Electrical Machines- II
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Lecture – 24
Double Layer 3 - Phase Winding – an Introduction

Welcome to 24th lecture and we have now come to a very important situation, where we are beginning to understand how the windings of a rotating electrical machines AC machines will look like.

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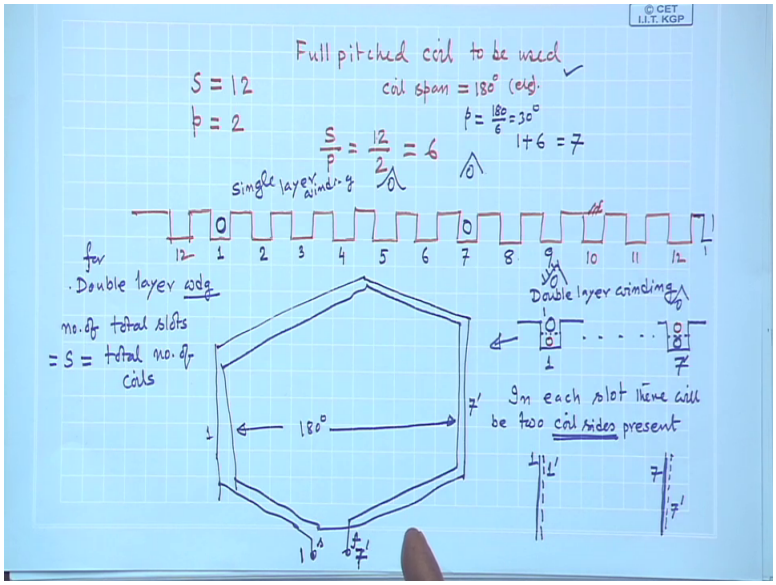

And, I was telling you that if you look at this example suppose a machine is having 12 number of slots equispaced and if you like you can calculate also beta the angle between two consecutive slots, which will be 180 by 6 that is 30 degree electrical. Total number of slots 12 number of poles number of slots per pole is 6. Therefore, a full pitch turn coil if I want to use, I must and I have numbered this slots. And based on this slot numbers I will now slightly change the coil naming coil side naming. Earlier I was telling 11 dashed to identify a coil. Now there is a slot definite slot in which a particular coil side will be present.

So, I will be naming them after the name of these slots. For example, this front end of this coil I will call it 1; and this coil side is 1 I will refer to like this. And this one is returning to 7 slots because I want to use a full pitched coil. So, perhaps I can name it as

7 that is also. So, it should not be understood as coil 7 I am talking about. Start of the coil is as slot number 1 and its finish is at 7. And this angle is 180 degree full pitched, this is one thing I will would like to tell.

Another thing I would like to tell that and you will see at the end all this slots should be freed up. So, that whole periphery is utilized with copper that is conductors ok. So, better utilization perhaps I will be using distributed, windings that is that is to be used in fact. Now apart from this, there is another important thing that is to utilize the slots space properly, what is done? Suppose this is slot number 1; and dot dot dot this is suppose slot number 7 the same thing I have drawn. And what is this term is called double layer winding.

We will be talking about. This is single layer in each slot there will be only one coil sight present. Therefore, each slot when it accommodates a single coil side of a particular coil, it is called a single layer winding. I have shown here 1 7; one coil side and this coil side of course, is having multiple turns; multiple turn coil. But, double layer winding what is done is that in each slot, in each slot there will be two coil sides present, two coil sides present and to separate coil sides will be present. Of course, therefore, this is that is if this slot if you imagine, it will be having a upper deck and a lower deck. For example, if I want to make a double layer winding of this, I will place what here and its return I will place it here understood this is how my winding will progress.

So, 1 and this lower deck upper deck 1 is one coil side of coil 1 7. If you use this double subscript now its finish is at slot number 7 and it will be in the lower deck. In the upper deck and lower deck of slot 1 and 7 there will be other coils. Therefore, in a double layer winding, each slot there will be two coil sides present. Therefore, if I know the number of slots total number of slots, how many total coils it can accommodate? How many total coils? Each coil require two coil sides therefore, if double layer winding is being used for double layer winding, I will write in short as wdg.

For double layer winding, number of total slots that is S is equal to S will be equal to total number of coils. Since each coil sides require each coil requires two coil sides therefore, how many total number of coils can be accommodated? Capital S. If it is a single layer winding number of coils that can be accommodated is equal to the number of

S by 2 is not? S by 2. Therefore so, this will enhance our utilization of the windings. So, it will look like.

