Electrical Machines - I
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Lecture - 04
Operation of Ideal Operation with Load Connected

Welcome to this next lecture that is lecture 4 on Electrical Machines I and we have started our discussion on transformer and we discussed several important concepts, which is essential to understand the working principle of transformer.

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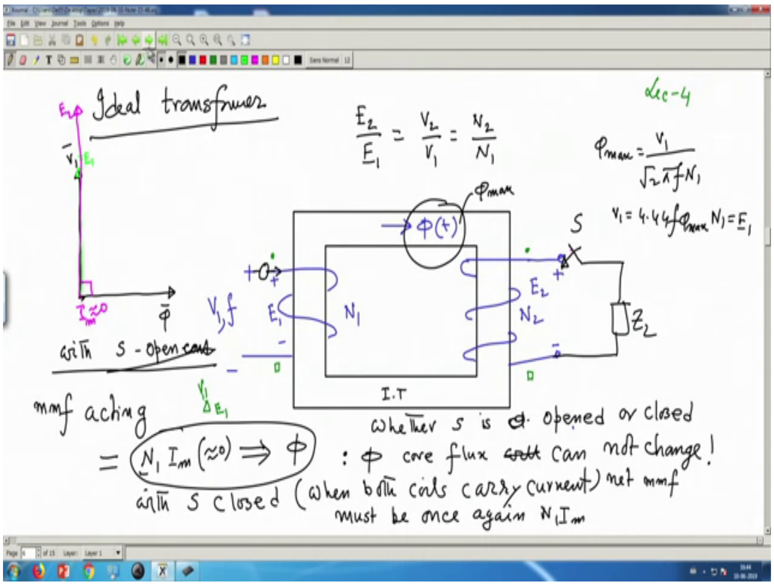

For example now, they in our last class I told several important things, one is that suppose there are now 2 coils and we are discussing about ideal transformer. Ideal transformer that is these winding resistances are 0, both the coils. There is no leakage flux and permeability of the code is infinitely large, which means that if we energize this primary coil with a known voltage at a frequency sinusoidal voltage; then, the current drawn is vanishingly small. And if that with the case then, there will be phi t, peak value of this phi t is phi max and this phi being time varying also links this coil and you have induced voltage.

Then, I told you about the dot marking; these are called dot marking., how to find out the dot markings? By applying Lenz's law. So that everything is now, I mean in place, one should not be thinking this way that way apply a given voltage at frequency RMS voltage of the induced voltage and its polarity with respect to this plus minus all things are now drawn polarity; instantaneous polarity plus minus. Then, the secondary instantaneous polarity is also this one and V1 and E1 will be same, there is nothing in between. Similarly, V2 and E2 will be same and also we noted that E2; E2 by E1 RMS value of then this voltage is V 2 by V1 is equal to N2 by N1. This is the essential thing of a transformer; therefore, you can change the level of voltage. Simply by manipulating the number of translation ok.

Now, this is the thing and then, in my last class I told you how to draw phasor diagram. You see, magnetizing current with the assumption that there is no leakage flux and mutual flux only. So, this coil to these AC supply, this coil will appear as an inductance what else because no resistance. See, essentially N1 d y d t is nothing, but l d I d t from your circuit analysis. You know, if time permits we will develop on that, but the point is so, if I want to draw the phasor diagram I will do it like this; this is my applied voltage. Carefully see, the current drawn by the circuit will be 0 will it be 0; not really vanishingly small current.

So that current will be lagging this by 90 degree, a small current, but that current produces the finite flux phi getting. These are the phasors. This flux will induced voltage in the primary coil and E1 has to be equal to V1; therefore, primary coil induced voltage will be like this also equal to E1. I told you in some books phi E1 in the 90 degree, but I know the whole story now, E1 only it takes in opposition with supply voltage, but with respect to time they are in phase when, V1 attends maximum; E1 attends maximum. So, I will draw like that.

Similarly, E2 will be along the same lines is length may be different depending upon if N2 is greater than N1. It will above and this angle will be 90 degree; I m magnetizing current is vanishingly small [FL]. Now, in today’s lecture we will further go that is so far the secondary circuit nothing is connected except while it deciding about dot convention I told something you connect very casually I told ok; connect then, the current direction whether you allow this e m f to act like that. But, now today we will see much more deeply what is going to happen if you connect something here.

