Electrical Machines- II
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Lecture – 23
How to Decide About Short Pitch Angle E

So, we were discussing about the Pitch Factor.

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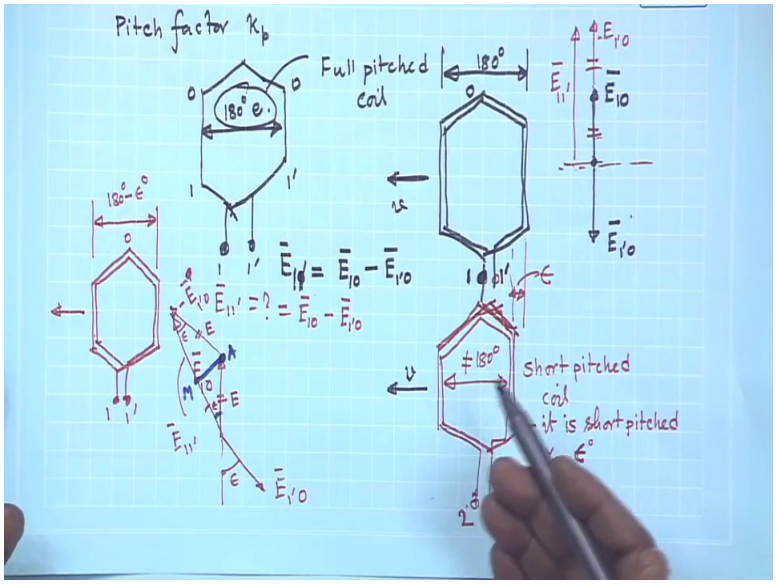

Pitch Factor means that coil span is slightly short of 180 degree. And why pitch factor pitch, why coils because we are telling from the very beginning try to make a full pitched coil 180 degree. But why that short pitched coil is necessary that I will right now discuss. But before that I wanted to find out that ok, if somebody has made not a full pitched coil, but a short pitched coil then the induced voltage how much by what factor it will be reduced. So, if you compare it with this you will find that, this is the diagram we drew last time. So, these lengths are all equal, this length, this length and this length is equal.

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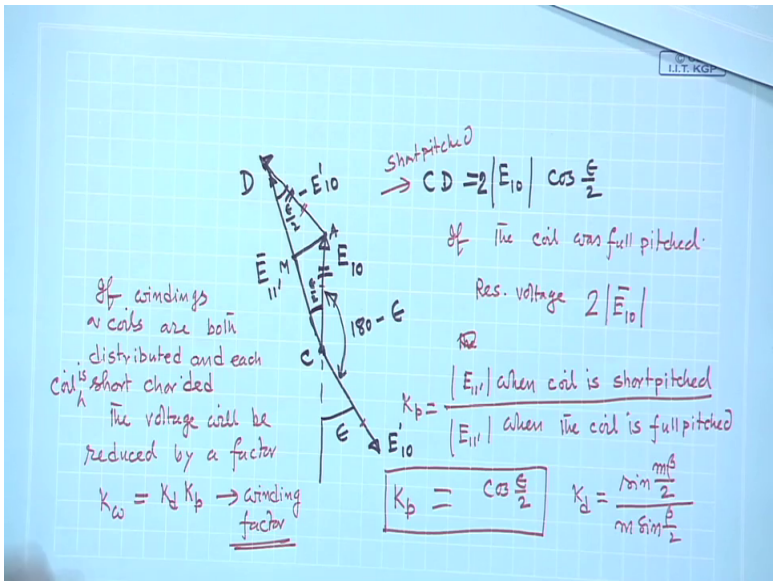

So, by applying simple geometry this is epsilon by 2, epsilon by 2 and resultant voltage will be 2 E 10 cos epsilon. And if it was full pitched, it is for short pitched resultant voltage. If the coil was full pitched, resultant voltage would have been 2 amplitude of E 10 that is all magnitude; magnitude of E 10 and E 1 dashed 0 are same. It would have been twice of that voltage this is the phasor diagram of that.

Therefore, the factor, the ratio; ratio of what? E 11 dashed when, magnitude of E 11 dashed when coil is short pitched divided by E 11 dashed when the coil is full pitched this ratio is called and this is denoted by K p. And this in this case if you substitute these things will cancel and you will be left with cosine epsilon by 2. So, K p is cosine epsilon by 2.

