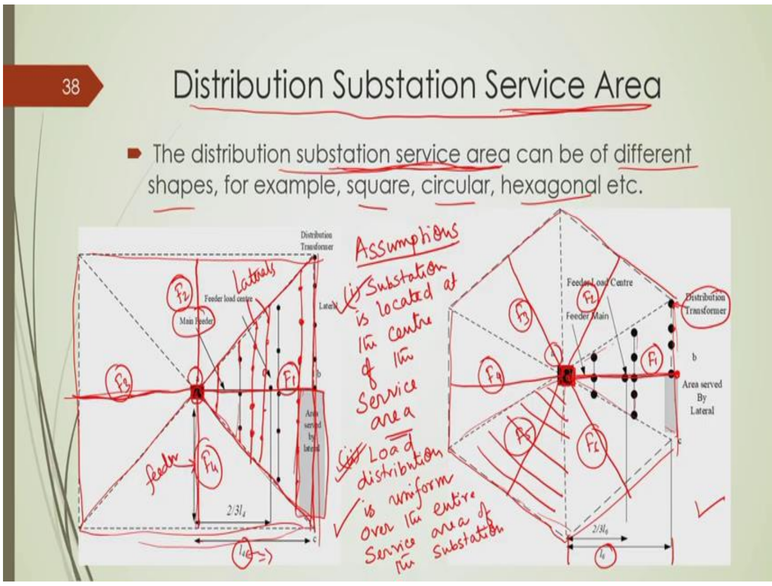
Operation and Planning of Power Distribution Systems
Dr. Sanjib Ganguly
Department of Electronics and Electrical Engineering
Indian Institute of Technology, Guwahati

Lecture - 11
Genaralized expression for voltage drop for radial distribution feeder

(Refer Slide Time: 00:33)



So in this lecture, I will basically talk about this distributions substation service area, different types of service area and will show you that derivation of a generalized expression for voltage drop ok. So, if you can follow my last lecture, I discuss how to determine these expressions for voltage drop and power loss for typical 2 types of feeders.

One is feeder with a uniformly distributed load with a service area with a rectangular service area; another example was similar to that this uniformly feeder with uniformly loaded, but its service area is of triangular ok. In both the examples, we determine the expressions for power loss and this voltage drop ok.

Now, in this lecture we will learn the different types of substation service area and in fact, their comparison in view of the voltage drops calculation ok. So, let us start with these two different cases. As we know, the distribution substation service area, it means that the area which substation serves ok or area under a particular substation.

So, we call it substation service area. It can be of different shaped; it can be of different shaped. It can be either of square, it can be of circular, it can be of hexagonal, or it can be of any shaped ok. But here we will try to understand two different shapes for this service area under a particular substation. One is square service area that is this example; another is hexagonal service area that is this example.

And we will try to compare the feeders of both the types ok. We will try to compare the performance or the voltage drop expressions for both the feeders ok. Now look at this example; here this is the point where the substation is located it is point a. Similarly in this example this substation is located at the center of the service area which is named as point a.

So, here we have some assumptions. The first assumption is that substation is located at the center of the service area. So, all this analysis is based upon this assumption ok. And we have another two/three assumptions also which I will let you know afterwards ok. So, the first assumption is that substation is located at the center of the service area.

So, this is a square shaped service area, this is a square shaped service area as you can see shown over this dotted line and we assume that substation is located at the center of the square ok. Similarly this is a case of hexagonal service area like this is a hexagonal service area where a substation is located at the center of the hexagon ok.

So, this is the assumption that we took and all this analysis is based upon this assumption that substation is centrally located ok, which may not be true for many practical substations or many practical distribution systems, but in this analysis we will assume that the substation is centrally located ok. And second assumption is that the load distribution is uniform; load distribution is uniform ok.

So, this is the second assumption. So, load distribution is uniform over the service area; over the entire service area of the substation; over the entire service area of the substation ok. So, these are the two assumptions. Based upon these two assumptions, we will analyze the performance of these two different types of feeders; one is located in a square shaped service area another is located in a hexagonal shaped service area ok.

Now, here our substation is located at the center and this is one of the feeder; it is shown or this is one of the feeders is shown and this is the main feeder; this is the main feeder which is marked over this arrow; this is the main feeder ok. And this main feeder is associated with several lateral feeders as you know this main feeder is associated with several lateral feeders like this, like this and this. Black dots are representing the nodes or loading points from where this load is connected.

And this is basically you know for primary distribution feeder; this is the location of the distribution transformer; this is the location of the distribution transformer which transforms the voltage level to the utilization voltage level from primary distribution feeder voltage level to the utilization voltage level and they are directly connected to the loads ok.

So, these all are connected to these primary feeders and some few are shown over here, but this load distribution is uniform; as I have shown you this is our assumption ok. And this you know whatever is connected to the main feeder; these all vertical lines; they represent you know this lateral feeder. They represent lateral feeder; they represent lateral feeders or simply laterals ok.

We call them laterals and these dots represent these load nodes ok, where we have this loads are connected ok, where we have this distribution transformer beyond which we have the customers load ok. And for a typical lateral as shown over this rectangle, it is the service area of this particular lateral. Similarly, we have many laterals along with this main feeder which constitute a triangular shaped service area under this feeder.

So, if you look at this example you can see that service area under this particular feeder is of a triangle ok. Similarly this is one particular feeder is shown over here. So, similarly we have another 3 feeders which they are. Each of these feeders is coming out from the substation like this, from the substation and they are associated with many such laterals and for each of the feeders service area is of triangle.

So, for example, for this is one feeder and this service area is this. This is the service area under this particular feeder. So, in total, we have four number of feeders for this example and if we can name these feeders as F 1, F 2, F 3 and F 4. So, each of them is marked with this red line main feeders; are marked with red line and you can understand that for each of the feeders' the service area is a triangle.

So, we have four triangles here which constitute a square service area under this particular substation; which constitutes a square service area under this particular substation ok. Similarly for hexagonal service area under a particular substation, this is the main feeder and these are the laterals; these are the laterals; this is one feeder shown and here also you can see the service area under this particular feeder is of triangle. So, service area under a particular feeder is triangular.