So, I will, what I am trying to tell? You imagine that there is some load which is still now open circuited that is a switch. Our discussion till now with S opened whatever we discussed with S opened. Now, the question is what happens if I close S; that is very interesting; mind you with S opened let me write with S opened, open condition S open condition; what is going to happen? Apply voltage frequency flux is created E1 E2, if you connect a voltmeter you can measure all the voltages and these current if you connect an ammeter is going to be very close to 0.

Since, it is an ideal transformer and so on [FL]. With S is opened, it is a magnetic circuit; single coil and mmf acting in this magnetic circuit with S opened; mmf acting is equal to N1 into this I m magnetizing current, which is very close to 0; no doubt, isn't? That was the net mmf which was acting and this mmf created a flux phi. This created, this flux phi inside the core N1 I m by reluctance, isn't? N1 I m created the flux phi in the core. So, N1 into this flux; so, amount of mmf necessary to create the flux phi is known to me N1 into I m.

Now, listen carefully what I am telling. You close the switch; imagine, you have closed the switch. The moment you close the switch, this coil 2 will carry current; isn't? This coil 2 because there is a source of e m f we have connected an impedance Z2 here. So, the magnitude of the current will be E2 by Z2 and so on. Therefore, to find out, what is the flux in the core of the transformer?

It looks like that this mmf; this mmf I have to take and then, net mmf I have to calculate divide it by the reluctance that will decide the flux ok. In fact, that is what is going; we have to do, but before that I tell you one thing that when, the S was open, what was the flux? How to tell flux? You tell phi max and frequency ok; phi max was fixed. I am writing it many a times root 2 pi f N1 that was phi max; it was fixed and this phi max has to be there in order that KVL will be satisfied on the primary loop.

Now, what I am telling? Whether the switch is opened or closed the flux in the core cannot change that is what I am telling; that phi max and its frequency of course, will remain same flux must prevail; why? Because primary has to satisfy the KVL equation that is V1 equal to 4.4.4 root 2two pi is 4.4.4 f phi max into N1; V1 is fixed. So, on the primary binding the KVL is to be satisfied; V1 equal to E1.

Therefore, phi max cannot change; no matter whether you have connected something on the secondary coil or not. In other words, what I am telling? Even, if you have connected some load on the secondary side. So that secondary coil is carrying current. Then, flux;

this flux cannot change. What it was? It will remain. Therefore, I will write it whether S is opened or closed phi that is core flux will not change; cannot change. If earlier, it was phi max some sin omega t it will be still phi max sin omega t. S is opened or closed, it does not matter, but then, we are slightly perplexed.

Second coil is carrying current. Primary was initially carrying a very small current. [FL] now, now I will tell you that way you better you think. If flux remains same and these 2 coils are carrying current now. So, what will be the net mmf necessary to create that original flux? You must understand this N1 I m when, S was opened created this flux in the core. What I am telling?

With S closed when, both coils carry current; when, both coils when both coil carry current with s closed net mmf must be once again N1 into I m because the N1 into I m created this original flux and I am telling with student; so closed or opened flux remains same; it cannot change. Why it cannot change? Because, this flux will make the KVL equation valid on the primary side; what was the mmf; which created this flux phi N1 into I m? Where from we concluded that? When S was opened?

So, with S closed; I am once again telling that flux remain same, but both the coils perhaps will carry current, but I am sure the net mmf once again has to be N1 into I m, it cannot be other than that because net mmf divided by reluctance; reluctance remain same. We will decide the flux and flux remain same. So, let us see, what happens? What I mean by these. This is the most interesting part of it.