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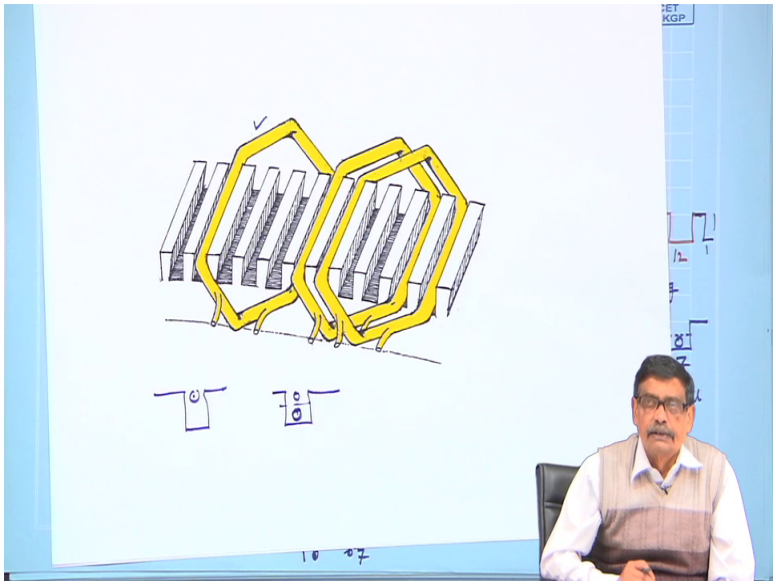

This diagram if you look at; these are the slots this is one coil, its start is at the above I think in 3 dimension if you look at this diagram, this is starting coil side and it finish comes out from this below. So, this is the thing is not this coil. Here its return is here you can physically see below this. Similarly this coil it is as another separate coil, its return is from below. So, in each slot there is two coil size as shown here and when this other slots will be filled up, everything will have two coil sides lower deck upper deck. And this coil size; obviously, the other coil side which will occupy this space upper deck will may will be a different coil with its own existence separate existence.

So, separate coils are used. So, double layered winding we note that the number of coils is equal to the total number of slots present [FL] this is one thing. Now, therefore, this coil what I will do is this, if we look from the top for each slot what we will see? I mean in a double layer winding. If you look from this slots what you will see? I will draw the other coil like this; another coil which will occupy this upper and lower deck like this. So, if you look from the slots, this slot number you will see one line only [FL] the upper conductor you can see. If you see the plan view from the top this is the length of the coil side. Of course, beneath this one there is another conductor another coil side of some

other coil. So, in a slot I will expect coil sides belonging to two different coils that is the thing.

However, the second one second conductor if you look from the top view you cannot see. So, what people do is this, second conductor they show it by a dotted line just beside it close by and name this as a one dashed. Understood that is whichever coil side will occupy the lower deck, they will be numbered same as this slot number, but with a dash 11 dash or 11 prime. Similarly for 7 there are two conductors and this slot, I will show it like this from the top if you look, you will see there is a conductor at the top that I should call side 7 and besides it, I will draw separated by a very small distance. So, that I can distinguish and I can understand what is going on I will write it 7 dashed so.

So, in this case therefore, if it is a double layered coil, if this is a double layer I should name it 1 and 7 dashed this side is 7 dashed. Assuming that it will be used in a double layered mode therefore, your coils sides should not be exactly parallel, it will be slightly tilted so, that they can really nicely fit in to this slots. The way I described, then these two coils are should not be exactly parallel it should be slightly below it. So, if we look any coil of a rotating machine and they are definitely using double layer winding, and the coil shifts are not exactly in same plane.

One coil side is slightly above indicating that whichever slot it occupies, it will occupy the upper deck and this one will be below deck and slight this thing. So, one goes and return to 7 dashed. There therefore, the coil side occupying the upper deck, I will call side by the number of this slot. The coil side which will be on the lower deck I will call once again by this same slot number, but with a prime attached to it so, that I do not make any mistake ok. If that be the case then we can proceed further. Then I will add another term that is suppose I say I with this specification only.

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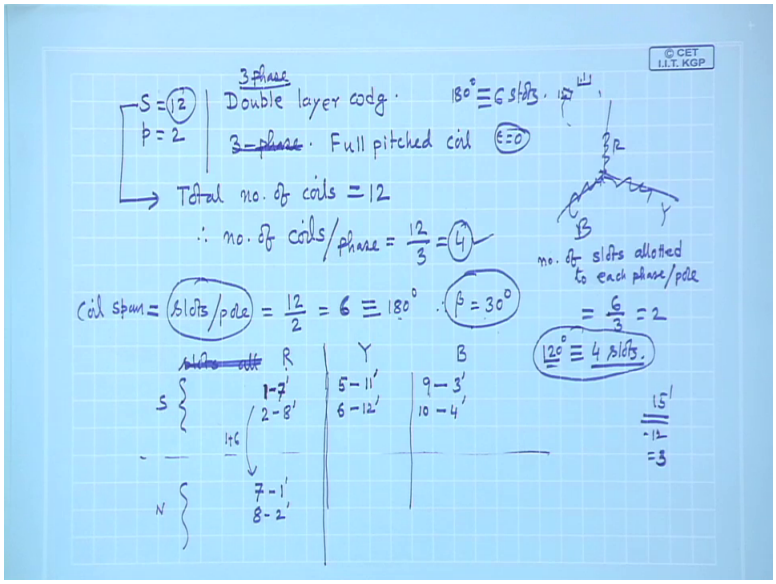

