Power System Analysis
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Lecture - 19
Power System Components and Per – unit System (Contd.)

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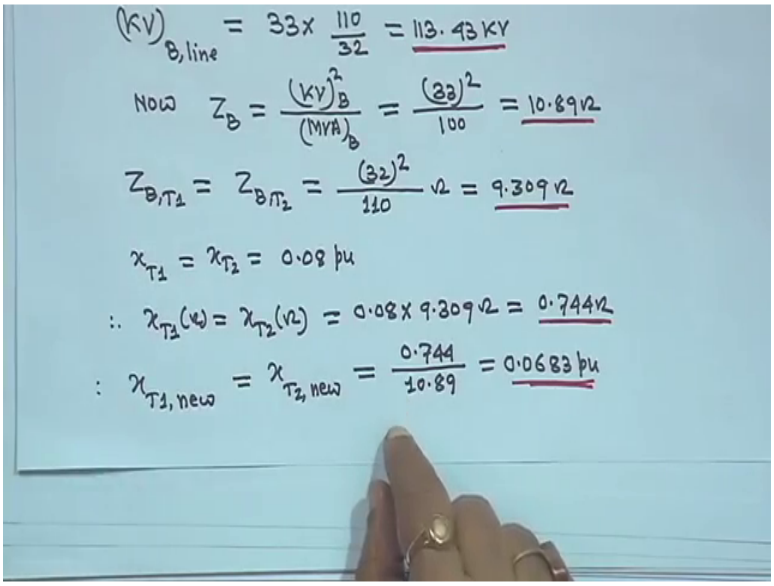

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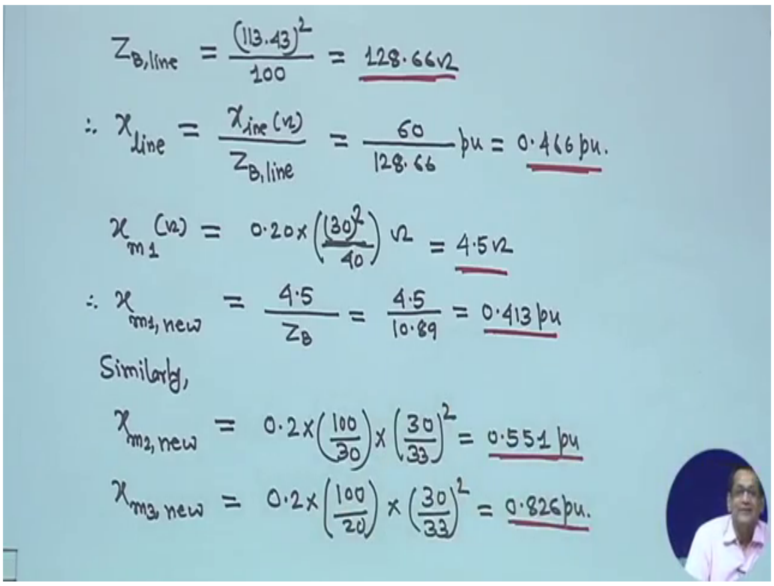

So, up to this we have seen right x 2 1 and this thing. So, as just to all of you I have to tell 1 or 2 things look actually this course before proceeding to this that so much, so many computations are there right. We all are human being by chance if you find that all these calculation I hope I have made correct, but there is a possibility that calculator pressing and these that I remember I am also commit some mistake in numerical values because you are not sitting in front of me that is why earlier also 1 or 2 places I made some corrections right for example, instead of e p upon e s I wrote V p upon V s we had it mean in the classroom immediately instead of corrected mean right.

Similarly multiplied that that x square multiplied instead of being division that corrected also, similarly all these calculations because you up had later you will see many more calculations right. So, if you I mean particularly when we will come load flow then economical load dispatch and falls studies right. So, if you find anything that calculation error or anything or any suggestion you please send me mail I will appreciate that right because huge collect your what you call computations are involved here right and anywhere if you see any error or anything, writing error or anything please mail me such that I can rectify myself right.

So, now Z B or Z B line that is this line base line voltage we computed it was 113.43 square upon 100 that is 128.66 ohm right and x line is equal to x line ohm upon Z B line there is per unit x line means x line per unit value I did it per unit understandable. It is 60 upon 128.66 is equal to 0.466 pu per unit. Now motor side now same thing you can use equation your what you call equation 16 that old values are new values. So, previously all I have explained. So, this all this things now you can make very easily right. So, I am writing directly you try. So, x m 1 ohmic value is 0.2 into 30 square upon 40 because first you have to converted on its own your ohmic value units own rating that is own base values right.

So, per motor 1 base MVA or base KV was 30 and base MVA was rate sorry, the rated base voltage of the motor was 30 KV and MVA rated MVA 40. So, it is KV square upon MVA that is on its motor this value always gives on its base your base value of motor rating right. So, 0.20 into 30 square upon 40 that is 4.5 ohm that is the ohmic values, but Z base we note n 0.89 ohm therefore, 4.5 upon Z B that is 0.413 per unit.

Similarly, other 2 you can easily calculate these 2 directly you can calculate using equation 16 right. So, x m 2 new is equal to 0.2 into 100 upon 30 into 30 upon 33 whole square whatever it is, it comes 0.551 per unit. Similarly for motor 3 you calculate same using equation 16 you will become 0.826 per unit right, once this is done then you draw the per unit diagram. That means this one, this is that single line diagram that is the schematic diagram of all these thing even and this is your per unit diagram.

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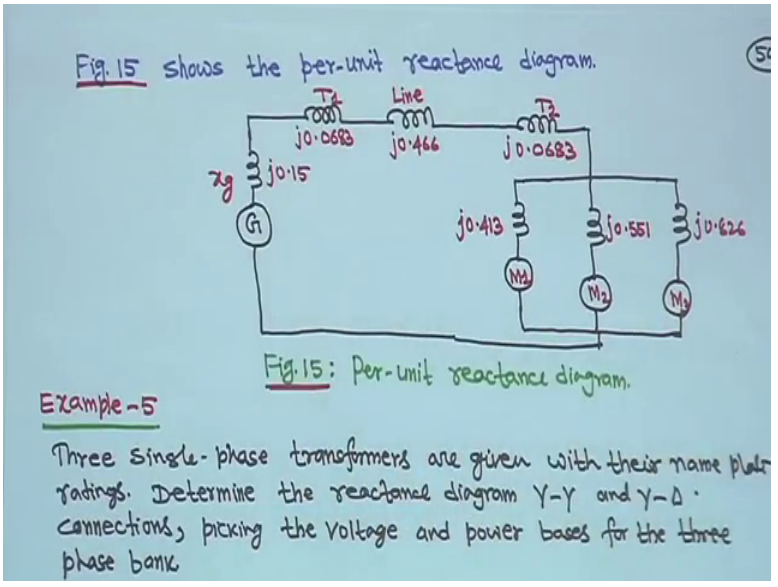

So, generator this is a generator reactance with 0.1 5 per unit. So, it is given then transformer convert T 1 also converted to a common base whatever you have done it was j 0.0683 per unit, then this is the line it is j 0.466 per unit and then this is transformer T 2 it is also both transformers they are same that same rating same reactance right. So, j 0.0683 per unit and 3 motors they have all are in parallel all are in parallel right.

