Course Name: Design of Electric Motors

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Title: Magnetic Fields in AC Machines-2

Greetings to all in the last lecture we have discussed the magnetic fields in a AC machine with respect to 2 coils where the mechanical displacement is it is there and electrical displacement or electrical ah electrically these 2 coils are in phase. But in this lecture we will see the symmetrical displacement mechanical displacement as well as electrical displacement with respect to the 2 coils. So, with respect to the last class we can see here we have considered the coils AA dash and BB dash and these 2 coils are mechanically displaced by 90 degrees and electrically we are giving the same excitation. But now we will give the excitation to the AA dash will be different and BB dash will be different. So, the blue colour one AA dash excitation to the coil AA dash. Now BB dash coil will excite with 90 degree phase shifted current waveform.

So, this is BB dash current. Here IAA dash is nothing, but IM sin omega t and IBB dash is nothing, but IM cos omega t. Here also the conductors are not moving we are exciting the conductors with the variable current or AC current and AA dash and BB dash mechanically displaced by 90 degrees and electrically also excited with 90 degree supply and individual magnetic field vectors will be same with respect to the conductors placements. Just consider the positive currents in both coils for a reference and apply a thumb rule and we can find the phi A and phi B direction.

These are the reference phi A and phi B direction. Now, we will analyze the what kind of magnetic fields are there with respect to this kind of arrangement. First I will consider at omega t equals to 0 degrees. Here current with respect to the AA dash coil is equals to 0, but BB dash coil it is positive and maximum. So, the flux vector resultant flux vector we will analyze.

This is BB dash and AA dash. So, AA dash there is no current in a coil AA dash. So, no need to analyze any flux loop or flux analysis and with respect to the BB dash coil the current is positive. So, at B terminal we will see the cross and B dash we will see the dot as per our reference. So, apply a thumb rule or flux loops will be in this manner for cross it will be clockwise direction for dot it will be anticlockwise direction.

So, the resultant flux vector is in this direction. Here resultant flux vector magnitude is nothing, but phi B magnitude right phi B is nothing, but phi M cos omega t here omega t is nothing, but 0. So, the resultant vector magnitude is phi M with respect to this particular point. Now, we will see with respect to the point omega t equals to 90 degrees. Before going to the 90 degrees first we will see the 45 degrees or pi by 4.

The current to the coil AA dash is positive BB dash coil is also positive. So, the resultant flux loop analysis or magnetic field loops how the magnetic fields will form inside the machine we will see now. This is B and B dash A A dash current is positive. So, here cross and here also cross with respect to the A and B terminals and A dash and B dash terminals it is dot current is coming out. Now, apply a simple thumb rule and identify the direction with respect to the cross we can say clockwise direction and dot anticlockwise.

So, these two flux loops loop 1 and loop 2 these two flux loops are in a additive manner and other two loops also in a additive manner because of the flux loops direction and the resultant flux vector is in this direction phi r. So, in order to find the phi r magnitude we can do the analysis with respect to the vector whatever the vectors we have considered as a reference these two or we can do the mathematical way also. First we will see the with respect to the vector additions phi A and phi B. So, here phi A is in this direction and phi B is in this direction with respect to our reference both phi A and phi B are positive. So, it will be in a same direction the resultant flux vector is in this direction now phi r.

So, here phi r is equals to phi A magnitude square plus phi B magnitude square square root the phi A is nothing, but with respect to the currents phi A equals to phi M sin omega t and phi B equals to phi M cos omega t. So, substitute 45 instead of omega t then phi M square by 2 plus phi M square by 2 since the sin 45 as well as cos 45 equals to 1 by root 2 then it will results phi M the magnitude of the resultant vector. Here also the magnitude of resultant vector at omega t equals to 0 it is phi M at omega t equals to 45 degrees again we are seeing phi M resultant vector magnitude.

Now, we will analyze with respect to the omega t equals to 90 degrees at omega t equals to 90 degrees the current to the coil A A dash is positive and maximum right it is a sin function and B B dash is a cos function and it is 0 with respect to the coil placements this is A and this is A dash and this is B and B dash B B dash coil is not carrying any current. So, there is no flux and A A dash coils are carrying a current and A is cross and A dash is dot that means, current is entering at the point A and current is leaving at the point A dash same analysis here also apply a simple thumb rule and identify the flux loop direction with respect to the cross it is clockwise direction with respect to the dot it is anti clockwise direction the resultant vector is in this direction phi r here phi B is absent.

