Electrical Machines - I
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Lecture – 39
Open Delta Connection

Welcome to lecture number 39 on Electrical Machines I.

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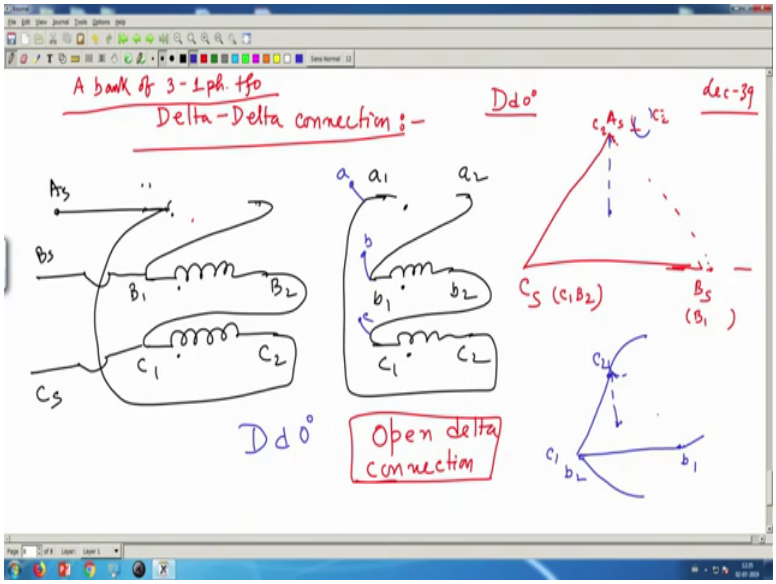

And we were discussing use of 3 single phase transformers to step up or step down voltage it depends upon the connections, what will become the line to line voltage, transformation. And also we have fairly understood what is the phase shift of the secondary voltage with respect to primary voltage and what are the possible connections familiar conditions like star delta, delta star, delta-delta and so on.

Now, you recall that, this 3 are individual transformers. And this is the delta-delta connection with D d 0, we have discussed this earlier. That is the phase voltages are in phase. In this connection, see this connection and I am talking in terms of 3 a bank of 3 single phase transformers; 3 identical transformers you take separate A 1 A 2 and I can connect them in delta-delta and so on.

Now, one interesting thing about this connection is that, you can have from this you can derive an interesting connection which is called open delta connection. Now I will put it

in a question form, that is suppose you are given two single phase transformers of identical ratings not three, then is it possible to change the voltage level from the source to the load side that is the question asked. So, 2 transformers I will give, is it possible to still transform a 3 phase balance voltage from one level to another that is a thing [FL]. In these complete 3 transformers when you are using, we have connected this transformers as delta-delta and D d 0 is the connection ok.

Now, suppose I say that, in this connection I will remove one transformer, say transformer A, I will remove; then what are the things will happen, that is a what I am planning to do I will remove this transformer as if it is not there. And other connections remain as it is, what do I mean by it is not there? It is physically not there; so it is open circuit here. A is gone, there is no A 1 A 2, got the point.

Similarly, it secondary is not there; that is there is a open circuit in place of transformer A, but nonetheless I have connected in this fashion. Then across a transformer B of course, same voltage has been applied B 1 B 2 because of this line voltage is balance 3 phase what I have done I have applied a B s C s across B 1 B 2; across C 1 C 2 I have applied a voltage C s A s because this connection is there, A is not there. But A s is connected here and C s is connected there. So, how much voltage I have applied, C s A s. So, in other words what I am telling if you A 1 A 2; where is A 1 A 2 here, remove A 1 A 2, then what I am telling I have applied a voltage across this is C 2 mind you.

So, across the C transformer C 1 C 2 has been applied and across transformer B; B s C s has been applied this phasor this phasor, but across A s B s it is also balance line to line voltage that voltage phasor exist. But A s B s has not been applied to any of the primary because that transformer A is missing, are you getting. So, this is the thing, but since I have applied a voltage here across. So, this I will first remove across c 1 c 2 there will be induced voltage parallel to these voltage these voltage across b 1 b 2 there will be induced voltage parallel to this B s C s, b 1 b 2 and b 2 c 1 are joint. So, it will be like this only and I will take output from this, from this and from this.

