**Power System Engineering**
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**Lecture - 44**
**Application of capacitors in distribution system (Contd.) & Load frequency control**

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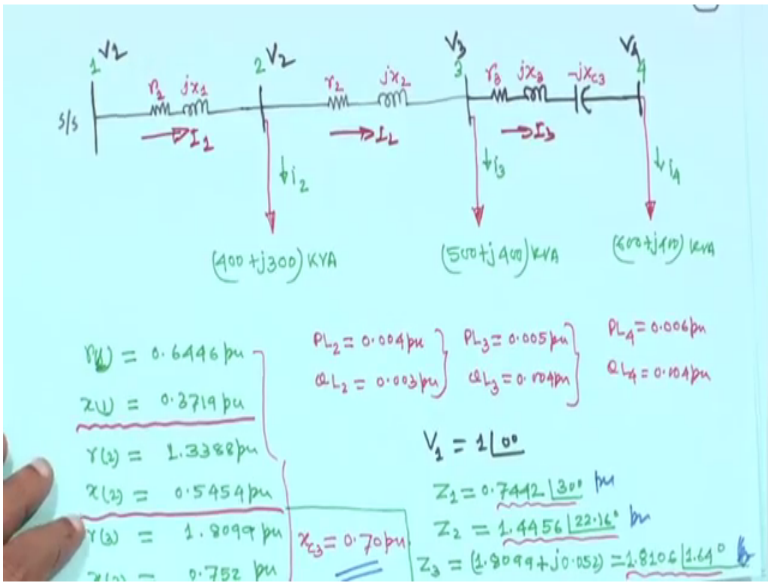


So with this x 3, x 3 value will conclude this we will compute all the values such that look two methods note for we use and one shunt capacitors some example I have given and one this one we have also given this 3 right, very simple thing.

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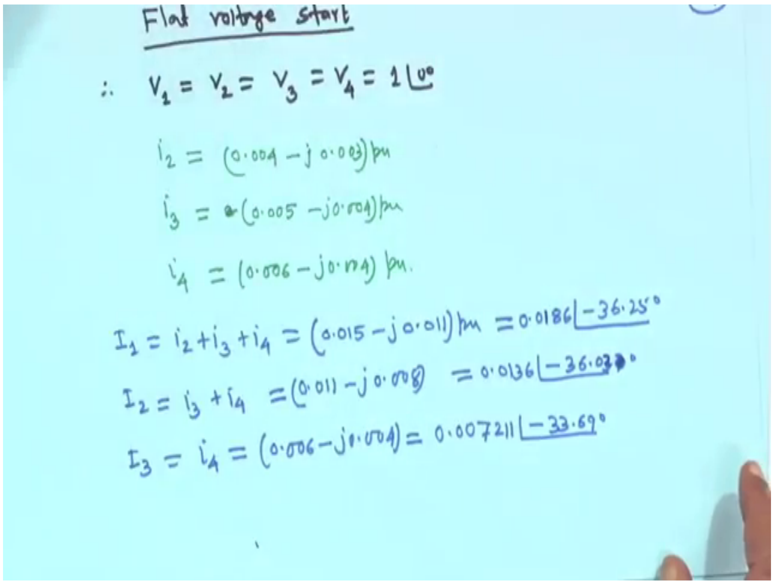


So, flat voltage start. So, in this case we are taking same thing that one angle 0 for all the voltage. So, initially it was a flat voltage start all these things initially have been calculated a series capacitor. So, i 2 is equal to 0.004 minus j 0.03 power you now it is understandable to you i 3 is equal to 0.005 minus j 0 0 0.004 per unit and i 4 is equal to 0.006 minus 0 0.004 per unit.

Now, is same way I 1 is equal to calculate i 2 plus i 3 plus i 4 if you calculate it will become 0.0186 angle minus 36.25 degree, I 2 is equal to i 3 plus i for if you do so, it will become 0.016 36 angle minus 36.03 degree and capital I 3 is equal to small i 4 that will become actually 0.007211 angle minus 33.69 degree right.

