Switched Mode Power Conversion

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Lecture - 10
Energy storage – Inductor

Good day to all of you. In this session we will see a few more problems relating to magnetic circuit elements. We will look at few problems here related to coupled inductors electromechanical energy transfer in the inductive circuits as well as non-linear inductors. We will solve a few problems relating to these aspects and then in the following sessions, we will go on to power conversion circuits.

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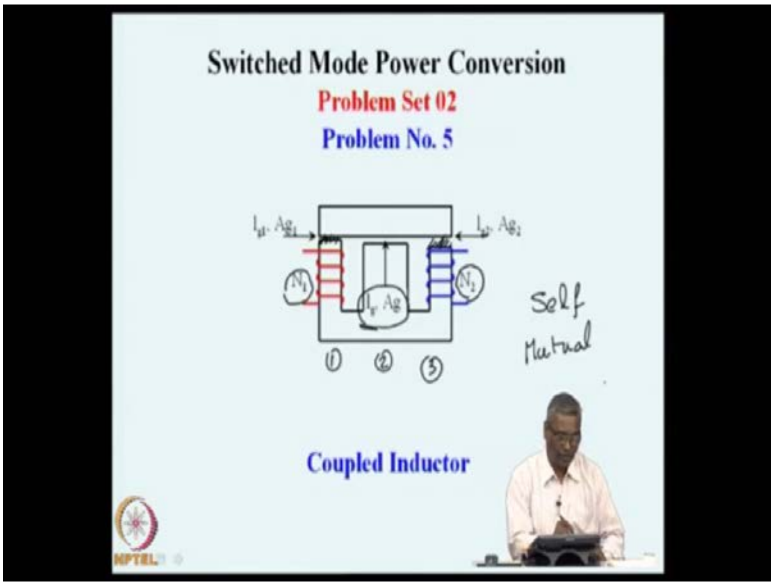

What you see here on the slide here is a coupled inductor, what you notice is an induct a magnetic circuit which has 3 limbs 1 2 and 3. There is a winding of N 1 turns on limb one and N 2 turns on limb 2 and limb one has a certain air gap l g 1 and an area of cross section of the magnetic path A g 1 and a limb 2 has a slightly larger gap l g 2 with an area of cross section A g 2 and then the middle limb has an air gap of l g and an area of cross section of A g as you see here.

The magnetic circuit has 2 windings, each of these windings will have a self inductance and these 2 windings will also have a mutual inductance. So, this kind of an inductor is a coupled inductor. There are 2 windings they are couple to each other with a certain coefficient of coupling. So, we wish to analyze this circuit and try to find out what are the self inductances and what are the mutual inductances?

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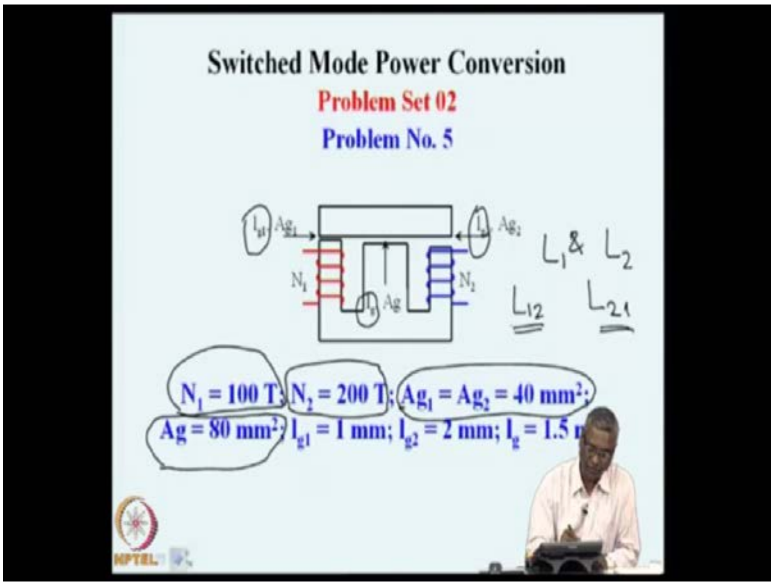

If we look at the geometry of this circuit the various gap lengths and area of cross sections are given here the gap one, l g 1 is 1 millimeter, l g 2 is 2 millimeter, l g is 1.5 millimeter, l g 1 is 1 millimeter and then the different areas of cross sections are also given. The outer areas are equal and they are 40 millimeter square each and the middle area is double the outer area which is 80 millimeter square in the central limb.

The number of turns are given here, the limb one carries 100 turns and the second limb the right-hand side limb carries 200 turns. In this particular geometry, we wish to know what are the various self inductances L 1 and L 2 and we also wish to know what is L 1 2 that is mutual inductance between the windings one and 2 in one direction, and in the other direction 2 one?

What is the mutual inductance on L 1 on account of current in second winding, the mutual inductance on winding 2 on account of current in winding one? So, these are the mutual inductances. So, we wish to evaluate these quantities. So, let us see how we get these numbers. We can see that this circuit has 2 excitations on the outer limbs N 1 and i 1 and N 2 i 2, where i 1 is the current in limb one. i 2 is the current in the winding 2 and then, the flux produced by this outer limbs find the return path through the central limb.

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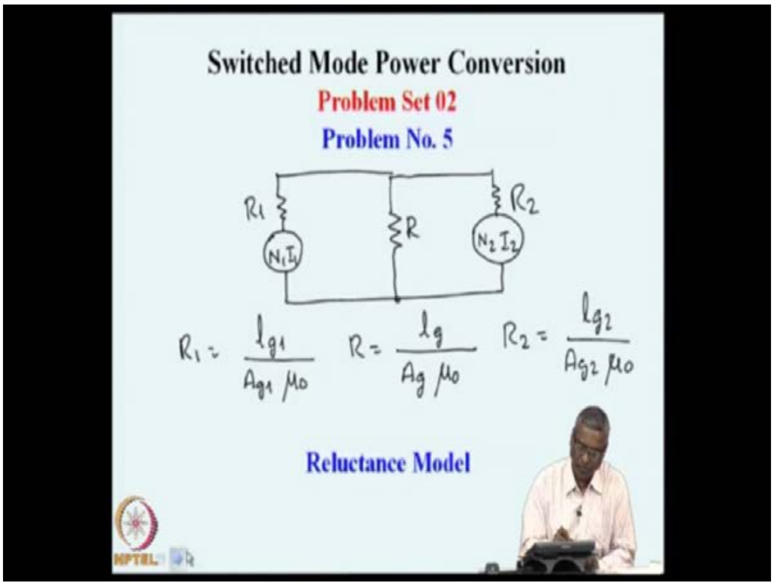

And it is possible for us to find a reluctance model for this particular circuit where you have N 1 I 1 is the excitation on limb one. N 2 I 2 is excitation on limb 2, in limb one has a reluctance of R 1 and the outer limb on the right-hand side has a reluctance of R 2. And the return path is through the central limb and central limb has no excitation, but has a reluctance of R. So, these reluctances, all the reluctances R 1 can be return as l g 1 divided by A g 1 and mu naught because the reluctance is mainly by the air gap and the magnetic material is assumed ideal and does not contribute to the reluctance.

And R will be l g divided by A g mu naught. The central limb has certain air gap and there also the reluctance is dominated by the air gap reluctance and we neglect the iron reluctance, and the outer limb 2 has a reluctance of l g 2 by A g 2 mu naught. So, it is possible to find out each one of these reluctances by evaluating that with the given dimensions that we have here.

