Electrical Machines – I

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Lecture – 40
3 Phase Type and Shcle Type Transformer

Welcome, to 40th lecture on Electrical Machine I course.

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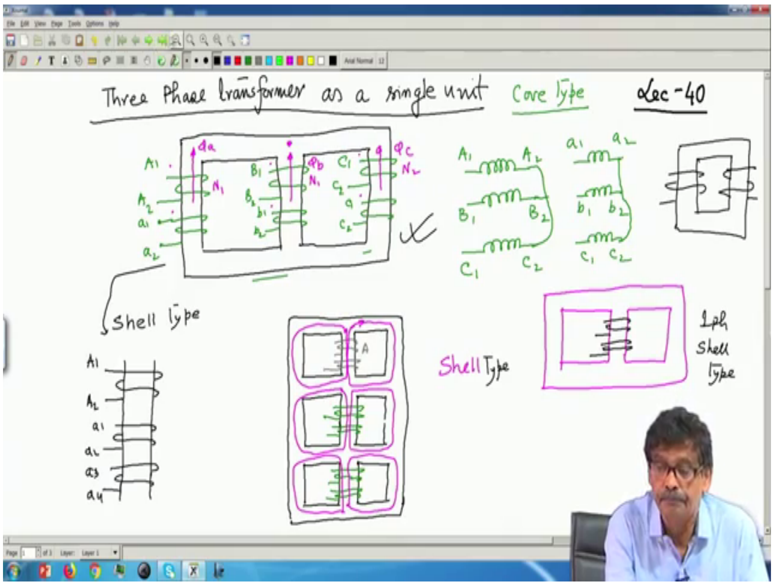

And, we have started discussing on three-phase transformer as a single unit and in our last class I so, told you that you take three single phase transformer imagine that you have taken three single phase transformer and you have joined the one of the limbs of each of them together and then the secondary winding you put on the outer limbs. And, then the flux in this central limb instantaneous value of the flux will be 0, because phi a, phi b and phi c they are 120 degree out of phase.

So, that material can be avoided and still this structure is somewhat awkward. So, a simplified way of making a bit of constructional features that is in fact, I am telling is that you take plane laminations with two windows like this. So, this is the lamination in one plane and put several of them to get the height or the width of this transformer that is in 3-dimension it will look like this which sectional view will be like this.

So, there will be three limbs and in each of the limbs you put coils of one phase say A 1, A 2 and its secondary instead of putting it some other place we should not do it in case of three-phase core type transformer core type transformer which is very easy to construct. And, then you have it is secondary and this terminals will be marked as a 1, a 2.

Similar is the case with B-phase winding. You have several its primary and its secondary. And, they are B 1, B 2 primary small b 1, b 2 secondary and finally, the C-phase winding C 1, C 2 and small c 1, c 2. And, so, basically the analysis will remain same as that of a bank of three single phase transformers. That is the representation of these in terms of coil I will show it similar to the previous one A 1, A 2 and its secondary's with the understanding that capital A 1 and A 2 they will be the dot terminals. B 1, B 2 and this is small b 1, b 2 and this is capital C 1 capital C 2 and small c 1, c 2.

And, then I could connect them in star-star, delta-star, y-delta and what not with some specific vector grouping ok. But, only thing here one must understand that suppose you connected this three in star in star and excited with secondary open circuited secondary also suppose star. So, this will perhaps give me know why perhaps it will give me Y Y 0 connection.

But, the point I want to tell you that with secondary open circuited primary energized, the reluctance of the flux of phi a and phi b will be different because the flux phi a will get divided like this into two parallel paths sorry, phi a phi b will be like this it will divide here itself in two paths and phi c will be once again like phi a it will be like that. Therefore, they reluctance may be different slightly. Therefore, the no load current required, magnetizing current required will be slightly different in the phases.

Now, if you energize it with balance three-phase source then one thing is clear as I am repeatedly telling you. Suppose, primary star connected; so, flux created by a phase phi a, its value gets fixed by this voltage is not n d phi dt suppose this primaries are capital N 1. So, what is the value of phi a max a phase? That phase voltage whatever you have applied across capital A 1, A 2 that divided by root 2 by f N 1. Similarly, if these voltage supply voltage is balanced so, this phi b will be also like that its strength phi b and phi c will be also like that, getting the point?.

