Power System Engineering

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Lecture – 40

Application of capacitors in distribution system (Contd.)

[noise]

ah. So, in the previous ah [vocalized-noise] lectures whatever we have discussed about that your ah capacitors particularly on the sand capacitors that ah that how it effects actually and we have also talked that ah effect of sand capacitor. Basically, it is a ah it is effect is local rather than global and ah primary objective of sand capacitor is to your what you call to increase the your reduce the power loss and do not much it improves the voltage profile of the network.

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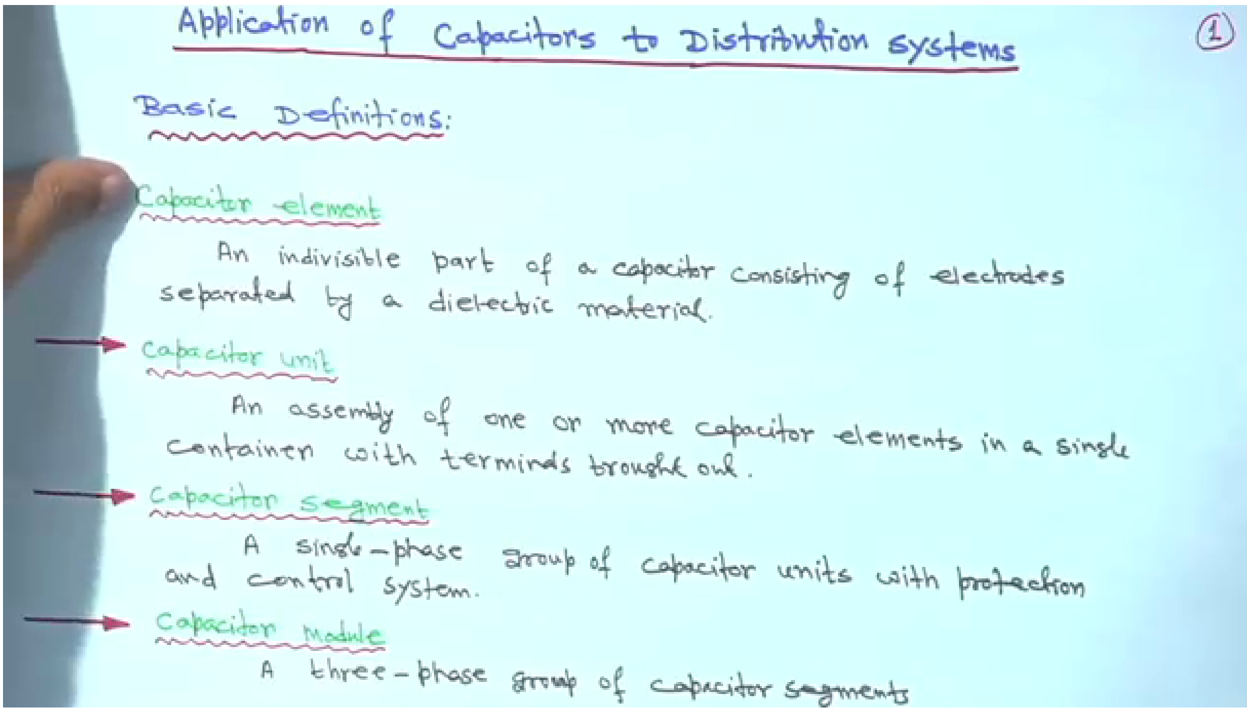

Now, when we will come to that application of your capacitors to distribution system. So, first what we will do; we will talk about little bit about series capaci[tor]- capacitors also in the distribution systems [vocalized-noise] ah application of series capacitor is restricted ah due to various reasons we will explain that and, but ah, but for high tension (Refer Time: 01:16) you may have series capacitors, but you need to you know have lot of protection different type of protection scheme for the series capacitors and there are many other reasons, but anyway.

So, first ah let us ah when we will come to this further we will discuss. So, first ah some basic definition actually we will not talk about the construction or other thing of capacitors, but some general ideas. So, first thing is the capacitor element right. So, as you know and indivisible part of a capacitor consisting of electrodes separated by dielectric material this you know; perhaps you might have seen in the, you know laboratory also and next is the capacitor unit.

So, an assembly of one or more capacitor elements in a single container with terminals brought out this also you might have seen [vocalized-noise] right. Then capacitor segments are single phase group of capacitor units with protection and control system and capacitor module a three phase group of capacitor segments. Now, whenever ah whenever we talk about ah all the; this course only we will talk about the application of capacitor in distribution system only that particularly from the ah point of view of ah you know that; how to incorporate in load flow studies? And what will be your ah [vocalized-noise] voltage magnitude? And what will be the power loss and regarding that energy saving due to capacitor placement right.

Suppose annual energy saving that is beyond the [noise] scope of this course, because it will consume lot of time and at the same time you need the help of computer without writing code it is not possible to actually explain that how things are, but ah, but we will see that ah how the energy ah saving is possible using your sand capacitor it is not only that that if you if you design sand capacitor in a distribution system in such a fashion such that ah I mean; if you can plan that ah you that all the all the reactive powers that actually load requires plus the reactive power losses in the ah distribution network. If you think that we will place the sand capacitor in the network in such a fashion such that it will supply that sand capacitor will supply all the reactive power required by the load as well as the reactive power losses then one can see that it will not draw any any reactive power from the grid.

In that case power factor at the your substation can nearly be maintain unity right. So, that is that is also proper planning is required such that it will not draw any reactive power from the grid and ah not only it is helping the distribution network if it draws ah I mean if it is not drawing reactive power from the grid means; that means, that is all the reactive component [vocalized-noise] of the current is supplied by the sand capacitor particularly for the distribution network it means that grid also will be relieved right, because in the grid also that ah current [vocalized-noise] current will be less in various branches.

So, in other way there will be [vocalized-noise] reduction in the power loss in the grid, but that is a total your completes ah studies required for that and it is not easy to do that, but from general intuition it helps actually both distribution [vocalized-noise] network of course, at the same time it grids right. So, all this things ah I mean with the hel[p]- general thing, whatever it is possible to some extent we will see that as much as it can be done from the classroom exercise point of view, but rest some some of some of the things I will tell you that how one can do it in the your what you call using the code. So, these are these are all the capacitor element or the basic thing.

