Power System Protection and Switchgear
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Lecture – 05
Fundamentals of Protective Relaying-V

So, today we are going to discuss the other several other types of relays and their construction. So, let us start with the induction type relay. So, induction relay operates on the principle of electromagnetic induction. So, basically it is a split phase induction motor with several contacts. So, the our main operating principle of induction type relay is because of interaction of 2 AC fluxes, the torque or force is produced on the movable element.

Now movable element it can be either rotor or it can be a disc or it can be a cup. So, depending upon what type of movable element we are using, if we use a disc type of movable element then the relay is known as induction disc relay and if we use the movable element as a router or cup, then we that relay is known as induction cup relay.

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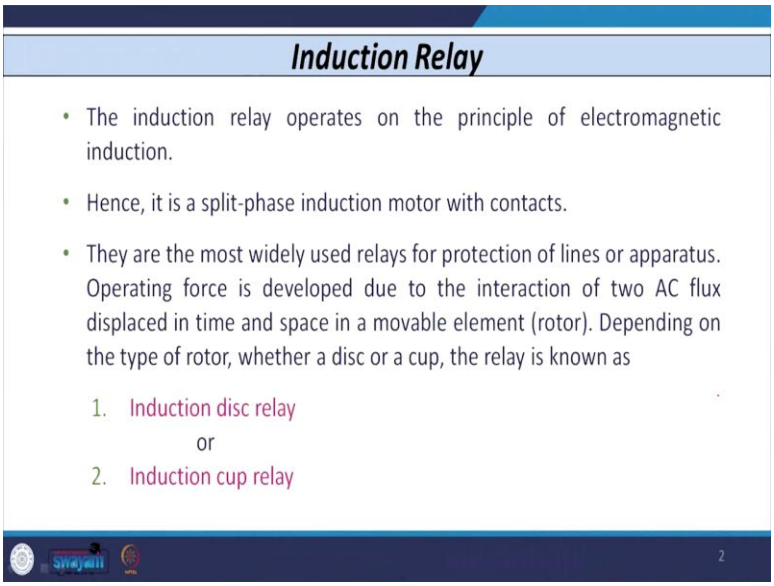

So, let us start our discussion with the first type of relay that is known as induction disc relay.

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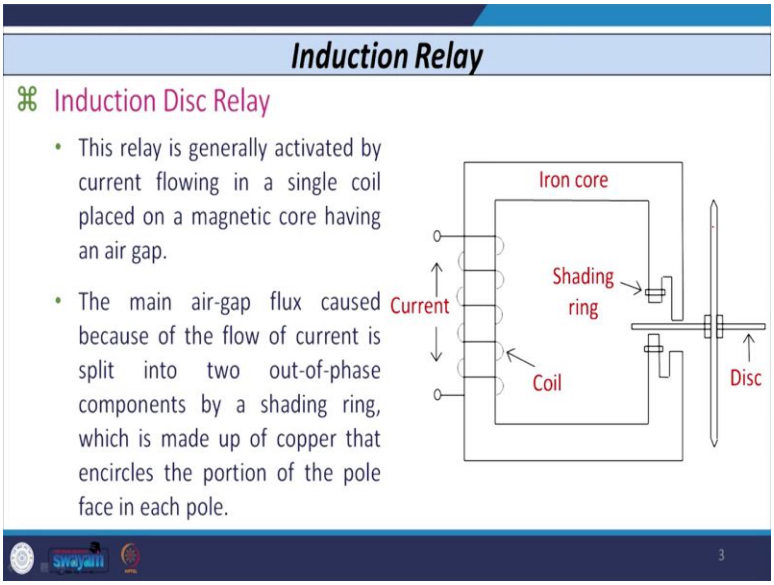

So, if I consider the induction disc relay, then we have the iron core. Now, this iron core is not continuous, but it is basically splitted, so, the air gap is there. And on this iron core the coil is wound and on this coil we are giving the current to the, the core of the this disc relay. Now, if I consider the induction disc type relay, then this relay is generally activated by current flowing in a coil which is wound on a magnetic core.

The main air gap flux that is caused because of flow of current that is splitted in the in the 2 parts. So, basically on one side you can see the shading ring. So, here either the on the pole pole, so, of this the copper shading band is provided. Now, this copper shading band between this gap which is called air gap and on this disc the is provided and disc is connected with the shaft and on this shaft the contacts, relay contacts are there.

