Operation and Planning of Power Distribution Systems
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Lecture - 12
Derivation of K-constant for voltage drop computation

In my last lecture, I discussed how to determine the generalized expression for voltage drop for a feeder which is connected to a substation and the substation service area can be of different shape; it can be square; it can be hexagonal. Basically these two different shapes of service area under a substation are discussed ok.

And if you remember my last lecture, you have seen that this expression for voltage drop for primary feeders, it is mainly proportional to the effective length of the feeder and this effective length of course, depends upon how the load is connected and also it depends upon the loading of the feeder. And apart from that if these are the two parameters; one is effective length; another is loading on which voltage drop depends.

And there is a proportionality constant, because voltage drop is ultimately proportional to the effective length and the loading of the feeder and the proportionality constant we call it constant K and in my last lecture, I discussed that I will show you how to derive this constant K ok. So, in this particular lecture I will start how to derive the constant K.

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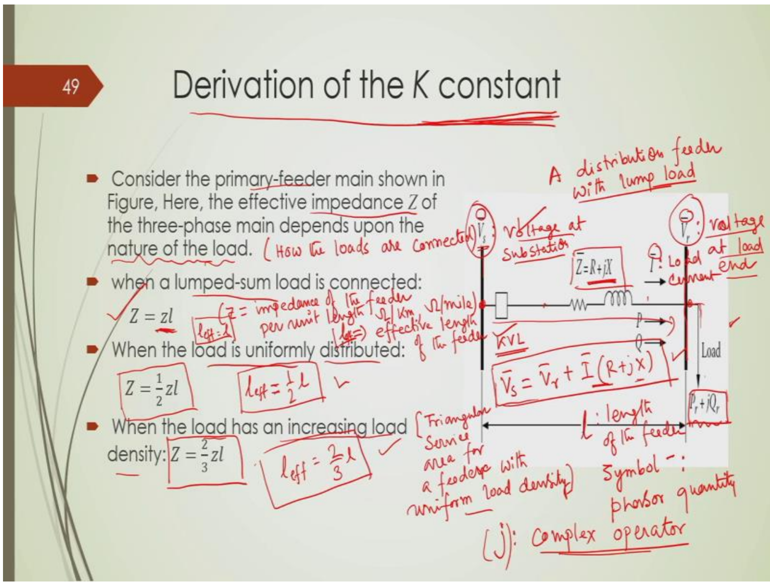

Now, look at this slide where we will be basically deriving this constant K ok. So, you know that we have this is a primary for a primary feeder the effective impedance Z; it depends upon how the loads are connected this not nature of the load. Basically how the loads are connected this nature of the load stands for how the loads are connected. So, it depends upon how the loads are connected or load configuration you can say ok.

Now, if we have a lumped load, means all the loads are aggregated and it is connected at a particular point. Now, under this condition this effective impedance is z multiplied by l, where l is the length of the feeder z is basically impedance of the feeder per unit length per unit length. Its unit is ohm per kilometer or ohm per mile depending upon what type of unit you are using for representing the length and l is basically length effective length of the feeder effective length of the feeder; length of the feeder.

Now, this effective length is equal to the actual length when we have lump sum load connected; that means, loads are aggregated and connected at the end of a distribution line like this. This figure shows that this is the substation and here we have all the loads connected and this is the power demand of that particular load. Now, if the load is uniformly distributed you know the effective length becomes. So, l effective becomes half of this actual length. So, this is already derived and if you put over this expression then you will get the actual impedance is half of zl.

Similarly, when you have load with an increasing load density; it means that it is of a triangular service area. So, this is basically representing triangular service area for a feeder; for a feeder with uniform load density with uniform load density; with uniform load density ok.

So, when we have that type of feeder this effective impedance becomes two third of actual impedance, i.e., it is basically because the effective length becomes two third of actual length. So, here l is representing the length of the feeder as I explained and this effective length is equal to actual length only when you have lump sum feeder. So, here l effective is basically l, but apart from that on all other cases l effective becomes different than l and accordingly this impedance value will change.

Now, what we will do in this particular section we will try to determine the expression for this proportionality constant K which relates that voltage drop with the effective length of the feeder and the loading of the feeder ok. So, in order to derive that we consider here basically a distribution feeder with lumped load distribution feeder with lump load here lump load means loads are concentrated at the end of this feeder. So, this is the end of the feeders where all loads are coming or concentrated or aggregated and this is what the load demand it is represented by P r plus j Q r ok.

And this impedance of this feeder is represented by R plus jX and this V s basically this voltage at substation or voltage at sending end. So, this is basically voltage at substation and this V r basically representing voltage at load end voltage at load end this I is basically representing load current or current drawn by this load current ok. So, I is basically representing load current or current drawn by the load.

Now, this bar symbol shows they are phasor quantities. So, this symbol bar is showing that they are phasor quantity ok. So, we have a load which is connected at the end of the feeder and this l is basically this is l is basically representing the length of the feeder this is length of the feeder.

So, we have a feeder whose length is l and it is connected to an aggregated load or lumped load at the end of this feeder which is shown over here and due to that you know I this current I that is load current; it remains constant throughout this line; throughout this line and this V s is representing voltage at the substation or the source side voltage and V r is basically representing that voltage at the load end or receiving end voltage or you can call it as load end voltage ok.

Now, what we will do first for this analysis, we will try to have a relationship with a sending end voltage and receiving end voltage. Now, how to get the relationship? We will simply apply Kirchhoff’s voltage law here KVL, we will apply and we will get a relationship of V s and V r. So, what will be the relationship of V s and V r? This V s would be equal to V r plus this drop across this feeder or voltage drop due to this line impedance.

So, this drop will be equal to nothing but I multiplied by Z and Z is of course, R plus jX ok. So, this is what we get by applying KVL at this sending end and receiving end side path. So, if you apply KVL at this path you will get that voltage at this point would be equal to voltage at this point plus voltage drop due to this impedance of the feeder and that voltage drop is equal to I multiplied by R plus jX.

Now, these are all you know this is a complex equation because these are phasor quantities and with this equation we can draw the phasor diagram as well; we can draw the phasor diagram. How can we draw phasor diagram? Here you look at; in order to draw the phasor diagram, we have to consider some phasor as a reference.

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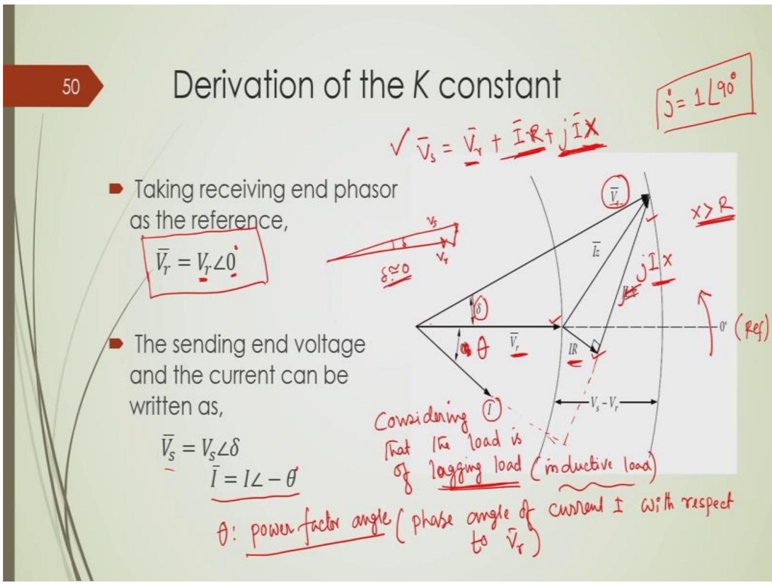

So, here, we consider receiving end side voltage or load end voltage as a reference. So, we put it over here; this is the reference. So, since we have considered this reference, so, we can write that angle of that reference phasor is 0 0 degree. So, it is represented V r at an angle 0 degree so that means, its magnitude is considered to be V r and its phase angle is 0 degree because we considered it is a reference phasor.