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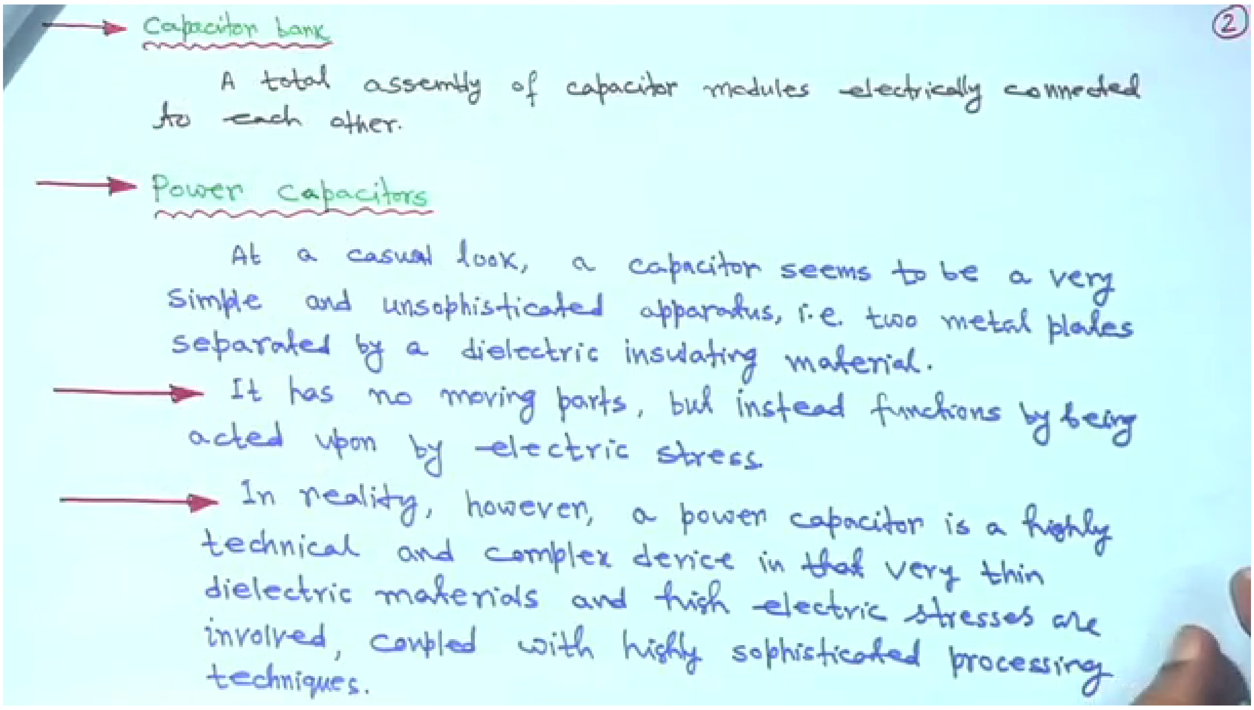

And capacitor bank is a total assembly of capacitor modules electrically connected to each other. So, these are capacitor bank actually that your first let me tell you something then something more I will tell that power capacitors. So, if you look at a casual look a capacitor seems to a very simple and unsophisticated apparatus that is two metal plates separated by dielectric insulating materials. So, it has no moving parts it is a static device, but instead your functions by being acted upon electric by electric stress right.

So, in reality; however, a power capacitor is a highly technical [vocalized-noise] technical and complex device in that very thin dielectric materials and high electric stresses are involved coupled with highly sophisticated processing technique actually in reality; that is ah I am talking about sand capacitor that actually reality sand capacitors actually ah you have a fixed type of sand capacitor and switch type of sand capacitor connected to the network.

So, particularly fixed type of capacitors it will remain connected to the system throughout the your what you call year of the ah [vocalized-noise] your throughout the year right it is it is a fixed one it will, but ah in addition to that that that is at the light load level, but when load level increases. Suppose, if you consider a variation of load throughout a day there will be epic load then optic load and be two in some medium ah medium load right.

So, all this [vocalized-noise] different load level suppose your light load level out of 24 hours; suppose 10 to 12 hours if it is happening the light load level. So, you have to first determine; what is the ah your ah capacitor optimize value at the light load level and that can be treated as a fixed capacitor which will remain connected to the system all through the year, but ah and any any load further increased that additional capacitor bank will automatically connected at various load level.

When load later I will try to explain you something such that those can be treated as a switch capacitor and it switch capacitor at a ah different ah your what you call that switch on and off that technique is different one is that ah copper wire is connected; if you see the voltage level has gone below certain ah [vocalized-noise] magnitude of the voltage then automatically capacitor will be switch capacitor will be switched on right and it will inject reactive power into the network.

Another point is the if you use the time load if you know the load profile of the network then you know from this time that switch capacitors will be switched on. So, automatically when that time will come that is capacitor bank will be ah your switched on and it will again inject reactive power at that load level. So, that control technique is different and another thing is that; that fixed capacitor is less expensive than switch capacitor switch capacitor is more expensive at least 2.5 to ah 3 times; whatever I know right and these because that control mechanism is there because switch on and off.

So, and another another aspects of the capacitor is whatever we will study in this course that capacitor we are treating as a [noise] constant power device, but in reality capacitor is a constant impedance type of element; that means, that when it reacts ah your injects reactive power into the network actually it is magnitude actually directly proportional to the voltage square of the voltage magnitude; that means, if vol[tage]- I mean at a rated value if voltage is 1; it will inject the same same ah bar or kilo bar or mega bar into the network; that as [vocalized-noise] as per the manufacturers specification, but if voltage goes below ah 1, then as a suppose it is 0.98 say.

So, suppose your capacitor is say 500 kilo bar. So, it will be 500 into 0.98 square right. So, it will inject less kilo bar into the network. So, little bit will ah express that, but in the classroom point of view it is [vocalized-noise] not possible using calculator to do that, but I will explain how things are.

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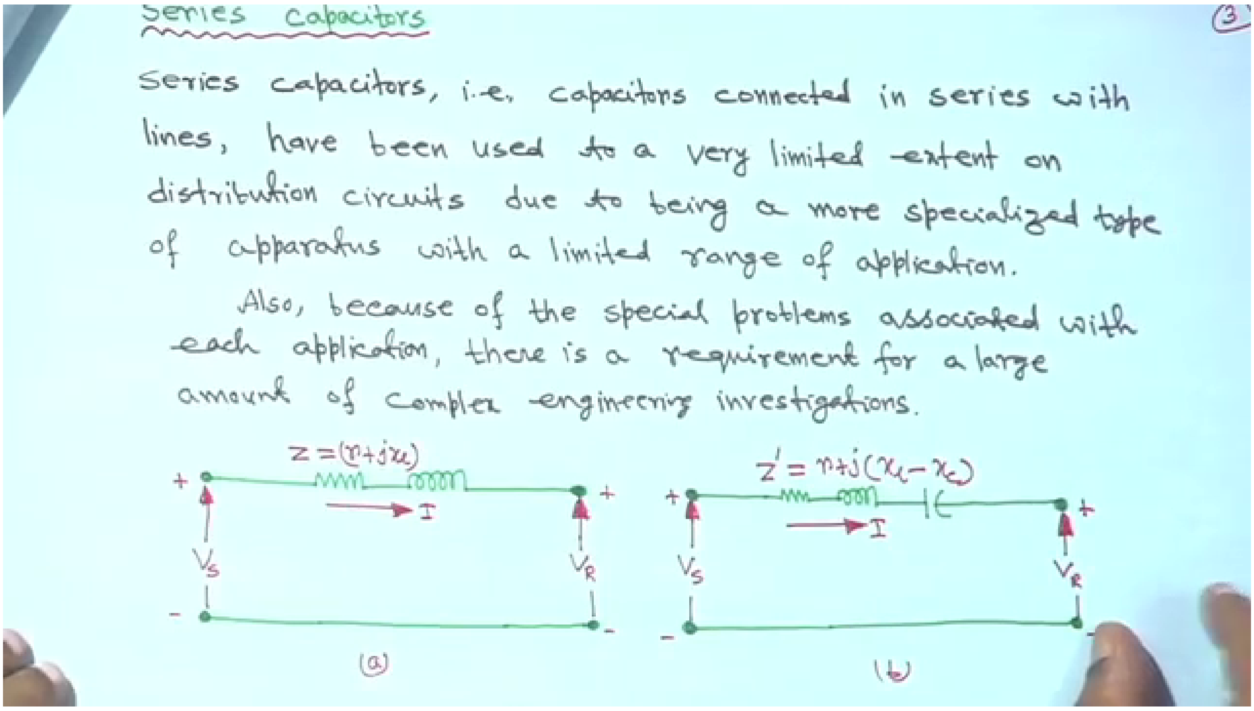

So, [noise] now first we will try about the series capacitor. So, generally ah [vocalized-noise] as it is application of capacitor that series capacitors ah used in distribution system is not much it is restricted, but in transmission system that ah your what you call that many applications of series capacitors are there, but there you have before appli[cation]- before ah you are using series capacitor you have to consider many other other factors also.

