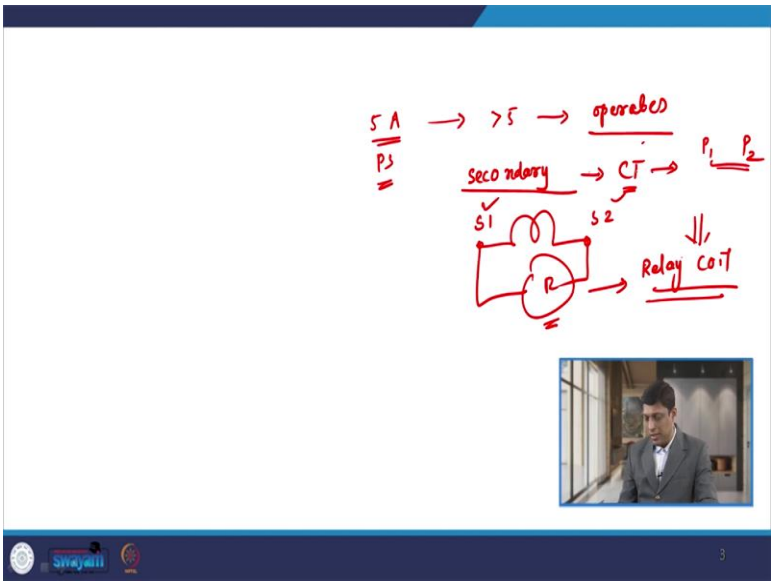

So, basically plug setting or pickup value is known as the value of the current about which relay starts operating. So, that means if I consider just give you an example, if I have a current value a that is let us say the current is five ampere and if current exceeds, let us say five ampere then relay operates. So, this five ampere is known as the pickup value or plug setting. So, relay which is known as overcurrent relay, it is always connected on the secondary of CT. So, it is it has only one input that is current so it is always connected on the secondary of CT that is known as current transformer.

So, when so this current transformer is normally denoted by this symbol and whenever I want to connect the relay across the CT then I am going to connect on the secondary side of the CT let us say its terminal is s1 and s2 these two are the secondary terminals of CT. So, relay is connected always across the s1 and s2, relay is connected means the relay coil is connected across secondary of CT and PT each relay has its relay coil and this this relay coil has some standard number. So, that two numbers that should be connected to the secondary of CT that is s1 and s2. Primary of CT that is normally denoted by the terminal name p1 and p2.

So, CT has four terminals p1 and p2 those are primary terminals, s1 and s2, these two are the secondary terminals and across this s1 and s2 relay is connected.

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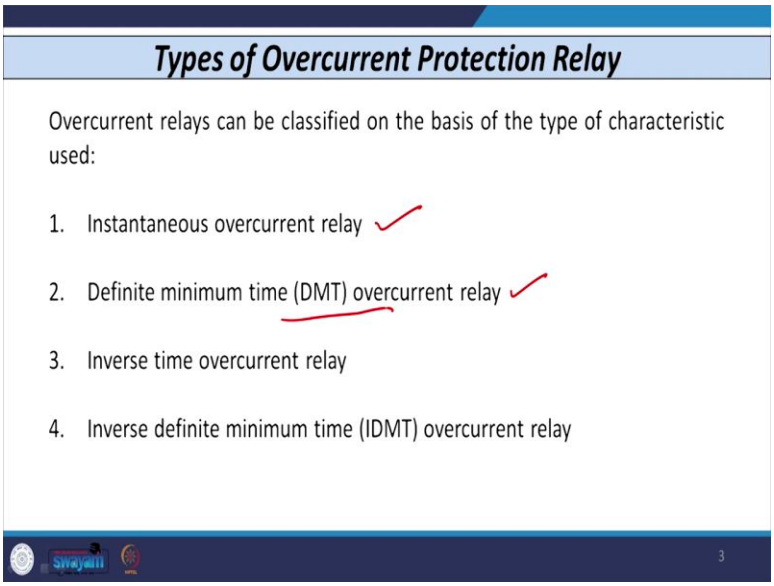

So, there are different types of overcurrent relays. So, it can be classified based on the characteristic, which type of characteristic we use, as I have discussed earlier that the relay that can be classified based on what type of characteristic that is used, what type of construction they have and what type of parts they are going to utilize. So, here let us see the classification of overcurrent relays based on the type of characteristic that is used by the relay.

So, the first type of law that is known as the instantaneous overcurrent relay. So, instantaneous overcurrent relay is basically the first type of relay. The second type of relay that is known as the definite minimum time overcurrent relay, the third type of relay that is known as inverse time overcurrent relay and the fourth type of relay that is known as inverse definite minimum time overcurrent relay.

So, let us start our discussion with the first type of relay that is known as instantaneous overcurrent relay. So, instantaneous over current relay, as the name suggests the relay operates if current exceeds the plug setting or pick up value then relay operates instantaneously. Now, actually in practical field no such relays is available that operates in zero time. So, we can define that if any relay operates in one cycle or maybe up to one to two cycle or one to three cycles. Say in terms of if I consider 50 hertz as the fundamental frequency, then if any relay operates in 20 millisecond to 40 milliseconds then those relay we can consider as instantaneous overcurrent relays.

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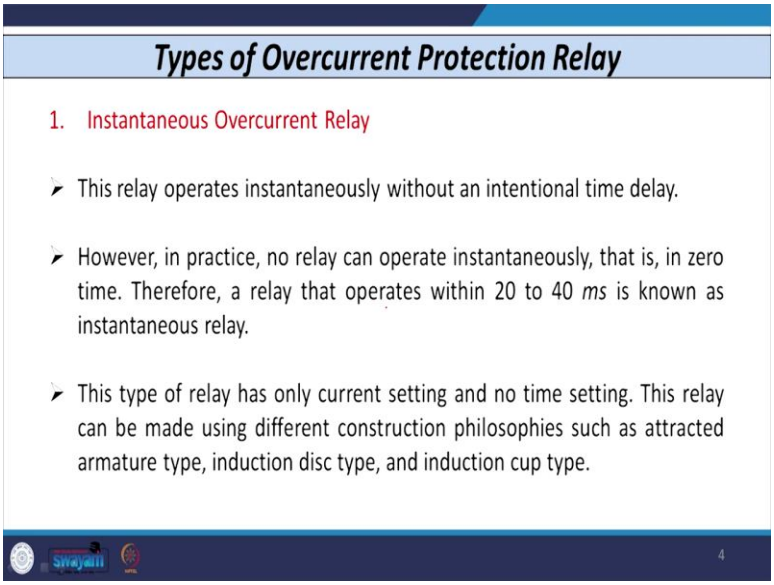

This type of relay has only one setting it has no time setting because it operates instantaneously though if current exceeds plug setting or some pick up value, then relay operates instantaneously there is no time involved in that.

