Course Name: Design of Electric Motors

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Title: Magnetic Fields in AC Machines-1

Greetings to all, in the last lecture we have discussed the magnetic fields in a DC machine and induction machine with single coil we have discussed. The summary of the last lecture, we can see here, the DC machine with one coil and two commutator rings, we have seen the rotating magnetic field, but it is not a symmetrical and it is rotating with respect to 180 degree span. Similarly, with two coils and four commutator segments and 90 degree is the commutator span and we have seen that here also rotating magnetic field is existed and it is not symmetrical, only 90 degree span of rotation we have observed. So, we have concluded that in a DC machines there is a rotating magnetic field, but it is not symmetrical. On the other hand, AC machine like induction machines and synchronous machines with single coil and AC supply is given at the stator side and we have concluded that there is no rotating magnetic field, the vector it is increasing and decreasing with respect to one particular direction that is what we can observe here. This is the one with respect to one particular coil.

In order to get the continuous torque and rotating magnetic fields or variable fields, we require the multiple conductors. So, we will consider the next example with two conductors or two coils. I can say, let us consider two coils in an induction machine or synchronous machine stator side. The conductors are not moving, the conductors are stationary.

The first coil is AA dash and second coil is BB dash. These two coils are mechanically displaced by 90 degrees. AA dash and BB dash, these two coils are displaced by 90 degrees mechanically. Why 90 degrees displacement is required and what happen if 90 degree displacement is not there? We will see in the coming lectures. Here I am considered as an example, 90 degree displacement between A and B coils and the current excitation to these coils is same.

I am considering the sinusoidal excitation pi 2 pi here 3 pi by 2 and this is pi by 2, this is I, here I equals to Im sin omega t, this is omega t. So, we are exciting these two coils with this kind of current. Both coils are excited with same current and rotor side, we can consider either two poles or multiple poles. As of now, we are discussing with respect to the magnetic fields at the stator side. So, no need to consider the rotor side magnetic fields at present.

Stator side magnetic fields we will analyze now. So, first we will see the individual coils, what kind of magnetic fields are there with respect to the coil A A dash. Consider a positive current for a reference. This is the reference vector with respect to the each and every coil. So, with respect to the A and A dash coil and positive current I am assuming.

So, with respect to the A, there is a cross and with respect to the A dash, there is a dot and the magnetic fields by applying a thumb rule, we can find the loops in this manner. So, with respect to the cross, apply a thumb rule, the flux loop direction will be clockwise direction and with respect to the dot, it is in anticlockwise direction. The resultant flux vector is in this direction that is phi A. Similarly, with respect to the coil B B dash, we will analyze. So, this is B coil B and B dash.

Here the current again I am considering positive only for a reference. B will be cross and B dash is dot, current is coming out. The flux loops with respect to the B that is cross and with respect to the dot, we will see the flux loops. So, with respect to the cross, it is clockwise direction, the flux loop direction, magnetic fields direction and for dot, it is anticlockwise that is in this direction. So, the reference with respect to the B B dash coil is reference flux vector is in this direction.

So, we will see the resultant flux direction with respect to the both coils at different instant from 0 to 2 pi. How the flux vector is varying, we will see. This is the current waveform at omega t equals to 0 degrees. The current is equals to 0 that is for both A A dash and B B dash coil, current is equals to 0 that means, flux equals to 0. There is no flux vector at this particular point and then next instant omega t equals to 45 degrees or pi by 4, if we will consider how the magnetic field vector will analyze.

So, current to the A A dash and B B dash both coils are excited with same current like this is A coil and this is B coil A A dash and B B dash both are excited with same current. These two are mechanically displaced, but electrically in phase. So, current is positive and it has some value at 45 degrees, the instant is this one. This is at pi by 4. So, we will see the conductor placements A A dash B B dash.

So, current is positive. So, at A cross and A dash dot at B cross and B dash is dot. Apply a thumb rule and draw the flux loops. So, with respect to the dot it is anticlockwise and next cross also we can see the loops. So, now with respect to the cross we can draw clockwise with respect to the dot anticlockwise.

