**Electrical Machines – I**
**Prof. Tapas Kumar Bhattacharya**
**Department of Electrical Engineering**
**Indian Institute of Technology, Kharagpur**

**Lecture - 94**
**Wave Winding (Contd.)**

So, we have been discussing with Wave Winding of the armature of a DC machine, ok.

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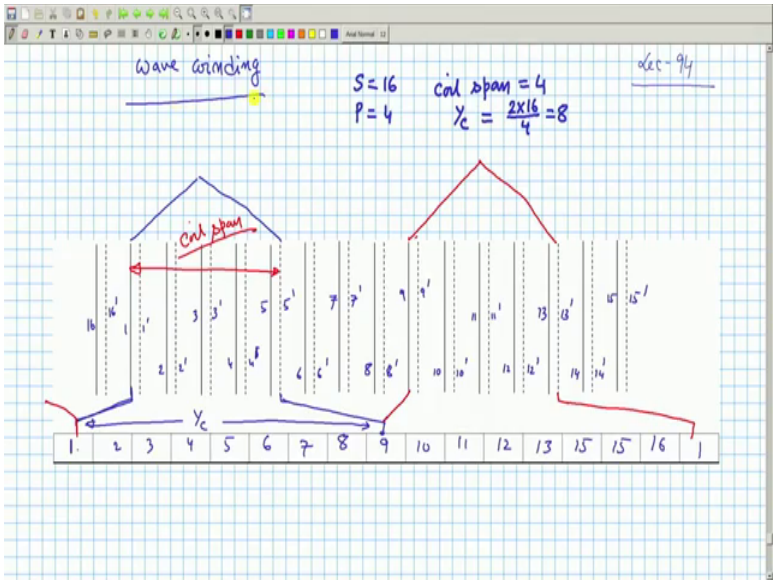


So, in my last lecture what I was trying to tell? There are two things coil span and each coil has got two terminals, they are to be terminated on definite commutator segments. In case of lap winding termination of the; of a particular coil ends are in the consecutive commutator segments. Now, suppose I plan with S equal to 16 and P equal to 4; coil span is 4 and I say that commutator pitch which gives me the difference of the commutator segment numbers where the coil ends are connected. Suppose I choose it is equal to 2 pole pitch apart 16 by 4 is number of commutator segments per pole is 16 by 4 into 2; that is 8.

So, you start with 1; 1 its return is 5 dashed, coil span is 4. So, 5 dashed, but then 5 dashed I am not terminating on 2, where I am terminating is that is 1 plus 8; next termination that is at 9. You come at 9, then the next coil is to be connected in series all the coils have to be connected in series; be it lap or be it web it does not. So, next coil I will start from 9, it goes to 9 slot number, returns from 9 plus 4 13 dashed and this end of

this coil one is terminated on 9 and the second one will be terminated on 9 plus 8; 17, but there is no 17, what is there? 1, once again.

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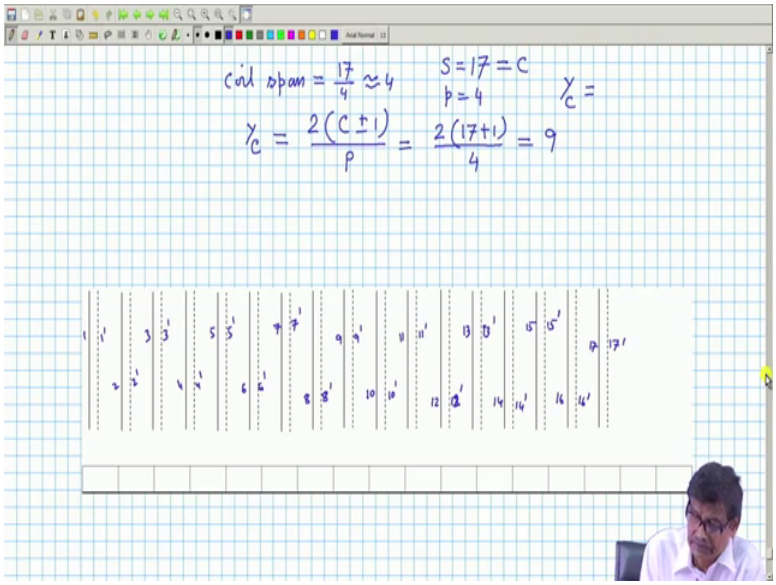