So, this relay can be made by different construction philosophies such as attracted armature type induction disc type, induction cup type.

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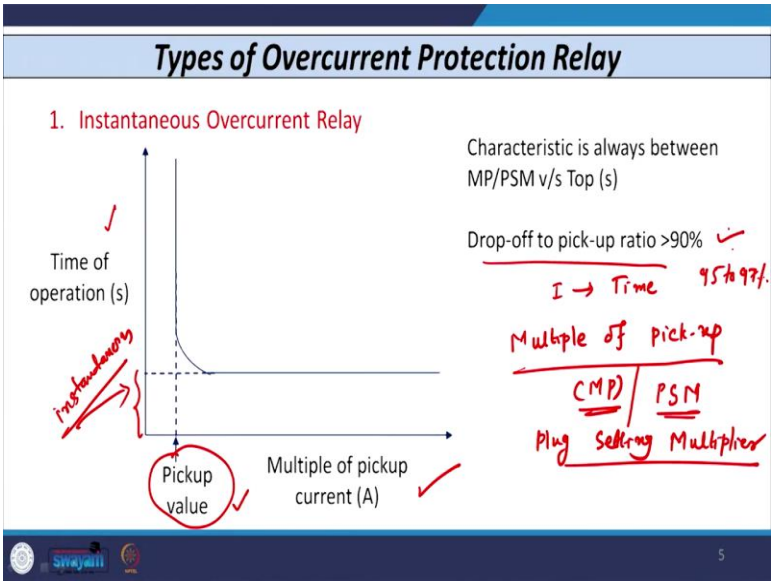

So, let us see what is the characteristic of instantaneous overcurrent relay. So, as you can visualize the characteristic that is shown here. So, on x axis we have multiple pickup current and on y axis we have time of operation. So, normally the question comes in mind that why the characteristic of overcurrent relay that is not the current versus time, but it is always the some multiple of pickup current versus time.

So, the reason is if I consider the characteristic of current versus time, then for different value of current I have different operating time. So, for even one for one and this type of this for different value of current which we called as fault current, because it is greater than the full load current and it is multiple of several times of full load current. So, for that if I draw the characteristic in terms of time then that is very difficult for the user as well as manufacturer to provide such characteristics. So, that is why such type of characteristic is always given in terms of multiple of pickup current.

So, this multiple of pick up current that is normally denoted by MP. So, MP is nothing but multiple of pick up current. Sometimes it is also known by PSM, which is known as plug setting multiplier. So, plug setting multiplier that is also similar to the your multiple of pick up current. So, if I consider multiple of pick up current on x axis as we have considered here, and if I

consider time of operation in second on y axis, then the characteristic of instantaneous overcurrent relay that is given by this, you can see that the pickup value I have shown here.

So, pick up value our plug setting if current exceeds this value then relay operates within some specific time period this time period that is instantaneous in nature. So, relay operates instantaneously if current exceeds its pick up value. The second thing very important is the drop off to pick up ratio of this relay.

So, whatever relay available in market it has some pickup value say this value we have set here some pick up value, it has also has some drop off value. So, drop value is when current gets discontinued, what will be the value of, at that particular point of time that is known as drop off value. So, if I take drop off to pickup ratio then this should be always greater than 90 percent then the relay is very good.

So, the whenever we design the relay or whenever any manufacturer designs the instantaneous over current relay, it tries to maintain the drop off to pickup ratio greater than 90 percent So, whatever relay presently available, it has the drop off to pick up ratio roughly around 95 to 97 percent.

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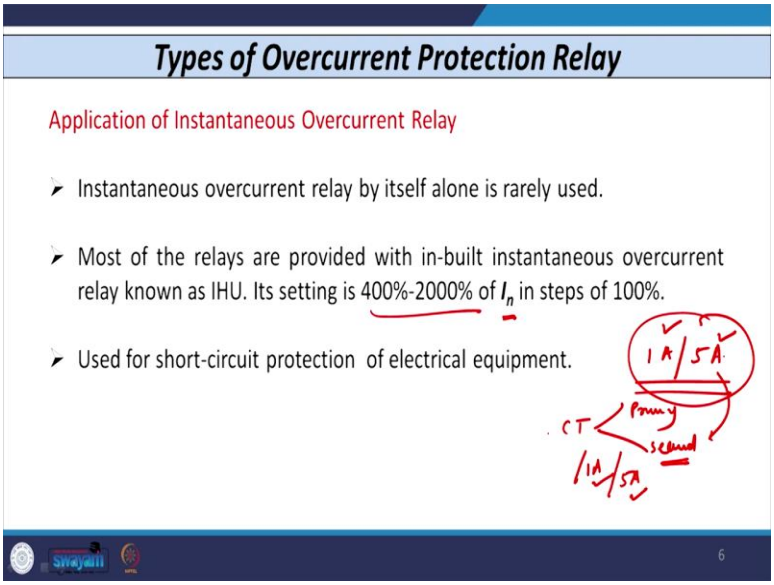

So, with this background, let us see what is the application of instantaneous overcurrent relay. So, instantaneous overcurrent relay as that can be used alone it can be rarely used. So, we cannot use as a single relay we cannot use directly into the field for maybe for protection of transmission line or distribution feeders. So, it is always used associated with some other type of relay.

So, most of the relay that is provided with instantaneous over current relay and this relay is known this relay has one setting that is known as IHU, instantaneous high set unit and its setting value is normally 400 percent to 2,000 percent of the iron where iron is nothing but the relay rated current, relay rated current that can be always either 1 ampere or it can be 5 ampere.