So, basically moving contact is available on this shaft. So, whenever the disc moves the moving contact moves and it touches with the another contact known as fix contact. So, if I consider the this type of induction disc type of relay. Then the because of interaction, see there are 2 flux here the operating quantities only is one that is current; so, which is going to produce the flux on the disc.

Now, whenever we have only one operating quantity that is current which is going to produce the flux, then obviously, whatever flux is there that is pulsating in nature. So, whenever this flux that is which is in pulsating in nature because on every half cycle, we have a natural current 0 in

this circuit. So, because of this whatever the relay is there they may have they may have observed the noise or chattery.

So, to avoid that, we are going to use the, we are going to generate the 2 different fluxes which are in displaced in time. So, because of interaction of these 2 fluxes and the design of this is carried out in such a way that the overall or the resultant flux that is always positive. So, that there is no chattering that is occurred on the relay. Now, the air gap flux is a shaded pole lags behind the flux of non shaded pole. So, the rotor which we have considered here as a disc that is pivoted.

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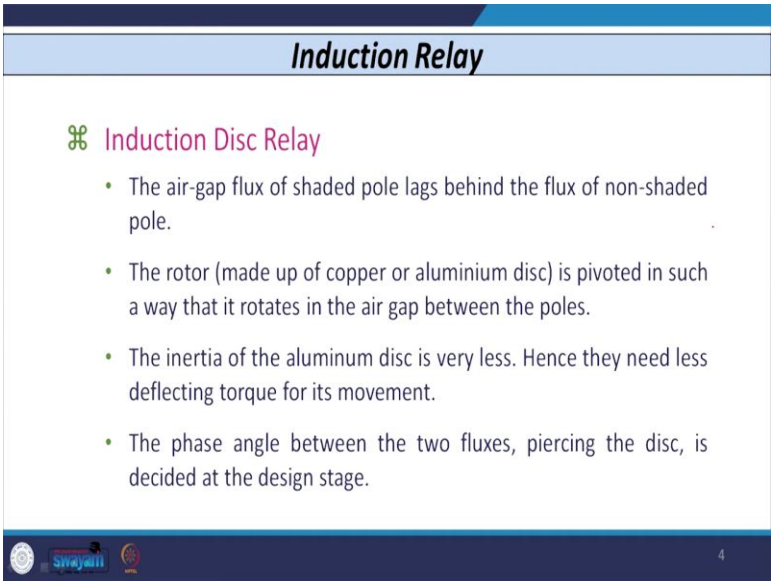

In such a way that it rotates in the air gap between the 2 poles. The inertia of the aluminum disc is very less usually we may use the any type of material for the aluminum disc, but this type of aluminum disc normally is similar to the earlier of electromagnetic type of energy meter. So, they need a very less torque for the movement or operation.

The phase angle between two fluxes that is decided at the time of design stage and as I told you earlier that it is so, it is adjusted in such a way that the resultant flux that is always positive in nature. The other type of relay, where we use movable element as a cup instead of disc so, this type of relay is known as induction cup relay.

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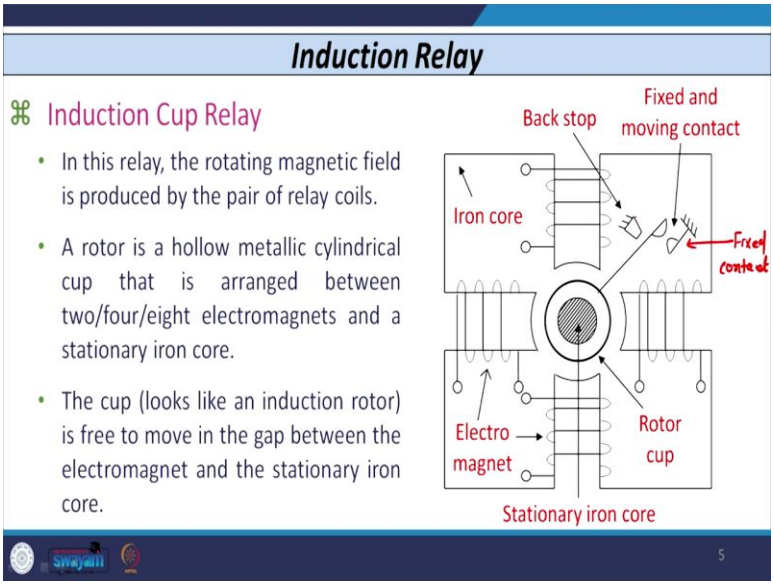

Now, in this relay, the rotating magnetic field is produced by the several relay coils, so we can use so our rotor is a hollow metal cylinder cup that is arranged between either 2 coils either or 4 coils or sometimes 8 coils.