Then what I am telling that these 2 voltage has 60 degree apart therefore, these voltage also will be 60 degree apart it is conditioned by these 2 phasors. Even if transformer A is not there, you will still get a balanced 3 phase output voltage, is not. So, it looks like that delta is not complete, open delta, got the point. Therefore, you can take output and once

again supply a 3 phase load; your 3 phase load will not fill anything balanced 3 phase voltage I am receiving. What was the line to line voltage in the previous case when all the transformers where there, these are the line to line voltage. Here also same, same line to line voltage you will get.

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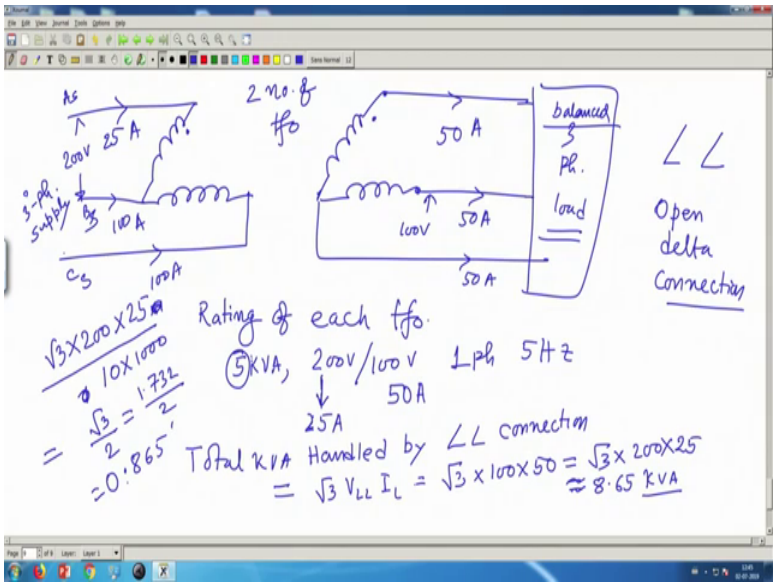

In other words in simplified diagram, what I am telling; suppose you what you have essentially done is, which transformers I have removed. If I draw it in a simplified diagram, I will do it like this; this is one transformer, this is another transformer, this is it secondary, this is it secondary and the third transformer is not there. And what I have done, I have connected 3 phase supply there A s B s C s, 3 phase supply.

So these voltage will be this line to line voltage whatever it is; I mean now look at this diagram separately ok. And what will be these voltage these will be B s C s parallel to this therefore, this third voltage gets automatically decided and 60 degree out of phase; therefore, I will take output from this, these and this and supply a 3 phase load.

Then you can change the level of 3 phase voltage from one value to another just by using 2 single phase transformers; that is what I want to convey to you. You do not even require 3 transformers. Remember I took the rating of each transformer, so 2 number of transformers mind you; and you get open delta connection like this it is mentioned. Rating of each transformer I took as 200 volt, 100 volt for easy calculation 5 kVA; single

phase 50 hertz what is the thing, what is the rated current of this side 5000 and oh this side 100 I will took, anyway how much it is 5000 by 200.

Student: 25.

This is 25 ampere rated current and this is 50 ampere rated current. Now I would like to know that what is the kVA rating of this type of connections; in case of 3 phase transformers in my first lecture on 3 phase transformer I told you, if the rating of each transformer is 5 kVA, total kVA which could be handled by this 3 transformers since 15 kVA quite logical; each one will give you 5 kVA. But in case of open delta connection which is called open delta connection; we would like to know how much kVA that can be handled by this open delta connection. The idea is pretty simple, mind you in this case the secondary winding in series with the line, what is the rating of the secondary side suppose this is 100 volt side, how much maximum current I will allow to flow 100 ampere because winding rated current is 100 ampere 50 ampere. So, sorry.

So, I can allow 50 ampere current to flow in this line in all the line this line and if these two are 50, phasor sum will give you also this is 50. So, I should not exceed this rated current. The moment it delivers 50 ampere here it will automatically by principle of transformer will bring 100 ampere there, are you getting. And these currents will be once again balanced 3 phase current, why not load is balanced; balanced load. Therefore, what is the total kVA handled by open delta connection will be equal to how much, if you calculate from the L V side it will be root 3 V L L into I L is not that is the formula.

So, root 3 V L L, in this case will be how much, if you apply here 200 volt.

Student: (Refer Time: 14:45).

This is 50; this is 25 thank you. So, if you apply line to line 200 volt here, line to line here you will get 100 volt. So, if you calculate from this side it will be root 3 V L L into rated current 50. So, which will be same as I will neglect the no load current etcetera. So, root 3 V L L into I L and this two will come same 100 230.