Similarly, we have many other; I mean we have five another feeders; one is this; another is this. So, I am just showing you here these main feeders, but these main feeders of course, are associated with some laterals. So, this is suppose F 1 that is main feeder 1; this is F 2; this is F 3; this is F 4; and this is F 5; and this is F 6.

So, for each of the feeders the service area under this feeder is of a triangular and each feeder is associated with many such laterals; many such laterals and load distribution for each feeder is assumed to be uniform. So, these are the things you have to know before we start this analysis ok.

And there are some nomenclatures, also I sincerely acknowledge for those nomenclatures for this Turan Gonen's book which I used as a reference for this lecture ok. So, I followed his nomenclature blindly ok. Now, this length of each of the feeder is represented by l.

And this suffix 4 says that it is the length of the feeder having 4 number of feeders ok; each of the feeders having same length for example, here you can see this length and that length this length and that length all are equal and they are assumed to be l 4. Now what this suffix 4 is representing that it is a case of substation where we have 4 number of feeders and they are connected in a square service area ok.

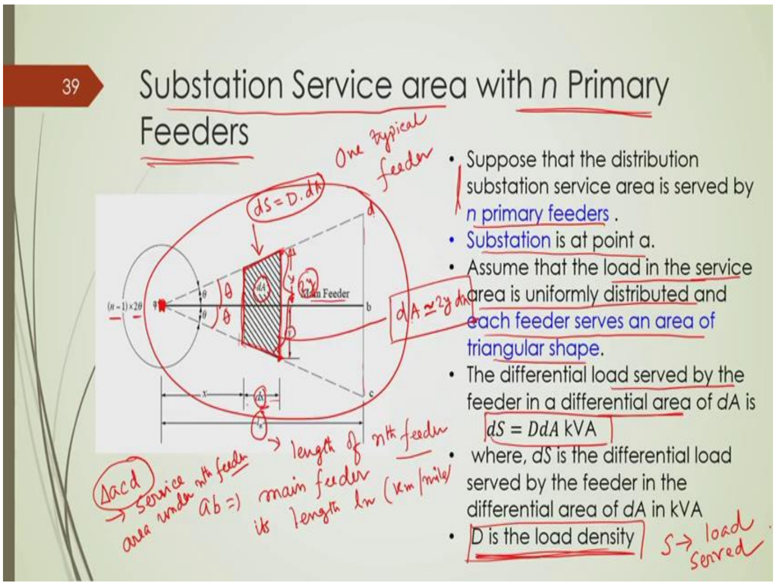
Similarly, here also this length of the feeder; length of the feeder means it is the distance between the substation and the distant customer of the main feeder. So, it is the length of the main feeder; it is the length of the main feeder that is the length of the main feeder and it is considered to be l 6 this l 6 is representing again, l is the length of the feeder in either in kilometer or in mile or in meter whatever you can say.

And this 6 represents, the suffix 6 represents that is it is associated with 6 number of feeders which are connected in a hexagonal service area ok, which are connected in a hexagonal service area. And each of the black dots are representing the position of the distribution transformer as I said beyond which we have the customers.

And what is the role of the distribution transformer? Just to convert or just to step down this voltage level of primary feeder voltage level to utilization voltage level. In India, as you know, primary feeder voltage level if it is 11 kV then utilization voltage level 3 phase is around 400 volt.

So, these distribution transformers are for step down from 11 kV to 400 volt ok. Now let us find out a generalized expression for voltage drop for these kinds of feeders ok.

(Refer Slide Time: 13:22)



Now, here we assume that we have a substation service area with n primary feeders with n primary feeders ok. We have a substation which is serving n primary feeders ok. And this is the location of the substation; this is the location of the substation and one typical feeder is shown over here.

So, this is basically representing one typical feeder; one typical feeder ok. And this length of the feeder is l n; here again n stands for this length of the n th feeder or length of the feeder which is associated with n number of feeders in a service area of a typical substation. Here also, we assume that the substation is centrally located. So, one particular feeder is shown over here if you look at this previous case. So, only one particular for example, this one is shown in the next slide ok.

So, this is the point where substation is located; this is the main feeder which is shown over here that is representing main feeder or trunk feeder whatever you can call. And its length is its length is l n either kilometer or mile ok and this bc is basically representing a lateral feeders. Similarly we have many laterals, not only one lateral.

Here also, we have this two assumptions valid; one is substation is centrally located and load distribution over the entire service area of this feeder is uniform ok. Now if we put this point as d then the service area or under this feeder is this a c d. So, a c d is basically representing the service area under n th feeder ok.

So, we have a substation having n number of feeders substation is centrally located load distribution is assumed to be uniform and one particular feeder that is the n th feeder is shown over here; its service area is the area under this triangle a c d a c and d ok.

Now, what we will do? The length of the feeder is also l n given. Now what we will do? Here is that at a distance x from the substation, we will take an infinitely small area; we will take an infinitely small area which represents d A; d A is a infinitely small area ok. And this angle that means, this c a b this angle is theta as is given and of course, by symmetry that angle that is d a b will be also theta ok, which constitutes the total angle this d a c as 2 theta ok and since it is n th feeder, we have n minus 1 other feeders and each of having may be this 2 theta angle ok alright. Now we have as we said n number of primary feeders under this substation which is located at point a and as we have shown you this service area is uniformly distributed load; that means, load is uniformly distributed under the sub service area of this particular feeder as well as all the other feeders under this particular substation.

So, each of the feeder is serving an area of a triangular shaped. So, here as I said, this triangle is representing a c d is representing the service area under this particular feeder ok. So, since we have taken this a small elementary length of d x to constitute this infinitely small area d A, so, let us find out the expression of d A in terms of d x ok. So, let us assume that this height of this distance is y so; obviously, this distance will be also y which constitutes this length from here to here this length is 2 y. So, this length will be of 2 y ok.

And this length is d x. So, this length is d x now; although this is of a trapezoidal shaped, but since it is a infinitely small, let us assume that it is a rectangular shaped. So, this d A can be written as in terms of this y and d x. So, d A can be written as where d A can be written as 2 y d x.