Now, these two flux loops with respect to the dot terminals that is this one and this one these two flux loops are in additive manner or in this region the flux will be a cancelling or I can say the both loops are in additive manner. So, the resultant flux loop will form in this manner and the direction is in this way and with respect to these upper two loops the flux direction will be in this manner and the loop will form like this way. So, the resultant vector is in this direction phi r. So, from the resultant or individual flux vectors also we can analyze the individual flux vector with respect to the B is in this direction and individual vector with respect to the coil A A dash is in this direction. So, the resultant if we will draw then this is the phi r addition of phi A and phi B this is phi A.

So, here resultant vector phi r equals to phi A plus phi B these two are the vectors. So, if you want to find the magnitude here phi A equals to phi m sin omega t and phi B equals to phi m sin omega t because both coils are excited with same current. So, in order to find the magnitude apply the vector analysis and phi r equals to square root of phi m sin 45 square plus phi m sin 45 square. I am finding the magnitude because already angle we know where it is lying. Now, this final answer will be phi m by root 2 square plus phi m by root 2 square.

If we will solve this equation the answer is phi m this is the magnitude at this particular instant at omega equals to 45 degrees that is this location. At this particular location we are seeing the resultant flux vector magnitude is phi m and displaced with respect to the phi A 45 degree leading and with respect to the phi B it is 45 degrees lagging we can say this is 45 degrees. Now, we will see that an instant omega t equals to 90 degrees at omega t equals to 90 degrees the current to the coils A A dash and B B dash positive and maximum. So, sin is maximum at 90 degrees. So, current is maximum here and flux also maximum phi A and phi B both are equals to phi m.

The resultant flux loop analysis will be same as this one only the magnitude will change that we will that we will see now this is coil A A dash this is B B dash current is same right positive only. So, at dash we are seeing the negative current draw the flux loops. So, in order to find the direction apply a thumb rule for dot it is anticlockwise direction in this manner for cross it is clockwise. So, these two flux loops this one and this one are additive manner and we can find the resultant flux loop will be in this manner and with respect to the cross loops these two flux loops are also in additive manner and the resultant flux here phi r. Here the magnitude is changing with respect to the current magnitude, but the resultant flux direction is not changing direction is not changing with respect to 45 degrees and 90 degrees because the current is in the same direction right.

So, from these two instance we can conclude that 0 to 180 degrees current is positive that means, flux resultant flux vector is in the same direction only magnitude will change. So, from 0 to 90 what it is happening initially the flux vector magnitude is 0 and after that it is increasing with respect to the resultant vector direction and at 90 degrees it will reach to the maximum. So, it is increasing from 0 to 90 degrees the flux vector magnitude, but the direction or angle is 45 degrees with respect to the phi a. So, here the phi a reference is here right. So, from that point it is leading by 45 degrees and from 90 to 180 degrees omega t equals to 90 to 180 degrees the direction will be same at 90 degree we will see the maximum vector magnitude and then it will be come down and it will reach to the 0 at 180 degrees.

So, here the magnetic field resultant vector magnitude is coming down from 90 to 180 degrees. So, these two things we can represent it in this manner. So, it is increasing from 0 to 90 then it is decreasing to 0 at 90 degrees to 180 degrees. Now we will consider the instant omega t equals to 180 degrees at this particular point current is equals to 0 and flux also 0 resultant flux because phi a and phi b both are 0 then resultant flux vector magnitude also 0 at omega t equals to 270 degrees what it will happen we will see these are the conductors position. Here the conductors are not rotating only the fields with respect to the AC supply are varying or we will see whether it is rotating or not at the end we will see by plotting the all vectors on a x y plot whereas, in a DC mission the conductors are moving with respect to the rotor movement keep it in mind that point these are the conductors at omega equals to omega t equals to 270 degrees current to the coils a a dash and b b dash is negative and maximum value negative means at a the current is leaving at the point or at the terminal a dash the current is entering and similarly for b also current is leaving and b dash current is entering we are changing the current polarity because the current is changed now.

