Electrical Machines - II

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Lecture - 32
Speed and Direction of Rotating Field

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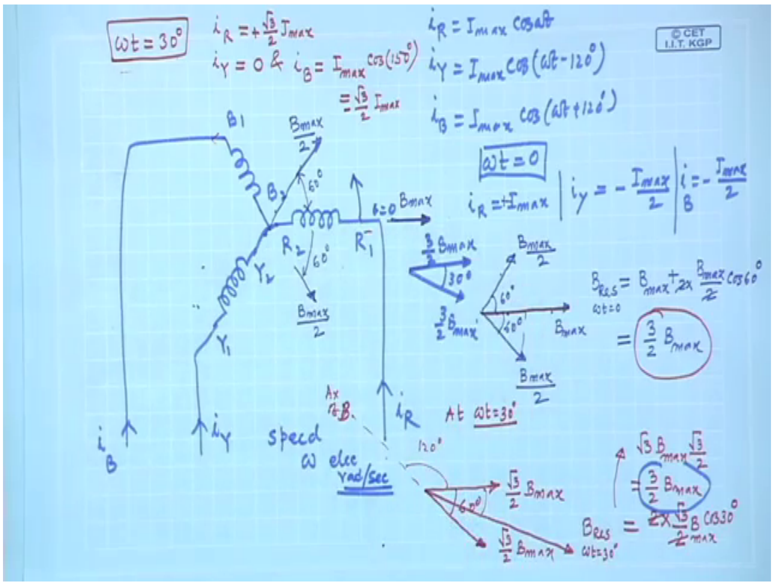

Welcome. So, were doing this trying to find out the resultant field, when time is such that omega t equal to 30 degree, all angles are electrical fine. So, I found out the R phase field, Y phase field is not there, so axis of B is this 120 degree apart. And it is carrying negative current; therefore the field will be like this. So, the resultant field will then lie here and obviously the B resultant at omega t is equal to 30 degree, we will be just 2 times root 3 by 2 B max and cos 30 degree.

Now, we know 2 equal forces p angle between them is alpha resultant is 2 p cosine alpha by 2 something like that whichever way you do or you can 30 degree its component here, vertical components will cancel out, so 2 p. And this cos 30 degree, so this one is 2 2 cancels, so root 3 B max into cos 30 degree is once again root 3 by 2 is equal to 3 by 2 B max.

So, what is your observation, observation is this coils are carrying balance three-phase current at omega t is equal to 0, I noted my time. The resultant field was horizontal and it is strength was 3 by 2 B max time passes omega t becomes 30 degree. And the resultant field then moves from these, so originally it was here at omega t equal to 0 it was there, time passes what is the resultant field 3 by 2 B max time passes by 30 degree resultant field strength remain same 3 by 2 B max and it moves 30 degree in this direction in the clockwise direction.

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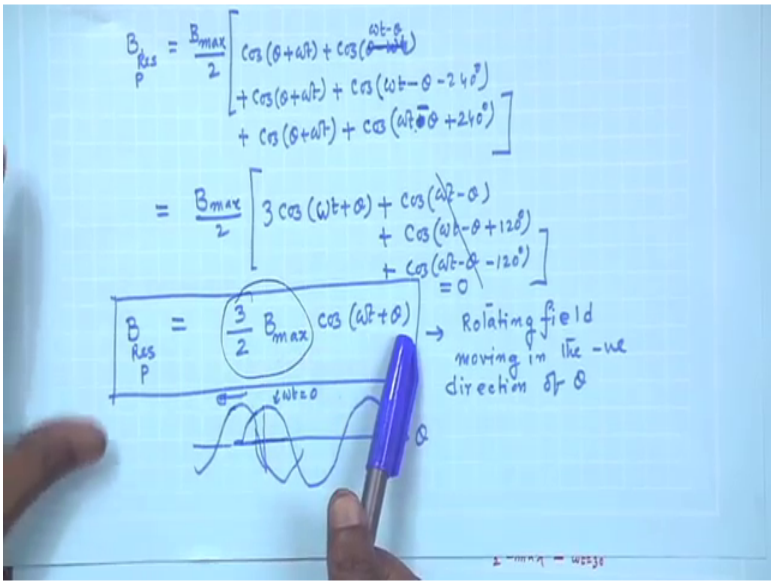

And it is consistent with this result, because we found that 3 by 2 B max cosine omega t plus theta is the equation of these, which told me that your resultant field is moving in the negative direction of theta. Positive direction of theta measuring this is theta equal to 0 this way. So, it has indeed moved in the negative deduction with keeping its amplitude same and coming here.