So, motor 1 j 0.413 motor 2 j 0.551 motor 3 j 0.826 and complete the diagram only thing is throughout the calculations, all this calculation I did not use j again and again it will become clumsy put in j everywhere rather you make as it is and after that in the circuit diagram you put j because from the using this, this voltage is given the motor terminal voltage by everything is given. So, accordingly you may have to calculate current and thing other thing that you will see during fall studies right, but this is that after that in the diagram we have put all the j values right.

Next is that example 5 right. So, this is actually that this is small one right that 3 single phase transformer are given with their name plate ratings, if you say any transformer name plate ratings are there everything will get from their right determine the reactance diagram when it is star star and star delta connections picking the voltage and power bases for the 3 phase bank; that means, we have 3 single phase transformer you are connecting the one is 3 phase star star another 3 phase star delta. See you have to find out that you are what you call you are what you call picking the voltage and power base for the 3 phase bank.

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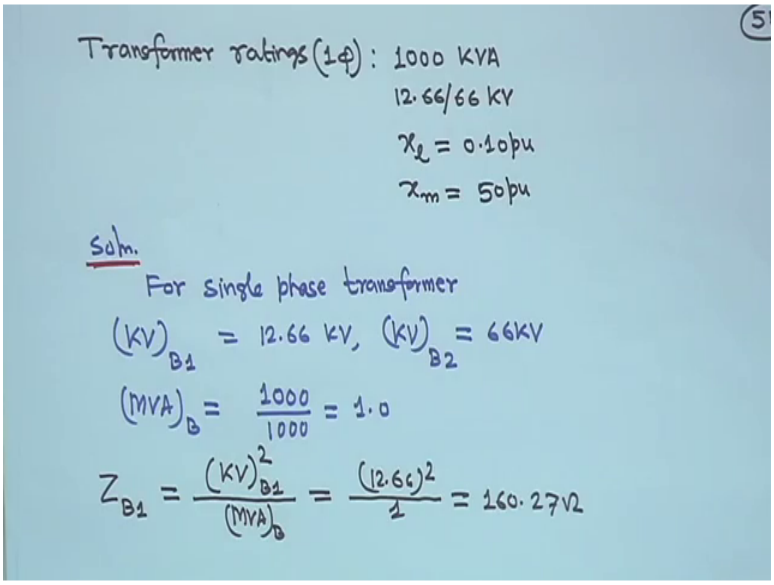

So, what we will do we will per unit whether it is star star or star delta right just the transformer ratings are given their single phase this single phase rating is 1000 KVA each that is your 1 MVA and voltage is 12.66 upon 66 KV for the single phase this data for single phase and leakage reactance is given 0.10 per unit right and it is your what you call and leakage and this case this x m is not motor it is your magnetizing reactance it is 50 pu is given right. So, what we have do is we have to see are that even it is if you takes per unit per single phase or per unit per 3 phase you will find they are same right, but this is for single phase per unit it is given, it is magnetizing reactance it is given 50 pu right.

Now, when you consider this for a single phase, KV base 1 12.66 KV and KV base 2 66 we have pa primary side 12.66 the secondary side is 66 KV right and MVA base 1 1000 KVA; that means, it is 1 MVA 1000 upon 1000 right. So, Z B 1 that is it is KV square B 1 upon MVA base that is 12.66 upon 1 that is 1 60.27 ohm, when you are considering as a single phase right.

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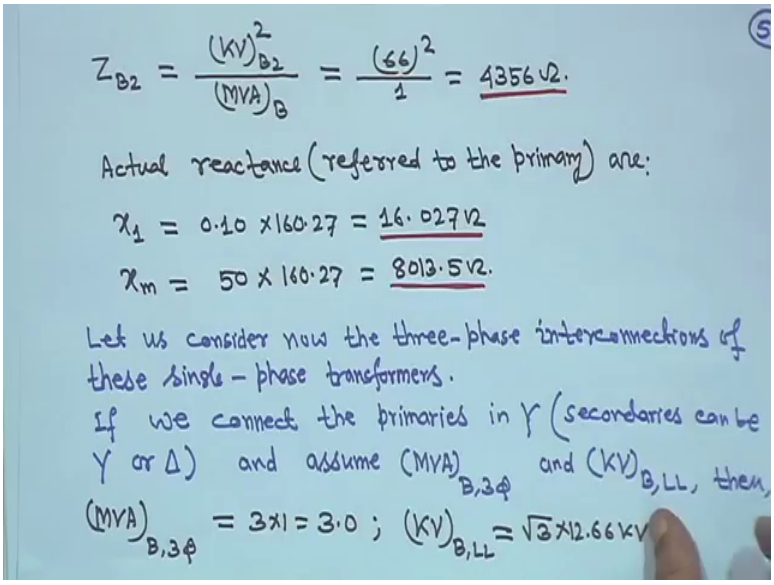

Similarly, that Z B 2 is equal to KV square B 2 upon MVA base that is 66 square upon 1 that is 4356 ohm right.

So, this is actually actual reactance referred to the primary are that x 1 is equal to 0.1 into 160.27 that is 16.027 ohmic values because this point was given the leakage reactance here it is given right, it was given x L we are writing as a x 1 referred to primary right. Similarly x m is 50 into 160.27 8013.5 ohm right now these transformer you are converts into star star or star delta some let us consider now the 3 phase inter connection 3 phase inter connection of 3 single phase transformers. Now if you connect the primaries in star secondaries can be star or delta because it is given star star or star delta right and the assume MVA 3 phase we will and KVA is line to line because for single phase rating was 1 MVA is single phase.

Now, 3 single phase connected. So, MVA phase 3 phase we will be 3 into 1 that is 3 right and KV base line to line it was single phase 12.66 say one side. So, it will be multiplied by root 3 earlier also in one example we have seen right. So, root 3 into 12.66 KV right.

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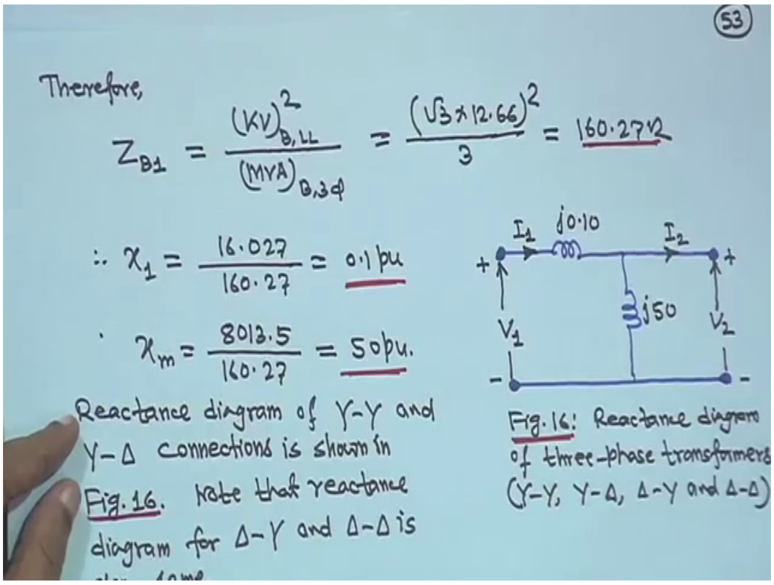

Therefore, Z B 1 is KV square base line to line by MVA base 3 phase that is root 3 into 12.66 square upon 3 that is 160.27 ohm therefore, x 1 will be original earlier we got x 1 is 16.027 ohm and x m is 8013.5 ohm therefore, x 1 will be your 16.07 upon 1027 upon 160.27 is equal to 0.1 per unit.