So, if you if if you that is why series capacitors; that is capacitor connected in series with lines have been used to a very limited extent on distribution circuit due to being a more sophisticated type of apparatus with a limited range of applications also, because of the special problems associated with each ah each application. There is a requirement for a large amount of complex engineering investigations, because we have to consider one thing for series capacitor from a general knowledge the first thing is the resonance right.

So, many factors you have to ah consider ah I mean you have to consider many things. So, first for example, if you consider this line say simple line say it is impedance z is given r plus j; this is actually figure one a b, but two more figures are there in the next page [vocalized-noise] and this is the sending end voltage and receiving the receive the receiving end voltage and there is ah your what you call; no series capacitor here, but in the figure b here you have connected a series capacitor having reactants x c. So, it is basically z dash is equal to r plus j x l minus x c x c is the reactants of the series capacitor.

In your circuit theory problem that series r l c circuit you have studied you have studied you have studied also the resonance [vocalized-noise]. So, for example, if your x c become x l. So, this part will be zero reactive part will be 0. So, it will receive at that time resonance will happen, but question is that you have to you have ah because there are many other consideration.

Generally, even if it is used that x c should be less than equal to x l if x c greater than x l it is over compensation right. So, little bit we will discuss ah series capacitor not much, but ah your ah as per as theory is concerned will be explained here, but in the numerical type we assignment we will give you some ah problem regarding a series capacitor, but this is sending end voltage, but this is receiving end voltage [noise] as soon as you put this here it is V R.

So, I should make it V R dash right; because as soon as you connect this one. So, from your commonsense you can make out this voltage drop will reduce. So, whenever you you have seen this is the current, I this is the current I and this is your what you call that series capacitor; then what is will be reactive power it will be basically magnitude I square into x c that is q c, that is reactive power that ah it is magnitude of I square into x c for the series capacitor. Now, if the load changes then this [vocalized-noise] I mean I mean it is something like this all this things I have not written here.

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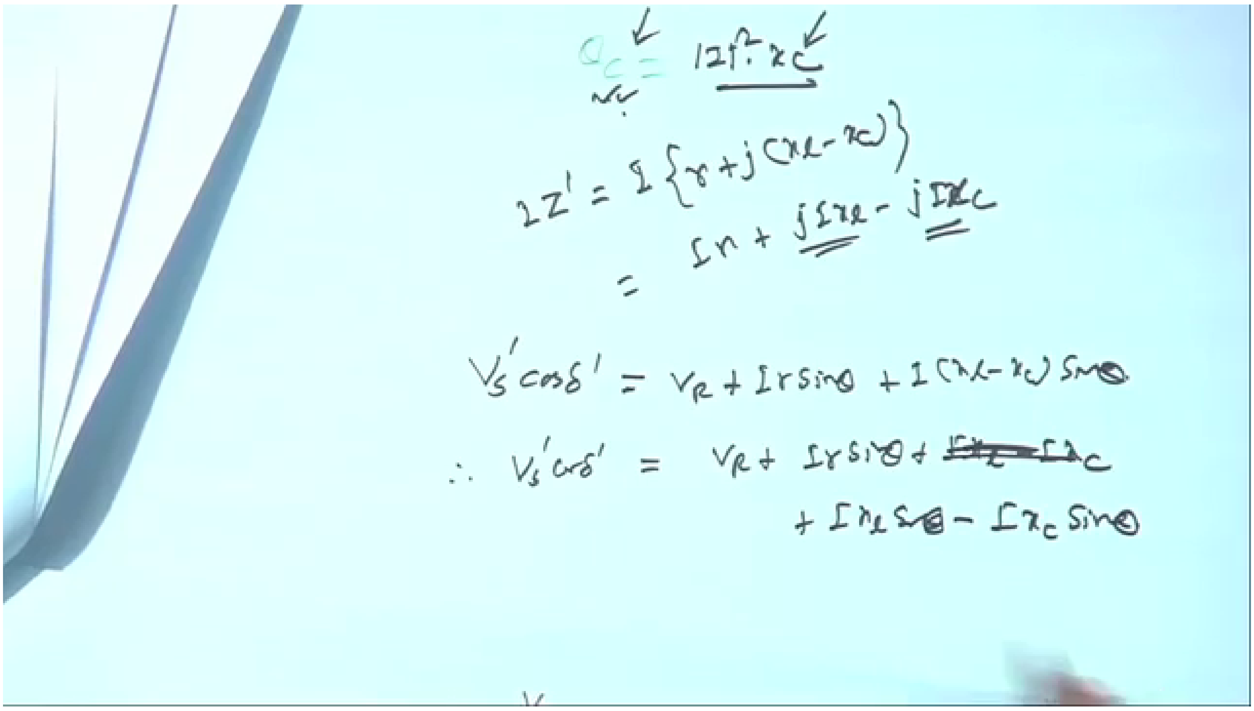

But, suppose suppose your Q c that series capacitor just hold down [noise] that [vocalized-noise] series capacitor Q c it is magnitude of I square into x c this is the reactive power from the series capacitor right.

So, if the load changes this is the current I some load is connected here say. So, if load changes it varies it cu[rrent]-; that means, current mag can increase or decrease. So, if the current is [vocalized-noise] decreasing that Q c actually if current is decreasing Q c decreasing, because x c remain constant assuming that the frequency of the network remains constant. So, if the current ah decreases then Q c will decrease if current increases Q c will increase; that means, this Q c actually it is a variable thing so; that means, [vocalized-noise] if ah this this; that means, this series capacitor what you can do is?

It is analogous to a voltage regulator right. So, I mean that is sometimes we call boosting transformer. So, it is your there also that there is a possibility that ah your what you call a? So, it is analogous sub series capacitor they say what that ah it is something like a voltage regulator later little bit we will talk about that, but so; that means, is Q c actually x c remain constant, but because of changing I that reactive power generated by this series capacitor actually it is changing. So, it acts like a voltage regulator. So, it is analogous to voltage regulator right.

