Electrical Machines- II
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Lecture – 21
Distributed Factor K d

So, we are in the 21 lecture.

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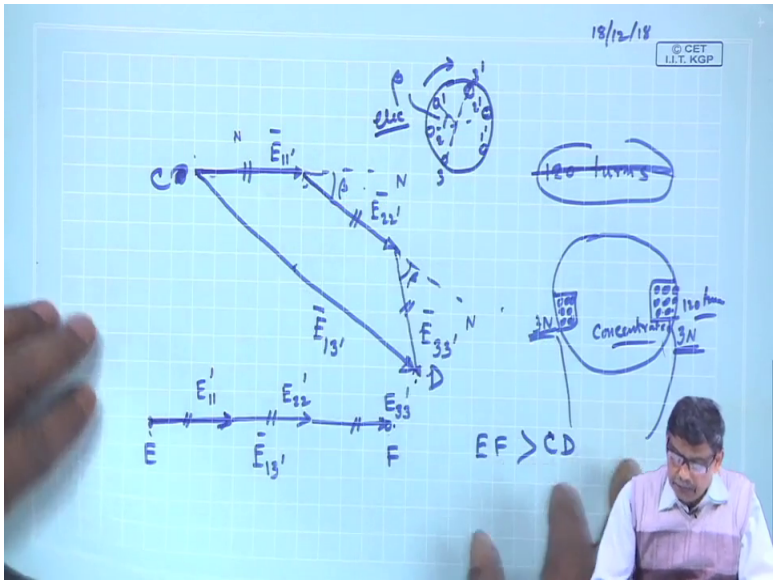

And in my last class I told you that coils will be distributed to use the surface of the machines more effectively.

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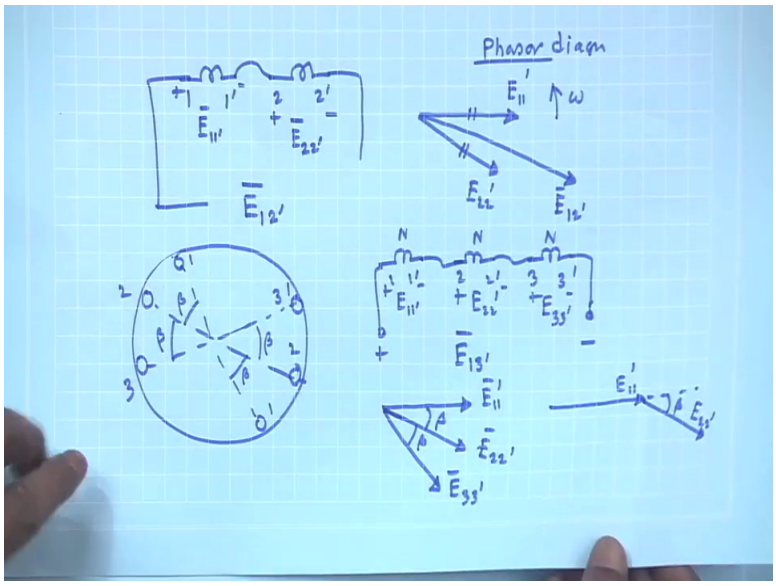

And, if there are 3 coils which are each one is having a N terms each one is having N terms and they are the coils are 1 1 dashed here I will write here. So, the coils are distributed in this way in a simplified diagram like this I am just sketching this is 1 1 dashed 1 1 dashed and then you have suppose 2 2 dashed.

So, this is 1 coil separate coil 1 1 dashed and this is 3 3 dashed and if this coils are displaced by some angle, this is the angle between 2 consecutive slot side by 1 slot it has been displaced this angle we are telling beta and direction of rotation I have assumed like this. And then whatever is happening to 1 1 dashed now same thing is happening to 2 2 dashed. Therefore, they have faced voltages voltage across this coils we will it will lag 1 1 dashed by beta and then voltage 3 3 dashed will lag by another beta angle and so on and the resultant rms voltage will be this and you now imagine all the coils are concentrated in this 2 slots.

So, that 3 N turns are there here, then these voltages would have been cophasal and this length will be just 3 times these voltages and you will get this one. So, this beta all the angles will be electrical. Now, at this point before I proceed further I would like to tell you one very important thing that is an electrical machines in generally could be multiple and you should be prepared for that to analyze. And, then we have to distinguish between electrical and mechanical angle that is there.