S equal to 12 p is equal to number of poles 2 and I want to make a double layer winding; double layer winding and that is a 3 phase winding because that is the most popular thing 3 phase double layer winding I want to make out of this things given to me; s equal to 12 p equal to 12. 3 phase windings are balanced windings ok. As you know this number s equal to 12 tells me that total number of coils is also equal to 12; 3 phase winding you are making that will be R phase Y phase B phase that is fine, but total number of coils will be 12.

Therefore I can say that number of coils and it is to be a balanced 3 phase winding; number of coils per phase must be 12 by 3 4. These are very simple calculations total number of coils 12 R phase must be having 4 coils Y phase B phase too will be having 4 coils each. Therefore, this these are the things I know quickly and also I tell you that I will make a full pitched coil use full pitched coil that is epsilon is 0 or (Refer Time: 15:53) epsilon that is the thing. So, then I calculate the value of beta.

So, first I calculate slots per pole is 12 by 2 that is 6 that is equivalent to 180 degree electrical therefore, beta is equal to 30 degree 180 by 6 I get that. And then there are 12 slots. First I will see any slots you can say this is on the rotor and any slot you can number as 1, but once you fix that other slot number gets fixed. So, 1, 2, 3, 4, 5, 6 I could call this also 1, 2 3 it does not matter we will say because after all things will be rotating ok.

So,. So, these are the numbering I have done, and this is the thing. Now there are two poles ok. First let me do it like this without much explanation we will explain it later, but you see how easy it is. So, there are two poles total number of slots are 12 therefore, it is expected slots allottant and slots per pole is 6, and under a pole north pole there will be total number of 6 slots available, and our common sense tells as you want to make a balanced 3 phase winding. Therefore, out of this total 6 slots allot two number of slots to r phase, two number of slots to Y phase and two number of slots to B phase that is quite logical, are you getting?

Now let me start so, that you will understand what am telling the moment I write it. What I will do? I will say that this is for R phase whatever I will write below. This is for Y phase and this is for B phase I will write it like this. And before I do the winding I want to tell only one point that everyone knows, but I am telling you should keep that in mind, it will reduce your hard way of understanding things one thing is very cleared. In whichever way the R windings are accomplished, Y phase winding will be exactly same as that of R phase winding but it should be displaced in space by winding 20 degree electrical that is all.

Similarly B phase will be similar to Y phase winding, which is similar to R phase winding phase B phase winding too will be similar to R phase winding, but displaced from R phase winding in space by 240 degrees. Or displaced in space by 120 degree from Y phase winding, that is how we draw [FL] we are used to draw like this is R phase this is Y phase this is B phase in our this thing. So, R Y B is the phase sequence. So, axis of R phase coil and Y phase coil, they are equal turns 120 degree apart that is all.

Suppose I decide that I will start with R phase. R phase I start with slot number 1 I put one coil side one. What will be its return coil side, what is a name of that? In which slot it will return this coil side? 1 plus 6 7 that is what I told you here same example; one it must return through 7, but the if this one is only upper deck returning 7 coil side I will name it as 7 dashed 7 prime. Because, it will be below from top you cannot see you can see the other coil side which will be eventually placed in the upper deck we will see that. So, this coil I will simply write it is 1 7 dashed.

So, I have started my R phase there are 4 coils will be there we know before doing anything else. So, one coil is put in its place 1 7 dashed. Now also I will be using

distributed coils for phase and per slot. So, number of slots allotted to each phase per pole will be equal to 6 by this is slots per pole is 6 6 by 3 that is 2 under each pole there are 6 slots available. So, I will be equal to each of the phases, because am thinking that this will ensure a balanced 3 phase windings. Why unnecessarily you show favor to a particular phase allotting more slots to that? It should be equal it looks like. So, I start with one give 7 dashed, then the second coil because two slots are available suppose. So, this 2, it should be 8 dashed.

So, R phase two coils and perhaps this is under say south pole or north pole whatever it is. First two slots I have allotted to R phase and this two coils I will call 1 7 dashed and 2 8 dashed coil spans are same and each coil is identical only thing their names will be different. So, 1 7 dashed and 2 8 dashed R phase is over. Now this is the starting of R phase; everything should be Y phase should be displaced from R phase by 120 degree electrical apart. Now beta is 30 degree therefore, 120 degree is equivalent to 4 slots is not? This number is known.

