Electrical Machines II
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Lecture - 30
Introduction to Rotating Magnetic Field

Hello. Welcome in our last class we discussed about 120 degree phase spread winding balanced, 3 phase winding and then, at the end we rather started a new topics, ok.

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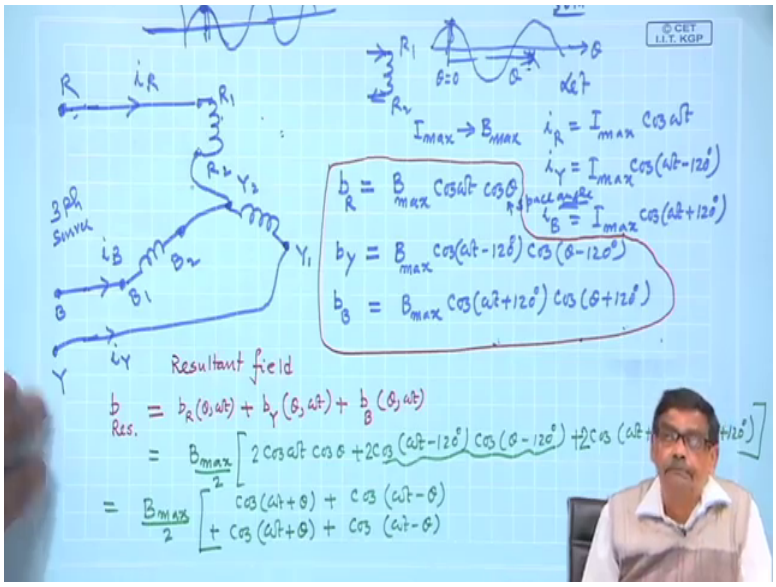

You have a machine with balanced 3 phase winding and with R phase terminals are brought out like this R 1 R 2 terminals and similarly Y 1 Y 2 brought out and B 1 B 2 these terminals are brought out.

And remember R 2 is the global finish of the R phase coil and this is the start of R phase coil globally because there may be several groups, each one of them is having a start and finish and then, if you further go down we have one each coil that has got its start finish, but none the less these are the global things. Therefore, start of R phase coil and Y phase coils start will be displaced 120 degree apart. So, this is how they are drawn, electrical apart. So, this whole angle is 360 degree electrical you can think of nothing wrong in that.

And then suppose you have connected these three in start and what I told is that I will energize it with 3 phase source, here I will connect and the source terminals are R and this is Y and this is B and the phase sequence is RYB supply source. So, this is different from your machine. So, this is the external thing and then, I will connect them with the help of a switch maybe energize these 3 coils and these 3 coils then being balanced is expected to draw from the supply a time varying current i R i B and i Y. Time varying current it is better you show it by small letters that is what I will follow that thing. Therefore, R phase is carrying a sinusoidal current Y phase and B phase too are carrying sinusoidal current.

But they are displaced in time by an angle of 120 degree that we know. Now, we ask ourselves, when a winding carries time varying currents like this, I would like to know what will be the magnetic field in the air gap that is b in the air gap. So, the plan is to do like go like this. That is for individual coil. You find out, you stand at a particular theta at a given position in space you supposed to stand and try to work out what will be the field there.

Now, this field now will be contributed by all the phases because each of them are carrying current, but they are not in phase. That is ok, but at a given instant of time. I want to know what is the resultant field. Therefore, we have to find out the field because of the surface coil, B phase coil and Y phase coil at that particular position theta and then, add them up to get the resultant field that is the thing I want to do.

Therefore, the question now comes that you have R phase coil, R 1 R 2. I know if you pass a constant current of some value i, then you will be getting some field generated that is what I last time I was doing.

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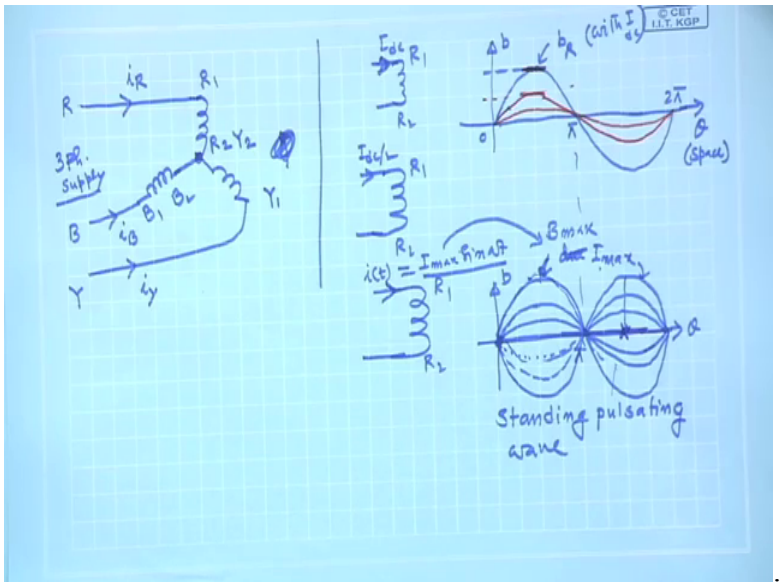

Let us not waste time on describing, but this is important if you pass some DC current. This is supposed these MMF distribution not B distribution in air gap of the machine of a particular coil. Now, if this current is up the amplitude because the maximum value of this b has to do with the number of turns and the current, we have seen this type to a form even if it is having harmonics I can after doing Fourier analysis get the peak value of that.

