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: 08

Lecture: 41

Title: Design of Induction Machine- Rotor Design -2 (Rotor MMF and Bar Currents)

Greetings to all, in the last lecture we have started the rotor core design right and we have discussed the how to select the number of rotor slots and how to select the air gap length. In this lecture we will continue the rotor design and we will discuss on the rotor winding how to select the number of bars and how to select the bar thickness and bar cross sectional area and bar current and etcetera. First I will start with the rotor winding. We will find the number of bars. The number of bars is equals to number of rotor slots Nb equals to Qr. Then we will calculate the bar current first.

For calculating the bar current, let us consider the MMF whatever we are sending from the stator side in between air gap is there. This is air gap and at the rotor side we are seeing rotor MMF. Whatever the MMF we are sending at the stator side, it is a combination of two parts. One is with respect to the air gap MMF for establishing the flux at the air gap and second thing is second part with respect to the stator MMF is torque component.

Stator MMF is a combination of the MMF required to establish the flux at the air gap and MMF required to deliver the required torque. If we will take the rotor MMF is equals to MMF at the stator side into some gamma MMF factor because in a practical machine we have the air gaps. There can be a loss also this gamma MMF represents the factor to match the rotor MMF and stator MMF. The MMF at the stator side is a combination of air gap flux plus torque component. MMF is nothing but N into I, the number of conductors or number of bars at the rotor side is nothing but Nb and current flowing through each bar is Ib and MMF at the stator side will be number of conductors into current flowing through each conductor into gamma MMF.

Here Z is nothing but 2 into number of tons per phase into total number of phases into I phase into gamma MMF. Generally gamma MMF will be 80 to 90 percent it is a factor. From this equation we can find the bar current, bar current is nothing but 2 into N phase into m into I phase into gamma MMF divided by number of conductors or number of bars at the rotor side. From here we know the bar current Ib RMS, here Ib RMS we can take I phase RMS. So, Ib RMS current we know from this equation number 30, I think yeah this is equation number 30.

Once we know the bar current then area of bar we can calculate it, area of the bar or cross sectional area of the bar is equals to I bar current RMS divided by Jb current density of the rotor bar. Current density of the rotor bar we have to calculate depend we have to select depends upon the which type of bars we are utilizing. For aluminum bars or copper bars we can select 5 to 7 ampere per mm square for designing the rotor. In order to increase the efficiency gamma MMF should be increased, gamma MMF factor we are considering 0.8 to 0.9. For increasing the efficiency the gamma MMF factor should be increased. Then the maximum current we can get at the rotor side if the maximum current we are getting at the rotor side then the maximum mechanical output power we can get at the output side eventually we can increase the efficiency. Now we will see how the bar current waveform looks like from that bar current waveform we will visualize what is the end ring current and end ring areas. So, here we can see the squirrel cage rotor this is the skewed rotor with n number of rotor bars and whatever the ending side this is the end ring, end ring depth will be this much and end ring length will be this portion.

If we will see here this is the thickness of the end ring and this is the width of the width or depth of the end ring and this is the thickness of the end ring that we can see here. So, the depth will be this one d e and thickness will be this one after the bar length whatever it may be the length it is coming after the bar that is the thickness of the end ring. Now we will calculate what is the current flowing through the end ring and what is the thickness of the end ring. In order to find the current flowing through the end ring we will see the rotor structure first. rotor has like this n number of bars and this is the end ring portion.

Consider here current is flowing through the all bars and half of the bars we will see the remaining current. So, the bar consist of all currents combination of all current or if we will see it will be a structure of the resistances in this manner. The current at this particular point will be combination of all branch currents. Here let us say I b, I b is nothing, but I 1 plus I 2 at this particular node. Similarly, if we will consider here one node the current with respect to this 5 bars will come together and flowing with respect to this particular point, this particular node.

Similarly, current is splitting into two parts. Current can go in two ways in a end ring and here entering in from both sides because it is a circular structure. The bar currents will be in this manner and end ring is carrying current combination of all bar currents. So, if we will draw the bar current waveform Ib. So, with respect to the bars we will see the bar current in this manner.