Now, with this, we will add all these two quantities; one is I R; another is jIX. Here j is our complex operator; j is our complex operator in electrical engineering; we use this j to represent the complex operator ok; these things I hope everybody knows; this is the standard nomenclature, we use being an electrical engineer.

Now, how to get this phasor of this resending end voltage? Since if we write this equation again this is basically V s is equal to V r plus I multiplied by R plus j I multiplied by X ok. So, this R and X represent the feeder actual resistance for this case because it is a case with lumped load and the feeder x represents the feeders actual reactance ok.

Now; that means, if we add this to drop with V r then whatever quantity we will get that will be the substation voltage or sending end or source side voltage. So, how to add this to drop? So, in order to add this to drop first, we have to locate the position of current phasor; we have to locate the position of current phasor with respect to the receiving end voltage; with respect to receiving end voltage.

And here we put this current phasor I, considering that the load is lagging considering that the load is of lagging load; lagging load means they are of inductive load; they are of inductive load which is true for the all practical loads because practical loads are of inductive which we know ok. So, that is why this current lags with respect to this load end voltage that is V r and we consider the standard nomenclature that this phasor is rotating anticlockwise ok; the all these phasor quantities are rotating anti clockwise.

So, we are taking at any particular instant a snapshot of this feature and which will give you a relationship with this sending end voltage and receiving end voltage or source side voltage and load end voltage or substation voltage and load end voltage ok. Now, since this IR drop R is basically a scalar quantity so, it should be in phase with this current.

So, we draw a parallel this line to represent this IR drop ok. So, this IR will be in phase of this current I and that is why they are in parallel. So, this IR basically phasor is basically a scaled value of I phasor I is multiplied with some scalar R ok. Now, what will be this j I L X? So, this is not JLX. So, this is basically representing jIX j I X ok. Now, this jIX means we have a j operator over here and j operator we know it has a unity magnitude, but ninety degree phase shift so that means, this jIX phasor will be in perpendicular with respect to this current phasor.

So, let us draw a perpendicular with respect to this I phasor. So, whatever we will get that will represent this jIX ok. So, this jIX again will be a scaled value of this I phasor, but it should be in perpendicular with respect to I now here this phasor diagram is drawn considering that X is higher than R which may not be true; which may not be true for a distribution network because in distribution network normally R is higher than X, but this figure is an indicative only. So, it does not represent the actual scenario. So, it is an indicative.

So, in that case IR will be higher j with respect to I X ok. So, these magnitudes are would be different, but this phasor diagram will remain same. Now, we got these three phasor quantities one is V r that is this V r; one is this IR that is this and one is jIX that is this. So, these three if you add then whatever you will get that will represent the V s that is substation voltage or source voltage. So, this gives us the phasor relationship.

And this V s will be a certain angle with respect to this reference phasor that is V r and this angle is considered to be delta and this is not theta I; this should be theta only. So, this I is lagging with respect to V r at an angle theta I is lagging with respect to V r at an angle theta. So, this theta is, we call it a power factor angle. So, theta is power factor angle and it can be also named as phase angle of current I with respect to this receiving end side voltage or load voltage V r ok.

So, it is basically the phase angle between the current phasor and the load end voltage ok. So, this since it is lagging, so, we represent it I phasor is equal to magnitude I at an angle minus theta; at an angle minus theta and this V s is represented as V s; it is magnitude at an angle delta; this delta is the phase angle of this V s with respect to the reference phasor that is V r. So, this delta is also representing the phase difference of V r and V s ok, alright.

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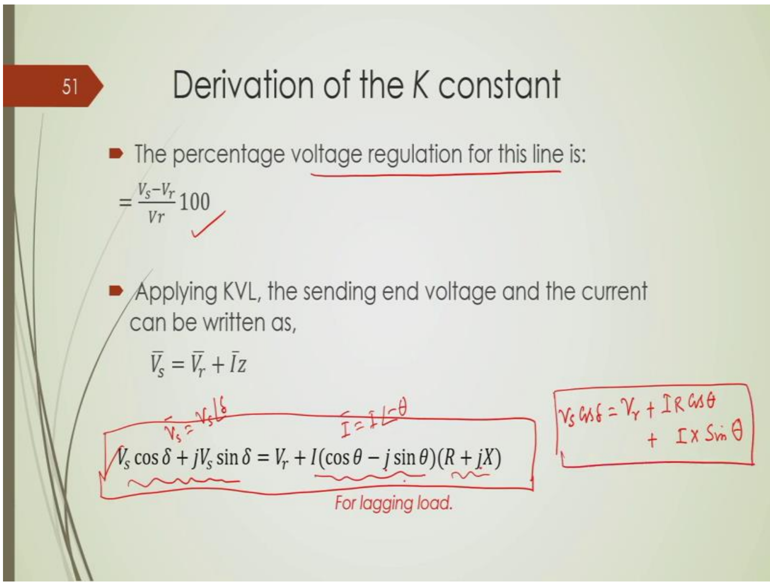

Now, what we will do? We know that this percentage voltage regulation for this line is this and we also know that if we apply this equation that V s is equal to this. If we replace this V s phasor with V s at an angle delta V r phasor with V r at an angle 0; this I phasor with I at an angle minus theta and this jIX phasor with j I at an angle minus theta multiplied by X. Then we will get these equations; we will get this equation; we will get this equation where this is nothing, but this V s phasor which is equal to V s at an angle delta. So, if you convert this from polar to Cartesian then you will get V s cos delta plus j V s sin delta.

Similarly, we know this I, it is basically equal to this I at an angle minus theta. So, if you convert again from polar to Cartesian it will be I cos theta minus j I sin theta. Similarly, R plus j X is known to us.

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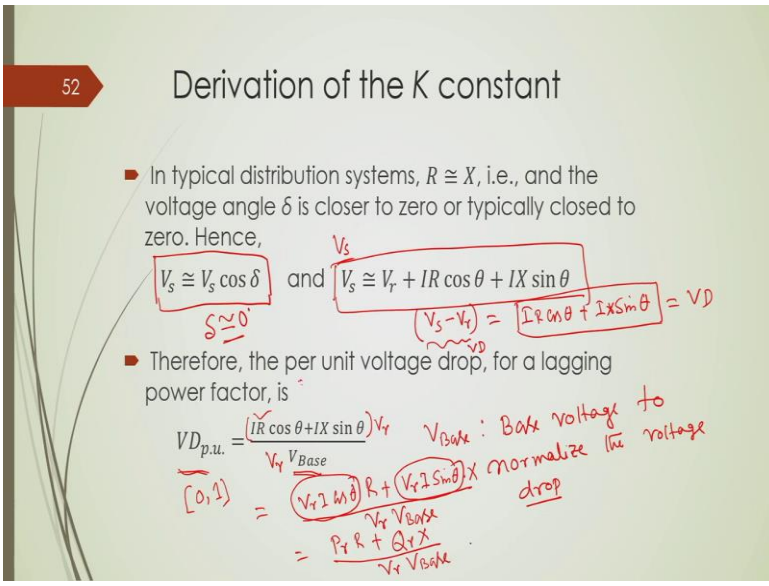

Now, with equating this real side with this real quantity of the left hand side and real quantity of the right hand side, we get a relationship of V s cos delta is equal to V s cos del. So, I can write it over here. So, we get it V s cos delta is equal to V r plus IR cos theta plus IX sin theta ok. So, here this j and this j will be multiplied. So, this will be minus j square so, which will give you 1 ok. So, this will be IX sin theta. So, this will be the equations by equating real part of both the left hand side and right hand side equation.