But I have not yet told you why coil should at all be short pitch, right now I will tell you. But you recall this two factors in any AC machines winding one is K d which is sin m beta by 2 by m sin beta by 2. By that factor voltage gets reduced and once again voltage may get reduced by a factor of cosine epsilon by 2 and which is called K d. And if windings are distributed at the and with which short pitched coils then the factor if windings or coils are both distributed, and short chorded, each coil is short chorded, and each coil is short chorded the voltage will be reduced by a factor K d into K p. And this factor is called winding factor, product of this K w is coil winding factor, understood.

Now, I can easily tell you the reason why it may be worthwhile to go for short pitching. You recall that the b distribution in space is not purely sinusoidal it will have space harmonics and these harmonics are odd, fundamental is first, the next predominant harmonic is third, and then fifth, seventh and so on. Of course, their amplitude are progressively decreasing is it possible then by selecting a suitable short chording can I eliminate one of the predominant harmonics.

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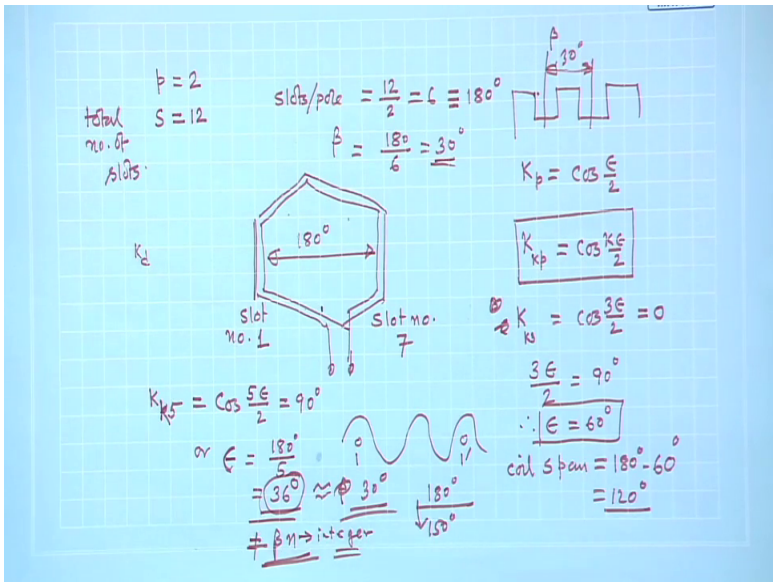

For example, if you have a two pole machine, p is equal to 2, and number of slot is equal to say 12, then slots per pole is equal to 12 by 2 is equal to 6 and this is equivalent to 180 degree electrical. Therefore, beta value is known 180 by 6 that is 30 degree you know. Suppose this point you listen carefully, we will discuss this at length the same points often, but right now what am telling suppose total number of slots this is total number of slots total number of slots, ok.

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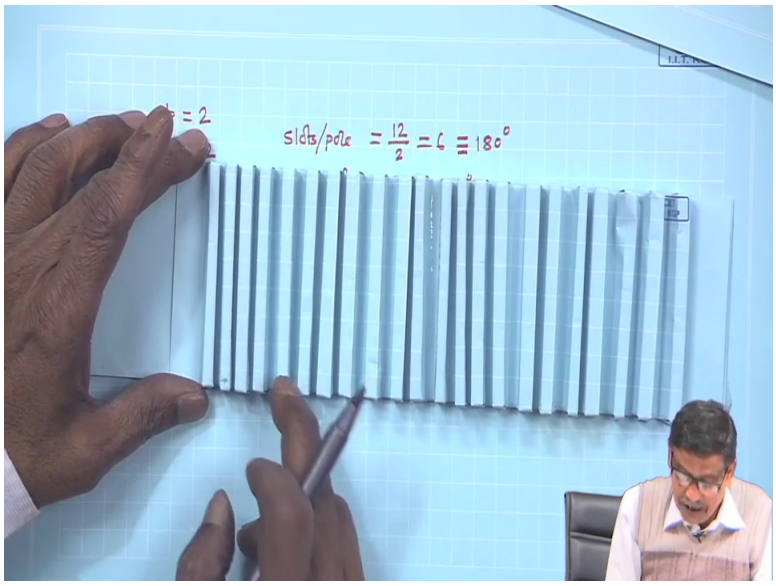

And suppose the slots are numbered like this 1 2 3 4 5 6 7 8 9 10 11 12 and this is of course circle, and after 12 once again 1 2 3 4 in the developed diagram I should show. But the point is suppose one coil side I place in slot number 1, this slot if I want to make a full pitched coil in which slot number should I place the return conductor, full pitched coil means 180 degree. So, I have to move by 6, because 6 slots if you move that will become 180 degree and its return should be here is not, return should be here.