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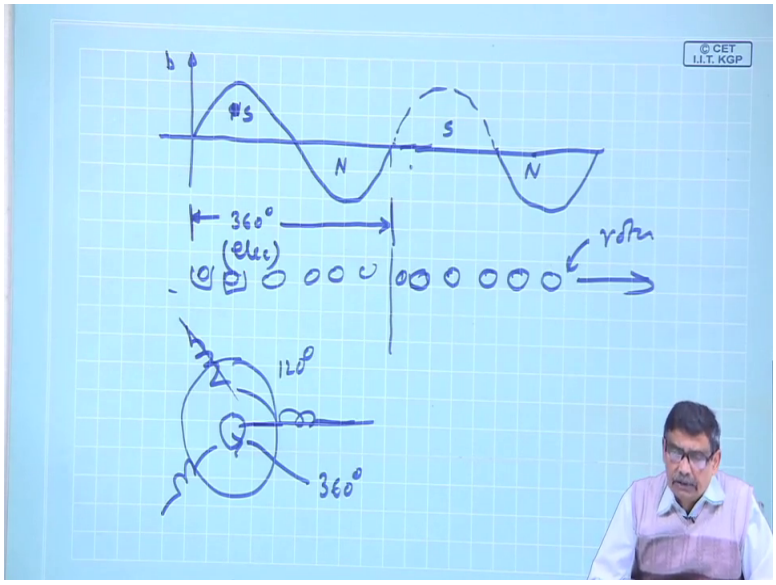

The point worth noting is this that after you have you are expressing everything is in a electrical degree this is 180 degree electrical, 360 degree electrical. After you are examining north south or south north say this is b distribution and once again this thing repeats 360 degree electrical and this thing is repeating. Now, interesting point should be noted that beneath this distribution there is air gap and there is coils moving, conductors moving. Now, at any instant of time this point you listen carefully and these are very easy to logical thing that there will be conductors here because, now they will be distributed in slots like this will see. But, the point I want to make it these are rotor conductors say rotor conductors they are moving, they are placed in slots they are moving.

Now the statement am going to make is that, this is once again south north whatever is happening under a pair of pole in the rotor conductors same thing is going to happen in the other pair of poles as well. What does it mean? That is suppose it is moving some currents this conductors are taking this is the field distribution, what I am telling under 1 pair of pole which ever conductors are present it is expected it is a symmetric machine under the next pair of pole, pair of poles similar conductors same number of conductors will be present and they are expected to carry current that is true.

But, what I am telling if you take a snapshot at a particular time and freeze the time there you take a snapshot then the distribution of the currents under this pair of poles and

under next or next pair of poles all will be identical why they should be different whatever is happening now at a given time. So, far as current distribution in the conductors, voltage induced in the conductors, their polarities these that whatever is happening to this set of conductors which are on that this pair of poles identical things will be there in this conductors as well which are in the underneath the second pair of poles. If it is a 6 pole machine; next pair of pole under that whoever is not staying at that time same way it will be held. Therefore, what people do is this they always although it could be a multiple of machine they will always examine what is happening under a pair of pole that is more important.

If you know what is the point that repeating that, that is why people draw like this they draw everything in electrical technique and show only a pair of pole as if it is 2 polar machine. And they will draw like this is R phase square this is Y phase square we will tell about this things I am just to giving you the idea what and this whole angle you say this is 360 degree electrical and this coils are 120 degree apart electrical.

So, all you measured in electrical terms and try to analyze the machine under a pair of pole because, nothing is going to change in the next pair of pole for a given instant of time that is one important thing you note that. So, a multi polar machine is often represented as a 2 pole machine and all angles are shown electrical that is all you analyze that that is it [FL]. Now coming back where I have left in the last class that coils will be distributed or concentrated for many a reasons is not 1 time.

So, many number of terms if you accommodate in a pair of slots rest of the place remains unutilized and also here how much how many conductors you can put in a particular slot there are restrictions on that space available in a particular slot is not infinite. Therefore, you have to distribute the coils 3 N times you want to use you distribute it in coil 1 1 dashed 10 times, 2 2 dashed 10 times, 3 3 dashed 10 times and they are displaced by beta electrical from one to the others start of each coil 1 2 3 is displaced. And if it is distributed then we say this 3 N coils have been distributed in 3 coils each of N times that is the thing ok, then I know how to calculate E 1 1 dash E 2 2 dash E 3 3 dashed then I find that this would be the resultant voltage.