One can go on doing like this ok. Take another stand omega t is equal to 60 degree, you will find that resultant field strength will once again remains 3 by 2 B max and it was initially here at omega t equal to 30 degree it came here, the length is same. At omega t equal to 60 degree, you will see it has gone by 60 degree strength remaining same. So, it look like that as if a sine wave of amplitude 3 by 2 B max is moving in the clockwise direction of this in space, what is this speed? Speed is same as omega. Because, whatever is a omega t is equal to 30 degree by that time, it has gone by 60 degree.

Therefore, speed is omega electrical radian per second, it must understanding about speed you will talk at great length after sometime, but this is the thing. Now, the question is it that we have to gone proving for various time for all the time is it true, yes it is true another nice way of showing that it this.

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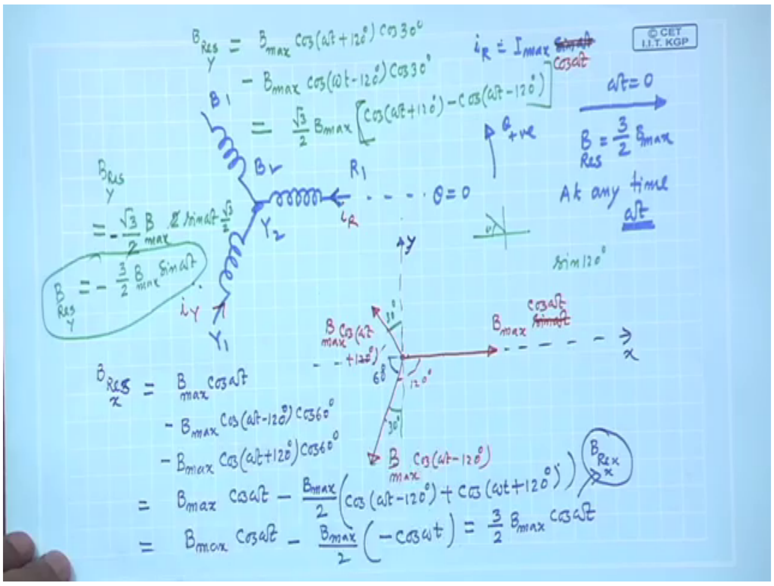

See go to the same diagram. This is your R phase, this is Y phase, and this is B phase. So, this is R 1, this is Y 1, Y 2 and this is B 1, B 2. When current enter through one terminal, field is away from this center, but it is direction of the field we have present. And this is by reference of theta is equal to 0 and theta I will measure positively in this collection theta positive this was the thing.

Now, I know at omega t is equal to 0, I will do for that case. So, omega t is equal to 0 I found, the field was here and it was 3 by 2 B max at omega t is equal to 0 B resultant. Now, suppose I will now say ok, instead of taking some discrete value of angles. Let us say that it this is omega t is equal to 0, then we say at any time omega t; any time omega t time passes any time any arbitrary time omega t.

In that case, this is the current i R is equal to I max sin omega t is not, this the current in R phase. What will be the field produced by this will be just these in this direction all the and the strength of the field is B max, because I max is there B max in to sin omega t. This will be the strength of the field along this line ok.

At some omega t, it may become negative. So, negative vector of this so equation will take care of this oscillation whether it is correctly this way or that way, so that sin omega t it terms, we will take care of that. Any arbitrary time t, this is absolutely correct if this is i R, your field will be this, because i R direction I have shown, I max sin omega t, so I max produces field. So, strength of the field is now a function of the time, I have drawn a vector look at any time t, this is a vector sin omega t or cos omega t?