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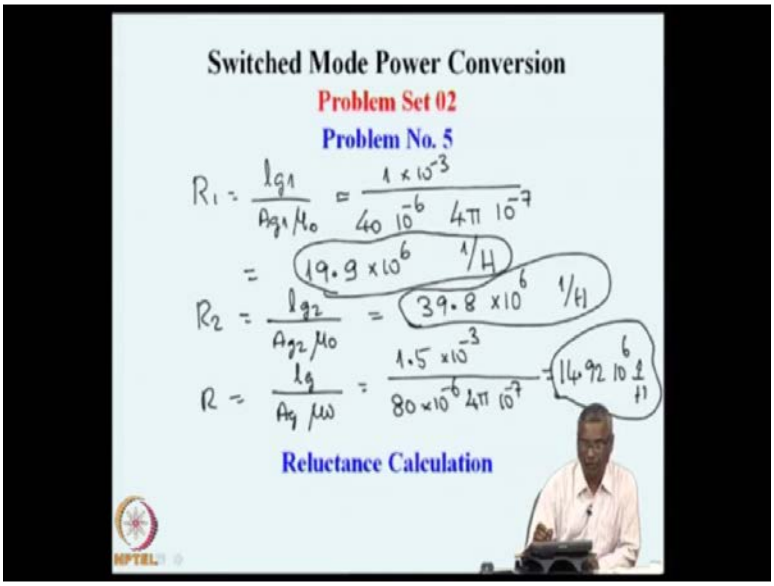

For example, Reluctance Calculations can be done now R 1 is l g 1 divided by A g 1 mu naught that is 1 10 power minus 3. All the units are in meter kilogram second system. A g 1 is 40 millimeter square, in meter square it is 40 into 10 power minus 6 and mu naught is the free space permeability, which is 4 phi and power minus 7.

This number if we evaluated, this turns out to be 19.9 into 10 power 6 in unit is 1 by Henry. As l has a unit of meter, A g has a unit of meter, will mu naught has a unit of Henry per meter. So, effectively the reluctance one has 19.9 into 10 power 6 per Henry.

Similarly, it is possible to find out what is R 2 R 2 is l g 2 divided by A g 2 mu naught and because l g 2 is double l g 1. All other quantities being equal, we can say that this is 39.8 into 10 power 6 1 by Henry. And the middle limb reluctance is given by l g by A g mu naught in the middle limb has a gap of 1.5 millimeter 10 power minus 3 divided by area of cross section 80 into 10 power 80 millimeter square, it is 80 into 10 power 6 minus 6 meter square multiplied by 4 phi 10 power minus 7 and this quantity is 14.92 into 10 power 6 unit is one by h. So, these are the 3 important quantities here. R 1 is 19.9 into 10 power 6 per Henry. R 2 is the 39.8 into 10 power 6 per Henry and R is 14.92 into 10 power 6 per Henry. So, all the reluctances have been calculated.

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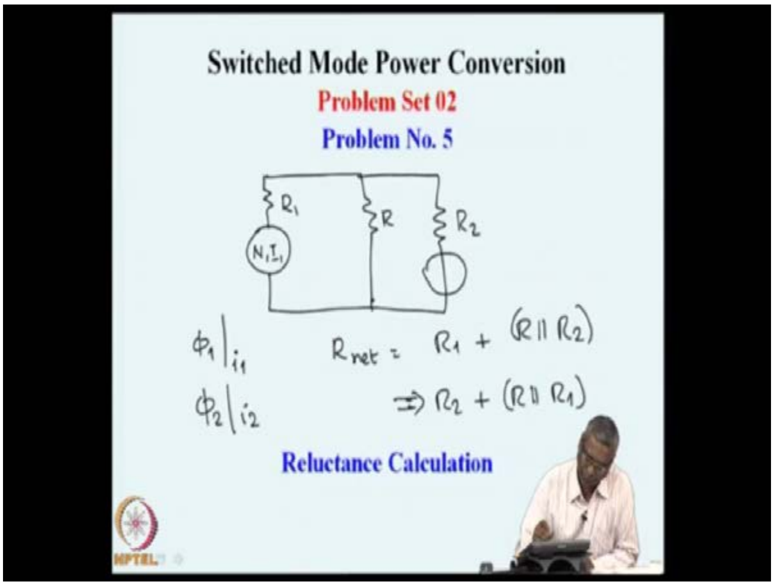

If we now try to find out, in the path for the excitation one alone when the second winding is not energized. So, we can say that the net reluctance in this case R net will be R one plus R parallel R 2. It is possible to evaluate the quantity, this would be the reluctance for finding out flux 1 on account of i 1. Flux 1 because of i 1 on account of i 1. Similarly, if we wish to find out flux 2 on account of i 2 then, the reluctance for that will be R 2 plus R parallel R 1 because now excitation will be in this limb.

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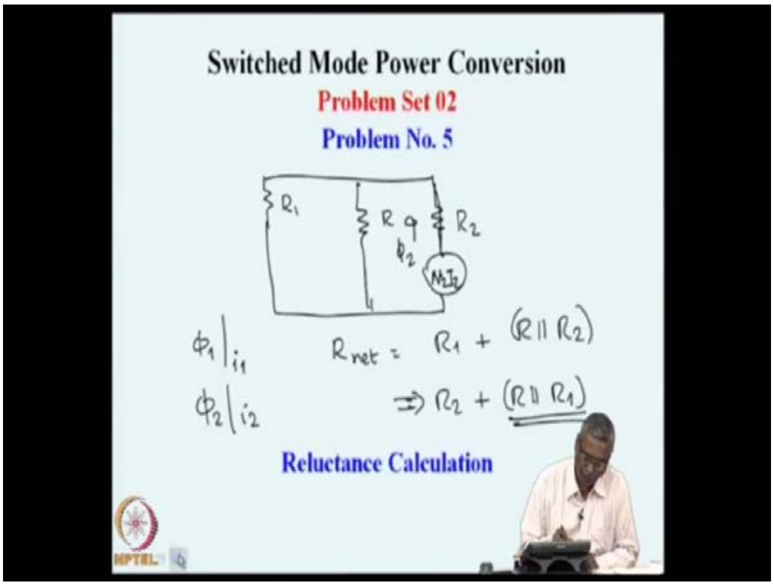

So, excitation is now N 2 i 2 and we are interested in phi 2 and that reluctance will be R 2 plus R parallel R 1. So, this is very similar to our electrical circuit and it is possible for us to find out L 1.

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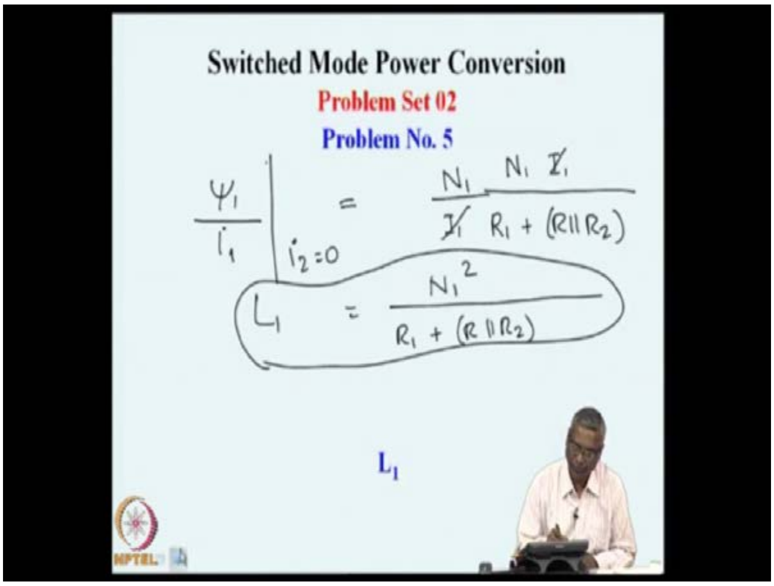

L 1 is defined as psi 1 flux linkage in 1 on account of divided by i 1 when i 2 equal to 0. So, this is a self inductance of winding one when that is calculated. Winding 2 is not excited or the current through that is 0 and winding one alone is excited. And this will turn out to be N 1 into the flux. The flux linkage is the product of number of turns and the flux, in the flux itself is N 1 I 1 divided by R 1 plus R parallel R 2, in this entire quantity divided by I 1. So, this will cancel and what you will see will be L 1 will be N 1 square divided by R 1 plus R parallel R 2. So, this is the expression for L one.

