



But here how it will look like I will show. RYB, incidentally what I have done is or I have used red yellow, I have used blue colour, for yellow 5 11 dashed.

Now, green color I am using for blue phase, please bear with make for this because no other colors are available. So, let me put the coil sides in for the B phase. So, B phase you see it is 9 3 dashed. So, where is 9 you know 9 3 dash, this column 9 3 dash.

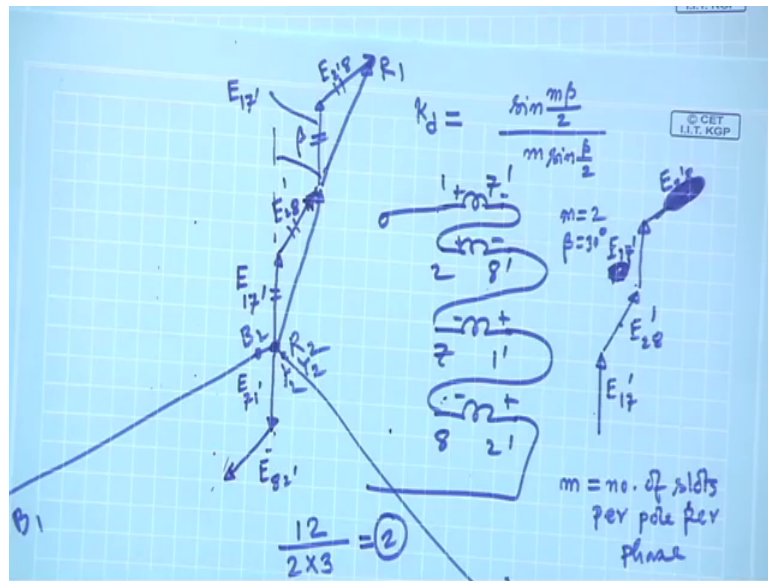
So, 9 and 3 dashed. So, 9 1 coil is here and then 10 4 dashed and then, you know 3 9 dashed. There is start of the 2nd group 3 and it is written is 9 dashed and finally, 3 10 dashed. 3 9 dashed is over 4 10 dashed. So, 4 and 10 dashed.

And you see everything is fine now. The winding is complete. Therefore, you see as I was telling you, so the this blue colour is actually green colour is B phase and blue colour I have taken day blue colour is your this is green colour is B phase and blue colour is your Y phase and red colour is red, this is red phase.

So, you see up, if you considered 180 degree, see this is the R phase conductors. 2 slots is allotted 2 slots are allotted to Y phase conductors these 2. And 2 slots are allotted to B phase conductors. So, each 180 degree you shared equally by R phase, Y phase and blue phase, but it is very tempting if that with the case I will first draw RYB, no, not like that. It comes actually B negative, but whatever it is 180 degree shared by all the 3 phases equally and that is why this type of winding is called 60 degree phase spread winding.

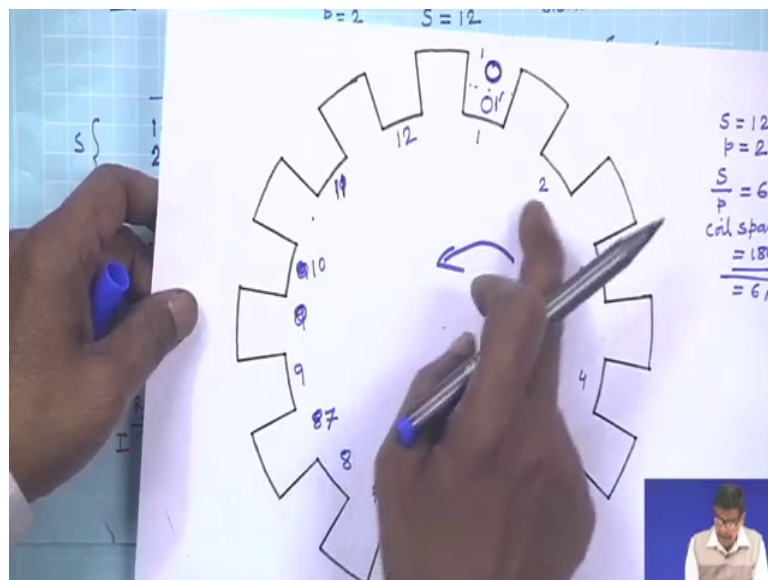
So, this is the 60 degree phase spread winding; [FL] in terms of I told you to complete this in it sense this for this winding. Suppose in terms of phasor diagram, how it will look like and how to calculate distribution factor because calls are distributed. Now, let us see suppose I say this point you listen carefully. This is the winding table.

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Suppose I say this is the voltage Phasor E17 dashed this coil voltage. It is there 2 8 dashed voltage. Suppose it is lagging this by what angle? Angle beta 30 degree. Therefore, it will be like this.