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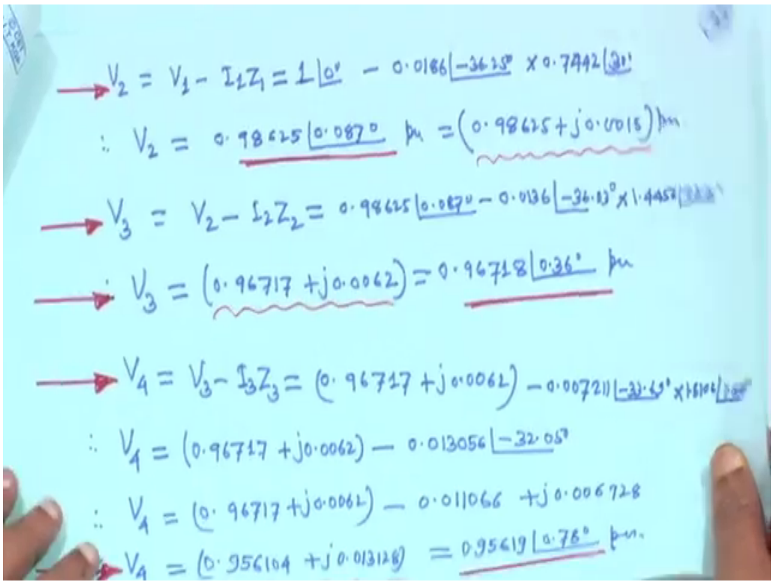


Next is that your V 2 calculation. So, same is V 2 is equal to V 1 minus I 1 0 and 1 angle 0 degree. So, put this V 1 is 1 angle 0 right, is equal to I 1 value substitute and your Z 1 also you substitute right and simplify. So, you will get V 3 is equal to 0.96718 right angle 0.36 degree per unit, right.

So, similarly V 4 is equal to V 3 minus I 3 Z 3. So, same as before first your V 3 you got this one, V 2 we got this one, V 3 is equal to this one, you substitute you will get this one right and V 4 also you just substitute I 3 and Z 3 right, because Z here is decrease it is 1.8106 angle 1.6 degree. So, in this case V 4 case you just do it and simplify you do all calculations and simplify, you will get V 4 is equal to ultimately 0.95619 angle 0.78 degree right this is your after first iteration after first iteration.

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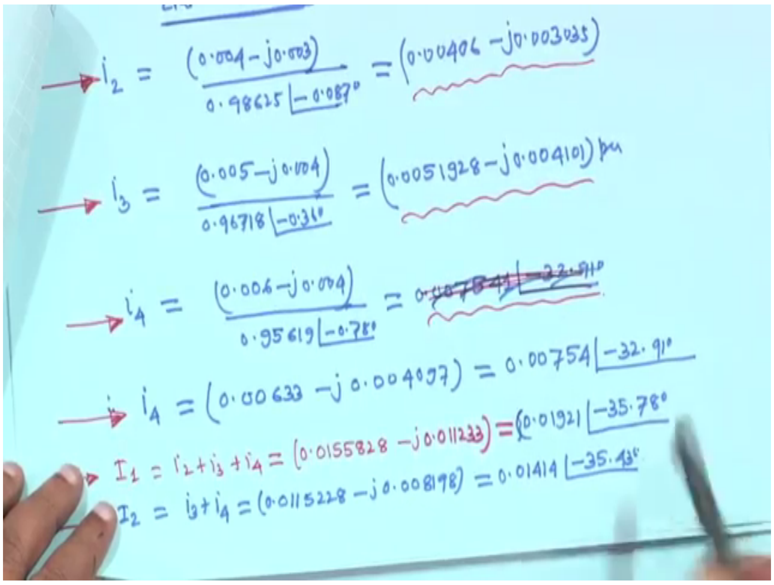


Now, now second iteration starts here this is second iteration. So, with this new voltages right we calculate i 2, i 3 and i 4. So, just you substitute all this thing PL minus jql is equal to your divided by b conjugate this formula you put it you will get this value 0.00406 minus j 0.003035.

Similarly, i 3 is equal to same thing divided by your V 3 conjugate whatever it is there right you will get 0.0051928 minus j 0.00410 right and similarly i 4 you calculate right. So, i 4 if you calculate this is this is do not take this is this is do not take alright. So, here it is here it is 0.00754 angle minus 32.91 degree, right.

So, these way small i 2 and second iteration you got. So, second iteration capital square can compute capital I 1. So, you will get 0.01921 angle minus 35.78 degree. Similarly capital i 2 will get small i 3 plus i 4 that is 0.0115228 minus the 0.008198. So, it is coming 0.01414 angle minus 35.43 degree.