So, a full pitched coil if one coil side is kept in slot number 1 its return should be in slot number 7, they should be 6 slots apart if this is the coil, and this is the full pitched coil then, full pitched 180 degree. So, 12 slots, 2 pole machine, 6 per pole that is equivalent to 180 degree, electrical beta is 30 degree, angle between two slots this and this are separated by 30 degree [FL].

I know that that this is the K p, K p I have calculated cosine epsilon by 2 and as I am now telling you that the b distribution will have a fundamental third, fifth harmonic. Suppose for K'th harmonic what will be K K p, K K p K'th harmonic pitch factor, it will be how much; replace epsilon by K epsilon by 2 that is all electrically it will be much more now. Therefore, this is the pitch factor for Kth harmonic is that clear and in the expression of the emf, net emf across the coil it should be multiplied with both K d and K p.

So, suppose I decide I know that there is third harmonic, fifth harmonic and I decide that I will try to eliminate the third harmonic voltage, let there be third harmonic b present in space and that will cause induced voltage here. But if you want to (Refer Time: 11:15) the third harmonic voltage one clue is here can I choose such a value of epsilon which will make third harmonic to; K pitch factor for third harmonic K 3 will be cosine 3 epsilon by 2. Can I make it 0? For what value of epsilon can I do that?

Obviously, this will be 3 epsilon by 2 is equal to 90 degree and I will say epsilon is equal to 60 degree. Therefore, I will try to tell that, while making the winding do not make a full pitched coil because in this machine I find third harmonic flux is very large b is large suppose, and I want to see that no third harmonic voltage is induced. That can be done by making the appropriate pitch factor of that particular harmonic try to make it 0, then you are sure there will be no voltage.

In other way of what does that mean why that no voltage will come, because that third harmonic poles for the arrangement of the conductors if you do like this coils span. So, coil span make it 180 minus 60 and that is 120 degree, not 180 degree 120 degree if you make then, fundamental voltage will be reduced here will be fundamental component K p also because the epsilon value is 60 degree for fundamental. So, that will be reduced by a factor cosine 30 degree cosine epsilon by 2, no doubt. But you assure there will be the pitch factor corresponding to third harmonic will be 0 because you have seen that while choosing epsilon value that 3 epsilon by 2 is 90 degree so that cosine 90 is 0 and epsilon from there you got epsilon 60 degree.

And why that will be this is possible no doubt if this third harmonic fluxes are like this then one conductor you can examine if it is 1 here, the other one is somehow under same north pole its return that is how it indicates. So, indicates that that is how K p 3 is 0 for third harmonic voltage, but fundamental voltage it will be there.

But if you choose 180 degree no doubt when if you consider fundamental voltage one is under center of the north pole, now the return conductor 1 dashed 0 will never be under the center of south pole. It will be under south pole only mostly, but, but it is not voltage is maximized it will be reduced. So, voltage induced gets reduced by both distributing the coils which is taken care of by the distribution factor K d and it is also reduced

because of the because of use of short pitched coils. By what angle angles I will short pitch; is decided by me.

If I want to eliminate suppose, in the same problem if somebody says, third angle let it be just for academic exercise I am telling. Third harmonic I do not know let it be there, but what will be the pitch factor corresponding to fifth harmonic I want to eliminate. We will see in 3 phase machine line to line voltage even if third harmonic voltage is at present in the coils they do not appear in the line to line voltage. So, may be at that time you will be interested to see that, fifth harmonic voltage I will try to nullify 0. And if you want to do it the pitch factor for fifth harmonic put K equal to 5 here K put K 5, it will be 5 epsilon by 2 and try to set it to 90 degree and then you will say epsilon is 180 by how much, 5, how much it is 36 degree.