Now, I must compare I told you if for sake of argument let us assume that somebody insists that no I will go for concentrated coils. If he goes he will claim that look here E 1

1 dash 2 2 dash and 3 3 dash they are in cophasal and you get maximum voltage compared to this because, the sum of this algebraic sum of this plus this plus this is less than this here it is as if algebraically we were adding this 3 voltages. So, I must now compare if the resultant voltage available across the combination of the 3 coils connected in series when they are concentrated and when they are distributed what is their ratios.

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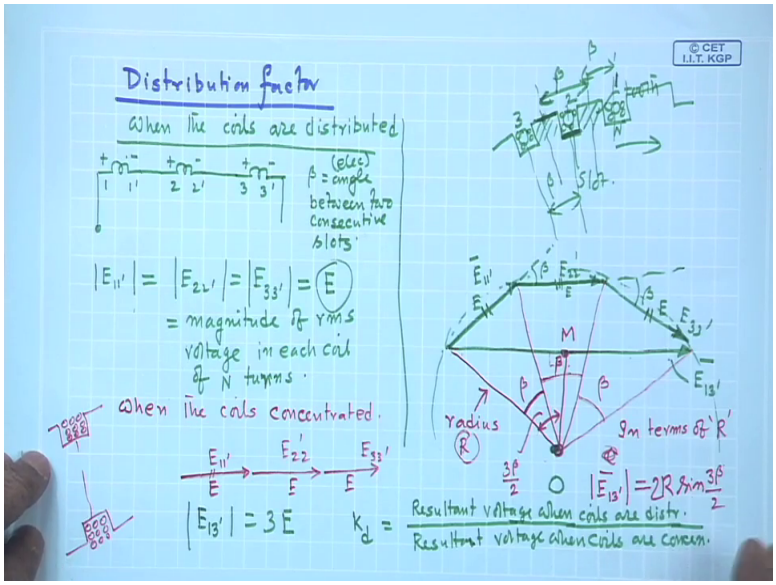

So, the problem statement is and. In fact, this is called distribution factor. So, let me redraw it. So, here I will draw vertical line and here when the coils are distributed. So, the connection is same 1 1 dash 2 2 dash and 3 3 dash and I will connect them in series and I will examine this resultant voltage. So, this is plus minus this is plus minus this is plus minus. Now, this 3 voltages and the angle between two consecutive slots is beta, beta is equal to angle between electrical angle it needless to say hence forth will say. So, beta is electrical angle is equal to angle between consecutive slots between two consecutive slots that is this line.

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This angle between 2 consecutive slots what is the angle because it is after all round I can calculate if it is 360 degree mechanical number of slots present I will suppose number of slots are 36, then 360 degree divided by 36 is 10 degree. So, I will say angle between this slot and this slot is 10 degree, but 10 degree mechanical and what is the electrical degree multiply that 10 degree with pair of poles if it is 4 pole machine then it should be 20 degree electrical got the point.

So, number of slots are like this, it is going like this. So, the angle between the 2 slots consecutive slots see this center of this tooth and center of this tooth this is also beta if the if the this part is called the tooth of the thing and this part where conductors will be placed is called slots. So, tooth pitch this is called tooth pitch and slot pitch they are all same that is this and this are same from length. So, angle when I say the angle between the two consecutive slot is beta I mean this or in this they are born on the same thing. So, beta is the angle between two consecutive slots and suppose I have distributed my coils in three consecutive slots.

So, here I have placed 1 1 dashed will be somewhere here I have placed 2 2 dashed will be somewhere that we have drawn earlier and 3 the start of each coil 1 2 3 they are individual coil each having N turns, I will also use this slots space effectively. So, each are having N turns 1 dashed you have understood it will be 180 degree electrical apart and so on this we have discussed [FL].

Now, the rms voltage induced in each coil magnitude of the rms voltage will be same that is E 1 1 dashed is equal to E 2 2 dashed is equal to E 3 3 dashed and let this be called E magnitude of the rms voltage is equal to magnitude in each coil of N turns. When the coils are distributed I have already seen that if you say that this is E1 1 dashed this phasor E 2 2 dashed will be lagging this assuming the direction of rotation this way, whatever in a field distribution 1 sees 2 sees that same field distribution after a movement of beta angle this is also beta.

