Electrical Machines - I
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Lecture - 48
Parallel Operation of Transformers - I

Welcome to lecture 48th and here we will start a new topic on transformer only, that is parallel operation of transformer which is an important topics, Parallel Operation of Transformers, ok.

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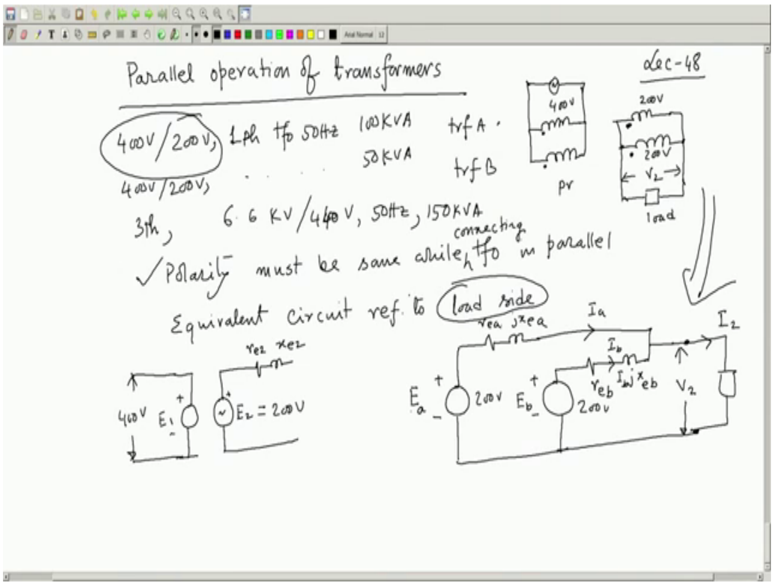

First of all why parallel operation of transformers are necessary that is a the topic from the title of the topic it looks like there will be two or more transformers which will be connected in parallel. What does that mean? Suppose, just if you have one transformer here with its primary and secondary like this and another transformer there; what is done; these are the primaries of two transformers say transformer A, transformer A and this is transformer B. Now, this not A B C phase, single phase parallel operation first I will discuss. So, operation of transformers.

So, what does that mean is this; the primaries will be connected in parallel and excited from voltage. Secondary winding too will be connected in parallel and load will be connected; got the point. So, two transformers, similarly if it is more than two another primary will be coming parallel another secondary transformer, C secondary will, A B has nothing to do A phase B phase just naming the transformers. So, so we let us first discuss this single phase operation.

So, this is what is meant by parallel connection. You connect the primaries in parallel, also secondaries in parallel to supply load and primaries to be supplied with a source. Naturally, this, there are some conditions you can just connect any two transformers in parallel. One of the conditions you can easily make out is that the voltage rating must be same. For example, if it is a 400 volt stroke single phase transformer, suppose 400 volt stroke 200 volt transformers. Rating some kVA ratings 400 volt, 200 volt, single phase transformer and all are of course, 50 Hertz. So, suppose 400 volt sight I will connect them in parallel and it is absolutely logical. Rating of each one of them should be rated voltage. So, they are connected in parallel and supplied from the same source.

Similarly, the LV side rating is 200 volt and we are going to connect them in parallel voltage cannot be different. So, the voltage rating of the primary and secondaries must be same. For example, you will never think of connecting a transformer of rating 400 volt, 200 volt in parallel with 100 volt and 50 volt, this two cannot be parallel for obvious results, ok. So, that is the thing. So, voltage rating there are certain condition, first of all to be full filled to connect the two transformers in parallel.

Before coming to the conditions which need to be full filled in order the two or more transformers connected to be connected in parallel, we must ask ourselves what is the need of connecting two or more transformers in parallel. For example, in power system particularly in distribution system suppose you, because in distribution system you know at the last level there is a transformer whose rating is typically 6.6 kVA to 44 volt, 3 phase, that we discussed earlier.

Now, suppose in a locality which is to be supplied with 44 volt supply. 44 means one supply line and neutral will go to every consumer 220 volt or 230 volt like that. But the problem is suppose a locality is growing initially the demand of power is not that high. Suppose, you select a 100 kVA transformers 6 points to give you an idea 6.6 kVA to 440 volt, 3 phase transformer it is; it is also true for 3 phase transformer, 3 phase 50 Hertz.

