**Electrical Machines – II**
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**Lecture – 38**
**How to Fix up Positions of Net Field, Rotor Field and Stator Field**

Welcome.

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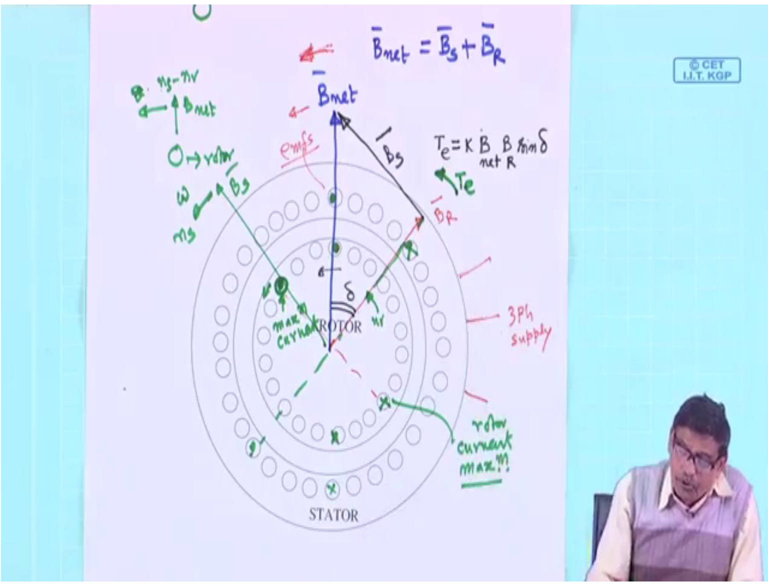


So, we were discussing about this field in an induction motor where is B S, where is B R and where is B net. So, I told you that you have energized these stator coils with a 3 phase supply with appropriate sequence. So, that let us assume it moves in the anti clockwise direction because I can always make it rotate in the anti clockwise and clockwise direction by playing with the phase sequence of the supply.

So, let us assume it is moving in this direction B net and this will be the net field is suppose there which is sum of B S plus B R. And I these dots indicates the at that instant when B net is suppose occupies this position; the conductors seeing this B net will have maximum induced voltage because VLB is the voltage. And the polarity I find out found out by applying right hand rule, but in an intelligent way here stator conductors is not moving therefore, it can be I have explained that.

So, this is dot and this is dot at that instant the induced voltage; although you must appreciate this point this is quite a complicated windings 3 phase R, Y, B all conductors are there. But no matter which conductors come here they are bound to have maximum induced voltage VLB that is the crucial thing to understand; so this is this.

Now, the question is suppose I ask you this is the maximum induced voltage; now suppose take the case of rotor winding this one, this rotor coil. I want to now sketch the rotor field suppose I want to where is the rotor field I want to know.

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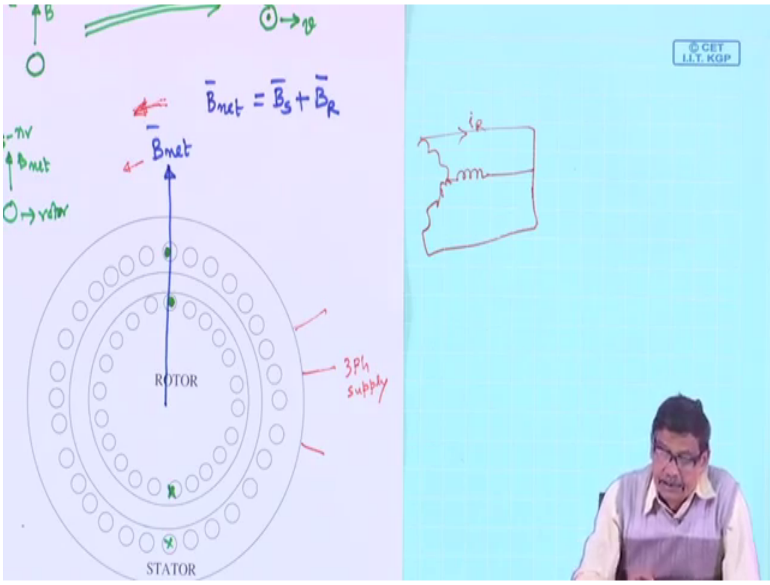


Now, you must appreciate one point; rotor winding you are shorting it, it's not rotor winding you are shorting suppose these are the rotor windings and you have shorted it.