So, so this is E 2 2 dashed and this is beta and E 3 3 dashed will lag once again by beta E 3 3 dashed and this length this length and this lengths these are all equal and equal to E, this is E, this is E, magnitude E. And the resultant voltage would be this one that is E 1 3 dashed will be this, now I would like to calculate, what will be this resultant voltage? Now, in this way you can go on adding distribute the coils further if necessary whether we will do it or not, but I can tackle the situation, if at this whole turns is distributed in four slots I would have added another phasor here to get the resultant voltage. But more you add you start losing voltages that is the thing [FL] now these angles are beta. Now you see this is the, this sides are equal here therefore, it looks like it is a sort of going to give you a regular polygon each of length E.

And regular polygon will have a circumscribing circle like this I can imagine it will lie on that tip of each phasor will lie on that circle. Suppose the center of the circle is here O, then what you do is this what is my goal my goal is to find out this resulting voltage an expression of that and resultant rms voltage and compare it. With the situation when all the coils were concentrated not distributed that ratio I want to find out. So, first I have to calculate this 1 3 dashed resultant. So, to do this I suppose assume the coils are distributed in 3 consecutive slots like starting of those are like this lengths are equal and I know each 1 of them is of magnitude E. Now what am telling this will be part of a regular hexagon if you go on adding further distribute, but we stop suppose somebody has stopped it by 3.

Then suppose this is the center of that circumscribing circle which will be at the corners here. Now what you do you join this points 2 to the center of this circumscribing circle. Then what will happen is this angle beta will be also this beta this angles too will be beta it will be like this. And you know because these are 2 sides are equal this angle is equal to this angle similarly this angle is equal to this angle. So, beta minus this things you do

and from that you can easily show this is beta therefore, this angle subtended by each. So, called chord of this circle which are equal in lengths will be same beta. Now my problem is to find the magnitude of E 1 3 dashed. So, to do this what you will do I will drop a perpendicular from here to this say this point is M.

And suppose the radius of this circle radius of this circumscribing circle is capital R suppose then in terms of this capital R this length E 1 2 3 dash can be easily calculated. How in terms of R which is radius I have written that in terms of R this amplitude E 1 3 resultant voltage magnitude of that can be easily expressed why because this angle is 3 beta therefore, this angle will be 3 beta by 2 and you know this length this length from this right angled triangle this is right angle. So, from this right angle triangle this length half of this one is nothing, but R into sin 3 beta by 2 that is all in to 2 then because this length.

This plus this will be resultant and this 2 are equal because it bisects any chord you drop a perpendicular from the center of a circle will bisect that chord. Therefore, 2 times of R sin 3 beta by 2 where from 3 beta by 2 comes this is 3 beta and this is 3 beta by 2. So, this will be the resultant voltage when the coils were distributed. And when the coils are concentrated; that means, all the turns are there is only a pair of slots here 1 1 dashed all the turns 2 2 dashed all the turns 2 all the 2 turns here 3 all turns here 1 dashed 2 dashed 3 dashed all are concentrated. So, same number of turns all are.

So, individually if this is 1 1 dashed they are diametrically opposite if this is 1 1 dashed they are diametrically opposite if this is 1 1 dashed this is 2 2 dashed they are cophasal. Now and this is 3 3 dashed what will be this voltage this will be same as this E magnitude of E 1 1 dashed will not change because of that. So, this is E this is E and this is E therefore, resultant voltage in this case is E 1 3 dashed resultant of this 3 is nothing, but 3 therefore, I have been able to calculate the resultant voltage when the coils were not concentrated that is distributed this is the resultant voltage and when the coils are distributed this is the resultant voltage.

Now the ratio of this two is called distribution factor and it is the resultant voltage when coils have distributed divided by resultant voltage magnitude of the voltage, when coils are concentrated same number of turns coils are getting you can compare only 2 things certain they are of similar type.