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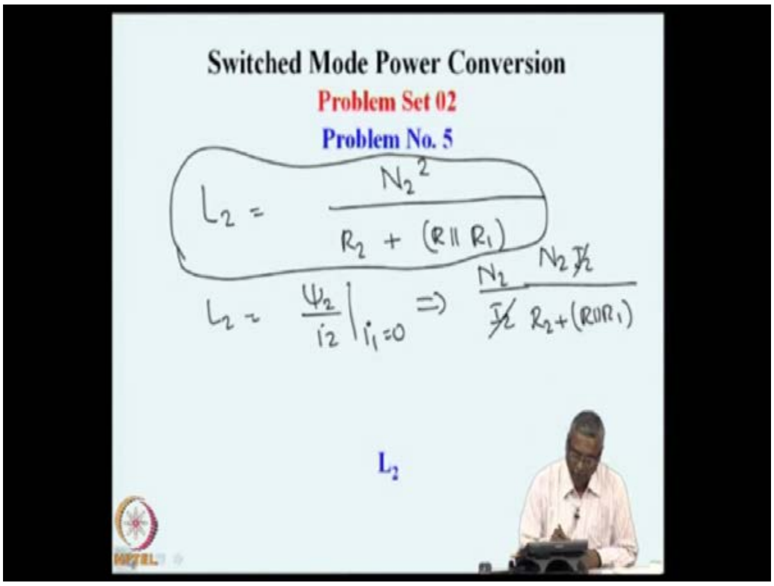

And in a similar way, if we find out the expression for L 2 that will turn out to be N 2 square divided by R 2 plus R parallel R 1. So, this came about because the L 2 is psi 2 divided by i 2 when i 1 is 0. So, that is N 2 into N 2 i 2 divided by R 2 plus R parallel R 1 divided by I 2 and that expression is what we have here is L 2.

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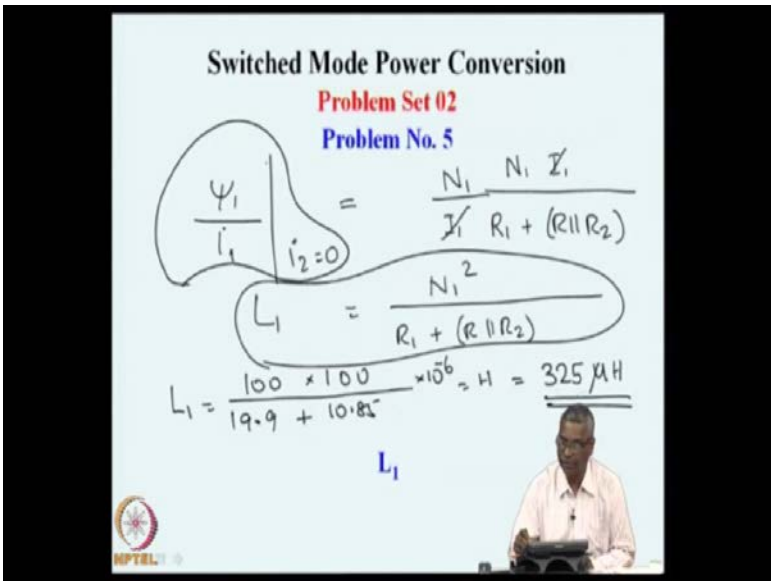

So, we might go back here and calculate this L 1 to be 100 into 100 because number of turns in winding one is 100 turns and R 1 is 19.9 into 10 power 6 per Henry and R parallel R 2 is 10 point 85 into 10 power 6 per Henry. So, this is in Henry and this number, if it is simplified will be 325 microhenry. So, what we see now is that, in the coupled winding L 1 is the inductance of winding one which is on account of excitation in one and the flux linkage in one. The definition of self inductance is flux linkage of winding one on account of current in one, when all other currents are zero and that is 325 microhenry.

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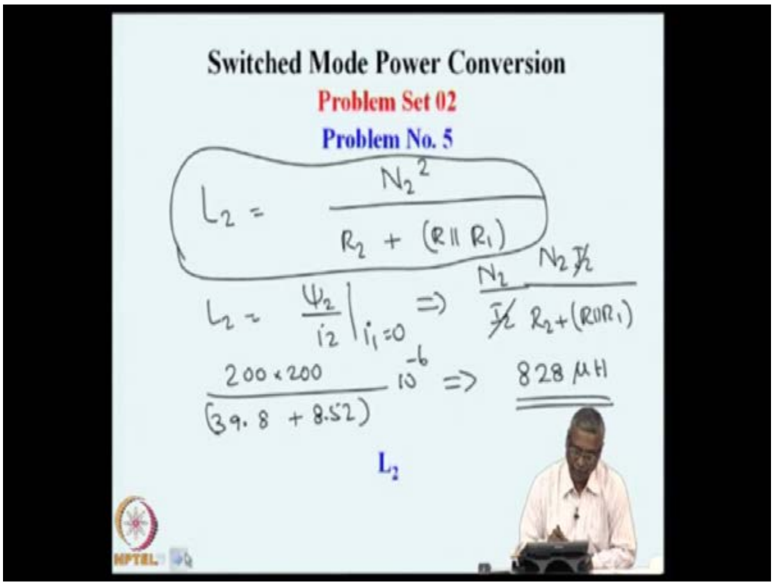

If we calculate a similar thing for L 2 that will be N 2 square which is 200 into 200 is number of turns are now 200 and R 2 which is 39.8 plus R 1 parallel R is 8.52 per Henry. So, that 10 power minus 6 this turns out to be 828 microhenry. So, winding 2 has a self inductance of 828 microhenry and winding one has an inductance of 325 microhenry; the next expression which we wish to do.

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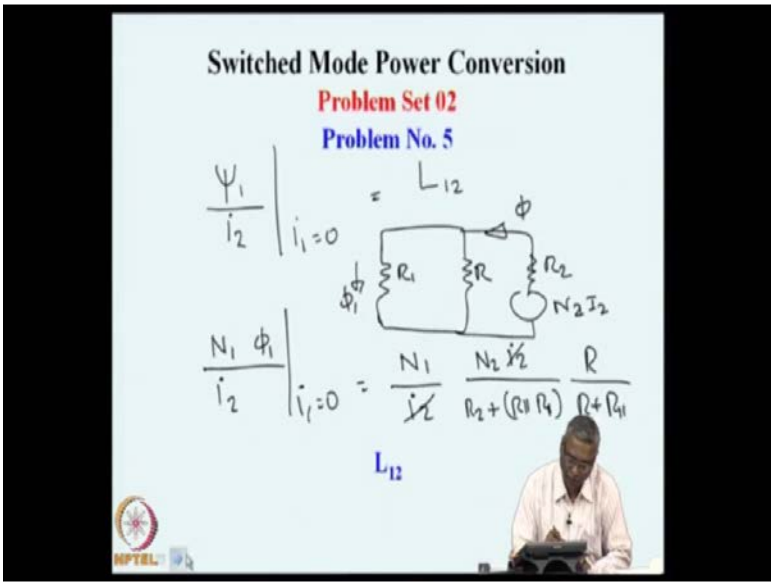

So, what is L 12? L 12 is flux linkage on winding one on account of current into when i1 equal to 0. So, this is the mutual inductance, the flux linkage on winding 1 on account of current in 2 winding 2. This is defined as L 1 2 flux linkage on winding one on account of current in 2 is L 12.

And in the equivalent circuit, if we draw this equivalent circuit we might see that, winding N 1 I 1 I 1 is zero so let us take the other case N 2. So, this is phi 1 now. So, it is N 1 and phi 1 on account of current in i 2, when i 1 is 0 and this should be N 1 by i 2. The current in this branch is N 2 i 2 divided by R 2 plus R parallel R 1 that is, a total flux coming out of this find that divides in this in the ratio of R by R plus R 1. So, this should be the expression for L 12 and this expression will be identical i 2 will cancel and this expression, when simplified will be identically for L 21 also L 21 also will have the same expression that.