So, this is standard that whenever I connect any relay across the secondary of CT that is two terminals as I explained earlier s1 and s2, then the rated current of the relay that is always either 1 ampere or 5 ampere so this is standardized. So, primary of the CT and one more thing is whenever I consider CT which has primary side and which has another secondary side and as the relay is connected on secondary of CT, so, secondary side of the CT that is always matched with this relay rated current.

So, if I have CT secondary 1 ampere then I have to connect 1 ampere rated current relay with this, if I have 5 ampere CT secondary then I have to connect 5 ampere rated current relay with this CT secondary, it is not possible that I have five ampere rated current relay and I connect it

with one ampere CT secondary it is normally not done. The main application of instantaneous overcurrent relays is, it is used for short circuit protection of electrical equipment. So, whenever I want very small operating time against very high short circuit magnitude of current, then such type of relay that is used.

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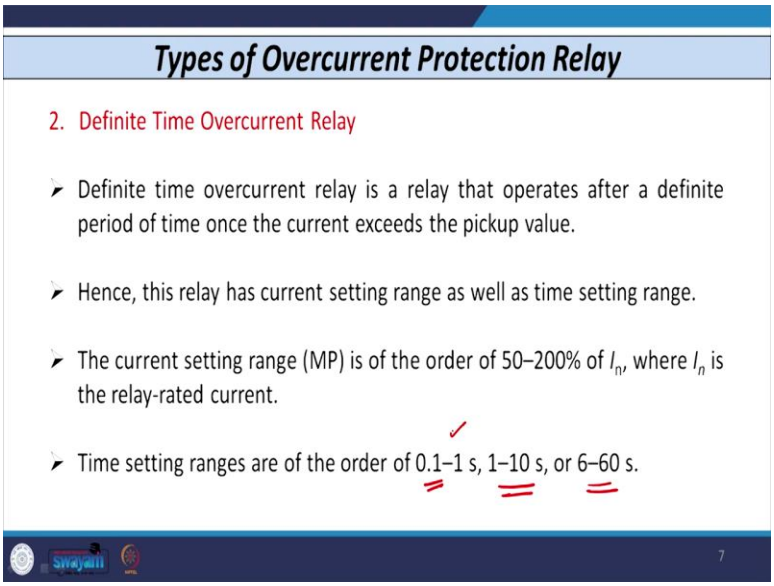

Let us see second type of relay that is known as the definite time or definite minimum time overcurrent relay. The definite minimum time overcurrent relays is a relay that operates after a particular definite period of time or after some preset value of time. So, if current exceeds pick up value or plug setting and whatever time you have set relay operates after that much period of

time. So, that is known as definite minimum time relay. So, this relay compared to the earlier relay instantaneous overcurrent relay which has only one setting that is current setting, this relay has two settings one is known as current setting and the other is known as time setting.

So, the current setting range as I told you earlier, normally we consider multiple of pick up current. So, its setting range is 50 to 200 percent. So, if I consider the setting range of the definite minimum time overcurrent relay DMT relay then it's setting range is given in steps of from 50 percent to 200 percent of relay rated current that is IM, let us say it is 1 ampere, so, it's setting range, this is the current setting range. So, current setting range is given from 50 percent to 200 percent of relay rated current that is 1 ampere and this is in steps of 25 percent.

So, starting if I start with 50 percent, then the it's setting ranges 50 percent, 75 percent, 100 percent, 125 percent, 150 percent, 175 percent and 200 percent. So, total seven setting range are available with reference to relay related current, this seven setting range are available for electro mechanical type relay. If I have the digital relay, if I have the digital relay, then you have a multiple ranges maybe from say any value if you wish so you have the any multiple type of range for digital relay. So, the on the other hand the time setting range for this definite minimum time relay that is of the order of 0.1 to 1 second or 1 to 10 second or 6 to 60 seconds.

So, if I use English Electric make relay, then earlier they are they were providing the setting range, time setting range of 0.1 to 1 second, some other manufacturers they provide also the time setting range from 1 to 10 seconds or 6 to 60 seconds. So, it depends on what for what type of application we are utilizing definite minimum type overcurrent relay. So, if I consider now how to achieve the time of operation or how to obtain or find out the time of operation of this definite time overcurrent relay.

So, if I consider now how to achieve the time of operation on how to obtain or find out the time of operation of this definite time overcurrent relay.

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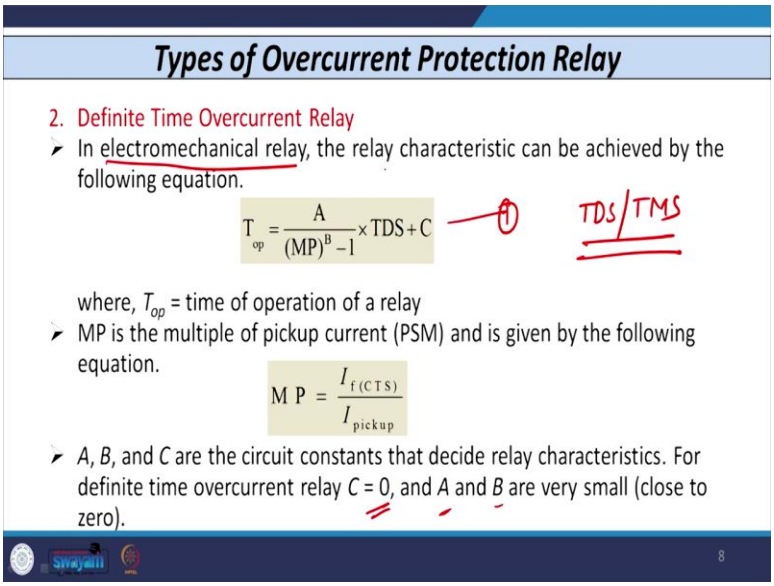