And it will depend upon the number of turns and i, ok. Therefore, this maximum b will depend upon this current I dc and the number of terms of that phase, ok. That is the thing and if you make the current up, then this will be also up. It will remain sinusoidal, but it will remain up. Further reduce the current, it will too like this and these therefore, I can apply when the coil is carrying time varying current. Now, the time variation of the current is not done by me now, as I was doing this while explaining the things, current will change on its own with respect to time harmonically or sinusoidally.

Therefore, sometimes and suppose the description of the current in time domain is I max sin omega t. So, sometimes current will be 0, sometimes current will be maximum and any values in between sometimes it will be minus maximum value of the current. So, what is going to happen is this. This sinusoidal nature this one top one is suppose corresponding to this I max, you get some B max with time as the value of current

changes. This amplitude gets changed and it will be sometimes doing like this sometimes when negative it will do like this. So, you will get a field patterned.

If you stand at any particular position, he will say the B is changing just standing there you can see and it is sometimes becoming north pole, sometimes south pole. Of course, the amplitudes it is bounded between to peak values that will swing. Now, such a field is called standing pulsating wave, it is not doing any movement this way that way, ok. It is just wave patterned is standing nature of the wave, but it is doing like these amplitudes getting bureau sometimes when the current attains 0 value, sometimes negative maximum, sometimes positive maximum that is what it is going to do is not. Therefore at a particular position because of R phase, this is the variation. Similarly so, this is only for R phase. I have told what is going to happen.

Now, the thing is all these 3 coils are carrying time varying current and these currents if you call it sin omega t Y phase current will be sin omega t minus 120 degree and B phase current will be sin omega t plus 120 degree and therefore, individually Y phase 2 will produce standing pulsating wave, but displaced from it by some angle 120 degree also and similarly, B phase will be doing like that. Therefore, I am not making it much clumps here by trying to plot B distribution.

Because of Y phase and B phase when i R is I max sin omega t i b is I max sin omega t minus 120 degree and so on it will become to clumsier thing, but nonetheless the idea is I will stand at a particular position and want to get the resultant; what I will see there? So, I have to add those 3 b's generated by individual phases and get the resultant. That is the idea. So, idea is very logical I mean. So, this is the thing i R.

Now, this current for the sake of advantage in calculations what I will do is, this let i R be called I max cos omega t because cosine and sin because the currents is sinusoidal it is drawing whether I will call it cosine or sin it is entirely my method. I start counting time. When the current reaches peak value cosine, this is my omega t equal to 0. So, cosine has the advantage cosine minus theta is cosine theta. So, people loves to use cosine terms. I will also do unnecessary juggling with mathematics does not help. So, let us assume i R equal to I max cos omega t. Therefore, I can say that i Y will be I max cosine omega t minus 120 degree all electrical.

And i B is I max cosine omega t plus 120 degree. That is all now. Because of this i R, there will be magnetic field produced in the air gap which I am calling b R and this will be proportional to B max cosine omega t and cosine theta. What is theta? Theta is space angle. Once again you must be very clear in your mind, see B distribution in space is sinusoidal only for fundamental component or I have seen that it is more or less sinusoidal I have made. This is my space angle, in the air gap I want to define a point.

Therefore, choice is entirely with me to choose theta equal to 0. So, I have chosen theta equal to 0 when the maximum value of B max say centre of the south pole that is. So, this will become then this B max cos omega t cos theta. Now, what is B max? B max is the maximum value of the flux density distribution due to I max because after all I know that which time this thing collapses becomes negative as I have told here. So, this B max is because of this I max, I think it is clear to you what I mean to say. So, this is very important, every step you try to understand what I am doing. So, I max gives rise to B max and b R can be expressed in this way.

What is theta? Theta is space angle and I have chosen my theta equal to 0, where B max is at its peak, that is all. If this is b R b y will be also going to I max is not the currents are displaced by 120 degree. So, this B max remains same, but only thing is this current is displaced by 120 degree. So, it will be doing like this cosine theta and whatever space angle you are measuring for R phase maximum, wherever it is occurring you are telling you are standing at a theta somewhere here and since the Y phase is displaced by 120 degree.