So, here we can observe that at 270 degrees at this particular point current is changed. So, with respect to that particular point or that particular current we have marked the dot and cross now draw the flux loops with respect to the dot and with respect to the cross we will see the flux loops. Now, with respect to the dot the flux direction is in a anticlockwise manner here anticlockwise anticlockwise here clockwise manner for a cross. So, these two flux loops are in a additive manner and these two flux loops will be in a additive manner. So, the resultant flux loop will be in this manner and with respect to the two dots the resultant flux loop will be in this manner and the resultant flux we can see here the resultant flux direction all loops are in the same direction.

So, the resultant flux loop direction also towards the same thing and these are the resultant flux vector direction this is a phi r here phi r is a combination of phi a vector and phi b vector. If you want to find the magnitude, so let us consider the vector plot phi a with respect to our reference phi b is a vector plot phi a with respect to our reference phi b is this one and phi a is this one. So, but now the current is reversed, so with respect to that phi a is in this direction and phi b also is changed to this direction this is phi a and that is phi b after the current reversal at omega t equals to 270 degrees. Here the resultant vector is in this manner this is the phi r here phi r equals to same phi m sin 270 square plus phi m sin 270 square square root. So, it will finally results into root 2 phi m at 270 degrees same as 90 degrees one 90 degrees we have not calculated the magnitude right.

So, it will be same as this one if you will substitute sin 270 is one and sin 270 is again one. So, phi m square plus phi m square 2 phi m square square root if you will do then root 2 phi m will come and the resultant vector magnitude with respect to omega t equals to 90 degrees also same that is square root 2 phi m. Next, we will see omega t equals to 180 to 270 degrees what it is happening. So, at 180 degrees it is 0 then the resultant vector direction at 270 degrees we have seen in this direction phi r equals to square root 2 phi m in between 180 to 270 degrees the resultant flux vector magnitude will increase in the same direction from 0 to root 2 phi m it will increase phi r increasing from 0 to root 2 phi m. Next from 270 degrees to 270 degrees 360 degrees at omega t equals to 270 degrees the phi r magnitude is root 2 phi m we have seen this thing at omega t equals to 360 degrees we will analyze now at omega t equals to 360 degrees current to the coils a a dash and b b dash is 0 that means flux equals to 0 resultant flux vector magnitude and the direction at 270 degrees it is in a fourth quadrant 45 degrees at 270 degrees from 270 to 360 the vector angle will not change only magnitude is coming down in this manner this is at 360 degrees.

So, if we will see from 270 to 360 degrees 360 degrees resultant flux vector magnitude decreasing from root 2 phi m to 0. So, we have analyzed the direction of resultant flux as well as magnitude. Now we will draw the resultant magnetic field or flux vector on a x y plot. Now, we will draw the resultant magnetic field or flux vector on a x y plot. So, we will draw the resultant magnetic field or flux vector on a x y plot.

So, first we will consider at omega t equals to 0 at omega t equals to 0 flux vector magnitude is 0 then from 0 to 45 it is increasing in this manner and it will reach to the 90 or maximum value at theta or omega t equals to 90 degrees that is root 2 phi m magnitude this is phi r from 0 to 90 degrees then from 90 to 270 180 degrees the same vector direction is same and magnitude is coming down and reaching to 0 and from 180 to 270 it is increasing to the maximum that is again root 2 phi m at 270 degrees it will reach to the negative side maximum and from 270 to 360 degrees or 0 degrees again it will reach to the same point where it started. Whatever, with respect to our analysis if we will draw the vector plot from 0 to 90 degrees the vector magnitude is increasing and then from 90 to 180 degrees vector magnitude is decreasing and it reach to the 0 180 degrees. Then, from 180 to 270 it is keep on increasing and at 270 degrees it will reach to the maximum then from 270 to 360 degrees again it will go back to 0. We can represent either this way or this way the resultant magnetic field vector with respect to 2 coils and same excitation where mechanical displacement is given to the 2 coils, but electrically in phase current is same here and mechanical displacement is 90 degrees. So, this kind of magnetic field is not a rotating magnetic field.

Here, the resultant flux vector magnitude is increasing and then decreasing. So, whatever the magnetic fields we have seen in this lecture that is not a rotating magnetic field it is increasing and decreasing varying with respect to the current. So, with this kind of magnetic fields we cannot make the symmetrical rotation with respect to AC missions. Thank you.