So, so it is terminated on 1, this 1 is same as previous to 1 here. So, after tracing only two coils winding cannot progress. So, if you want to have another alternative winding other than lap with this sort of idea; then you see you have to make some compromise somewhere. The compromise which is made is this one that is what we will do; what we will do is this we will make S equal to I will make that is the coil span I will not insist on let it be perfectly one pole pitch apart. Let it be a little bit this way that way we lost some little bit of voltage that can always be compensated by increasing the field current etcetera.

So, the idea is the commutator pitch Y C what you do you. So, slot number even multiple of number of poles will not do after tracing only two coils everything goes I mean no further progress. So, suppose I say S equal to 17, total number of slots is 17 and P is equal to 4. So, coil span is equal to 17 by 4 is not an integer; so I take it be 4.

So, I am not using to be very correct I am not using a full pitch coil one slot less got the point? So, this is how I choose the coil span and winding pitch a commutator pitch I will do it like this 2 C plus minus 1 by P. So, that it becomes equal to 2 number of commutator segment is C 17. So, 17 say plus 1 I choose by P is 4. So, that it becomes equal to 9; got the point? Therefore, commutator pitch I will it is also approximately

equal to 2 pole pitch apart plus minus 1. So, 17 plus 1 you take suppose that is 18 by 4 that is 9.

Student: (Refer Time: 05:49).

Hm?

Student: 17 minus 1 (Refer Time: 05:53).

Let us see ok; I have suppose just chosen whether things materialize or not we will see. So, I will; so there are now 17 slots if you count it and I will number them as 1 1 dashed, 2 let me do it slowly, 3, 3 dashed; 4, 4 dashed; 5, 5 dashed; 6, 7, 7 dashed; 8, 8 dashed, 9, 9 dashed; 10, 10 dashed; 11, 11 dashed; 12 like that I numbered them 13 dashed, 14, 14 dashed; 15, 15 dashed; 16, 16 dashed and this is 17, 17 dashed. What is there after this? 1 1 dashed once again like this, this numbering goes, ok.

Now, suppose I say that since I have already put the numbers; I should have better do it so that no confusion I will re number them please bear with me, it is like this. So, that it looks like a wave that feelings must be there.

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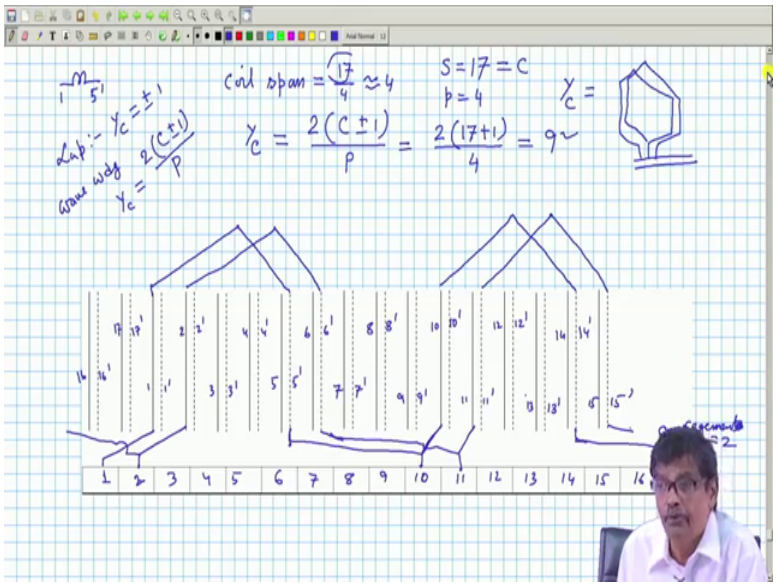