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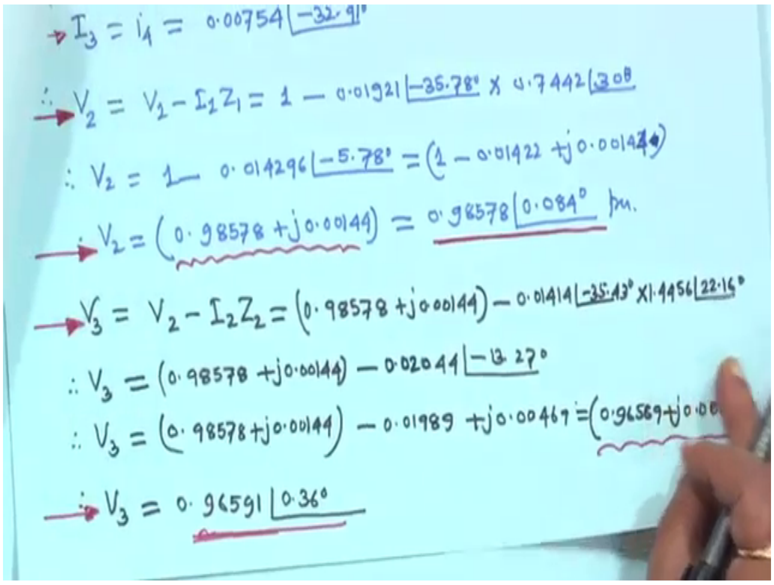


Similarly, i 3 is equal to small i 4. So, it is the same value of i 4 this value therefore, you calculate V 2 right you put all the value I 1 V 1 Z 1 everything you put you will get V 2 is equal to 0.98578 angle 0.084 degree.

Similarly, V 3 is equal to V 2 minus I 2 Z 2 put this V 2 value here and this I 2 and Z 2 value here right and calculate. You will get V 3 is equal to ultimately 0.96591 angle 0.36 degree and this is your in what you call your real part and this is the imaginary part of this one right. And this V 4 is equal to V 3 if this value is substitute right.

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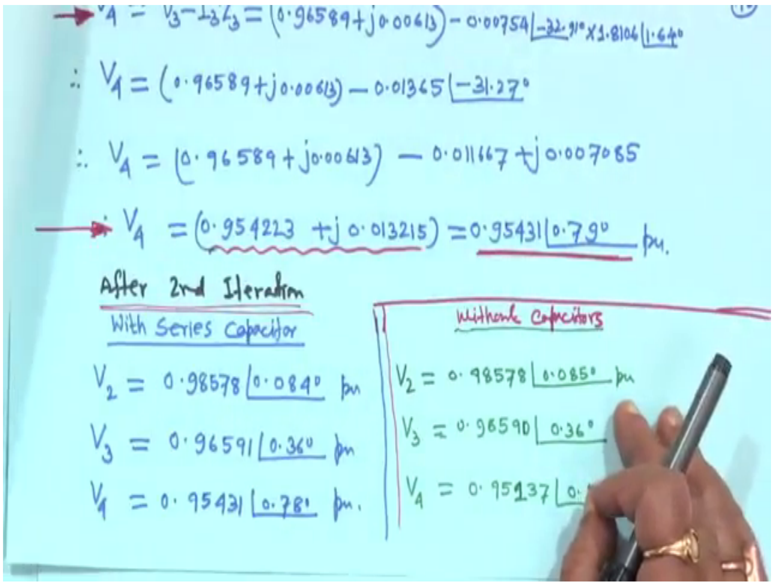

So, V 4 is equal to V 3 minus I 3 Z 3. So, that is your V 3 i 3 and Z 3 Z 3 here is decrease value right because of that series capacitor. So, if you solve it and do this that people will become 0.9543 on angle 0.79 degree per unit. Now this is after second iteration.

After second iteration with series capacitor this is the voltage without series capacitor that is at the very fast load flow studies method one this value rewriting it is 0.98578 here also looked 0.98578 almost no change in the voltage.

Even almost no changing the angle helped 0.0850084, similarly look this one 0.9659, 0.9659 an almost no change almost unchanged it is unchanged right. And if you look at this one 0.95137, but this is 0.95431, but here it is improved at is 137 that is 431 the voltage are improved because I told you at the beginning that series capacitors you have connected here. So, voltage will be improved here, but here and here it will remain unaffected right there will be no change in voltage almost it will remain same.

So, I suggest that you put the same manner of the capacitor in branch one and please try to see that you are what you call that what is happening to the voltage V 2 V 3 V 4 you will find without any series capacitor will find here voltage will improved right all voltages will improve. So, this is what your what you call that your series capacitor.

With this now, again I will come back to that you are regarding some explanation there regarding use of your shunt capacitor just hold on just hold on that your before these things these are that these are the point right. These are the point, that your first thing is that even economic justification for shunt capacitor.