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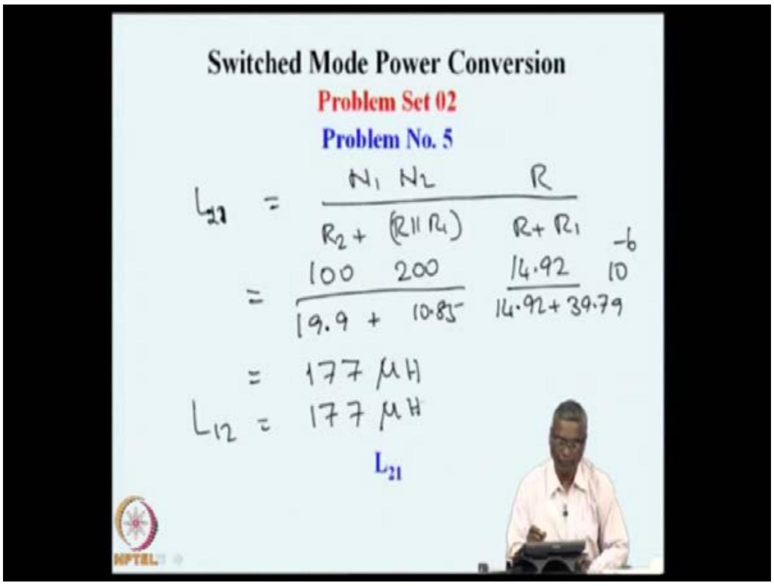

So, this when simplified will have 100 turns, 200 turns divided by 19.9 plus 10.85 R parallel R 1 and R by R plus R 1 is 14.92 by 14.92 plus 39.79 10 power minus 6. So, this expression and simplify, it turns out the 177 microhenry, and this is also the same as L 12. This is also the same as 177 microhenry. So, in linear circuit this will always be so that, the mutual inductance of one and 2 will be the same as the mutual inductance 2 and 1.

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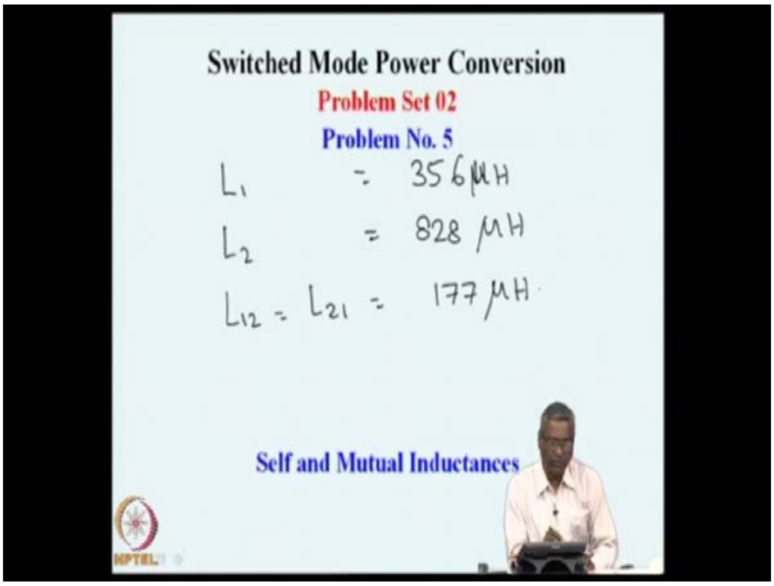

We had seen this self and mutual inductance 356 microhenry and the second one was 828 microhenry and the mutual inductance was 177 microhenry.

So, in all these cases the method of analysis is to draw the magnetic circuit in the form of its electrical equivalent circuit, where the excitations are the M M F magneto motive forces and the circuit impedances or the reluctance magnetic reluctance of the branches. So, from this equivalent circuit it is possible to find out the required ratios, which are basically flux linkage per ampere defined appropriately. If it is a self inductance, it will be flux linkage on winding one on account of current in winding one.

If it is mutual between winding A and B, it will be flux linkage in winding A on account of current in winding B. This is one of the common circuits that we will come across in many power conversion circuits, where we will have magnetic circuits which are a couple to each other, where we will have to find out the mutual inductances self inductances and the flux couplings and so on.

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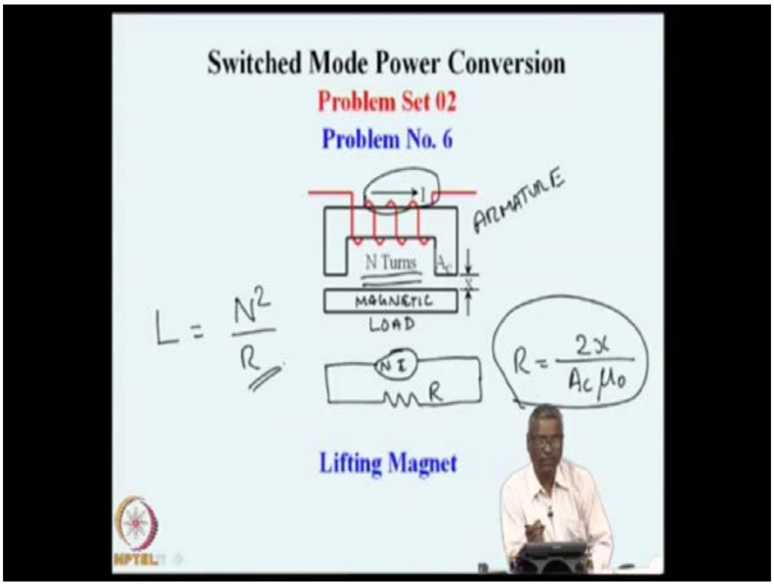

We will go on to a slightly different magnetic circuit, where we see electromechanical energy transfer in a magnetic circuit. What you see here is a simple idealized magnetic circuit, where there is an armature which carries a winding which has N number of turns. And the winding carries a current of I amperes and there is also a load on the armature.

The armature has a load which is also of magnetic material and the idealized magnetic circuit has excitation of N turns carrying a current I. And if we assume the magnetic circuit material to be perfect highly permeable, then there are air gaps on either side of this. x on this side and x on this side and then the load which is also a magnetic material, which has a high permeability material. On account of that, this also will have an equivalent circuit of N I is the magneto motive force and the circuit has a reluctance of R. And this reluctance is decided by the air gap which is x on this side plus x on this side divided by the area of cross section which is AC and the magnetic permeability of the material. So, in such a configuration we know that the reluctance of the magnetic circuit is length of the magnetic path divided by the area of cross section of the magnetic path multiplied by the permeability of the magnetic path.

Here the magnetic path has high end component and air component reluctance dominates. So, we have neglected the reluctance of I and path and what we see here is 2x by Ac mu naught and the winding can also be considered to have an inductance which will be N square by reluctance. This definition also we had seen earlier that the inductance of a magnetic circuit can be seen as square of the number of turns divided by the reluctance of the magnetic path. So, with these quantities known, we might go on to understand a little more of the circuit.

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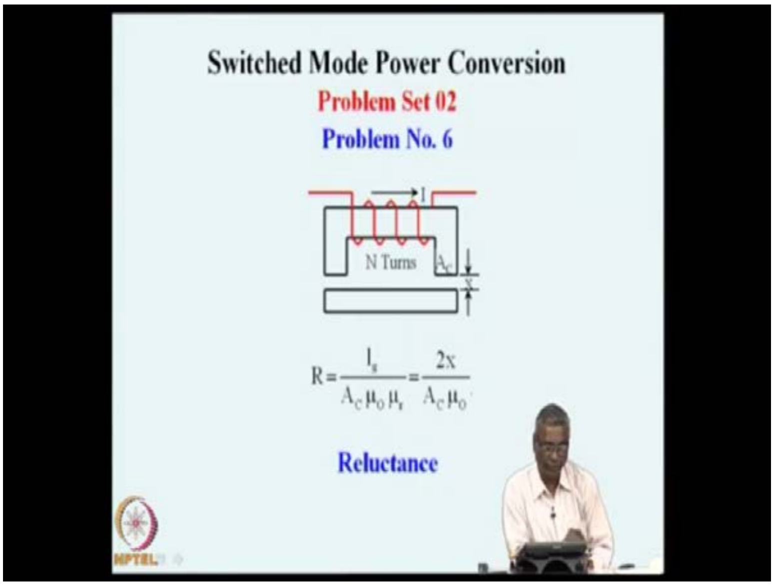

What we see here is the reluctance and reluctance is given as l over A mu naught mu r general expression. And in this particular case, gap is 2x and area of cross section A c and the reluctance is dominated by air and which is A c mu naught.