So suppose you erase this numbers and say that this is suppose 1 dashed got the point? 2 2 dashed this numbering is arbitrary you start from here to 3 3 dashed, 4 4 dashed, 5 I will do quickly, 6 6 dashed, 7 7 dashed, 8 8 dashed, 9 9 dashed, 10 10 dashed, 11 11

dashed, 12 12 dashed, 13 13 dashed, 14 14 dashed, 15 15 dashed and this is 16 16 dashed and this is 17 17 dashed. This is the scenario and let the commutator segment be numbered as this is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 like that its numbered.

Coil span I cannot make full fixed coil; 17 slots 17 by 4 approximately 4. So, first coil if I start it is I will start with coil side 1 and I will start from commutator segment 1; this is the first coil where will be it returned? 1 plus 4; 5; so 5 dashed. So, it will come here please follow me carefully, it is 5 dashed.

Student: (Refer Time: 10:07).

Oh sorry this is a 1 1 dashed; thank you. So, this will be 1, it will goes like this then comes back to 5 dashed. So, it comes here and this is the other end. This other end I will now not do 2 C by P alone which will not be integer. So, for that I added plus minus 1 and suppose I have taken plus 1; so 17 plus 1 by 4 into 2. So, 18 by 2 it is 9. So, this is commutator pitch where the other coil ends will be terminated.

It will be then terminated at where? 1 plus 9 that is in commutator segment 10, is not? So, I will take it here and I will terminate it there this is how the first coil is there in the slots physically. Then what I will do? Next coil this commutator segment will give you the number here. So, I will then connect this to 10, coil number 10 and 10 plus 4 that is 14 dashed. So, it will come to 14 dashed and then the other end where it should be connected? 10 plus 9.

Student: (Refer Time: 11:55).

Then it will come to 2 is not? So, this ends goes here and comes here I have not used a different colour for the second coil, let it be like this. So, it will come now like this, it will be finished here; got the point? So, trace the two coils and it will go to commutator segment 2 that is what here it is, 2. Then which coil I will start? Coil 2 1 1; 10 10 I started.

So, start of the next coil will be now this is 2. So, it will I will start with this 2; 2 plus 4, 6 dashed. So, I will go there and come to 6 dashed this is the end of this coil where it should be terminated 2 plus 9; 2 plus 9 is 11. So, it will come to 11 and then you start

from 11; 11 plus 4, 15 dashed is not? 15 dashed and where this fellow should go? This 11 plus 9 that is 20; 20 means 3, it will come here.

So, winding never stops it now progresses that you started with 1, then the next coil then another next coil and so on. I hope you have understood, so to make a wave winding this number; the total number of slots should not be an even multiple I mean an multiple of the number of poles, you cannot then progress. After only tracing number of coils which is after two coils for example, for 4 pole everything will be over.

So, you have to connect several coils in series, all the coils in series for that matter. So, you have to sacrifice the coil span. So, I have sacrificed it is not a full pitch coil; I am now sure 17 by 4 approximately 4 close to a that is what I believes. Similarly the commutators pitch Y C I will; so that it gives you an integer value I will multiply with 2 by P; approximately two pole pitch apart and C plus minus 1 2; it is 9, you can take also the minus sign, ok.

So, it was giving you a progressive winding that is time it will give you a progressive winding, you can easily verify that; got the point? Therefore, in the wave winding; so far as the coil span is concerned it is close to full pitch coil and it is a commutator pitch which makes the difference with lap winding. In case of lap winding lap winding Y C is always equal to plus minus 1; simplex lap winding.

In case of wave winding; wave winding wave winding Y C should be equal to 2 C plus minus 1 by P where C is equal to the number of slots which should not be an multiple of the number of poles of the machine and then you can proceed to calculate the; proceed to complete the winding diagram.