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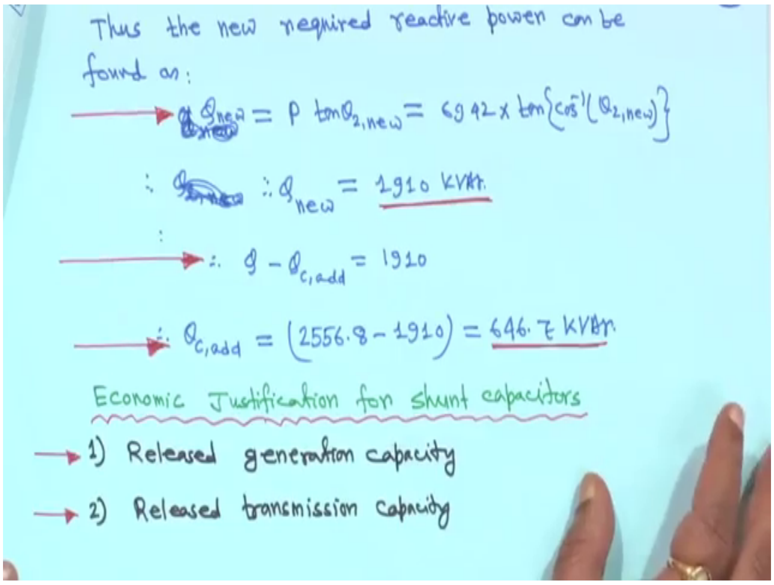


Here look here you try to understand certain things that although it is a it is not possible to solve in the class all these things, but some ideas you have. First thing is release generation capacity this is actually you what happen that you think like this I am just telling you just listening just listen that suppose is generator suppose in power plant synchronous generator, right.

So, if generates power real power as well as your reactive power is also require basically its rating is in terms of mega mem here. So, whenever you are putting shunt capacitors you are on the distribution side that means, you are compositing basically kilowatt right or megawatt whatsoever. So that means, the network is actually not drawing that your that whatever compensating you are putting network actually not drawing any reactive power from the source.

So, if I assume that if it is so, then what will happen then in the as it is telling that it is released generation capacity; that means, that on the side of the generator that it need not supply all the reactive power to the load because something you are compensating. So, naturally generator in terms of generator mva capacity that mva will be released because generator needs less mva as compared to without capacita and capacitor. So, that is why actually it is called released generation capacity.

Second thing a release transmission capacity is idea release transmission capacity means that in the transmission line that you have different type of conductors right, you have different type of conductors and every conductor that is thermal capability that is the maximum current carrying capacity or maximum temperature rise.

So, whenever you are putting capacitors; that means, it is the reactive component of the current is getting compensated to some extent; that means, magnitude of the current on the transmission side will decrease right will decrease. So that means, that is that that is that is; that means, the other way actually that transmission line or transmission network right it will be less loaded compared to having without any or shunt capacitor.

So, that is why it release transmission capacity means actually it is basically that network loading or transmission line maximum carrying current carrying capacity whatever it has. It will carry less amount of current I write compared to that; that means, transmission line can be further over further loaded because it will draw less amount of reactive component of the current to the transmission line because of the shunt capacitor.

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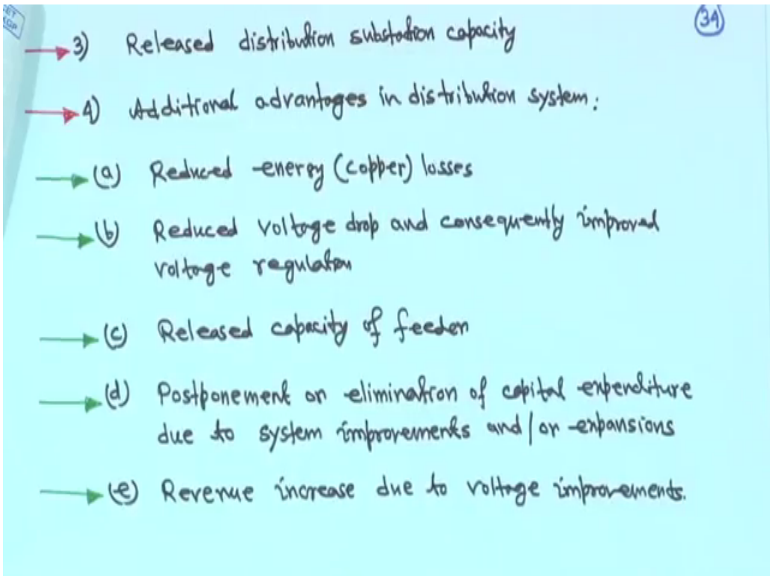


Now, third thing is the release distribution substation capacity. So, I told you that in distinguishing system as soon as you as soon as you connect the you are what to call that reactive power this support the shunt capacitor then what will happen that substation from the substances and it will draw less reactive power therefore, it therefore, the if it is so, then it is releasing distribution substation capacity that will apparently this as if substation capacity increase.