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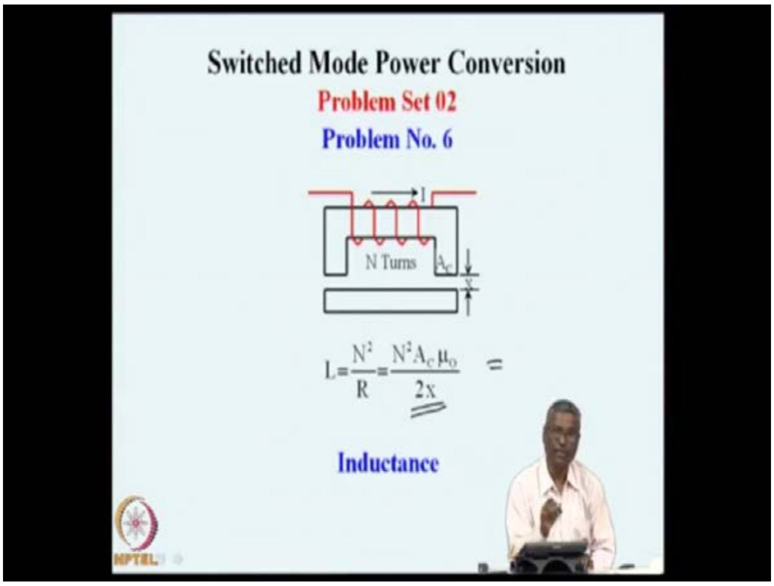

And we can extend this and go on to the next idea that, the winding is seen to have an inductance of L which is N square by R. In this particular case it is N square by reluctance which is 2x by A c mu naught. So, what we see here is the inductance of this circuit which is proportional to the square of the number of turns and the area of cross section and permeability of the air gap and inversely proportional to the gap 2 times x because of the 2 gaps.

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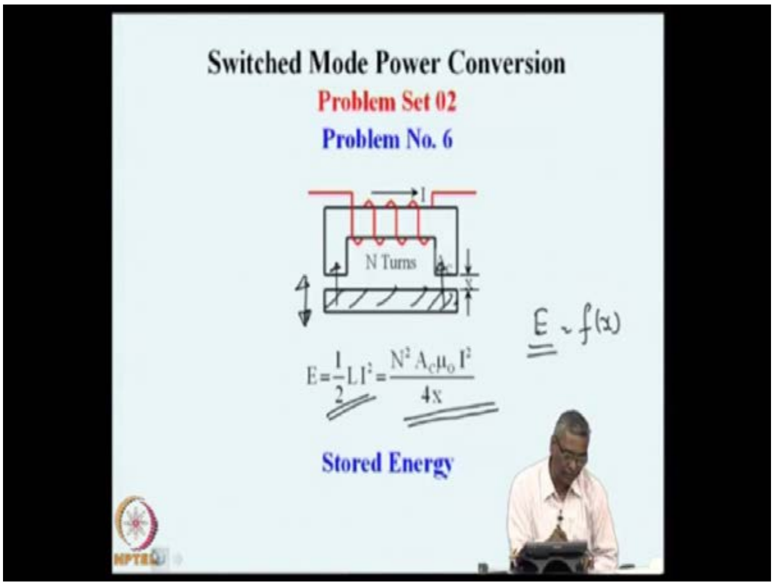

We can go on to see how much energy is stored in the system. Here energy stored can be seen as half L i square. And in terms of other expressions, it is number of turns square multiplied by A c multiplied by mu naught and I square and 2 times 2x which is 4x. So, what we see here is the stored energy in this circuit. Now because stored energy is a function of x as this part as the load part moves up and down x changes. When x changes, stored energy in the system changes and in such a situation on account of the magnetic field between the armature and the load, there will be a force of attraction between the load and the armature and this force of attraction is related to the stored energy.

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This can be expressed as the force is exerted is the rate of change of stored energy. This can be proved very simply, because of the conservation of the energy. If the stored energy changes that is because of the force that is supplied and distance moments. So, F into d x is d or F is d by d x and this expression is the lifting force. The load of the magnet is lifted up with a force which is equal to this quantity.

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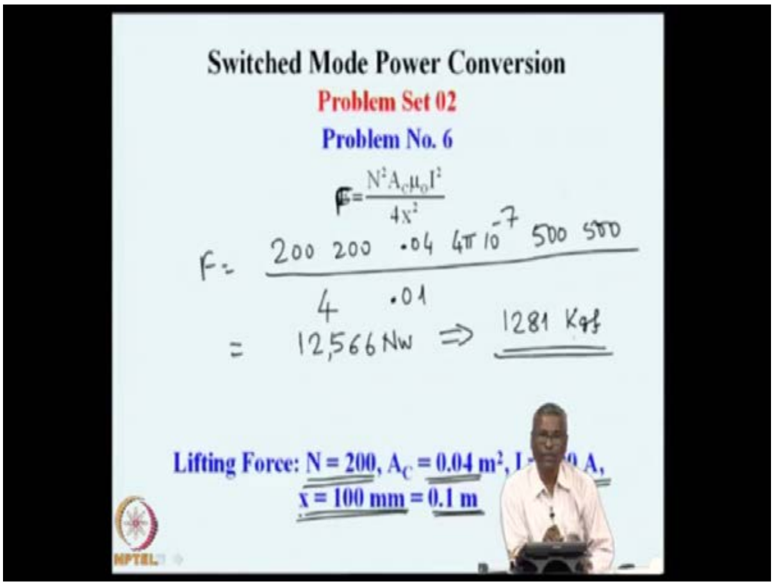

We can calculate for a system of this nature, where the number of turns is 200. Area of cross section is 04 meter square, may be 200 millimeter by 200 millimeter is 0.2 meter by 0.2 meter, 0.04 meter square in the winding carrying a large current of about 500 amperes and were x is about 100 milli meter, which in meter scale is 0.1 meter. So, in such a case it is possible for us to find out the stored energy the or F the force is N square A c mu naught I square by 4x square and this force can be calculated as 200 into 200 which is the number of turns square and Ac is 0.04 and mu naught is 4 pi 10 power minus 7.

Current square is 500 into 500 and this entire thing divided by 4 and x square is .1 square which is .01. So, if this is evaluated, simplified and evaluated it turns out to be 12,566 Newton. And this would be is 1 Newton is g times k g force, this is also equal to 1281 k g force 12 5 6 6 divided by 9.81 will gives you a lifting force in this particular system, when 500 ampere of current is flowing 12 81 k g force. Where is this useful?

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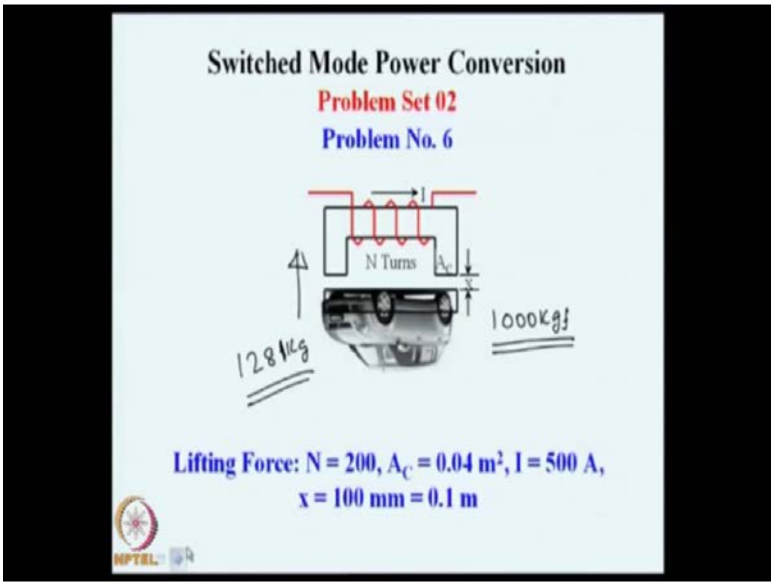

So, this kind of magnets can be used to lift material in the form of, you would have seen that in junkyards the condemned cars are lifted and compressed in order to make them for scrap. In such a case, a typical maruthi car has a weight of about 1000 kg. So, with such magnetic it is possible to lift a load of that nature with this kind of configuration. So, this problem has a related in a magnetic circuit. How do we find out the stored energy as a function of the mechanical dimensions? And when stored energy is varied as a function of mechanical dimensions? How it can be used to find out what are the forces that are generated? Electromechanical forces in this particular case, a lifting force in the direction shown from the load to the armature and the evaluation of this lifting force, we calculated was about 1281 kg which is more than the weight of a typical Maruthi car here. So, this can be used in this configuration. It can be used to lift weights of this nature. This is a problem where we try to convert what we know in electromagnetic circuit to the electromechanical force calculations and so on.

