Electrical Machines - II
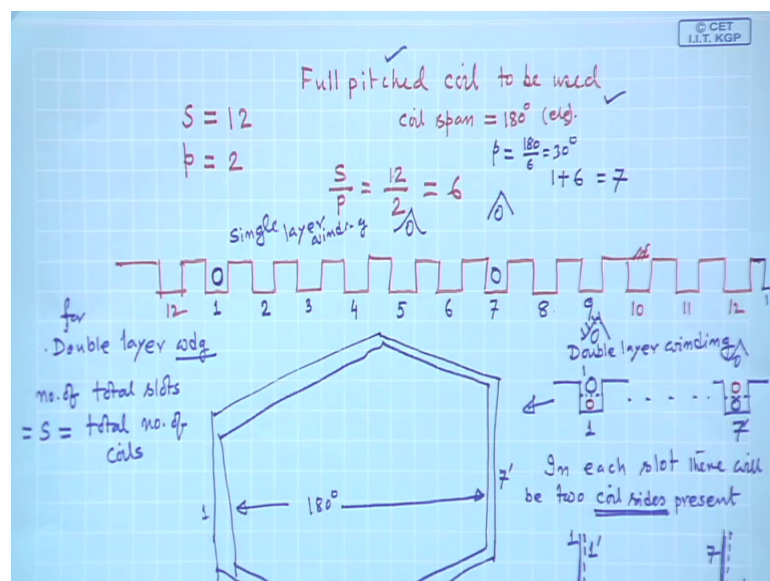**Prof. Tapas Kumar Bhattacharya**
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Lecture – 25
Winding Table 3 - Phase Distributed Winding

Welcome to this new lecture and although lecture is new, but we started the topic in our last class only and our plan was to make a 3 Phase Winding.

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And the data we used in the last slide, last time is suppose there are 12 number of slots and I want to make a 3 phase winding with full pitched coil and which will produce a 2 poles. So, first thing is you calculate S by P that is number of slots per pole 6 from which I can calculate beta because, 6 slots is equivalent to 30 degree therefore, separation between 2 consecutive slots will be 30 degree.

And then I told that I will make a double layer winding. So, in double layer winding essentially in each slots there will be 2 numbers of conductors you recall; just quickly reviewing.

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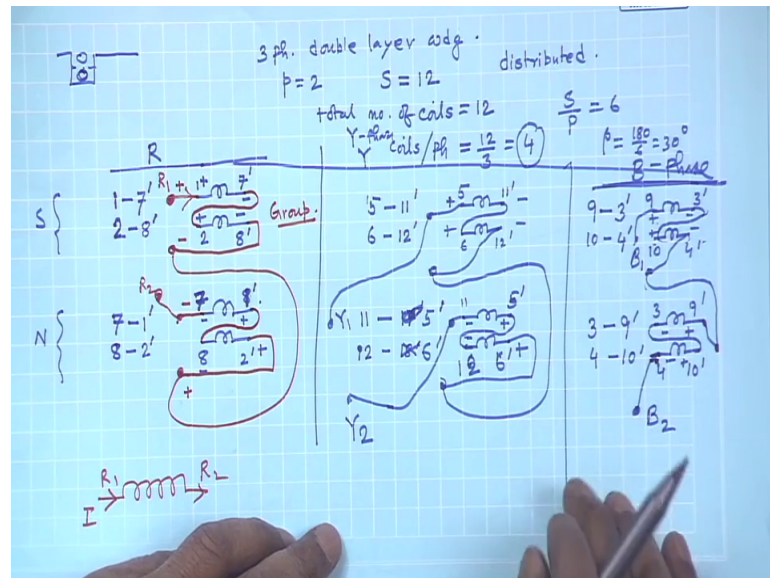
So, 2 number of coil sides will be there in each slot and this coil sides may belong to the same phase group or may belong to different phase group that will see, but the essential thing is each coil side will have a upper deck coil side and lower deck coil side. And this 2 coils are distinct coils separate coils; obviously, cannot make a coil with 2 coil sides residing in same slots alright that is not be a reason.