So, here in this figure, you can see that we have used 2 pair of relay coils. And you can see that on the first pair of relay coil that is the upper side and the lower side we have one coil and the other pair of relay coil that is, we have on the left hand side and we have on the right hand side we have the another coil and this coil is wound on electromagnet. Now you can see on the at the center, you have a stationary iron core and on this iron core you have a rotor cup and on this rotor cup the two contacts are connected one is known as moving contact and the other side lower side the contact that is known as fix contact.

So, this contact we can call it this is a fix contact and the other contact which is on upper side, this side which is connected to this rotor cup that is a moving contact. So, when and again with this moving contact, you can see there is another device known as back stop. So, the main function of this back stop is that it does not allow the rotation of this cup on the other direction. So, that is why its rotation is restricted only in particular region.

Now, in this case the the cup, which we called as an induction rotor, that is free to move the in the gap between the electromagnet and the stationary core and because of movement of this whenever the as the moving contact is associated with this router cup. So, whenever the the cup

moves, it has to move in as very small distance. So, whenever it moves and touches to the fixed contact, the circuit is energized and further tripping that is initiated.

So, the rotating field that is introduced in the rotor cup, that is when the any when then the causes the copy it has to rotate in particular direction and the rotation depends on the magnitude of the whatever AC quantities we have applied. The there are several advantages of induction cup relay with reference to induction disc relay. And the very first advantage is that the induction cup relay is more efficient than the induction disc relay because as I told you earlier that it has to travel a very small distance and with that distance it produces a very high torque compared to the induction disc relay.

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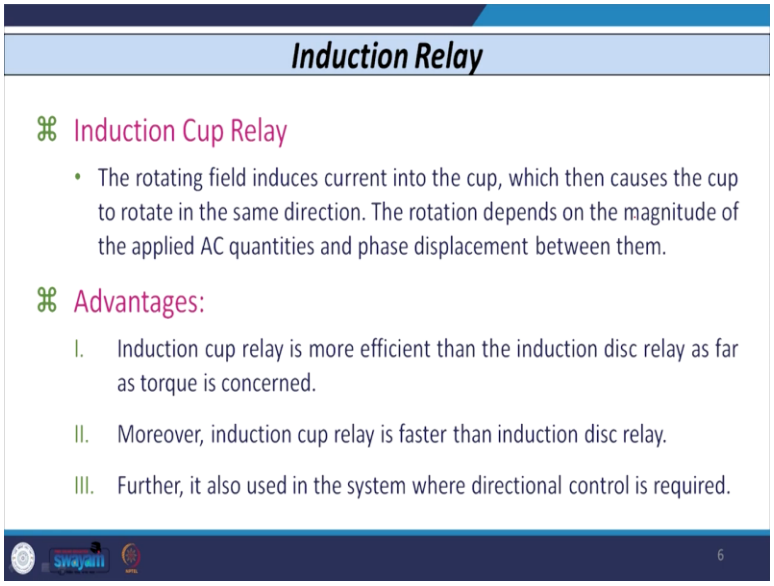

Moreover, the second advantage of induction cup relay that is, at its operation is faster as it has to travel a very small distance with reference to induction disc relay. And the third very important point that it is basically used where the directional control is required. So, if we want to introduce the, if we want to use the directional relay and this type of directional relay is required, we will see later on in further lectures, that the directional relay is required where the magnitude of fault current change changes its direction.

So, when we have a radial feeder fed from both end or when we have a parallel feeder or when we have a ring main system or network, where the direction of current changes in both direction with a for a particular bus, then we need a directional relay. So, in that case that type of relay, the

main construction used that is of induction cup type relay. So, now, let us discuss the other type of relay which is known as balanced beam relay.