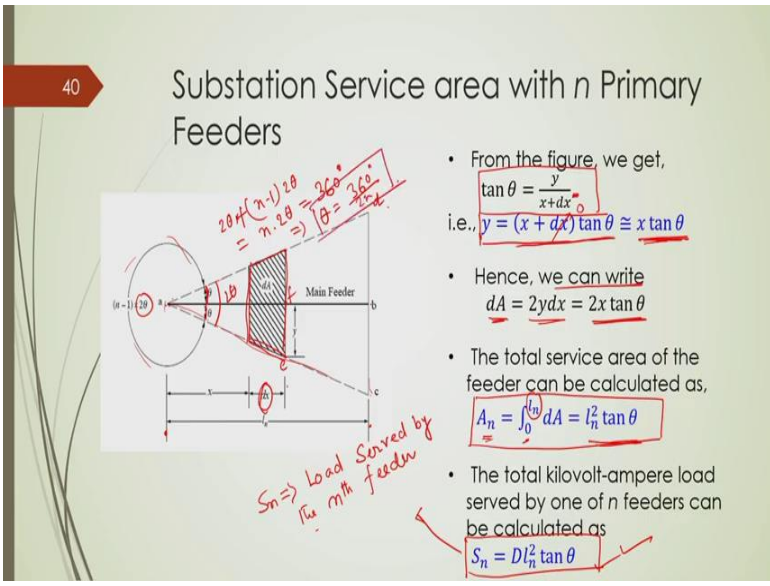
So, this is the expression for infinitely small service area which is located x distance away from the substation. Substation is located at point a and this infinitely small service area of this feeder is located x distance away from the substation. So, here we have this length of the primary feeder is d x.

So, we determine this d A in terms of x and y that is d A is equal to 2 y d x. So, this is not exactly, but it is approximately true, assuming that this infinitely small service area is of rectangular shape ok. Now what would be the load that is served by this infinitely small service area? So, this will be of course, this area d A multiplied by this load density and load density is assumed to be capital D; load density is assumed to be capital D.

So, so, the load which is served by this particular area will be equal to this. So, this load is represented with a symbol S capital S ok. So, this d S is basically representing load served by this infinitely small service area which is equal to load density multiplied by this area because load density; it is in order of I means its unit is let us for distribution network is typically a kilowatt per kilometer square or kilowatt per mile square.

So, if you multiply it with kilometer square of this area or mile square of the area, it will give you that much of kilo watt served by that particular area. So, this d S d if you multiply it with d A then whatever you will be getting that will be basically the load which is served by the small elementary length infinitely small elementary length ok. So, here our S is basically representing load served ok.

(Refer Slide Time: 21:27)



Now, we have some sort of more analysis. So, since this angle is theta. So, if this is d already we have considered. So, if we consider this point is e and this point is f then you know this y by x plus d x x plus d x is, dot is by mistakenly it is given, equal to tan theta. So, tan theta is equal to y by this length that that is x plus d x. So, y is written in terms of x as y is equal to x plus d x tan theta.

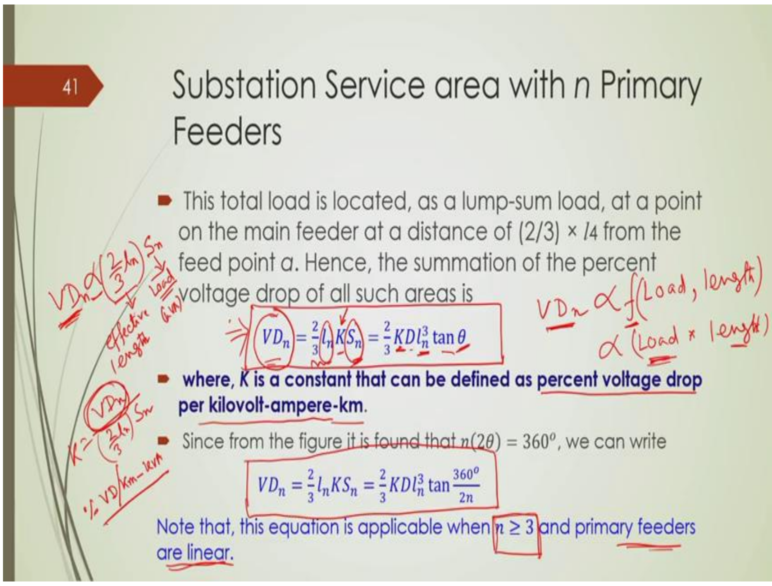
Now, as I have said this area is of infinitely small. So, d x is infinitely small length. So, it is close to 0. So, approximately y can be written as x tan theta it just by considering d x is approximately 0 ok. So, therefore, area of this infinitely small service area is given as d A 2 y d x which we got from this last slide this one d A is equal to 2 y d x. So, if we replace this y with this expression like x tan theta, d a will come out to be 2 x tan theta ok. So, d A will come out to be 2 x tan theta.

Now, we integrate this d A for the entire length of the feeder with a limits of 0 to l n where l n is representing the entire length of the feeder, so, if we vary this x from 0, 0 is the point where substation is located and l n is the point where extreme end customers of the primary feeder or main feeder is located that is point b.

So, if you integrate on this particular you know limit, so, what we will get? This you will get A n which is basically the area under this particular feeder. So, this A n is basically representing you the area under this particular feeder that is the area under this triangular service area of that particular feeder which constitute this triangle a d c ok.