So, that was the thing, then I told about the numbering of this slots. So, numbering of this slots can be made quite arbitrarily ok, you start with any 1 slot and you can make numbering. So, our problem is I want to make a 3 phase double layer, winding double layer winding with p is equal to 2 and total number of slots is equal to 12.
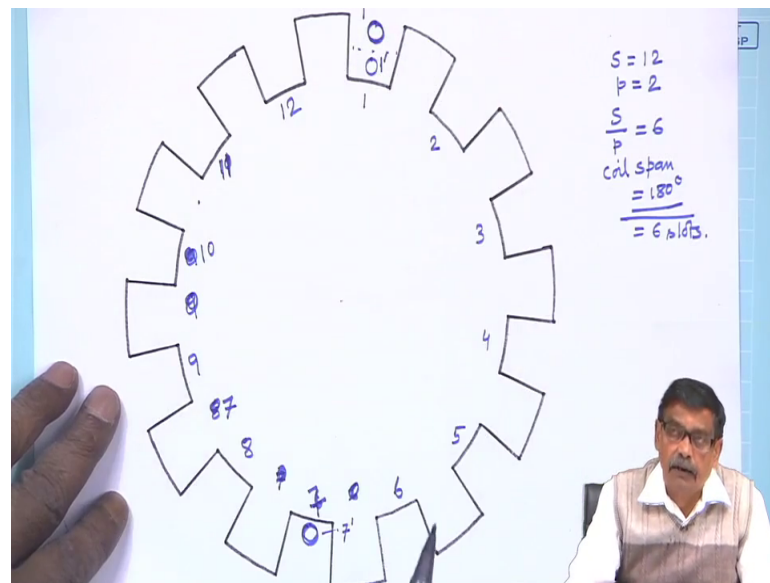
So, I have just drawn a actual view of the rotor slots like this. So, I can number them in any way I like. So, let us start from this say 1 2 this is 3 4 5 6 7 8 9 no, this is not 9 this is 9 slot where the conductors will be placed 10. So, 1 2 3 4 5 this should be 6, this should be 7 you clearly write a the open space at the slots 6 is here this will be 7 open 6 7 then this is 8, this is 9, this is 10, this is 11 and this is 12. So, this 12 number of slots are there. Now, what I am telling in each slots will be coil sides and there will be 2 coil sides. So, there will be one upper deck and one lower deck. So, if number of slots equal to 12 and p is equal to 2 then S by p is equal to 6. So, if a coil if you start if and the coil sides who whoever will be present will be numbered by the slots number.

So, any coil side here will be called a 1, only thing is the upper one I will call 1 and the lower one I will call 1 dashed that is the things should be remembered. Now, in my last class I told you the coil span is equal to 180 degree always true which means 6 slots. Therefore, if I have started with coil 1 it will start here and its return will be in the 7 slots here and that return I will make it from the lower deck. So, this coil sides I will call 7 dashed. So, 1 7 dashed is a coil 1 dashed if it is present I will call it 1 dashed below, but this coil 1 7 dashed why it is diametrically opposite because p equal to 2 mechanical angle is equal to electrical angle.

So, this is this way I will do it. So, this is how this windings will proceed anyway let us redo it. So, I will be doing like this there are 3 phases total number of coils must be 12

because it is double layer 12 and coils per phase ultimately has to be 12 by 3 4 that should be 4 coils of r phase 4 of y and 4 of b phase. Now how to start this suppose you have R phase I am trying to do I will write R phase. So, R phase will be 1 and 7 dashed and this I will represent side by side also by a symbolic coil 1 7 dashed with this terminal that is start of coil 1 R phase coil 1 1 and its finish is at 7 dashed, now then I will be using distributed windings distributed.

So, I next coil which will belong to R phase I will call it 2 8 dashed coil span is said all coils are identical. So, this will be like this 2 8 dashed, now under each pole slots per pole is 6 therefore, 1st two slots I will allot to R phase under a pole next 2 slots to y phase and next 2 slots to b phase equally they will share that 180 degree span. So, after I have allotted 1 2 here 1 and 2 first and second slots to R phase there should not be any immediate R coils coming under this pole that is how I have told.

Now, each phase will have 4 coils therefore, it looks like 2 coils are over this is suppose under South Pole it is like this therefore, other 2 coils should be under North Pole. Now, therefore, starting of the second group of coils of R phase will be then from the slot 1 plus 6 7 and that is the start of the second group first coil of R phase that is what I will write and then this will be 7 plus 6 13 dashed, but 13 dashed is nothing, but 1 dashed it will be like this. And then immediate next slot I will allow to also to r phase and it should be called 2 dashed if any mistake point out. So, it is like this therefore, and this coil will be 2 no 2 7 and this is 8 dashed and the second coil 7 and 1 dashed I am. So, sorry and then 8 and 2 dashed.

Now, suppose under south pole the polarities of the starting terminals or plus this is plus this is minus this is minus therefore, this coils 7 1 dashed the polarity of 7 because, it is under North Pole must be opposite minus plus. And similarly this one will be also minus plus see all this all 4 coils of the r phase has been has been completed in the 3 phase winding because each phase will have 4 coils and we have completed 4 coils.

