Electrical Machines - I
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Lecture - 49
Parallel Operation of Transformers - II

Welcome to lecture number 49th on Electrical machines 1. And we have been discussing about Parallel Operation of Transformer which is an important topic.

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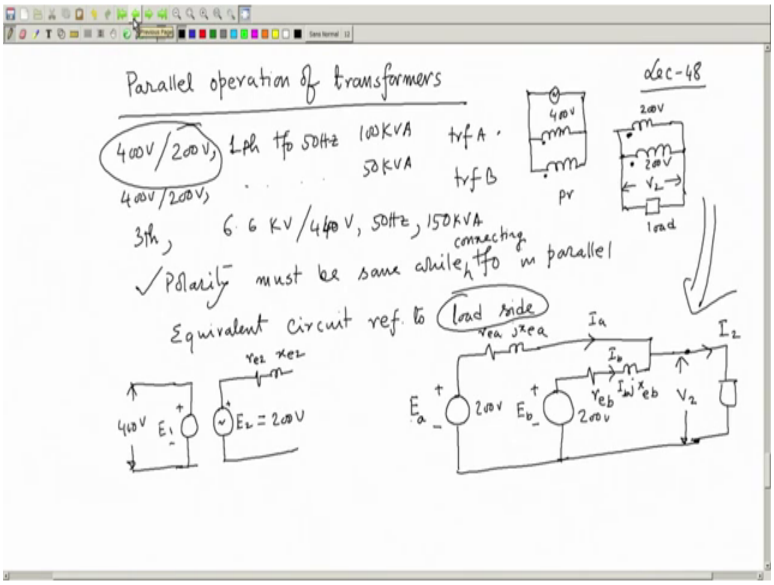

And recall that we in our last class I took an example and told that suppose you have got two transformer, one transformer is transformer A, another is transformer B, then if you want to connect them in parallel what does it really mean is that connect the primaries of transformer A and B parallel and energize with its rated voltage. Of course, before paralleling, we must ensure that the voltage ratings are same, primary voltage and secondary voltages are same, then only you can parallel otherwise not.

Similarly, the secondary coil voltages of transformer A and transformer B, they are connected in parallel and that will be used to supply the load. Now, the necessity of a connecting two transformers in parallel, we also discuss that. And told that in case you have a single transformer supplying a load and if the load demand has increased, then you must have purchased another transformer of higher KVA, instead of doing that purchase another transformer of lower KVA, but having same voltage ratings and connect them in parallel. So, that the old one even not just moving from the circuit. So, in this way as demand increases perhaps you can connect two or more transformers in parallel and supply the new load demand each one will contribute to the load.

As an example I told that suppose we have two transformers of voltage rating 400 volt and 200 volt. And one transformer rating is in the next page perhaps I wrote ok. These two transformers you are connected in parallel. Now, also voltage rating should be same and while connecting them in parallel, we must ensure polarities same polarities must be connected both on the primary and secondary side. So, this was actually that polarity, this will ensure plus plus here ok.

In general E a and E b maybe slightly different, because after all these two transformers are two different transformer exact matching of the secondary voltages when primary is energized with rated voltage which are connected in parallel is very much unlikely. But nonetheless let us assume that the secondary voltage as a general case suppose the induced voltage is E a and E b, and four for this transformer it will be close to 200 volt, this will be also close to 200 volt. And these two voltages will be there and there is load connected, this is your load impedance. And all the equivalent circuit parameters are referred to the secondary side to load side.

And so transformer A equivalent circuit is simply E a rez xea and so on; here also E b this one. Then we would like to know that this is a simple circuit otherwise that the circuit is to be solved, but we will be interested to load for a given load current I 2, suppose this is known, this is known, then what will be I a and I b that is how this currents will be shared. And in case of transformer, you know current rating circuit KVA ratings only, voltages are maintained same almost. Therefore, whenever I say current ratings it means their voltage ratings; so, I KVA ratings.