Now, once you get that we have some approximation that V s cos delta is approximately equal to V s; why it is so? Because this delta angle is normally close to 0; this delta angle is normally close to 0. Now, why this delta angle is close to 0? Because if you look at this phasor diagram generally these phasors this V r and V s these phasors magnitude wise they are much higher than this two drops that is IR and jIX ok. So, voltage drop is some few percentage of the actual voltage maybe 5 percent or maybe maximum 9 to 10 percent that much only, but it will be some fractional part of this actual voltage quantity.

So, therefore, if it is so, then this angle if you draw this in scale then it will be something like that if suppose V r is that much then these two drop will be that much only which gives this V s like this and which is eventually making this delta angle very close to 0 ok. So, this is true for any sort of practical distribution feeder.

Now, once it is written that V s is equal to approximately V s cos delta it is replaced in the left hand side. So, we get these equations and you know this V s minus V r this V s minus V r; these are the you know magnitudes only the difference of the voltage magnitudes at the substation voltage and at the load end voltage; this is nothing but the voltage drop which we are intending to derive. So, this will be equal to IR cos theta plus IX sin theta ok, so that means, our voltage drop becomes IR cos theta plus IX sin theta ok.

Now, if you want to convert this voltage drop if you want to normalize this voltage drop then what you need to do, you have to divide it with some base voltage. Now, here we are dividing this with this base voltage where V Base is the base voltage to normalize the voltage drop to normalize the voltage drop.

Now, once you divide this both side of the equation, so, left hand side we will get voltage drop per unit that means, whatever value of voltage drop will come that will vary between 0 to 1 and right hand side this equation will be IR cos theta plus IX sin theta divided by V s ok.

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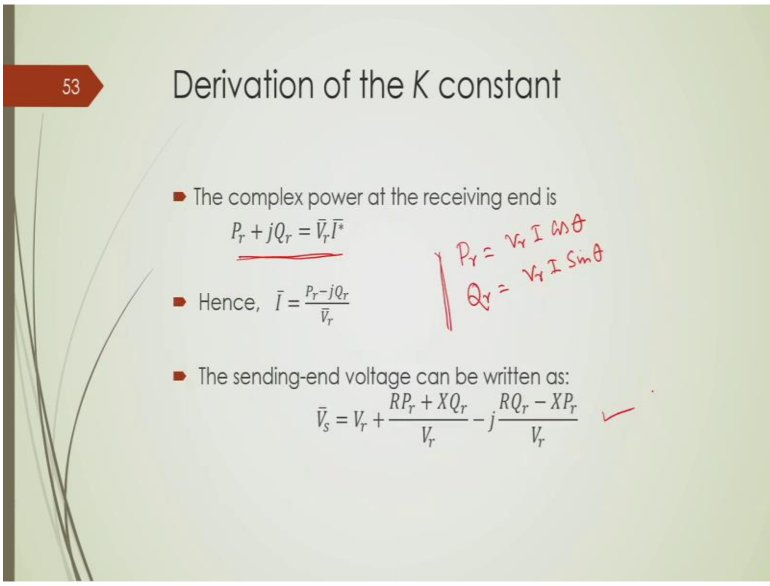

Now, we have some further simplification of that equation. We know that complex power at receiving end holds these equations. So, we also know this from this equation P r will be equal to V r I cos theta and Q r will be equal to V r I sin theta because you know that V r its angle is 0 and I conjugate its angle becomes I at an angle theta. So, if you determine then you will get this equation.

Now, in this equation we got this IR cos theta plus IX sin theta. So, if you multiply both numerator and denominator with V r then in the numerator we will get V r I cos theta multiplied by R plus V r I sin theta multiplied by X divided by V r V Base which is nothing, but this V r I cos theta. As I said, it is nothing but P r that is P r multiplied by R and this is nothing but Q r so, this is Q r multiplied by X divided by V r V Base. So, this is exactly what is done over here ok.

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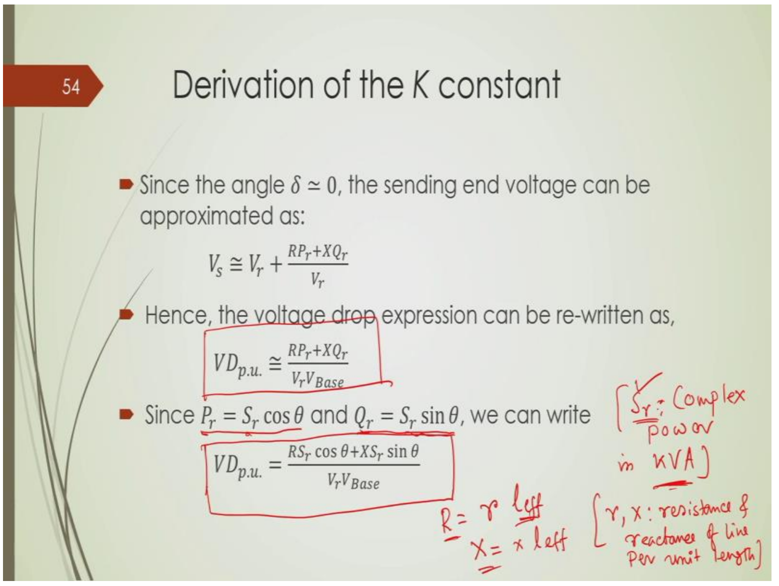

And then you arrived at this equations ok. This equation and further simplification is possible if you put this P r is equal to S r cos theta and Q r is equal to S r sin theta; here S r is basically the complex power in KVA or MVA. So, in distribution network normally loads load demands are in KVA.

So, if you put this, you know that this relationship of active power and reactive power with this complex power that is active power is equal to this complex power multiplied by cos theta reactive power is equal to complex power multiplied by sin theta. So, if you replace this P r and Q r with this, we will get this relationship ok. So, this gives you this relationship of VD u as a function of S r that is the complex power or KVA demand of the load.

Now finally, we arrived at this expression of voltage drop in per unit that is equal to this. We can replace R is equal to small r multiplied by l effective and we also replace X by small x multiplied by l effective where small r and small x. They are you know resistance and reactance of line per unit length per unit length and if you multiply with this effective length of the resistance. So, then you will get the value of R and similarly you will get the value of capital X.

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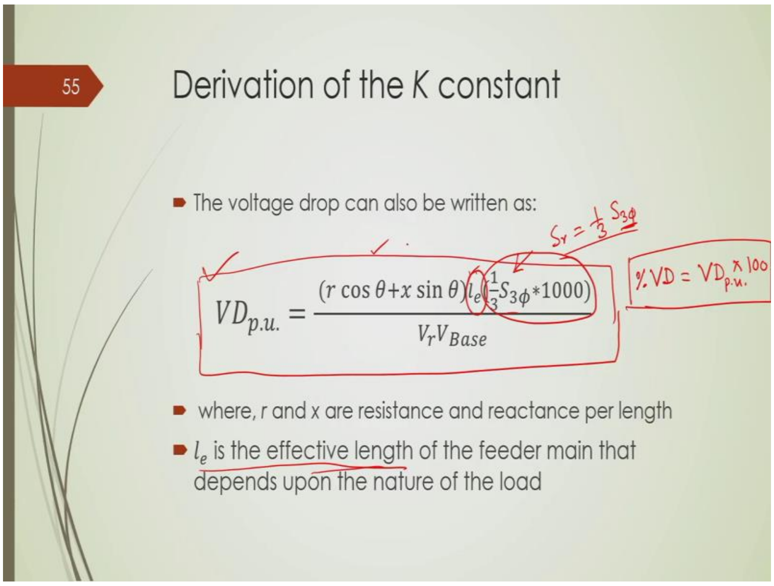

So, if you replace this with this here l e is basically representing this effective length effective length of the feeder. So, you will get this one and this S r is basically representing one third of S 3 phase where S 3 phase is basically 3 phase power demand of the load because loads for a primary distribution feeder are of 3 phase. So, its demand is represented by 3 phase demand. So, one third of that will be S r ok.