Now, this three fluxes as if we will presume they come here and meet they vanish because phi a, phi b, phi c are 120 degree apart clear. But, nonetheless in the limbs this limb it has to be phi a, in this limb it has to be phi b because KVL is to be satisfied in the primaries and this is phi c. So, phi a, phi b, phi c perhaps will meet here and vanish and he let themselves because they are 120 degree apart. So, things are expected to work why not ok. So, this is the thing.

Then you can proceed. So, far as connection is concerned with the understanding that these are dots there is no difference in the making connection. So, like star-star, delta-star, star-delta and so on with this transformer also. So, no point in repeating in that but so, this is called core type. There is another type of a three-phase transformer possible that is called shell type I will just sketch that shell type and write it like this shell type.

Here it is much more symmetric so far as the reluctance this dash is concerned and the flux paths are independent. What they do is this as if you have taken. I will just mention this core type is much more popular easier to construct, shape is fine and this is the third one this is the sectional view of the stampings. These are windows, this is the iron portion.

Here what is done the windings are placed here primary, secondary. Similarly, this is for a phase I am not going to mark the terminals it will become too clumsy. So, this is for a phase say I will take this color and this is for say B-phase it is primary, it is secondary and C-phase primary, secondary got the point? So, here you see how this flux paths will be there this. So, you see the windings are placed on the central limb not on the outer limbs and the flux if you energize the primary A-phase it will produce phi here, it will nicely closed onto itself getting the points?.

Similarly, for B-phase flux paths will be like this as if they are independent three single phase transformers. In fact, they are, but only thing the windings are on the central limb and here also C-phase flux will be somewhere playing this, but here the fluxes do not have that is they interact phi a phi b phi c directly that is why the no load current will be slightly different. So, this is called shell type oh I have written.

Anyway in this cell type some people say a shell type is that type of transformer where iron similarly in the single phase single phase transformer also you could have a in fact, there are single phase 3 number of shell type transformers you can make a single phase transformer in this way. In contrast with the core type; core type single phase was what? It was like this here is primary winding, there is secondary winding and they may be put in the same limbs distributed on both the limbs primary, secondary, but effectively it is like that.

Here the primary and secondary will be put here just get the idea that is all. So, this is single phase shell type people say that in single phase I do not impresses the winding in the core type coil impresses the one as you can see iron is also showing, but anyway operation etcetera will be similar flux paths will be different. So, so this is shell type transformer three-phase of which this core type is more very much popular and they are use to to make say power transformers all core type.

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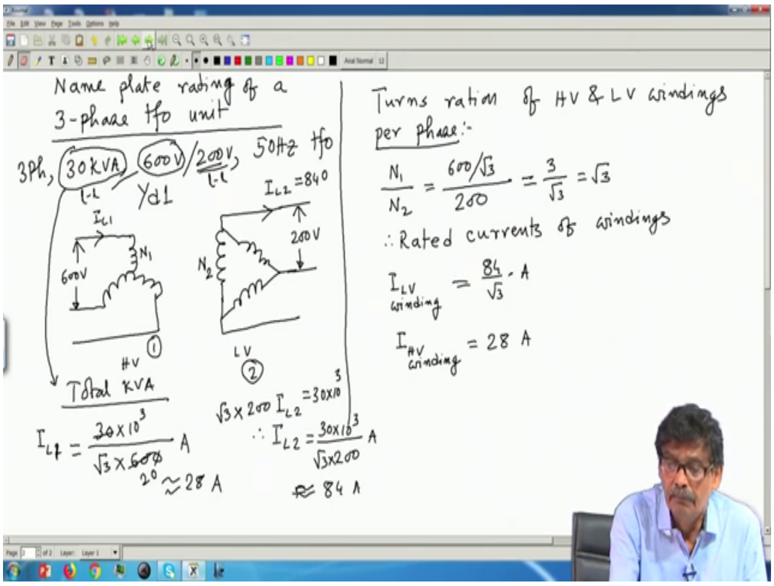

Now, after telling this I must tell what about the nameplate rating of a I will draw a vertical line and write like this nameplate rating of a 3 phase transformer unit. It will be written as suppose 30 KVA say I am just giving some number say 600 volt stroke 200 volt which is not very practical numbers, but just I am giving you for easy computation 600 volt, 200 volt, 50 hertz and before that 3 phase 3 phase 30 KVA 600 volt 200 volt 50 hertz transformer. Mind you, it is not the collection of three single phase identical units and this is the name plate rating.

