Electrical Machines - II
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Lecture – 22
Pitch Factor K p and Winding Factor K w

Welcome to 22 lectures on Electrical Machines. And I remember that in our last lecture we were discussing about distributing a coil and derived an expression for distribution factor and coils are distributed and the distribution factor will be generally less than 1 and we got this expression you know that is Kd.

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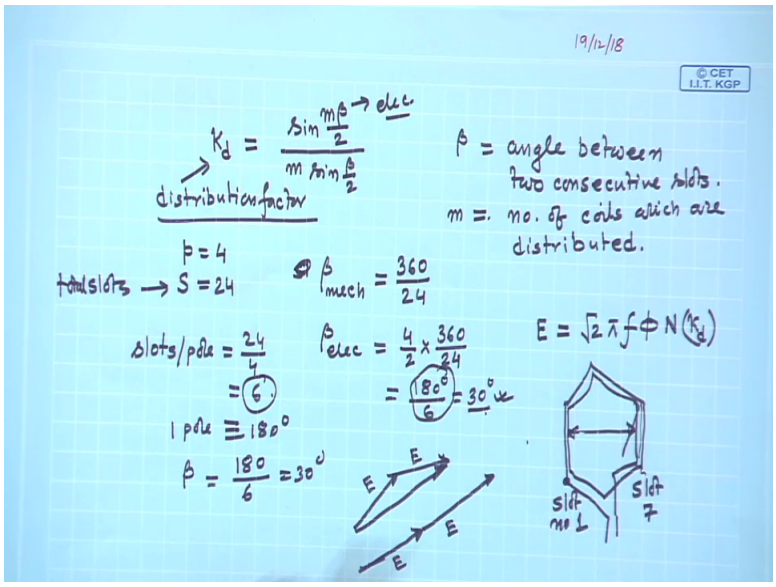

If I write the formula straight away it was like this sin m beta by 2 divided by m sin beta by 2. What is m? What is beta? Beta is the angle between 2 consecutive slots angle between 2 consecutive slots in electrical degree and m is the number of coils number of coils which are distributed which are distributed so this is very important. Therefore, I will now first tell you how to or what does this mean actually.

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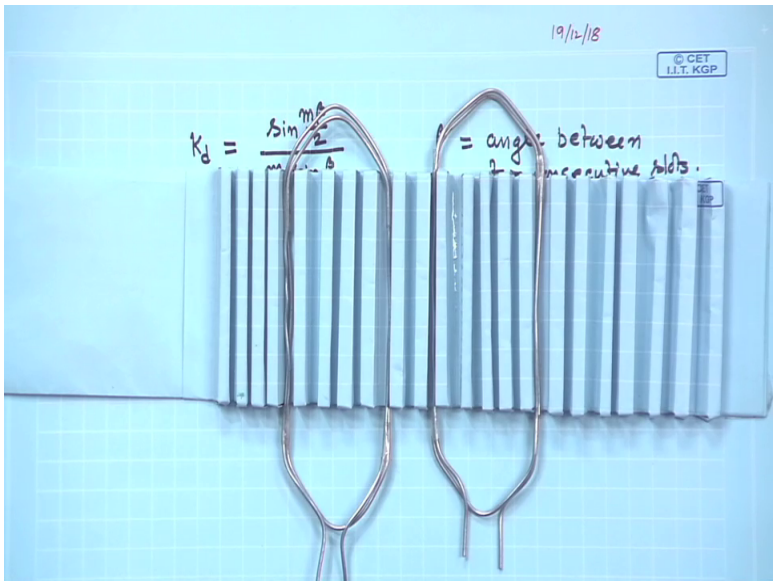

It means that if you have the slots here and if you have suppose 2 coils this 2 coils each one of them is having 2 times here 2 turns you can easily see and you could make them accommodate in one slots only a pair of slots only and then you connect this 2 coils in series here. Therefore, total number of turns will now become 4 as if it is a multi turn coil with 4 turns.

Now, rest of the slots are underutilized nothing is there, instead of doing this what we are doing the second coil we are suppose we are putting it here after 2 slot pitch, then the coils are distributed in this fashion or by a 1 slot pitch like this. Now in this case once again you connect them in series and get this 2 as your output time if this 2 should be joined and you get the output here. Now, if you do like this you assume that your poles are moving here the voltage induced in this coil will be lagging this coil if the field is moving or if the field is stationary that is what I was telling.

If you know it from this to this voltage will lag this voltage if you move it from left to right. If you reverse the direction of a rotation then this will be leading whatever is happening here, the same thing is going to happen after some time delay in this coil. That is why we were telling that the voltage is induced in the distributed coils they will be phase displaced in time essentially and the resultant voltage will be sum of this 2.