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Cos I must write cos where because cos is so nice a function. So, B max cosine omega t, this you will be the field. What will be the field produced by the Y phase current at any time t omega, it will be 120 degree apart. And this will be B max cosine omega t minus 120 degree, because at time omega t R phase current is cosine omega t, Y phase current is cosine omega t minus 120. So, this lengths may differ, I am not because this is cosine omega t, this is cosine omega t minus 120, they are not of equal lengths or a part with 3 by 2 I do not know.

But, arbitrarily depending upon that instant, I should adjust this length. On the top of it, this current may be negative instantaneous value, then this equation will give you a negative quantity, which means actually your these opposite. So, equation takes care of that results all of the vectors so, it is a short of generalized approach, but none the less this angle is 120 degree electrical.

Similarly, B phase we will be may be like this omega t and it will be B max cosine omega t plus 120 degree is not. This will be the B phase, this is Y phase and I want to add this three vectors up. So, at any instant omega t of course that once you fix of omega t, this is a constant length that is what we did earlier a by a constant length, this that we found.

Now, to find out the resultant of these three space vectors, what we do. Let us say how to find out this resultant of these three, let us assign this is my x-axis let us say and let us say this is my y-axis ok, then what I will do, I will find out the x components of this three summed up. And also some of the y component of this three, then the resultant field vector x component will be sigma x component of component vectors and sigma y components of the component vectors that is the idea.

So, let us calculate B resultant x component, what it will be? It will be you can see B max cosine omega t, this calculation you watch out carefully. So, B max cosine omega t is positive x it is there. Then there are x component for this and for this vector which are in the negative deduction. So, it must be then minus B max cosine omega t minus 120 degree this one, but this angle is 60 degree this angle remain 60 degree, this into cosine 60 this is not negative of that, because it is in the you can easily see.

Similarly, this component minus B max cosine omega t plus 120 degree into cosine 60. And this must be the resultant field x component, because the constituent vectors of B resultants are this this this, so this is the thing. Now, cos 60 degree is half so, what I can write it is this B max cosine omega t that is there and this is minus B max cosine 60 is half this and this is cosine omega t minus 120 degree plus cosine omega t plus 120 degree this is not this.

And this I can simplify in an intelligent way is this that this is B max by 2 and this one must be minus cosine omega t, because sum of cosine omega t plus cosine omega t minus 120 plus cosine omega t 120 is 0 that result is known. So, some of these two is nothing but negative of this and which simply becomes 3 by 2 B max cosine omega t. So, mind you this is what, this is the B resultant x component ok.

Similarly, I find out the B resultant Y component, let me do it here with different color. So, B up to these a B resultant y component will be for all the component vectors take the projection on the y axis. So, for B max it cannot be for R phase no projection so, only for this and this, so it will be so for this one concerned, it will be B max cosine omega t plus 120 degree. And then this angle; this angle is 30 degree, because this is 60 so 30 in to cosine 30 and for this it should be negative minus, because its projection here is negative.

So, minus B max cosine omega t minus 120 degree and once again this angle is 30 cosine of 30. And this if you cosine 30 is root 3 by 2, so it is root 3 by 2 B max and you will be left cosine omega t plus 120 minus cosine is it correct omega t minus 120 hopefully no mistake anywhere, resultant of this one so, this will be the thing.

And B resultant y, it will be root 3 by 2 B max, this one you take this negative sign common and you will be having cos a minus b minus cos a plus b, which means 2 sin a sin b. So, sin 120 degree is how much? Sin 60 degree so, 2 sin a and sin 120 degree is so sin of 120 degree. So, sin 120 degree is here, which is 60 degree plus all sin. So, sin 60;

sin 60 is root 3 by 2, so into sin 60 root 3 by 2. So, this will then become minus this 2 goes and it will be 3 by 2 B max sin omega t so, this is B resultant Y.

So, what you have done, we have calculated for any instant suppose this was my omega t equal to 0 instant from that and at that time I new the resultant field was horizontal I new that, then I am telling that let any time passes time become so omega t from omega t is equal to 0, then what is the resultant field and what will be its magnitude I want to calculate. So, I get at omega t any omega t, I find out the say that is this lengths need not be same, then I find out this three I want to sum where there is a time varying term, but nothing wrong in that length at any time t this is suppose the lengths.