Also you will be provided with the connections for example, it may be given as Yd1; that means, the high voltage side will be connected in star, low voltage side in delta and I know how to connect them. So, henceforth what I will do because connections once I have understood, I will just tell that this transformer the normal way of drawing star and delta connection I will do the primaries are connected like this even I will not mark a 1, a 2, a 3, a 4. We know that whoever has connected he has connected properly so that you achieve this Yd1. Similarly, the secondary; secondary is delta connected. So, it will be like this is not and connected correctly ok.

Now, for solving problems this that it is better you draw this so that easily you can interpret the data. Now, what this 600 volt means? This 600 volte means that this is HV side, this is LV side, this you listen carefully. This means line to line voltage, mind you. Similarly, secondary side voltage unless otherwise specified which will never be it is like that only, but still I am telling if nothing is specified otherwise this will be also line to line voltage.

So, this is line to line, mind you and this is also line to line voltage. This is very important thing to note, not that this primary winding voltage rating is 600 volt or 200 volt what about the current rating I told you in a transformer KVA and voltages are given, current values are not explicitly specified. From KVA and voltage informations you have to find out the rated currents of the winding. In this case, this 30 KVA is the total KVA total KVA.

Therefore, from the total KVA and line to line voltage I will be able to calculate the line currents of the respective side not the winding currents. For example, if I say the if I call this is side 2, this is side 1 I will say this line current I L2 will be given by root 3 into secondary side line voltage that is 200 volt root 3 v l l into I L2 is equal to 30 KVA and from which I will be able to calculate I L2. Mind you, this from this formula you will be able to calculate the line current of this secondary side.

Similarly, primary side line current that is I L1 neglect that no load current which will be 5 percent of that rated; this is the rated line current of the secondary side. Similarly, rated current on the primary side line current I L1 will be equal to same KVA 30 into 10 to the power 3 volt ampere by root 3 into 600, got the idea? Approximately how much it will be these values? Anyway, you calculate then tell me.

So, this is these are the line currents I will be able to in ampere mind you calculate it. So, see these comes out to be 30, one 0 goes this is 2, 2 roots 3 is 2 into 1.7 1000 by to 500 about.

Student: (Refer Time: 20:09).

This one say approximately say 28 ampere or so, correct 1000 by? I do not think it is more than that.

Student: (Refer Time: 20:25).

So, this currents I will be able to calculate I will write it down. Now, then one may ask question what is the turns ratio of the windings? How to find out turns ratio turns ratio of HV and Lv windings or turns ratio per phase. If you are asked to calculate the turns ratio suppose the number of turns of the primary winding is N 1 and secondary winding is N 2 then I will say N 1 by N 2 will be how much the voltage across this which will be 600 by root 3 divided by N 2 line to line voltage is 200 by 200. This will be the turns ratio, that is 3 by root 3 is equal to root 3 here ok.

Student: (Refer Time: 21:54).

Student: 280 per.

280 ampere about 280 ampere this will be this is the HV side. So, LV side it will be higher and we will be able to calculate. So, the rated currents of the lines are known. Therefore, rated currents [FL] this can you calculate tell me this value? rated current of rated currents of.

Student: Around 840.

Around 840. So, this is around 840 ampere. So, rated currents of windings, it is not this 840 or 280 LV rated current that is this current I LV winding. Rated current will be this is 840, therefore, that divided by root 3 because it is delta connected so much ampere. Similarly, I HV winding rated current that will be same as the line current. So, that is 280 ampere, getting the idea?

Therefore, you must remember on the nameplate of a three-phase transformer of a single unit compact three-phase transformer no three separate transformers you have put together for connecting it a to work it as a three-phase transformer not like that a single unit of three-phase transformer, whatever KVA is given it is the total KVA whatever voltage ratings are given at the line to line voltages of primary and secondary side.