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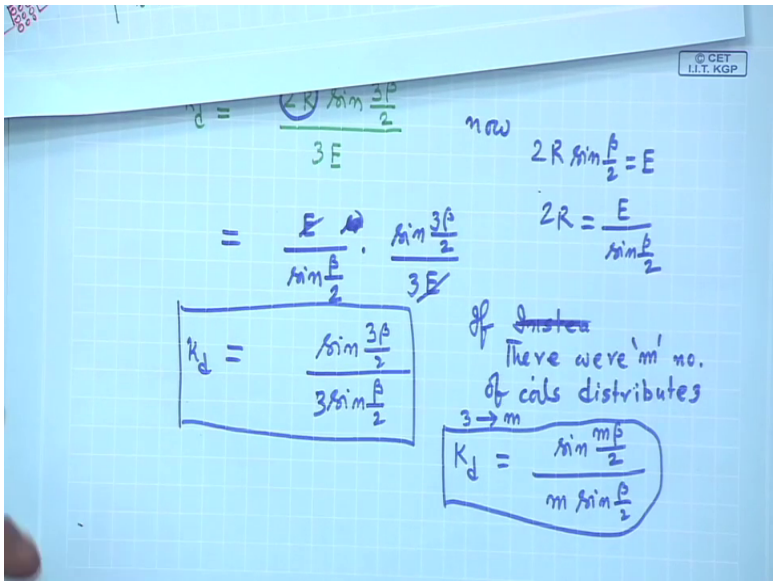

So, this is the thing therefore, K d will be equal to 2 R sin 3 beta by 2 divided by 3 E that is the thing. Now the question is this R is disturbing I mean that is this radius.

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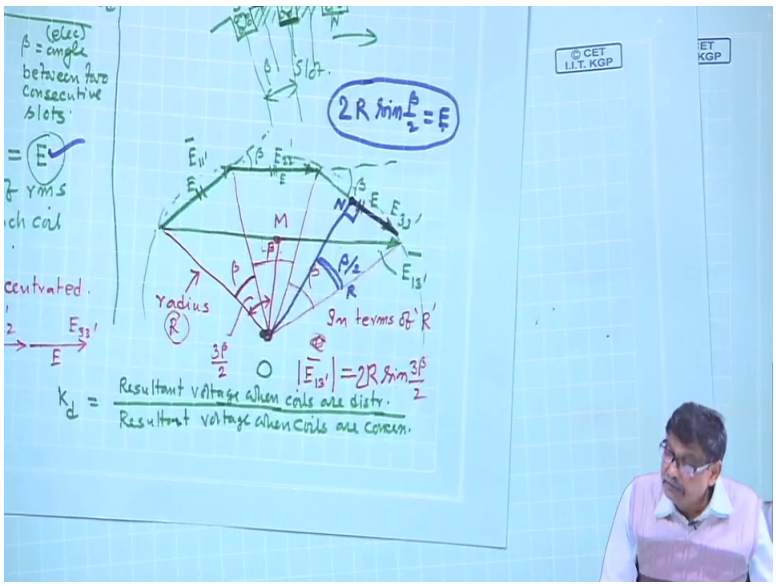

Now, this radius can be related with E from a small any of this small triangle for example, what you will do is this if you drop a perpendicular from this to this say call it ON this length is R this is R and this angle is beta by 2 because this is beta say this is B beta by 2. So, from this small triangle you can easily see R sin beta by 2 R sin beta by 2 is this length it is a right angled triangle I have dropped a perpendicular. So, R sin beta

by 2 is this and 2 times of that is this length and this length I had assumed to be E. So, this is equal to E. So, this equal to E so, where is that. So, so here now I will utilize this result that now I will write 2 R sin beta by 2 is equal to E. Therefore, 2 R is E by sin beta by 2 and that you substitute here for 2 R.

So, E E by for 2 R E by sin 3 beta by 2 and this things were already there sin 3 beta by 2 by 3 E and it then goes it becomes sin 3 beta by 2 by sin beta by 2 very simple formula to remember. So, if you have distributed 3 coils the ratio of this voltages it will be a number less than 1 only thing is it can be generalized by telling if instead of. If there were n coils tested of 3 if there were m number of coils distributed there was a 3 here this 3 was here.

If there were m number of coils distributed angle between them beta then in general K d should be done replace 3 by m I have done for a specific number. So, it will be sin m beta by 2 divided by m sin beta by 2 this is the distribution factor. So, if you know the coils are not distributed it is the resultant we will expect out of this total number of turns if you know the value of K d distribution factor then will simply multiply with this. So, go through this we will continue with this in the next lecture.

Thank you.