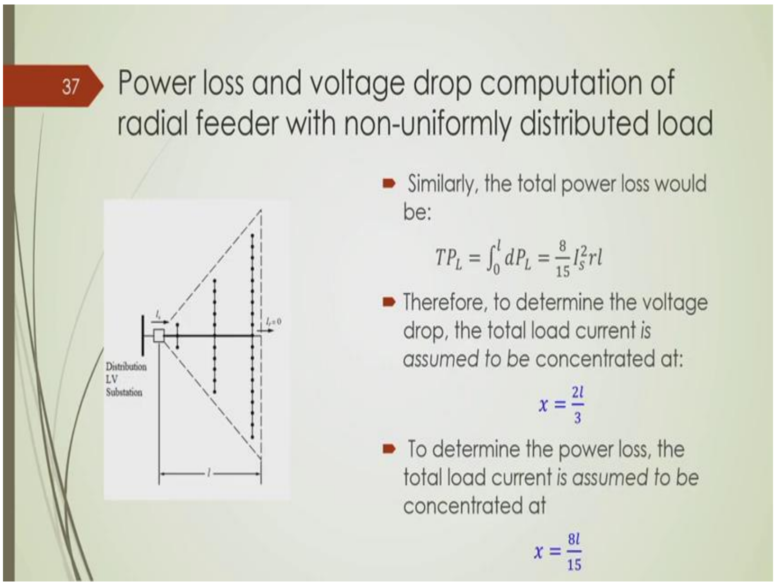
So, if expression is coming out to be l n square tan theta ok, where theta is that angle theta is that angle l n is basically the length of the feeder ok l n is the length of the feeder. Now if we multiply this particular service area, if you multiply with this particular service area with load density then whatever we will get, that will be the load served by that particular feeder. So, here S n is basically representing; S n is basically representing load served by the n th feeder.

(Refer Slide Time: 24:47)

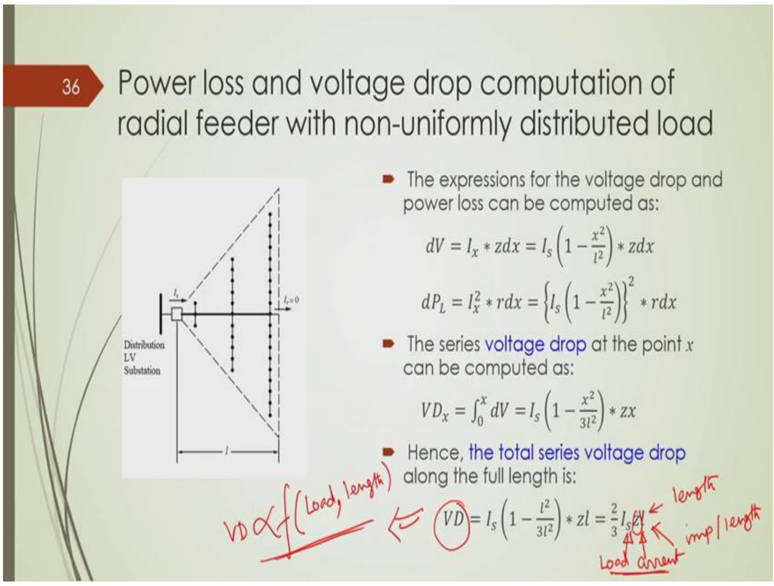


So, whatever s n will give that is basically the load served by this n th feeder ok so, that will be load served by n th feeder. Now, we will try to determine the voltage drop of this particular feeder ok; voltage drop of this particular main feeder ok.

(Refer Slide Time: 25:15)



(Refer Slide Time: 25:16)



So, this voltage drop expression as you can see in my previous lecture, this voltage drop expression typically depends upon some parameters; one is I s; one is z; another is l ok.

Now, this small z is basically the impedance of the feeder per unit length ok. And it is normally fixed for a particular type of feeder configuration ok; l is basically length of the feeder; l is length of the feeder; this z is impedance per unit length and this I basically representing load current.

So, thereby this voltage drop expression, we can consider that voltage drop is function of this, since as I have shown you this z is almost constant; we ignore it two third is of course, constant it will vary from different service areas; one service area to another service areas. So, two third and z if you ignore then basically this voltage drop typically vary it is a typically function of this load and load is represented by load current as I have mentioned at the very beginning and this length of the feeder length of the feeder.

So, voltage drop is typically function of load and the length of the feeder. So, with this, we will try to determine the expression for voltage drop of the n th feeder, the voltage drop of the main feeder of the n th feeder under a particular substation which is serving n number of feeders ok. So, this VD n again stands for the voltage drop of the main feeder of the n th feeder under a particular substation.

So, this VD n, we can understand that it is proportional to this load function of load multiplied by load and also this length ok. So, this function is as you know that it is simply nothing but it is proportional to load multiplied by length ok. Now this load let us represent that this load is S n ok and this length of the feeder is l n ok the load is S n and length of this l n.

So, VD n is proportional to l n multiplied by S n; now since this service area is of triangular, so, we know the effective length of the feeder to compute this voltage drop will be two third of the actual length. So, we can write this VD n is proportional to two third of l n multiplied by this load demand and load demand can be either represented as I said either load can be either represented by the load current or the load power consumption.

So, here we consider this consumption is S n ok; S n is basically the volt ampere consumption of the load. So, VD n is proportional to two third l n it is the effective length and this S n is basically representing this load ok in KVA in kilovolt ampere ok. Now if we just remove this proportional symbol with a proportionality factor K then this we can get the expression for this voltage drop as two third l n multiplied by K multiplied by S n which is the load served by n th feeder ok.

So, two third l n is basically representing the effective length of the feeder; K is representing the proportionality constant or a constant parameter and this S n is basically representing the load served by that n th feeder ok. Now as we know that this expression of S n already we determine from this expression if you put it over here.

So, this we will get l n square tan theta and this l n is multiplied with l n square. So, this will give you l n cube and d will come; obviously, because of this S n and this K is the parameter constant or constant parameter and this tan theta comes because of this s n ok; because of this expressions ok.

So, once you get that this will basically represent this; this will basically represent a generalized form of the expression for voltage drop. Now this is voltage drop up to what? This is the voltage drop of a primary feeder; this is the voltage drop of the primary feeder. This not the maximum voltage drop, but this is typically voltage drop of the main feeder ok.

Now, this could be maximum voltage drop I will come to that later on. Now then; what would be the unit for this constant K? Because you know this is the proportionality constant which is representing the ratio of this voltage drop to the multiplication of length and this load ok. So, its unit will be of course, this percentage voltage drop per KVA ampere kilo volt ampere that is per KVA-kilometer.