Naturally at this voltage when you distribute the coils total voltage will be less than if all the turns were accommodated in a pair of slots and the factor by which that voltage will

be accommodated is called the distribution factors. So, what you do you calculate the induced voltage for all the turns and multiply with simply with Kd. Now suppose in a simple example am telling you suppose you have a 4 pole machine p is equal to 4 ok, total number of slots this is slots total slots is S and that you say is equal to 24 and then how to calculate the slot angle beta you can do it in several ways.

One of the way is slots per pole or 24 slots are there over 360 degree mechanical, therefore beta mechanical will be simply 360 by 24 and of course I need beta electrical this is electrical angle.

So, it must be multiplied with p by 2 this mechanical and divided by multiplied by p by t. So, 4 by 2 in to 360 by 24 this way it can be written or you can see it is equal to 180 degree divided by 6 that is 30 degree electrical this is the thing you have to put it in this formula and m is what m is how many coils you are distributing. Instead of 2 coils we could have 3 coils although I do not have the 3rd coil suppose this is displaced and this is present and another third coil is there it is kept here and all this 3 are connected in series that number is m.

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I have always done.

Student: In that arrangement (Refer Time: 07:25).

That is just for this thing I am telling suppose these are all. So, you distribute the coils by definite number of slots, for example by 1 slot I will distribute. So, beta electrical this calculation is correct 30 degree, another way I calculate it this like this 30 degree see slots I always calculate the same results slots per pole is 24 by 4 that is 6 and 1 pole pitch is 180 degree 1 pole is equivalent to 180 degree electrical.

So, beta in electrical degree will be 180 divided by how many slots make 180 degree so that by 6 30 degree that is the this thing. You can be straight away mentally total number of slots, slots per pole you calculate that is equivalent to 180 degree electrical then divided by that slots per pole that is 6 you get 30 degree.

So, this is all you calculate and then the induced voltage, whereas in case of distributed coil I just tell you give you this is the resultant voltage of 2 coils and if this 2 coils were

not distributed resultant voltage would have been this each one is E E here also E E. But what this Kd is telling you that you calculate as if the coils were not distributed, whatever is voltage that you simply then multiply by Kd if it is distributed to the RMS voltage that is the thing.

So, RMS voltage of induced in a coil groups, so these are called coil groups then one group another so this makes this these are the things. So, distributed coils you connect in series, then if it can be written as root 2 pi that f which comes equal to pm by 2 pi is the flux per pole. And suppose N is the total number pf turns of the coils then that n in to you simply multiply by Kd that is called the distribution factor Kd is the distribution factor and the reason for distributing a coil I told you has to think about it ok. Now that is another factor which is called pitch factor pitch factor.

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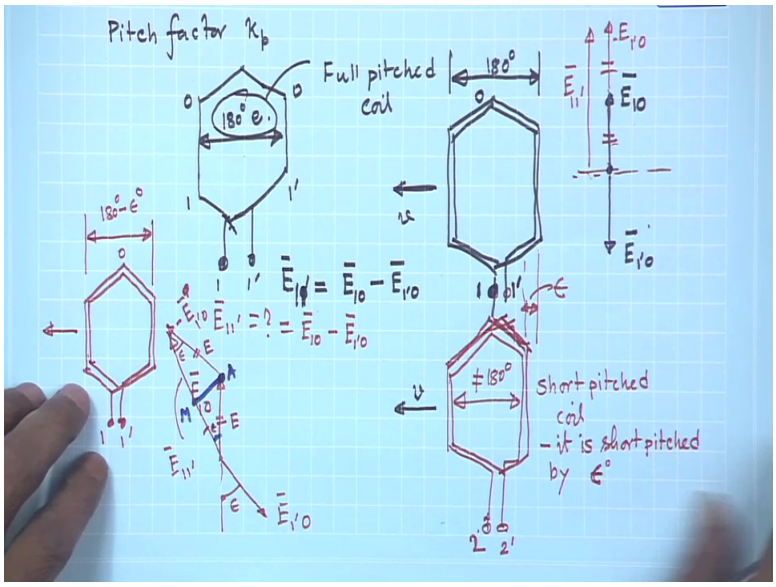

Which is denoted by this symbol K p p stands for pitch factor. Now what is a pitch factor? Pitch factor is this I told you for any coil like this multiple turns are there this is the coil turn terminal. So, when these are joint means this it goes several times.