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If you assume the rotor is rotating in this direction. South pole so whatever is happening to coil 1 after beta degree, one slot pitch angle something is going to happen to phase 2 coil. Therefore, this will be E 28 dashed this phasor.

And this length and what is this angle? This is this beta 30 degree in this case, this is over. Now, I want to do E 71 dashed. So, this is 17 dashed and B E 71 dashed will be where E 71 dashed. Mind you it will be 180 degree out of phase because this is also start of the coil 1. So, whatever is happening to coil side 1 now, after 180 degree same thing is going to happen to conductors placed in slot number 7

Therefore, it will lag this coil side voltage or the coil voltage itself by 180 degree. So, your these voltages will be if I draw it, I should draw of equal length. This is E 71 dashed. Similarly E 82 dashed will be lagging it by 180 degree. This way lagging this way E 82 dashed. This way it is lagging. Now if somebody by mistake he just added without bothering this plus minus plus minus, then this instead of taking it here negative if he goes on adding like this what will be the net voltage?

It will be 0 in that case that is if this four voltages are added, you can easily see like this. I think you have got me that is 17 dashed 28 dashed and then, another coil 71 dashed and another coil is 82 dashed. If you just blindly connect like this and claim that these two or R phase terminals, then you are gone.

Gone means these are plus minus, these are plus minus and this is minus plus, this is minus plus. What will be the voltage between these two points? 0 and this your phasor diagram also tells, some of these two voltages will be this phasor and some of these voltages will be this phasor there will be phase opposition and 0. That is why while connecting the group of coils in a machine, one should be careful that is groups of coil you connect. So, what is to be done to get total voltage? So, this is suppose E17 dashed, then E28 dashed that is fine.

Then, what you do is, this you take the negative of E 17 dashed. That is what exactly we have done, we have reversed the connection. So, then this voltage is E 71 dashed and then, take E 82 dashed. This, this then this and it was E82 dashed so, you should take E2 dash 8. So, this must be marked as E2 dashed 8. Correct now? So, this we and these two these group voltages. Now, will be I am sorry it should be like this you know, E 71 dashed is correctly drawn.

Student: Minus 7.

1 dash 7 is it, I have opposite it 17 dashed and then, E 28 dashed and then, these two voltages E 28 dashed it will be this and this. So, what I am trying to tell you, here only this then add the negative of this and negative of this, that is this and negative of this. This is what? This was E 71 dashed so, it must be called E17 dashed. This voltage was what? E 82 dashed so, it must be called E2 dashed 8 and then, these group voltages will be in phase, because lengths of each one is same.

So, this will be the voltage between R 1 and this is your R 2. Understood? I mean at this part I have reversed it, then add it to the previous group voltages. So, this will complete R phase. Similarly for the Y phase those group voltages you add, but ultimately Y 1 Y 2 will be like this Y. You may not have connected R 2 Y 2. It will be like this and B phase will be Y 1 Y 2 will be here and B phase will be B 1 B 2. Therefore, in phasor diagram also you see that reversal is necessary. You cannot blindly go on adding this in series get the R phase voltage.

So, this is how, now what I am trying to calculate. Suppose I want to calculate the distribution factor of this winding distribution factor you remember it is  $\frac{\sin m \beta}{m \sin \beta}$  by 2 divided by  $m \sin \beta$  by 2 is not. Question is what should be the value of m I should take? Value of m you go to a group it is 2, m is 2 beta is of course 30 degree electrical that is all.

Of course you can take m equal to 4, then 2 that 2 cancels out. So, to calculate the distribution factor that m should be number of slots per pole per phase, in this case this was 12 slots, number of pole was 2, number of slots 3. So, 2 comma to calculate distribution factor. What is the pitch factor? Pitch factor is 1 in this case because I have not shortcut at the coil. So,  $K_p$  is 1, ok. Let us take some another example, so that we can practice it much more, we can handle this situation much more efficiently [FL].

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In the meantime you this one also, this is actually the rotor of a coil. You can see this is how it will look like. These are the slots and these are the teeth where I am placing double layer coils just to tell you what is going on in a machine. This is the thing and we are looking from one end and showing the slot like this, conductors all along the length of the machine which is perpendicular to this plane, [FL]. Now, let us take another example. Suppose I say that I have total number of slots 24.