KVA I am not writing. Now, what I am telling; suppose, you see that presently the kVA rating is say 100 kVA, the will be sufficient to cater the consumers because it is a growing area, load demand is growing. So, suppose you decide, I will now buy a 150 kVA transformer, 50 kVA will be another margin and start giving power to the consumers. But as you know the as the area is growing every 5 or 7 years the load becomes doubled, ok, approximately I mean. May be after 10 years the power demand will become 300 kVA.

Now, naturally this transformer now be in sufficient because from this transformer which is rated at 150 kVA if you want to derivate 300 kVA that means, it will be over loaded. See, kVA means current, mind you, the voltages as are approximately same even under with the concept of regulation there will be slide voltage difference these that that is there. But, nonetheless the transformers will be come over loaded. You cannot pass current kVA is synonymous with currents, voltages are almost same.

Therefore, if the load demand increases then this transformer which you installed initially after 7 years the load demands suppose becomes 300 kVA. What is the option left; then you have to purchase another transformer of same voltage rating, but 300 kVA is not and do away with this transformer remove this transformer,. But that is not to economic proposition, because these transformer is otherwise healthy and cost of a 300 KVA transformer with same voltage ratings is going to be definitely higher.

Therefore, perhaps what other alternative is you purchase another transformer of similar ratings and connect them in parallel. So, that the combined kVA is 300 kVA and it will last for another 5 or 7 years, after that perhaps another transformer you. So, your cost of investment is reduced at a time you do not have to purchase a very big transformer and this is the very practical solutions in some areas. For example, it is now a village, gradually growing industries may come up and things like that a big residential complex. So, demand will go on increasing and it is therefore, needed to connect the transformers in parallel.

The advantage of connecting the transformers in parallel is another important thing. That is, see, if you if the load depend is one 300 kVA suppose it has gone to and suppose you are using a single transformer which is catering that 300 kVA load, but if some fault occurs in that transformer the transformer is to be taken out for repair works or whatever it is. And then there will be no power to the consumers. You cannot then provide any power because the transformer is out of order. But had there been two transformer operating in parallel, it is very unlikely that both of them has simultaneously has become faulty or needs servicing; is not?

Therefore, in such a situation if two or more transformers are connected in parallel catering a certain amount of load if it so happens that one it is likely that one transformer will become faulty, why all of them suddenly becomes faulty. So, one of them becomes faulty; you remove that that is to be that you take out. Then the kVA you can supply will be less no doubt one transformer less whatever its kVA rating, but nonetheless some of the consumers maybe supply power that is a no main thing, I mean in one case if it is a single transformer everything is blackout, if one transformer develops fault.

But if more transformers in parallel, one transformer goes out of order take it out and then you can you can restore service back, but not to all consumers and that you can rotate somehow to satisfy all the consumers by switching, disconnecting, some consumers at some point of time reconnecting some other consumers. So, these are the nice points of having at least at the distribution level some transformers operating in parallel.

The cost of each unit is small. In fact, you can, if two or more transformers are operating in parallel, you can keep one transformer ready, I mean not in use what it is, as a backup. So, if one transformer is faulty temporally power will be interrupted to some consumers, but connect that new one and take this for servicing that is the whole idea very simple logic nothing great things. But that is why the operating transformers in parallel assumes importance, ok.

Now, we will come to the to the important thing that is if I want to operate two transformers in parallel what are the conditions to be satisfied. One conditions I have already seen because you will be operating in parallel. So, voltage ratings must be same, ok; is that kVA rating should be same? Not at all; kVA rating is current ratings. So, KVA ratings may be different. One; you may have 100 kVA this transformer, it will be operating in parallel with another 200 volt, something 50 kVA transformer no problem. kVA rating may be different. But only thing is when they will be operating in parallel; what is kVA rating; kVA rating mean essentially current rating of a either HV or LV.

So, you must see that this transformer both of them are operating in parallel is low voltage side should not exceed it is rated current, that is the only condition individually.

For this transformer, its low voltage current rating will be certainly to time this that should not exceed that is the only thing.