Now, the question is how to connect them first thing is this connection interconnection I will show by separate wire that is this 2 I will connect in series and I will say this is a group of coil distributed coils similarly this 2 I can connect in between series and I will get its terminal like this ok. So, this is called first group and this is the second group. Now the voltage therefore, if ultimately what you will do you will connect at this 2 coils

in series with this group that is this 2 groups are to be connected in series then one should be careful about the connection this is the minus and this is plus. So, plus minus and now it should be connected like this. So, that all voltage becomes additive. So, this will be the 2 terminals of R phase available for external connection supply etcetera.

So, first of all there are 2 groups of coil these are called groups in a group immediately some coils will be connected in series that takes care of distribution of the coil and under each pole it will be like this R phase. So, while connecting this you should be careful, I will explain it with phasor diagram also slightly later, but let us complete them what is going to happen to Y phase Y phase that is this is Y phase column. See if this is the number of slots you are starting your R phase coil 1 and 7 dashed [FL] one let me complete this with respect to R phase coil where things are ultimately let me take a another because (Refer Time: 12:59).

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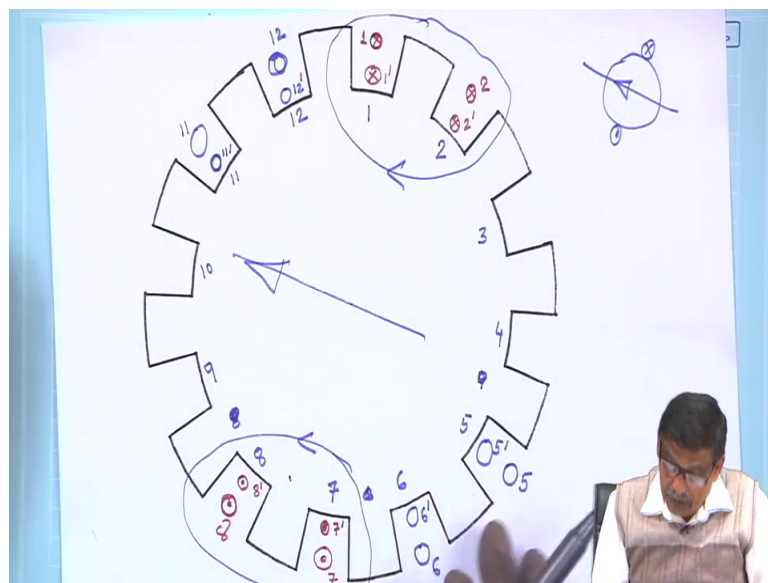
So, this is let me write it clearly so, that no confusion remains. So, this was slot number 1 2 alternate 3 4 4 5 6 1 2 3 4 5 6 is it 6 and dashed take slot 7 8 7 8 I may call as mistake here this is 9 10 11 and 12 ok. So, R phase coil the winding I have shown here like this, but in actual disposition of the coils will be like this. You take the first coil and let me use a red wire to indicate R phase. So, it is one on the torque this is one and its return is at 7 diametrically opposite because it is a 2 pole machine it is 7 dashed, this is 1 not 10 1 and

this is 7 dashed then the how the coils have been distributed the second coil 2 belonging to R phase only and 8 dashed 2 and 8 dashed.

So, this is 8 dashed and this 2 will be connected in series like this, then the start of the next group of coils of R phase is from 7 I will draw it a slightly bigger sections. So, this is 7 and its return is at this one 1 dashed 7 1 dashed is a coil and 8 2 dashed is another coil and I am telling the R phase there are 4 coils R phase windings, R phase part of the winding is over. Now whole you connect them in series you must recall this 1 1 dashed 2 2 dashed all are same polarity if it is cross squares all of them are cross and these are will be all dots. So, starting of 7 will be opposite polarity as that of 1 that is why this polarity reverses here starting of this coil this you can verify. So, after you have done this and all these things are connected in series appropriately correctly then these are the 2 terminals I will call it R 1 big R 1and big R 2 machine R phase terminals.

And if they carry current now suppose you get this whole thing now becomes and R phase terminal R 1 R 2 and if suppose you pass some current DC current through R 1 and current comes out from R 2 then the currents how it will look like current enters through one for this first coil. So, it will be cross currents comes out from 7 dashed it will be dot then current enters through 2 it will be cross current comes out from 8 dashed because of this connection all are in series and you are passing some current like this then this 2 and cross and this 8 dashed will be dot 8 dashed will be dot and then current enters through 2 dashed.

So, current enters through 2 dashed cross and currents comes out slot 8 2 dashed 8 because through 8 current is entering through 8 and 7 current is entering this will be the current pattern and this will be crossed. Now if you just see if you see a machine has produced how many poles it is if this 2 are R phase terminals you just excite it with dc current to test that and this will be the current distribution. If this is the current distribution I know it has produced to 2 poles because this 2 cross can be grouped together and this 2 dots can be grouped together and your lines of forces will be like this here.

