Behavioral and Personal Finance
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Lecture # 37
Self and Mutual Inductance

Welcome to my next lecture on network analysis, lecture number 37. So, far we have seen that there are three basic elements resistance inductance and capacitance is, but there will be another, not a new element but there may be a coupled coils present in a network and a coupled coils or they are mutually coupled coils. Then apart from self-inductances of the coils, another term appears which is called mutual inductance.

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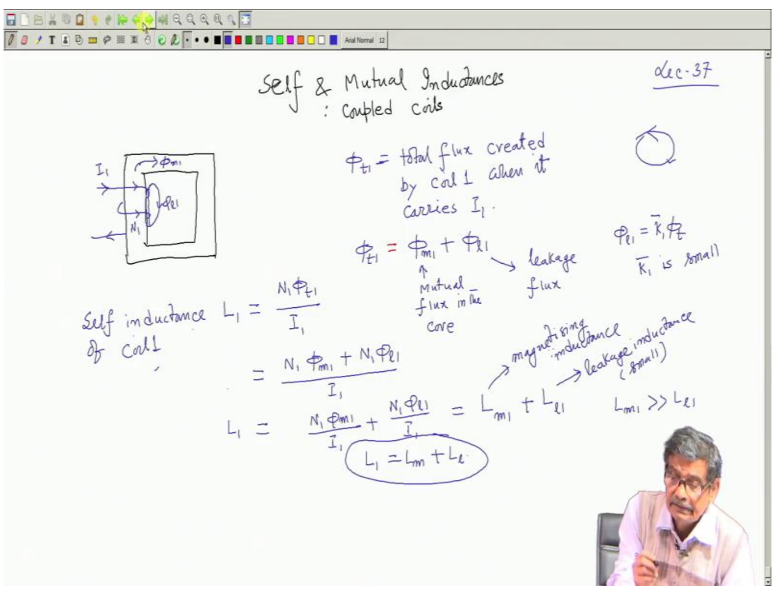

Today I will just define very basic things about that and also try to calculate the energy stored in a couple of coins. Recall that if you have a coil, if you have a magnetic circuit like this suppose it is magnetic material and if you have a coil with N1 times and if you pass some current through the coil, say constant value of current, then what happens is this, the current flows like this. So, in this way if you draw it means we are showing correctly the sense of the winding.

Now, when current flows through a coil in this fashion, suppose, current flows in a loop like this, then there will be flux produced. Then direction of which will be indicated by the thumb.

Therefore, here it will be, if current flows at any instant of time in this direction some flux will be created in the core and this flux is created by this current I1 this is coil number 1 and it will create a flux file.

Now, this flux will be this flux is called the total flux created by the coil. So, phi t1 is the total flux created by coil 1, when it carries I1, and number of turns of this coil is I1 and we know how to calculate phi t1 this phi t1 will have 2 parts, 1 part phi t1 we can be written as phi t1 can be written as phi m1 + phi l1 so phi t1 is the total flux created it will have 2 parts 1 is called phi m1 and there will be another part which will not go to the which will be linking the coil alone it will not flow through the as a mutual flux.

So, this 1 is called mutual flux in the core, so, this total flux is 1 has 1 component, we have written phi m1, 1 corresponding to this coil 1 and this is called Mutual flux it will be in the core and this part is called leakage flux we will be completing their paths through a part of the code through the fast coil and through the air. Then it is not in the core, but nonetheless total flux created by the coil number 1 when it carries current I1 is this 1 and what is self-inductance.

By definition self-inductance have coil 1 will be is defined as flux linkage per ampere, so, flux is total flux that is N1 phi t1 total flux linkage when you pass 1 ampere current that is you divide by 1, this is what is self-inductance all about clear. And this can be also written as N1 if you put this phi m1 + N1 phi l1 divided by I1 and it can be written as 2 components that is N1 Phi m1 / I1 + N1 phi l1 / I1 mind you this leakage flux will be a little fraction of the total flux created.

For example, phi ll 1 can be expressed as some say k1 bar into phi t a little portion, if the coupling if all the flux can be 95, 98% of the total flux created will be confined to the core maybe 2% 3% is leaking. So, K1 takes care of that anyway So, this is the thing so, self-inductance of a coil of course, to calculate self-inductance total flux linkage is to be taken because that is the definition of inductance of a coil sometimes what is called it this inductance is called the magnetizing inductance L m1 on and this is called the leakage inductance L l1.

So, this term is called magnetizing inductance and this is called leakage inductance. So, total inductance self-inductance of a coil has got 2 components in general a component which is contributed by mutual flux, this phi m1 is mutual flux and the another component is leakage flux and these inductance will be pretty small K1 is small number is small. Small means few percentage of the total flux created, but anyway this is the thing. So, self-inductance of the coil is L m1 and L l1, L m1 is much larger than L l1 that also we can like L m1 is much larger than these. So, this is this thing.