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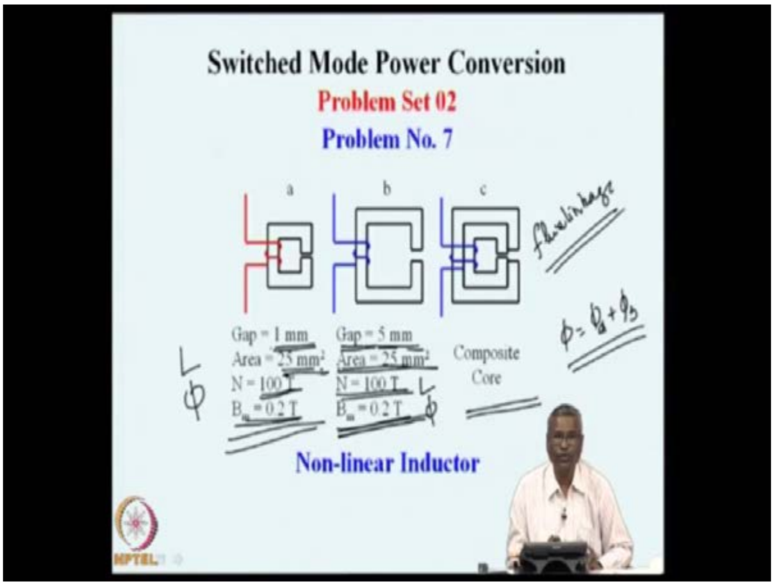

So, we will next go on to look at a magnetic circuit where we try to get non-linear characteristics. What I have shown here is a typical non-linear inductor. Later on we will see where applications for such inductors come in? Now you have here totally 3 magnetic circuits one 2 and 3 A, B and C. In circuit A, you have a simple geometrical simple core which is wound with 100 turns and the material that is used for the core has a maximum flux density limit of 00.2 tesla and the area of cross section of the core is given to be 25 millimeter square and the core has a gap of 1 millimeter.

The core B has 5 millimeter gap, area of cross section same as before 25 millimeter square and it also has 100 turns and the material is same so that, the maximum flux density 00.2 tesla. Now it is possible to combine these things so that the core A is inside core B and the same winding is passing through both of them, a composite core as shown here. So, this circuit is really a superposition of circuit A and circuit B. So, if we wish to analyze such a composite circuit, it is possible to do analysis based on one circuit at a time and then combine the results in order to get the behavior of the composite circuit.

So, let us look at one by one. What is the inductance of winding a? What is the flux of winding a? Similarly, inductance of winding b, flux of winding b and this c being a superposition of that it will give rise to 5 will be 5 a plus 5 b. So, by combining the characteristics, it is possible to find out the flux linkage characteristics of the composite core, flux linkage of the composite core and the flux linkage characteristics with respect to with current will give us the required inductance for the composite core. And we will see some non-linear results here, which will give us an insight into building such non-linear inductors in some special applications.

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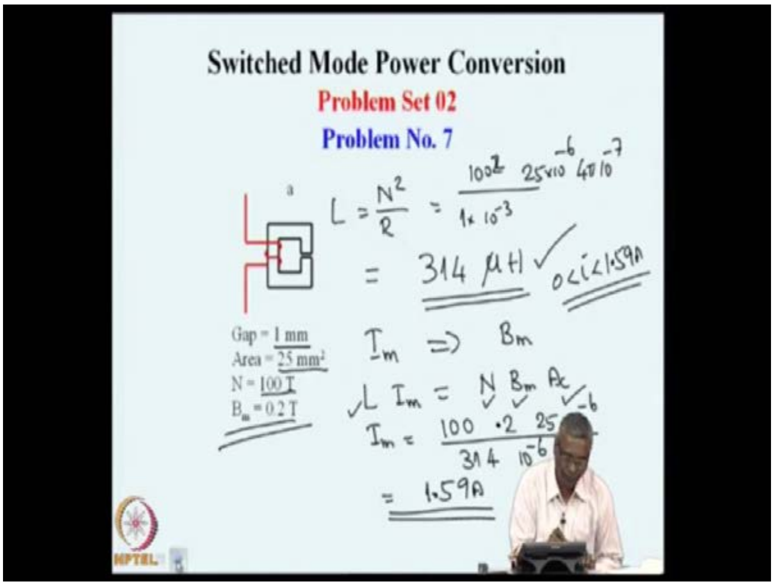

So, I am now looking at winding a only. This has a cross sectional area of 25 millimeter square air gap of 1 millimeter and number of turns are 100 turns. So, it is possible to find out the inductance of this switch is N square by reluctance which is 100 square divided by reluctance is 1 millimeter into 10 power minus 3 in meter and area of cross section is 25 into 10 power minus 6 in meter square. And mu naught is 4 pi 10 power minus 7 Henry per meter. So, if we evaluate this quantity this turns out to be 314 microhenry.

So, the inductance that we have here has a value of 314 microhenry, but then because it has a limited air gap if we keep passing more and more current at certain current, the flux density will reach B m 0.2 tesla. So, beyond that current the circuit will saturate. So, let us find out what is the current I m which corresponds to maximum flux B m. So, this is very easy to calculate because L into I m is equal to N into B m into A c because L i is N

5. So, if we equate this, in this all these numbers are known to us N is known, B m is known, A c is known, L is known by this calculation. So we can find out what is the current at which this core will saturate so that, will be 100 turns B m is 0.2 A c is 25 into 10 power minus 6 divided by 314 into 10 power minus 6 microhenry.

So, this number when we calculate it turns out to be 1.59 amperes. So, what these calculation show is that this inductor ideally will have an inductance of 314 microhenry so long as current is less than 1.59 amperes. Because we have assumed everything ideal as the current reaches 1.59 ampere, the circuit will saturate.

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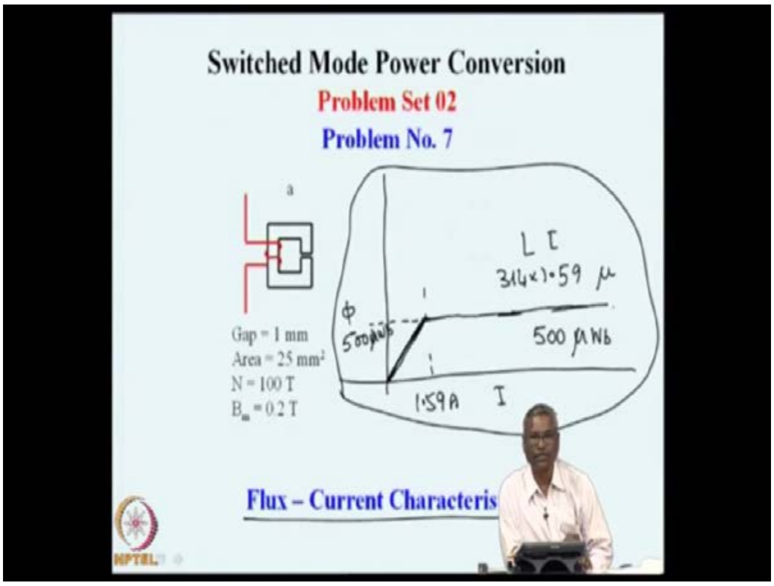

And so we can plot the flux versus I characteristics as up to 1.59 amperes. The inductance will be constant. So, the flux will keep on increasing as the current is increasing. As we reach 1.59, the flux level saturates and this number where the saturation occurs is L into I which is 314 into 1.59 micro and that number is 500 micro flux microweber, and so this number is 500 microweber. We can say that, this is the flux current characteristics for the core a, which linearly goes up to 500 microweber corresponding to current of 1.59 and after that because the core has saturated. The flux does not increase anymore and even if you excited with more and more current flux remains the same. So, we can see that the flux linkage characteristics or flux current characteristics of the core one is linear upto 1.5 ampere and after that it is saturated with constant flux.