So, this much total kVA it can handle, but it may look like you are using 2 transformer rating of each transformer is 5 kVA perhaps can you just calculate these two.

Student: 8.6 5 k

8.

Student: 6 5.

8. 65.

Student: Approximately.

Approximately. So, this is 8.65 kVA, but you will be rather surprise to see ok, at least I am using 2 transformers it is kVA rating should have been 10 kVA I mean I would expect 2 transformer I am using. So, without overloading any of the transformer I see that no, it is not 10 kVA it is slightly less than that. Therefore, why it is because this is the line current and the winding currents are same ok. And it is a 3 phase system and the factor by which this kVA will be reduced is then I was expecting, see I will calculate this number root 3 into 200 into 25; I was expecting and with respect to whom, when all the 3 transformers we were using what is the kVA handled by.

Student: 10.

By the (Refer Slide Time: 17:21). So, it will be.

Student: 10.

10, but this should be multiplied by 10 to the power this should be multiplied by into 1000 is not how much it will become?.

Student: Root 3 by 2.

Root 3.

Student: By 2.

By 2, how much it is approximately 1.7.

Student: Its 20 angstrom.

0.1732 by 2; so one point?

Student: 0.865.

Therefore the capacity will be about 86.5 percent of the expected capacity or common sense tells 2 transformers you are using, then 10 kVA you can extract from the transformer, no it is not going to be like that, it will be only lesser. But nonetheless this connection was popular I mean still may be also popular because of the fact see the advantage, although I have not told you anything about a 3 phase single unit transformer, 3 individual transformers I am connecting.

Now, in earlier days the advantage of using 3 single phase transformers are there are at least two biggest advantage.

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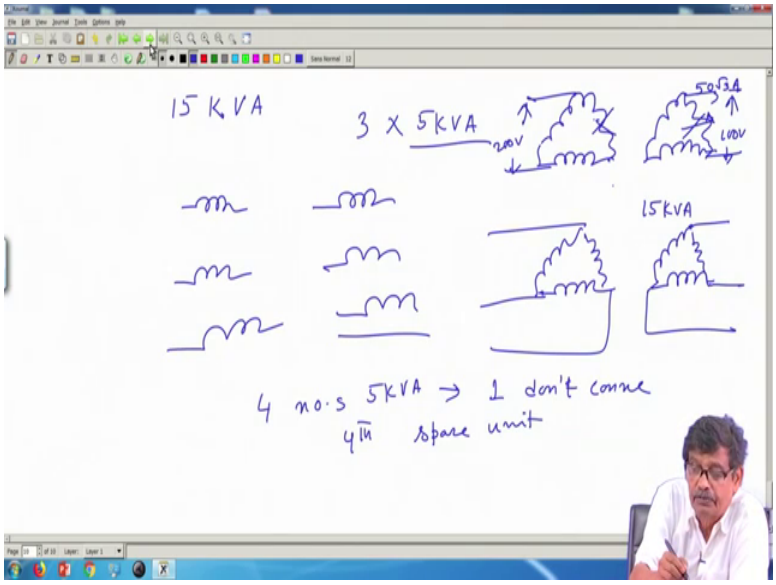

One is suppose your total kVA you have to handle 15 kVA, I mean I am going other way around suppose my 3 phase load demand is 15 kVA. So, you by 3 5 kVA transformer to achieve this and connect this 3 individual transformers star delta whatever is necessary depending upon the voltage level; but 15 kVA you will get. So, you will buy 3 single phase transformer each of 5 kVA rating, is not. Each of 5 kVA rating you buy and no open delta I am telling you connect this 3 phase star delta whatever way, so total kVA of the system will be 15 kVA fine.

But the advantage of this method is that, if suppose one transformer develops a fault ok. Let us take that previous example in this simple connection same number because then it will be clearer, suppose it was delta-delta connected then you apply 200 volt here, here

you get 100 volt is not. Suppose the connection is same 5 kVA each, so 15 kVA you get; what is the rated current of the L V side we have seen.

Student: 50.

50 ampere. So, 50 ampere here now, compare delta-delta full connection then line current you can apply 50 into root 3 ampere you can allow and then the total kVA becomes root 3 into 100 into 15 to root 3, 15 kVA it is good. And you are stepping down the voltage, you are, supplying 3 phase load that you should be always in your mind that thing is playing.