So, this will be also cosine theta minus 120 degree, because y is already displaced from R phased axis by 120 degree that we have seen while doing the windings of the machine. In fact, this is what we achieved by having a balanced 3 phase winding R phase mmf and Y phase axis there 120 degree apart, ok. So, this will be b y and b B because of B phase current it will be B max. This current is cosine omega t plus 120 degree and this is cosine theta plus 120 degree. These are the 3 equations.

So, there is in this description there are two things. So, one is a space angle theta and a time variable coming in terms of omega t. What is omega? Supply frequency 2 pi f that has come from some machines generators. So, we do not bother at the terminals what is available this is the thing. Therefore, at a given theta and at a given time you can

individually calculate b R, b y, b B and add them up and tell at this theta and at this omega t b value at that point will be this much, but no point in doing that. Let us try to calculate for any given theta and omega t, what will be the resultant field. Resultant field will be b resultant is equal to b R which is a function of theta omega t theta omega t plus b y. This is also function of theta omega t.

And plus b B this is also a function of theta and omega t as depicted here. These 3 terms you have to add. So, you will write it like this that it will be B max if you add them up. This is common to all take that out and it will be cosine omega t cosine theta plus cosine omega t minus 120 degree. Put these values here simply cosine theta minus 120 degree mind you cosine 120 minus theta cosine theta minus 120 are same.

And plus cosine omega t plus 120 into cosine spaces there theta plus 120 that is all. This will be the resultant field and this is nothing, but B max you divide by 2 and in fact, this step I can do it here. Now, divide by 2 and multiplied by 2 and you know what I am going to do. So, 2 cosine a cosine b that formula I will apply. So, if you apply that formula, it will be cos a plus b plus cos a minus b. So, it will be cos a plus b plus cos a minus b this will be thing. This term if you at cos a plus b will be omega t plus theta this I am writing below plus this plus cos a minus b, this becomes omega t minus theta and then, the last term plus cosine.

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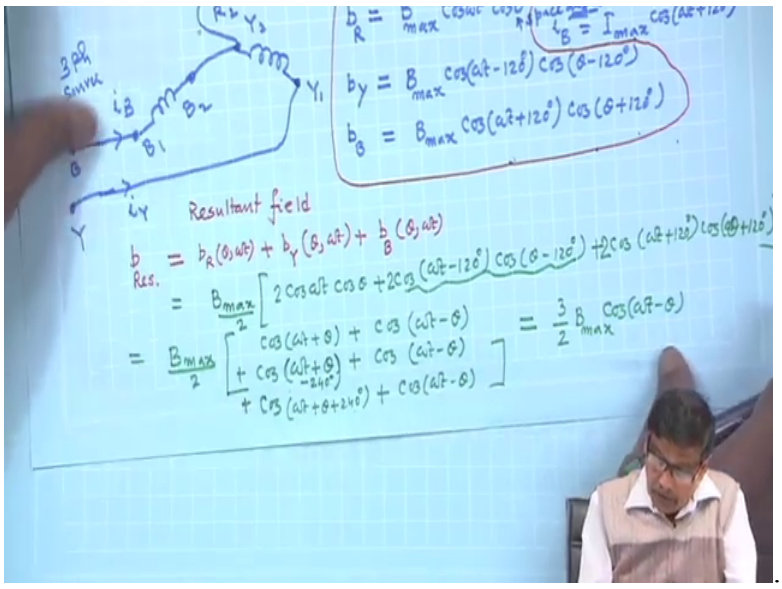

It will become have I missed a point, it will be minus 240 degree, this thing. And this is plus cos omega t plus theta plus 240 degree and this will become plus cosine omega t minus theta. So, all the systems are to be added. Now, why I have written in this fashion is simply because if you look at the terms which are in the first column that we have written, it is cosine omega t plus theta, this is cosine omega t plus theta minus 240 degree and this is cosine omega t plus theta plus 240 degree. What will be the sum of all these 3 terms? It has to be 0 because 3 is sinusoidal terms effectively this is 120 degree apart. You can add 360 degree and subtract 360 degree.

So, it will become equivalent to plus 120 degree. Here it is minus 120 degree. So, any sin cosine terms displaced by 120 degree apart will give rise to 0. Do not try to further I mean expand each of these terms and cancel out these terms cos x plus 120 plus cos x minus 120 will be always 0, no matter what is the value of x. So, this then becomes equal to 3 by 2 B max cosine omega t minus theta that is the thing.

