Course Name: Design of Electric Motors

Professor Name: Dr. Prathap Reddy B

Department Name: Electronic Systems Engineering

Institute Name: Indian Institute of Science Bengaluru

Week: 09

Lecture: 48

Title: Magnetizing Inductance of Induction Machine

Greetings to all, in the last lecture we have discussed the equations to find the magnetizing current based upon the MMF drops at the various parts of the machine. In this lecture, we will discuss the magnetizing inductance, how to find the magnetizing inductance. The magnetizing inductance we can see here, it can be calculated with respect to the magnetic energy stored at the air gap. Generally, the field energy is equals to half Li square. If you will represent the magnetic energy stored at the air gap in terms of flux density and magnetic field intensity with respect to the volume integral, we can represent like this integral B dot H into dV. If we take the volume integral and if we will convert into two dimensional that is d theta, then lg into lg is nothing but length of air gap into radius from the center point of the rotor to the air gap.

Then length of the core divided by 2 integral 0 to 2 pi B of theta that is flux density is varying with respect to the angle and flux intensity with respect to the angle into d theta. This is the final equation to find the magnetic energy stored at the air gap. Here theta denotes the angular measure in the circumferential direction, r is the radial direction. Generally, we can consider for a machine r is equals to DIs by 2, the distance from the center point of the rotor to air gap.

If we will consider this is the center point of the rotor and this is air gap, so this one we can consider it approximately D Is by 2. Then le is the axial length axial direction, the core length and after performing the integration in radial axial direction, typically the magnetic energy stored equation will be like this. If you want to calculate the inductance, so relate these two equations, equation number 41 and 42. Based upon those two equations, l is equals to field energy divided by I square, that is what we can see here in the equation number 43. Everything will be same as the equation number 42 divided by I square is coming.

By utilizing the equation number 42 and 43, we will calculate the magnetizing inductance. Already we have calculated the magnetizing current, that is I square term we know and we have to calculate the inductance term magnetizing inductance. First we should calculate the magnetic field density and magnetic field intensity, B and H values we will see and then we will do the integration. Based upon the energy equation half integral of B dot H into dV volume integral, so the limits will be minus pi by P to plus pi by P 1 pole pitch into B into H d theta. Here lg will be the length of the air gap and D I s by 2 is the radius from the center of point of the rotor to the air gap midpoint and l e is the length of the core, all three dimensional length we have covered and integral of B into H d theta is nothing but energy stored at the air gap.

Now, the flux density has the identical variation with respect to the stator mmf at the air gap. The flux density value will be what we have considered is a cosine side function Bg is equals to the maximum value into cos theta electrical. The flux intensity with respect to one phase of a three phase thing is nothing but H into l that is mmf is equals to two third of the actual mmf with respect to the three phases. Here we are considering mmf with respect to one single phase. So, Ha is equals to two third of mmf per unit length into cos theta electrical.

Here the mmf total mmf is nothing but peak fundamental stator mmf that is F s 1 is equals to 3 by 2 into 4 by pi number of turns per pole into k 1 is the winding factors into I s. So, this I s we have to calculate at the end that I s is nothing but magnetizing current. So, if we will substitute the B value and H value in the energy equation, energy equation if we will substitute. So, this is the term with respect to the beta and this is the term with respect to the H. Then both B and H values are varying with respect to the angle theta e that is P into theta by 2 and remaining are the constants like Bg 1 and 3 by 2 4 by pi and number of turns poles and winding factor k 1 and current I s everything will be constant will be taken out and the function will be is equivalent to the integral of cos square of theta electrical into d theta.

So, if we will do the integration for this thing cos square theta we can represent as a 1 plus cos theta by 2 theta by 2. Theta 2 theta is nothing but by 2 will be cancelled only P into theta will be there here theta will be mechanical angle. So, if we will do the integration it will be theta by 2 plus 1 plus P into theta by sin p into theta by P substitute the limits. Then the energy stored at the air gap is equals to half bg 1 peak fundamental flux density into 4 by pi into winding factor number of turns into I s divided by number of poles into D I s by 2 into D I s by 2 and pi by P. So, this is the final equation for the magnetic energy stored at the air gap.

Let us substitute the B value and H value and then do the integration. So, both are with respect to the functions cos theta. So, cos square theta divide into 2 parts 1 plus cos 2 theta by 2 and do the integration finally, we will get the magnetic energy stored at the air gap. Now for a balanced winding the flux linking with the each of the individual poles is identical if 4 poles are there flux linking with respect to the 4 poles will be identical. So, the total flux linkages with respect to the per pole is equals to the flux linkages divided by P.

If you want to calculate the flux linkages for n number of poles that will be lambda m s is nothing but flux linkages is equals to number of poles into inductance into current. This is with respect to flux linkages per pole. This equation flux linkages with respect to the P poles. So, we will calculate the magnetic energy stored in the air gap with respect to the P number of poles. Earlier we have calculated the magnetic energy stored in the air gap with respect to the per pole.

Now, n number of poles are there that is P is the number. So, if we will make the multiplication of the magnetic energy with number of poles P then this is the total magnetic energy stored at the air gap that is W m is equals to number of poles into the flux or energy stored with respect to the per pole field energy per pole. Now, by equating the inductance based energy equation and then energy stored at the air gap equation, we can calculate the magnetizing current i magnetizing. So, this is the equation with respect to the field energy stored at the air gap in terms of number of turns per phase and Bg 1 and 2 by pi equation number 41 9 I am explaining. And then from equation number 41 half l i square we can see based upon these two equations we can calculate the magnetizing current per phase.

Here magnetizing current also we know sorry here 40 also we have derived already magnetizing current per phase. So, by substituting magnetizing current and magnetic energy with respect to the all poles then if we will equate of l i square is equals to omega field energy then we will get the inductance value that is magnetizing inductance per phase. The equals to 3 by 2 into 4 by pi number of turns per phase square by number of poles into winding factor square pi D by P is nothing, but pole pitch into l e that B g 1 into 2 by pi will give the average flux density and F s 1 is the maximum mmf per stator with respect to the stator side.

So, after knowing all these variables we can calculate the magnetizing inductance per phase. What in order to derive the magnetizing inductance we have to equate the half l i square is equals to the P total number of poles into the field energy based on that thing we can get the final equation for calculating the magnetizing inductance.

The equation number 50 will give the magnetizing inductance. Once we know the magnetizing inductance and current magnetizing current then we can calculate the voltage at the air gap. Voltage at the air gap peak value is nothing, but V is equals to omega into magnetizing inductance into magnetizing current. So, V gap rms like voltage at the air gap rms value is equals to 1 by root 2 of peak value of the voltage at the air gap. If you want to calculate the rms line to line voltage into root 3 will give the rms line to line voltage.

So, by calculating this voltages at the air gap then we can modify the required supply voltage with respect to the required supply voltage how much maximum value of B g is possible and how much mmf is possible at the air gap. To mmf required to establish the actual flux density at the air gap we can recalculate it by knowing the voltage at the air gap. With this I am concluding in this lecture we have discussed the equations to find the magnetizing inductance per phase and then how to calculate the voltage at the air gap. Thank you.