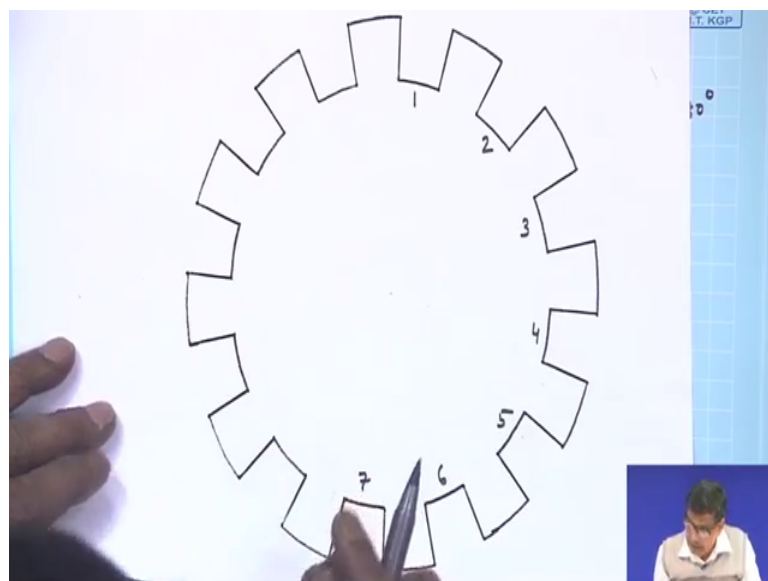
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And p number of poles of the machine is 4, 4 pole machine I want to do and I want to do double layer winding. P is equal to 4 double layer and I will allot under each pole equal number of slots to each phases. Therefore, number of first thing s by p number of slots per pole is equal to 6. Therefore, this is also equal to coil span in terms of slot numbers, coil span is it clear and that is equivalent to 180 degree electrical.

Therefore, in this case also beta is equal to 30 degree to be noted down, ok. So, this is the slots per pole and that is coil span [FL]. What is the total number of coils? Total number of coils it is a double layer winding. So, it must be 24. Therefore, I would expect when the winding is complete, each phase will have 24 by 3 is equal to 8 coils. Total of 8 coils must be there [FL].

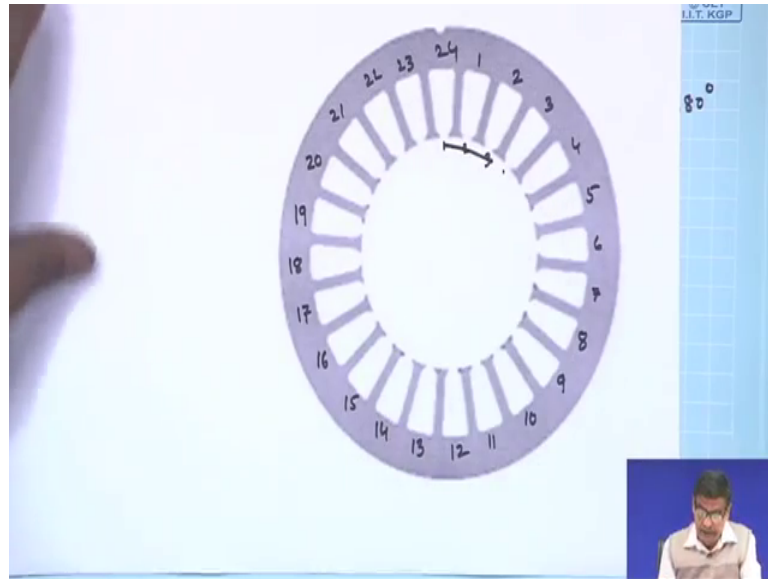
Now, I will start the winding. Now, this time first what I will do that is very simple. That is why I am telling I will not first show this sections etcetera, but I know now it is 1 2 3 4 up to 24 for example it is like this.

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Suppose you say this is 1 2 3 4 5 6 7; it is 24? 24 is not there? So, if bigger one, so bigger one is only 23rd [FL]. I will anyway it is there thank you this I will show.

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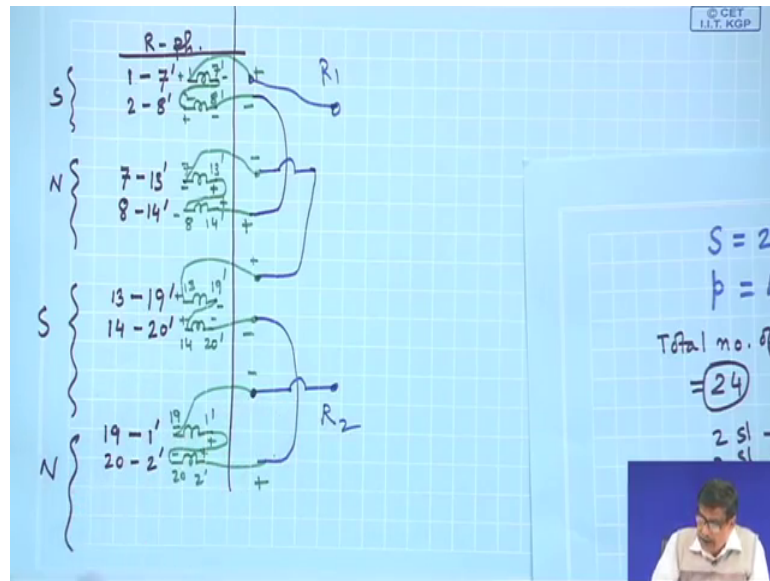


See these are 24 slots. So, this is 1, this is 2, this is 3 or I will write here 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 slots are there. Now, in this I will use double layer winding. This is the thing and this I will show later. First I will not draw this, but this is the thing I am getting [FL]. So, and I will distribute the coils. So, number of slots available per pole is 6.