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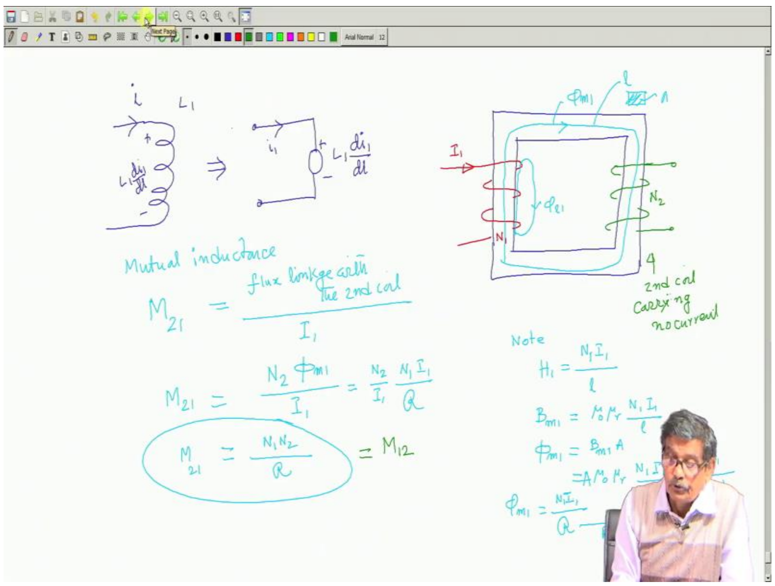

Now, the, inductance of a coil so, henceforth I will not draw the magnetic circuit, I will simply draw this 1 and I will say that the inductance of the coil is L1 and it is suppose getting a current and I which may be time ready . If it is a time varying current then we know that there will be induced voltage in the current L1 di1 / dt we have done so many currents and since inductances a can store energy sometimes we will represent these also as a source with this polarity of the 1 and mind you L1 consists of those 2 component of fluxes while calculating L1.

So, this is also because inductor inductance of capacitors can store energy they may be also represented like this without any loss of t and depending upon the value of di1 / dt, sometimes this inductance is going to store energy sometimes it will come back energy to the supply here there is some sources connected and so on. So, anyway that is the case. So, this is how we presenting. Now, I will draw the same diagram, this part is very important you know trying to understand these your magnetic circuit.

This is your coil number 1 within 1 turns and in carries a current of I1 and suppose there is another coil like this having into turns and suppose this second coil. This is the second coil, I am not passing any current, no current getting no current only first coil get the current. And if first coil carries current we have seen that it will produce a liquid flux here. Phi l1 this indicates who has produced this flux coil 1 current I1 has produced that is where you want and there will be flux mutual flux like this, which is fine.

And if it is DC current there will be no induced voltage here because this phi l1 and current I1 will have constant value by applying this rule right and rule it will have constant value and nothing is going to happen. Now, meeting mutual inductance between these 2 coils is defined as mutual inductance M 21 that is how I will write the second 1 is that coil 1 is getting current, what is the flux linkage with the second coil when 1 ampere flows in the first coil.

So for either 1 whatever is the flux linkage, so for 1 ampere what is the flux linkage per ampere or the second coil. Now, obviously you can see it is the mutual flux which is going to link the phi l1 will only link the first coil, so I should write it then flux linkage with the second coil will be N2 phi m1 divided by I1 that will be the thing is not M 21. No, this mutual flux can be calculated note that this coil is carrying a current of value what is the mmf which has produced this 1 it is N1 I1 want is not that is what has produced this mutual flux I am interested in mutual flux Crossley to know how much will be the flux linkage per unit can be here.

And if I1 ampere is here what will be the flux linkage there. So, note that phi m1 how to calculate phi m1 anyway I will doing like this. Note that H1 produced by first coil N1 I1 divided by L. What is L, L is the length of this flux spot, average length and length of the flux but we know this H1. How much will be B m1 it will be mu 0 mu r into N1 I1 by l this L is the flux of the length of the mutual flux part.

So, this will be this what will be phi m1 will be by B m1 multiplied by the cross sectional area suppose it is uniformly cross sectional area. So, it will be B m1 into A and let us assume linear magnetic circuit are constant at least you have constant inductance I must say that it is operating in the linear so, B m1 into A is cross sectional area of the core. So, it will then be equal to mu 0 mu r N1 into I am substituting the value of B m1. So, in N1 I1 divided by l, this will be the area value strength of the mutual flux.

Then by definition M 21 will be equal to N2 and mind you this quantity N1 I1. 1 is called the mmf and bring everything down. It will be 1 over mu 0 mu 1 by L / A I can bring it there this quantity is called the reluctance phi m1 = N1 I1 divided by called this quantity is called reluctance constant it depends on the core only core physical dimension and cold properties means you did not mean mu 1 meanwhile, so as the cross sectional area.