So, we get this relationship this is what our VD per unit means its value will be a fractional lesser than 1 and if you multiply it with a 100 then it will be percentage voltage drop. So, percentage voltage drop percentage VD is equal to VD per unit multiplied by 100 ok, alright.

So, we get the relationship of voltage drop as a function of these feeder parameters, feeder line parameters and also as a function of this feeder loading and this effective length.

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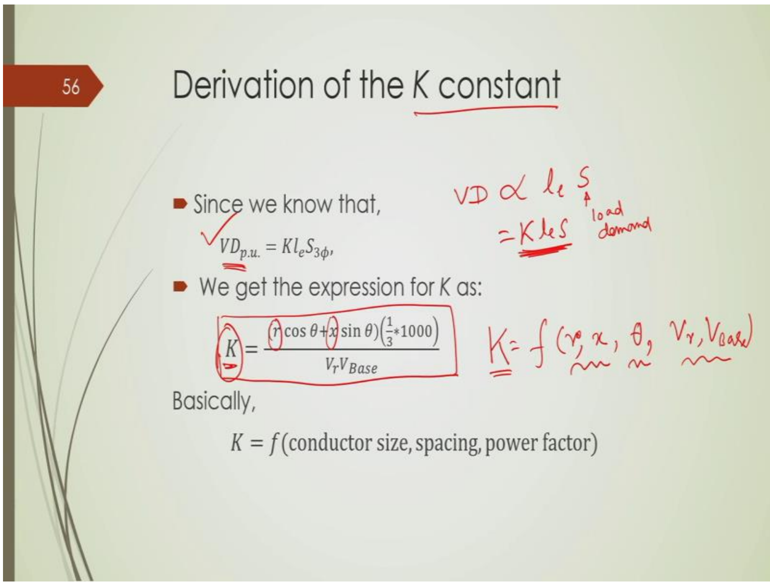

Now, we know this actual voltage drop equation; it varies as already we have mentioned this voltage drop is proportional to l effective multiplied by S; where S is basically the loading load demand and its proportionality factor is nothing but the parameter K so, l e into S. Now, if you compare this equation with previous equation then this is effective length of the feeder and this is what my loading.

So, if you exclude this, whatever will remain that will represent the constant of the proportionality; that is parameter K; that is constant K. So, constant K equation is coming out to be this ok. And now you can understand how this constant K is; what are the parameters which basically impact on this value of this constant K. Now, you can find that this is a function of R.

So, basically constant K is function of r, it is also function of x, it is also function of theta, it is also function of voltage V r and V base; that means, this constant K this parameter K it is represented in capital K it depends upon this line resistance and line reactance; that means, it depends upon the line impedance also it depends upon the power factor of the load also it depends upon the voltages ok. So, these are the things which will influence the value of this parameter K ok.

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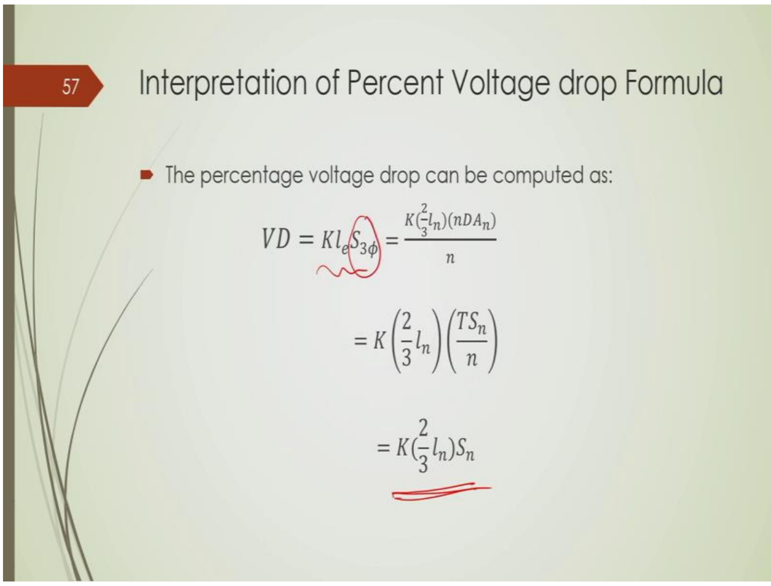

So, for a typical feeder we can simply replace this effective length and this S 3 phase by this and you can find out the expression of voltage drop like this ok. So, this can be understood.

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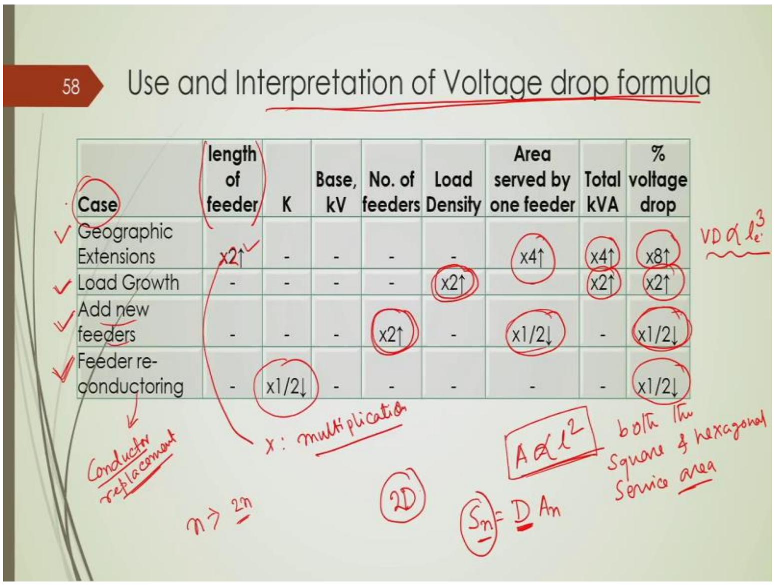

Now, we have some interpretation of voltage drop formula and we will try to understand what are the parameters directly influence this voltage drop of a typical feeder; what are the parameters which influence this voltage drop expression. So, we have four different cases: this is case 1; this is case 2; this is case 3; this is case 4. So, in first case, we assume that all other parameters remain same except the length of the feeder is double. This ‘multiplied by 2’ this symbol is shown multiplication ok.

So, keeping all other parameters same what would happen if the length of the feeder becomes double or if we increase the length of the feeder twice of the actual length. Then looking at this equation you can understand this. If this feeder length is double then voltage drop, because first of all this area of this one feeder, will be 4th because 4 times of the actual feeder area.

Because already we know that A is equal to l square; this will already be determined. In fact, this is true for both this is proportional to l square for both the square service area square and hexagonal service area hexagonal service area so; that means, if we make this feeder length twice of the actual length the area that the feeder can serve will be four times of the actual feeder area or feeder service area will be the 4 times of the actual feeder area.

And this will also increase this kVA or load that the feeder can serve and this will increase the voltage drop 8 times of the actual voltage drop because already you know this voltage drop VD is proportional to effective length cube. If length of the feeder increase twice, so, voltage drop will be increased 8 times of the actual voltage drop so, which is off course, not permissible. So, that is why length of the feeder, if we increase, it will have direct impact on this voltage drop.

Second case is if load density is increased twice keeping all other parameters same; load density of the feeder is increased twice of the actual load density so that means, capital D is increased twice. So, actual load density will be 2 multiplied by this load usual load density.

So, what will be that impact? This will impact because you know this area of the feeder will remain constant because area of the feeder only depends upon the length of the feeder, but this load served by this feeder will be twice of this actual load; the feeder is serving because you know you can remember S n is basically equal to capital D multiplied by A n.