So, from which directly you will not be able to say what is the turns ratio of the coils. Unless it is same connection that is star-star connection, turns ratio will be same as line to line voltage, got the point, any mistake? So, so this is this point must be very clearly understood. On the other hand, when I was using three single phase transformers the rating of each one is known and then depending upon the connections we decided what should be the line to line voltages that I have discussed earlier you must refer to that.

But, so far as three-phase transformer is concerned this is how it will be it is rating will be specified ok. Unless once again I am telling the same connection star-star or delta-delta ratio of this line to line voltages will be same as ratio of the turns ratio of the transformer ok. So, this is how it is to be done ok. Let me correct it. So, this connection this will be 280 ampere please, this is 280 ampere. Sure [FL]?

Student: Right.

1000 by it was a 20.

Student: (Refer Time: 25:58) 20 root 3.

20 root 3 that is the mistake and it will it was 84.

Student: 84.

Please correct that, I have not calculator 84 and therefore, I LV rated current will be 84 by root 3 and this rated current will be 280 only 28 ampere clear? So, so given the ratings you will be able to calculate everything including the turns ratio of the coils. [FL] Now, I will.

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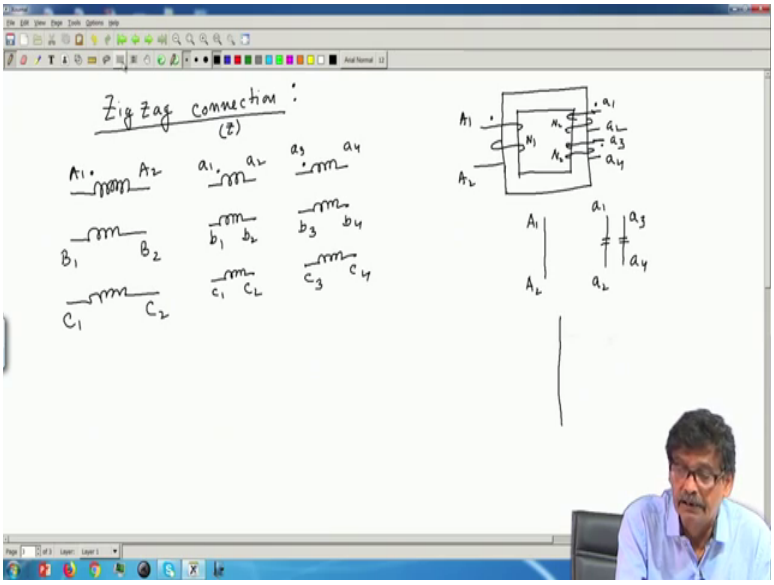

Tell you about another connection first, then I will discuss about when to use stars connection, delta connection, on the high voltage LB side etcetera those some points I will discuss, but before that another connection I will discuss. So, now I know that so far as connections are concerned only thing you will ask for where are my primary terminals with polarity marking A 1, A 2 capital where is secondary small a 1, a 2 and so on, then you can connect it and it is same for both the kinds.

Now, another connection I will just tell which is also very interesting connection which is called zigzag connection in zigzag connection it is usually denoted by z like star y delta d zigzag connection is denoted by z and why zigzag connection is necessary that also we will discuss. But, first let us for academic interest let us try to see what this connection essentially means. At the end it will turn out to be equivalent to star connections.

Let me explain. Suppose, and it does not matter whether you are using three single phase units or a three-phase transformer as a single unit. For example, to connected zigzag transformer you must have for a particular phase say I am drawing here suppose three single phase transformers I have taken. So, far I was telling this is the primary winding and there was one secondary winding a 1, a 2 is not and similarly, another transformer with b 1, b 2 small b 1, b 2.

But, in this case to carry out zigzag connection for each primary phase you must have two secondary coils, identical. This connection is very interesting a 3, a 4 and I will say that all odd number terminals are dots, it means this. Similarly, for B-phase and C-phase which I am not drawing three single phase transformer. Naturally if a you apply a voltage phasor if the voltage applied in the primary across this transformer A 1, A 2 on the secondary's you will have two separate, but equal length phasors or the secondary because their number of turns are same N 2, N 2 and this is N 1, is not? If you excite it with some voltage then same voltages will be induced and the this lines will be equal.