Similarly, x m will be your 8013.5 upon 160.27 that is 50 per unit.

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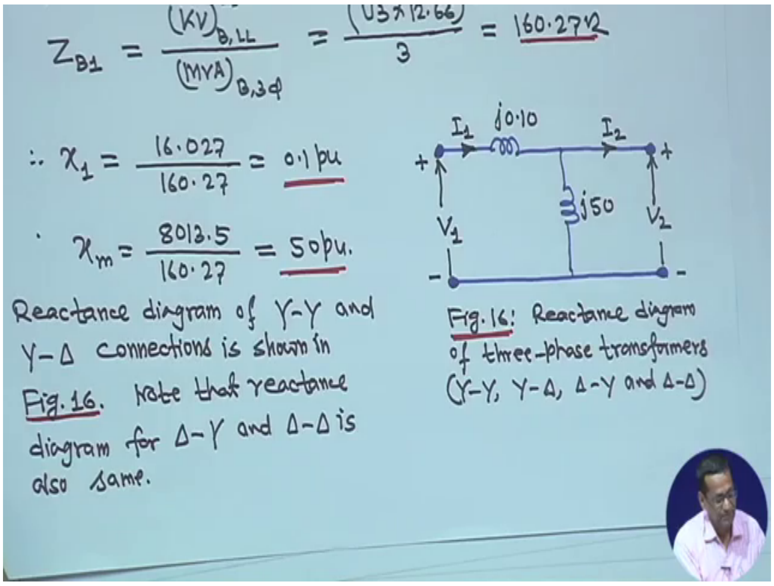

Therefore reacted react; that means, whether it is a single phase or 3 phase this per unit values remain same right therefore, your reactance diagram was star star and star delta connections is shown in this figure note that reactance diagram for delta star or delta delta will also be same right. So, this is your magnetizing co shown in parallel j 50 right, r m is not consider in this example just to show you that is all and this is your j 0.10 and this is other side and showing a direction of the current I 1 and I 2 this is voltage V 1 and this is voltage V 2 on the secondary side right.

So, just to show you after this you will, after this per unit system other interesting thing you will later you will find the method of voltage counter all right.

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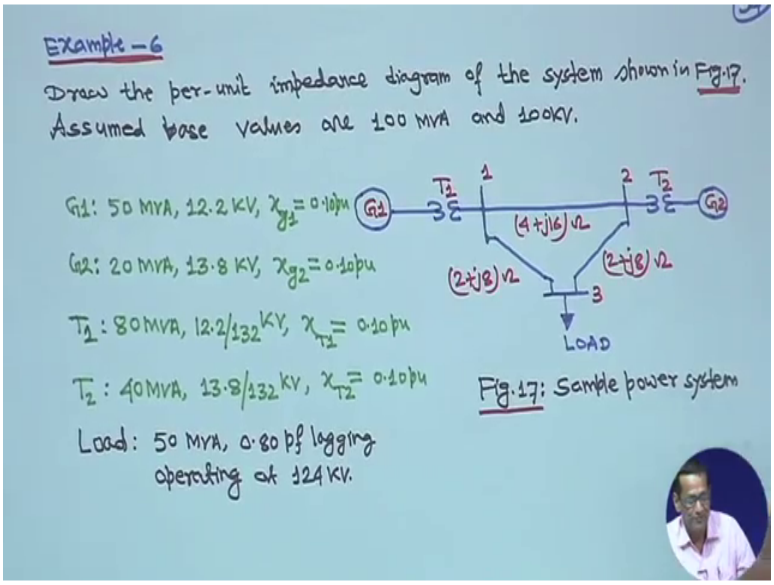

So, now for example, 6, also you have to find out the per unit diagram here 1 generator is there I will come to the data first it is if you think it is a 1 2 3. So, I will come something like a 3 was problem right. So, this is generator 1, this is generated 2 and load is here it is load right, this is transformer T 1, this is transformer T 2 and 1 to 2 line impedance is 4 plus j 16 ohm and 1 2 3 it is 2 plus j (Refer Time: 11:28) half of this actually, half of this you have taken for easy calculations and this 2 to 3 is 2 plus j 8 ohm right and this is load, load is given here.

So, generator 1 this generator 1 is 50 MVA 12.2 KV and its reactance is given 0.10 per unit, generator 2 that mean this 120 MVA 13.8 KV and this reactance is 0.10 per unit that is x g 2 right. Therefore, this T 1 transformer 1 is rating is 80 MVA that mean this one 12.2 primary side and 132 KV the other side right. So, low voltage side is 12.2 KV and this generator also 12.2 KV and other side is 132 whether line side and transformer T 1 reactance is 0.10 per unit transformer T 2 this one is 40 MVA, but is starting 0.8 KV 1 132 KV that is the your high voltage side right and this thing your x T 2 is equal to 0.10 per unit right.

So, this whenever if we load is 50 MVA load is 50 MVA 0.8 lagging power factor and operating at 124 KV that mean this voltage of this bus 3 is actually 124 KV right and whenever transformer is given 30 is here it is given where transformer 1 12.2 132 KV that is the low voltage side this side and when you going to generator to it is written 13.8 132 KV actually this side is 13.2 and this side actually 1 low voltage side is always the generator side right although, but it will be given like that only right. So, it is actually this side low voltage side the terminal voltage of generator 13.8 and 132 KV is this side this way it will be given.

So, there should not be very confusion and this is the sample power system diagram right and load is I told you 15 way MVA and 0.8 for lagging, but operating at 124 KV although line is 132, but due to the load and other thing voltage as say fall into 124 KV right.

