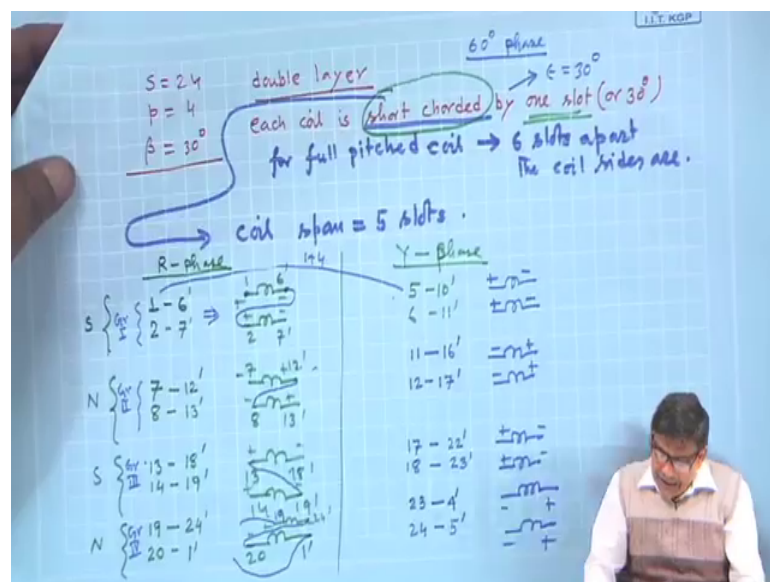


Electrical Machines - II
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Lecture -28
120 ° Phase Spread Winding With Examples

Welcome to 28 lecture. We were discussing about the double layer 3 phase balanced winding; how it is wound. It is necessary to know these basics then only we will be moving rather at a increased space through the course; if these basics are clear. And it is also very interesting to know how the windings are laid in 3 phase machines AC machines.

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So, last time the problem I was discussing was I want to make a double layer winding, but this time each coil will be short corded by say one slot this angle is given. And this specification is total number of slots 24 number of poles 4 and the electrical angle between the 2 consecutive slot is beta is equal to 30 degree. And if it is a full pitched coil then; obviously, 6 slots will be the coil span or 180 degree electrical, but I have been told to make a winding which is short pitched by one slot that is by 30 degree which is; that means, epsilon is 30 degree and a coil span is 5 slots.

Now for the R phase I completed this. So, what is the thing? Once again 60 degree phase spread winding I am want to do 60 degree phase plane. What does that mean? That 180

degree of space will be equally shared by R phase Y phase and B phase coil sides. Therefore, if it is 60 degree then each under 180 degree span 2; 2 slots will be shared by R 2 will be shared by Y 2 will be shared by B.

So, I start with the R. So, first 2 slots 1 to 6 dashed and then 2 to 7 dashed and this is supposed under South Pole and corresponding representation in terms of coil it makes sense to represent it like this. Because between 1 and 6 dash I mean that there is a coil with true terminal 1 and 6 dashed so 2 7 dashed. Then for R phase the next group of coil this is one group mind you group I of R phase.

Similarly, this will be group II, but what will be the next 2 consecutive slots allotted to R phase? It will be 180 degree after that because after all South Pole will finish after 180 degree so it will be then 1 plus 6 7 and 8 should be allotted. Then 7 and 12 dashed 12 dashed is its return it will be like this so on. And this is group III and this is group IV group IV and this is how we got. And polarity of the voltages we know if we assign start of a coil to be positive under South Pole then 1, 2 will be under South Pole plus plus minus like that, but this time the start of the same R phase second group coil will be 7 minus plus for obvious reason.

Because direction of rotation is same only polarity of the poles has reversed; so like that we have decided this. Then we will of course, connect them in series to get the group terminals group terminals are available. Now for Y phase short coding a coil by one slot does not change all the things other things remain same that is Y phase should start after 120 degree apart. So, that slot number is 4 so start of Y phase must be this to this 5 how do I get 1 plus 4 so, because 4 slots corresponds to 120 degree electrical and so on.

Similarly 5 10 dashed 6 11 dashed and once you get this one this is group 1 of Y phase. Similarly group II of this thing will be this will be 11 5 plus 6 11 and 11 plus 5 16 dashed. Then 12 17 dashed and here it will be 13 plus 4 that is 17 and then plus 5; 22 dashed, 22 dashed and 18 23 dashed. So, all together for there are 24 coils so 8 coil should be there; so 1 2 3 another 2 will come.

And this will be 14 here 14 plus 4 18 is it no or 19 this is 19, 10 plus 4 23 is not it? And 23 to 5 that is 25 dashed means 1 dashed and then 24.