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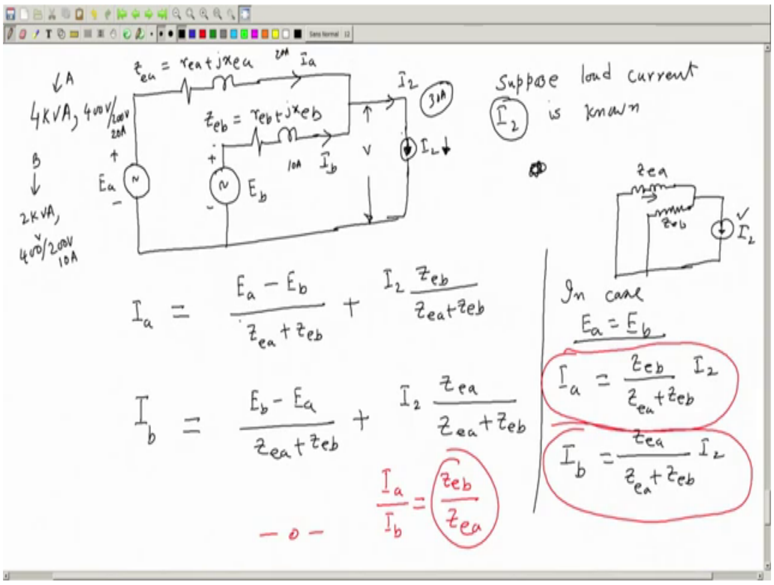

So, then we just found out these expressions that for a given I 2, if this is known your I a will be this much and I b will be this much. In general if E a and E b are not equal, it will be a general expression like this. But since E a and E b will be very close, so and if they are absolutely equal, then of course, I a will be equal to simply this and this one that is this part, this second terms will be much higher compared to this terms. So, approximately I a will be this and I b will be this, why approximately if E a equal to E b, this will be the case.

Even if E a is slightly different to E b, I can calculate the exact values, but also this will give you an idea how I a and I b will be. Mind you these are all phasors here, I a, I 2, I b I 2, I 2 is known. Now, the ratio of I a and I b has become equal to Z eb by Z ea ok. So, up to this point, we have done.

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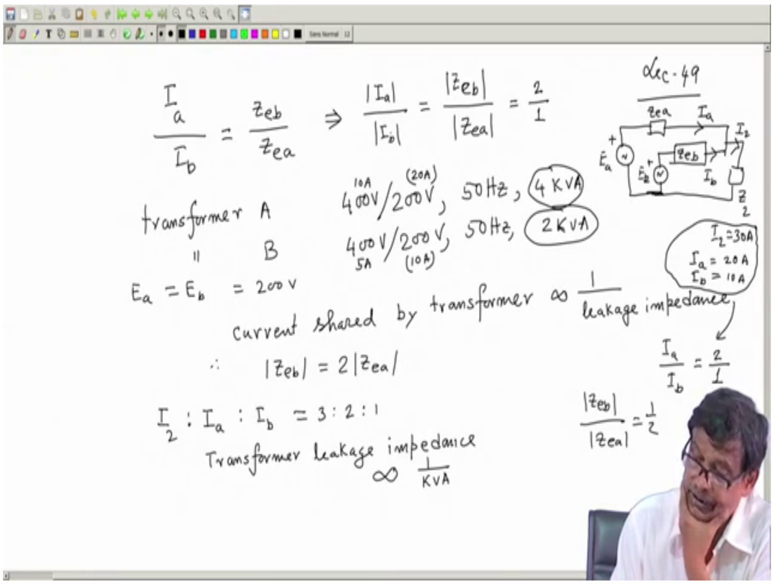

Therefore, we have seen that in the transformer it has come like this I a by I b is equal to z eb by z ea is it not, which also means that this is phasor relationship. This also means that magnitude of I a is to magnitude of I b will be equal to magnitude of z eb divided by magnitude of z ea that is how it will be shared ok. This equation is very important. From this equation we will also put another conditions for those two transformers A and B for better load sharing, and what is that condition that we can get from this equation that is why this equation is important.

Now what is that? So, suppose you have two transformer, suppose transformer A is of rating 400 volt, stroke 200 volt, 50 Hertz. And transformer B has got a same voltage rating it must have 200 volt 50 Hertz that is fine. And the KVA rating of transformer A is suppose 4 KVA and this transformer rating is suppose 2 KVA ok. Therefore, rated currents of transformer A on the low voltage side, how much it will be?

Student: 10, 20.

Ah?

Student: 10, 20.

This will be 10.

Student: That is (Refer Time: 08:46).

This is 20, 20 ampere, this side current. And this rated current is 10 ampere. So, this information I have. Similarly rated current of this side will be 10 ampere and this side high voltage side current will be 5 ampere is it not. But anyway we have referred everything to the LV side we have connected the secondary side 200 volt side in parallel.