Then the third important point is which is rather practical problem after you have got this two transformers which you want to operate them in parallel, you must ensure that is very important, polarity, polarity test, polarity must be same while connecting transformers in parallel, while connecting that must be same, otherwise you cannot do. So, voltage rating and it should be connected in parallel with the due regard to their polarity, otherwise there will be problems.

So, what do I mean by this? This is suppose the polarity of transformer A marking, this is the polarity of transformer B and this is the correct way of connecting. If somebody connects this secondaries for example, by mistake like this then what is going to happen; dot becomes plus 200 volt, here dot becomes plus 200 volt load you have connected, but it will find a 400 volt acting in the circuit creating a huge it is equivalent to short circuit. So, this should be avoided. It is not allowed at all. So, polarity is a must condition before you connect transformers in parallel [FL].

After telling this there are other conditions which will be clear as we go along, ok. Now, where from to start? It is like this see if you see the connections the connections I have already told. Now, I will always neglect the no load current in these analysis. No point in taking that. Instead because no load current is only 5 percent of the full load current of the given transformers compared to be load current it is nothing. Therefore, to get quick and good estimate of the current distributions in the transformer when they are operating in parallel you better do not take no load current into account, ok.

So, transformers which will be in parallel, I will always draw the equivalent circuit, equivalent circuit refer to load side. For example, in this case it was 400 volt, [FL] 400 volt this is suppose the load side. So, correct I finally, put these two correct polarity, then only you can connect. So, this is dot, this is dot. Polarity test I will do accordingly I will connect them in parallel. Therefore, if you draw the equivalent circuit refer to the load side then what happens is this. The primary side will have I will only show the induced voltage E 1 and this is E 2 the induced voltage on the secondary side, ok; and here I will show the all the parameters in this way r e 2, x e 2 and here I need show r 1, x 1 that is what the equivalent circuit means. So, refer to the other side I will draw the equivalent circuit of each of the transformers, clear.

Therefore, if you draw the equivalent circuit referred to the secondary side or load side, it will simply becomes now like this, because of this parallel connection this is the induced voltage of transformer A and this is the equivalent impedance of the transformer that is r ea and j x ea. I have paralleled it with respect to the terminals available. Similarly, the second transformer I will only consider two transformer, E b. Mind you, this is the secondary voltage if you want to write 2 you can write, but this I will avoid, otherwise I have to carry on that 2. So, this is this thing and this is the second transformer.

And it will have its resistance and leakage reactance, all referred to the secondary side, suppose this is the thing and where are parallel them here getting. So, this is thing and here is your load. So, this thing is equivalent to this thing when translated into equivalent circuit, got the point. So, r ea, x ea is what? It is secondary resistance and reflected primary resistance, that is why I have not shown any resistance here. Similarly, r eb, x eb will be like that and this is the connection.

Now, in general if the voltage rating are same, so here if you apply 400 volt here. So, this induced voltage will be 200 volt, so here also it will be 200, here also it will be 200 volt and you get the current. Now, at this point I will tell you that, see after all these two transformers are different transformers.

So, sometimes what happens, this secondary voltages when you have applied same primary voltages to the primary of these two transformers; there may be a slight difference for example, this is 200 volt, this may be 208 volts because of some they are not after all identical there may be always slide difference. In that case what happens is that if the switch is open then there will be a circulating current, which is limited by the sum of the leakage impedance of these two transformers.

Anyway, people say that, little bit of difference of voltages may be allowed provided it does not cause a large circulating current. So, this although a is equal to E b is the most desirable thing, but there maybe a little bit of allowance that can be allowed and maybe it is 200, this maybe 210 or so 5-10 percent this way, that way you can do but any way; so, generally that is way I have wrote E a and E b. I am not sure there will be most probably equal and fine.

Now, to understand the other important conditions to be fulfilled this circuit is drawn and then I say that what I should ask is that let us try to calculate. Suppose, and this voltage is what; this voltage is the terminal voltage V 2, common secondary terminal voltage here, this is V 2, is not.; and this is the secondary current I 2. Now, you see the moment you connect these two transformers in parallel, this load current is going to be shared by secondaries of these two and accordingly there will be reflected current in their primaries. So, any way we are looking. So, if the secondaries of the transformers are carrying rated current as I told you primaries are also taking rated currents no problem. Therefore, only one side I will focus on, ok. So, it is like this I 2.