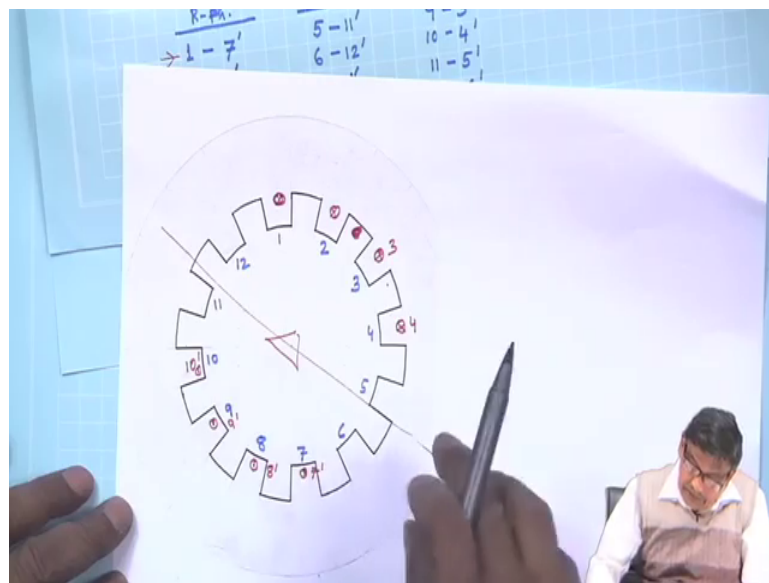
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23 plus 5 28; so 4 dashed 4 dashed and this will be 5 dashed is that clear? So, there are altogether; so this is group I, group II, group III, group IV but and the coil representation will be like this. I will not complete this because you have understood and you can do the rest of the things. So, then polarity of the assigned polarity should be assigned to the induced voltages like this. Under South Pole if it is plus this will be reversed, this will be plus minus plus minus and this is minus plus and minus plus. Then you have to connect all these things in series so that they will be all additive voltages just in the same fashion of this so I am not repeating that in this way.

You can see, you can still complete a balanced 3 phase winding voltage, but this time it is one slot coil span is reduced by one slot or 30 degree so we can do that ok. So, it can be extended to any number of poles I hope you will be able to do for 6 pole machine 36 slots; you and if even if it is short coded by a given number of slots, if it were short coded by 2 slots, then coil span would have been 4 here in this case. But you will soon see that everything is nice all these slots will be filled up nicely and windings can be completed, but by how many slots you should be short chorded? It is to be decided depending upon which harmonic voltage you want to reduce.

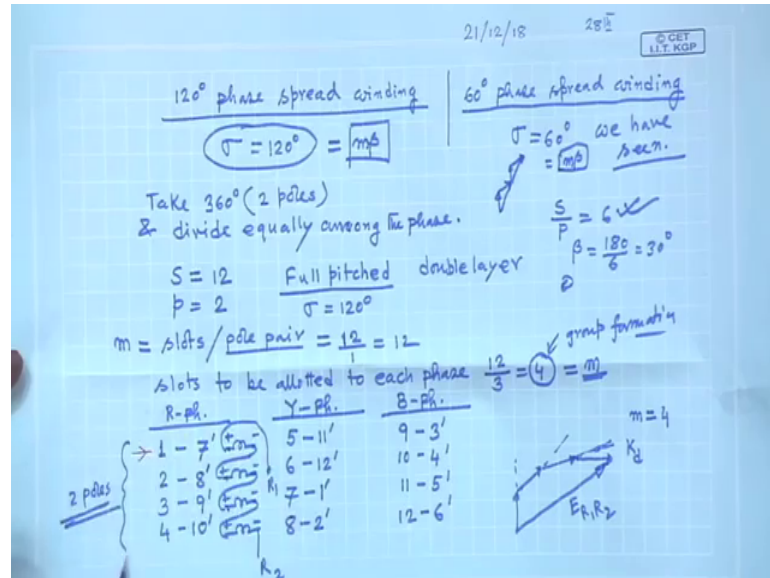
So, this is the thing I shall now and I am not doing translating this to this winding you will be in a better position to do that.

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Now, today I will just the last of these windings that I will tell is there is another winding that is called 120 degree phase spread winding.

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It is sometimes used 120 degree phase spread winding see the what is the other thing we have studied? 60 degree phase spread widening. Generally this phase spread angle is denoted by this letter sigma ok sigma equal to 120 degree here it was sigma equal to 60 degree. And this we have done we have seen this the 60 degree phase winding in fact, we have been doing all the time 60 degree phase winding.

What does it means? That 180 degree space or one pole this slot should be equally shared by R Y and B phase that is what we have done. Now the question is what is then is phase spread sigma 120 degree, it says that instead of 180 degree over which you equally divide R Y and B phase you take 360 degree electrical take 360 degree space that is about 2 poles take 360 degree and divide equally divide equally among the phases ok divide equally among the phases.