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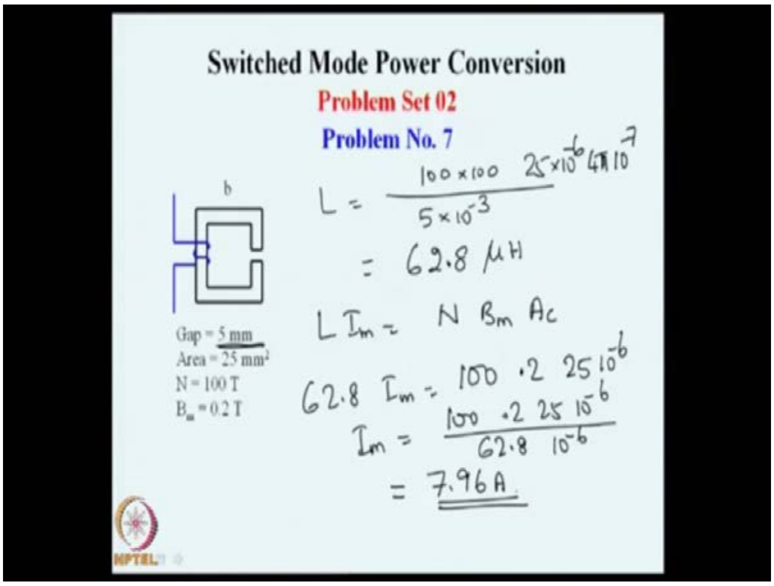

The same idea can be extended for extended for the bigger core. The inductance in this case will be same 100 turns and the area of cross section number of turns square divided by reluctance which is 5 millimeter into 10 power minus 3, that is meters and then area is 25 into 10 power minus 6 and 4 pi 10 power minus 7. This will be the inductance and this number works out be 62.8 microhenry. So, compared to the previous circuit this circuit has a higher gap in so higher reluctance number of turns are the same. The reluctance has increased by a factor of 5 and inductance has dropped by a factor of 5.

The earlier numbers that we saw was 314 microhenry and this is 5 times less, which is 62.8 microhenry. Now in this case also, it is possible to find out at what maximum current this will reach the peak flux density of 00.2, 62.8 into I m is 100 turns. B m is 0.2 tesla, A c is 25 10 power minus 6 or I m is now just as before 1000.2 25 10 power minus 6 divided by 62 point 8 microhenry. So, because this is 5 times less, all the other quantities are same. This inductor will saturate at 5 times the previous current or 7.96 amperes. It has a lower inductance because of higher reluctance and because the reluctance is higher, flux will be lower and it takes a higher current to saturate.

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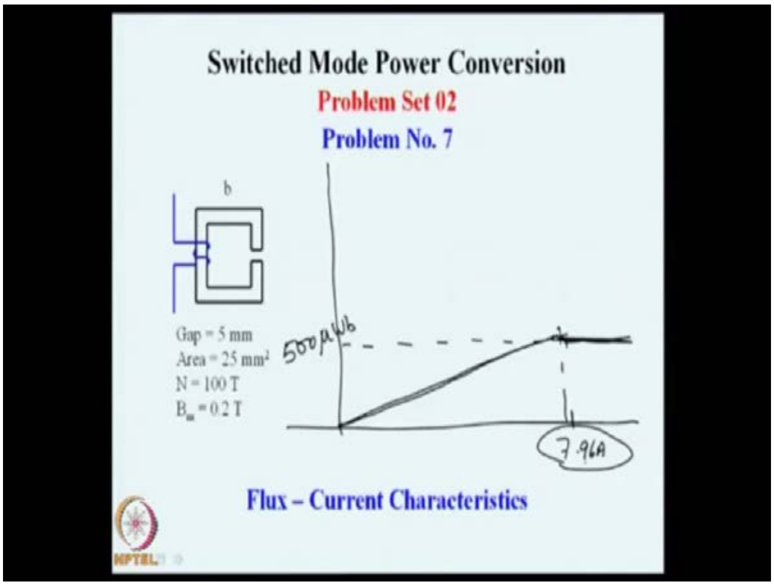

So, if this plot for this the flux linkage, flux verses current characteristics. We will see that at 7.96 amperes, it will reach again the peak flux is same as L into I which in this case also is 500 microweber. But this core is linear up to 7.96 amperes.

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Now our next question is, supposing we put these 2 cores together, the way we have shown as a composite core how will the flux current characteristics look like and what will be the values of inductors?

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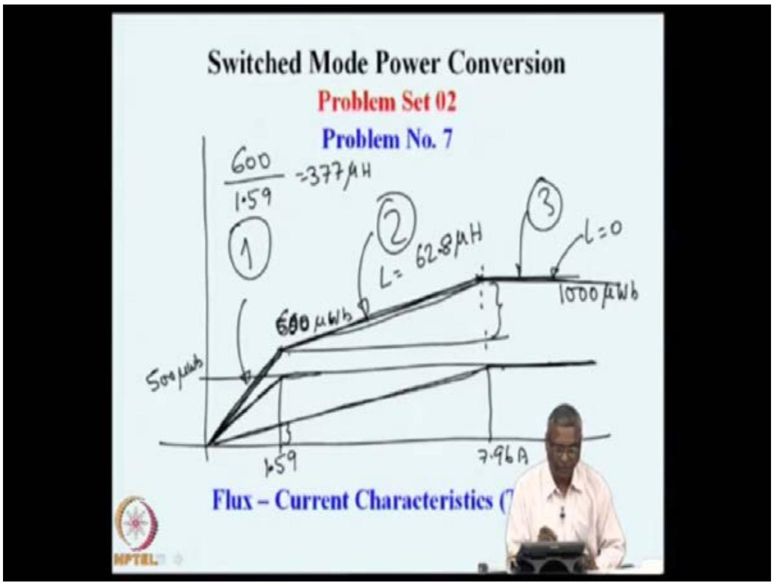

So, let us plot it. So, this is the second core's characteristics which reaches a maximum of 500 microweber at a current of 7.96 and the smaller one reaches maximum of same 500 microweber at 1.59.

And if I now add at every point the individual fluxes so at this end, I will find my flux would be 1000 microweber, 500 on account of the first one and 500 on account of the second one which is 1000. And in this end 500 on account of the first one in this small account quantity, on account of the second that number is this is one fifth. So, this also will be one fifth which is 50. So, this will be 550 microweber. So, you can see the composite flux characteristic has 3 regions1, 2, 3. So, in region one both the cores are contributing to the inductance, the flux is increasing with current.

In region 2, core one has already saturated. So, the slope of this line and slope of this line are equal, the same everything is shifted by certain amount of flux. And in region 3 both the cores are saturated and we do not have any flux change as the current is increasing. So, it is possible to find out now, the inductances at various points. For example, in region one the inductance is 550 microweber divided by 1.59, flux divided by current is our flux linkage divided by current is the inductance and that number will be 500. It is fifth I am sorry this yeah this will be 600 microweber

So, in this region it is 600 divided by 1.59 and that is 377 microhenry, the inductance is now more. It is more than 314 plus the other one. So, practically both of them got added because the flux has increased and current remains the same and in this region, in the second region, the first core has saturated and there is no change in the flux. So, this would have if you see the change in flux divided by change in current this in this region, the inductance is effective inductance is same as 62.8 microhenry and then this region L is 0. So, effectively we have made a magnetic core which has flux current characteristics.