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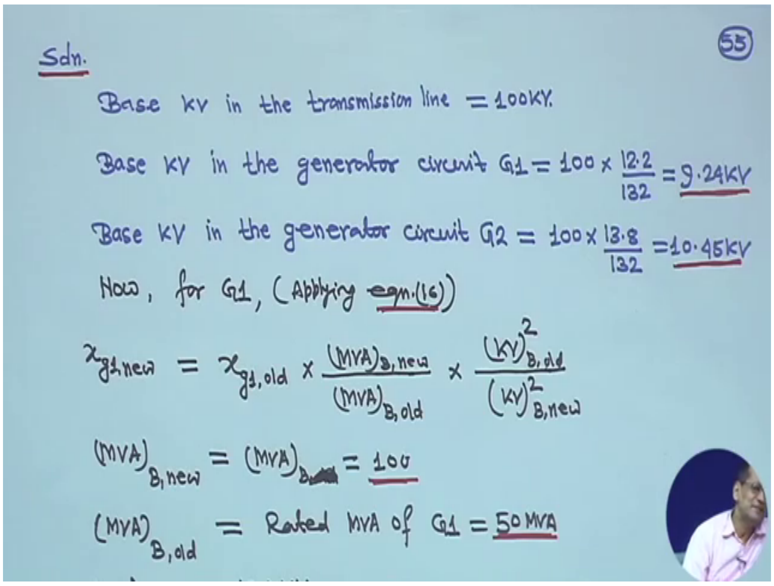

So, base KV in the transmission line we assume nothing has been mentioned here. So, we will assume 100 KV right we will assume say 100 KV just this arbitrary you have instead of 132 or something I have taken 100 KV such that all transformation will be easier for you right. Whatever your base voltage you say whatever answer you get in per unit or you will converted to real unit at the ten you will see the same thing is coming right.

I have taken here 100 KV when you will solve this problem you take base voltage is 130 KV and solve it right whatever per unit values you get, but if you try to convert into the real quantities you will find the same values and base KV in the generator circuit then 100 into 12.2 by 132. So, 9.24 KV this 100 KV intentionally I have made it for transmission line such that I can show you all the transformation right. So, it is 100 and, but this one actually twelve point this transformer actually it is 12.2 by 132. So, line side will be generator 1 will be base voltage will be 100 into 12.2 upon 132.

So, 9.24 KV with right, it will go down similarly in the generator side g 2 will be 100 into 13.8 by 132. So, it will be 10.45 KV right. So, all transformation you have to make on the common base. Now for G 1 you apply equation 16 right. So, equation 16 we are writing here that suppose there this one there it was written x new is equal to x old something, but for gen in general that x g 1 new is equal to x g 1 old into MVA base new upon MVA base old into KV square base old upon KV square base new you assume that MVA base new is equal to MVA base is equal to 100 right. So, that you assume 100.

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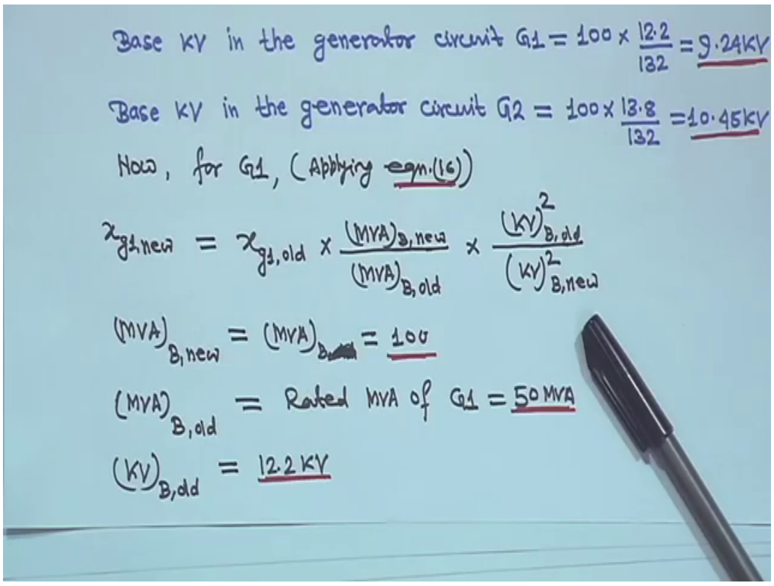

Now, MVA base old is equal to rating rated MVA of G 1 that I want to mean wherever you will take old MVA or old KV means it is the rated voltage of the generator or transformer or motor right and a old MVA means it is the rating of the generator transformer MVA rating of the generator transformer or motor.

These are always your old values right. So, there should not be any confusion right. Therefore, MVA base volt that is why I am writing MVA base volt is equal to rated MVA of G 1 is equal to I is given data is given it is 50 MVA and KVA base old that is 12.2 KV this is also generator terminal voltage that is also given here 12.2. So, any rated value I mean rated KV on MVA all old values means the rated your old base means it is your oh your what you call these are all the old base right and new one is whatever you assume. So, this is your KV base volt that is 12.2 KV therefore, and your KV base new whatever you have computed right that KV base new for a generator 1 is 9.24 KV and for generator 2 10.45 KV.

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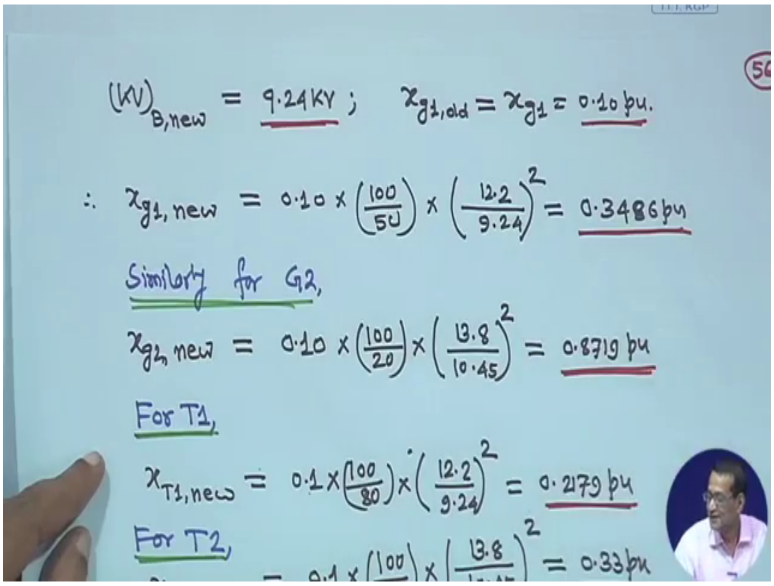

That means that KV base new now on the rewriting this for your understanding only 9.24 KV and x g 1 old is equal to x g 1 is equal to 0.10 per unit x g 1 old means whatever reactance of the generator is given that is old value. Now x g 1 new is equal to we are applying this formula applying this equation 16, this is actually equation 16 right. So, if you put it, it will be 0.1 into 100 by 50 into whatever data you substitute here you will get 0.3486 per unit. Once again I tell you that all this calculus and I have I have making it if I see calculator phasing error always may be there, but I will request you make it off your own, all this calculation if you find any error you just send me the male that is all right or. So, I will this has there I can rectify myself right.