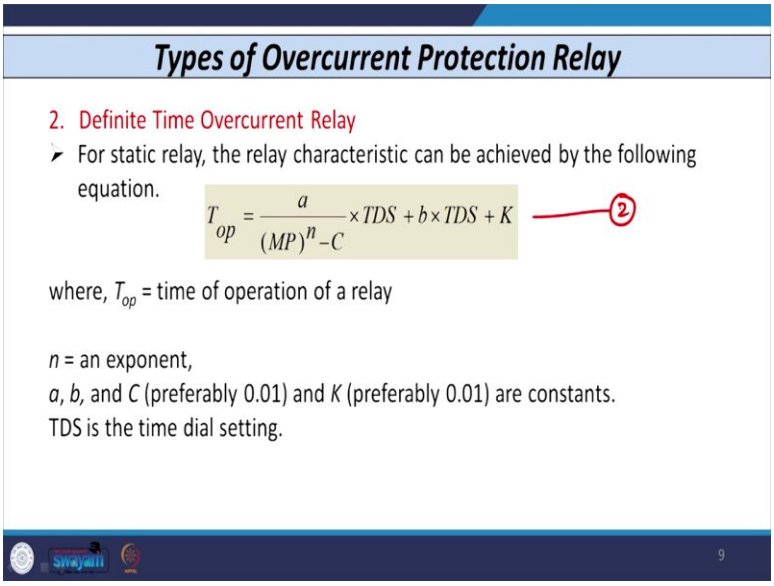

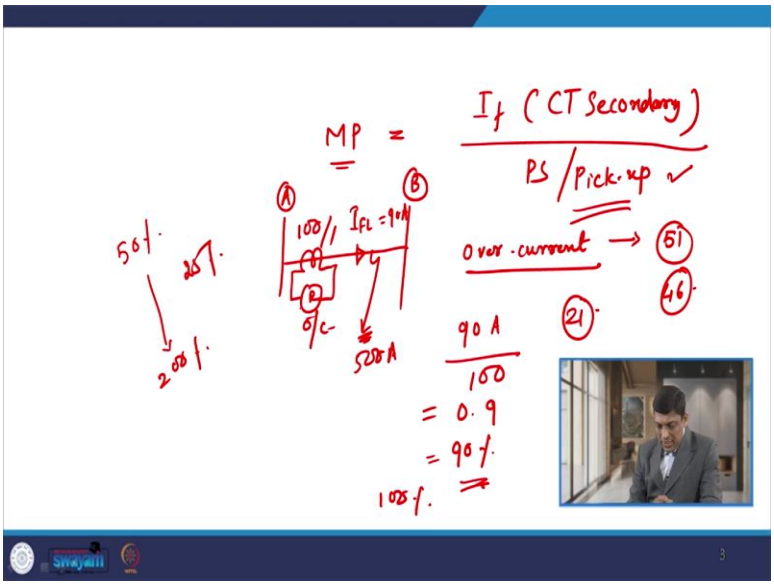

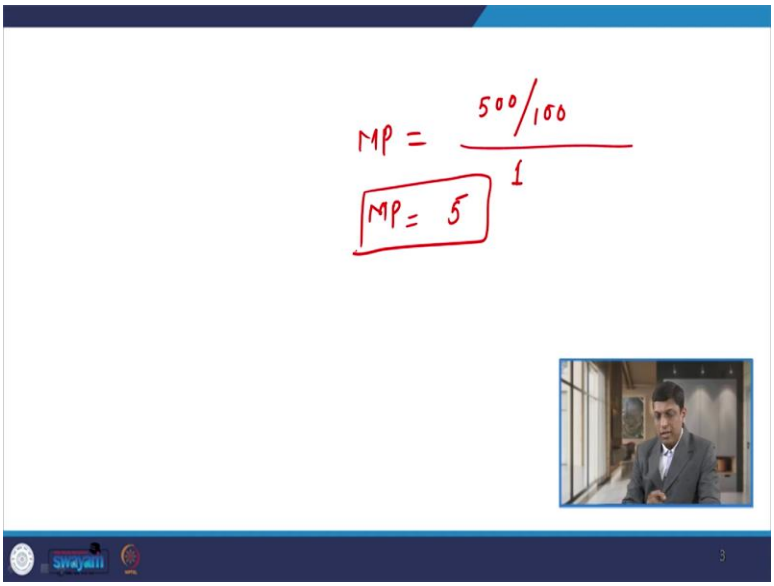

So if I consider the electromechanical relay, then the relay characteristic can be achieved by the equation as shown. So, the equation is on left hand side you have Top which is known as time of operation of relay in seconds and from on right hand side we have the A divided by MP raise to n minus 1 into TDS plus C. So, here MP is nothing but the multiple of pick up current. So, if I consider the multiple of pick up current MP, then MP is defined as the fault current referred to CT secondary side divided by the plug setting or pick up value of the relay.

So, if I consider say one feeder connected between two bus A and B and if I consider the one CT say it's ratio is 100 by 1 primary 100 secondary 1 ampere and I have connected one relay here say overcurrent relay. So, normally in actual field all this relay, whenever I mentioned the name

of the relay, the relay name is not written completely so I am not going to write the relay name as say overcurrent relay, instead of that, they denote this relay with the number.

So, overcurrent relay is the given the number that is 51. So, if I consider the other type of relay, then say the some other type of relay, then they are the number that is given to that relay that is different, say if I consider negative sequence relay the number is 46 if I consider the distance relay the number is 21 and so on.

So, there are several numbers given for our assigned for each specific type of relay. So, in this case if I consider the fault current on this feeder is let us say 500 ampere. So, in this case and let us also consider the full load current of this feeder is let us say 90 ampere. So, the plug setting of this relay is nothing but the 90 ampere that is the full load current divided by CT ratio that is hundred. So, the value is 0.9 if I convert this value in percentage, it is 90 percent. So, plug setting or pickup value of the relay that should be always greater than 90 percent. So, as I told you seven settings are available from 50 percent to 200 percent insteps of 25 percent.

So, the highest higher than this value that is nothing but the 100 percent that we can select as a plug setting or pick up value of this relay over current relay 51. So, if I want to find out the multiple of pick up current for this case with 500 ampere is default current, then the multiple of pickup current that is given by default current referred to city secondary. So, fault current is 500 ampere and if I referred on secondary side, then the CT ratio is 100 by 1 and divided by plug setting of the relay that is 100 percent of relay rated current, let us say relay rated current is one ampere than the plug setting is hundred percent of 1 ampere that is 1 ampere.