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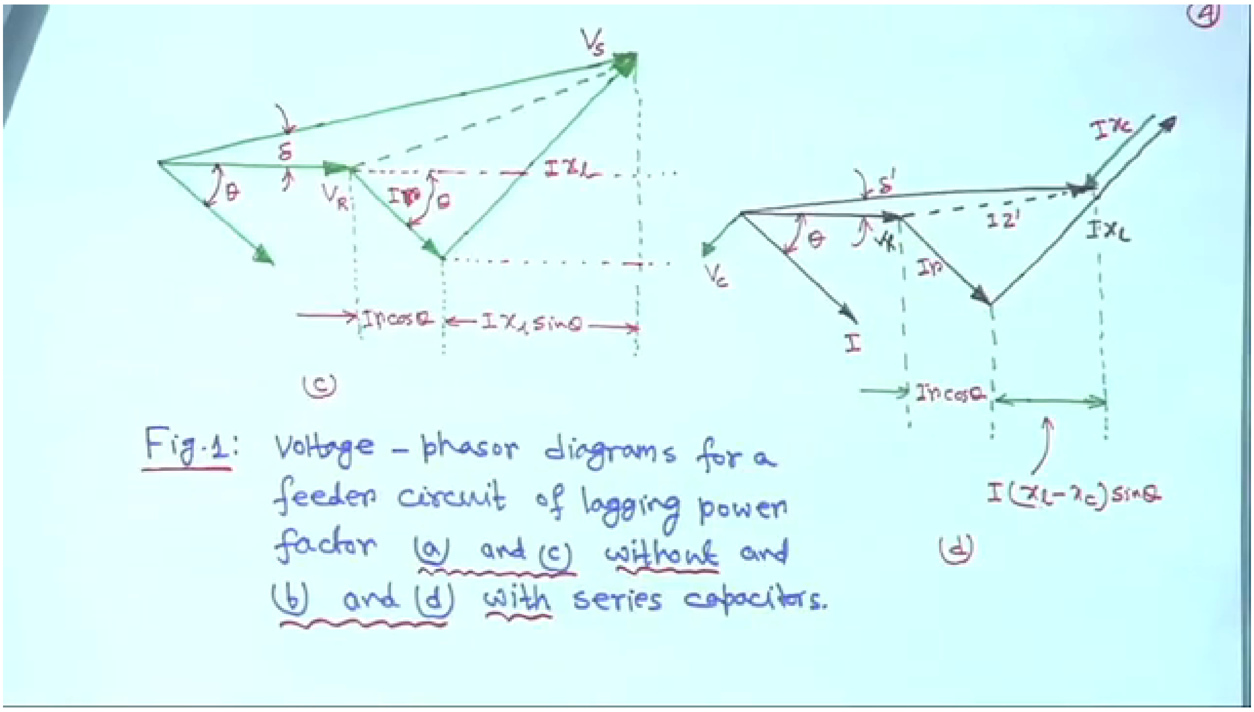

So, if you if you [noise] draw the phasor diagram for this one this is I, this current we are taking as a lagging current for the [vocalized-noise] leading current also we will see, but this is lagging current right. So, corresponding [noise] to this diagram figure a this diagram [noise] this is the phasor diagram we have seen also for approximate voltage drop this thing.

So, this is V R right and this current is lagging by an angle theta. This is actually this this phasor is I r this angle is theta and this angle is 90 degree, I x l then this is the V S this portion is I r cos theta this portion is I x l sin theta this I have told you in that your what you call previously for approximate ah method [vocalized-noise] approximate calculation in distribution system.

And when ah when you have a here I have missed this one this is V R this is V R. So, when you are putting series capacitor means [noise] that; here you look the if voltage drop. Suppose, the voltage drop in that ah your I z dash I z dash is equal to a; it is I then it is r plus j it is x l minus x c right so; that means, if you multiply this this I r is ok then it is j I x l minus j I x c.

So, this from this one this is getting subtracted [noise]. So, that is why; [noise] when you draw the phasor diagram for this one [noise] this is actually your ah V R; this angle is theta the current is lagging here current is lagging theta. So, this is I r and this is [noise] I x l; that means, your; that means, your [noise] ah this part I ah I x l and this is minus I ah your I your what you call; I x c this is not I c it is sorry it is actually I x c right.

So, this is I x c [noise]. So, this part. So, you have to subtract. So, it take arrow downwards or it is on the same line, but just to just to show you that how things are. So, this is actually I x c. So, and this voltage drop will be I z dash and this is your new value this this is actually new value of your this thing say say V S dash right. So, this is; that means, ah here and this angle is delta dash earlier it was delta now it is delta dash.

So, with that you will find delta dash actually it will decrease, because this V S actually is ah your V S dash actually is equal to V R plus I r cos theta plus I x l minus x c sin theta. So, this is the new position of the V S dash right. So, [vocalized-noise]; that means, your if you place the ah series capacitor right if you place the series capacitor. So, from that you can make out what will be the value of V S dash, because it is decreasing because I into x c part is getting decreased right. So, in that ah in that ah diagram. So, if you try to find out what will be your ah series capacitor that approximate thing, then this angle is delta dash same as V 4 right same as V 4.

If you make a horizontal line thi[s]- like this and this distance is given this distance is given. So, V S dash cos delta dash; that is your V S dash cos delta dash is equal to V R this V R is equal to V R plus I r sin theta plus I r sin theta, whenever writing this I i actually magnitude right magnitude understandable plus ah this part I into x l minus x c ah sin theta. So, I into x l minus x c sin theta right; that means, your V S dash cos delta is equal to V R plus I r sin theta plus I x l minus I x c ah sorry [noise] ah plus I x l sin theta minus I x c sin theta right. So, this this delta dash actually it is smaller than also this one previously we have made an approximation. So, this delta dash can be considered as a too small very small; that means [noise] ah; that means, you can write that [noise].

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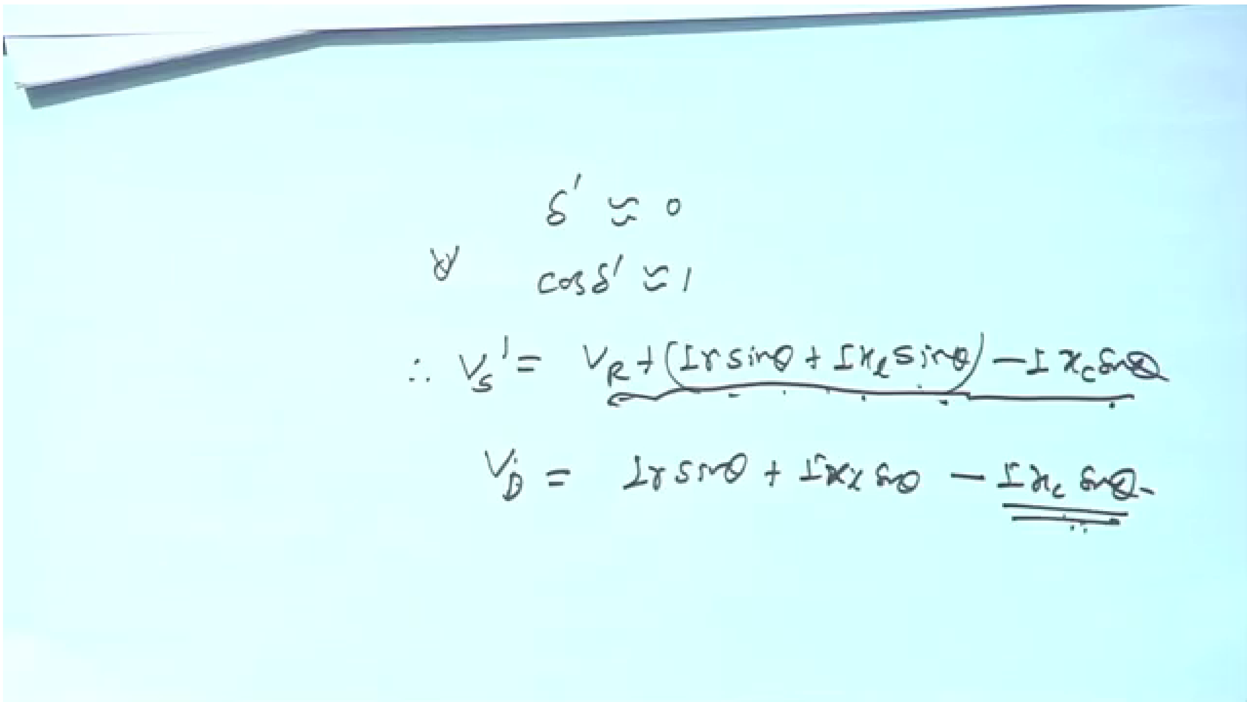

