Course Name: Design of Electric Motors

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Title: Efficiency and Loss Calculation of SRM

Greetings to all in this lecture we will discuss the loss calculations as well as efficiency analysis of switched reluctance machine. The analysis with respect to the efficiency is same as induction machine, here also we will see the copper losses with respect to the stator winding there is no copper loss at the rotor side and core losses in both stator as well as rotor. But while calculating the core losses hysteresis and eddy current losses we should not go over ahead with changement constant we have to follow the method one what we have discussed during induction machine analysis that is loss per kg with respect to the operating flux densities what will be the losses per unit per kg we can consider into mass will give the core losses and mechanical losses will be same that equations we will see once again. Here we can see the losses happening in switched reluctance machine copper losses and core losses and mechanical losses and the advantage with respect to the switched reluctance machine will be there is no windings at the rotor side because of that reason there is no copper loss at the rotor side. And how to calculate the copper loss means that is simple power is equals to I square or loss and we have to consider the temperature effects and AC resistance effect with respect to the skin effects and proximity effect also we have to consider and resistance is nothing, but rho l by a and length of the total coil we have to calculate and resistivity of the material copper we have to select and cross sectional area of the wire based upon that thing we can calculate the resistance and this resistance is nothing, but at the atmospheric condition or ambient temperature if we will vary the temperature based upon the losses or operating temperature we have to calculate the copper loss and here ms is nothing, but the number of phases conducting at one particular instant or complete how all number of phases we can consider here total number of phases. And then resistivity with respect to the different materials we can see here resistivity with respect to the aluminum resistivity with respect to the copper and resistivity with respect to some insulating materials also we can see here and temperature coefficients also we can see with different materials for copper temperature coefficient will be 0.0068.

So, based upon the temperature coefficients and resistivity we have to calculate this copper losses here ms is representing the number of phases. And for core loss calculations we have to follow with respect to the method one what we have discussed in case of induction machine here the stingman coefficients and other frequency terms will not come in the SRM that will give the some wrong calculations. So, here power loss factor into mass we can consider for doing the core loss calculations first identify the maximum operating flux density points with respect to all regions.

So, based upon let us say we are calculating the core loss with respect to the stator back iron what is the operating flux density. Similarly flux density at the stator pole based upon this flux density values we can calculate the loss per kg let us say flux density value 0.8 tesla. So, with respect to different frequencies we can find the losses here. So, here frequency representing from one position of the rotor to next position what will be the time required based on that time we can calculate frequency here.

And for a grain oriented electric steel and non grain oriented electric steel what is the loss per ah kg we can see in these two ah images and the references also I have presented here. And mechanical losses and bearing losses also equations will be same the mechanical losses are equals to bearing losses plus windage losses the bearing loss depends upon the shafts feed bearing type and properties of the lubricants and load on the bearing. And windage losses with respect to the friction between the rotating surface and surrounding airs we can see the windage losses. And the windage losses we can are divided into two types the loss with respect to the air gap region and loss with respect to the end end ah region of the rotor. And bearing loss equation is this one it is same for a induction machine as well as the switched reluctance machine and omega e represents the angular angular frequency of the shaft and mu represents the frictional coefficient and F represents the load acting on the bearing and D is nothing, but inner diameter of the bearing.

And windage losses we can calculate based upon this equation this in detail about this equations already we have discussed. And these are the windage losses equation how the ah Reynolds number is depends upon the windage losses or influence the windage losses and with respect to different ah different Reynolds number and different windage losses we will get it. So, that we have to analyze in detail and torque coefficients ah for windage losses with respect to the ends of the rotor will be like this manner and here tip Reynolds number we have to consider. So, based upon the Reynolds number with this equation we can we can calculate the windage losses at the end of the rotor and stray load losses the losses with respect to the load current and it is spatial harmonics caused in the windings and laminations and frame and etcetera with the losses which are not considered in the windage losses or copper losses and core losses. The remaining losses we can consider it as stray load losses that are ah in terms of percentage also we can consider for induction motor it will be 0.3 to 2 percent and for salient pole synchronous machines 0.1 to 2 percent the same for ah switched reluctance machines also it will be in the range of 0.1 to 0.2 the stray load losses. The detailed analysis with respect to the efficiency calculations we can see in this literature the loss and efficiency calculations of switched reluctance machine using the ah different analytical method.