Therefore it looks like if you have started R phase from slot number 1, Y phase start should be from slot number 1 plus 4 5. So, starting of Y phase should start from 5 and its first coil starts from 5, but coil span is same no matter whether it is R phase Y phase or B phase symmetrical 3 phase winding I want to make therefore, it will start from 5 to ensure that 120 degree business displaced and what should be its return? Coil span is same that is 6. So, 5 plus 6 11 and it is shown in the upper deck without prime.

So, it must be shown as 11 dashed. So, this difference should be 6 and this should be this similarly this starting from starting of B phase coil should be after 120 degree from Y phase therefore, another 4 you go, that is 5 plus 4 this is 9 and its return should be 9 plus therefore, 120 degree I will go from slot number 1 starting of R phase is from 1, starting of Y phase should be after 120 degree and 120 degree is equivalent to 4 slots. So, I have added 4 to 1 that is 5 starting and then its return should be 5 plus 6, 11 and 11 dashed because lower deck. So, I think it is ok. So, this is the thing similarly B phase will start from Y phase after 120 degree.

But 120 degree corresponds to 4 slots therefore, it should be 5 plus 4 9 and coils span is 6 all the time. So, this is equal to coils span you know is the slots per pole and full pitched coil I know is no question of short chording the coil therefore, it should be 1

from 5 and 9. Then add 6 to 8 you get 15 dashed, but 15 dashed is nowhere because there are two slots what to do? Because you. So, see I told you it is a round machine.

So, one to if you start from here reach here 12, then after that once again one starts. So, 15 dashed means you subtract from 15 that 12 whatever number indicate 15 minus 12 that is 3. So, it should be 3 dashed got the point. So, 1 7 dashed is the first coil of R phase, then first coil of Y phase must start there should be a spacial shift of Y phase by 120 degree electrical and 120 degree electrical is equivalent to 4 slots.

So,. So, you add 1 plus 4 you get 5, but coil span each coils are identical. We are calling it by different names, that is different thing, but coil span is 6 only. So, it will be 5 11 dashed. Similarly B phase starting should be from 5 plus 4 120 degree that will be ensured B will be shifted from Y and it is 9 and then it should end 9 plus 6 15, 15 dashed, but there is no slots marked as 15 what you will have is slot 1 and here it will be 12 slots as you move come here, then once again it will be 1 2 so. So we have to subtract actually 12 to get this number 3, and then say 3 dashed. Then I want to distribute the coils of Y phase also because under each pole I will have two consecutive coils, that is what I have done for R phase.

Then I must do this 5 11 dashed and 5 6 12 dashed this is what I will do. This one once I get this I will say this is 10 and this is 4 dashed understood. So, what I am doing is, I am making the windings like this it is a two pole machine suppose under one pole. Let us this writing of south north is for my convenience I am doing, but any way two poles I have allotted to R phase. Then if you have started the winding from slot number 1 for R phase 1 7 dashed 2 8 dashed 5 11 dashed and so, on. Now the question is, but before doing all this things I knew that, total number of coils will be 12 and each phase will have how many coils total coils will be 12 because double layer.

So, number of coils per phase should be if you count there at the end, it should be 4. So, look at R phase oh I have done got only two coils accommodated in those slots. So, another two coils still remaining for all this phases for R phase Y phase and B phase, where they will be position. At least I will give you some indication and I will continue with this. Suppose you see the other pole; that is you have started R phase and under one pole you have allotted two slots here, then the next two coils which will be also distributed should start from after 180 degree.

Because angle between south and north pole pitch is 180 degree, 180 degree is equivalent to 6 slots. So, it should start from 7 that is 1 to 7 how do I get? You have started assuming it is under south pole 1, then the and adjacent to that two 8 dashed then next pole whatever you have, that will be separated from this pole by 180 degree which means 6 slots. Therefore, other two coils must begin from 1 plus 6 this how do I get? 1 plus 6 7 and once you get this number no looking back coil is full pitched. So, it should be 13 dashed, but 13 dashed is not there it should be one dashed, subtract 12 from 13, it will be like this. And allot two consecutive coils to R phase and then it should be 8 2 dashed like that. Please try to complete this Y and B phase by this logic and we will continue with this in our next class.

Thank you, but this idea is must be very clear double layer winding what it is, total slots, if it is double layered number of total slots is number of coils, and this calculations do not require any winding to be like that ok. 12 coils will be there as simple as that. Balanced 3 phase winding you want to do at the end you must come up with 4 coils of R phase with 4 coils of 5 phase and 4 coils of B phase. This number 4 is also achieved just like that. But do not forget to calculate beta: what is this slot angle that is slot pitch.

Thank you.