So, these are the coils say 1 1 dashed, I told you try to make sure that if this is 1 0 I was calling this is 1 dashed 0, I told you to see that that the other coil side 1 dashed 0 is if 1 0 is under the center of a South Pole at any time try to see it is 1 dashed 0 is placed in such a slot that it comes under the center of north pole, that is opposite under opposite polarity

of equal strength it should come so that you get maximize the voltage or in other words the coils span this is called span of the coil and it is equal to 180 degree electrical.

For example, in this machine the coils span should be if you want to maximize voltage slots per pole is 6 that is equivalent to 30 degree, if your first coils side in slot number 1 your return coil side should be in slot number 1 plus 6 7 that should be the position at the coil.

I mean so in slot number 7 the return coil side ma must be present, such that this will be 6 slots which is equivalent to 180 degree electrical because 6 in to 30 is 180 and this will ensure that the induced voltage is Blv Blv 2 Blv this voltages will be additive in nature or al in to 2 LV, where m is the number of turns of this single coil anyway so this is the idea.

Now the interesting thing is that you can do it like this. So, suppose full pitched coil you place is here suppose the number of coils it is full pitched. Now what happens if suppose I hit the coil in such a way it is not this separation is not 180 degree but suppose it is less by some angle 1 slot pitch angle ok.

Suppose it is placed here that is the coil span is made if it is 30 degree between this slots it is made 150 degree, then also I you should get some RMS voltage across this, but this time it is expected the voltage will be less. Now I will explain why it will be less and by what factor it will be less and that factor is called the pitch factor, at the coil being a full pitched coil so such a coil which is having 180 degree electrical coils span is coil in literature as full pitched coil.

Instead of that if you have a coil so a full pitched coil suppose it is let us try to understand so clearly what am telling. So, this is suppose a full pitched coil, what would have been a start pitch coil so that this angle; this angle is 180 degree, you can also state this in terms of slot numbers that is 6 as I told earlier for that particular point.

Anyway I could have a coil which is this is 180 degree electrical it could be like this, I start here go there but come back from here I get these diagram is slightly mess messy I does not very nicely, but you get the idea, I could make a coil in this fashion and this angle is not equal to 180 degree.

In fact, it is less than with respect to this is 180 degree electrical this is less by this angle and this angle is I will denote it by epsilon and then this coil is called a not a full pitched coil a short pitched coil and by what amount it is short pitched, it is short pitched people say this wires it is short pitched by epsilon by epsilon degree it is short pitched. So, by what amount it fall short of 180 degree is the short pitched angle epsilon and I must if I find out what is the induced voltage between this 2 coils and compare it with this.

So, this is 1 1 dashed this is also 1, so this is another coil 2 2 dashed having same turns their starting slots are same returning slots are different and this 2 coils I have moving in a stationary magnetic field, then how to calculate the RMS voltage induced in this coils. Remember here to calculate the RMS voltage now I will go straight away to phasor diagram this is suppose this terminal is 1 and this terminal am telling o because this 2 are joint and this is one dashed and suppose it is moving from right to left.

Suppose the conductors see I will be often telling it is moving from left to right or right to left, but you must understand what is the difference between this two nothing weight is difference. But the difference is if somebody says it is moving in this way the conductor is moving from left to right, I will say o E 1 dashed of this voltage is leading E 1 o that is all and if it moves in this way field patterns will remain same I will say then E 1 o will lead E 1 dashed o very simple because 1 o for see whatever it sees 1 dashed o sees after this much angle of 180 degree.

So, in this case suppose the coil is moving in this way, if the velocity v fields are above and below south, north etcetera. So, suppose I say this is the E1o voltage where will be E1 dashed 2 phasor sinusoidal voltage distribution, so that it will be sinusoidal only time varying at. So, E 1 dashed will be then lagging with by 180 degree, whatever is happening to 1 o in terms of time same thing is going to happen to 1 dashed o after 180 degree.

So, we 1 dashed o will be here and you recall how you found out this E 1 o I want to find out what should I do this point. So, I must find out the potential E 1 1 dashed I want to find out 1 1 dashed it will be then this phasor minus this phasor. So, E 1 o will be E 1 o minus E 1 dashed o but E 1 dashed o is here, so I have to add to E 1 o negative of E 1 dashed o that is E 1 o 1 dashed o is here to this to this you know I had E negative of E 1 dashed o, the lengths are same so that you will get twice the voltage.

So, another way of telling that twice the voltage will be available if the coil size 180 degree electrical apart all the times. So, you will be twice E voltage that this will be the this phasor will be E bar 1 1 dashed if it is moving like this. Similarly you can do if it is moving like that E 1 dashed o will be E 1 o and the 1 dashed 1 will be the difference of this 2, but in any case we will always get twice the voltage is that clear.