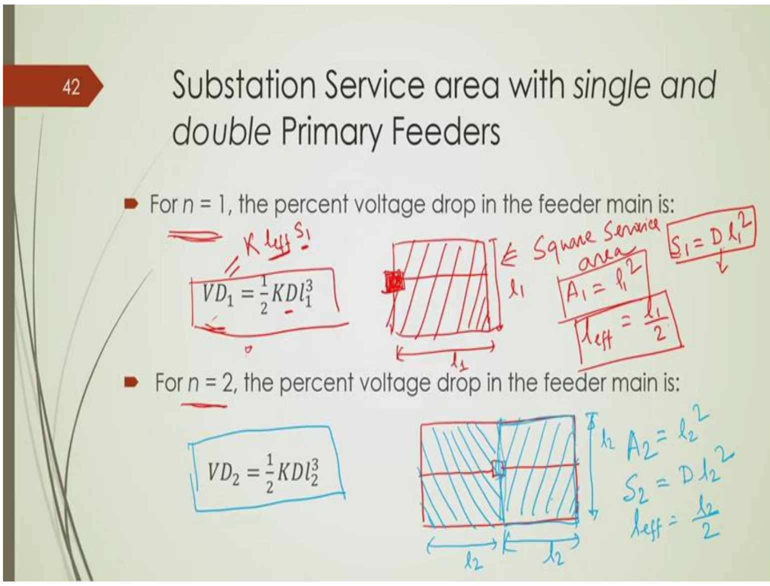
So, its unit will be off-course, K, since it is equal to VD n divided by two third of l n that is effective length multiplied by S n. So, this VD n let us represent it with percentage voltage drop percentage VD and this l n is represented its length, either can be represented by kilometer or mile. So, let us represent it by kilometer multiplied by this KVA, KVA is the unit of the load. So, its unit is percentage voltage drop per kilometer KVA or percentage voltage drop per KVA kilometer both are same ok.

Now, only one thing we will do that is we will can replace this theta with some as a function of n how can we do that if you go back and see this figure. So, this angle is 2 theta and as I said we have another n minus 1 number of feeders, each of them having 2 theta angle like this. So, overall this 2 theta multiplied by n which is you know sum of 2 theta multiplied by 2 theta plus n minus 1 multiplied by 2 theta. So, this is basically giving you n multiplied by 2 theta which is equal to 360 degree ok.

So, this gives you theta equal to 360 degree divided by 2 n ok, 360 degree divided by 2 n. So, we will replace this theta with this 360 degree by 2 n and we will get a generalized expression for voltage drop up to the end of this main feeder, up to the end of this main feeder. But this expression is valid for number of feeders more than equal to 3 and these primary feeders of are linear in the sense that load distribution is uniform ok.

So, this equation is constant with total number of feeders greater than equal to 3 and these primary feeders are of linear in the sense that load distribution of the feeder is uniform ok.

(Refer Slide Time: 33:30)



Now, we will be having some case studies; we will be having some case studies. Let us first consider what will happen this voltage drop expression when n is equal to 1? When n is n is equal to 1 that previous expression is not applicable. Now, what could happen when you are having a single feeder system?

In single feeder system either we may have this rectangular service area or we may have a square service area or we may have a triangular service area. Now if we have a square service area like this whose you know this is the main feeder and this is the service area ok.

So, this length of the main feeder is l; here again 1 stands for this substation is associated only 1 feeders this substation is associated with only 1 feeder which is having square service area square service area. So, if it is true then this length will be also l 1. So, this

A 1 will be equal to l 1 cube and other assumptions are valid only thing is the substation is not centrally located because only 1 feeder we have.

So, substation is not centrally located here rather substation is located at the extreme end of that service area and this feeder length is l 1. So, of course, A 1 will be equal to l 1 square because it is a square service area and because of this type of service area you know effective length of the feeder to compute this voltage drop is basically equal to l 1 by 2.

So, this one already we determined in previous days lecture. So, if you multiply this l 1 by 2 with this A 1 and this capital D is basically this load density. So, total loads will be equal to S 1 is equal to D multiplied by l 1 square so, this is basically S 1. Now if you multiply this S 1 with l effective and the parameter K is there then you will get the overall expressions for VD 1.

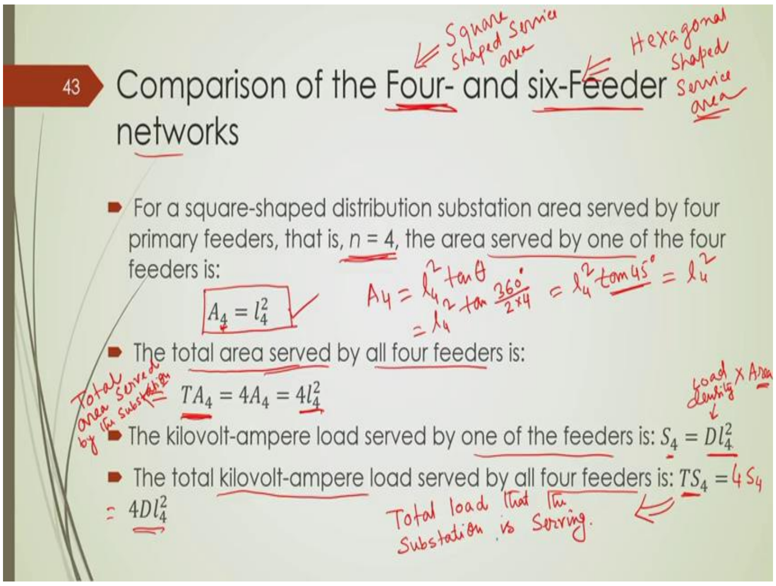
So, VD 1 is nothing but as you have shown this l effective multiplied. So, constant K is equal there K multiplied by l effective multiplied by S 1. So, if you put this expression for l effective as half of this l 1 and S 1 expression is D higher capital D you know its load density and l 1 is the length of the feeder. So, if you replace them then you will get this expression ok.

Similarly, here also we can find out when n is equal to 2; here also we have a 2-feeder case where substation is centrally located and the service areas of each of the feeders are of square. So, this is the service area of one particular feeder which is having length of l 2 and this is the service area of another feeder which is having length of l 2 ok.