These are the induced bar currents with respect to the rotor structure. Now, end ring is nothing, but combination of all these currents. If I will consider the average current with respect to the half cycle all currents are in upward direction. I am assuming the average current will be same with respect to the bars all bars. Here current will be in opposite direction.

This is for bar current average currents. Now, the end ring current is nothing, but combination of all bar currents where we will see the maximum current means the combination of all these currents will flow from this direction to this direction or half of the current is flowing in this direction and half of the current is flowing in this direction, but on one particular junction we will see the maximum current here. So, at this particular point we will see the maximum end ring current and it will be varying with respect to the sinusoidal manner in a same way like bar current, but why it is 90 degree phase shift means at this particular point only we are seeing the maximum current. So, this is the bar current sorry end ring current I end ring current. So, whatever the current is flowing through each bar is splitting into two parts and flowing in the end ring.

Now, the current flowing through the end ring is equals to how many number of bars are coming with respect to one pole. This is with respect to one pole right one pole pitch. So, with respect to one pole pitch how many number of bars are coming that number of that many number of bars by two right I end ring current is nothing, but this current is splitting into two parts and here entering into the two parts and flowing through the bars and leaving in two parts right if requires we can draw the diagram. So, here bar current is entering here and leaving in two directions and entering also in two directions right consider here current is entering and here also current is entering so, current is entering into this bar in this way here leaving from the bar in this way similarly all bars having some current and the total end ring current is nothing, but I b into the bars per pole number of bars per pole bars per pole by 2. So, here bars per pole is nothing, but number of bars is nothing, but N r by P into 2 this is I b current flowing through the each bar.

Let us consider this current is I b maximum. So, the total current is flowing through the end ring is nothing, but I b maximum into N r by 2 P. Now, we have to calculate the what is end ring current maximum since the I r is a sinusoidal quantity end ring current to find the maximum value I r maximum is equals to 2 by pi I b maximum into N r by 2 P this will give Nr into I b maximum divided by P into pi this is equation number 31 this is the maximum current flowing through the end ring.

Now, what is the end ring current in terms of rms to find the area we require the rms value right I er is equals to rms both sides we have the peak values. So, by root 2 by root 2 we can do it and N r into I b rms by number of poles into pi this is equation number 32.

So, here both I er as well as I b bar current and end ring currents are sinusoidal quantities. Once we know the rms current of the end ring we can find the cross sectional area of the end ring A c r equals to in terms of I er rms by current density of end ring. So, current density of end ring we have to select depends upon the aluminum or copper which type of material we are utilizing to design the end ring based on that thing we have to select the current density. From here a area of cross section with respect to the end ring is known, but from the design we can see here rotor structure here area of the end ring is equals to this one is the depth into thickness right depth is nothing, but d e and thickness is nothing, but t e right depth of the end ring into thickness of the end ring x axis into y axis length is nothing, but the area. So, from these two equations we can find the d e r and t e r, but these two are the two unknowns right we know the area of cross section, but two unknowns we have.

So, one value either depth of the end ring or thickness of the end ring we have to assume one value if we are assuming d e r then calculate the t e r. One value we can assume and other value we can calculate it this is the way to calculate the bar current end ring current and area of the end ring and area of the bar. We can see here the bar currents will be sinusoidal and it these currents are induced depends upon the rotating magnetic fields I am repeating it and average current if I will consider almost same in all bars if I will assume then the currents will be in this manner this currents entering in one bar is leaving into two parts in one direction in other direction I b by 2 and other direction also I b by 2 like that how many bars are there per pole that is nothing, but bars per pole with respect to one particular conductor we are seeing I b by 2 in a end ring with respect to the n number of bars per pole that is Nr by P this is the total current that is what we have derived here. So, the end ring current is equals to I b into Nr by P into 2. So, this is the I bar current sorry end ring current with respect to the maximum bar current and the maximum end ring current with respect to the maximum bar current and area of the end ring and area of the bar we can calculate it with this I am concluding this lecture.

In this lecture we have discussed the how to calculate the bar current and how to calculate the end ring currents. In the next lecture we will discuss about the slot geometry of the rotor core. Thank you.