If delta dash is ah very small; that means, cosine delta dash approximately one; that means, you can write that equation V S dash is equal to V R plus I r ah sin theta plus I x l your sin theta right this much was already there minus your I x c sin theta right; that means, earlier without series capacitor approximate thing was this was this was approximate voltage drop. Now this is the total; that means, voltage drop is equal to actually I r sin theta plus I x l sin theta minus I x c sin theta this voltage drop means that that is equivalent to your voltage raised right, because this much drop means that this much of voltage raise.

So, that is your; this is your voltage drop equation. So, if we say [noise] that V S dash is equal to this one this one without series capacitor now not because of these this much you what you call ah this much of minus I x c it is sin theta this much drop extra is there it is subtracting from this 1. So, this is actually voltage drop mean this is equivalent to your; what you call the voltage raise in that network.

So, this is [noise] the approximate equation [noise]. So, in; that means, [noise] that is why your [noise] or not shown all this things is what I told you that voltage ah if voltage drop is getting reduced means the amount of reduction actually equivalent to the voltage raised right understandable [noise].

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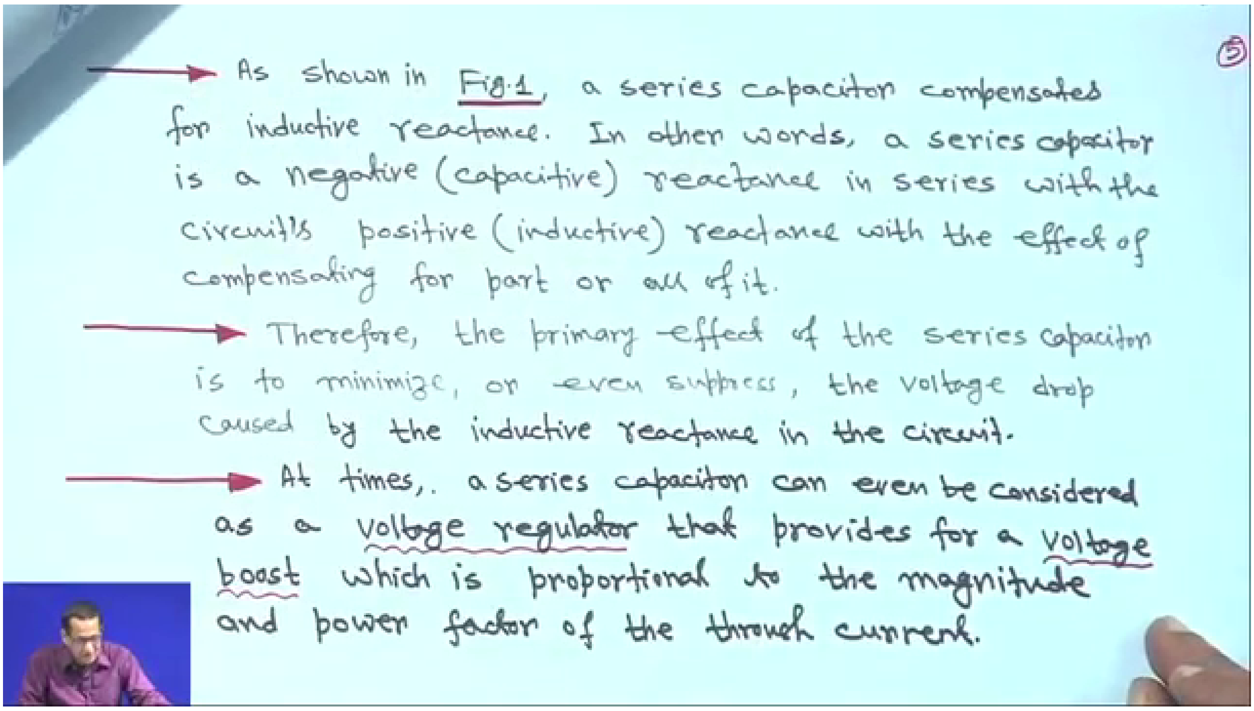

Now, therefore, as shown in figure one I told you that those figure one is series capacitor compensates for inductive reactant because it is x l minus x c right; that is why is compensating in other words a series capacitor is a negative your reactance in series with the circuit with positive react. When negative reactance means it is capacitive positive means it is inductive with the effect of compensating in the part of part or all of it I told you right.

So, if all of it means that your x l minus x c it will be resonance condition right therefore, the primary effect of the series capacitor is to minimise or even suppress the voltage drop caused by the inductive reactance in the circuit. So, what we are doing; using series capacitor actually it actually it ah reduces the voltage drop in the line naturally it; that means, it is helping to ah your what you call the voltage increase in the network right, but at times series capacitor can even be considered as a voltage regulator I told you because that provides for a voltage boost which is proportional to the magnitude and power factor of the through current right; because Q c is equal to I square x c.

So, main purpose of the series capacitor is that it actually it is main purpose is or primary objective is to increase the [vocalized-noise] your voltage level of the network right and as you know that (Refer Time: 21:03) it also reduce the power losses; because we have in the load flow studies the power loss [noise] equation.