So, if you increase capital D twice then S n will be increased by 2 times and since S n will increase voltage drop will also be increased twice because you know that voltage drop is directly proportional to the loading of the feeder so; that means, if load density increase to twice of the actual value it will result in twice of the actual voltage drop ok.

Now, the third case is, if we add new feeder; that means, keeping all other parameters same number of feeders we increase to twice; that means, n is increased to twice n ok. So, what will be that impact if we have same amount of customers, but we increase the number of feeder off course, this area served by one feeder will be half of the actual feeder and which will result in actual voltage drop would be which will result in the voltage drop will be half of the actual voltage drop ok.

Because, if area becomes half and then, obviously, this load demand will be also half load which is served by one feeder will be also half and which will result in voltage drop becomes half of the actual value. Now, sometimes, we change the conductor. So, this is called feeder re-conductoring; it is also called conductor replacement ok.

Suppose, if we have a feeder and its conductor size or is conductor we change and what will be the impact of this? Since you know the constant K in that case your number of feeders will remain same, the feeder service area will remain same everything will be same, but this constant K which depends upon which proportional to this feeder parameters r and x this will change ok.

So, if we assume that this K becomes half, then this will also indirectly impact to the voltage drop because voltage drop is proportional to the parameter K, as well. So, if K becomes half voltage drop will be also half. So, these are the three possible cases, sorry four possible cases which we can study.

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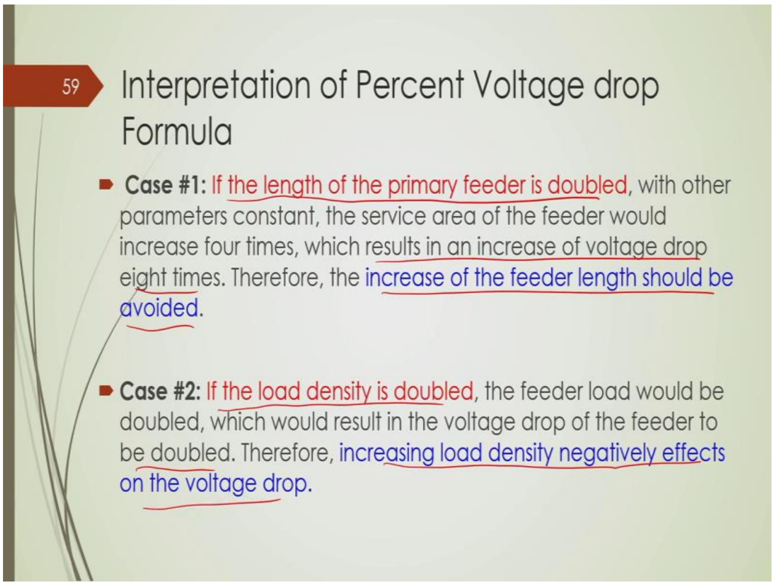

So, if you look at this, my interpretation on this is written over here. So, case 1 is if the length of the primary feeder is double which will increase the voltage drop eight times; which results in the voltage drop eight times and therefore, increase of feeder length should be avoided this is one of the thumb rule.

Then case 2 is if the load density is double then it will result in voltage drop of the feeder to be double. So, therefore, increasing load density negatively effects the voltage drop. So, these are the interpretations.

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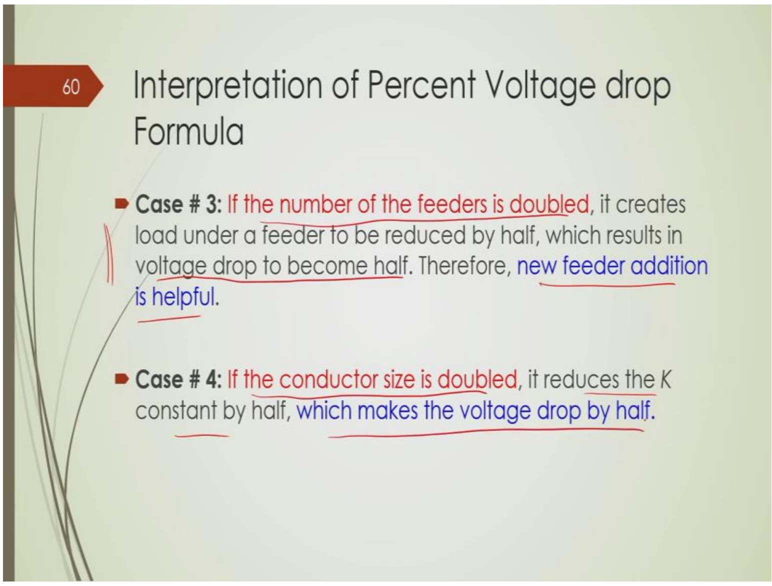

Now, if the number of the feeders is double. So, what we will get the voltage drop would be half; each of the feeder voltage drop, main feeders voltage drop will be half therefore, new feeder addition is helpful to reduce the voltage drop. If you get a voltage drop for a typical feeder is very high we can exercise this option of course; it needs some capital investment ok.

Now, if the conductor size is double which reduces the value of K by half and thereby it results in the reduction of the voltage drop to the half ok. So, these are the possible cases.

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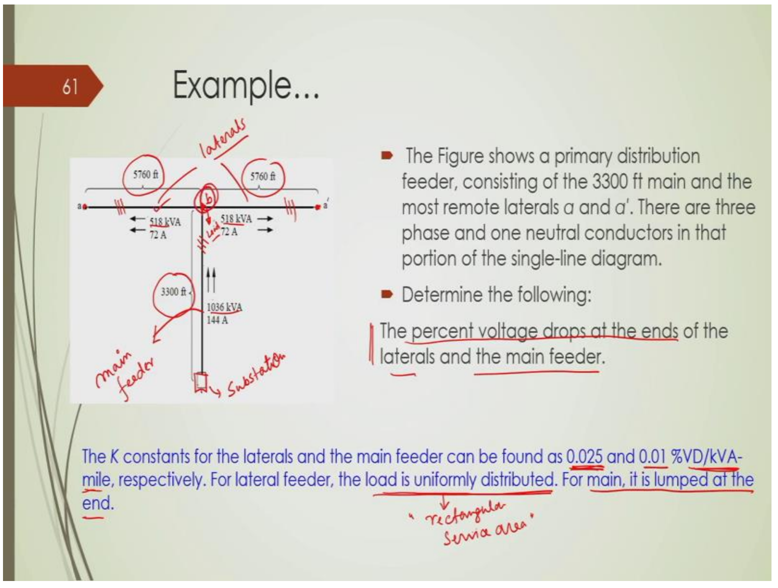

Now, we will discuss two numerical examples related to this. Look at this first numerical example. So, in that numerical example, we have a substation located at this point. So, here is the substation and this is the main feeder; this is the main feeder and these two are lateral feeders; these two are lateral feeders ok.

Now, the dimension the length of this main feeder is given 3300 feet and this dimension of the laterals are also given 5760 feet and 5760 feet each ok. Now, it is mentioned that all are of three phases. So, this is the single line diagram. So, this feeder is of three phase and it is also mentioned that how much load demand each of how much load is carrying by the main feeder and the lateral.

So, this main laterals are carrying 518 kVA each and main feeder is carrying 1036 kVA ok. So, it is also mentioned that what is the value of K constant. So, K constant for laterals are given to be 0.025 percentage voltage drop per kVA mile and then for main feeder K value is given as 0.01 percentage voltage drop per kVA mile.

And it is also mentioned that for lateral feeders, load is uniformly distributed; load is uniformly distributed and if nothing is mentioned it should have been also mentioned that they are of rectangular service area; rectangular service area. So, if nothing is mentioned we assume that it is an automatically rectangular service area with uniformly distributed load and for main feeder it is lumped at the end; that means, for main feeder the load demand is lumped at this point. So, we have lumped load ok.