And then I want to add this three. So, while adding, what I have done? I have calculated the x components of each of the components added them up and I can tell that must be the x component the resultant B vector, similarly the y component so we have calculated, so separately so B resultant x.

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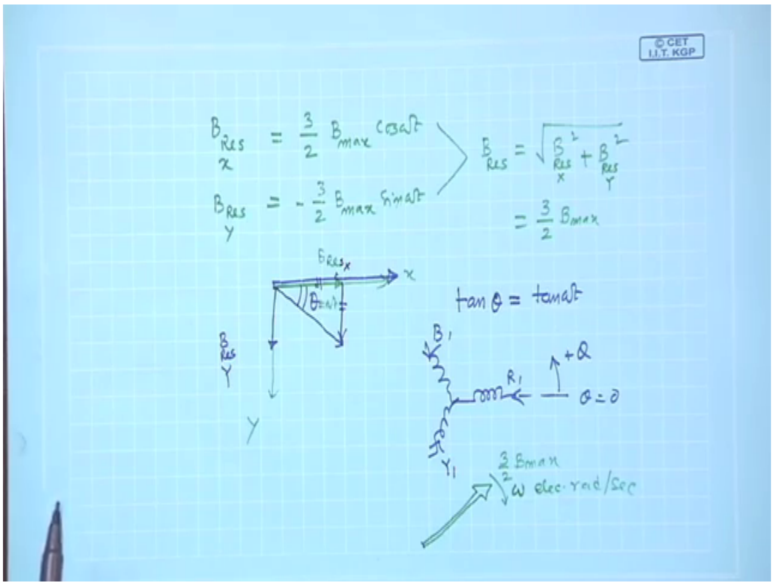

So, finally what we have got it this B resultant x component is equal to 3 by 2 B max cos omega t. And B resultant y component I have calculated this one, which is minus 3 by 2 B max sin omega t this is the think. So, what will be then the B resultant; B resultant magnitude, it will be under root B resultant X square plus B resultant Y square. And that is nothing but 3 by 2 B max is not and where will be is position my x-axis was like this, my y-axis was like that x, y axis.

And this was by B resultant X B resultant X and this was my B resultant Y and the resultant is this. So, what is this angle, resultant with B resultant X is this by this tan inverse of that. So, the angle will be the this theta if I call this is theta tan theta is nothing but this magnitude that is tan omega t that is all is not. So, these angle is this magnitude divided by this magnitude, which is omega t. Therefore, we see as time any arbitrary time is gone, then the resultant field that omega t is equal to was their of my amplitude 3 by 2 B max time passes by omega t that also moves by angle omega t in the anti-clockwise direction, I mean same thing we looked at from different angles.

Therefore, the conclusion of this lecture is this that when a balance three-phase whitening, you must be clear about your theta equal to 0 and positive theta. If this way you have connected and past current i R, i Y, i B of phase sequence R Y B, you will see that eventually what happens is this I am drawing by some sketch, I will do it like this. A resultant magnetic field of amplitude 3 by 2 B max and it is speed of rotation is omega, because this clearly shows this angle is omega sin omega t by cos omega t.

So, time passes omega t, it moves by same omega. Therefore, with a speed omega electrical radian per second; radian per second, it moves in this way ok. Some people say a to in language they say the resultant fields field will move from leading phase current to lagging phase current, I mean forget about all math mathematics it boils down to if R phase is carrying with respect to Y phase leading, so from leading to lagging phase it moves, strength is 3 by 2 B max, what is B max? Each phase produces its own pulse rating magnetic field, the amplitude of that B max which corresponds to I max so, this is the phase magnitude ok.