Now, let us do the same thing from the second coil here, in the second coil similarly let us assume it is moving in this direction with some velocity etcetera, so and this point or I will draw it more cleanly so that there is no problem in understanding. So, this is a short pitched coil red ones this is 1 this is 1 dashed and this point is 1 and this span of the coil is not 180 degree, but it is 180 degree minus epsilon degree this is the span of the coil.

Therefore, what will be my I would like to find out E 1 1 dashed is how much? Here also same thing suppose you assume the conductor is moving and your field above or below are stationary, so it will see South Pole, North Pole successively as it moves from right to left.

So, suppose I say that E 1 0 is this voltage phasor assuming sinusoidal b distribution this will be the phasor E 1 0. Now the question is where is E 1 dashed 0 it is not now same thing is going to happen. So, this conductor 1 dashed o after 180 minus epsilon not after 180 degree as in this case. So, E 1 dashed 0 can be drawn like this lagging this whole angle is 180 this angle is epsilon, this is the thing what is going to happen is not. Therefore, I want to find out E 1 1 dashed which is nothing but E 1 0 dashed 1 0 phasor minus E 1 dashed 0. So, this 2 phasor from this phasor I have to subtract this how can I get that, so this is E 1 o to this we have to add negative of E one dashed 0 so add it parallel to this and so on.

So, this is minus E dashed not E dashed E 1 dashed 0 this phasor and your resulting voltage will be this if this 1 will be your E 1 1 dashed get the point this is the thing. Now your voltage in each of the coil side they will be magnitudes will be the same, if it is E this will be also E right coil side I am not sketching.

So, what will be this thing I want to find out, so to find out that one recall at their you got a perpendicular from this point here say A M this point you called A geometry and then forward the this angle is epsilon this angle t is epsilon because this 2 lengths are equal. Therefore, the resultant voltage is this length it will be epsilon this is epsilon and this is

sorry one thing I made a mistake, this is epsilon it does not ensure that this is epsilon this I mean it looks like it goes so I will rewrite.

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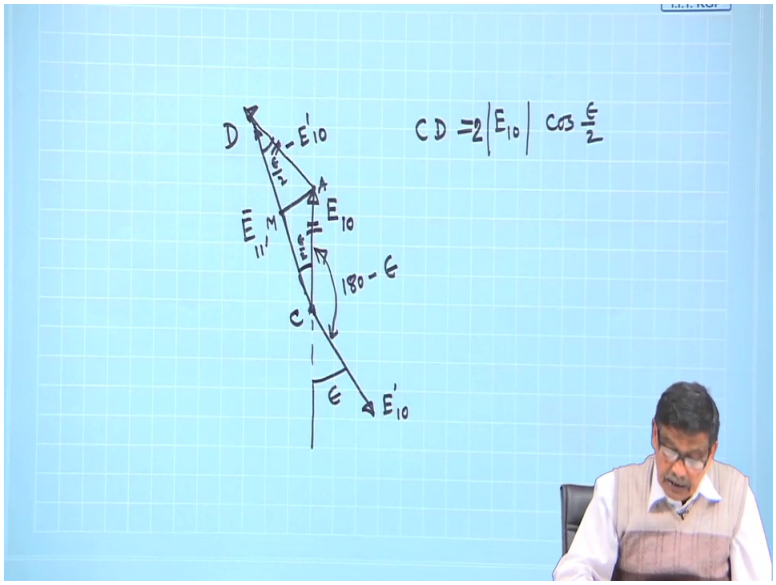

So, what you do is this is E 1 0 then to this and E dashed 1 0 will be somewhere here of same length E dashed 1 0 and this angle is of course epsilon that is fine. Now E 1 0 and this things you add so this is minus E dashed 1 0 and I am telling this is the resultant voltage E 1 1 dashed and this is the thing.

Therefore, this angle will be how much this angle is will be epsilon by 2 and this will be epsilon by 2. Why because this is epsilon this angle is 180 minus epsilon 180 minus epsilon and this angle will be sum of this 2 external angle and this 2 sides are equal so everything is fine now.

So, this is epsilon by 2 and this is epsilon by 2 and then you drop a perpendicular from this here A M and your resultant voltage this length say if I call it say some name if you give say C D length C D will be this plus this. So magnitude of E 1 0 this into cosine epsilon by 2 and also another same thing E by 2 so this will be 2 times this will be the voltage length C D, we will continue with this in the next lecture further and I will take the ratio.