So, these information are given and you are supposed to determine the percentage voltage drop at the ends of the lateral and at the main; that means, percentage voltage drop at the ends of these two end and a dash and at this point let us consider this point is let us say b. So, percentage voltage drop at this point as well as at these two points a and a dash, since both the laterals are identical. So, you can assume there will be same voltage drop at the end of both the laterals ok.

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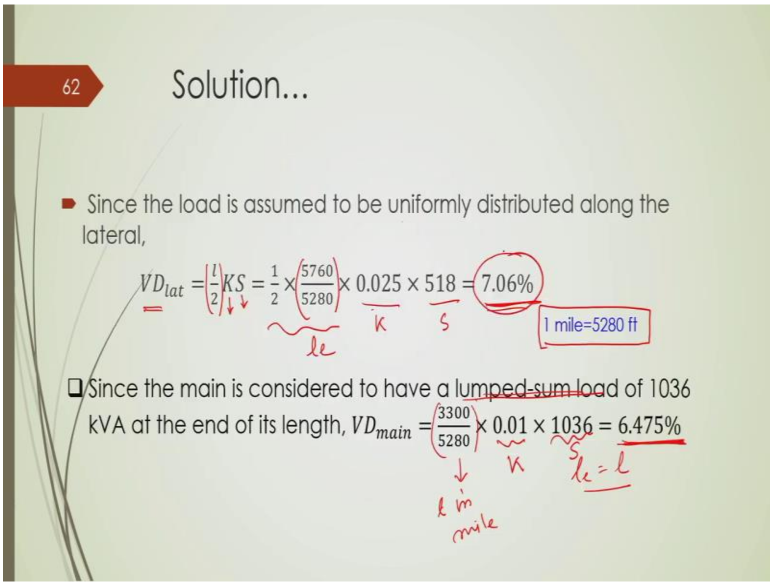

So, in order to find out voltage drop of the laterals, since they are of uniformly distributed and we assume that service area of the feeder is rectangular, so, the voltage drop expression will be effective length of the feeder that is l by 2 multiplied by this constant of the proportionality that is K multiplied by S ok. So, this is nothing but the expression for voltage drop and we know the values of all.

So, this one is basically converting this mile this feet to mile because ultimately this expression for capital K or parameter K its unit is percentage voltage drop per kVA mile. That means we have to multiply it with the kVA demand that it is feeding and with the effective length of the feeder. So, if you can multiply then you will get this voltage drop. So, effective length for this type of feeder is half of the actual length and S is already given that is it is 518 kVA and K value we directly took it from here.

So, K value of the lateral feeder is 0.025; if you put it over here and this is K value; this is value of S; this is the value of l effective. So, once you multiply all these things, you will get this percentage voltage drop directly because K parameter is given to be percentage voltage not per unit voltage drop ok. So, this is coming out to be around 7 percent voltage drop ok. Now, 7 percent voltage drop will occur between this point b to a dash and between these two points b to a; this one has to understand.

Now, for determination of voltage drop at the main feeder which is having lumped load, for lumped load we know that effective length is equal to actual length. So, in that case you simply do, this is representing actual length of the feeder in mile. So, this is l in mile this is the value of K and this is the value of the load it is serving that is S. So, if you multiply these three we will get the voltage drop at this point b; at this point b; at this point b so that means, from substation to b we get a voltage drop of 6.475 percent and from main feeder to the laterals from b to a dash the voltage drop we got as 7.06 percent ok.

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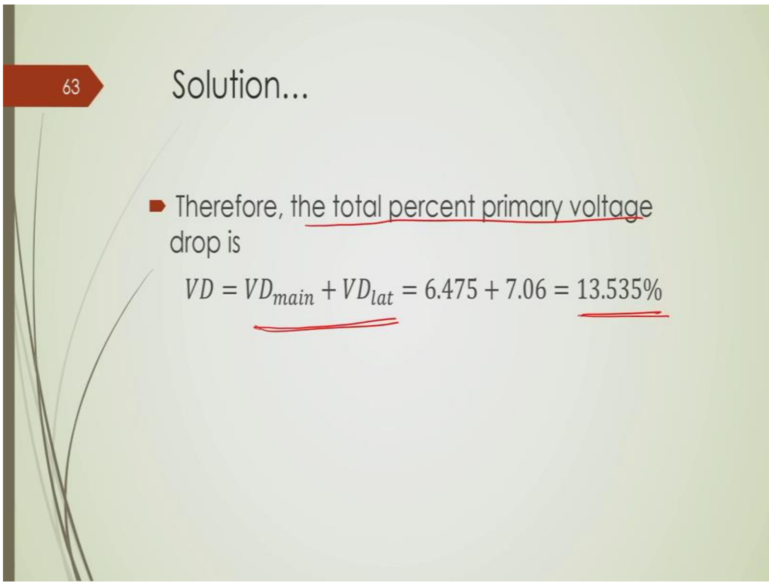

So, total voltage drop from this you know in the primary feeder starting from the main feeder to the lateral will be simply summation of these two, i.e., arithmetic summation which is equal to 13.535 percent ok. So, this is what the answer, alright.

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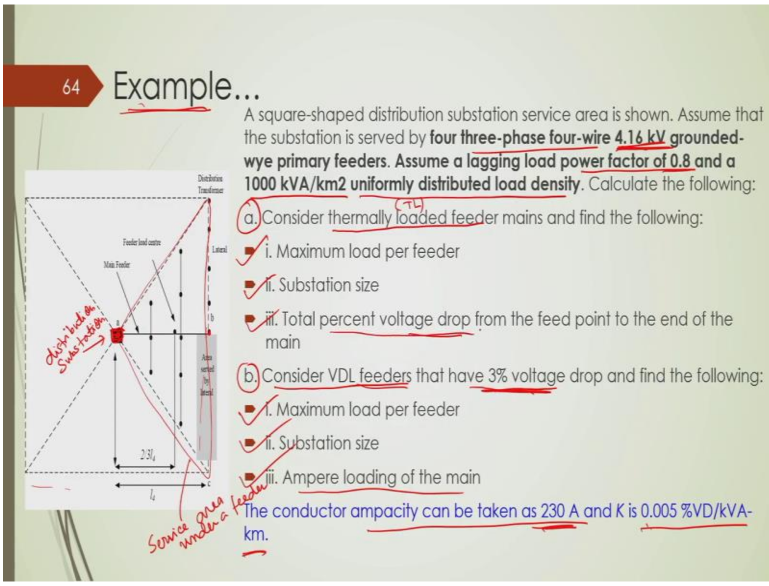

Now, we have another example another numerical example ok. In this example, it is mentioned that we have a square shape; we have a square shape service area under a distribution substation which is located at the center at the center point of the service area. So, this is where your distribution substation located; distribution substation located ok.

This is where the distribution substation is located; this is what your main feeder starting from a to b and these are the laterals; these are the laterals which is known to us. So, here it is mentioned that these feeders are of three-phase four-wire and the voltage line to line voltage of the feeder is given 4.16 kV; the power factor of the load is given 0.8 and the load density is given as 100 kVA per kilometer square load density is given as 1000 kVA per kilometer square.

And it is uniformly distributed load density, but because of this you know the service area of the feeder is square and we have four number of feeders like this. So, service area under a particular feeder will be off course, triangular. So, this is what the service area under a feeder; under a feeder ok.

Now, the ampacity limits are given as 230 ampere and this capital K that is parameter K value is given as this 0.05 percent voltage drop per kVA mile kVA kilometer. So, we are supposed to determine the maximum load for the feeder assuming that this feeder is thermally loaded that is feeder is of TL, also the substation size, and percentage voltage drop.