So, that this side of the rotor iron will become a North Pole this half will become from this center it will become the South Pole. Therefore, by distributing the coil if it is a 2 pole machine that distributed current patterns after all this thing if coils were not

distributed all there in 1 and 7 dashed, then it will be like this and your field will be like this 2 poles. Similarly, if these currents are distributed now they can be grouped together and you still get 2 poles that is the thing [FL]. After this is over and we have understood 1 to 1 correspondence of this to this, but as am telling if you have understood where the return conductor is to be placed and you make this winding table first then that is it you need not even draw this diagram any way this is the thing for Y phase what is going to happen. Y phase start of Y phase first coil will start after a gap of 120 degree from the start of R phase and that must be 120 degree electrical.

So, after 4 slots 4 in to 30 degree because angle beta is 180 by 6 30 degree therefore, the second coil must start from 1 plus 4 5 and then of course, all coils are identical its span will be 11 dashed 5 plus 6 and then 6 12 dashed and the next group of Y phase coil will start from after 1 pole pitch that is 1 plus 6 7. So, 5 plus 6 7 11 and 17 dashed if am wrong please point out. And then this is 12 and 18 dashed, but there is no 17 dashed total slot is 12 so, subtract 12 from it. So, this will be in fact, 5 dashed is not and 12 18 dashed.

So, 18 minus 12 6 dashed is it. So, this is how this Y phase coils will look like. Similarly, you assume that this group of coil this is under North Pole and the symbolic representation of this can be made with terminals 5 11 dashed 2 coils distributed 6 12 dashed. And if it is under North Pole the polarity will be plus minus plus minus and this is 11 5 dashed and this coil will have 6 12 dashed 11 5 dashed 12 6 dashed it will be.

But since it starts 11 is under South Pole if polarity reverses and therefore, this 2 groups I connect in series to get first group of Y phase this column is for Y phase and this two also you connect in series. So, that this 2 voltages are additive these are the 2 terminals of the second group of Y phase coil, but the point is the polarity has reversed we have to make all this 4 voltages in additive mode.

So, plus minus plus minus then you must have plus minus and then if you place another plus minus and this 2 I will call the Y phase terminal Y 1 Y 2, which is available to the user. Similarly, let me do quickly this phase R and B phase here before doing B phase let us see how it looks like it is slightly it may look not boring, if you are understood the pattern or the logic behind placing the coils it is a good practice let us do it. So, for Y phase what I am telling it has started from one. So, it must start from 5. So, let us use this

blue colors. So, Y phase first coil will be this 5 and its return will be; obviously, 11 dashed this is the first coil then the second coil is 6 and 12 dashed. So, 6 after coil sides are numbered without prime so, 6 and its return will be 12 dashed.

But, the next group of Y phase coil start from you know slot number 11. So, I will write with a bigger thing that is 11 second group of first coil and its return must be of course, it is a full pitched coil its return must be 5 dashed. And the next coil under South Pole it will start from 12 and we will return from 6 dashed and the interconnection of this 2 coil should be done following this. So, this is how the Y phase 4 coils I completed Y phase Y phase will be 4 coils belonging to each phase it will be there. Similarly for B phase what is going to happen, B phase it should start after 120 degree electrical from Y phase, therefore, 5 plus 4 it must start from 9 and then 9 plus 6 15 dashed, but there is no fifteen dashed it should be 3 dashed then 10 4 dashed.

So, these are the distributed coils in the first group of a phase. So, this is each terminals are 9 3 dashed and it is 10 4 dashed and this is plus minus imagine that this 9 10 under North Pole or South Poles of particular pole polarities like this and I will connect them in series, these are the group terminals. Then the next half it will be 9 plus you know 5 plus 6 11 9 plus 6 is 15, but there is no 15 it should be 3 and if it is 3 then 3 plus 6 is 9 dashed is not second group and then 4 10 dashed. And similarly it will be 3 9 dashed and 4 10 dashed, but the priority of doing this voltage must result. So, because this third point is like this and this 2 also I should connect them in series.

So, that voltages are additive, but while connecting this 2 groups I must be careful as I was telling. So, plus minus plus minus then once again correct something is wrong plus minus plus minus this is minus plus minus plus. So, any number is wrong everything is fine. So, I will connect them in once again series. So, plus minus plus plus minus that way it can make this it was coming opposite or here I made mistake plus minus plus minus.

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Correct. So, anyway this 2 will be your b phase terminals and can be marked as capital B 1 and capital B 2, we will continue with this and we will take slightly not complicated, but a machine with 4 number of poles how to do it same way, but you must understand the logic.

Thank you.