So, the multiple of pickup current that comes out to be 5 in this case, right? So, in this equation the multiple of pickup current that is fault current on CT secondary side by plug setting that is calculated like this the value of TDS that is nothing but known as time dial setting of the relay or sometimes it is also known as the time multiplayer setting of the relay so both are same.

So, time multiplayer setting of the relay is nothing but on the dial setting of time setting of the relay, the manufacturer is providing time dial setting from 0.1 second to 1 second insteps of 0.05 second or some other range. So, this dial setting is known as time dial setting and this is this based on this time dial setting time of operation of relay that varies.

On the same equation if I consider A, B and C then capital A, capital B and capital C these three are the constants and these three constants are depends on the what type of characteristic you want to obtain and that is to be decided at the time of design of the relay. So, normally for definite time overcurrent relay the capital value of C that is considered as 0 and the capital value of A and B that is almost close to 0. And if you put this value in this equation, then you can obtain the or you can calculate the time of operation of the definite minimum time relay, if I consider the static relay.

So, earlier equation this equation one that is applicable for electromechanical type relay, if I consider the static relay, then for static type of relay, the time of operation of relay that can be given by this equation let us say equation two. So, in this equation if I consider on left hand side the Top is the time of operation of relay in second, the MP is the same as I explained earlier it is multiple of pickup current and it is obtained by fault current refer to city secondary divided by plug setting of the relay, exponent n is an exponent so, that depends on again what type of curve we wish TDS is the time dial setting of the relay and the value of B and the value of k value of small a and value of capital C all are constant.

So, a, b, the value of c is normally very small 0.01, K is also very small that is also 0.01 and the value of small a and small b that depends on what type of characteristic we wish to achieve.

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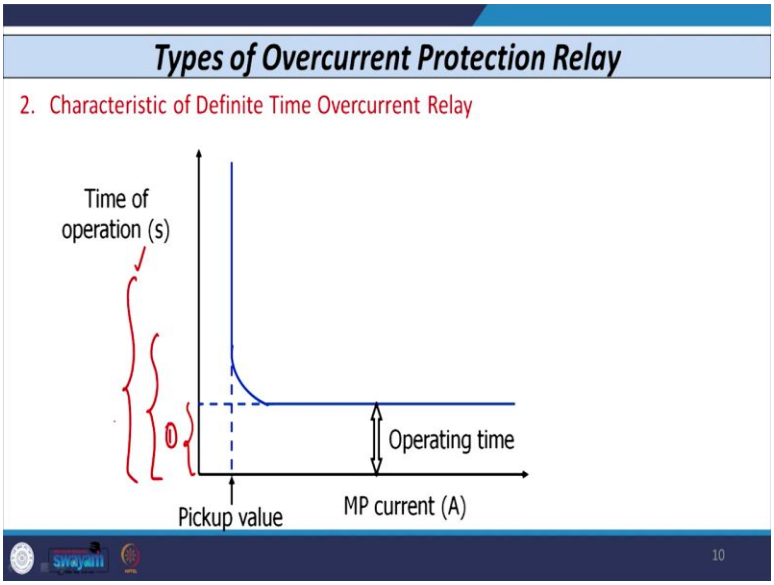

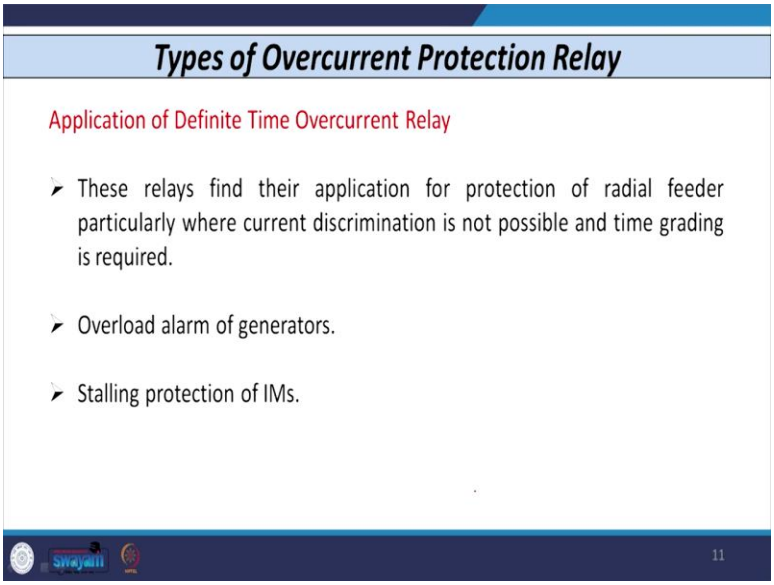

So, with this background let us discuss the characteristic of definite minimum time overcurrent relay. So, as you can see that on x axis I have considered the multiple of pickup current and on y axis I have consider the time of operation of relay. So, you can visualize that the on the x axis where I have considered the multiple of pickup current, you have the pickup value so, if whatever value you have set or plug setting, if current exceeds that value, then relay operates in preset time.

So, this time you can you have to set on the time dial setting. So, this time you can vary. So, this time can be at one case it is like this, this time can be like this, this time can be like this. So, this you can vary. So, the main point is how to the relay of definite minimum time relay operates, if you set some pick up value, then if the current exceeds pick up value irrespective of magnitude of fault current whatever it is on x axis relay operates after some preset time that is which you have set on the relay after that much time period relay operates. So, that is why it is known as the definite minimum time relay.

What is the application of defining minimum time overcurrent relay? So, this relays find their application in the protection of radial feeder where current discrimination normally is not possible and you have to use some other type of discrimination that is time discrimination. So, in that case, you have to use such type of relay. Sometimes this type of relay is also used for giving overload alarm of the generators or induction motors also maybe in case of transformer also we can use this type of relay.

If I use induction motors, then for stalling protection of induction motors also we can use definite minimum time relay because stalling is a phenomena that occurs induction motor but that in that case instantaneous tripping is not required. So, we can give time delay TP with the help of definite minimum time overcurrent relay.