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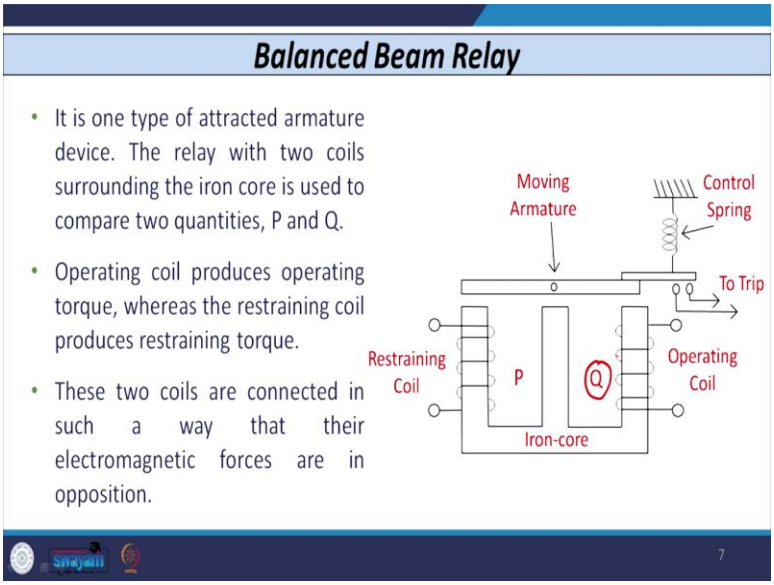

So, as shown in this figure in this balance beam type relay, there are the only 2 limbs of the iron core, the 2 coils are wound as you can see in the figure on the right hand side of the limb there is a one coil which is known as operating coil and it is denoted by the Q. So, Q is known as operating coil and whenever we give this apply to this it is going to produce the flux or force in one direction.

Now you can see on the other limb left hand side of this core there is another coil wound that is of restraining coil and the direction of restraining coil and operating coil are opposite you can see the how the way in which the operating coil is wound and the way in which the restraining coil is wound both are different. So, whatever force is produced by a restraining coil that is in opposition to the force produced by operating coil.

So, whenever the any force produced by operating coil exceeds the restraining coil plus some the force required for the spring. So, you can see on the upper side there is a movable armature and along with that movable armature we have a control spring. So, control spring is required in because whenever the operating called produced by the Q coil and the restraining coil, restraining force produced by the P coil when both are equal, then the spring force comes in

picture and because of that, the movable armature remains in normal condition and in no tripping is given to the tripping contact.

Now, wherever the operating coil or operating force produced by operating coil exceeds the restraining force produced by a restraining coil plus the some force produced by spring, then this type of relay operates and the whatever movable armature the beam is there, that gets deflected in downward direction and what because of this contact associated with moving armature that contact stretches with the trip and further tripping is initiated.

So, the name of this relay is given is balanced beam because in normal condition, the operating force produced by operating coil and the restraining force produced by restraining force both are equal. So, the beam, beam remains in balance condition and no tripping is given. And in case of fault when any particular operating coil, the current carried by operating coil gets a very high value compared to the full load current or normal value, then the force produced by this coil that is higher than the restraining force produced by a restraining coil plus spring force. So, then the beam gets deflected and further tripping is initiated.

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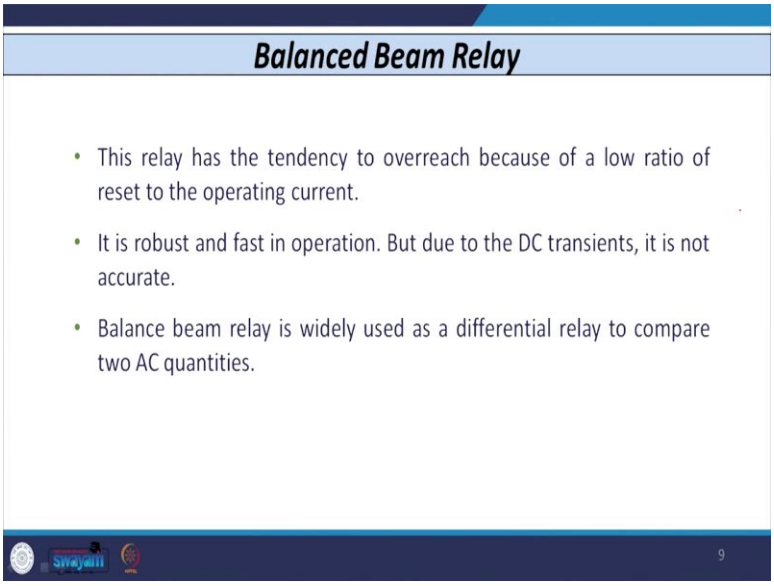

So, this type of relay has a tendency to overreach because it has a low ratio of reset to the operating current. Now, what is the low ratio of reset to the operating current? So, whenever the such type of relay operates, it operates on the principle of Kirchhoff's current law. So, current entering and current leaving to the circuit that remains same.