Because distribution system substances transfer mode is there and without capacitor whatever transformer supply kv over supplying because of the shunt capacitors that kv supply will be reduced because of this shunt capacitor all the real power will remain same because we are not compensating any connecting any real power devices like such as distributed generation, but reactive power. So, that is why it will release the distribution substation capacity because transformer loading will be less because it will supply less reactive power because you have shunt capacitors on the distribution side.

Now, additional advantages one is reduce energy losses. So, naturally I square r loss will it is, and sometimes I make one English rhyme type of thing that energy is power multiplied by hour. So, whatever power losses will be there multiplied by time. So, that will be your energy loss.

So, naturally as I square r loss getting decreased means basically energy loss is getting decreased right because system is on for 24 hours. They reduce voltage drop and consequently improve voltage regulation naturally if your voltage is because of shunt capacitor the reactive component of the current is getting decreased therefore, that in the line the voltage drop will be reduce hence the voltage will do not match when voltage will improve. So, naturally voltage regulation will be better.

Then release capacity of the feeder that is another thing the same like a releasing transmission system capacity. Now, here it is distribution side there is transmission side meaning is same; that means, your that your distribution line or distribution feeder because of the shunt capacitor reactive component of the current will decrease.

Therefore, is current you are carrying capability will increase in the sense that you can add more load right because of these because it will magnitude wise it will do a less amount of current because of the shunt capacitor right. And these are I told you postponement or elimination of capital expenditure due to system improvement or an expansion due to this all this reason.

And the revenue increase due to voltage improvements that because voltages improve nearly energy consumption will be better, right. So, naturally revenue increase due to this thing will be more, but let me tell you one thing that distribution actually as an as an engineer actually what we will look into you will look into how much you are investing and how much actually revenue being generated or collected, right.

So, basically difference of this thing will be gain or loss whatsoever. So, whatever suppose if you if you are an utility then you will see how much energy is suppose at the your what to call how much energy is generated and how much money you have collected from the consumers. If you see that this difference is positive; that means, you are gaining and if you say it is negative means you are what you call you are a loser. So, as an engineering point of view you will see that how much you have invested at how much you have earned right.

So, here also same thing how much energy is generated and how much revenue is collected because everything actually matters in terms of money. So, that is why that and distinguishes inside you have thousands of figures eleven thousands figures mostly right and particularly India and many other countries this 11 (Refer Time: 12:32) feeders. So, there will be heavy power loss particularly the distribution side I square r loss a technical and non technical both losses are available are there right , but our concern here is only that technical losses. So, these are these are the certain things. But you have to do the proper design of the distribution system.

Now, before this closing this distributional part few things I would like to I would like to tell you then we will move to the different topic. One thing is generally what do you whatever you see that suppose you have a this kind of distribution network this kind of distribution network right, coding writing for this one for distribution side is not difficult one it is quite easy right.

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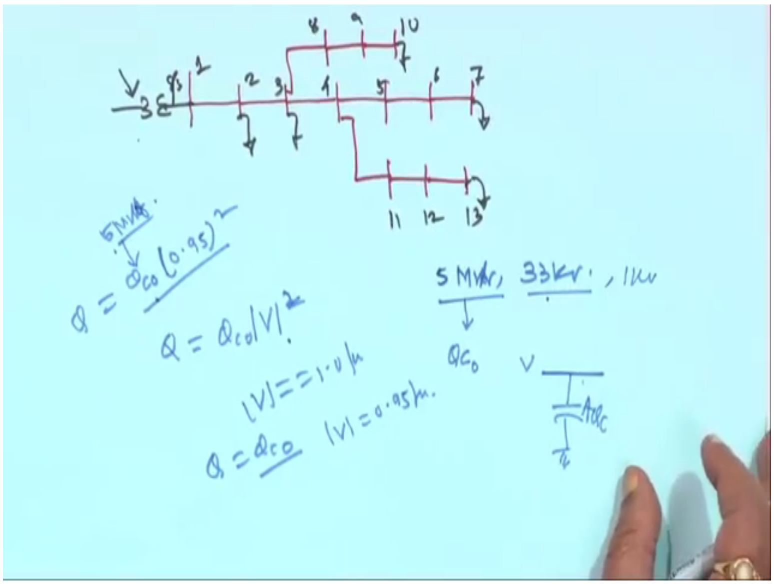

So, suppose you have this kind of network some lateral branches I am taking just for the purpose of explicit this kind of network I am taking and suppose node numb this is your substrate substation means I told you that it is coming from the grid right. And this side I have told you at the beginning this side maybe you are on this side this side maybe I mean this heightens inside it maybe 33, maybe 66, maybe 130, maybe even 220 right , but ultimately it is stepping down to this side is 11 kv.