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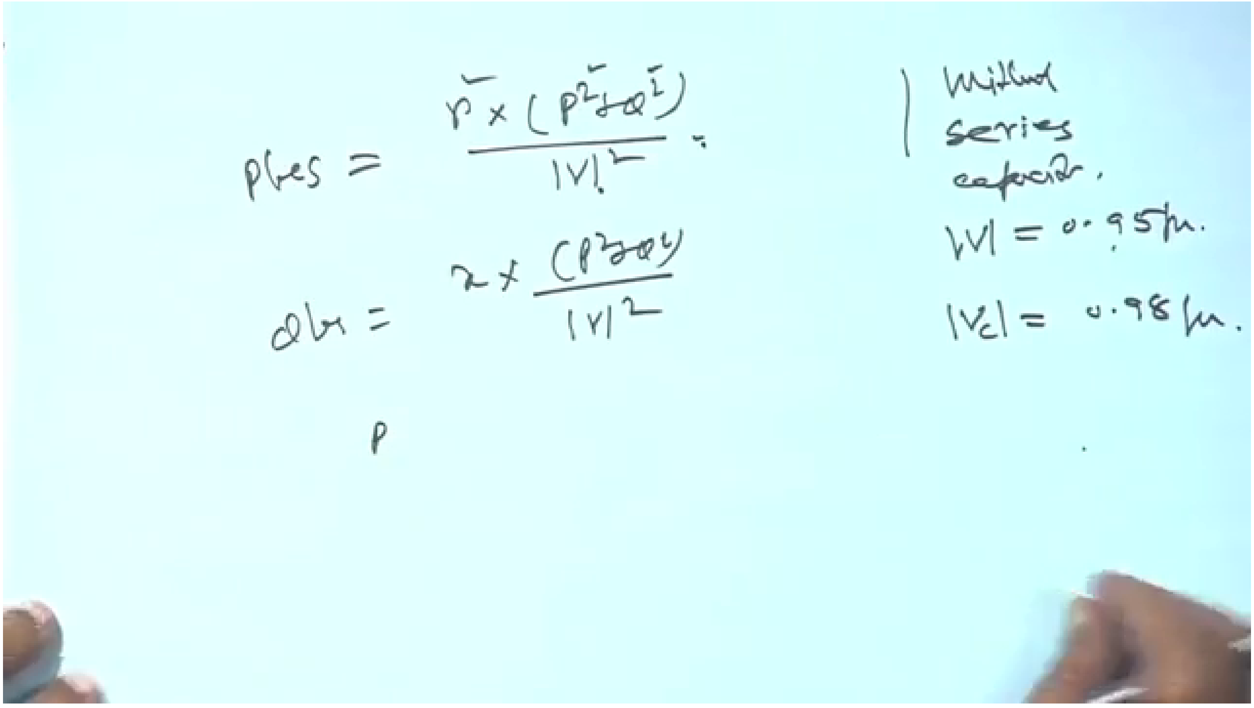

We have seen that your what you call power loss just in general I am writing power loss is equal to r in general P square plus P square [noise] divided by voltage square this we have seen this is the power loss right; this is the P loss and q loss is equal to x into the same thing P square plus Q square [noise] upon voltage magnitude square.

This is the power loss equation and because of the [vocalized-noise] series capacitor placement in the line that voltage is improving if the voltage improves a improves although this thing this thing is unchanged right all this only little [vocalized-noise] due to the improvement of the voltage there will be a power reduction in power loss, but that is ah quite less right that is quite less, but do not match it improves the your what you call a it [vocalized-noise] your reduce the power losses; because it voltage is improved voltage is getting improved right, because suppose for example, suppose without series capacitor.

For example, without for example, say without series capacitor right suppose your voltage was V 1 say magnitude was zero 0.95 per unit right. So, whenever when I suppose with series capacitor say with series capacitor. Suppose when you put the series capacitor say it is becoming 0.98 per unit suppose voltage as improved [vocalized-noise]. So, as soon as this voltage is improved basically numerator is increasing right [vocalized-noise] so; that means, compare to this one then what will be the your sub just just for just for your sake of understanding suppose suppose this one ah this one suppose P loss [noise] let me write you in a better fashion such that [noise] understand your ah your concept will be clear.

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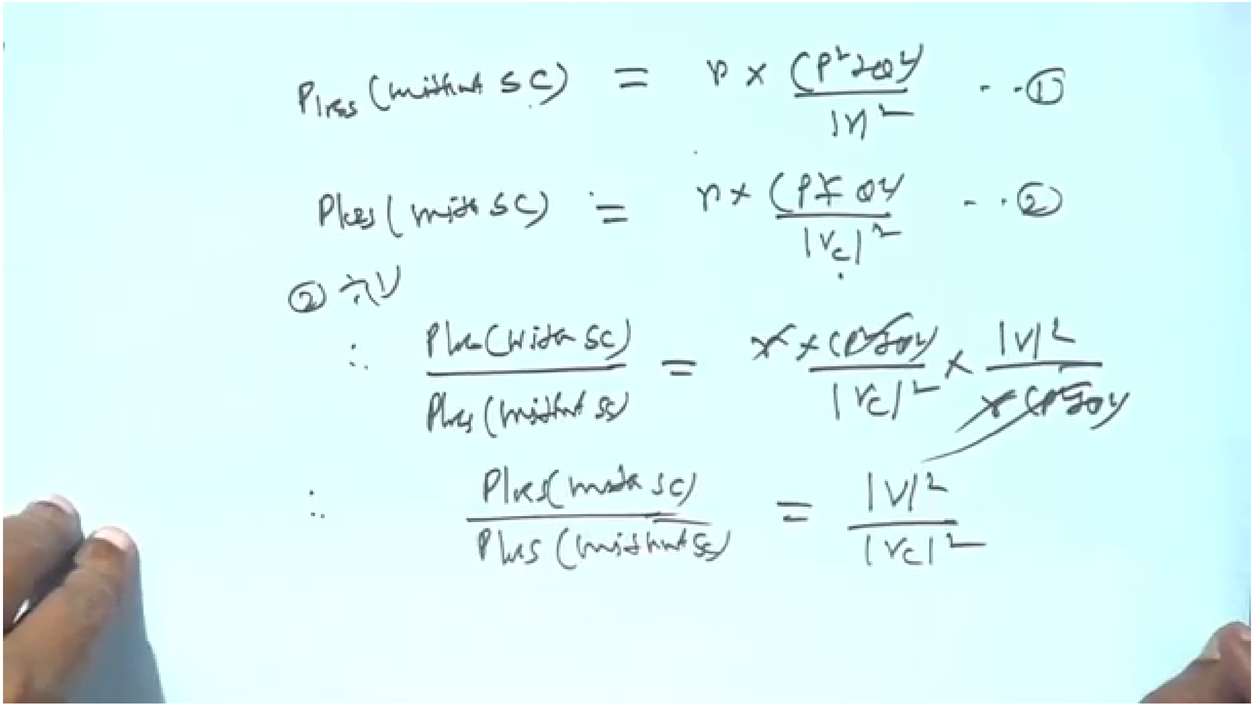

Suppose this is P loss just for your understanding without your series capacitor I am making S C series capacitor is equal to say only one r into P square plus Q square upon magnitude V square right. Similarly, say P loss with series capacitor with series capacitor S C means series capacitor say r into P square plus Q square upon your say due to the capacitor voltage. Now we are making say V C same voltage this same load, but instead of this thing V C.

Now, if you divide this suppose suppose this is your equation 1 and this is [vocalized-noise] equation 2; suppose 2 divided 1 equation 2 divided by 1; that mean P loss that is with series capacitor [noise] not sand capacitor it is series capacitor right divided by P loss without series capacitor you just divide it it is with series. So, r into P square plus Q square upon V C square into V square divided by r into P square plus Q square. So, this this will be cancelled right; that means, your P loss with series capacitor divided by P loss without series capacitor is equal to your V square upon V C square right.