If fault is external and the fault is internal then this principle is not followed. So, it has some the operating coil or some pickup value, same time when the current is withdrawn or when the operating force produced by operating coil is lower than the restraining force plus spring force, then it has the resetting, it has some resetting value depending upon this this force. So, this ratio has to be maintained in certain limit, but sometimes it may possible that this type of relay is not a capable to maintain such type of ratio.

However, it has some advantage also, it is very robust and fast in operation. So, where we need instantaneous operation for particular if we want to protect the winding of either transformer or generator or motor and we we wish to obtain the instantaneous operation for any type of fault inside the winding, then such type of balance beam type of relay that is used for the apparatus protection.

So, this type of relay is widely used as I told you earlier as a differential relay, when we want to compare the two quantities, entering quantity and leaving quantity for a particular winding of the machine, then such type of relay that is used. Now, with this background, we have discussed earlier the we started our discussion with induction relay, one is disc type relay and the cup type relay, then we have discussed the balance beam type relay.

So, with all the, an earlier also we have discussed the attracted armature type relay. So, with this background let us discuss some equation means how the torque is produced, when we have either a single operating quantity that is current or we have a two operating quantity that is current, two current, different currents or we have two different operating quantities a current and voltage as it is used in directional relay. Then also let us see how the torque is produced. So, this type of torque production of torque whatever equation is given.

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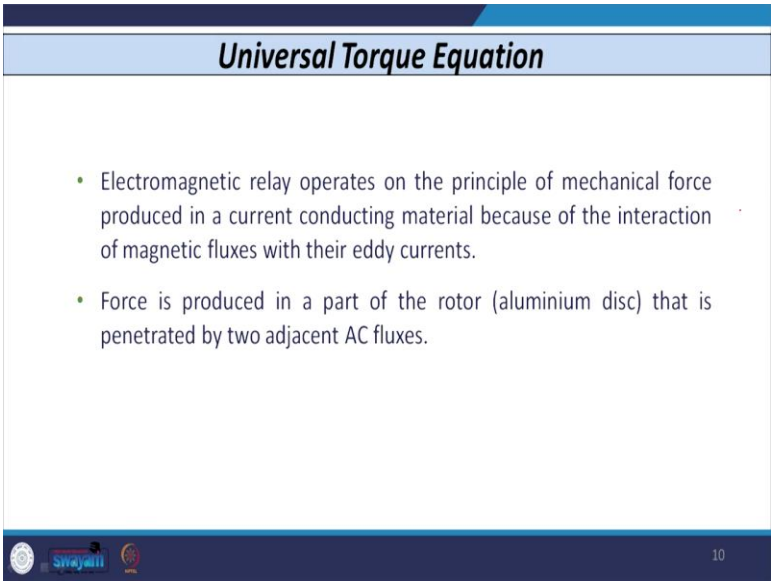

That is known as universal torque equation. So, electromagnetic relay operates on the principle of mechanical force produced because of current flowing in the coil due to interaction of two fluxes with the Eddy currents. So, the force producing one part of the rotor that is the penetrated by two adjacent AC flexes.

So, whenever various quantities are shown, so, if I consider the individual voltages are produced because of the flux around itself with the rotor then the current flows in the rotor, because of that the flux is produced and because of interaction of two fluxes, the force or torque is produced or it is exerted on the moving part that is we can consider a disc or a cup.