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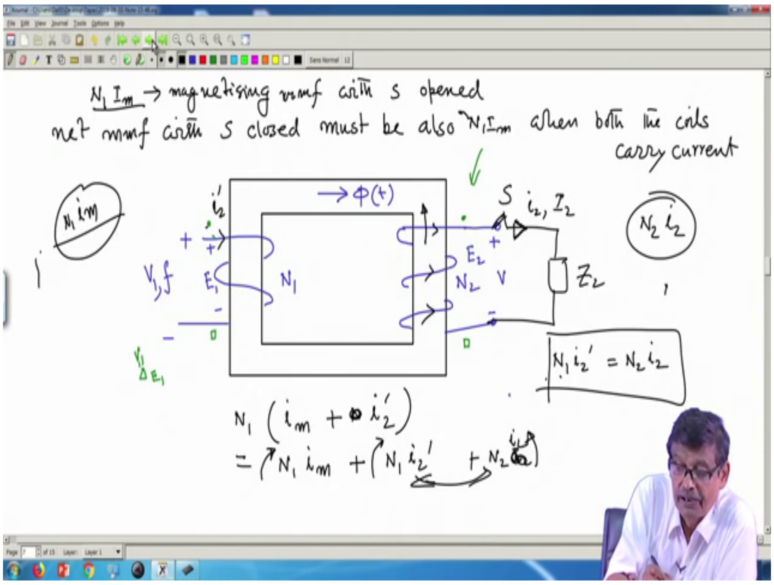

So, this is the thing. So, here what I am telling. We are now discussing this a this thing Z2; this is my S and instead of telling that I m is 0; I will tell let magnetizing current, A is very small finite. So, initially N1 into I m is the magnetizing current magnetizing mmf with S opened, net mmf with S closed must be also N1 into I m when, both the coils carry current. Now, how such a thing can happen? Let us see, suppose you now connect this switch, it has become a seat of e m f. Therefore, it will deliver some current I 2; RMS value of that current is suppose I 2, instantaneous current.

Therefore, secondary coil will create and mmf N2 into I two, instantaneous values or N2 N2 capital I 2 RMS value of the current. Primary prior to closing of the switch was carrying a current of I m magnetizing current. Now, when the secondary will carry a current I 2, it will try to create flux; you will see this one. It will try to create flux in the opposite direction; isn't? Your thumb rule it try to creates flux in the opposite direction.

Therefore, when you close the secondary switch like this your primary cannot be a idle spectator may a spectator to this event that you are doing this. What it will do? Immediately, the moment you try to draw some current through the dot of the secondary of the transformer; it will draw additional current say I 2 dashed of such magnitudes that N1 into I 2 dashed is equal to N2 into I t2.

This I 2 dashed is called reflected current. Therefore, I want to draw current from the secondary of the transformer, I know. Then, it has produced 10m m f N2 I 2, which is acting in the anti clockwise direction; it tries to create flux, but I am telling the moment you do that primary draws extra current. So, what is the primary mmf N1 into that original magnetizing current plus plus I 2 dashed; this will be the total that is equal to N1 I m which acts to create flux in this direction plus N1 I 2 dashed from the dot current is coming out it also create flux in this direction clockwise direction flux.

And, on this magnetic circuit apart from this 2 mmf say third fellow occurs, which is N2 I 2 or I will write plus create this way. Therefore, in the earlier case when S was opened net mmf acting in the magnetic circuit was N1 I m; when you close the switch, what is the net mmf acting in the circuit?

Let there be n N1 I m and this 2 will cancel out because N2 I 2 creates flux in this one and N1 I 2 dash create flux in this one and if this 2 are equal they will cancel out. So, net mmf how much it is acting now? Once again, N1 into I m; this is the most crucial point. And this, the transformer has to do for all the time. That is why; it is true for instantaneous values also.

So, what is the thing going on? Initially, the net mmf in the transformer was N1 I m; I am telling with student: closed. Once again, the net mmf has to be N1 I m. Therefore, if secondary delivers a current of mmf N2 I 2; let me write here small letters N2 I 2, if it delivers a current I 2 hits mmf. Therefore, this mmf it will be compensated by the primary by drawing additional current I 2 dashed over an above I m such that not any value of I 2 dashed of this value.

So that this two mmf s once again balance and net mmf will be once again N1 into I m. That is why people say the moment you want to draw current or power out of the secondary terminals of a transformer. Primary cannot be a may are spectator to this event. The moment you do this primary will react. It will draw additional current such that N1 through the dot terminals mind you through the dot if you show the current going out; then, only this two fluxes will mmf.

Therefore, net mmf once again will be N1 I m; these two will cancel out because from physical directions I know. So, this will be the thing. Later, I will a tell you about this whole lot of physic physical way of understand in the thing; there is easier way of understanding that a look here if you draw power output from the secondary of the transformer. Primary current must increase; how it can ah? Because this is the only two points where I am pumping power into the system and you are taking power out of the system between these two.