But unfortunately you can see for this machine we are considering the number of slots I told some 12 etcetera, is it, where that page gone; oh here only. So, angle between two consecutive slots this angle is 30 degree and for this machine it is 30 degree piece for all this slots. And you look that, if epsilon is chosen is 36 degree then the fifth harmonic component of the voltage will be totally null nullified, it will not appear across the coil. But however, you cannot short pitch a coil by 36 degree, least number by which you can short chord a coil is a multiple of 30 degree.

Anyway this will not determine to short chord the coil still. Why? Then what I will do is this epsilon whatever number I have got I will try to see by what short slot angle beta this is beta, how much it is close to integral multiple of beta. In this case nearest value is 30 degree, ok, so I will short chord it by 30 degree, ok. It will not completely nullify that but certainly cosine 18 degree, I mean if you do like that that will be much less because it will be close to not 90 degree but around 90 degree it will become because it is closest thing possible is 30 degree, in that case I will choose 30 degree only. And it will reduce the fifth angle in voltage considerably that is the in important point. Therefore, coils after studying this things we conclude that it is necessary to distribute the coils. Why it is necessary? Distribution of the coils primarily means that you use more of the slots here. Try to use distribute the coils that is one aspect.

Second aspect is if this coils are distributed when they will carry current they will also produce approximately sinusoidal b distribution because a single coil, it is single

rectangular mm of distribution of b distribution, but we have shown that if the many coils are displaced in space and connected in series instead of keeping all the coils concentrated, the mmf distribution can be made a straight ones, moved towards your sign wave. So, that the effect of harmonics still it will be present that will be considered (Refer Time: 20:22) that is one thing.

And why short chording? Short chording is necessary assuming that, ok, space harmonics cannot be totally eliminated there will be chord harmonics present like third, fifth, seventh etcetera. And for a given number of total slots number of poles etcetera I can calculate the beta. What is beta? Angle between two consecutive slots or angle this is same as angle between two consecutive teeth. Whatever it is I know that beta therefore, the pitch factor I have found out for any K'th harmonic this thing it is cosine K epsilon by 2 then it tells me ok, perhaps by choosing appropriate epsilon. What is epsilon? Epsilon is the angle by which we call it short chorded by what slot I will reduce so that it will become short pitched by epsilon degree.

So, I then try to say, perhaps third harmonic voltage I want to reduce it to 0 in this case am lucky it is third harmonic you want to remove I will immediately say cosine 3 epsilon by 2 is 0 90 degree and if so happen epsilon is 60 degree. So, by 2 slots integral multiple of 30 degree is very much clear.

So, if it is slots per pole is 6 full pitched coil means 1 7, I will place the return conductor not at 7 but at 5, then it will be a short pitched coil reduced by two slots it is short of full pitched by two slots and then I will get it. If you want to eliminate say fifth harmonic for some reason or the other you do not like fifth harmonic, ok. In that case what will be the case? Third harmonic I do not mind I mean something academic exercise I am telling, ok.

If I going to want to is fifth harmonic then I will try to examine by what angle I should short chord the full pitched coil this is cosine 5 7 by 2 to 0 because cosine 90 is 0. Then I come out with an epsilon value which is not an, not equal to an beta a multiple of beta say n beta it is not equal to it cannot be expressed like that.

Therefore, there I am slightly disturbed because I am not sure what to do. But I am telling you then see it this 36 degree nearest multiple of the beta this is close 30 degree, 60 degree you will be two higher value. So, nearest closest value of beta m is 30 degree

that is m equal to 1 of this one it is integer any. So, use a short pitch angle of epsilon. So, the coil span will be not 180 degree if you short it will be 150 degree better use it. And then you assure third harmonic or fifth harmonic voltage will be reduced considerably. You cannot get 36 degree that is it.

Therefore, I have now told you two very important factors and how to calculate them, ok. There will be several problems given in your tutorials. Next topic will be now we are ready to start a 3-phase winding how it looks like, ok. So, and we will try to make a 3-phase winding and before that I will now change because you will see that a 3-phase balanced winding if you want to make it essentially becomes a number games, very simple. Because in a very rhythmic fashion this windings which may be very complicated at one end but after all it will become purely a number games. So, what we will do is, this convention we will follow.