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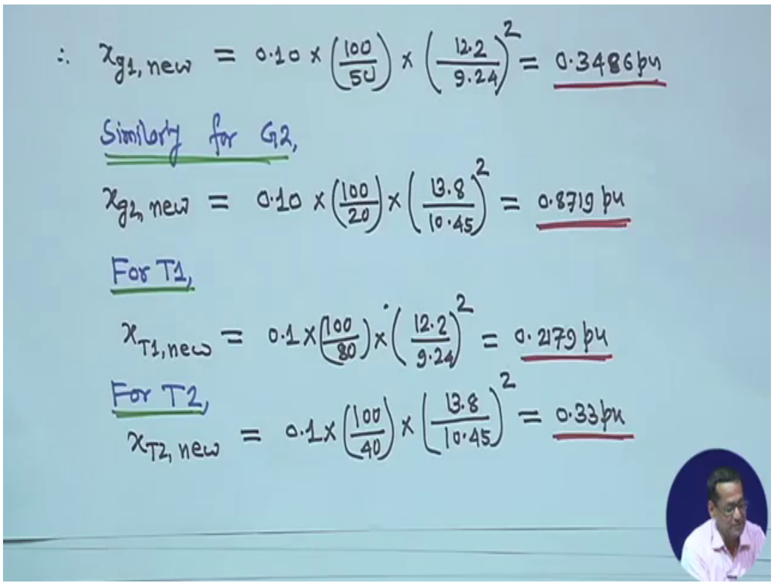

So, similarly for g 2 x g 2 new is equal to using this formula you will get 0.8719 pu right and for transformer T 1 x T 1 new is equal to same way you calculate using the same formula it will given 0.2179 per unit similarly for transformer T 2 x 2 it will be 0.33 per unit. So, this intentionally I have taken this such that in one problem all sort of conversation to per unit can be shown right because this are the this calculations are ok.

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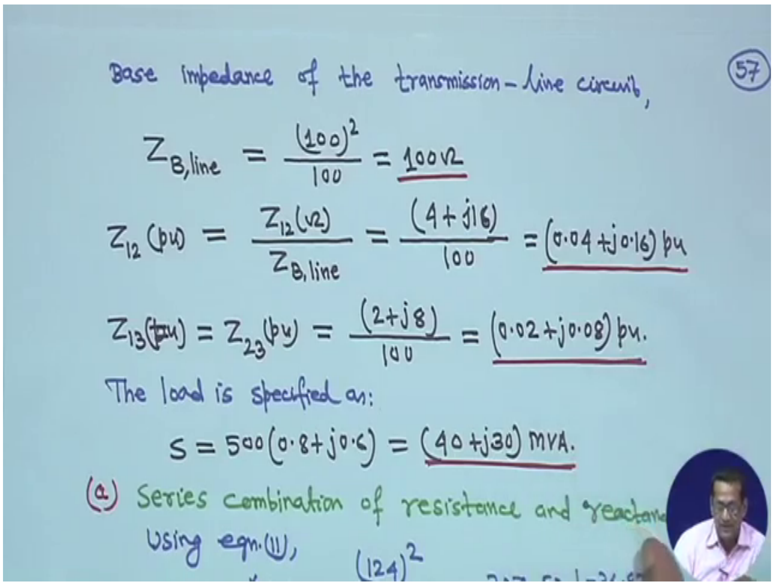

But in the later stage you will see huge computation for all this things right for other topics. So, did in base impedance of the transmission line you have taken 100 KV your base voltage and base MVA 100.

So, Z B line is a 100 square upon 100 that is 100 ohm right. Now Z 12 line 12 its impedance was given four plus j 16 ohm that is we Z 12 if you Z 12 ohmic value by Z B impedance of the your base value of the line right line impedance, 4 plus j 16 upon 100. So, it is come 0.04 plus j 0.16 per unit and Z 13 per unit is equal to Z 23 per unit because both are same both line have the same impedance is equal to 2 plus j it upon 100 that is 0.02 plus j 0.08 per unit right.

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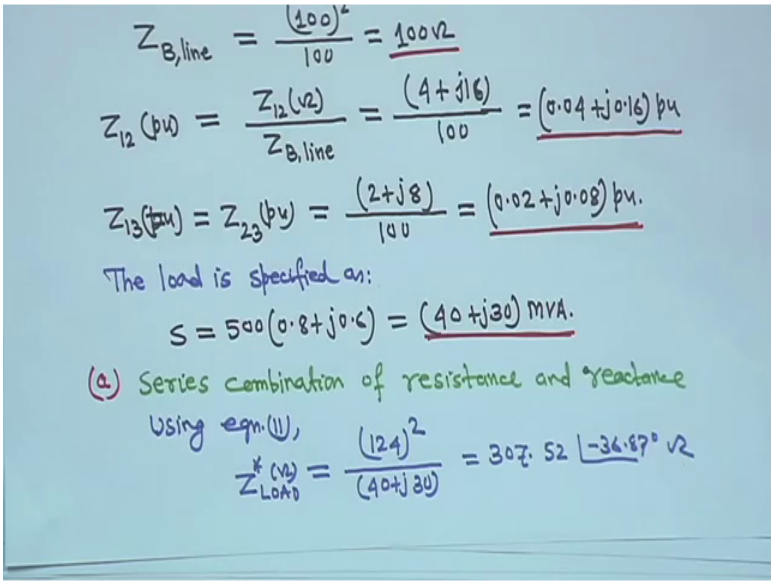

Now, load specified is given it is it is given power it is given 0.8 power factor lagging right. So, that is why 500 0.8 plus j 0.6 right. It is listen one thing.

If lagging power factor is given right for the load that mean load actually is load means its consuming power right is consuming power from the source right. So, whenever load is lagging power factor means it will be 0.8 plus j 0.6 right. So, I suggest they do not take it minus then, then it will be miss type because load consume powers of convention is that load always consume power and generator it actually injects power into the line right. So, it will be 4 plus j 30 MVA as it is 4 plus j 30 in bracket we are putting MVA otherwise this 40 actually megawatt and 30 actually megawatt, but together so it is MVA right. Now this things are there load actually nothing is say that whether it is a series or parallel right there is I mean it is a load, but whether it is loads are series in parallel nothing is said.

So, I will take series combination of resistance and reactance right and parallel parallel combination also can be given, but partly I will show you, but either you do it right. So, using equation 11 that when you go back to the equation 11 , I do not know where it is go on equation 11 is for away from here now right which suggest right if we see if I will get it otherwise directly you can go back right, just for not if I find it here I will see that now it has mixed up actually, does not matter.

So, use equation 11 use equation 11. So, Z star load that is conjugate is ohmic value it is base their that base voltage that a load voltage was given that 124 KV. So, it is 124 square divided by 4 plus j 30 for sorry 40 plus j 30 that is 307.52 and we will 36.87 degree ohm that is j impedance of the this things is conjugate this is conjugate right. So, Z conjugate of load is 307.52 angle minus 36, sorry minus 36.87 seven degree ohm right. So, this is your Z conjugate right. Now this is impedance ohm you right.