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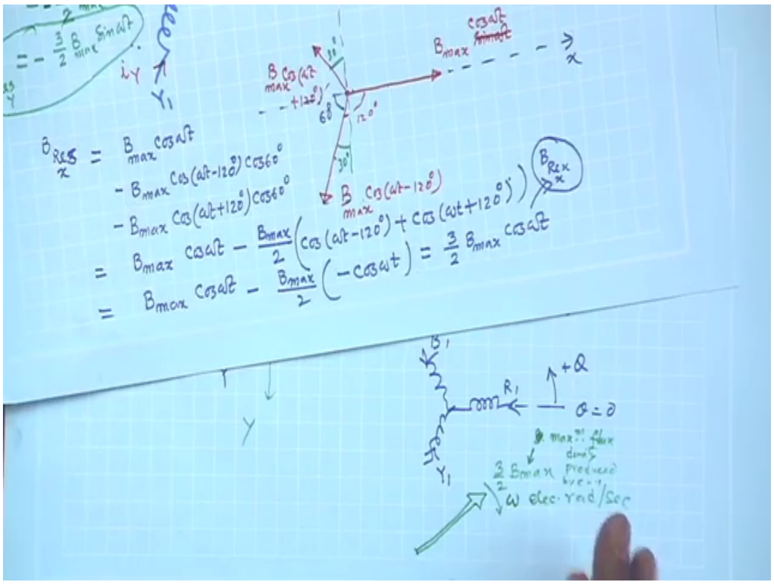

B max is each the maximum B flux density produced by each phase and that will be same for all the phases, because same I max is flowing.

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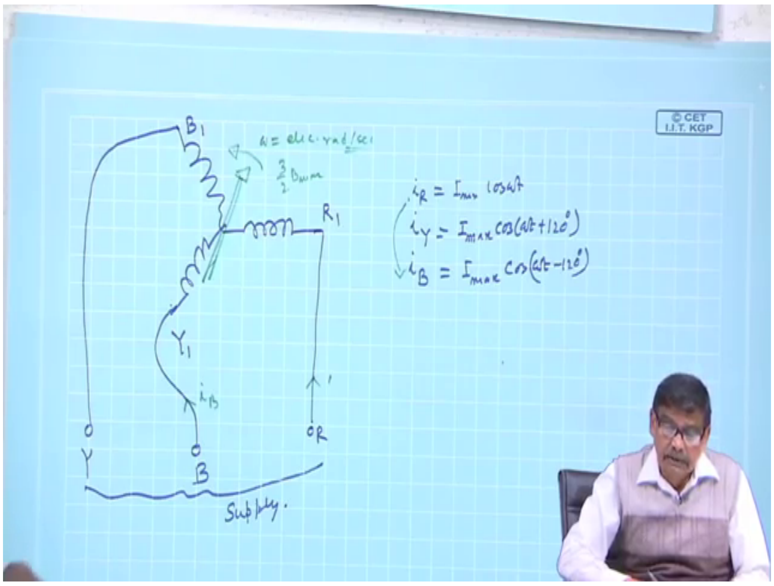

After we have done this, I will ask you a simple question, suppose, I have a winding like this, it is your R 1, this is Y 1 and this is B 1. Now, if this three coils is a energiest once again by balance 3 phase currents, but with the supply phase sequence reversed that is you connect R to R phase R to R phase the supply R to R phase.

Supply Y to B phase, and supply B to this Y axis, these are supply names. Name what happens is this the i R if you call it I max cos omega t, i Y will be leading phase sequence is reversed supply phase sequence, it will be I max cosine omega t plus 120 degree. And i B is equal to I max cosine omega t minus 120 degree, you will find once again the rotating magnetic field this produced, but it will move from it will be doing this resultant field will be produced, but this time it will be moving like this. Because, R phase is the leading I mean leading to lagging it moves R Y B, whichever phase currents lag current so i R is this, i Y carry is a leading current and this is Y.

So, this is i B; i B is let be write this is i R, i B is lagging. So, from R to B, it will move, whoever is lagging i R oh i B is the next lagging. So, it will be move like this in the anti-clock wise direction. Therefore, a rotating magnetic field of constant magnitude will be produced by a balance three-phase coils, which carry balance three-phase currents. And the amplitude of the field is constant and this speed is also constant omega that is the electrical speed electrical radian per second.

So, this actually was first suggested by Nikola Tesla. Before that it was all DC supply and people we are doing this that then he told that if you can see the example is any way in the next class, I will tell that important thing. But, the point is if a balance three-phase winding, the coils are stationary that is the most important thing. And we have been able to produce a rotating magnetic field without mechanically rotating anything ok. And the magnitude of the this field is constant at all time not at omega t is equal to 0 or 30 degree in discrete times, we have shown that it is no matter what is the value of omega t. The this field strength will be always moving ok, we will continue. [FL].