So, in in terms of winding table what I am telling with this parameters; I will do now like this.

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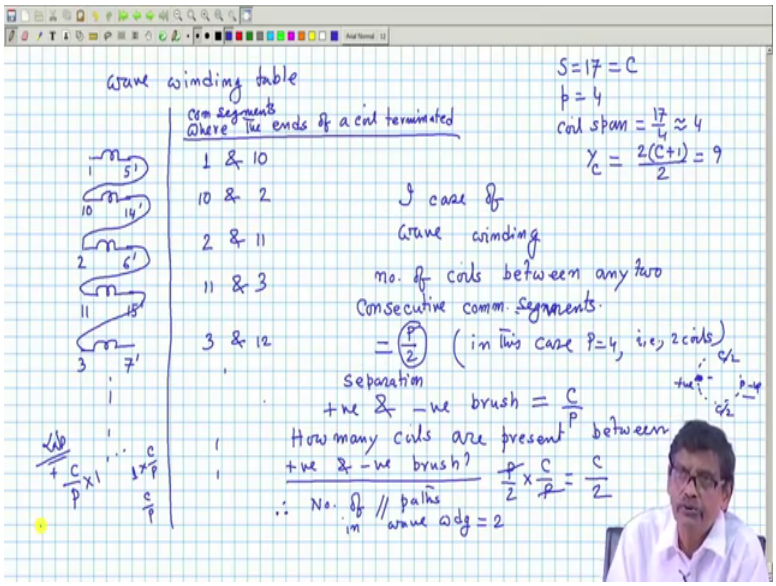


Let me come to this winding table wave winding table. For what I am doing the table? S equal to 17 which is equal to C, p is equal to 4, coil span is 17 by 4; I have to get an integer otherwise I cannot do anything approx chosen 4 and winding commutator pitch is 2 C I have taken plus for the earlier plus 1 by 2 I have taken which has come out to be 9.

So, how do I do the winding table? I will do like this. First coil where from I started? I started from commutator segment 1; 1 what will be where it will return? 1 plus 4, 1 plus 4 that is 5 dashed this is the first coil, ok. If this is the first coil then I will ask commutator segments where the ends of a coil are terminated where the ends of a coil terminated where the ends? So, I started from commutator segment 1 only. So, 1 and 1 end its end should be terminated 1 plus 9; commutator segment 10 got the point? That is what we got.

Student: (Refer Time: 19:21).

Still I am showing 1 5 dashed, these are the coil span and 5 dashed is terminated in commutator segment 10, then I start coil number 10. So, and these are to be in series. So, next coil is 10; it should start from commutators this will dictate where from this coil side will come and 10 plus 4; so 14 dashed. So, the commutator segments to which these are terminated this is of course, 10 and 10 plus Y C is equal to 9; 10 plus 9 is 19; 19 which means 2 because 17 at the slot; so this is nothing but 2.

Then the next coil is I will start from 2 and 2 plus 4 that is 6 dashed and 2 is 2 and 2 plus 9 is 11; 11 is a valid number, so 11. Then I will take the next coil as 11; 11 plus 4 15 dashed no problem and 11 is 11 and it will be 11 plus 9; that is 20 that is 3 and so on, then I will start from 3 7 dashed.

So, you can find a pattern of the numbers; I do not have to refer back to that diagram after few steps I know what is the weight of this. So, 3 and 3 is 3 here and 7 dashed 3 plus 9 that is 12 dashed; 12 and of course, I will connect all of them in series like this dot dot dot dot; I am not completing this you please complete, ok.

So, conclusion is in case of lap wave winding; in case of wave winding number of coils between this is very important statement between any two consecutive commutator segment will be always equal to P by 2, where P is the number of poles. In this case P was 4, you can easily see this diagram refer to this diagram. Between commutator segment 1 and 2; how many coils are there? Trace one coil and then the next coil in series and it goes to commutator segment 2.