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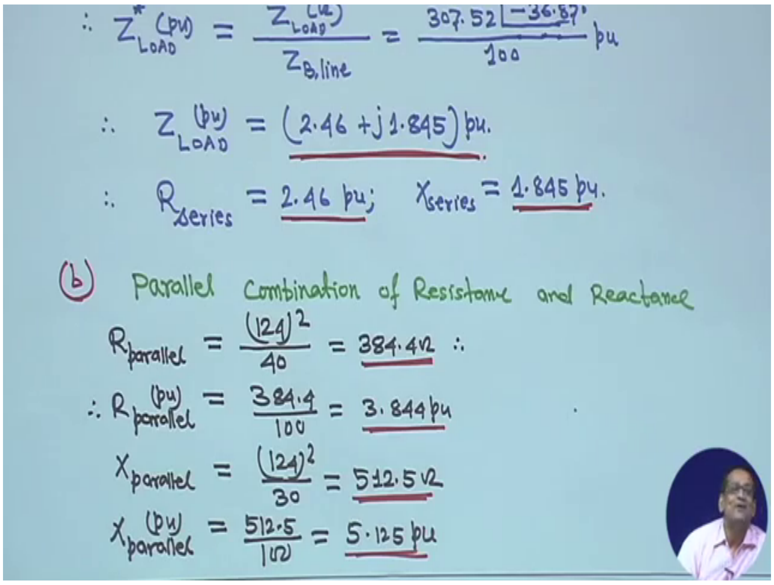

Now, this per unit value that Z star that is conjugate per unit value that is Z pa conjugate this ohm divided by base impedance of the line Z B line right.

So, it was 100 ohm for the base impedance. So, 307.52 angle minus 36.87 degree right. So, that is 2.46 plus j 1.84 per unit right it was Z conjugate here now both if you take conjugate on both side again right. So, it will be Z load per unit and this angle will become plus right my minus it will be positive right that is why it is 2.46 plus j 1.845 per unit. So, conjugate is taken actually and both side that is why it is this one therefore, r series is 2.46 per unit these are resistance part and x series is 1.845 per unit only parallel connection of resistance and reactance will be r parallel will be 124 square upon 40 right and that is your resistive part load wise 40 plus j 30 right; that means, your 40 megahert is the base value.

So, that is why 124 square upon 40 384.4 ohm and r parallel per unit is 384.4, but to 100 ohm is the base impedance. So, 3.844 per unit right similarly x parallel the 40 megawatt is coming for the 40 plus j 30 load 30 megawatt. So, that is why 124 square upon 30, so 512.5 ohm. So, x parallel per unit will be 5.125 per unit. Upto this I have shown rest for parallel part you will do it right, but I will I will show you only the series connection, only the series connection.

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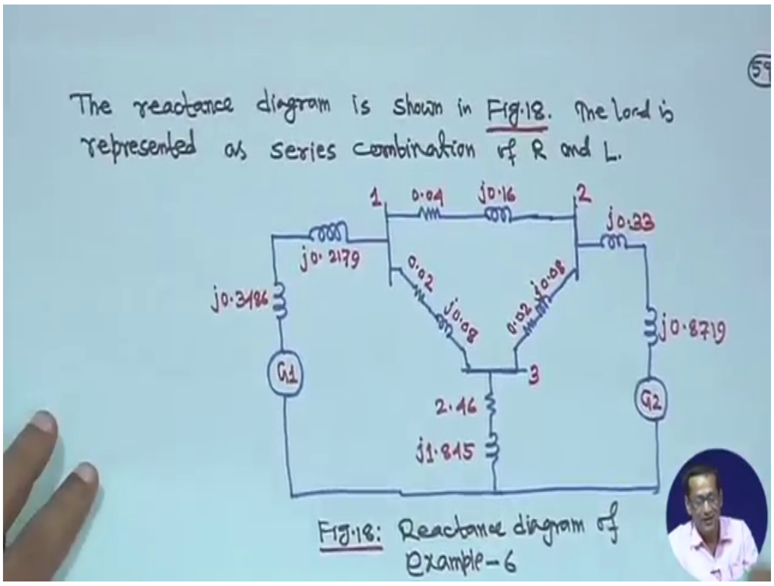

So, this is that this is the diagram this is the per unit diagram reactance diagram right. So, so this is generator 1 j th 0.3486 per unit and this is your what we call transformer j 0.179. Then 3 lines are there 0.04 plus j 0.16 and this to reactance for this 2 line impedance for this 2 lines also shown. This is also transformer your T 2 j 0.33 and this is generate to reactance and after this load 2.46 the resistive part and this is your series reactance part this is the load and diagrams this connection is complete right. Now this one I have made it parallel one I have showed you only this part parallel one, I have showed you only this part. So, you can compute you can make this diagram right.

So, this is your per unit diagram this is actually, this is actually required for falls studies and another thing later you will see. So, how this thing, but if you if you instead of 100 KV base voltage if you choose some other base voltage also this parameters will be different because thing will be different, but ultimately when you solve the network and you will convert them all the values voltage current power and impedance in the real values you will find the same values right. So, from this I think this will be the last example for you right after that we will go to the new thing.

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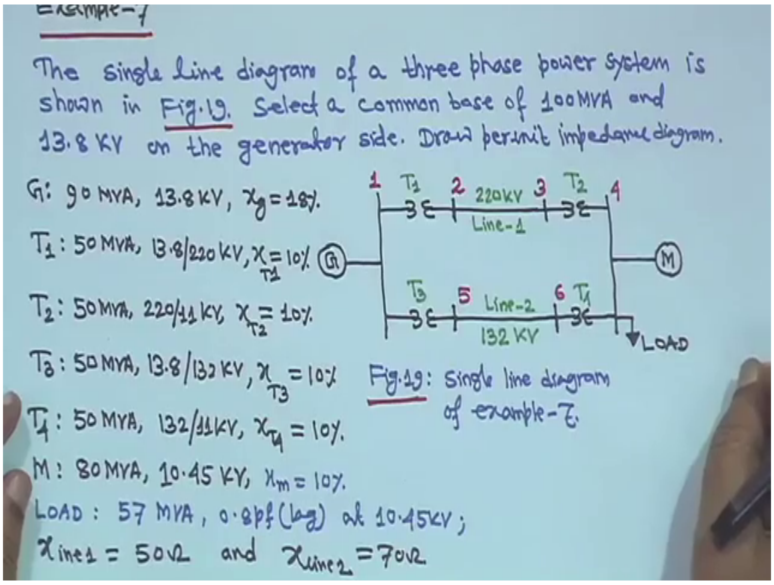

So, there is a you know this is a parallel circuits are there T 1, T 2, T 3, T 4 - 4 transformers are there, line 220 KV line and this is line 2 is 132 KV line this is 132 KV line right and this transformer rating also general is 90 MVA and 13.8 KV, x g is given, T 1 transformer T 1 50 MVA 13.8 by 220 KV transformer reactance is given. Then transformer T 2 also reactance given and this is another one motor region another load connected here also right transformer T 2 50 MVA 220 upon 11 KV 10 percent reactance is given. Transformer T 3 50 MVA 13.8 by 132 KV 10 percent is given and motor 80 MVA 10.45 KV reactant 10 percent is given load 57 MVA this is the load is also there 57 MVA 0.8 power factor lagging at 10.45 KV because generator is motor is 10.45 KV.

Line 1 impedance is 50, reactance is 50 ohm this line 1, line 2 this one 70 ohm and you have to find out that your per unit impedance diagram right. So, this problem we will quickly we will make it right and this one we will make it quickly.