Now, suppose in this case one of the transformer develops a fault, then I will say can I still supply the load; I will say yes. If suppose this transformer develops a fault, because this three are 3 separate transformers it has developed a fault, then this transformer you remove from the circuit. So, that your connection will become something like this and I will say look here you still will be able to supply the load, but not 15 not 10 kVA, but some 8.65 kVA that is what I want to convey to you; but nonetheless it is better than nothing. Suppose one of the transformer develop fault you can immediately rest or supply, but supply a load slightly less than the rated kVA, 15 kVA certainly you cannot supply, but it is not 8 kVA 10 kVA as well to be slightly less, but something is better than nothing sort of thing happens. Not only that when you use 3 single phase transformers in such cases what people will do, each transformer rating is 5 kVA.

So, keep by 4 at the very beginning and in case of fault keep 1 in reserve waiting. So by 4, 5 kVA transformer, phone numbers 5 kVA, one you do not connect; spare it is the fourth one is spared transformer, spare, spare unit waiting outside. If such a situation occurs one transformer develops fault you remove this transformer bring that fourth one here. What is the advantage of this method? This spare unit which you are purchasing is only of 5 kVA rating, you will see that if it is a single 3 phase unit of transformer of 15 kVA; if one of the winding develops fault then you have to take shutdown and correct that faulty.

In case of 3 phase unit you will see this open delta connection cannot be used; because after all this transformer has developed fault you will have to take some corrective action. And there also that transformer has developed a fault of 15 kVA single unit then the spare of that it will be of also of 15 kVA unit. So, lot of money is to be invested you

know, that is not a good solution. Therefore, in those applications where you can use take the advantage of open delta connection, even if you do not have any spare units still you can maintain supply till that transformer is repaired ok; then connect it if you do not have a spare unit and like that you can maintain ok.

So, this is a very interesting connection open delta connection, I hope you have understood what it means; but the capacity of the transformer is reduced.

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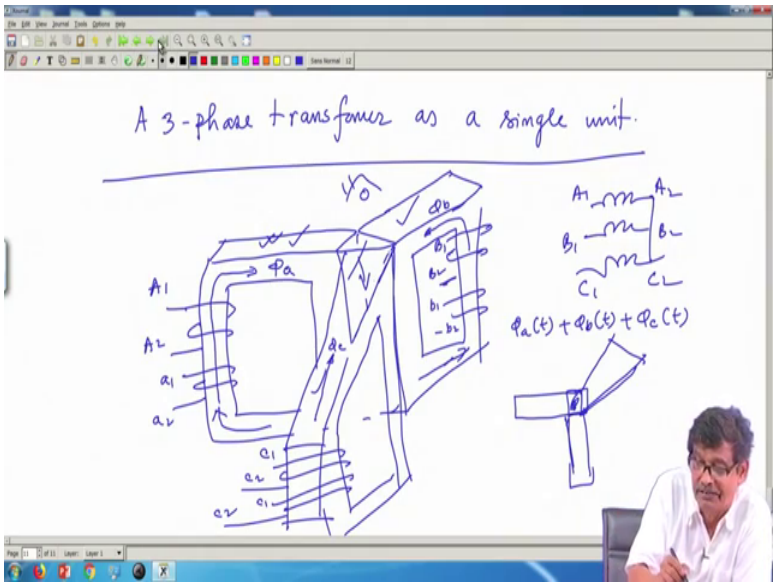

Now, I will just today tell you about A 3 phase transformer we will come back to this connection once again; A 3 phase transformer as a single unit ok. So, how it can be first let me draw this diagram is slightly tricky to draw; what I mean to say that suppose you have a transformer like this, very rough sketch I will do, but you will get the idea. This is the, suppose one transformer and to understand what is going on, this is this transformer with iron core. And what I will do here I will have 2 windings on the slim, imagine I have 3 such iron core got the point; because this diagram I cannot draw so nicely, next time I will show some drawn diagram. But the idea is interesting, what is done is you take another similar unit and suppose you have put it there, got the point you will get the idea hopefully.

Another iron core, and here also you have got 2 coils; one will be primary another will be secondary on the same limb. Bring another third unit and put it here, this time I will make a mess of it, but any way try to get the idea. This is the third one another similar

this is like this got the idea, you have and remove this one. Here is the third unit, where also there will be this one its core. That is 3 units there is a central common iron; one goes like this another like this, then need not be 120 degree apart nothing like that you join them somehow, the central iron. And here also you have two windings in the outer limbs 1 and 2; I think you have got the idea.