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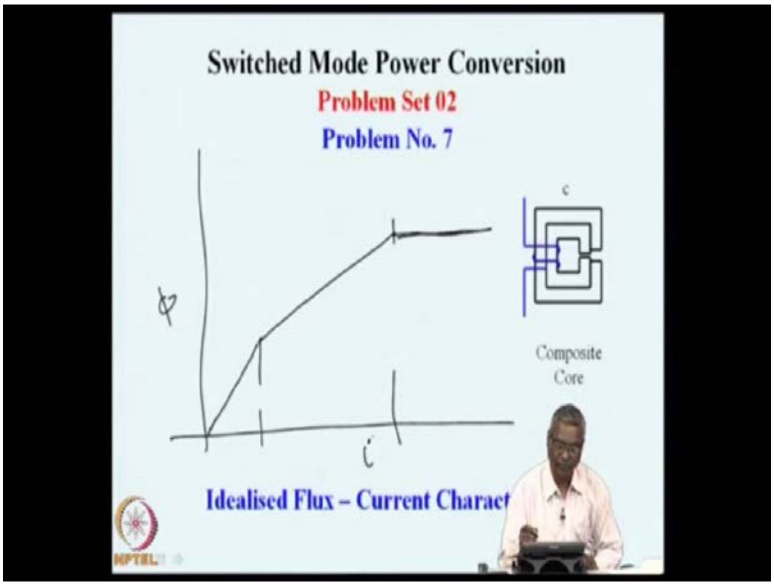

So, it is the flux level current characteristics has one slope in region one, another slope in region 2 and then flat slope in region 3. So, by using a composite core it is possible to shape the flux verses current characteristics to have different sections.

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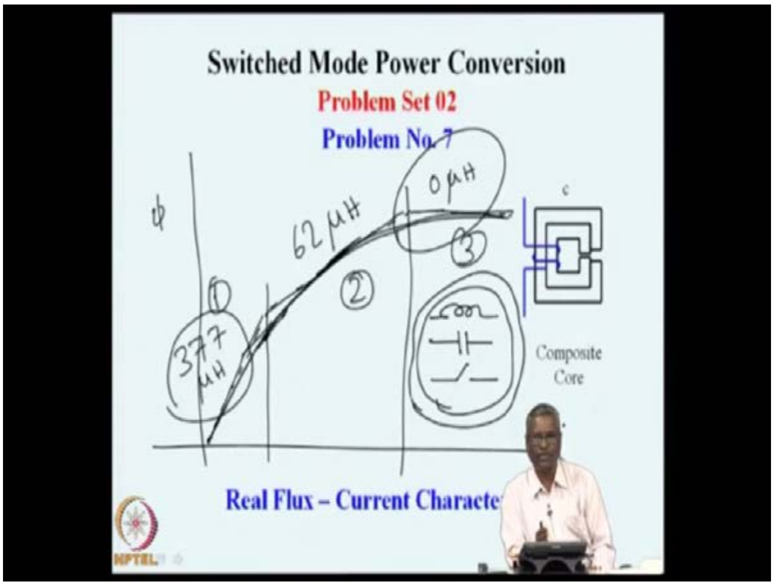

If we build an ideal, if will build a real inductor with this kind of asymptotically, it will have the behavior of what we have seen, but in reality because none of the materials are ideal. So, you will see a tangent to all this will be our real flux linkage characteristics.

A real magnetic circuit of that nature will have a smooth non-linear characteristics, but it can be piecewise linearized one straight line in region one, one straight line in region 2, one straight line in region 3 with 377 in this case in the region one and 62 microhenry in region 2 and very low 0 microhenry negligible inductance in region 3.

Where does one need such non-linear characteristics of inductors? So, it is possible that in certain circuits when the current is very small, when the circuit current is very small. We may like to have large inductances so that, that current that small current is smoothened much better, but when the magnitude of the current in the circuit is very large we can afford to allow a higher ripple. So, the value of inductance can be lower. The actual inductance to be used in the circuit may be lower. In many practical applications we may like to have a large inductance at low currents and low inductance at large currents so that, right at the no load conditions a light load conditions to the high load conditions are the rated load conditions, the current ripple the smoothening effect of the inductor is nearly the same. Such inductors are also called flying chokes because the value of the inductance is a function of the current that is being passed.

In this case as you go to higher current you can see that, the tangent of this line or the incremental inductance keeps changing as the current is increasing and the incremental inductance becomes smaller and higher currents and larger at lower currents. This is a very important a positive a feature of non-linear inductor which can be utilized in many applications in order to have merely constant ripple whether the unit is at like load are at rated load.

What we have seen up to now with this set of problems, we have also covered coupled inductors, non-linear inductors and then the electromechanical energy conversion properties that happen in any magnetic circuit and the earlier we had seen problems relating to transformers, inductor design and so on. And before that we had spent an hour looking at the switches, their conduction properties, blocking properties, switching characteristics and so on. So, effectively right now we have look at the different components that go into.

We have seen the inductors, capacitors, switches. All the elements that go into power converters have been seen and we have also worked on a few problems relating to the inductor design, transformer design, capacitor selection, calculation of power losses in the switches during conduction, during switching and the characteristics of switching, characteristics of conduction and so on.

We have also seen some advanced topics like coupled magnetic circuits, non-linear magnetic circuits and so on. In the coming few lectures, we will try to see how these components are put together to achieve the functions of power conversion. The power conversion is done from a source to a sink.

We had seen in the very earlier lectures that, the motivation of transferring power from a source to a sink is because of the different requirements on the load and the different capabilities of the source on account of incompatibilities we try to put a power converter circuit which tries to match the load with the source and that matching is done using inductors, capacitors and switches, so that the power conversion is done efficiently without any losses.

Notice again all these 3 components are lossless components because they are loss less the converter itself is loss less, ideally without losing any energy we transfer from the source all the energy that we take and then pass it on to the load. How this is done with different circuits and how do we calculate the different performance indices of power conversion and so on will be carried out in the next few lectures. There are certain rules by which inductors, capacitors and switches can be connected together. So, we will start with those rules. These rules have to be followed if we want to make sure that the power conversion takes place without any loss in power as well as elegantly know be we should not do certain things when we are handling electrical power and these things are such as maintaining constant energy flow and so on. So, these are the first ideas which we will start with you would say that these are fundamental ideas which are forced upon us on account of conservation of energy. We must not do in any circuit, anything that will try to violate conservation of energy principles. So, these principles when apply to the circuits will result in very simple rules of how to connect an inductor to a switch? How to connect a capacitor to a switch? So, with these rules as the first fundamental axioms we will try to put together a very simple circuit to start with and then go about trying to find out the operation of power conversion from a source to a sink and what are the performance measures that one should look at? What are the ideal properties? What are the non-idealities? What are the effects of these non-idealities on the ideal performance figures and so on. So, those things will be our next part of the SMPC course.

You can say that up to now, we have covered about a ten lectures in these ten lectures we have concentrated on all the components that are going to go into a power converter and before that we looked at what was the prior art that is how power conversion was done before switches were being used and even before that in the first lecture, we looked at an over view of the complete process of switch mode power conversion. So, in the first part up to now in the first ten lectures, we have seen the devices and the prior art and an over view or in the other order we saw over view first then the prior art of power conversion in the devices that are used for power conversion to do it efficiently.

In the following part we will see how these components are connected together in the form of a circuit and how they operate and what are the performance measures? How power gets converted from the source to the sink? What are the converter gains? What are the efficiencies and what are the non-idealities? What are the effects of these non idealities? Are all the things that we will be seeing in the next part of the lecture, that part will have probably about ten lectures covering the performance of the basic circuits of power conversion. Ideal as well as non-ideal and then we will on go on to the in the next third part we will try to look at real power conversion circuits. What was saw seen in the idealized circuit will be taken on further to see the real circuits and also the dynamic performance of these circuits and eventually we will try to design a several power converters circuits.

Thank you very much.