So, in that case A 2 will be that the area served by each of the feeder; this will be this l 2 square because this is also assumed to be l 2 because this service area under a particular feeder is assumed to be square. So, A 2 will be l 2 square. So, S 2 which is representing the total load served by each of the feeder is basically D into l 2 square and since the service area is of square again this l effective will be equal to l 2 by 2.

So, if you put it all this expression over there. So, similar to this previous one, you will get the expression for voltage drop when n is equal to 2. Here substation is centrally located; load distributions are of uniform; these two are primary assumptions and another assumption is that each of the service area of the distribution feeder is square shaped ok.

(Refer Slide Time: 38:13)



Now, we have some comparative study particularly for two distribution networks; one is having four numbers of feeders; another is having six numbers of feeders. So, four-feeder network means it is a of a square shaped service area square shaped service area and six-feeder networks means it is of a hexagonal shaped service area hexagonal shaped surface area ok.

Now, we will be having some comparative study for these two cases. In fact, these two cases which I have shown you in first slide today. So, this is one case and this is another case ok. So, what would be the comparative performance of both the cases? One is having square shaped surface area another is having hexagonal shaped service area under a distribution substation and substation is centrally located load distributions is uniform both this assumptions will valid.

Now, as you can see that if n is equal to 4 you can find out what would be the area served by this each of the feeder. So, each of the feeder will serve an area of l 4 square. So, basically this you can derive from this expression this as you know A n is equal to l n square tan theta. So, we can find out A 4 is equal to l 4 square tan theta and as we know theta is equal to 360 degree by 2 n; so, l 4 square tan 360 degree divided by 2 n 2 n is 4 here; so, 2 multiplied by 4.

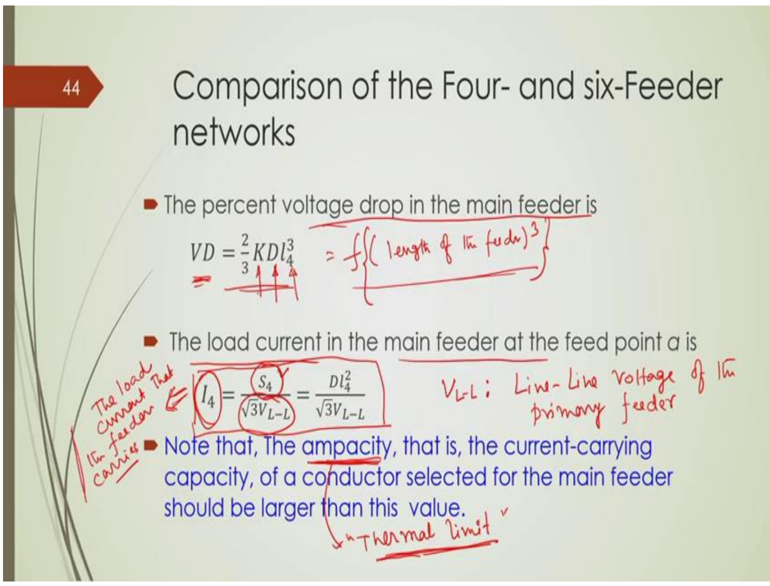
So, which will give you l 4 square tan 45 degree which is nothing, but 1. So, this is l 4 square ok. So, you can find out that A 4 is equal to l 4 square where this suffix 4 represents that this is a feeder if this is basically area under a particular feeder for a substation having 4 number of feeders ok. But this area is under a particular feeder the area which is served by a particular feeder for a substation which is serving four feeders ok.

Now, then what will be the total area served by all these four feeders? So, this will be 4 multiplied by A 4 and this is represented by TA 4. TA stands for total area served by a particular substation. So, TA stands for total area served by the substation ok. So, this area is the total square shaped service area that we are having. So, this is 4 multiplied by l 4 square.

Now, similarly we can also find out how much load served by one particular feeders when we have a square shaped service area. So, this is nothing, but S 4 already you determine that is equal to D multiplied by l 4 square; this is nothing, but density load density load density multiplied by area this area is already determined that is l 4 square. So, we get this how much load in KVA that one particular feeder will serve.

Similarly, total KVA served by all these feeders is equal to TS 4. TS stands for total load served by all these four feeders which is equal to 4 multiplied by you know S 4; this is nothing, but 4 multiplied by S 4 which is equal to 4 D l 4 square. Now this TS 4 is also representing total load that the substation is serving. So, this is basically representing the total load that the substation is serving ok.

(Refer Slide Time: 43:11)



Now, what would be the expression for you know voltage drop of the main feeder. So, this already we determine that the expression if you put you know theta as 360 degree divided by 2 multiplied by n then this will be tan 45 degree and so, this expression will be 2 up by 3 K multiplied by D l 4 cube ok.

Now, here one can understand one thing that the voltage drop of the main feeder depends upon this parameter K; it depends upon the load density; it depends upon also the length of the feeder. So, this voltage drop is function of cubic length of the feeder cubic length of the feeder. So, if we write in text, it is length of the feeder cube.

So, this is the function. So, basically this voltage drop will vary with cubic length of the feeder. So, feeder length if you increase then voltage drop according to this length will be cubic value of this particular voltage it will vary in a cubic form ok. And also how to determine this load current in a particular main feeder.

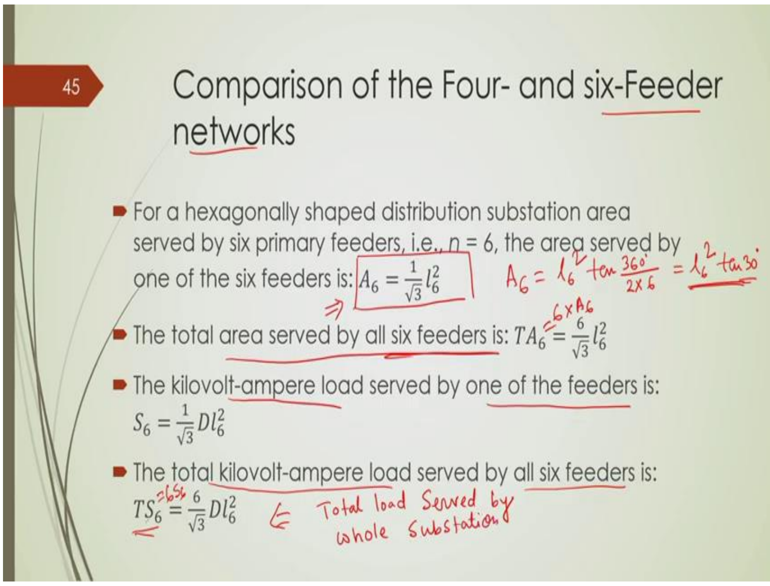
So, this you can find out as we know this load current is nothing but total kilo volt ampere served by this particular feeder divided by root 3 multiplied by line to line voltage of that particular feeder. So, here V L to L is basically representing line to line voltage of the primary feeder ok.