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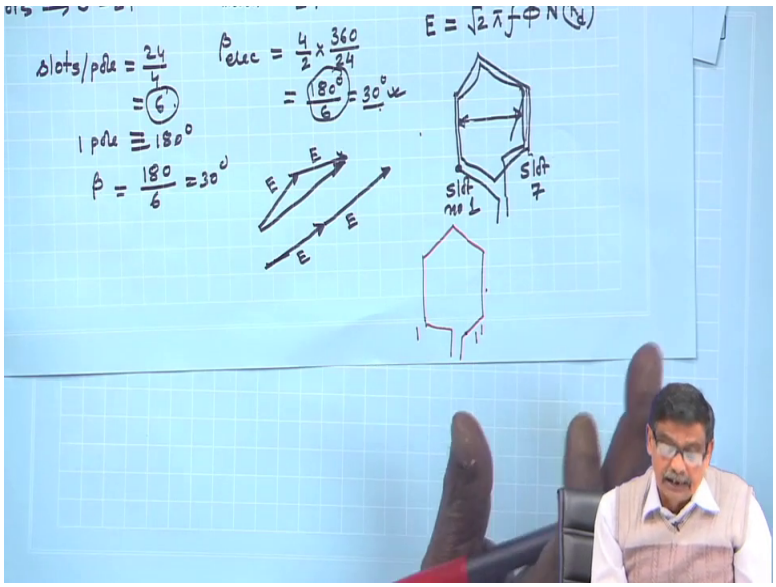

So, far I was telling that I will name the conductor of coil sides in this way. If one coil side here, I was telling that its return coil sides are I was calling it one dashed, is not that is what I was doing. But I will now slightly change that. What is that? That changing I have already done, one example I have taken.

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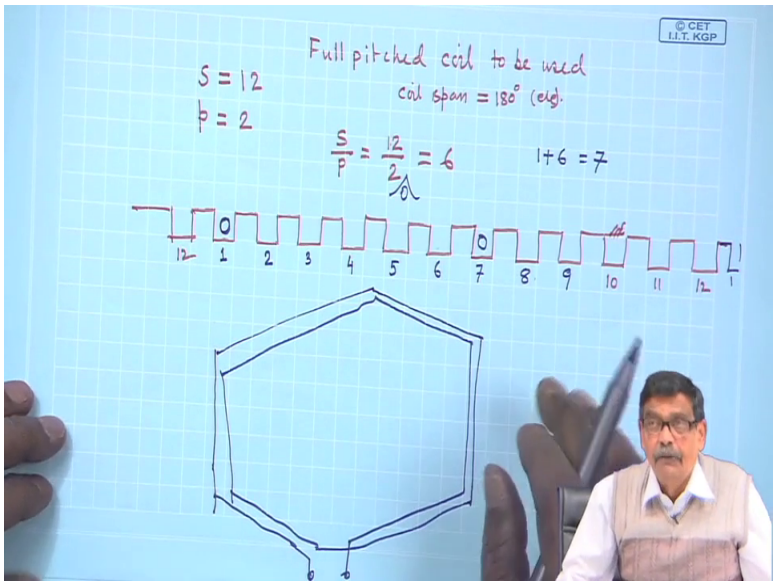

Suppose the total number of slots, no harm in repeating that problem and p is equal to 2. So, I want to use full pitched coil, we will come to short pitched coils slightly later. Full pitched coil to be used, which means that coil span is equal to 180 degree electrical is appears electrical.

So, how to calculate this angle? Calculate slots per pole which is 12 by 2 and you get a number 7. Now, these slots are like this slots, tooth slot, tooth slot, it goes like this in the developed diagram and 12 such things are there. So, suppose at this slot is 1, slot numbering will progress like this 1, 2, this is 3, where I will place the conductors 4, 5, 6 and then let me draw so that 6, this is 7, 8, 9, ok. Let me draw further, this (Refer Time: 27:54). It goes like this source 8, 9, 10, 11, 12 and after that once again it will be 1. And in fact, before this it was 12, because circular thing I have unwrapped and put it on a plane paper like this.

Now, what I will do, only this much I will tell time is not there. What I will do is this one coil side will be placed here one and full pitched coil is to be used, then its return other coil side must be placed at 1 plus 6, that is 7; it must be placed at 7. That is this coil full pitched coil will look like one, it goes like this and if we look from the top and it comes out. Of course it is multi turn coil, say two turn I am showing this is the thing.

Anyway I will stop now. We will continue with this.