Therefore to carry out zigzag connection we must have for each phase two identical secondary's. In case of three-phase transformers it mainly means that that is if I go to previous page which I have already drawn for A-phase I have drawn only small a 1, a 2, but there is no space to accommodate another coil what I will do here is that this limb only I am sketching. Suppose, I can also do like this. This is the primary winding A 1, A 2 and there will be two secondary's like this a 1, a 2 and a 3, a 4 and this I will do for B-phase and C phase as well that is each phase must have two identical secondary coils. So, through that is the thing.

Therefore, the connections will be. So, now, I will simply draw the coils to execute connection for example, A 1, A 2. Now, there are now two secondary coils a 1, a 2 and small b 1, b 2 then for B-phase B 1, B 2 and it will also have two coils b 1, b 2 and b 3, b 4 and finally, it will have C 1, C 2 and small c 1, c 2 and c 3, c 4 with the understanding that these are dots all odd numbers. I am sorry, this will be a 3, a 4. The arrangement is understood absolutely.

Then what I will do? I will make it suppose primary I have connected in star ok. So, I will clean this portion now. I know what it is ok.

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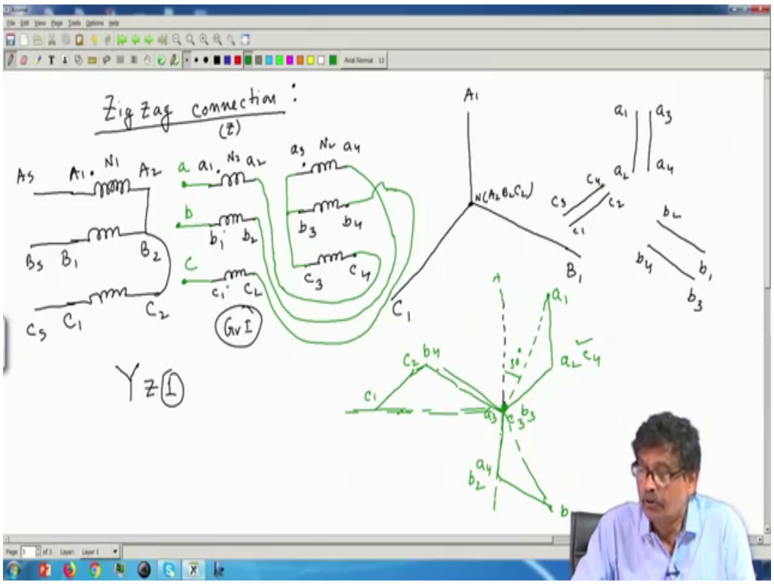

Now, primary I will connect in star a valid star for example,. I will connect short A 2, B 2, C 2 and give supply to A s, B s and C s supply and these are the primary phasors. And, this is A 1 which is same as A s, this is B 1 same as B s and this is C 1 lengths are equal and this is your neutral A 2 B 2 C 2. Now, on the secondary coils I have not connected it anything, but I have now these voltages available to me to play with. What I mean by this that is I will then have on the secondary side this two voltage a 1, a 2, a 3, a 4.

Similarly, I will have parallel to b 1, b 2, b 1, b 2 and b 3, b 4 and also I will have these voltages c 1, c 2 and c 3, c 4, is not? Six voltage phasors will be available to me to belonging to each phase. Now, what is zigzag connection means these two phases two secondary coils you connect them in series ok. The rule is these two coils take this is suppose group 1, this is group 2 you say take a phase coil and connected in series with either b or c phase coils in the second group that is you do not connect a 1, a 2 and a 3, a 4 in series there will be mixing of phases.

So, the these voltages are this one a 1, a 2 of course, you can connect them into series then it will be normal effectively a single coil of 2 into turns see this is N 1, this is N 2 and this is also N 2 all of them are N 2, N 2, N 2, N 2, N 2, N 1, N 1. So, what you will be doing in a sense is that you will connect two coils in series and try to achieve the connection.