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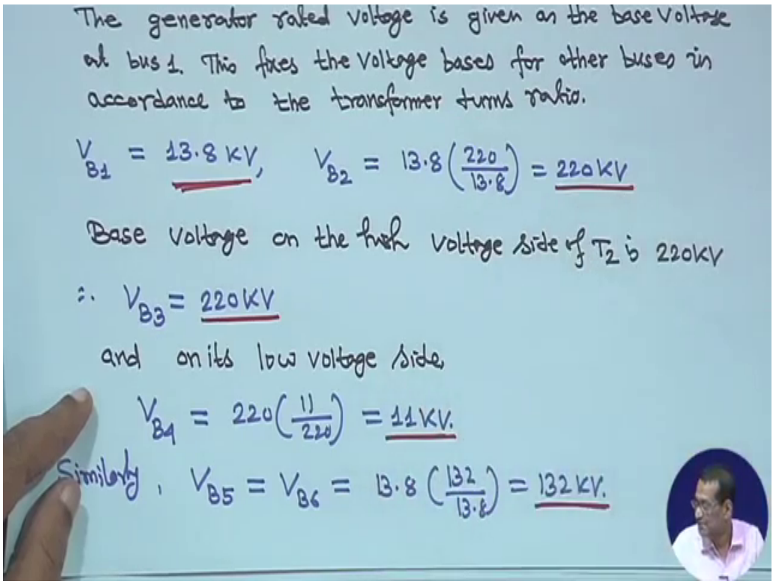

So, the generator rated voltage is given as the base voltage at bus 1. So, right this fixes the voltage bases for other buses in accordance to the transformer trans ratio. So, generator actually 13.8 KV, so we have taken base voltage of this V B 1 13.8 KV. So, naturally V B 2 will be 13.8 220 upon 13.8. So, 220 KV; that means, this line voltage also will be base voltage will be 220 KV right.

Now, for base voltage of the high voltage side of transformer T 2 is V B 3 will be 220 KV; that means, this side base voltage for the transformer will be 220 KV because line voltage is 220 KV therefore, and on its low voltage side it will be 220 into 11 by 220. So, 11 KV side 11 KV, this side will be 11 KV base voltage right. Now similarly V B 5 is equal to V B 6 13.8 into 132 by 13.8, so 132 KV; that means, your this side and this side, this side and this side base voltage that is V B 5 V B 6 this side 132 KV I mark 1 2 3 4 5 6 right, 6 has bus it has been marked right.

Therefore V B 5 V B 6 this thing this base voltage is chosen such that base voltage for other things automatically will be transferred right, so directly.

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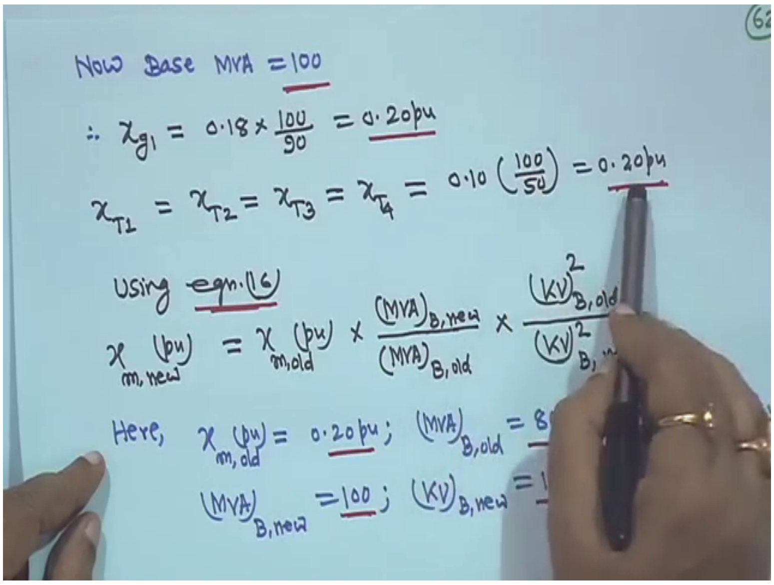

So, base MVA we have chosen 100, but generator base different. So, you have to convert to their that is your new base. So, 90 MVA is the generator rating that is their old base MVA and this is the new 100 MVA 100 is the new base MVA. So, 0.18 into 100 by 90 in 0.2 per unit, all transformers are 50 MVA rating and 0.10 per unit, so 0.1 into a 100 by 50 because 100 MVA is the base, 0.20 per unit.

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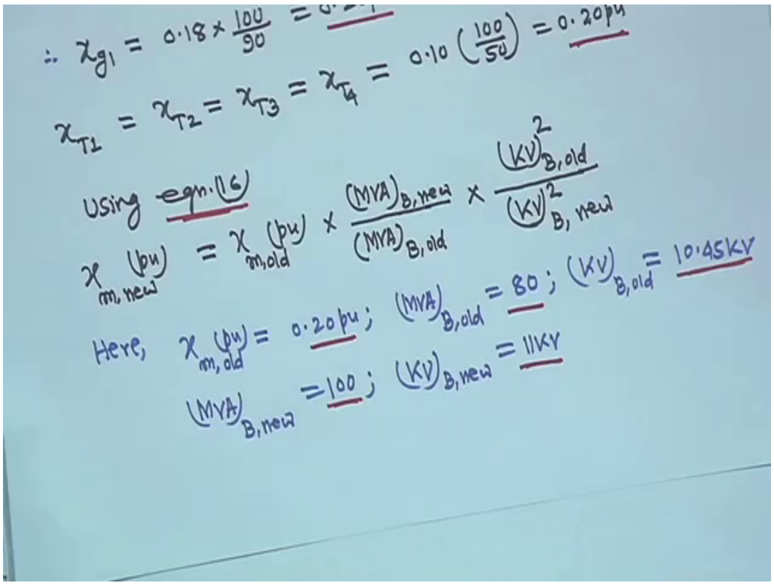

Now, using equation 16 this is the same that new and old relationship using equation 16 right. So, x m old per unit 0.2 per unit MVA base old 80 KV a base old 10.45 KV, MVA base new is 100 KV, a base new is equal to 11 KV all this things are given before.