So, suppose this is substation, this is substation this is node 1, node 2, node 3, node 4, node 5, node 6, node 7, node 8, node 9, and say node 10, node 11, 12 say this is thirteen node everywhere load is there. Although I am not showing, but everywhere load is there load is there everywhere load is there right everywhere load is there.

Now, what I want to tell that basically there are 3 types of load or composite type of loads that are available, one is constant power, one is constant current another is constant impedance. So, I will I will put a question to you and you will write to email give one or two examples of constant power load, give one at least one example of constant current load and give one example of constant impedance load of course, constant impedance load I will tell you here right. So, if you have any other thing you can let me know right.

So, basically what happened this capacitor actually it is a constant impedance device. Generally that it is connected to the your what you call yeah frequency of the system if it is a 50 hertz or 60 hertz that frequency is generally not changing that way right it is around nominal frequency, but sometimes little less than 50 sometimes a little more than 50 right. So, those are so that means, it is a basically constant and impedance type because reactance of the shunt capacitor will remain constant, right.

So, in that case what happens suppose you are buying capacitor. So, manufacturer will give you say 5 megawatt capacitor right and they will say nominal voltage nominal voltage means suppose if it is written say 33 kv right it is a nominal voltage. So, if I take 33 kv or 11 kv whatsoever right does not matter. So, ultimately it will give mega bar it will kv. So, if you convert it to per unit, so basically 5 mega watt will be there.

So, I say 22 kv or 11 kv whatsoever whatever way you write right that manufacturer will give like; that means, the if the voltage level at the time if it is a 22 kv then then only 5 megawatt will be injected, if it is more than 33 kv then it will inject perhaps more than 5 it is less than 33 kv it will be injecting less than 5, but, right.

So, basically it is a constant impedance device shunt the capacitor is a constant impedance device; that means, it suppose initial value if something is given like this manufacture Q c 0 therefore, you are actually Q will be Q c 0 then magnitude of the voltage square. That means, suppose this is your this is the node where voltage is there and here you have you have where capacitor is connected right it is Q c, it is Q c this is a voltage right therefore, where it is connected only that point voltage it will be Q c 0 V square that is this one why it is coming V square proportional to I will ask you to do this 3 4 lines equation and see any book it is there.

I am not doing it for you should write it like a previous power system analysis course those who have taken I put many things many of them solve it. This is 3 4 lines I will not mention the book which book is there then you should find out every textbook will find this right, but this thing you have to understand that it is V square; that means, per unit V is per unit Q c 0 also per unit it does not matter even if per unit or even kilowatt it does not matter this V is also this thing. So, how things will happen?

For example, suppose if V is equal to that mod V is equal to 1.0 per unit that is if it is 11 kv or 33 kv it will be 1 per unit means 11 or 33; that means, your Q should be is equal to Q c 0 that mean exact power will be injected. But if it is not, suppose mod V is equal to at particular node 0.95 per unit; that means, your Q should be is equal to Q c 0 then it will be 0.95 V square right. That means, suppose it is suppose, for example, it is 5 megawatt, 5 megawatt then if you take it square 0.95 square I do not have calculator how much it will come you calculate that with that amount of thing it will it will or what to call it will inject.

That means, for example, suppose if it becomes say for example, 0.85 or 86; that means, if it is a 5 mva megawatt right then 0.86 into 5 so that means, roughly 4.3 mega bar will be injected instead of 5 because capacitor actually it is a constant impedance type of load; that means, whatever example you have taken we have collected a capacitor or 400 kilohertz.

So, that does not mean that it is injecting although from the because there I have treated everything as a constant power that is why I have taken everything right. If I try to do constant impedance of capacitor and other composite load it will be difficult for the classroom purpose. So, that is why that is why if your manufacturer rating will be like this, but ultimately in reality it will inject less, but if voltage goes more than that if you say voltage goes 1.01 it can also happen does not matter. So, in that case it will be it will be little bit more it will inject, but in general case it will be less.