So this 1 is nothing but into NR / Il and phi m1 I can write it as M1 I1 by R reluctance of the magnetics is it. So, M 21 will simply become equal to anyone into productive number of turns divided by the law that is all into 1 just noted now, the way I have defined mutual inductance it is in this fashion in the same way I could energize only coil to and define the self-inductance of coil to and the mutual inductance caused by coil to let us do that quickly but effectively

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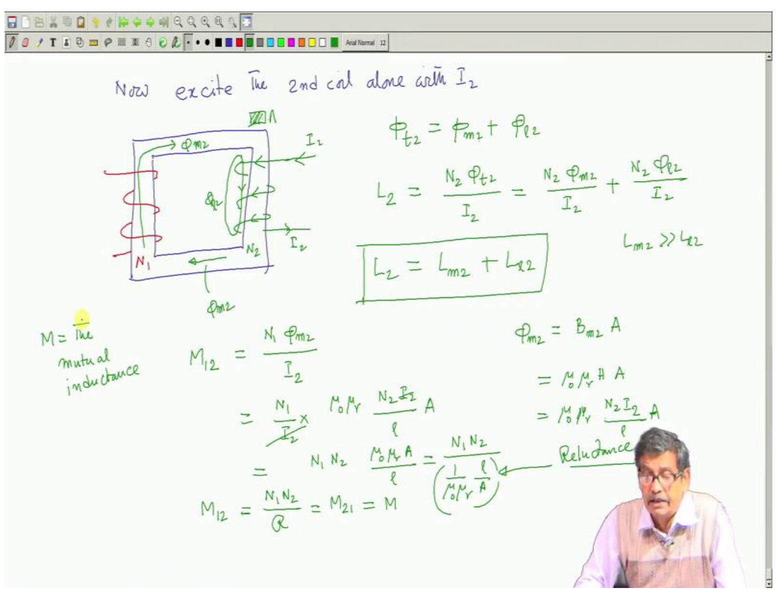

So, in the second case now excite the 2nd coil alone with some current say I2. So let us draw it quickly. So this was the thing. This is the core and there were 2 coils 1 coil was there with in 1 turns but this time I am not going to excite these, this coil and the second coil was there we tend to turn and what I am telling is I am exciting it with some current tied to some source I have connected and current will be flowing like this it is not.

Now if current flows like this, then flux will be produced once again this will produce a flux which will have 2 components 1 is phi m2 and another flux component will be there which will be liquid flux by phi m2. So, when second coil get this current, if phi t1 phi t2 I will say total flux created by the second coil will be in the same way which will flux which is going to link the first coil + delicate flux. What these 2 indicates second coil is only getting and this will be the distinct then self-inductance of the second coil will be flux linkage with the second coil.

When the second coil carries 1 ampere current that is per linear current and that per linear current is right I2 I write it like that and these 2 will have them to component into N2 phi m2 + by I2 and this total self-inductance of the second coil can be written as some magnetizing inductance of the second coil caused by mutual flux + the leakage flux of the second coil and L m2 will be much higher than L m2 to for a coupled coil.

So, this will be L2 when you have energized the second coil flux is produced here and it is only the mutual flux I am to which will link the first coil then I will say that the mutual inductance of the first coil when second coil carries current I will write him on to and this will be equal to M 12 mutual flux value is phi m2 and it is linking in N1 number of times. So, in N1 phi m2 by I2 ampere current in the second coil that is it that that will be the mutual inductance of the second coil way first coil when the second coil get this current.

Here I have not assumed any current carried by the first coil so, this will be the situation. Now, in the same way what will be here I will right straight away in N1 this let me do also. So, so, how to calculate phi m1 to you see phi m2 to will be equal to B m2 into cross sectional area, what is A is this cross sectional area of the core. So, B m2 is how much it will be called to mu 0 mu r into H into A What is H is I / l is the length of the flux remain same. So, mu 0 mu r what is the mmf inti H2 I2 / l is the unit ampere that is A this will be the thing.

So, phi m2 to is this put this value of N1 / I2 is here into mu 0 mu r into N2 I2 / l into A this I2 goes and you will be getting N1 N2 into mu 0 mu r into A a divided by l which is nothing but N1 N2 divided by one over mu 0 mu r by l / A and this quantity we have seen it depends on the physical dimension of the court and the properties of the court same material. So, this is called this is the reluctance this term is reluctance same for the mutual flux either you excite this side or that side. Therefore, M12 will be equal to N1 N2 by R reluctance and in the previous case when you excited on the first coil then also mutual inductance M21 was N1 N2 by R.

So, here also I will say M 21 is N1 N2 / R but these we have seen is same as M12. Therefore, the mutual inductance either you calculate by exciting the primary 1 coil fast coil, calculate mutual inductance whatever you will get, if you excite the second coil then also you will get the same mutual inductance got the point. So, M 21 is equal to M 12 was there any inconsistency in the suffix of a M 12 to what I told here, this was there, then this is M 21 indicating flux linkage there then second coil is current.

So, a 1 2 second coil is the current came on to and we find that this is equal to M 21 and therefore, instead of writing an M 12 I now define him by a single variable. So, I say that m is equal to be mutual inductance which is sim whether you calculate by exciting first coil see the flux linkage in the second coil or the excite the second coil calculate the flux linkage in the first coil. Therefore, from this we will further carry on in our discussion of mutually coupled coils, thank you.