Now, the question is what will be your I a and the I b. Who decides how much of this I 2 will be flowing through I a and how much of the I 2 will be flowing through I b? I am not writing two everything is with respect to load side mind you, clear. So, that that is one important thing I must see.

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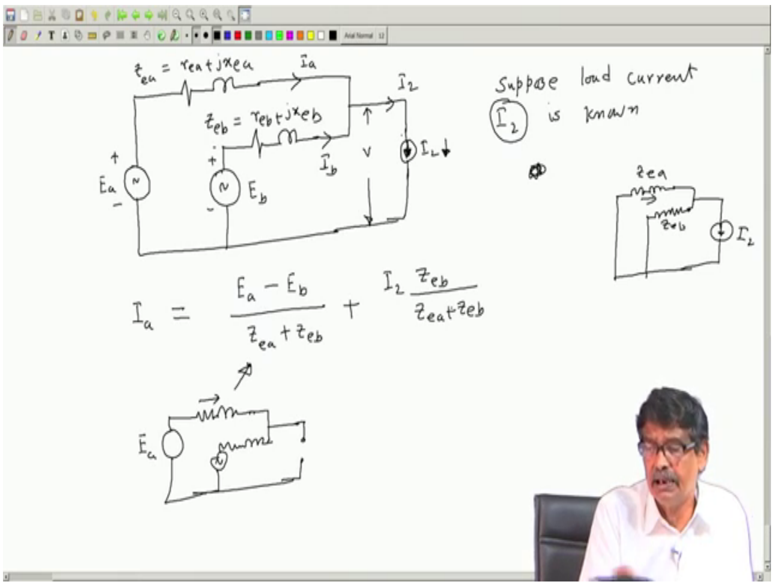

For example, so this is the circuit once again I am drawing. So, this is your E a, a c this is your r ea plus j x ea leakage reactance. Second transformer this is the thing, because it is connected in parallel. This is r e b plus j x eb and then I have connected them in parallel with due regard to the polarity means this plus plus and then I have connected a load here. So, what is this statement of the problem, please note down.

What I am telling is suppose load current is known, I 2 is known you have connected some load and you find it is drawing this much current it is known. I want to know what is I a and I b that is the thing and if I find out I a and I b then I will perhaps get some more conditions which is which will be necessary for better sharing of the load because as I told you the KVA ratings of these two transformer may be different. For example, you just help me if necessary in calculation simple thing.

Suppose, I have this transformer, one transformer is 400 volt, another is 200 volt, ok. I first I will do it like this. This part at least can be done whatever time is left. Now, so how do I find out this? It is circuit problem, what else; I know E a, E b and I can find out. But I will do it and I will assume E a, E b are not same. They will be same that is the most desired thing, but the as I told you there maybe a little difference. So, E a, E b are there and what will be the current shared by this.

The best way and there are several ways you can calculate it and this voltage is v. You can apply nodal method this that to calculate the current. But the nice way of calculating it is this since I 2 is known, what you can think of in the circuit is that this impedance can be removed and you can tell there is a current source, you must be knowing that, that in a circuit if current in a branch is known then replace that component by this current source. Currents in other branches is remains same, how does it matter, is not that is. So, it can be replaced by current source in this direction.

Since, it is known in terms of I 2 I want to know what is I a and I b. Now, in this circuit there are 3 sources E a, E b and there is a current source. I will apply super position and in one stroke I will get I a and I b, see how. This I a should be equal to, I will apply superposition, ok. For example, I will assume E a and E b are present and this current source is not there that means, it is open circuited, remove it, then because of E a and E b current I a in this direction will be simply E a minus E b divided by z ea plus z eb this is your z ea and this is your z eb, is not. So, for these two sources current will be this current source is open circuited then plus I must remove this source because these are voltage sources.

So, I will put them short circuit and I will assume only current source is present.

So, if you put this short circuit means what these two are in parallel and this is the total current. So, when this term is let me draw because for me it is simple, but so only these two sources are present means this and this and current source is open circuit then calculate this current, that is what I did, E a minus E b by this. Then only current source is present then it will circuit will be like this z ea, ea shorted, z eb, eb shorted and you have only this current source, that is the load current I 2 and how the this will be shared; this rule is already known.