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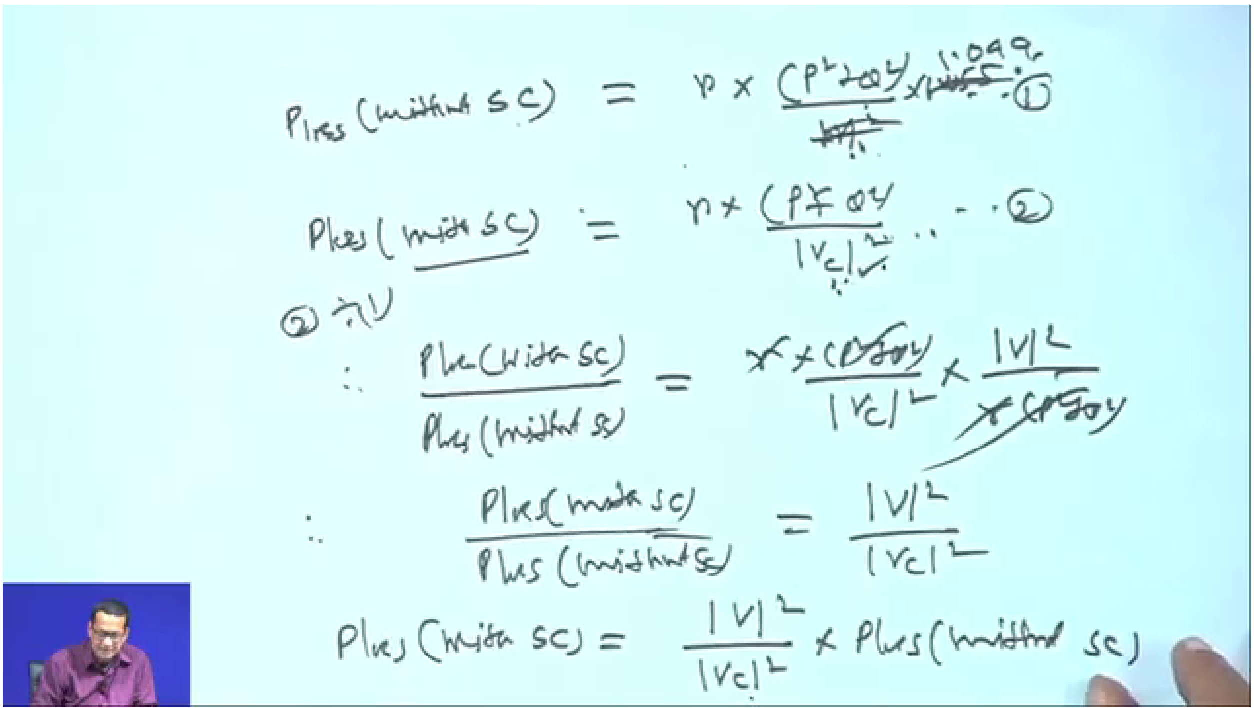

Therefore ah [noise] therefore, P loss with series capacitor P loss with series capacitor is equal to magnitude of V square by magnitude of V C square into P loss without series capacitor right. So, if you are for example, [noise] suppose suppose if it is.

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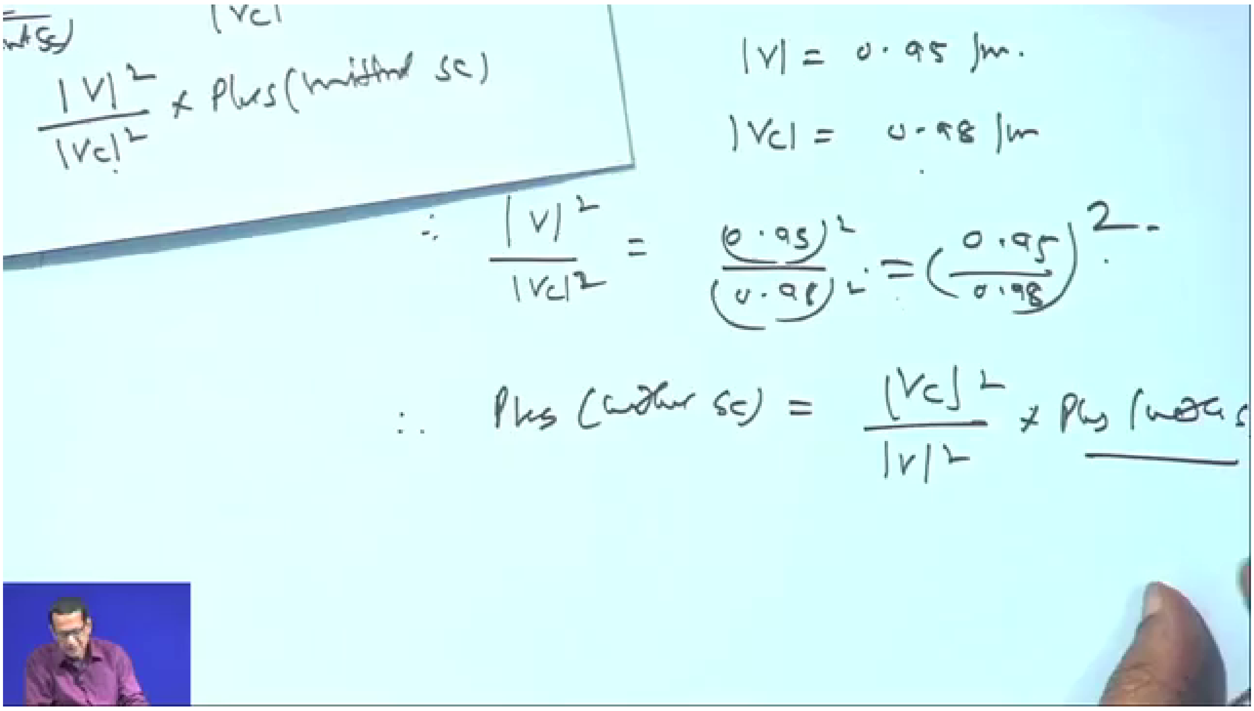

Suppose if before series capacitor if it is V is equal to say 0.95 per unit and suppose after suppressing capacitor say 0.9 per unit right; that means, your V square [noise] upon V C square [noise] from this equation only from this equation only [noise] it is actually it will be 0.95 square [noise] divided by 0.98 square right. [noise]

So, that is actually 0.95 by your ah 0.98 right; ah ah that is your what you call P loss; without series capacitor series capacitor and P loss without series capacitor. So, just a minute P loss with series capacitor actually it is V C sorry; ah this is your P loss with series capacitor is equal to this 1 into this 1. So, it is V square upon V C square [noise] yes. So, if you take that V C is point [vocalized-noise] ah V C is equal to your 0.98 and V square is equal to this thing.

So, you can find out what will be your P loss with series capacitor. So, in that case what will happen this is square actually this is square right. So, whenever whenever you put that ah your series capacitor; because that voltage is improving right voltage is improving. So, naturally your ah what you call that ah this power loss [vocalized-noise] will ah because of the improved voltage because it is ah your much less. So, power loss will be higher it is much smaller much improved. So, it will be square will be also less.

So, power loss will what you call will decrease to some extent; because of this your what you call that ah [vocalized-noise] voltage improvement. So, initially [noise] it was 0.95 say per unit you have taken. And now after the series capacitor voltage magnitude has changed to 0.98. So, V square upon V C square right now as soon as you put it therefore, this thing this will be; that means, this equation can be written as P loss without series capacitor right is equal to V C square [noise] upon ah your V square right into P loss without series capacitor. [noise]

So, whenever whenever you put this one whatever whatever will be there that your what you call that your ah power loss will do not much, but because of the improvement of the your ah voltage it will ah it will what you call it will increase for ah right for a for for a simple case another for a simple case [noise] right [noise] ah another thing for example, suppose V is equal to you have taken 0.95 per unit.