What do you think, this is a lagging power factor? Yes it is because the current induced voltage because of net field and that has produced current in the rotor circuit i R, i y, i B and this currents will lag this induced voltage by some phase angle. Therefore, although the induced emf is maximum for this conductor, but current in this conductor is not maximum. Maximum value of the current will occur after some time depending upon the power factor angle of the rotor R and X and it is the current which decides B R not the polarity of the induced voltage that is very interesting.

Therefore, although these are the dots indicating emf's; you know this dots indicate emf's big value of emf occurred there no doubt, but the current is not going to be maximum here. And if you look at it is at this instant here rotor is moving after some time this conductor will leave this place and come over here is not and perhaps at that time it will attain the maximum current. It is obvious because after some time delay the current will attain maximum value.

Therefore, I can say with confidence that this is the maximum induced voltage here; perhaps this conductor saw this event slightly earlier, this fellow is now having maximum current because, it has already crossed and come here. So, although maximum voltage is in this conductor maximum current is carried by a conductor which has already seen maximum voltage and then its current has picked up because it is lagging power factor. Therefore, maximum current perhaps will be here in this case this is dot and its diametrically opposite whoever is there it is 2 pole configuration you better do this will be the maximum current.

Once again repeating, this conductor is seeing maximum voltage induced, but not the maximum current. Because after all it is a lagging power factor load on the rotor side load means it is shorted; so its internal impedance R and X. Therefore, the current it this conductor will have maximum value after certain time, but after certain time this fellow has moved to this position because the rotor is moving in this direction with a speed nr.

So, some time has elapsed; it has supposed come here therefore, right now when this conductor is having maximum induced voltage; some a one of the conductors on the left hand side will have maximum current. Because he has already seen the maximum voltage now we have its current has become maximum. Let us assume this conductor is taught whether these or this it depends upon exact power factor angle of the internal impedance of the rotor coils that is there, but that is lagging I know. So, let us suppose this is dot, this is crowd and this is current direction rotor current; rotor current maximum dot cross.

Now, I told you one thing while discussing rotating magnetic field rotating magnetic field some field is moving gesture.

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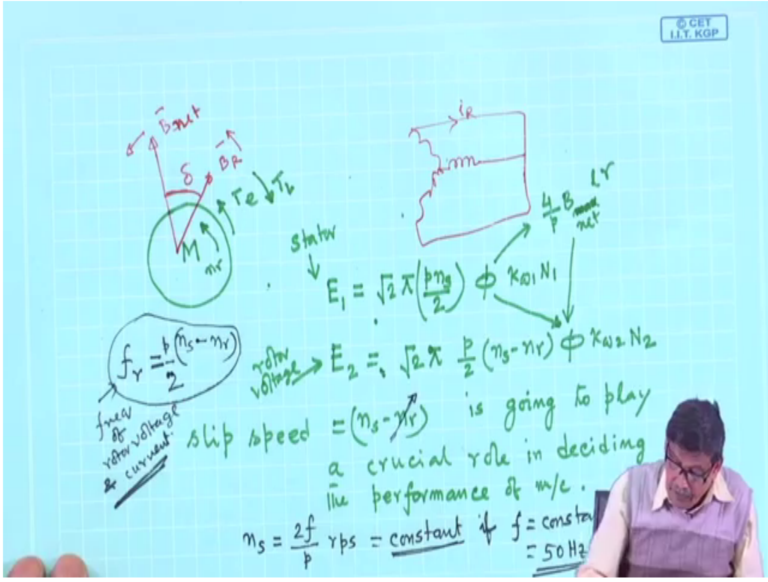


You understand that this is B net rotating; it is like doing like this, but about one interesting thing is where the position of this rotating field at a given time; it is difficult to say at every instance, but at some positions I can say at very clearly where the rotating field is right now at. What is that? Whichever phase carries maximum current rotating suppose at this instant I find R phase is carrying maximum current, the rotating field resultant rotating field must be along the R phase axis.