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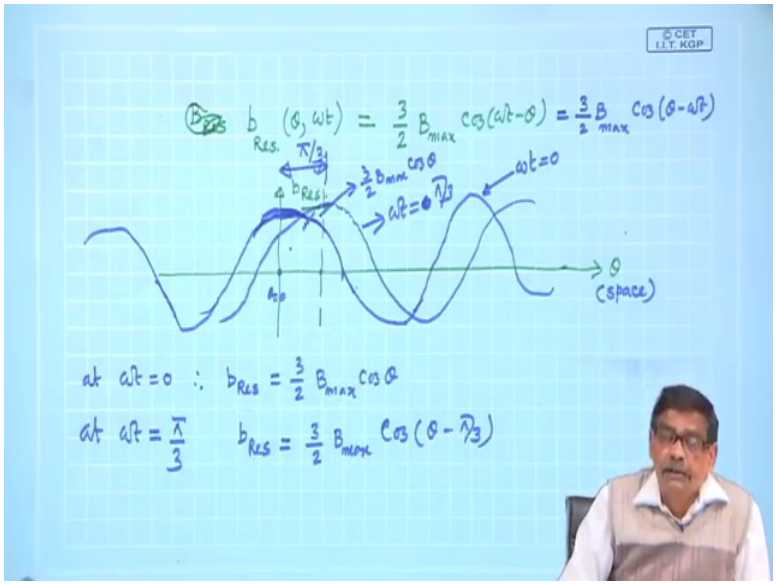

So, B resultant this is one of the most important result b resultant. Sorry I will be using b resultant which will be a function of both theta and omega t becomes this. Individually b R was producing this B max cos omega t cos theta b y like this, but when you add them up at any value of theta and omega t, you can predict the feel that particular position at a given time from this rather simple expression cosine omega t minus theta and now,

suppose I say that ok, that is fine and I want to sketch this way form, what do I do against theta?

Because I am interested to know against theta how this b resultant; b resultant is the important thing. I have taken all the currents in different phases, added them up. So, that will be the resultant field. Now, how to sketch this waveform? So, here I am sketching b resultant. Before that you must notice one thing that what is B max? B max is the maximum value of the flux density distribution contributed by a particulate phase. For example, B max is nothing, but one phase when it carries maximum current, what is maximum field that is all, the b distribution this is B max or in this one it is individually they are standing pulsating wave.

The maximum swing this b will have B max. So, that is known. Now, there are two variables theta and omega t. How to sketch it? I want to get for different theta. Those who knows straight away, they can tell perhaps the result I am telling you it will be a moving pulsating, a moving field it will become, but anyway I will go from fundamental.

What I will do is this since there are two variables, you want to get theta. What you do, you sketch this waveform for different value of time. Are you getting? I will sketch this waveform for different values of time and as you can see that is why I chose this cosine form. This can be also written as 3 by 2 B max cosine theta minus omega t. This is one and the same thing. Cosine theta is cosine minus theta you know. So, it is better we write it in this form. So, as to explain it correctly, suppose I will now sketch this waveform omega t as a parameter, ok. I will say at omega t equal to 0 how this waveform will look like.

This waveform at omega t is equal to 0, the equation b resultant omega t I have fixed is nothing, but 3 by 2 B max cosine theta. So, it will be something like this. It will be something like this. This is my choice theta equal to 0 it also is present here. You must understand these things because it is a rotating machine. Both sides it is there it will be, so with this card I will attach a rider that it is at omega t equal to 0 I am talking about predistribution of the machine which is cosine. It will be like this.

Now, if I say time passes and at say omega t equal to say pi by 3 time passes, such that omega t becomes equal to pi by 3 what will be b resultant? b resultant will be 3 by 2. B

max it will be cosine theta minus pi by 3 is not it will become because omega t is now pi by 3 I have assumed, some time has elapsed.

So, it will be like this and this way firm also I can draw because the equation of this curve mind you it is 3 by 2 B max cosine theta and now I am asking you to sketch a waveform which is 3 by 2 B max cosine theta minus pi by 3, means what? The same waveform which is lagging this omega t equal to 0 waveform by an angle of 60 degree is not that is the thing. Therefore, this peak this is slightly not drawn very it will be suppose this is 90 degree so, 60 degree suppose here. So, this waveform will be with same 3 by 2 B max it will be something like this.

And you attach a rider omega t equal to pi by 3 as I have done. Therefore, as time passes I should know that it is a sinusoidal distribution and it is shifting towards, right. You know it is shifting it take another time omega t equal to 90 degree, then this original cosine waveform have will shifted by 90 degree. So, here this angle is pi by 3. Therefore, for any arbitrary time it will shift by that angle omega t. Mind you this is a sketch of b versus space and time I am attaching like this to each waveform to see that this is nothing, but a moving cosine wave from left to right. Please go through this carefully because this is one of the most important thing based on which induction motors, synchronous motors and various other combination of these two have been developed, ok. So, rotating magnetic field will be the easy topics right now and which is very important.

So, next class I will tell you, if it is moving like this, what is its speed and in which direction it is really moving. I will put it more logically those things in the next class.

Thank you.