So, whatever 5 mega bar you thought it will give it is not therefore, you need exact analysis by treating the capacitor as a treating the capacitor as a constant impedance load right. So, this is one thing. That why it is constant impedance load you write that I think it will take 1 2 3 4 5 lines 5 or 6 mathematical equation if you write it to a small equation you will get it this one. This is one thing for the your what you call for the shunt capacitors.

Now, another thing is although beyond the scores that DG thing also I have told, distribution generation at least the concept I have told, but we will not discuss that this is one thing. Second thing, second thing is that there are so many here you have thirteen nodes, but you have to find out which node actually gives the best location for the placement of the shunt capacitors right.

But you have the load flow coding say assuming that you have the load flow coding of a system then you have to find out there are several you know several different ways are there to find out the best locations of the shunt capacitor or our DG also right. But here I will tell you that just I will explain that simple thing.

That suppose to find out the best node of the which node actually giving the best result if it is a single capacitor placement then it is not at all a problem right. For example, suppose you consider node 2 right what we will do node 2. Suppose I am just putting one graph suppose this is your this side is your say I am putting a capacitor I am connecting a capacitor say at node 2.

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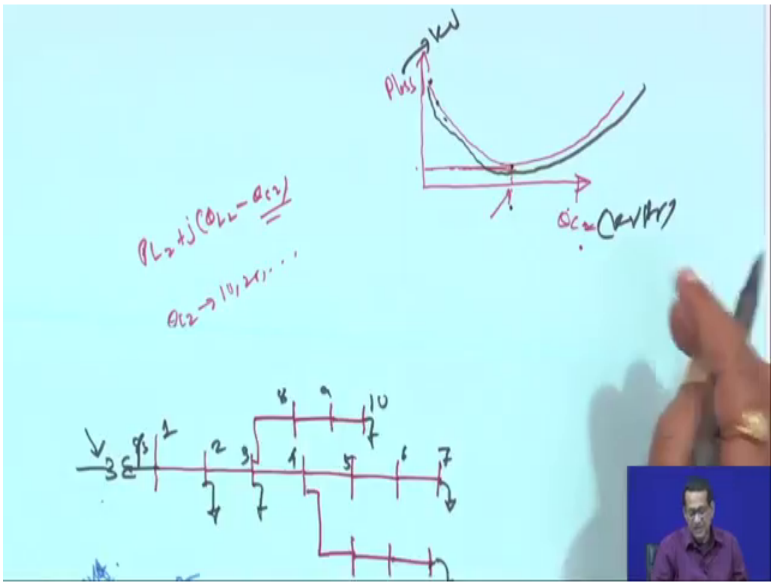


So, this side is say Q c 2 right and this side is the total power loss this is the P loss of the network right. So, what you can do is suppose you are connecting I am not putting it connecting it here, but suppose capacitor is connected at this node Q c 2, what you can do is then you are load 2 PL, your PL 2 plus it will become actually j Q L 2 minus j Q C 2 because I am connecting capacitor Q c 2 in the load flow data right you just increase the Q c value in a state. Service suppose Q c 2 in step 10 20 like this you go on increasing and this side this side will be your Q c 2 go on increasing.

Then what will get you will get a graph like this it will be something like this and this will be your minimum loss for capacitor and this is this is the this is the optimum value of the Q c value right. Similarly remove this capacitor from node 2 remove this just one at a time just one at a time connect another capacitor at node 3, and again you again if you plot the graph then again somewhere it will start and we gain it may go further down right. This way this way although you need not plot the graph every time, so what you have to do is that you have to just you have to see that when you write the code actually you have to see this loss is decreasing, right.

So, I mean this is that first point, this is the second, this is third if you take the difference of the current minus the previous then it will be negative. So, as no as long as the difference is negative it is decreasing as long as it is positive just previous point to stop right and that is called Q c 2 value and this is the loss right.

Similarly for each one and one at a time you have to take and you have to find out of all this which one is giving you the minimum value of the loss and corresponding capacitance capacitor value kilowatt this is actually kilowatt, this is a kilowatt, and this is actually your kilowatt right you will find that which is the best value of the capacitor for single capacitor. If it is 2 or 3 capacitors then of course, you have to go for some optimization technique that is the beyond the scope, right.

So, and it does not necessarily mean that at the end node will the best location no right it will be some place higher it will give you that your what to call that best minimum power loss. But at the same time one has to consider that your what you call that improvement of the voltage right that also that also it will be there.

