Course Name: Design of Electric Motors

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Title: Calculation of SRM Inductance: Aligned Inductance -2

Greetings to all, in the last lecture we have discussed the inductance calculations with respect to the aligned condition of switched reluctance machine right. So, in this lecture also we will continue the same thing like how to calculate the inductances of a switched reluctance machine based on analytical approach. We can see here in with respect to last lecture with respect to the region 1 flux path 1 we have calculated and flux path 2 we will calculate in this lecture. So, in with respect to flux path 2 that is leakage flux path 2 we have 4 loops this is 1 2 3 4 leakage fluxes n is equals to 4 here in the first step. And in the second step we have to find the length right step 2 with respect to the path 2 what will be the length of flux path l equivalent 2 is equals to length of the stator pole 2 that is we can consider the flux loop in this fashion for easy analysis. So, even though it is flux lines are flowing in this fashion.

So, we can approximate the shape of the flux loop in this fashion this is the flux path with respect to the stator yoke and this is the flux path with respect to the stator pole and this is the arc length with respect to stator slot air gap region. So, we can see the flux path here this is the one. So, like this flux lines are flowing I am approximating as a quadrature of the circle that is one fourth of the circle we can assume based on that we can calculate the length we can see here this pink color loop. So, this is the leakage flux loop here and here as well as here.

So, length of the flux path in the stator pole and length of the flux path in the air gap region that is stator slot region plus length of the flux path in stator yoke region. Consider the length of flux path flowing through the stator pole is hs by 4 this region this length will be hs by 4 I am assuming here hs is nothing, but stator pole height flux path is equals to hs by 4 hs I am considering as length of length or height of the stator pole. So, one quarter portion only this leakage flux is flowing I am assuming this thing equation number 20 and length of the flux path in stator yoke is equals to again hs by 4. I am assuming with respect to the quadrature of the circle right angle based. So, this region also I am assuming hs by 4 and this region also I am assuming hs by 4 and this arc length we can calculate based upon the quadrature of the circle and length of air gap region with respect to the stator slot is equals to r into theta right. So, here r is nothing, but h s by 4 theta is nothing, but pi by 2.

So, it will this is equation number 22. So, these are the three different parts of the flux path 22 and lengths we have calculated with respect to this way here length with respect to the stator pole length with respect to the stator yoke I am assumed I assumed as h s by 4. So, this numbers we can vary also because the leakage flux magnitude is very small. Next we will calculate the cross sectional area. Step 3 cross sectional area with respect to the stator pole region.

So, this is the cross sectional area right. So, here flux lines are flowing in this direction pink color line you can see here if not I will use black color line. So, flux lines are flowing here in this direction similar parallel to the pole axis. So, we have to find the perpendicular area with respect to the blue color one perpendicular to that flux lines flow that is one-fourth of width of stator pole I am considering x axis length and y axis length into length of the core I am assuming. So, if requires I will draw that thing.

So, this is the stator pole right. So, here the leakage flux the leakage flux lines are flowing in this fashion. So, this width is nothing but one-fourth of width of stator pole I assumed and this width also and to calculate the area one-fourth of dcs that is width of the back iron we can assume. Then based on that thing we can calculate area with respect to the air gap region of slot region this is this one this area this region area we have to calculate Ags2 is equals to h s by 4 x axis length into y axis length l e I am calculating. So, here flux lines are coming in this fashion right to the slot region.

So, the perpendicular area will be height is nothing but h s by 4 into y axis length will be le based on that thing this area of cross sectional area with respect to the air gap region we can calculate in this fashion this air gap region in terms of slot stator slot region area with respect to the stator yoke is nothing but one-fourth of actual depth of stator yoke or stator back iron because the leakage flux I am considering one-fourth of the flux width of the stator yoke. So, this width I consider as one-fourth and then into length of the core.

So, this is equation number 23 with respect to the step 3 we have calculated the area also and step 4 we have to analyze the magnetic equivalent circuit. So, the leakage flux is flowing through the stator like we can see here. So, this is F2 mmf 2 because the mmf with respect to the leakage flux is very small right the mmf responsible to produce the leakage flux we can assume F2 is equals to one-fourth of F actual m m f or even small also we can consider either one-fourth to one-sixth or one-eighth we can consider the m m f which is responsible to with respect to the leakage flux.

So, this is F2 and then the magnetic capacitance with respect to the stator pole and then magnetic capacitance with respect to air gap in the slot region and then magnetic capacitance with respect to the stator yoke. So, this is with respect to one loop. So, like this four loops we have that we can observe in this figure. So, this is loop 1 loop 2 loop 3 and loop 4 these circles are the valence. So, flow variable will be d phi 2 by d t.

So, based on this thing we can analyze the equivalent circuit with respect to the network analysis and equivalent reluctance we can get it reluctance effective reluctance is equals to reluctance with respect to the stator pole reluctance with respect to the stator slot region reluctance with respect to the stator yoke region this is equation number earlier equation number 23 this is 24 and 25.

So, how this equation has been derived means based upon the equivalent circuit analysis that is 1 by C magnetic capacitance equivalent equivalent is equals to 1 by magnetic capacitance with respect to the stator pole plus 1 by magnetic capacitance with respect to the stator yoke plus 1 by magnetic capacitance with respect to the slot region. So, from this equation we have to derive this thing this is equation number 25 then we can write this is equation number 26.