Therefore, 2 slots I will allow to R phase, 2 slots I will allow to Y phase, 2 slots I will allow to B phase, like that the previous way only [FL], then what I am going to do look here carefully.



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This is for R phase. I am doing same thing. Let me start from start number 1, 1 first coil of R phase I am going to where should be it written full pitched coil. I will be using full pitched coil that is coil span is also 6.

So, 1 plus 6, 7 dashed is your first coil and 2 slots I will allow under each pole. So, next one will be 2 8 dashed is not. So, 2 slots are over for R phase under a pole. Suppose this is under a north pole, south pole say whatever it is. Now the big question is I will first complete the r phase. Very simple. Now, the question is where from under north pole the R phase second group will start, where from? It will start if this is another north pole beginning. So, a south pole beginning it must start after at the north pole beginning whatever it is and that separation is 6.

So, it will be 7 13, 7 so, slots per pole is 6. So, 7 it will be a. So, here I have not made any mistake 1 7 dashed. So, next one it will start from 7 and then, coil span is 6. So, 7 13 dashed and then, 8 14 dashed, then once again south and once again it will start from 13. The separation and 13 plus 6 19 dashed and then, it is 14 and 20 dashed. See without referring to this circular diagram and numbering I can carry out this straight away, provided you know what you are really doing.

So, total number of slots was 24, total number of coils is also 24. It is double layer. So, each phase will have 8 coils and then, angle beta I have calculated electrical angle number of slots per pole is 6. So, 180 by 6 is 30 degree. These are immediately I can

calculate. I will keep it like this 6 and then, full pitched coil I am using so, if you are starting at 1, it is written must be at 7 dashed, ok.

If you are starting at 5, it is written must be at 11 dashed. It means that, so how many coils? 1 2 3 4 5 6, there is another north it is per pole machine. So, then once again it will be 19 and then, 25 dashed, but that is no 25 dashed. Total number of slot is 24. Sorry total number of slots is 24. So, it must be 1 dashed 25 minus 24, then 20 and 2 dashed and if I draw the coils and name it 1 7 dashed.

Very interesting I mean 2 8 dashed and this is 7 13 dashed and this is 8 14 dashed. These are 13 19 dashed. Any inconsistent number you can point it out to me if I have done any mistake. 24 20 dashed and then, you have 19 1 dashed and this is 20 2 dashed. So, all the 8 coils has been drawn and these two I will connect in series, get one group, another group, another group, another group.

So, if you decide that you will distribute the slots such that under one pole it is equally divided among the phases that is each phase will occupy 60 degree, then you know number of groups of coils that will be available will be equal to the number of poles. So, let us assume also that suppose this is plus, this is minus. So, this will be plus, this will be minus, but if you say that this conductor 1 under south pole influence of south pole has a plus of 2 start up start terminal, then this side this is also start of another group of R phase coil, but it is under north pole. So, it must have terminals like this.

So, under south pole whoever is it will be like this and under north pole it will be like this and then, you connect this in series and get these two terminals, connect them in series and get these two terminals. These are group, 4 groups are there for R phase only and similarly these two in series you get two terminals here. These two in series you connect. So, if you see the polarity of the group, this is plus this is minus, this will be this is minus, this is minus plus minus plus minus plus and once again this is plus, this is minus and last one is this is minus, this is plus.

Each group will have same another voltages to have two terminals of R phase. All these coils should be connected in series. Let me at this stage tell you it is not necessary you connect always in series. It maybe I can make R phase, I tell that all groups you connecting parallel that can also be done we will see that, but with series connection. So, what will be the connection done? So, plus minus, then once again I will do plus minus,

so that voltages are additive and once again I will do plus minus and plus minus and once again I will do plus minus. And these are the two terminals of the R phase R 1 and R 2 side understood. So, coil spans will be like that.

Now, therefore I have no matter what is the number of poles, these calculations are vital and proceed in this way and in my next lecture I will translate this. So, this is nothing, but number games that is all provided. You have understood what is what that is what is coil span, how to place them, how to make a coil, then I will translate this diagram in into this for R phase that list and show you indeed 4 poles will be produced, ok.

Thank you.