Therefore, if you consume power here; ultimately, power has to come from this place; from this place here. Therefore, this power must balance. We will discuss about those things later, but I hope you have understood. So, what I am trying to tell because this is so important a point in understanding the transformer.

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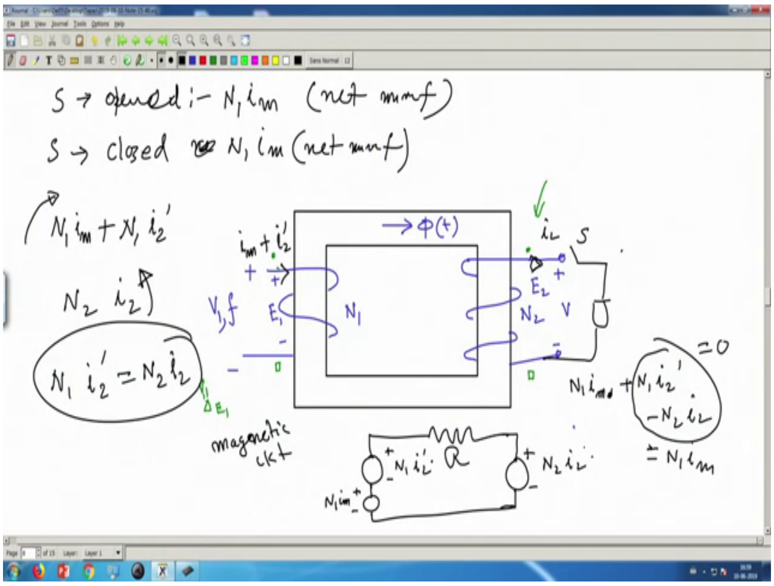

So, what I told? Let me review this because this is so important. There I connected a switch and a load; isn't? I am trying to understand what is going to happen when the switch is closed because after all you cannot just step up or step down the voltage without connecting not connecting anything across this secondary; we have to deliver this power to some load.

So, this is the thing. So, initially with S opened; S opened I am concluding that S opened. Net mmf acting is N1 into I m. With S closed; once again, I am telling. In this case, this was also net mmf; secondary current was 0 net mmf was this. With S closed net mmf N1 into I m must be net mmf.

Why? Because flux level cannot change, but mmf is contributed by this coil current and it is number of turns; this coil current and this number of turns. So, net mmf of the primary coil is N1 I m plus N1 into I 2 dashed and this is in the clockwise direction flux it creates. Net mmf of the I mean mmf contributed by secondary, if u show this is the current; it is N2 I 2 and it creates flux in the opposite direction. Therefore, this two mmf s N1 I 2 dashed and N2 I 2, if this two things are equal for all the time mind you I 2 is wearing sinusoidally.

Then, everything is fine; this two will cancel out. So, if I; if I draw the magnetic circuit like this suppose magnetic equivalent circuit magnetic circuit. It will be; there are two mmfs plus minus N1 I m and here also plus minus N1 I 2 dashed. Here is the reluctance of the magnetic circuit and here is another mmf acting in the opposite direction; what is that? N2 I 2 and this is I 2 dashed.

What is the net mmf acting? N1 I m plus N1 I 2 dashed minus N2 I 2 divided by reluctance. So, net mmf is N1 I m plus N1 I 2 dashed minus N2 I 2 and this has to be equal to N1 I m. How this can happen? If this were equal; this must vanish to 0, that is why the moment you want to draw some current I 2 primary will immediately react and draw additional current I 2 dash on top of I m which was vanishingly small that is fine. So, it will draw a current of I m.

So, please go through these particular topic discus among yourselves with your friends; the arguments put here to conclude that no matter whether the switch is opened or not flux level in the core of the transformer is remains fixed and it is decided by only V1 and f no matter whether this is closed this is opened. Because, the moment s is closed it will draw current, but flux level in the core has to remain same because it has to satisfy. It has a duty to satisfy the KVL equation on the primary loop. You cannot have circuit KVL is not satisfied.

Therefore, it must be E1 and E2 is root 2 pi f phi max N1. So, phi max cannot change. T The moment you close; then, what happens? Initial mmf was N1 I m with student: opened. Final net mmf has to be N1 I m; if these two are equal; these and these are equal, these two mmfs will cancel each other and flux remains N1 I m by reluctance that was the idea. Please, go through it; hope you have understood.

Thank you.