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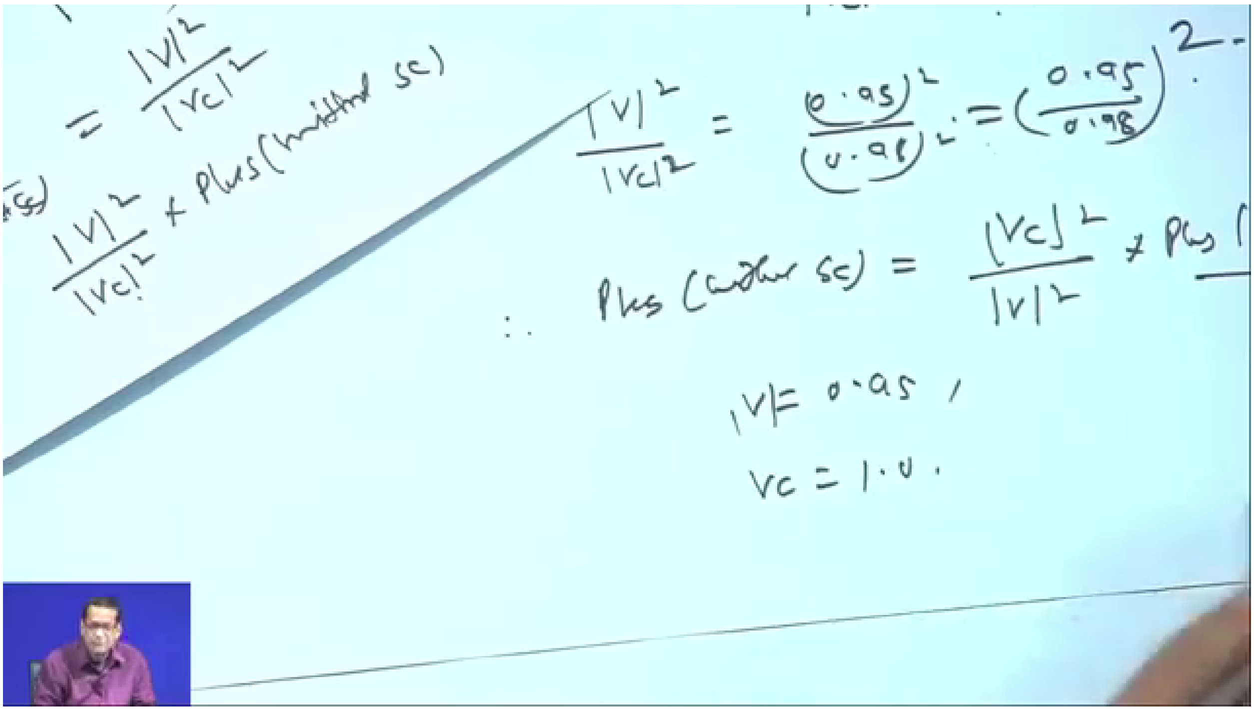

For example suppose V C is equal to 1.0 [noise]. So, in that case for for ah purpose of explanation if V C is equal to 1.0 it will be r into we we your P loss without series capacitor will be if V C is 1 r into P square plus Q square, but if it is 0.95 you say. So, it will be approximately 1.055 something if you take if you take V is equal to your 0.95 square.

So, it will be not 1.055 it will be ah your 1.05 roughly it will be your 1.099 something it will come right so; that means, with without without series capacitor the r into P square plus Q square is multiplying by this much it is higher, but if it is suppose V C is raised to 1. So, it will be just r into P square plus Q square. So, with series capacitor that your loss will decrease; So, that way; that means, whatever whatever P loss with series capacitor and without series capacitor right whatever it was there it is a P loss with series capacitor by P loss without series capacitor. So, it is r into P square plus Q square upon V square into V square upon r into P square. So, this 2 will be cancelled. So, it is coming actually V square upon V C square.

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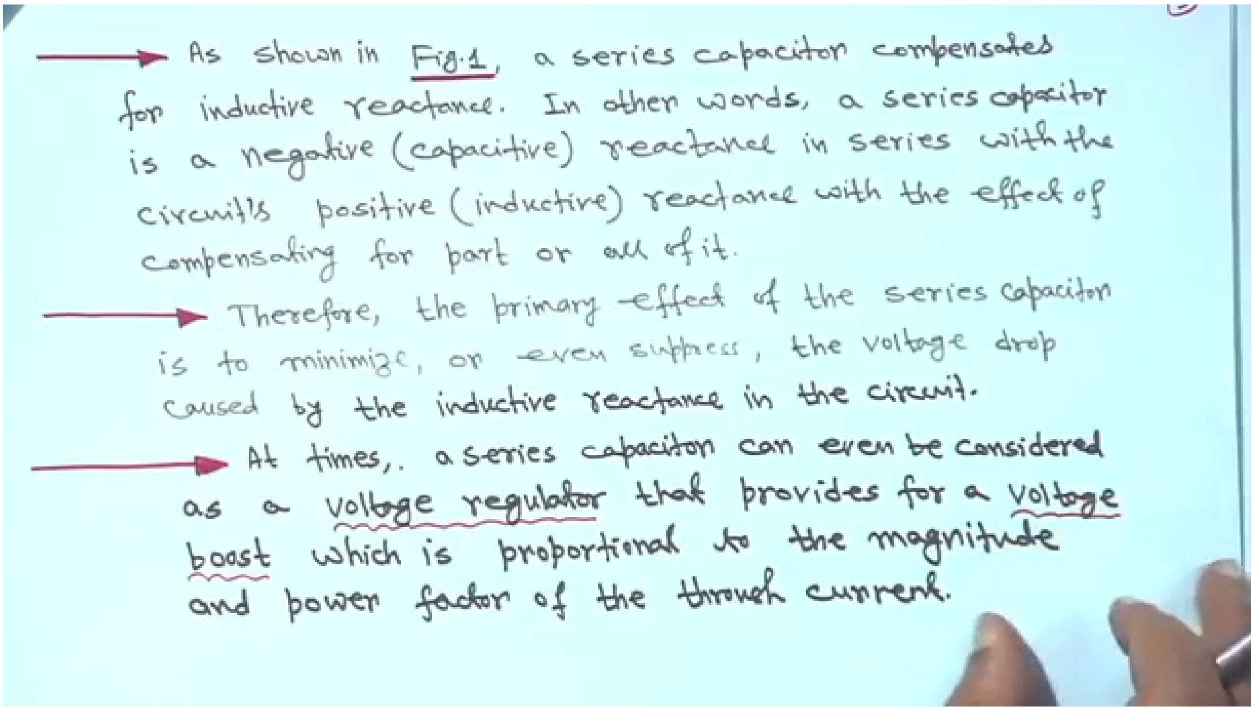

So, this way that your what you call that; [noise] loss ah your what you call the loss will decrease [noise] and and simply [noise] simple expression is [vocalized-noise] maintained the P loss is proportional to your what you call with series capacitor ah V square upon V C square into P loss without series capacitor right. So, P loss without series capacitor you whatever you have you mainta[in]- you pu[t]- put it there. So, you will find that [noise] approximately that [noise] ah to some extent it reduce the losses right

Thank you very much we will be back again.