So, for example, this current will be because of I 2, the total current I 2 into impedance of the other branch divided by sum of the impedances is not that is all in one line we will get this current instead of solving so many questions. So, and this equation is important necessary. Now, if you get this, if you get this will be I a, clear?

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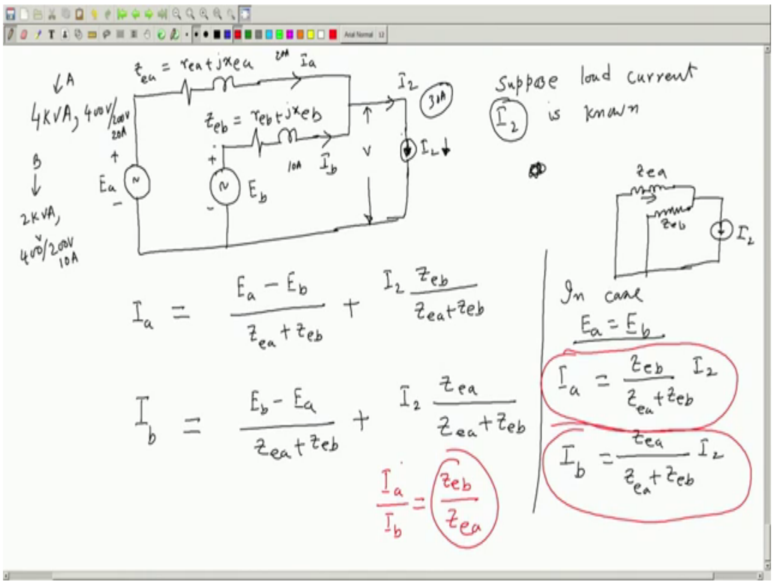

Now, similarly what will be I b I b will be equal to this current because of all these 3 sources present, first assume this is absent, then this current I b in this direction will E b minus E a by z ea plus z eb plus when this current source is present these two are shorted, these two become parallel. So, the total current I 2 into impedance of the other branch z ea divided by z ea plus z eb. This is the thing.

Therefore, for a known load current how the currents in the winding of the transformers on the secondary sides will look like is this and in case, in case E a is equal to E b it will be further simplified to I a, so this is the circulating current part. As I am telling if there is a slight mismatch that circulating current part can be calculated. So, I a in case E a equal to E b it will be simply z eb by z ea plus z eb into total load current I 2 and I b will be equal to z ea divided by z ea plus z eb into I 2.

See, what we what we really want. Suppose, the rated current of this transformer is known, if you see that I just tell you one rating. Suppose, a one transformer is 4 kVA transformer A and transformer B is 2 kVA, kVA ratings may be different and the voltage rating of this transformer is suppose 400 stroke 200 volt and voltage rating of this transformer is also same 400 volt by 200 volt and I am looking things from the 200 volt side, is not. That is what I told, load side. What is the rated current of this, LV side rated current?

Student: 20.

20 ampere and what is the rated current of these?

Student: 10

10 ampere; LV side rated current is 10 ampere. Therefore, I will see that this transformer since I have connected one 4 kVA and 2 kVA, this transformer I should expect should supply 6 kVA, 4 plus 2, 6 kVA and maximum load current I can allow is then 30 ampere, is not?

May be load; so, 30 ampere current I would like to supply to the load. But here I should also add, this 30 ampere when it will be supplied I will demand that transformer A supplies 20 ampere and transformer B supplies 10 ampere, then only I will be most happiest man in the world, ok. Your load is taking 30 ampere, your transformer A is capable of delivering 20 ampere, transformer B is capable of delivering 10 ampere and this is the most desirable thing, is not, it should happen,.

But the distribution of this total current is fixed by this relations; it looks like, who decides that out of this 30, 20 will be carried by these and 10 will be carried by this is decided by this because if you take the ratio I a by I b. Who decides that? If you take this ratio from this; it will be what?

Student: z eb by z ea.

z e b.

Student: z ea.

By z ea. It is not that simply I have connected, I have done my job, ok, this fellow automatically takes, no. It depends on relative values of z eb and z ea. So, read this portion very carefully and think about the answer that is I should then put condition what should be the nature related values of z eb and z ea such that this 30 ampere should be divided according to their KVAs.

Thank you.