If Y phase is carrying maximum current then rotating field will be along the Y phase axis. So, these are the inputs I am already having; now here is the situation where I conclude out of so many conductors they may belong to R phase Y phase B phase I do not care, but I am certain about one thing that this conductors carry maximum current it may belong to R phase Y phase.

The resulted field of rotor then must be perpendicular to this line is not it? That result in rotor field must be here this is the most interesting part. Although it may look like very stupendous task array what to do, but I can easily make it out; when B net is here I am sure B R will be on its right. By what amount of course, that is to be found out because I have to then find out what is the exact power factor angle; then I can locate these conductors which are having maximum current now.

So, what is the thing? B net right now it is here I have identified the conductors which we will carry maximum current right at that instant when B net is vertical. And I conclude this conductor is carrying maximum current and then by using the fact that whichever coil is carrying maximum current; B R will be perpendicular to that coil axis or along the coil axis; coil axis is a perpendicular line there. And then I get B R; B R has to be here and the B R is there then I will say; B R plus B S is B net.

Therefore your B S must be there; this is very interesting. So, I can now just starting because B net is going is B R plus B S for which the induced voltage will be there; what is the point of calculating induced voltages separately for B R B S this that. I start from that assumption B net is suppose here at that time, then I conclude these conductors on stator and rotor they must have p key emf with this dot by applying right hand rule correctly.

And then dot then I argued that this conductor is having maximum voltage; does not mean it is carrying maximum current. Why? Because rotor you have shouted induced voltage is there current in the rotor circuit must be the induced voltage by the impedance of the rotor circuit which is inductive R X.

And therefore, if this is the maximum voltage instantaneous maximum voltage at that time maximum current will not come onto the conductor after certain time lag lagging current. And so this particular conductor will have maximum current when this conductor is also moving. So, if you allow some time to elapse this conductor must have moved to the left and at that time it will have the maximum current. But suppose I am asking you this conductor is having maximum voltages, not maximum current can you tell me which conductors then is having maximum current.

Then I will argue perhaps a conductor like this will have maximum current because it has already seen the maximum induced emf when it was here rotor is after all moving this way. Therefore, this coil is carrying maximum voltage induced voltage, but this fellow perhaps will carry maximum current and once I know that then I know that whichever coil is carrying instantaneous maximum current, the direction of the resultant field because of that rotor current must be along the axis of that coil which is this. And once you fix this up you have started with B net, then B S must be this that is all understood.

So, this did and then everything B net, B R, B S all are moving with synchronous speed, so, this angle will be delta constant. So, that is why I we discussed the production of the torque by considering DC current at a particular position ok. But I am sure that same result I can you use and say the electromagnetic torque produced will be K some constant, B net magnitude of that B R into sin delta where delta is this torque angle.

You can say another interesting thing for example, this is B S; I have got, if I ask you what is B S? B S is the if I draw it separately it will be the way I have drawn this two are equal as; suppose B S is here, is not B S is that is how I got B S. If I ask you tell me out of so many conductors on the stator slots which conductor is carrying maximum current? I will say this is B S then draw a perpendicular line here and perhaps and not only that I will be also able to tell the direction of the current i max clear.

If your B S because of stator current; what is the stator field rotating all are rotating with synchronous speed omega electrical speed or ns mechanical speed. So, I can also picks up where this rotor currents will be ok; I told you one thing that what is called the direction of the torque of the induction motor, I applied Faraday's law and told you. In fact, I have applied Lenz's law to explain that that is rotor cannot, but rotate in the same direction as that of the rotating field.

If you have rotor were stationary if you close the rotor circuit at T equal to 0; I told that T equal to 0 plus everything is stationary, but both the fields are moving with synchronous speed. And let time passes the rotor moves with speed and are then also a steady torque will be produced. Because the angle between these 2 fields B R and B S they will be time invariant and you will get torque, but one can also apply what is known as left hand rule to find out the direction of the torque produced ok.