Similarly, assuming the second question is, question b, is this. This was question a; question b is considering the feeders are of VDL feeders that means, feeder is a voltage drop limited feeders where this voltage drop is limited to 3 percent voltage drop is given to be 3 percent you are supposed to determine all these three; one is maximum load per feeder, substation size and ampere loading of the main ok. So, previously it was voltage drop, but here voltage drop is given to be limited at three percent. So, we are supposed to determine the loading under this particular condition. Now, look at the solution.

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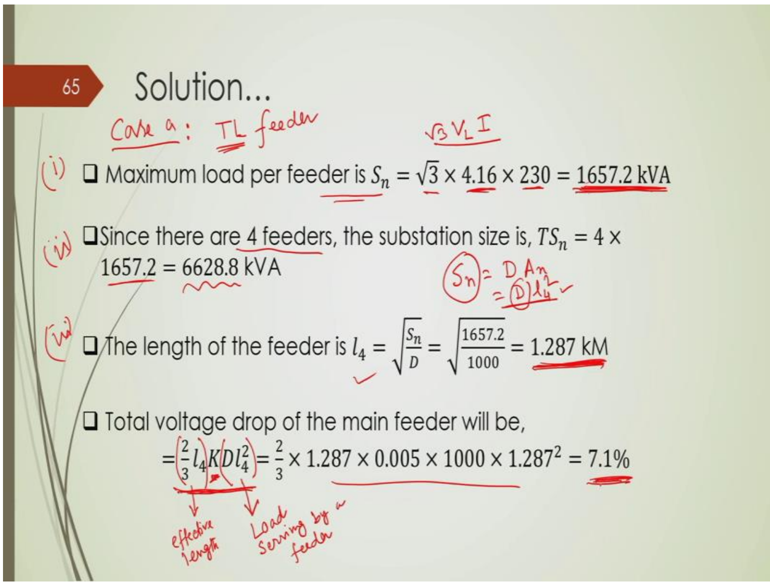

Now, first of all, since in this case, the case a, in this case a, the feeders are of TL feeder; that means, thermally limited feeder. So, here feeder loading is limited by the ampacity limit of the conductor. So, we know this ampacity is given as 230 ampere we also know that the voltage of the feeder is 4.16 kV line to line. So, we can determine that maximum possible loading per feeder is nothing, but root 3 multiplied by it is nothing but root 3 multiplied by V L multiplied by I.

So, this gives you root 3 multiplied by 4.16 multiplied by 230 this gives you that much of kVA, 1657.2 kVA. Now, since we have four identical feeders for typically this type of substation service area. So, total substation size would be 4 multiplied by the maximum loading of each feeder that will be equal to 1657.2 that is given to be 6628.8 kVA ok.

Now, in order to get voltage drop, we have you know this is solution number 1 this is solution number 2 and in order to get solution of the third question that is total percentage voltage drop let us first put this voltage drop expression; this is nothing but effective length of the feeder this is parameter k and this is nothing but that load the one particular feeder is serving.

So, this is effective length of the feeder this is also off course, you know that is constant K or parameter K and this is the load which is serving by a particular feeder serving by a feeder. So, K is known to us; only thing you have to know that length of the feeder which is not given here, but we can find out once you know that how much loading you can do in a particular feeder so, which is given over here.

So, we know that S n is equal to D multiplied by A n which is equal to D multiplied by l 4 square for a this type of feeder. From this D is known to us; S n is known to us; we can find out l 4 like this which is coming out to be 1.287 kilometer. Now, once you get this l 4 or length of the feeder you put it this expression you get this value of the percentage voltage drop which is coming out to be 7.1 percent this is for case a.

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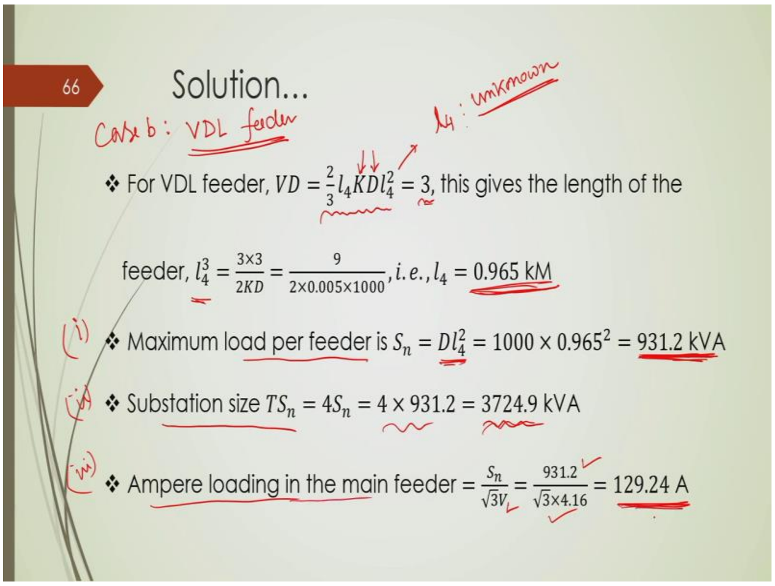

Now, in case b example for VDL feeder, voltage drop limited feeder where the voltage drop of the feeder is limited to a given percentage of voltage drop, now, for VDL feeder you know it is percentage voltage drop is given. So, we put this is the expression of voltage drop. So, here K is known to us; D is also known to us. So, therefore, we can find out this only unknown quantity is the length of the feeder.

So, l 4 is the unknown quantity; it is the unknown quantity. So, therefore, we can find out the value of l 4 from this known quantities and it is coming out to be 0.965 kilometer ok. So, this will give you that maximum load per feeder which is D multiplied by this area of this area served by particular feeder which is l 4 square.

So, that is coming out to be 931.2 kVA. So, this is the solution 1. Once, you get this solution, solution 2 is very easy, since we have four identical feeders. So, the total load that substation can serve which is equal to 3724.9 kVA and this is the solution of third question that is the ampere loading of the feeder or the maximum loading of the feeder; if you want to limit this voltage drop to be 3 percent this is equal to S divided by root 3 V l; root 3 V l.

So, line voltage is given S n is known to us that is this 931 and so, we put all these things we will get 129.24 ampere. Now, at this point, let us compare these two solutions to understand what is the difference.

So, here you can see when your thermal loading is limited then length of the feeder is much higher than this feeder ok. And that will result in higher amount of load, it can serve and also that will result in higher amount of voltage drop, but when we limit this voltage drop to 3 percent which means less than half of this actual voltage drop then length of the feeder becomes less, but you can serve lower amount of loads under this condition.

Under this condition, substation size also becomes very less as compared to the previous example which was 6600. Now, here it becomes 3700, almost slightly higher than half of this value, but here this ampere loading is also less; it means that it is this you know load that it is serving is much lower than the ampacity limit or the maximum serving load is limited to very less value as compared to what it could have been served by this ampacity limit.

So, this is what one should understand.

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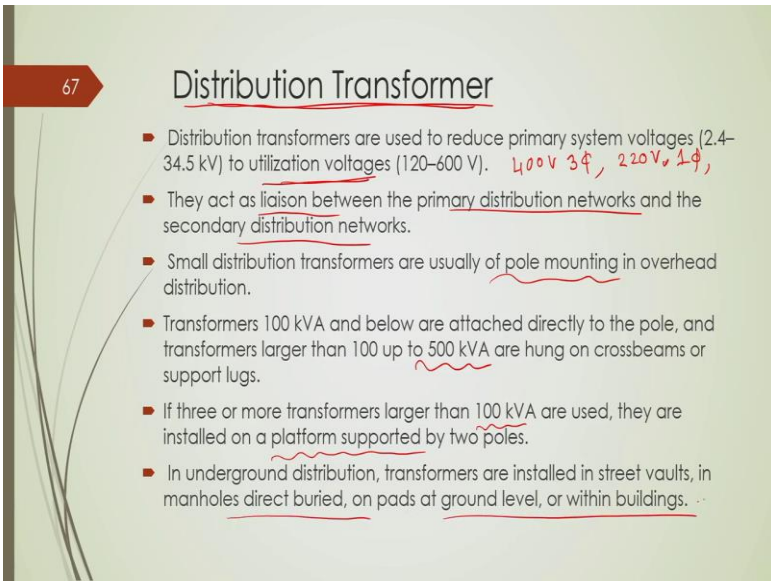

Now, another important thing is that because with this I will complete this part of the lectures which is distribution transformer. And this distribution transformer is the basically used to step down the voltage level feeder voltage level to the utilization voltage level in India it is around 400 volt 3 phase and which will automatically 220 volt single phase ok.