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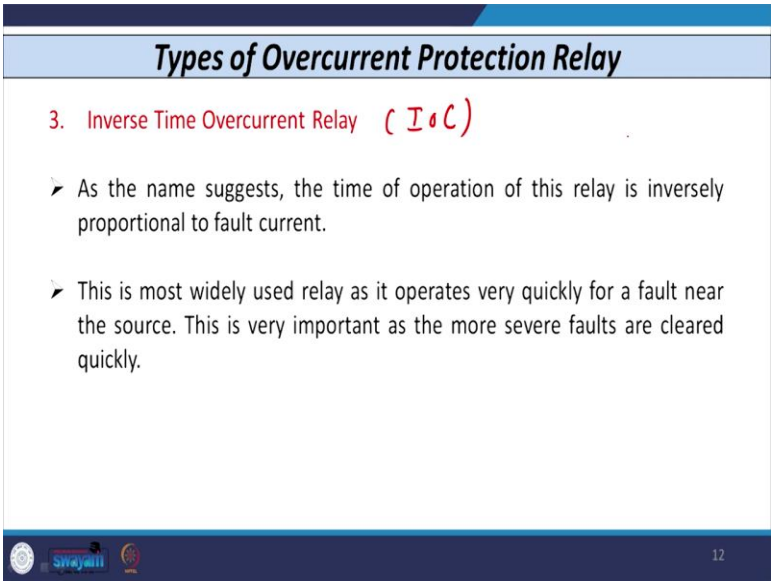

So, now, let us see third type of relay that is known as inverse time overcurrent relay, it is also denoted by the letters IOC inverse time overcurrent relay. So, as the name suggests the time of operation of this relay that is inversely proportional to the fault current and it is most widely used relay because in whenever you use this relay, I fault occurs very near to the source, then the minimum time of operation is achieved and relay operates with minimum time.

So, the tripping time is also very less and we can save the equipment against the whatever is the magnitude of fault current which is going to damage the equipment, so that we can save the equipment from the hazard of the damage done by the higher magnitude of fault current.

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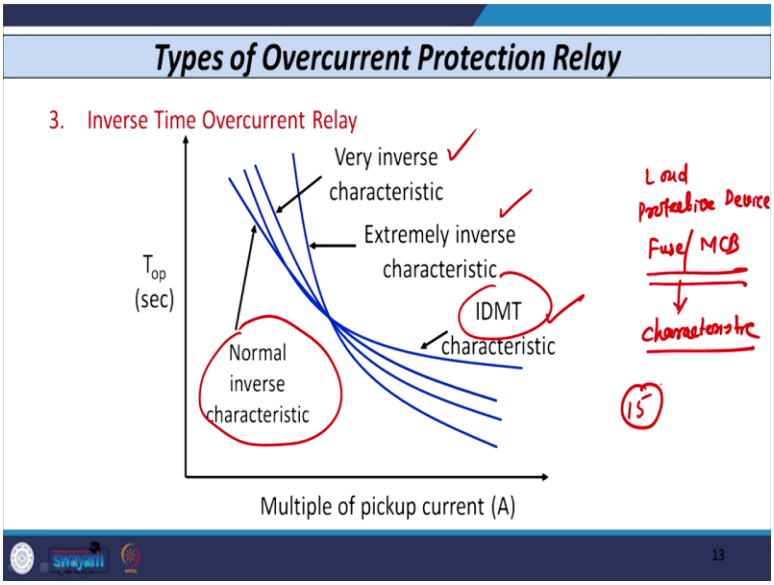

So, let us see the characteristic of inverse time overcurrent relay. So, I have shown four different characteristics. So, you can see that the first characteristic that is the normal inverse characteristic. So, this type of relay is known as normal inverse type inverse time overcurrent relay. So, it is normally given by the name inverse time overcurrent relay having normal inverse characteristic. So, when I have normal inverse characteristic the characteristic curve is like this. I do have the other type of characteristics.

So, inverse time overcurrent relay with very inverse characteristic and inverse time of overcurrent relay with extremely inverse characteristic. So, you can see this type of two characteristic I have showed where the curve becomes more steeper and steeper. I have also shown the another type of characteristic that is IDMT characteristic in which the relay is known as inverse the definite minimum time relay.

So, we will see later on that what is IDMT relay, but, in inverse time overcurrent relay three characteristic I have shown that is normal inverse, very inverse, and extremely inverse and depending upon the requirement, what type of curve we wish and what type of, for what type of application we are utilizing, we can select appropriate characteristic and we can consider the each and every inverse time overcurrent relay, the main how to achieve this type of characteristic.

So, I told you earlier we have discussed two equations one for electromechanical relay and another for aesthetic relay. So, by adjusting the value of several constants as we have discussed earlier, we can have the normal inverse characteristic we can have the very inverse characteristic and we can have the extremely inverse characteristic. The manufacturer is providing different types of characteristic because, whenever we installed such type of relay, we have to coordinate the this type of relay with the load side device load side protective device.

So, normally load side protective device, load side protective device is either fuse or MCB. So, this fuse or MCB has some specific type of characteristic or curve. So, whatever characteristic of this fuse or MCB has, we have to coordinate exactly with the, the overcurrent relay which we have installed, so when we coordinate overcurrent relay with fuse or MCB characteristic, we may need different types of characteristic like normal inverse, very inverse, extremely inverse.

So, that is why manufacturer is providing such type of characteristic. If I consider the digital relay, then total 15 type of characteristic that is provided by digital relay starting from normal inverse, very inverse, extremely inverse, rarely inverse, standard inverse, medium inverse and so on.

So, depending upon the application and requirement, you can consider or select specific type of characteristic. So, if I consider the inverse time overcurrent relay, as I told you earlier by adjusting or selecting the several constants, we can obtain the each and every type of characteristic.