By applying left hand rule there; for example, here if you see this is the conductor which carries maximum current; it is your B net. So, B net will be like this cos theta, it will be still like this. Therefore, you apply left hand rule B this is i and you will find it is experience a torque like this therefore, this is quite interesting.

So, although it may look at the very beginning there is a 3 phase winding with so much complexity this that, but essentially in space; these are all space phasers flux density. Nowadays you will be hearing about what is the speed space vector control of induction motor speed this that. So, you should have a fair knowledge of how to fix up those positions.

So, I hope you have understood this very clearly therefore, this. So, it looks like that B R tries to the direction of the torque is from B R to B net; a cross p sort of B R to B net this is the torque and the electromagnetic torque will be in this direction. So, in a motor mode we have already told you that in a motor mode; if you have a motor I will now simply show like this, your aim will be there and electromagnetic torque will be in the direction of rotation of the rotor nr; electromagnetic torque is the driving torque that is one thing.

And opposing mechanical torque that is called the load torque that will be there and also I will just symbolically show that on this that B R; if it is here, after some angles B S is there and this angle is delta and everything is rotating in this direction for.

Student: (Refer Time: 19:56).

I am so sorry this is B net thank you; so, B R to B net. Now, let us come to the induced voltage expression; I told you that E 1 RMS value of the induced voltage in the rotor is root 2 pi p ns by 2 relative speed between the field and the conductors stator this is stator per phase voltage stator root 2 pi here, then phi.

This flux per pole with respect to whom should I calculate? With respect to B net that is this flux per pole should be 4 by p; B max net l r; where r is the rotor radius, l is the length of the machine, p is the number of poles. So, this is the flux per pole and I must calculate it with respect to B max net that is B net; B net is B max net. So, B net corresponding to that I will calculate and also and into kw 1 winding factor and N 1. Similarly, per phase rotor voltage should be also calculated like this; root 2 pi p by 2 and this is ns minus n r assuming rotor is moving with some speed ns minus n r and this is same phi same 4 by p B net l r into kw 2 N2 [FL].

Here at this point I will do one just simplification to this term [FL]. We have seen that in induction motor this relative speed which is called slip speed is going to play crucial role in deciding the performance of the motor etcetera. Why? Because the magnitude of the induced voltage in the rotor depends on n s minus n r may be larger voltages induced;

depending upon this difference n r could be very low rpm then difference will be large more induced voltage will be there.

But if n r is close to ns very less induced voltage will be there and induced voltage will decides the current in the circuit and current we know we will decide about the B R hence the torque. Therefore, it looks like n s slip speed ns minus n r is going to play a crucial role in deciding the performance of the machine straight I mean there is no doubt ; performance of the machine means in terms of torque power these that. So, for example, if n r equal to ns rotor there is no induced voltage you cannot expect any torque to be developed this that; no power, no mechanical power output unless torque is there.

Therefore ns minus n r is going to play a crucial role of which n r is variable. We will show you that depending upon the mechanical load present on the machine n r value is decided, but n r can change as at least I have seen it when I have started the machine n r was 0 then gradually its speed went up. So, n r changes, but n s constant ns is 2 f by p mechanical speed is constant if f is constant.

In earlier days this supply frequency was constant; I could not do anything supply frequency is 50 hertz; that is all, but in present day context f may also vary, but let us assume steel our grid voltage is 50 hertz. So, I will assume I will run the machine from constant frequency supplied 50 hertz; then this is constant I can assume.

So, speed of the rotating fields are constant and n r making and I told you ns minus n r is going to play a crucial role, but because that will decide what will be the magnitude of the voltage not only that will also decide what will be the frequency of the voltage because frequency of the voltage in the rotor circuit or current is n s minus n r into p by 2 2 by p R p by 2.

So frequency of rotor current of rotor voltage and rotor current ok. So, these 2 things must be understood; this can be assumed to be constant, frequency of the rotor current depends upon rotor speed and also the induced voltage in the rotor depends on rotor speed and rotor speed may change. Anyway we will continue with this in the next class, but we are going now to a detailed discussion on the induction motor after this; after we have understood where is B S, B net, B R clarifying the things.

Thank you.