So, between 1 and 2; two coils are there, had it been a 6 pole machine you would have would have got 3 coils and in case of lap winding between any two commutator segments how many coils are present? Only one, got the idea? So, this is the thing important thing which will; so, number of coils between any two consecutive commutator segment will be always P by 2. In this case P equal to 4 that is why that is two coils will be present [FL], all said and done. So, this way I can complete the winding and I will close the winding.

Then I will decides about the plus minus voltages, the same way as I have done in case of lap winding and will perhaps put the brushes. But one thing is certain the separation between a positive and negative brush; separation, separation between positive and negative brush will be C by P; what else. Because if we have identified that plus brush should be where the negative brush must be C by P separation after is not plus voltage polarity and negative voltage polarity it depends upon C by P nothing else that is also true in case of lap winding, ok.

So, separation between positive and negative brush in terms of number of commutator segment should be pi that is C by P. Now, if that be the case then I ask how many coils are present between positive and negative brush? How many? Between two consecutive

commutator segment it is P by 2. So, between C by P commutator segments how many coils? It will be P by 2, this into C by P; it has to be is equal to C by 2; no matter what is the number of poles.

If you have identified the positive and negative brush, separation between them has to be C by P in any case no matter whether it is lap, wave whatever way you think. In case of lap winding between positive and negative brushes; how many coils were present? C by P coils were present, C by P into 1 in case of lap is not; one positive and negative brush C by P coils will be there, but in this case it is C by 2 coils.

Therefore, this C by 2 coils where are the other C by 2 coils that is from the other side if you look. Therefore, armature is divided into only two parallel paths; no matter what is the number of poles of the machine that is what is important. Therefore, number of parallel paths in wave winding will be always 2 because C by that is these are the two brushes; from this end if you see between two commutator segments P by 2 coils like that if you proceed; you get C by 2 coils here. If you have proceeded in this direction, you would have got same C by 2 coils here and these are the positive and negative brush, is not?

Between two commutator segments if you proceed in one direction you will get C by 2 coils. If you have proceeded in the other direction same C by 2 coils that is fine total number of coils is C; same as the number of slots it is a double layer winding number of slots equal to number of coils. Therefore, armature will be always divided into two parallel paths, no matter what is the number of poles of the machine.

But in case of lap winding; it is not to be like that because number of coils present between two consecutive commutator segments is 1, lap winding. How many coils are present between two commutator segment? It is 1, separation between the brushes is C by P. So, how many coils will be present between a pair of brushes? C by P coils will be present.

Then this plus and negative brush in case of lap winding armature will be un even with respect to this pair of brush. On one side there will be C by P coils and on the other side there will be C minus C by P coils; that is why another pair of positive negative brushes will be required if it is a pole machine, to make it symmetric about the positive and negative brushes.

But in case of wave winding only two brushes minimum will do; it will be evenly divided always. Hopefully you have understood it with some you please complete this winding table and try to understand that a simplex wave winding and simplex lap winding we have discussed and why this winding is called wave, we have we can easily understand because it progresses like a wave. And in case of lap why it is lap because the first coil will be like this, second coil will be on the lap of the first coil and so on.

Therefore, in case of lap winding; the number of parallel paths happens to be equal to number of poles of the machine that we have earlier discussed at length. In case of wave winding number of parallel paths is always equal to 2, that is why lap windings are adopted for large voltage, for small voltage large current machine; outside current may be made larger so that it will be divided into several parallel paths within the armature. Wave winding is generally adopted for high voltage and low current machine.

Anyway I conclude this lecture today, I will take only one concluding lectures or perhaps in the discussion of the course; I will conclude everything, but please go through this notes carefully whatever has been uploaded and try to understand the essential things which I have told. And of course, we will have some open session where I can discuss the points you will be raising. And hopefully you have enjoyed the course I wish you all the very best and do the tutorials properly.

Thank you.