And they act as a liaison between primary distribution network and secondary distribution network. Secondary distribution network basically we call the line beyond this distribution transformer which is directly connected to the customers and they are these distribution transformer; are of various ratings starting from few kVA to up to 500 kVA and small distribution transformers which are rated less than 100 kVA. So, they are directly pole mounting in overhead distribution line and larger than 10 kVA size, they are installed in a platform supported by two poles.

Underground distribution transformers are installed in street vaults in manholes direct buried or pad or ground level in the building ok.

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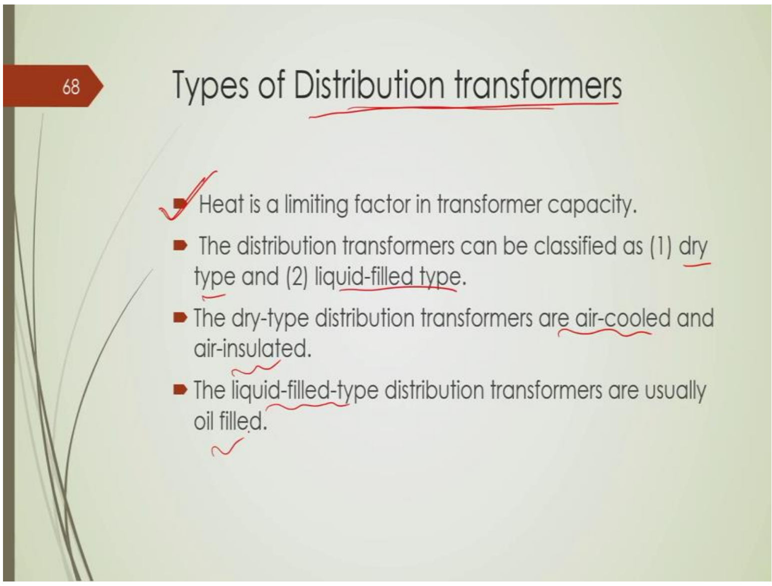

So, I am not going into detail of these different types of distribution transformer because this is not purposefully kept on in the syllabus of this course, but you can off course, make a self study on different types of distribution transformers; only some few important things you should know that heat is basically the limiting factor for the rating of the distribution transformer or capacity of the distribution transformer.

And we have different types of coolant arrangements, cooling arrangements which may be dry type of coolant and liquid filled type. Dry type of coolant is also called air cooled or air insulated distribution transformers which are of very small size; nowadays, rarely used, but liquid filled type distribution transformers are usually oil filled and is mostly used; sometimes some extra blower is also fitted which is called secondary coolant in order to cool down this oil inside the transformer.

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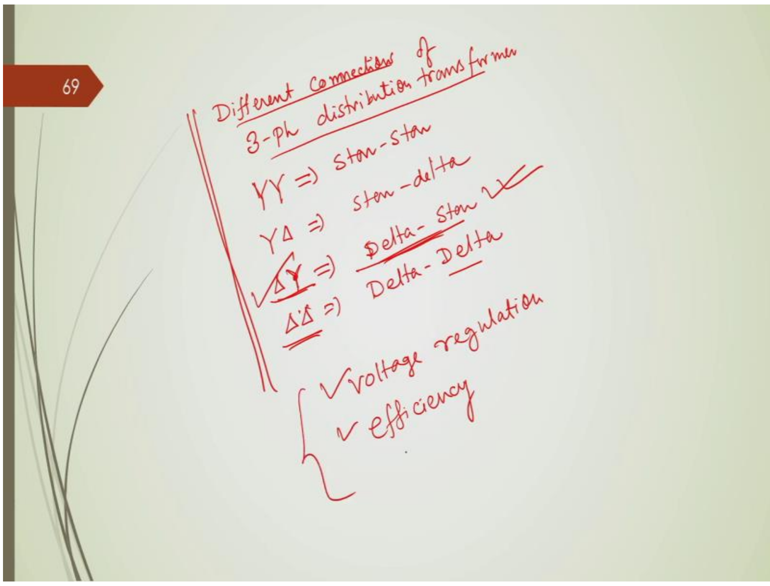

And we have different types of the connection of distribution transformer which I will not discuss in detail; different connections of 3 phase; different connections of 3 phase distribution transformer which includes star-stars that means, both primary and secondary side are connected with star connection or star-delta that is primary side is star connected secondary side is delta connected; similarly delta-star which is you know, primary side is delta connected and secondary side is star connected or delta-delta where primary side is also delta connected secondary side is also delta connected.

But in distribution transformer, we normally use delta star connection for residential customers because this star connection gives you flexibility to of having this neutral and we need a neutral to supply the single phase loads because residential customers mostly are of single phase load. So, this delta-star is normally used, but different types of connections of distribution transformers are possible; they have individual merits and demerits.

So, those things, I will not be discussing here; if one has interest he or she can have self study ok, alright. And also, there are some other you know features like voltage regulation of the transformers; voltage regulation and efficiency calculation of the distribution transformer those issues are also usually taught in electrical machine course.

So, I will not be discussing here if one has any interest he can have a detailed study on this.

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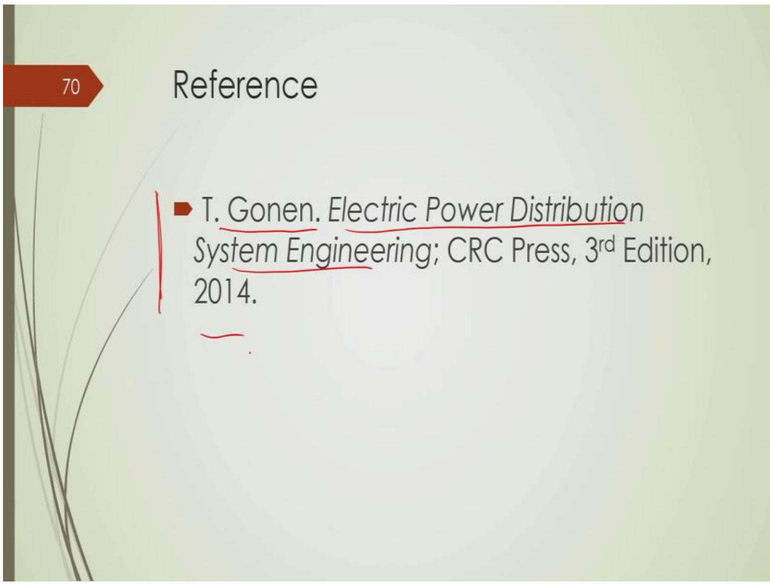

And in order to study all these concepts, you follow this Turan Gonen's book which is Electric Power Distribution System Engineering, means 3rd edition I have followed over here, but subsequent edition is also there.

So, whatever materials I am providing over here in this course are mostly taken from this particular book and if somebody wants to have a self study on this distribution transformer he can go through this one chapter of this book which is basically focused on the discussion of distribution transformer ok.

So, with this I will complete this module 2 ok.

Thank you.