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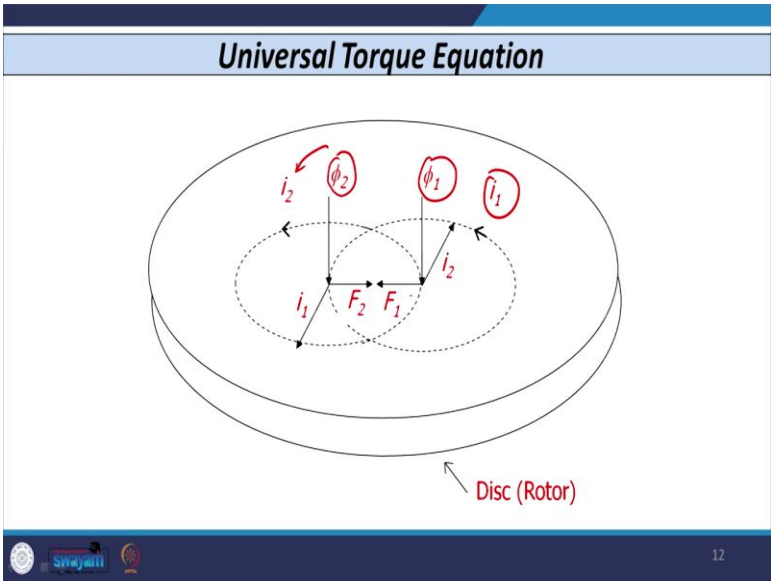

And that cup rotates in particular direction. And when it touches with things contacting the relay, whatever further initiation that is carried out. So, now let us to discuss this letter consider a disc. So, here I have consider one movable element that is as a disc rotor. So, in this disc you can see I have drawn the two dotted points. So, we can see that if I consider the flux produced by one, one particular operating quantity, so, when, whenever I give to the one coil which is wound on a core, one supply then it is going to produce a flux let us say that is given by the phi 1.

So, this phi 1 is because of the current i1. So, because of this the one force is exerted on let us say the effort which is in 1 direction that is left hand side whenever I have another coil which is wound on the core. So, that is going to produce a flux phi 2 and this flux phi 2 is because of the current i2 and because of this the force produced this F2 and that is on the right hand side direction we have considered here the both forces F1and F2 are in opposite direction. So, the resultant force F that is the difference of F1 and F2.

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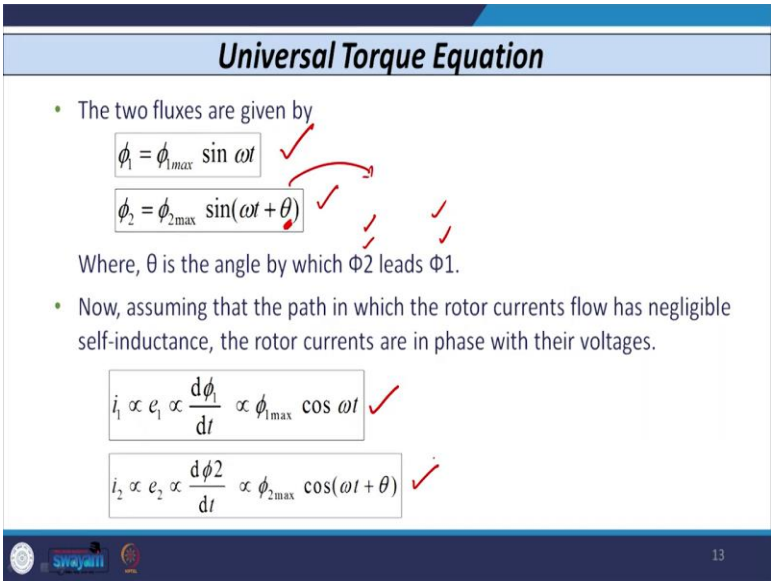

So, if I consider that the flux produced that is phi 1 here in this case this phi 1 that is given by phi 1 max sine omega t, that is one point and the other flux that is phi 2 which is given by the equation phi 2 max sine omega t plus theta. Where theta is the angle between the 2 flux phi 2 and phi 1. So, there are two possibilities either the flux phi 2 leads phi 1 that is one possibility and the other possibility is that phi 2 lacks phi 1. So, that is the other possibility.

So, depending upon what is the possibility the angle theta that varies? So, now if I assume that the path in which the rotor current flow that has negligible self inductance then the rotor currents that is given by. So, I as I told you earlier that this phi 1 is because of the current i1. So, i1 that is given that is proportional to the e1 and e1 is given by the differentiation of this phi 1 with respect to time.