So, 3 iron structure of single phase transformer you have put together, mechanically. Now what I will tell you name the terminals as A 1 A 2 and it secondary small a 1 a 2 on the same. Similarly this is suppose B 1 B 2 and this is small b 1 b 2 and this is C 1 C 2 and small c 1 c 2. Now you imagine that A 1 B this 3 coils while showing the connection I have done like this A 1 A 2 suppose star connection I have done B 1 B 2, C 1 C 2 suppose primary; then this transformer will develop a flux, secondary is open suppose phi a.

Similarly B 1 B 2 will also develop a flux say phi b going these way, function of time. And third transformer will develop a flux, this diagram so badly drawn any way try to understand; the this is phi c, but this phi a, phi b, phi c will be 120 degree out of phase because the applied voltage is balanced 1 by root 3 is coming.

So, how the flux path will be completed phi a goes there, through the central iron it comes then it goes there. How phi b will be completing it is path, it will go like this through the central iron it will come down and go there. And similarly phi c it will go like this through the central it will come. If you see the top view of this thing that is easier to draw; what I am trying to tell this is one transformer iron, this one you will be able to see. This is another transformer plan I am saying are you getting and oh sorry this is the third one like this, if you look from the top you will see this three things.

Now, this is the common iron here this three you will be able to see like a finding out things. Now if I ask you what is the flux in this common iron, how much it will be? It will be 0, because phi a t plus phi b t plus phi c t their 120 degree apart in time, their instantaneous values will be 0; as I a plus I b plus I c in a 3 phase system summed up to be 0, balanced 3 phase system. Therefore, it looks like this central iron whether you connect it or not it does not matter it does not carry any flux.

So, phi a will get it is return path via phi b this iron and this iron, as it happens in a 3 phase 3 line current system. I a plus I b plus I c is 0 whether you provide that neutral path

or not; if I a I b I c are balanced 3 phase current it does not matter. Anyway so next step is therefore, this iron portion central that thing can be removed. And not only that we will see in our next class, if you remove this central iron, you save some iron definitely. Because central portion I know it will not carry any resultant flux at any point of time if it is a balanced 3 phase system; then the weight will be reduced, but nonetheless still the structure of the transformer will be pretty awkward. See in the working place if you keep it these projections will make a very inconvenient piece of equipment to work with.

So, what people do is this.

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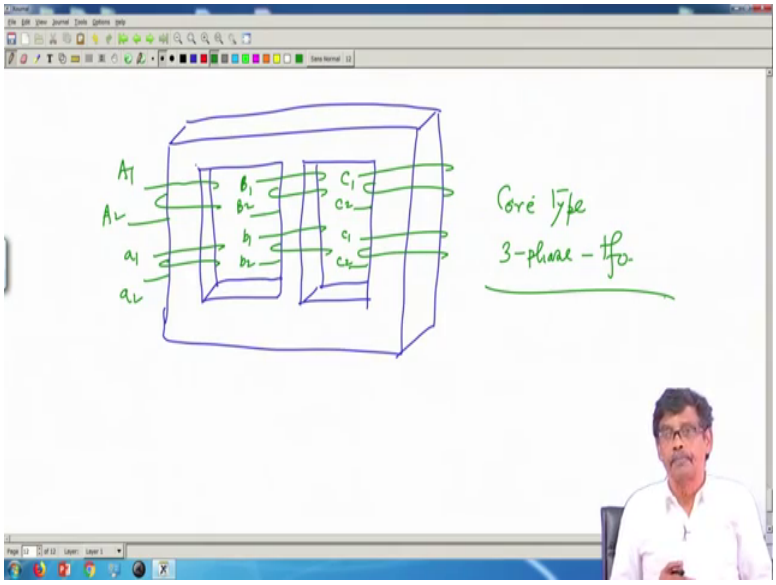

They will I will just draw today and then they make it much more simpler. They say do not go for this projections, make it absolutely rectangular. This is the iron laminations stack one about them and this is (Refer Slide Time: 34:26) limb this is in plane. So, it will look like these are this is, got the point. I do not know whether this we will be able to see and then you make your connections like this is A 1 A 2 this is we will continue with this next time do not worry, small a 1 a 2. Similarly for b phase, so these are the 3 limbs B 1 B 2 and small b 1 b 2 and finally, this is suppose c 1 c 2 capital C 1 C 2 and small c 1 c 2 number of turns of capital numbered coils are same N 1, small number coils are same that is and this is called core type transformer, core type 3 phase transformer. We will discuss with this next time.

Thank you.