So, phi r magnitude equals to phi A maximum magnitude that is equals to phi M sin omega t that is phi M sin 90. So, the resultant vector magnitude is phi M and direction

we can find from the vector plot analysis next instant at omega t equals to 135 degrees we will see at omega t equals to 135 or 3 pi by 4 the current to the coils A A dash is positive B B dash is negative we can observe from the figure here. So, here at 3 pi by 4 this is the instant at 3 pi by 4 at this instant the current with respect to the A A dash is positive and B B dash is negative we can see the current waveform at 3 pi by 4 also at this instant. So, with respect to this particular current currents what kind of magnetic fields will be there we will analyze now. This is coil B B dash A A dash.

So, A A dash current is positive then there is no change in current this side cross and this side dot, but B B dash current is changed. So, B at B terminal the current is leaving at B dash terminal current is entering apply a thumb rule then the flux loops will form in this manner for dot it is anticlockwise for cross it is clockwise manner similarly, for coil B also then the direction will be in this manner. So, here these two flux loops are in a additive manner this is flux loop 1 and flux loop 2 the conductors which are carrying the same current and those flux loops with respect to that particular conductors are in a additive manner. So, the resultant flux loop will form in this manner and the direction is in this manner phi r. So, here phi r is a combination of both currents phi A and phi B both fluxes will be there and if we will solve the flux vector magnitude at 135 degrees again it will results to the phi m just substitute phi A and phi B values and find the magnitude with respect to the vector analysis.

So, the phi B vector with respect to our reference this is phi B and this is phi A this is the reference with respect to positive currents. Now, the current with respect to the B B dash is changed. So, B B dash phi B vector is in a opposite direction and phi A vector is in a same direction. So, the resultant will be this one phi r. So, the same resultant vector direction we can analyze here and phi r magnitude is nothing, but phi A magnitude and phi B magnitude square it and take the square root then you will get the phi m.

Next, we will analyze at omega t equals to 180 degrees at the instant omega t equals to 180 degrees the currents if we will see I current to the A A dash coil is nothing, but 0 B B dash coil is negative and maximum. So, only B B dash conductor is carrying the current and it is in a opposite direction. So, from the vector analysis directly we can analyze it or we can do with the thumb rule like magnetic field lines. So, here our reference phi B and phi A are in this manner. Now, phi A is equals to 0 and phi B vector is reversed then the resultant vector will be in this manner.

This is phi B new phi B with respect to the negative maximum current and phi B is nothing, but resultant flux vector and the magnitude is nothing, but phi m because the magnitude is in a opposite direction. So, phi m we can consider, but direction is in a opposite manner at omega t equals to 225 degrees current to the coil A A dash is negative B B dash coil also negative. So, for simplicity we can analyze with respect to our vector analysis phi B is in this direction and phi A also reversed with respect to the currents. So, this is new phi A and this is new phi B then the resultant vector now in this direction this is phi R. The same thing we can analyze with respect to the flux loops also like this is conductor B and A B dash A dash.

So, current is reversed. So, the A conductor will see the dot or current is leaving and at the B terminal or B conductor also seeing current is coming out and at the A dash and B dash current is going in then flux loops with respect to the dot and cross will be in this manner. For dot we have to consider the anticlockwise manner for cross clockwise manner for cross I am considering clockwise like this and for dot anticlockwise. So, the resultant flux direction we can see. So, the resultant flux will be in this direction these 2 flux loops are in a additive manner and 3 and 4 loops are also in a additive manner the resultant flux loops we can observe in this way and the direction is in this way.

So, from the vector analysis also we have concluded that resultant flux will be in this direction from the flux loops also resultant vector is in this direction magnitude we can find easily with respect to the vector addition analysis. So, here phi A we know and phi B also we know the magnitudes then we can find the resultant vector magnitude phi R equals to here also phi M will come. Just phi A and phi B values you just substitute in this equation phi A equals to phi M sin omega t and phi B equals to phi M cos omega t. Similarly the currents I am assuming phi A and phi B are also same with respect to the I A A dash and B B dash. Next the remaining instance at 270 degrees we will see omega t equals to 270 degrees compared to the coil A A dash is negative B B dash B B dash current is 0.

So, only phi A will be there that is in a reverse with respect to the reverse current right. So, the flux vector with respect to our reference is reversed now. Phi A is nothing, but resultant flux vector phi R that magnitude is phi M.Since we have reversed the vector. So, the minus will be covered accordingly and at omega t equals to 325 degrees current to the A A dash coil is negative B B dash coil is positive.

So, our reference vectors I will draw first this is phi A and phi B. So, now, the phi B B dash coil is getting same positive current then phi B is in this direction A A dash coil is getting negative current. So, phi B should be reversed sorry phi A should be reversed this is phi A. So, the resultant vector is in this direction that is phi R. So, phi R is equals to vector addition of phi A plus phi B.

So, phi A is nothing, but phi M sin 325 plus phi M cos 325 take the squares and root consider the square root with respect to the 90 degree displaced one because of the 90 degree displaced one 2 A B cos 90 term is equals to 0 this term is equals to 0. So, no need to consider this term directly you can take the squares of the term phi A and phi B magnitudes and take the square root then the resultant will be phi M.