So, this is the thing, and this is the circuit this is one voltage source this is z ea. This is another voltage source on the secondary side, this is z eb and these two are in parallel z 2. And this is what I told your I 2 load, and this is I a, and this is I b, and this is E a, this is E b. And assume E a is equal to E b that is both are 200 volt is equal to 200 volt ok, so that is fine.

Now, I have this relationship ok. We will see that for a given current, load current the current shared by transformer A and that of transformer B are in the inverse ratios of their respective KVAs that is current shared by transformer is proportional inversely to its leakage impedance, I a is proportional to 1 by z ea, is it not. So, it is proportional to inversely proportional to leakage impedance.

Now, what is the important thing? See here, I would like to have our intention will be I told you in the last class as well that when I see transformers whenever it is in operation it is always nice to operate the transformer as full load. It will because that is why your investment will then become meaningful, why then purchase so much KVA, so much voltage transformer. Therefore, when this two transformers are operating in parallel, I would like to have 30 ampere is supplied to the load, and 20 ampere is carried out by transformer A; and at that time and 40 ampere is carried out by transformer B that is the most I mean best thing one can think of is it not.

So, if I 2 is equal to 30 ampere, and I a is equal to 20 ampere and I b is equal to 10 ampere. If these happens that is the best thing, all transformers will be under full load condition, KVA handled by transformer A will be then whatever its KVA; 4 KVA, transformer B – 2 KVA and the KVAs supplied to the load will be approximately 6 KVA, nothing is better than that ok.

Therefore, but we then find that I a by I b is z eb by z ea. Therefore, you see the ratio of I a by I b here; I a by I b, this demands that I a by I b ratio should be 2 is to 1, is it not. If this base thing happen, then I a by I b must be 2 is to 1, which means that 2 is to 1, which implies that the impedance of transformer B should be twice the impedance of transformer A. From this now therefore; if therefore, z eb must be equal to twice z ea, then only such a thing is possible.

If for example, it is the other way round that is suppose you find you have purchase two transformers and you find that z eb by z ea is equal to suppose up, just opposite leakage impedances are like this. Then what is the implication? Implication is see the ratio of the currents I a is to I b is to the total current I 2, this ratio; my desirable thing is it should be 3 is to 2 is to 1 that is what I want.

But if it is other way around, then the ratio of currents will be just opposite the transformer having a higher KVA is having higher impedance is it not. The KVA of this transformer is 4 KVA; higher KVA transformer must have lower impedance. Otherwise, what will happen, the moment you start loading the transformer which is capable of supplying more current for a given load current, it will always take less current and the other transformer which is lower KVA will share more currents.

So, a situation will soon occurred, the transformer be having lower KVA will carry rated current and the transformer A has not yet reached rated current, I thing a I got the idea. This is very important. Therefore, I should then now add another important point that is if you want to have a meaningful parallel operations of transformers, then I will say voltage ratings must be same, KVA ratings maybe different. Oviously, why KVA rating should be same, KVA rating is different, but I will demand the transformer leakage impedance should be inversely proportional to their KVAs.

So, I must have transformer leakage impedance should be inversely proportional to their KVAs, then only you get this nice division of load currents. Now, mind you the ratio of the currents magnitude of the currents is z eb by z ea. Now, I say that magnitude of the impedances, leakage impedance should be inversely proportional to the KVA ratings fine.

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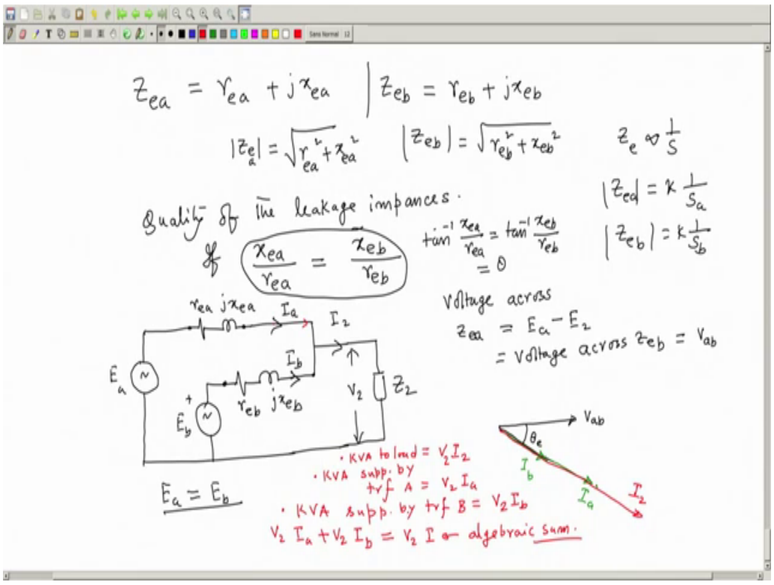