So, d phi 1 by dt, if I do it, then we have d phi 1 max cos omega t. And same way as I told you earlier, the phi 2 is because of i2 and i2 is proportional to e2 which is given by the differentiation of another flux phi 2 with reference to time. So, d phi 2 by dt that is given by phi 2 max cos omega t. So, let us consider now what is the total force exerted on the disc or router.

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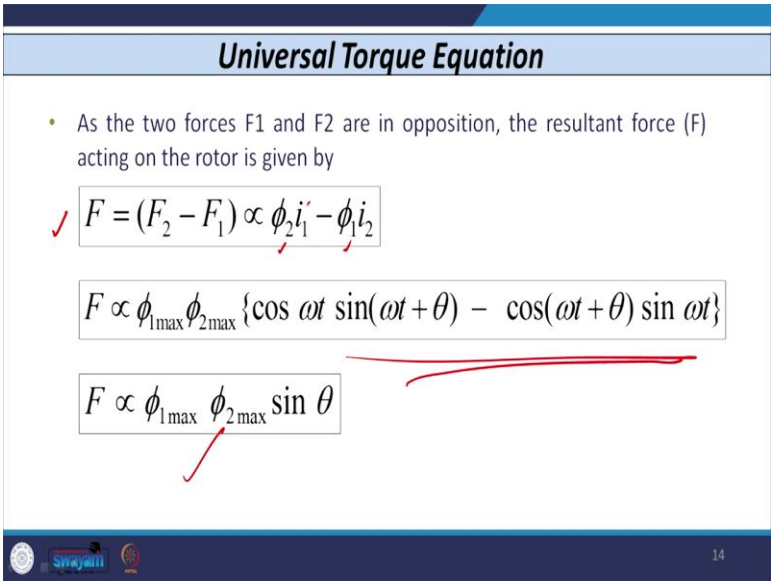

So, that is given by F which is nothing but the F2 minus F1 and that is given by phi 2, phi 2 i1 and phi 1 i2. So, you can see in this figure this F1 is because of phi 1 i2 and F2 is because of phi 2 i1. So, if I put the value of phi 2, that is phi2 and phi 1 as I told you earlier, phi 1 and phi 2 is given by phi 1 max sine omega t and phi 2 is given by phi 2 max sine omega t plus theta. And if I again put the value of i1 and i2 which we have already obtained here, that is the phi 1 max cos omega t and phi 2 max cos omega t plus theta, then we have the value of force which is given by this equation and if I solve this equation then finally, we get the equation that is known as F is equal to phi 1 max phi 2 max sine theta.

So, the theta as I told you earlier that is the angle between two fluxes phi 1 and phi 2. So, we can we can derive a few conclusion from this equation that is, F is equal that is the final force exerted on the rotor that is given by phi 1 max, phi 2 max and the angle between phi 1 and phi 2 that is theta. So, this what we can conclude it is clear that the magnitude of force develop on the rotor that depends on the angle theta, which is the angle between the 2 fluxes phi 1 and phi 2.

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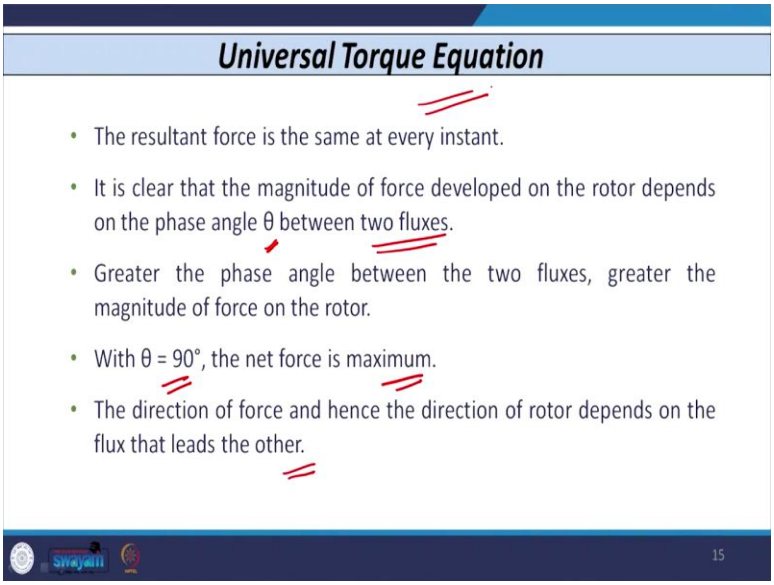

So, this angle theta that plays an important role, greater the this angle between the 2 fluxes, the greater is the magnitude of force because this angle as I told you, it is the sine of angle. So, sine of angle this theta that is maximum when angle is theta is maximum. So, greater the angle between 2 fluxes, greater is the force exerted on the router. When theta is equal to 90 degrees. So, sine 90 that is maximum 1.