After calculating the reluctance we can find the flux with respect to the path 2 flux is nothing but the m m f which is responsible to produce the leakage flux that is one-fourth of N phase into I divided by effective reluctance that is r equivalent to equivalent 2 this is equation number 27 then reluctance with respect to the stator pole reluctance with respect to the stator yoke reluctance with respect to the gap region that is in terms of stator slot region we can calculate. So, stator pole will be l length of stator pole with respect to the leakage flux path divided by mu naught mu r into cross sectional area of stator pole 2.

So, length also we have calculated area also we have calculated then we can get the reluctance same way we can calculate this one as well as this one. So, already length with respect to the stator yoke and area of cross sectional area with respect to the rotor stator yoke also we have calculated same way the reluctance with respect to the gap region we can calculate based upon this cross sectional areas in step 3 and length in step 2.

So, this is equation number 28 finally, with respect to step 5 we can calculate the inductance with respect to the flux path 2 l is equals to number of loops into n phase into phi 2 divided by I this is equation number 29.

So, from this equation we can calculate the inductance in aligned condition with respect to flux path 2 the number of leakage flux paths in this figure in aligned condition are 4 into N phase into phi 2 divided by I. So, here phi 2 is nothing, but one-fourth of the actual mmf divided by equivalent reluctance of flux path 2 then the resultant inductance in aligned condition.

So, complete inductance with respect to the aligned condition aligned condition inductance is equals to summation of these two flux regions flux region 1 is with respect to this one and flux region 2 is with respect to the leakage fluxes region 2 and region 1. So, l a is equals to sigma j is equals to 1 to x l a j will give the final aligned inductance. So, here l a is equals to with respect to two regions l a 1 plus l a 2 that is aligned inductance with respect to flux path 1 aligned inductance with respect to flux path 2 this is equation number 32 in l a 2 is nothing, but equation number 30 and l a 1 we have calculated in the earlier lecture. So, we can based on this equation we can calculate this is equation number 18 and equation number 19. So, this is the final inductance equation to calculate the aligned inductance this is the equation with respect to the aligned position.

So, the regions we have with respect to the flux part we have divided the regions like region 1 and region 2. So, with respect to the region 1 the inductance will be l a 1 with respect to the region 2 the inductance will be l a 2. So, finally, the sum of these two inductance will give the actual aligned inductance value same way we can calculate the inductance for unaligned position this is the flux plot with respect to the unaligned position. So, this is the actual flux plot with respect to the FEMM simulation and this is the flux plot considered for analytical calculations here we can see the same assumptions in the stator back iron and rotor back iron we will consider the flux lines are in concentric circles and in the stator pole and rotor pole we will consider the flux lines are in parallel with pole axis and in the air gap that is in this region. In this region the flux lines are considered similar to the flux lines flowing in the actual flux plot the highlighted portion we can see here with respect to this plot I am redrawing the flux lines here.

So, from this flux plot we have to divide the regions or we have to find the flux loops similar flux loops to analyze the inductance let us say with respect to the this green color one consider flux region one. So, this is region one and this pink color one you can consider as region two and green color one as region three and this one as region four the lines which are flowing in this manner and leakage fluxes we can consider it as region five. So, in order to calculate the inductance with respect to the unaligned condition the flux plot we have divided into five regions based on this five regions we will calculate the inductance that is inductance with respect to the unaligned condition is equals to sigma j equals to 1 to x l u i here x is equals to five like we have divided the flux plot into five regions. So, unaligned inductance with respect to the region one unaligned inductance with respect to the region two unaligned inductance with respect to the region four same way up to region five we have to calculate at the end we can add all those inductances then we can get the final inductance with respect to the unaligned condition. So, here l is equals to unaligned inductance number of similar flux loops into n phase into five flux with respect to each and every region divided by i.

So, final inductance we can calculate from this equation, but each and every inductance with respect to the each region we have to calculate based upon this equation. Same way we can calculate the inductance in intermediate positions we can see here the how the flux lines are flowing from aligned position to unaligned position step one step two step three and step four and step five exactly it will reach to the aligned unaligned condition each step the angle is 5.625 degrees. So, here also we have to find the number of flux regions with respect to the actual flux plot. So, let us say this one in this flux plot we have to divide this flux lines or flux plot into different regions let us say this is region one and this is region two and this is region three and this is region four and leakage fluxes are there means that is region five.

So, with respect to all these regions we have to find the inductance in intermediate positions also based on that thing we can find the inductance. So, intermediate inductance with respect to aligned to unaligned position we can calculate it is equals to sigma j equals to 1 to x x is representing the regions like five regions I am assuming here with respect to the flux plot or more number of regions also we can assume for accurate calculation of the inductance x is x is nothing, but 5 l intermediate inductance with respect to each and every region. So, this intermediate inductance with respect to the region is equals to number of similar flux loops into N phase into flux with respect to the that particular region divided by current.

So, based on these two equations we can find the inductance during intermediate positions also. So, with this I am concluding this lecture in this lecture we have discussed the procedure to find the inductance of SRM in aligned position unaligned position and intermediate positions. Thank you.