Here also the power loss coefficient they are calculating that power loss coefficient in terms of ah loss per kg into mass we can consider. So, if we will go ahead with hysteresis coefficients and the stingman coefficients the analysis is ah not accurate. So, for that thing some equations they have derived in this literature the eddy current losses we can see here. This is the equation for eddy current losses and this is the equation for hysteresis losses here also the mass into the power loss coefficient will give the hysteresis losses. If anyone is interested ah they can go through this literature to find the loss and efficiency analysis of switched reluctance machine.

And now we will discuss the data sheets or design specifications of the switched reluctance machine. This is one switched reluctance machine data sheet with respect to the KEHUI application note and the advantage of switched reluctance machines we can see lower starting current and higher starting torque, robustness, simplicity and reliability and higher overload capability and excellent dynamic response all these are advantage and how it will work with respect to this data sheet we can see the efficiency curves as per the standards also we can see here. These are the efficiency standards or efficiency constant torque efficiency curve and varying load efficiency curve with respect to the at the rated speed here output power and efficiency. The blue color line representing the system efficiency and red color line representing the motor efficiency. The technical details with respect to the controller as well as motor we can see here rated voltage is 514 volts DC and insulation class we can see here and working system continuous work system S 1 and S 5 the duty we can say in this with respect to the standard it will come in S 1 as well as S 5.

S 1 represents the continuous load type and S 5 represents the intermittent cycle work including the electric brake like in intermediate loads it will support with respect to the S 5 standards and S 1 standard for continuous loads supporting and protection level IP 54 what we have discussed with respect to the induction machine it will be same and overload capability 150 percent rated torque for less than 60 seconds and 200 percent rated torque for less than 30 seconds and 300 percent rated load torque rated torque for less than 15 seconds this is the overload capability. So, for example, if we will apply the 300 percent rated load greater than 15 seconds then the machine will not able to deliver that much torque and it may damage and temperature check and motor standard also we can see here the details about motor standards are given here KSM is represents the product type and one represents the motor design sequence and 315 represents the motor size and height of the output shaft axis and the remaining details also we can see from this data and this is the controller specifications as per this designer and these are the controller technical parameters and same way with respect to the literature as per the IEEE explorer. So, this is another reference to design the 50 kilowatt switched reluctance machine. So, we can see the comparison of switched reluctance machine with IPMSM. So, what is the outer diameter stack length and shaft length and straighter to rotor air gap and winding type and wire diameter etcetera we can see here and torque density and maximum efficiency and maximum output power and maximum power speed range all those things we can see here.

So, whatever the analytical equations we have discussed we can calculate for 50 kilowatt machine and we can verify with respect to this paper and same way we can see here different details with respect to the prototype air gap and iron core material and wire diameter and number of turns slot fill factor and etcetera and different materials also what type of materials used for this designing this machine also we can see. So, this is the another design for 60 kilowatt machines how the what is the outer diameter and rotor outer diameter stack length and torque, DC link voltage and start fill factor, iron loss efficiency etcetera and these are the different type of materials used for motor construction. So, if anyone is interested they can calculate with respect to the equations what we have discussed related to the SRM based on that thing they should get the numbers approximately near to this numbers given in these three literatures and this is specifications with respect to the 60 kilowatt motor. So, the data sheets with respect to the switched reluctance machine for high speeds where they can go through this literature and for normal machines for 50 kilowatt we can they can see this literature and with respect to this company manufacturer application note they can go through this literature also. So, with this I am concluding this lecture.

In this lecture we have discussed the loss calculations and efficiency analysis of the switched reluctance machine and the data sheets with respect to the switched reluctance machines. Thank you.