But z ea itself you know z ea is what is inside, it is r ea plus j x ea all with respect to secondary side similarly z eb is equal to r eb plus j x eb. And I a saw that the magnitude of z ea which is equal to root over of r ea square plus x ea square and magnitude of z eb this z ea is equal to root over r eb square plus x eb square. So, if this magnitudes are inversely proportional to the KVA that is fine, but then another condition maybe put that about the quality of the impedances, quality of the impedances of the leakage impedance, if x ea by r ea this angle of this impedances are also suppose same, got this ratio. So, leakage impedance angles they are same.

And magnitudes I will put them in the inverse ratio that is z e I have seen that this is z ea is 1 by that is z ea is equal to sum k time 1 by s a KVA rating; z eb magnitude same k type 1 by s b that you have seen. Then I am saying that ok, if you just meet this condition's, then you may think yourself [FL] what happens this square root of this square plus this square and square root of this square plus this square can be chosen in such a way that ratios are, the ratios of the currents the way I told. But what about the quality, we is it going to make any difference? The answer is yes; about the quality also you have to think a bit.

Now, what it is? Look back, I will write here. So, here the thing is very simple idea, this is E a and this is your r ea, x ea. And this is your E b equivalent circuit refers to secondary side of both the transformer, and this is your I 2. And here is our secondary load, this is z 2 ok. And these are all phasors, I am not putting bar magnitude I will put that modules sign I b. And let us assume that E a is equal to E b that is a case we are studying, these two phases are same.

Now, voltage across each of the impedances, I will calculate. These voltage is suppose V 2, then what is the voltage across z ea, it is equal to E a minus V 2 which is same as voltage across z eb because same B 2 and E a equal to E b. So, same voltage has come here. So, suppose the voltage across z ea and z eb are same let that voltage be denoted by sum voltage V ab suppose I say. So, I draw that first here I will just give you the idea suppose this is the voltage across this and across this, that I have drawn.

If the qualities of impedances are same, then I a will be lagging by some angle theta not power factor angle ok. What is theta? If this case, I am telling this case; if this is the case, then I am defining tan inverse x ea that is the power factor angle of the leakage impedances x ea by r ea which will be same as tan inverse x eb by r eb, and that let it be theta or say theta e sum equivalent impedance, it is power factor angle. It will be I a.

And similarly your where you will be I b? I b will be also lagging V ab by the same angle theta e under this condition, therefore, you are I b will be which transformer I took more this is 2 KVA I b. So, its current will be less [FL]. So, this is your suppose I B. I will clean it. This I will write it as I b. And this one will be your I a, it will be like this.

What is the current supplied to the load I a plus I b, phasors sum of these two, but their co-phasor I a and I b. So, current supplied to the load will be this one, this plus this, I 2, is it not, this will be the thing. What is the KVA supplied by this transformer? It is V into I a, where V 2 into I a [FL] a, here I write KVA to load is equal to V into I 2. KVA supplied by transformer A will be how much, this voltage is V 2 means this voltage is V 2 this transformer is delivering what is this voltage V 2, V 2 into I a. So, this is V 2 this is V 2 in to I a.

And KVA supplied by transformer B, B is equal to V 2 into I b. And if the quality of the leakage impedances are same, it will be the algebraic sum of these two is this one, that is then V 2 I a plus V 2 I b will be equal to V 2 I algebraic sum that will be the case, clear.

Therefore, you see I will not only demand that the leakage impedances should be inversely proportional to their KVA ratings, but also I will say it will be very nice if the qualities of the leakage impedances are also same, then tan inverse x eb by r eb is equal to tan inverse x ea by r ea. And we will get the most desirable thing.

For the example, we have taken 6 KVA, 4 KVA and 2 KVA transformer we have parallel them. If the leakage impedances of these two are in the ratio 1 is to 2, 2 is to 1 that we have seen. And also the angles of each of this leakage impedances are same, qualities are same, then your output KVA you will be also 6 KVA and that is the best thing. Apart from of course, this polarity should be same, voltage ratio should be same that is the first thing. Second if we go much deep into it, then we have come to this conclusion. We will carry on with this in the next class.

Thank you.