So, one coil from this group this is a suppose group I and this vertical coils group II. So, take one coil here and take either b or c whatever will be relevant that we will discuss. Similarly, B phase and other from this one. These two you go on connecting in series and to achieve some what is called zigzag connection ok. So, the question is, what is to be connected and how. The whole idea is that for example, I would like to connect the primary in Y, secondary in z I would like to connect.

And, here also it is like say 1. Zigzag connection although it is not yet done, but I told you it will come effectively a star connection that is.

Student: (Refer Time: 38:23).

Student: 1 ampere.

Um most probably 1, let us see ok. Y z 1 effectively star connection, but two coils will belong to two different phase groups and at the end 3 terminals will be shorted. Therefore, whatever will be the neutral just like start this side that will be a neutral and from neutral to one of the lines if you try to go you will encounter two coils in series belonging to two different phases ok.

Now, if this is the thing this is a 1 N therefore, A-phase from the secondary if it is 1 suppose this is the secondary neutral which one will become neutral I am not sure yet. Suppose, it is neutral, this is the A phase of the primary and I am telling it is one means 30 degree lagging. So, what I will do I will draw a line 30 degree lagging here. So, neutral to A-phase on the secondary side must lag this was my A 1 this vertical line primary; secondary A phase voltage, we will lag the primary a phase voltage by 30 degree.

Now, the question is how this phasor can be achieved? It can be achieved see this was a 1. So, I must this phasor this phasor can be realized by bringing this a 1, a 2 here and then you can easily see this phasor is parallel to C-phase. Suppose, I have decided in this outer coil see it will be a 1, a 2. So, so I will write here as c 4, c 3. See this phasor is c 3, c 4 plus a 2, a 1 can give me this one.

So, this is one phase voltage now once you have drawn this the result is obtained B-phase will be 120 degree apart from this line. So, draw a line here and here I must expect some b 1 must come. How that b 1 will come and this phasor can be broken up into this plus this. So, if it is b 1, b 1 is available this must be b 2 and who will provide me this phasor? It must come from some A-phase a 1, a 2 has already been used now a 3, a 4 is remaining. So, a 3, a 4, got the point?

And, where will be my C-phase it must be horizontal after this one this is 30, this is 90. So, here it must come and these voltage must belong to some C 1.

Student: (Refer Time: 42:25).

Hm. So, so, what it should be a 1, b 1 and this is c 3 c 1, c 1, c 2 is available fine c 1, c 2. I mean this lines are all equal please forgive me for this one and this will be provided by whom by B-phase. B-phase one voltage I have used b 1, b 2, so, b 3, b 4, b 3 b 4. Therefore, effectively now after knowing this I will come for connection it will be as I told you sort of star connection three terminals must be shorted. So, and I now know which 3 are to be shorted. So, a 3, b 3, c 3 are shorted then what I see a 2 must be joined with c 4. So, I will take a piece of wire and I will clean this now that group II previously written will be there [FL]. That is the problem anyway and it is being recorded.

Student: (Refer Time: 44:14).

[FL] in the. So, this you take a piece of wire and connect here. So, so a 2 is to be connected with c 4; connect it, and this will go to your load, a phase. Similarly, come to the. So, this is over a 4, b 2 is to be shorted where is a 4? a 4. So, a 4 and b 2 are to be shorted it will be like this and this will come as b phase terminal. Similarly, c 2, b 4 are to be shorted c 2 and b 4 are to be shorted and that will come as your secondary c phase terminals. So, you can see this is called zigzag connection.

So, zigzag connection is essentially a sort of star connection three term, you must required two identical coils you cannot do anything and we have just discussed how it can be done. Now, the big question is what for all this things that is there, but suppose I say you that a transformer each phase has got two secondary’s, then it looks like these way also one can get a balanced three-phase output voltage. Rule is you take one coil here I specify the rule belonging to one phase a-phase then you see this coil is in series with c-phase coil belonging to a other phase; b-phase coil in series with a phase coil.

And, mind you, these are the dots and c-phase coil is connected to b-phase and you get this connection. More on this connections in next class.

Thank you.