So, windings are distributed in this case winding is distributed 60 degree for a particular phase. In this case windings I will I mean spread over 120 degree for each of the phase. For example, let us take S equal to 12, p is equal to 2 and I ask you do a full pitched winding; full pitched winding because I know how to take a little short pitched. So, take full pitched winding, but the winding should be sigma equal to 120 degree that is the

thing and double layer it is always double layer. These are the inputs given to me and I have to make a winding table for this one.

So, there are 2 poles; so over 2 poles there are 12 slots; therefore under this 2 pole total number of slots should be equally divided ok. Therefore, what is that? So, slots and this gives you the value of m that $m \sin \beta$ by 2 by $m \sin \beta$ by 2 in the distribution factor while calculating. So, m it is slots per pole pair it is pole pair. So, in this case it will be 12 only; slots per pole pair is 12 by 1 that is 12 ok.

And then out of this 12 so slots and that is 360 degree. So, slots to be allotted to each phase will be this 12 divided by 3 4 and this will be the value of m per phase, so 12 slots are there over 12 poles per pole it will be this is the value of m . So, what will do is this very simple otherwise it is tuple structure so I can complete that winding table in this space.

So, suppose R phase and you start for R phase with slot number 1. And incidentally we have calculated slots per pole is 6 and β is equal to 180 by 6 30 degree separation between 2 consecutive slots is 30 degree. Therefore, coil span is also 6 so 1 7 dashed will be the first coil. Then 2 8 dashed, but then do not stop 4 earlier we were doing 60 degree phase spread so 3 9 dashed and 4 10 dashed.

How many total coils are there? 12. So, for each phase there will be 4 coils that is it. So, in that is the group is now 4 in one stroke nothing like here you give a gap, then put 3 in the under south pole not like that you go on placing this. Because you have been allotted 4 slots for immediate group connection this is for group connections group formation it will be clearer. So, this is R phase then what should be Y phase? Y phase should be then 1 plus 4 5 and 11 dashed.

And then continue 6 12 dashed, if any mistake point out that 6 12 dashed 7 13 dashed is 1 dashed. And 8 2 dashed and Y phase is over and then B phase 5 plus 4 after 120 degree the phase starts. So, 9 plus 6 15 dashed that means, 3 dashed 10 4 dashed 11 5 dashed and 12 6 dashed. So, this will be these windings.

And in this case is it just looking at it can you tell it is 12 slots no natural. So, what I am telling is in this case we do like this at least one I show so that you can understand. This is the thing and this is suppose this slots; so I name these slots 1, 2, 3, 4, 5, 6, 7, 8, 9, 10,

11, 12. So, what it is telling is to complete the R phase winding 1 7 dashed. So, R phase let us use red color only so 1 and 7 dashed. So, 7 dashed is there it is 2 pole machine that is why diametrically opposite. Then 2 8 dashed 2 8 dashed, 3 2 8 dashed I made a mistake oh sorry 3 3 9 dashed, is it not 3 9 dashed and 4 10 dashed.

So, this is 8 dashed and you see all the 4 coils for R phase has been done. As I told you I will not do for Y phase and B phase they will be exactly same, but this start will be for Y phase from slot number 5 with different color I can reproduce this. But the point to be noted is here I have distributed the coils in 4 consecutive slots not 2 then went to under south pole not like that. So, 2 poles are there under 2 poles all the coils has been distributed. And if they carry current; suppose these are carrying cross current through the 1 current I am allowing to enter therefore, these will be all cross cross cross cross others will be dot dot dot and dot.

And as expected 2 poles will be produced like this here lines of forces will be like this. So, that this side will become North Pole of this iron hop and hop South Pole. In the exactly same fashion, if I wish I can put other conductors for Y and B phase each one of them has to produce 2 poles and they will produce it. So, this is the thing then the question is I will this must be pointed out that in this case.

See this is one 2 poles here 2 poles ok. Therefore these coils if you take 4 coils are there for this and the induced voltages, if you sketch you say this voltage 1 7 dashed; 1 7 dashed I am not writing it should be reproduced here it will become too clumsy. So, plus minus, plus minus, plus minus, plus minus this way I have to write the voltage indicating that this potential 1 and potential 2 2 will lag this by angle beta, this will lag by beta, this will lag by beta.

So, the polarity of the voltage of this coil side with respect to that will be like this; therefore, while forming this is one group that is all. So, it will be all for 4 are to be connected in series like this. And these two will be your R phase terminal R 1 and R 2 similarly for Y phase and B phase it can be done. So, in 60 degree phase played winding per phase voltage will be like this. If this is the first coil voltage second voltage will be lagging it by beta, then this voltage will be lagging it by beta. And the fourth coil voltage will be lagging by same angle beta and this will be the resultant voltage say E R 1, R 2.