Now, if we put this values, expression S 4 here S 4; already we determine in the last slide that S 4 is equal to D l 4 square. So, if you replace this S 4 over here, you will get the expression that how much load current the main feeder is carrying. So, this is basically this I 4 is basically the load current that the feeder carries ok.

So, I 4 is basically representing the load current that the feeder is carrying or the feeder carries. Now there is another concept called ampacity limit or thermal limit. So, this ampacity or thermal limit both are basically essentially having the same meaning; it means that every conductor because you know this distribution feeders they are basically nothing but they consist of some typical conductors 3 phase conductors and each of the conductors in a particular phase has certain capacity, certain ampere capacity and that capacity is called the thermal capacity or thermal limit; sometimes it is also called ampacity limit. So, this maximum current 1 particular feeder is carrying should not exceed that ampacity limit that is what 1 of the constraint of designing a particular feeder.

So, what is the objective of determining this I 4? I 4 is basically representing the load current which is carrying by this particular feeder. And this load current or maximum value of this load current should not exceed the ampacity or thermal limit of that particular feeder and this ampacity limit basically depends upon what type of conductors we are using to build that particular feeder ok. It depends upon conductor material; it depends upon the conductor size cross sectional size.

(Refer Slide Time: 47:46)



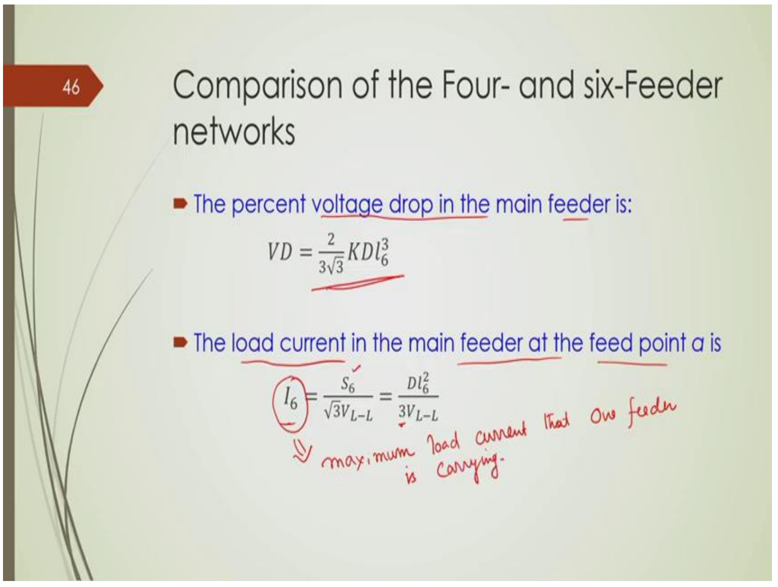
Now, similar to that we will also determine that areas served by a particular feeder; for a six feeder distribution networks with a hexagonal service area here A 6 will be equal to 1 upon root 3 l 6 square; here again you can find out like this; A 6 is basically equal to l 6 square multiplied by tan 360 degree divided by 2 n here n is equal to 6 this is 2 multiplied by 6 ok.

Now, this will give you l 6 square; this will be give you tan 30 degree. So, tan thirty degree we know it is 1 upon root 3. So, that is why this 1 upon root 3 will come. In fact, this all this analysis you can do also geometrically for a particular service area ok. So, once you get this area served by a particular feeder, so, total area served by all the 6 feeders; that means, this is the total service area under the substation for a hexagonal shaped service area is equal to 6 multiplied by A 6.

So, this is nothing, but 6 multiplied by A 6 which is equal to this 6 root 3 divide multiplied by l 6 square. Similarly the total load served by 1 of the feeders each of the feeder rather is equal to D multiplied by this area of individual feeder. So, this is equal to 1 upon root 3 D l 6 square. Similarly, total load or total KVA load served by all the 6 feeders that is TS 6 is equal to 6 multiplied by S 6.

So, this TS 6 is basically equal to 6 multiplied by S 6 ok which is equal to this. So, this is how we can determine the total load served by this whole substation. So, this is nothing, but total load served by whole substation ok that is basically TS 6.

(Refer Slide Time: 50:05)

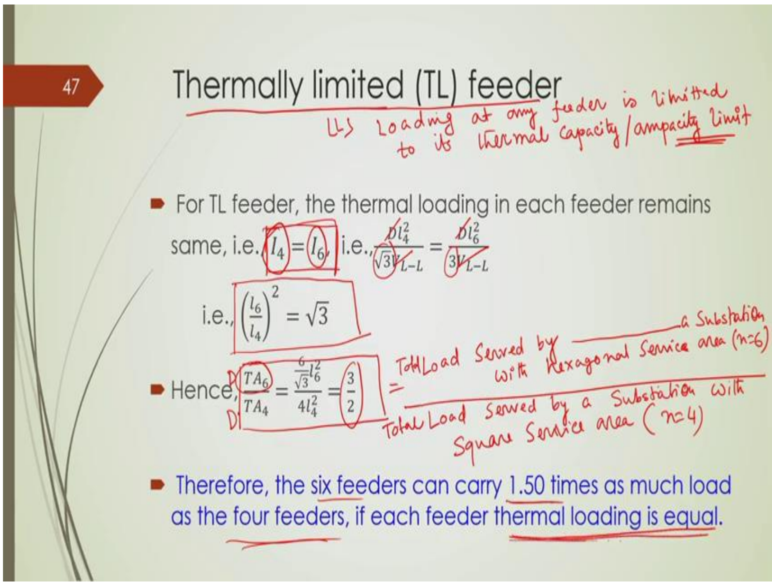


Now, you can also find out that expression for percentage voltage drop for the main feeder which is nothing but if you put this expression of tan 30 degree there in that previous example then you will get this expression in the generalized expression.