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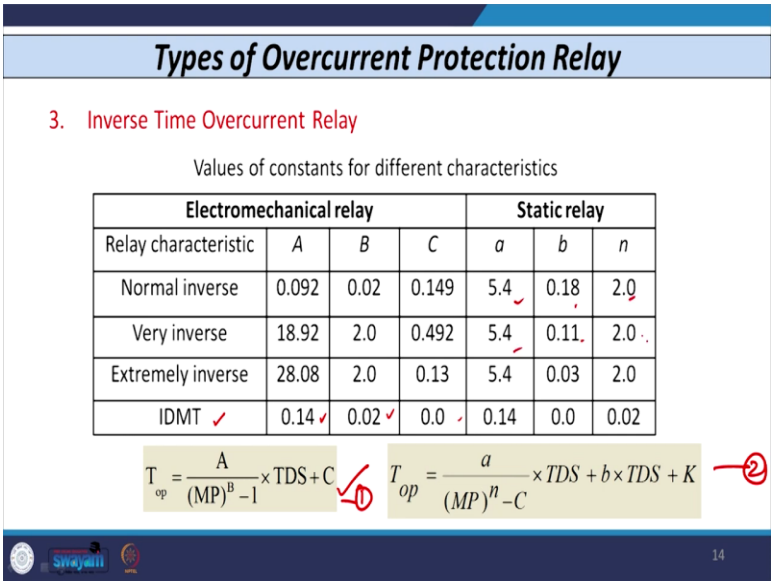

So, if I consider electromechanical relay, where the equation is given by this equation 1. So, you can see that in that this equation, the constants are capital A, B and C. So, if I wish to use or obtain normal inverse characteristic, then I have to select the constants 0.092, 0.02 and 0.149 and hence accordingly I for very inverse and extremely inverse I have to select the appropriate value of capital A, capital B and capital C. Similarly, if I want IDMT characteristic that is inverse definite minimum time characteristic, then I have to select the values that is of A 0.14, B that is 0.02 and C that is 0.

Same way for static relay also the equation is shown here below that is 2, we can select the appropriate values of cap small a, small b and small n and for each specific type of characteristic by selecting this values right each and every value, we have the different types of characteristic we can achieve.

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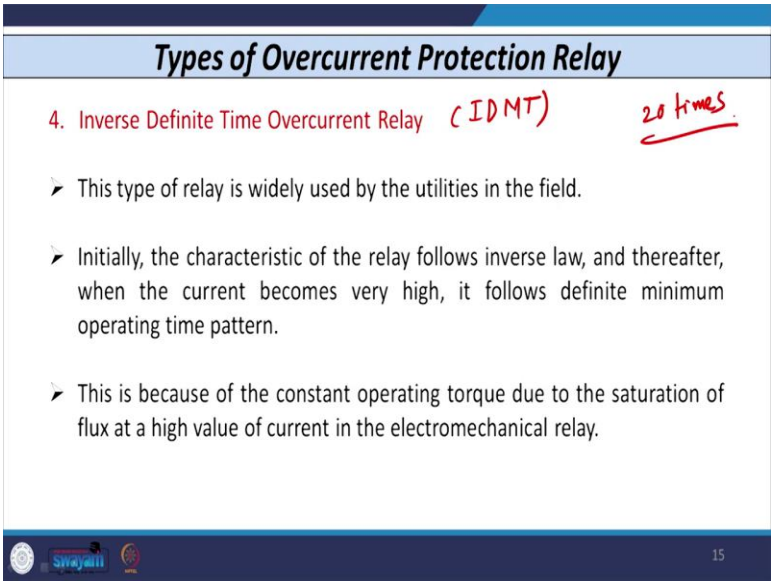

The fourth type of relay that is known as inverse definite minimum time overcurrent relay. So, this relay is known as IDMT type relay, this is the most widely used relay, because the operating principle of inverse definite minimum time relay is achieved by two different relays one is the inverse overcurrent relay and the other is the definite minimum time delay relay.

So, initially are in for several magnitudes of current which is multiple of full load current or pickup value, the time of operation of relay IDMT relay is inversely proportional to the current and after some point of time where the magnitude of current becomes very high, let us say the 20 times the pickup value. Then, after this point, the time of operation of IDMT relay that is again switched over to the definite minimum time relay.

So, up to pick up value or multiple pickup of one to 20 the time of operation of IDMT relay is inversely proportional to magnitude of current. And after if the multiple of pickup current exceeds 20 or some specific value as decided, then the time of operation of IDMT relay that becomes constant and it follows the definite minimum time principle. The main point of the IDMT relay is that why we are utilizing two different inverse time overcurrent relay and definite minimum time relay for obtaining the IDMT relay?

The reason is, because after several magnitudes of fault current say 20 times the full load current or pickup value, the torque which is produced or exerted on the disk of the rotor for electromechanical relay that becomes constant because of the constant flux produced. So in that

case the whatever the arrangement is done, it is done in such a way that we can have the two different characteristics that is initially it follows inverse time over current relay characteristic and later on it follows definite minimum time relay characteristic.

The now for all this four types of overcurrent relay which we have discussed starting from the instantaneous over current relay first, second definite minimum time relay third that is inverse time over current relay and the fourth is the inverse definite minimum time relay.

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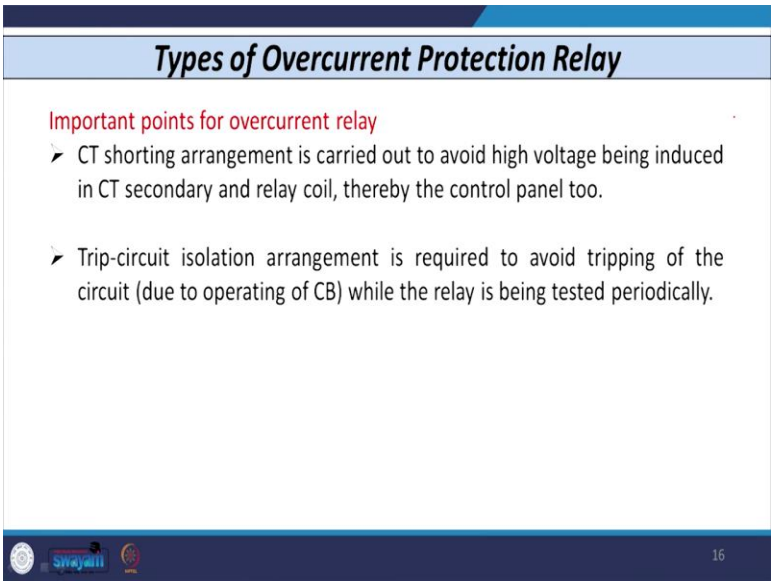