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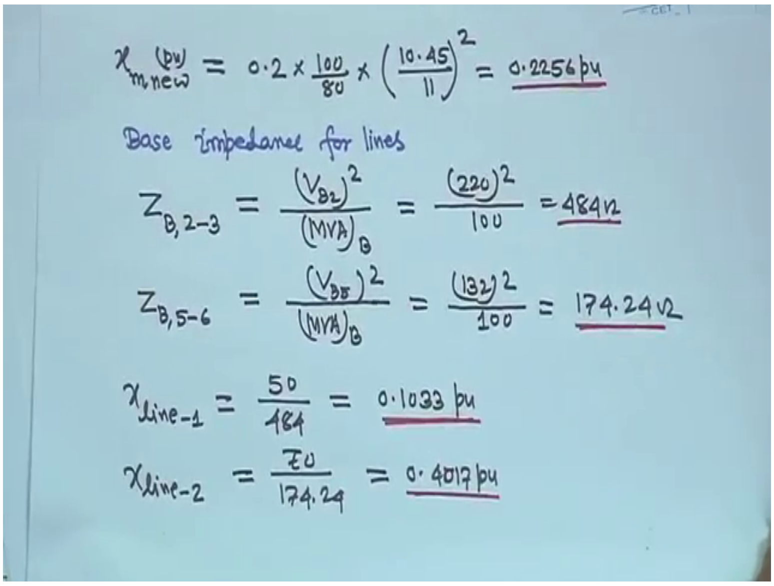

So, you one by one you will put it, one by one you will put it and you will get x m new per unit 0.2256 per unit then base impedance for lines 2 3 5 6 all you calculate V B 2 square upon MVA base you will get 484 ohm. Similarly for 5 to 6 V B 5 square by MVA base 132 square by 100 174.24 ohm.

Line 1 base imp per unit impedance it is 50 484 - 0.1033 per unit, line 2 it was 70 upon 174 because 70 ohm much given 174.24 – 0.4017 per unit right. So, this all line and generator computed.

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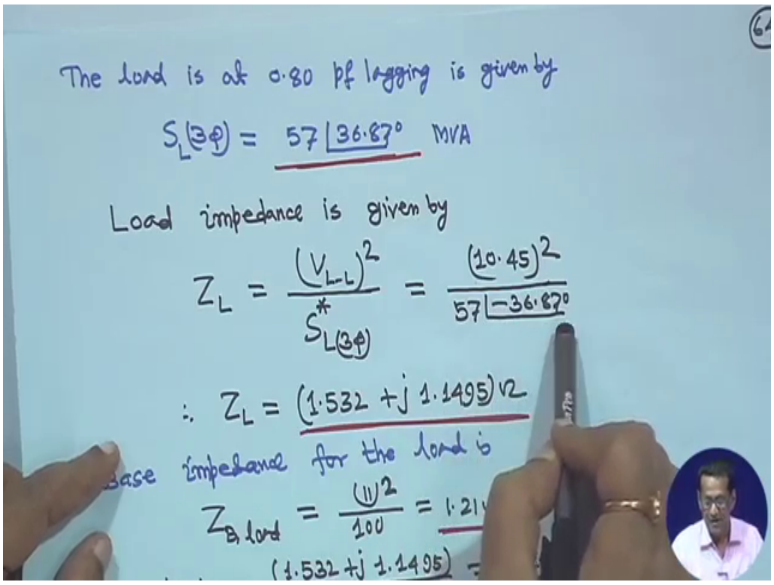

Now, the load is at 0.8 power factor lagging. So, it is 57 MVA. So, S L 3 page is 57 angel 36.87 degree MVA. This we have seen before and load impedance is given by V LL square upon S conjugate L 3 phase right that is 10.45 square 57 angle minus 36.87 degree, these also we have seen therefore, Z L will be 1.532 plus j 1 0.1495 ohmic values right. So, this is actually ohmic values right.

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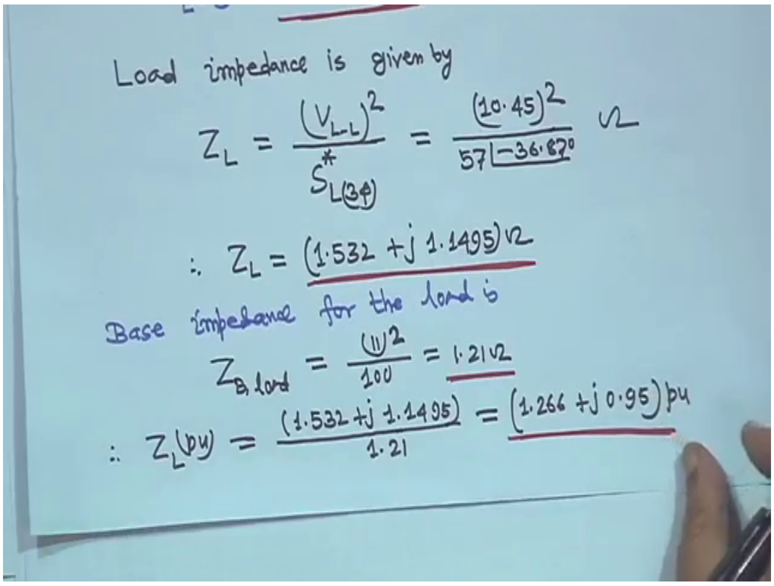

Now base impedance of the load is which is actually we have got 11 KV on the other side. So, 11 it is given. So, 11 square upon 100 that is 1.21 ohm right all data are given therefore, Z L per unit this whole thing you divide by 1.21 you will get 1.266 plus j 0.95 per unit right. So, this one I made little bit faster because all examples we have shown right.

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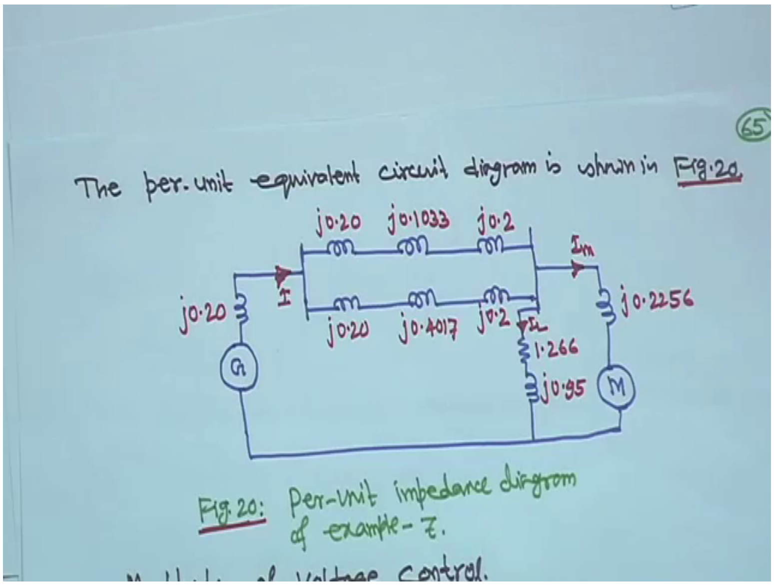

Therefore per unit equivalent circuit diagram is shown in figure 20 that mean these diagram right, this is generator then you have 2 parallel lines transformer then line then again transformer 0.2, 0.1033, 0.22, again this and for other line this is j 0.2 because all transformer per unit was same.

So, T 1 T 2 T 3 T 4 they have after conversion point this thing, but this time line it is 0.1033 and this is j 0.4017 and motor and load there in parallel. So, motor this side x m 0.2256 this is motor and this load resistive part is also there 1.266 and j point 0.95. So, this is that per unit diagram. So, for this your per unit per unit some 7 different type of problems I have shown you right and next time we will take that method of voltage control and you will find that your what you call your tap changing transformer right off and on load, at the same time different type of method of voltage control we will find things are interesting.

Thank you.