So, those things if you take 2 or 3 capacitors peaks which combination those things are complicated, but this is what one can solve the capacitor optimization analytical technique. But the way I have told you that load flow one it is very easy one to derive the code right, but exam purpose you need to write code, but I am just telling those who are doing b tech project or this even master project also many are doing like this note through another thing.

So, this will help you a lot right. So, anyway with this I do not know whether I am missed anything or not regarding this application of capacitors to the system right, but with this we will go to the new topic, right.

So, capacitor thing is over good assignment problem will be given to you right and your job is to solve those things have patience and you have to solve those things right. With this that that application of capacitors to distribution system everything is covered now, right, so after that we will go to the load frequency control chapter.

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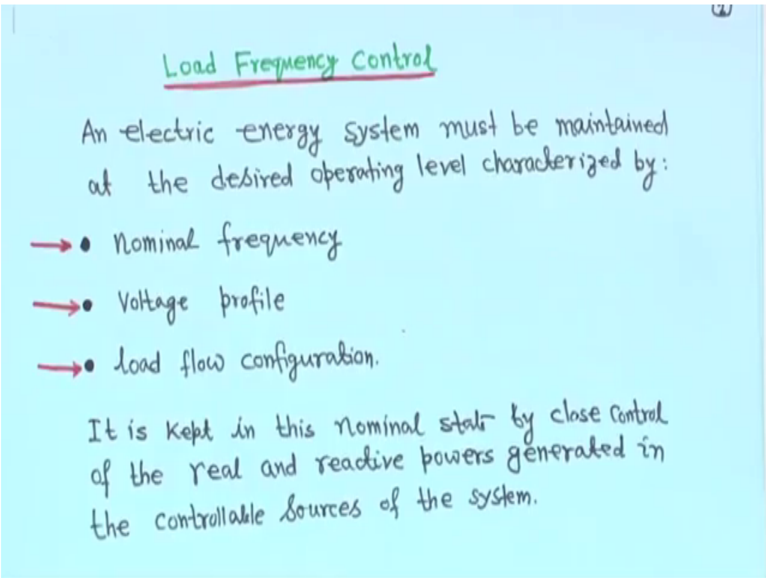


And I hope this load frequency control just try to understand this well right. I will move very slowly for this one because it is it is a control system will come here right and you have all studied control system. And second thing is state space analysis and you will find things are easy things are easy, but you will see that you are understanding each and everything.

So, before moving to that before moving to that what I am what I supposed to tell you that generally the power system right, or we call here we have written an electric energy system same thing right generally you will find that loads are changing continuously right, increase decrease all the time right.

Some loads are switched on, some loads are switched off it is continuously changing right, throughout that day sometimes. But if you if you consider you know a small your clutter is in type of things small change in load, but that is all the time happening suppose sometimes we are switching on the you are switching off your switch point at home or industry also in off peak hours and loads will be switched off, right.

So, this at the time you will find that there is if there is a load flow studies we have seen that in the power system analysis course that decouple load flow right in the decoupled load flow, that your if real power changes right real power changes then your voltage angle is changes right. And it leaves the bus voltage magnitude, I mean I mean almost unaffected and in voltage angle change means the frequency is changing either depth or omega now you take.

And if the similarly if the reactive power changes right there is small change in reactive power then voltage magnitude will be affected, but it leaves the your what you call voltage angle delta or the frequency. So, these two things are totally decoupled right for small changes.

So, similarly your same concept same concept or same philosophy will be V will be applied here and later will come what is load frequency control right. In general actually before moving anything that sometimes we use the term automatic generation control right.

Actually whatever I have understood right that automatic generation control actually is equal to load frequency control plus economic load dispatch together right. So, economic load dispatch is not there then automatic generation control is equal to load frequency control, why idea is something like this that suppose you have a thermal unit right only I will consider your thermal units.

So, every thermal units come our optimal operation of power system in the last your course we have seen that every generator has a your cost characteristic right. Suppose your load demand has suddenly increased to say from 1000 megawatt to 1100 megawatt.

So, there is 100 megawatt increase of the load and suppose in the power system you have 4 or 5 generating units right and each generator in generating units they have different cost characteristic. Then according to according to then you have to that 100 megawatt load you see are among the 5 units in such a fashion such that your operating cost will be minimum right, that means, economic load dispatch its coming.

So, that is why automatic generation control is equal to load frequency control plus your economic load dispatch, but economy load dispatch will not be there because already taught in this your previous course.

And second thing is that economic load dispatch and automatic generation control both are combined together then it may not be a classroom exercise right, it will be it will be a master pieces exercise or master course. So, only we will take the load frequency control.

Thank you very much. We will be (Refer Time: 28:02).