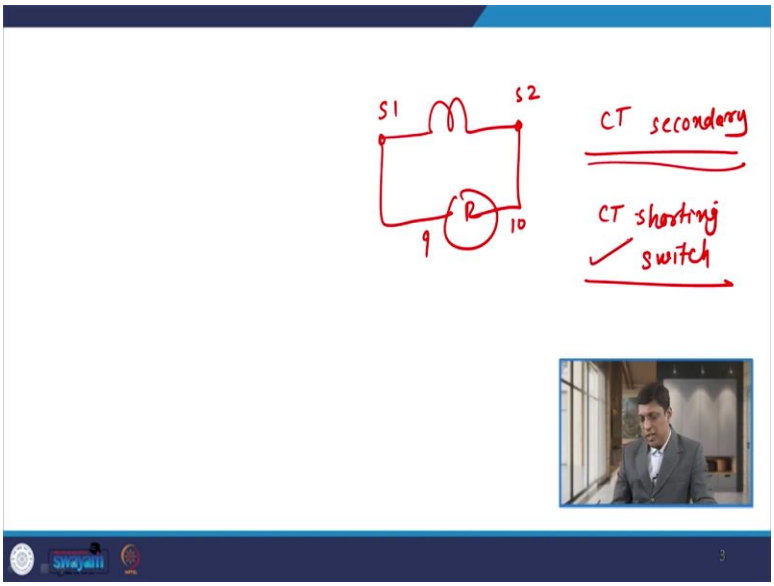

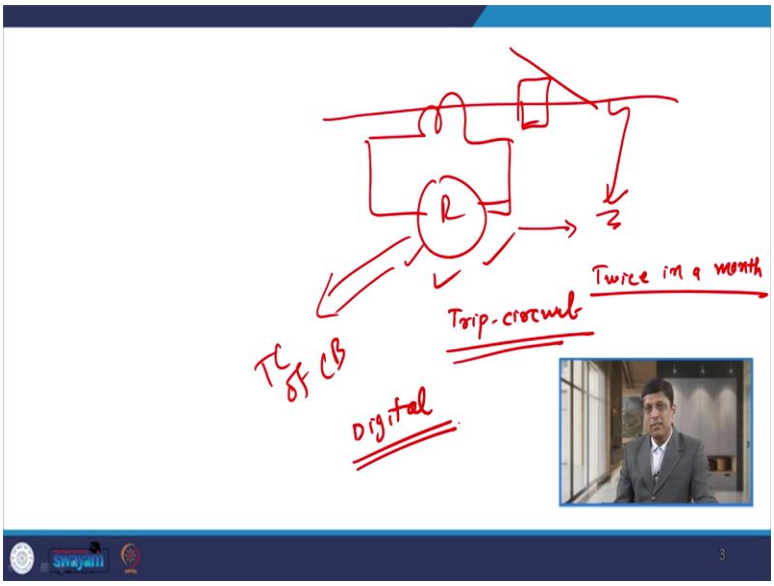

So, all four types of overcurrent relay two points are very important the one point is CT shorting arrangement that is to be carried out to avoid high voltage that is being induced across the CT secondary. Now the what is this CT shorting switch? So, whenever I as I told you earlier I CT has two terminals on secondary side s1 and s2 and I am going to connect the relay coil across these two terminals, let us say relay number is 9 and 10 for electromechanical relay.

So, whenever I remove this relay or from this s1 and s2 because relay is always connected on CT secondary, then CT secondary should not be open circuited, if I open circuit the CT secondary and keep open then very high voltage is induced or produced across CT secondary and if person is working in the substation, then he may get a shock on the against this very high voltage available across CT secondary.

So, mostly in the actual substation, almost all the CTs are provided with the device known as CT shorting switch. So, the function of this CT shorting switch is whenever you remove the relay from the CT, then automatically the CT secondary automatically closed by this CT shorting switch. So, this is very important point when you consider any type of overcurrent relay. The next point you have to consider that is that trip circuit isolation arrangement.

So now, we know that the whenever I connect any relay across the CT secondary, this relay has to operate only and only when fault occurs on the line, right? Say this CT is connected and if any fault occurs on this feeder or line then this relay has to operate, but we do not know at what instant fault occurs sometimes fault may occur maybe twice thrice in a year or sometimes it may

not occur maybe for two years. So, this relay has to operate only in case of fault. So, periodically we have to carry out testing of this relay the normal practices we have to carry out the testing twice in a month.

So, when we carry out periodical testing of the relay, then what we have to do, we have to remove the relay from the case from the panel and then we have to give some external in current injection through current injection test kit to the relay and we have to check whether the relay disc if it is electromechanical mechanical type or maybe static relay or digital then we have to check whether relay operates with specific time period as given by the manufacturer or not.

Now, when we carry out some type of testing, this relay coil or relay contacts that is associated with the trip coil of circuit breaker. So, whenever we carry out periodic testing of this relay, relay contacts, relay operates and it gives signal to the trip coil of circuit breaker and circuit breaker will further give initiation command and if I can if I have connected the breaker here then breaker may become open.

So, to avoid unnecessary opening of circuit breaker while we are doing periodic testing of the relay, then we have to use some circuit known as trip circuit isolation. So, trip circuit isolation is a type of circuit in which when periodic testing of the relay is carried out, then the trip coil of circuit breaker then that is bypassed. So, even though relay operates, it will not give or issue a signal to the circuit breaker and unnecessary operation of circuit breaker that can be avoided.

The question may come sir, if we are doing periodic testing and fault occurs on the line what will happen? So, in that case as a primary relay on which we are carry out periodic testing, that relay is not going to operate, but we do have some backup relay. So, we have to rely on backup relay itself unless and until we use digital relay, which has a capability of self checking self testing feature. So, we need not to carry out periodic testing of those relays, it is capable to carry out its checking itself and we can avoid such thing.

So, with this background, we have considered in this lecture, we started with different types of overcurrent relay starting from instantaneous over current relay, definite minimum time relay, inverse time overcurrent relay, and inversed definite minimum time overcurrent relay and we have discussed that how the how what is the characteristics of each and every relay and what is the for what, using what equation we can achieve those different characteristic of the relay.

So, by selecting different constant we can achieve the different relay characteristic for different types of overcurrent relay. Now, how we can utilize this relay in actual field, that we will discuss later on in the next class. Thank you.