This information's values I am not writing it is understood E_{17} dashed, E_{28} dashed and so on. So, this will be the R phase voltage you now see in earlier case for 60 degree phase spread we had group voltages like this 2 groups for 2 groups it was like this and so on this is how. Therefore, here distribution is more distribution of the coils of a particular group is more and K_d to calculate K_d the value of m which should be taken is now 4 that is what I wrote.

This m you must not misunderstand mean in this way slots to be allotted to each phase; globally if you see total number of slots, whether it is 120 degree, whether it is 60 degree phase spread; it looks like one third of the total slots must belong to R phase, one third of Y phase must belong to Y phase like that it will be there. But that is not the issue; issue is that in immediate succession of a coil there will be 4 numbers instead of 2 which you used 60 degree.

Of course, 2 is not a unique number depending on the number of slots, number of poles that number itself may vary, but with respect to the examples we are considering this is how it should be looked at. And your distribution factor in this case will be less that is why 120 degree phase spread is not that popular. In other words, what I am telling is this σ if you look at it is nothing, but m into β . How many coils you have distributed in a group that number into β is the number of angles occupied by a particular phase.

This is also m β is not it has to be like this. Therefore, this is how this 120 degree phase spread winding can be wound.

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$K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \frac{\beta}{2}}$

120° phase spread winding
 $\sigma = 120^\circ = m\beta$

60° phase spread winding
 $\sigma = 60^\circ$ we have $m\beta$ secn.

Take 360° (2 poles) & divide equally among the phase.

$S = 12$ Full pitched double layer
 $p = 2$ $\sigma = 120^\circ$

$m = \frac{\text{slots}}{\text{pole pair}} = \frac{12}{2} = 6$

slots to be allotted to each phase $\frac{12}{3} = 4 = m$ (group formula)

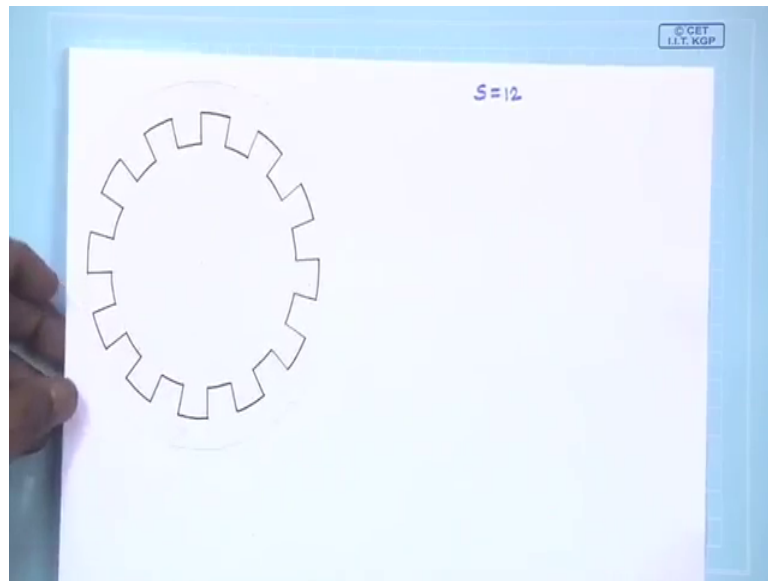
R-ph.	Y-ph.	B-ph.
1-7' $\left(\frac{1}{2} \right)$	5-11'	9-3'
2-8' $\left(\frac{2}{2} \right)$	6-12'	10-4'
3-9' $\left(\frac{3}{2} \right)$	7-1'	11-5'
4-10' $\left(\frac{4}{2} \right)$	8-2'	12-6'

$m = 4$

You will get a successful 3 phase balanced winding and you can do some examples, but the point I want to say that K_d is equal to $\frac{\sin m\beta/2}{m \sin \beta/2}$ divided by $m \sin \beta/2$. This m value is not that number of slots per pole per phase that is true if it is 60 degree phase spread winding that number will change if it is a 120 degree phase spread winding. You should be very careful while solving problems 120 degree phase spread winding m is not equal to number of slots per pole per phase, it is rather number of slots per phase per pole pair that is the difference.

Anyway, but this K_d value will be lower compared to a 60 degree phase spread winding because we were only spreading 2 coils so voltage loss is less here. Anyway this is 120 degree phase spread winding only thing to give a complete treatment to this I will try to see what happens if it is a 4 pole wide angle ok.

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Suppose the same 12 slots I say that S equal to 12; S equal to 12 or S equal to 24. So, S equal to 2 12 in 12 nothing to show we will continue next time this thing.