So, the net force produced or exerted on the router that is also maximum. So, the direction of force and hence the direction of router depends on the flux that leads to the on the other side. So, this is a very important conclusion as far as the universal torque equation is concerned. Now, when we consider this type of equation this type of universal torque equation that can be applied to different types of relay, it can be applied to let us say the all types of overcurrent relay.

So, we can consider the attracted armature type relay, we can consider the induction type relay, it is also equally applicable to the distance relays and it can be also equally applicable on the balance beam type relay that is the differential relay. So, this the application of this universal torque equation that can be on different types of relay and we will start our discussion now with the first type of relay that is used in the production of transmission line as it is also used in the protection of distribution feeders also and that type of relay that is known as the overcurrent relay.

So, this type of scheme that is known as current base relaying scheme. So, such type of scheme that can be widely used in actual field. So, if I consider the current based relaying scheme, then that there we are going to use the all types of different types of overcurrent relays and this is used at the level of the let us say the overcurrent relaying scheme.

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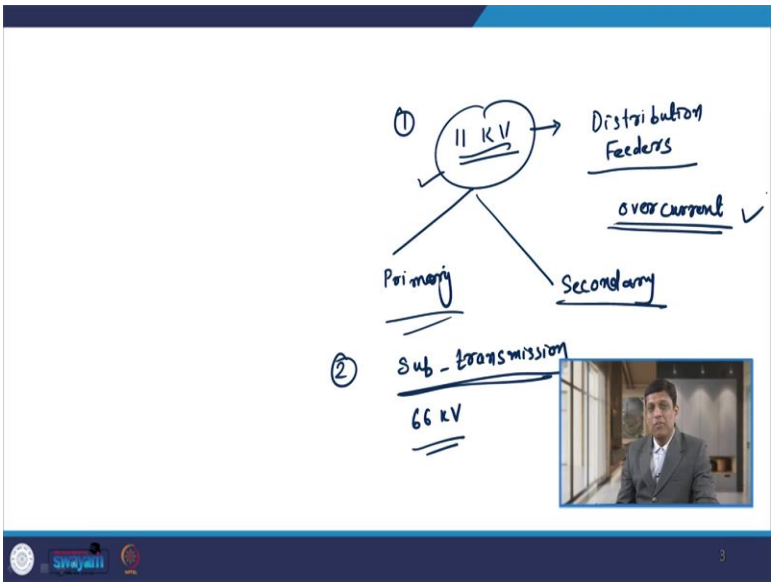

That can be used up to the distribution network, so up to the 11 kV, so, we have the distribution feeders. So, if I want to protect such type of feeders, then up to 11 kV there are 2 types of distribution; primary distribution and the second is the secondary distribution. So, for both primary and secondary distribution we can we are going to use the overcurrent relay. This overcurrent relay that can be made up of attracted armature principle or it can be made up of induction principle. So, this is one of the application.

The second application is we can use such type of overcurrent relay for sub transmission line also. So, if I want to protect sub transmission lines say 66 kV then also such type of overcurrent relay that is used. So, in the next class we will we will discuss further on the overcurrent relaying scheme. So, in this lecture we have if I just summarize then we started our discussion with induction type relay that is induction disc relay and induction cup relay.

Then we have considered the other type of relay that is balanced beam relay in which you have which is widely used for differential protection of any apparatus. And then later on, we have discussed finally, the universal torque equation that can be applied for all types of quantities. So,

what is what will be the force exerted on the rotor or movable part that we can derive with the equation then we have discussed that the force exerted that basically depends on the angle between the 2 fluxes.

So, higher the angle higher is the force exerted on the router. So, with this conclusion I stop here and in the next class, we will further carry out our discussion on the overcurrent protection of the transmission line and distribution feeders. Thank you!