If we will see the resultant magnetic flux vector on a x y plane this is x and y at 0 degrees where is the flux vector we will see that thing. So, at 0 degrees we have seen in this direction right the flux vector is in this direction and 45 degrees it is 45 degree towards clockwise manner and same way from 0 to 360 degrees we have analyzed the resultant magnetic field vector. So, this is at 0 and then at 45 we have seen at this particular point and then at 90 degrees the resultant flux vector is in this position and at 135 degrees here and then at 180 degrees and then at 225 then 270 degrees 325 degrees and then again at 360 degrees is equivalent to 0 degrees.

We can see here the flux vector is rotating symmetrically with respect to 360 degrees with respect to one particular reference like let us assume our reference is phi A B is here or phi A any reference thing you can consider with respect to this reference the resultant flux vector is rotating symmetrically 360 degrees with respect to one particular cycle of a current and if you will give a continuous AC signal then it is keep on rotating this vector magnitude because of this reason this kind of magnetic fields we will call it as a rotating magnetic fields where the rotating magnetic field magnitude is same and it is rotating with respect to one particular reference symmetrically over a 360 degrees. This is with respect to two phase or two coils where the two coils A A dash B B dash both coils are mechanically displaced by 90 degrees and electrically also we are giving 90 degree phase shift. Because of the symmetrical mechanical distribution and symmetrical electrical excitations we are getting the symmetrical rotating magnetic fields. If we will change the electrical phase shift electrical excitation angles or mechanical displacements we will not get the symmetrical rotating magnetic fields that also we will see as an example. So, first I will change the excitation with respect to the one particular coil we can see here I am considering as a example this is the example what we have analyzed as of now just I reversed the coil A and A dash and the excitation is same.

So, what kind of magnetic fields we will see and how the rotating magnetic field vector is there that also we will see. So, with respect to the instant one let us consider the instant one at 0 degree omega t equals to 0 degrees then here cross is there and then at B dash it is dot current is entering here and leaving at the B dash terminal and the current in a coil A A dash it is 0 then the resultant flux loops will be in this manner and the resultant flux direction we can see in this way this is the resultant flux vector at one particular instant where omega t equals to 0. Similarly at omega t equals to next instant at omega t equals to 45 degrees that is instant two we can see here where the flux loops will be in this manner and the resultant flux loop with respect to these two dots will be additive and these two cross will be in additive manner and the resultant flux vector is in this direction for instant two at omega t equals to 45 degrees. So, the resultant flux vector is this one at omega t equals to 0 we have seen the resultant flux vector here and at omega t equals to 45 degrees the resultant vector is here that we can observe here. Then if we will change the instant from 45 degrees to 90 degree instant this is the instant two at 45 degrees and then instant three at 90 degrees where the current to the A A dash coil is maximum positive maximum and B B dash coil is 0 we can see this one and with respect to that there is no magnetic fields with respect to the B B dash coils and with respect to the A A dash coil at A we are seeing the cross and at A dash we are seeing the dot.

The flux loops will be like this manner apply a thumb rule for the cross it is a clockwise direction for dot it is a anticlockwise direction of flux loops and the resultant flux vector is in this direction and the same thing is drawn in the x y plot. Similarly, at an instant 3 pi by 4 both currents are there in the coils A A dash and B B dash same thing we have discussed as of now and the resultant flux vector is in this way. Apply a thumb rule and identify the flux loops and after that do the which loops are in a additive manner and then identify the direction this is the resultant flux vector direction. Similarly, at 180 degree instant this is 180 degree instant where both coils are not getting the currents only A B B dash is getting the current and A A dash coil there is no current. The resultant vector flux vector direction is in this manner and we can see that one in the x y plot.

Similarly, from 180 degrees to 360 degrees also we can analyze and the resultant vector and how the rotating magnetic fields or magnetic fields inside the machine we will see in this slide. So, if we will change the instant here we can observe if we are changing the instant or currents are changed with respect to this instant then automatically the resultant vector and the magnitude of the resultant vector is not changing, but it is rotating with respect to the current magnitudes that is what we can observe from these three figures. This is the figure which is representing the magnetic fields and this is the figure which is representing the currents and the last figure is representing the resultant vector on a x y plane we can see here it is rotating. So, this is the symmetrical rotating magnetic field with respect to the two coils or we can say two phase mission like we can consider that the principles of two phase induction mission or single phase mission with auxiliary winding which is sitting at 90 degree displacement we can call it as a two phase mission where this kind of magnetic fields will be there inside the mission for single phase induction motors. Next we will discuss the if there is no mechanical displacement what kind of magnetic fields will be there and how the rotating magnetic field vectors will be there that we will see in the next lecture. Thank you.