And also you can find out the maximum load current that one particular main feeder at this feeding point because you know, since each of the feeder is having a triangular shaped, so, maximum load current will occur at here and slowly it will reduce to 0 at the end point or beyond this the last customer of the feeder.

So, maximum load current will take place at the substation and that load current we can determine as this I 6 which is equal to S 6 divided by root 3 V line 2 line now; since if you put this expression of S 6 that we got over here that S 6 is equal to 1 upon root 3 D l 6 square, so, you will get this root 3 and this root 3 will be multiplied will give you 3 and this numerator will be equal to D l 6 square. So, this is the maximum load current one feeder is carrying. So, maximum load current that one feeder is carrying ok.

(Refer Slide Time: 51:48)



Now, next we will have two important concepts; one is called thermally limited feeder; another is called voltage drop limited feeders; I will come to that. Now what is thermally limited feeder? In thermally limited feeder the loading at any feeder is limited to its thermal capacity or ampacity limit ok. So, as I said few moments before that every conductor is having some ampacity limit.

So, here the feeders loading is limited up to this ampacity limit; this is one of the constraint I will again discuss when I will talk about power distribution system planning that each of the feeder’s maximum loading is limited to the individual ampacity limit. Now if we have two different types of feeders, or two different types of examples, two different types of substation service area; one is your square service area another is your hexagonal service area.

And for both the types, these feeders are constructed with same types of conductors with same material, same size same construction then they are obviously, would be limited by individual thermal limit. If so, then off-course, the maximum current carrying by one particular feeder should be equal to the maximum current carrying, but by one another; I mean feeder which is having different service area.

So, here I 4 is representing the maximum current which is carrying by square shaped service area; I 6 is basically representing the maximum current carrying by the hexagonal shapes service area. Now if we equate these two both the equations we obtained in these 2 examples; one is this I 6 another is this I 4; if we equate these 2 and if you look at this 2 expressions both the expressions are function of this l 4 D and, where voltage and DV l l and d are assumed to be same for both the cases.

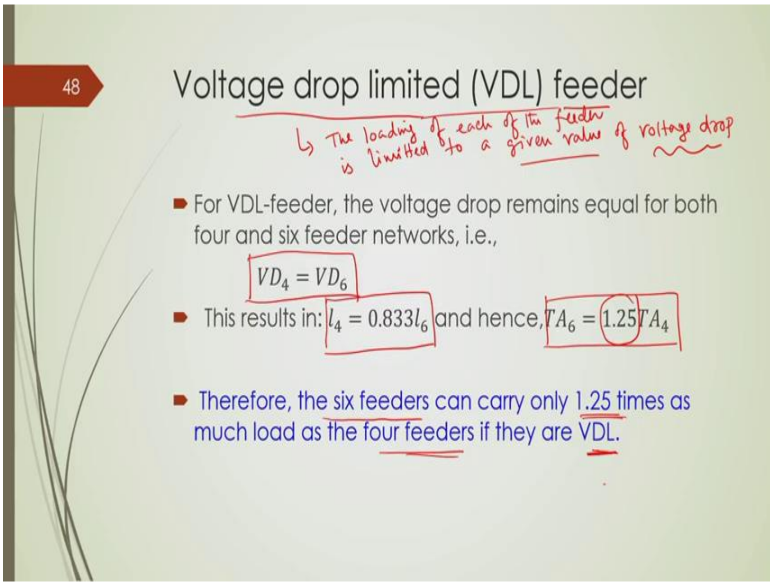
So, this D will be cancelled out this V L L this V L L will be cancelled out, but here we have 3 factor because of that 1 upon root 3 term in the served area and whereas, we have root 3 factor. So, this gives the relationship of this length of the individual feeders which is l 6 by l 4 square. So, this has to be root 3 if we have to hold this condition true.

Now, under this case we can also find out the ratio of the total area served by the particular feeder. So, this ratio is TA 6 by TA 4 which is same as the total load served by hexagonal feeder and a feeder with a hexagonal service area to the total load served by a feeder with a substation having square shaped service area. So, this you can find out simply by putting their individual expressions and that is coming out to be 3 by 2.

So, it means that in the numerator although it is area, but if you multiply it with capital D from both sides. So, whatever you will get that will the load served by individual feeder of individual types of substation service area. So, here this is basically a ratio of load served by a feeder of a substation with hexagonal service area hexagonal service area with n is equal to 6 that number of feeder is equal to 6 to the load served by a feeder not a feeder basically this t is representing the total load.

This will be total load served by a substation with hexagonal service area that is n is equal to 6 to the total load served by a substation with square service area that is n is equal to 4. So, if it is the case then you can see with this 6 feeder a substation having 6 feeder is carrying off course, 1.5 times as much as load of the a substation having 4 feeders if your loading is limited with the ampacity limit that is thermal capacity limit.

(Refer Slide Time: 57:21)



Now, similarly voltage drop limited feeder means each of the feeder loading is limited to a given value of voltage drop. So, here the loading the loading of each of the feeder is limited to a given value of voltage drop. So, we will specify that you can design a feeder, but that feeder should not have more than let us say 5 percent of voltage drop; the main feeder should not have more than 5 percent of voltage drop.

So, if under this case you know voltage drop expressions for both the example should be equated and this gives you a relationship with this length of the feeder for n number of 4 number of feeders and 6 number of feeders and thereby in similar way you will get the total area served by the 6 number of feeders and 4 number of feeders; that means, 1 is hexagonal service area another is square service area and that is coming out to be a factor of 1.25 times.

So; that means, when your feeder is limited with this voltage drop then if we have a hexagonal service area with 6 number of feeders it will carry 1.25 time, that means, only 25 percent more load as compared to a substation with a square service area having 4 number of feeders ok, if they are limited with voltage drop limit. So, this is called VDL feeder ok. So, with this, I will stop today.

Thank you.