Operation and Planning of Power Distribution Systems
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Lecture - 09
Substation bus schemes and primary distribution network topology

So, in my last lecture, I started discussion on this Power Distribution Networks: a Brief Overview, ok.

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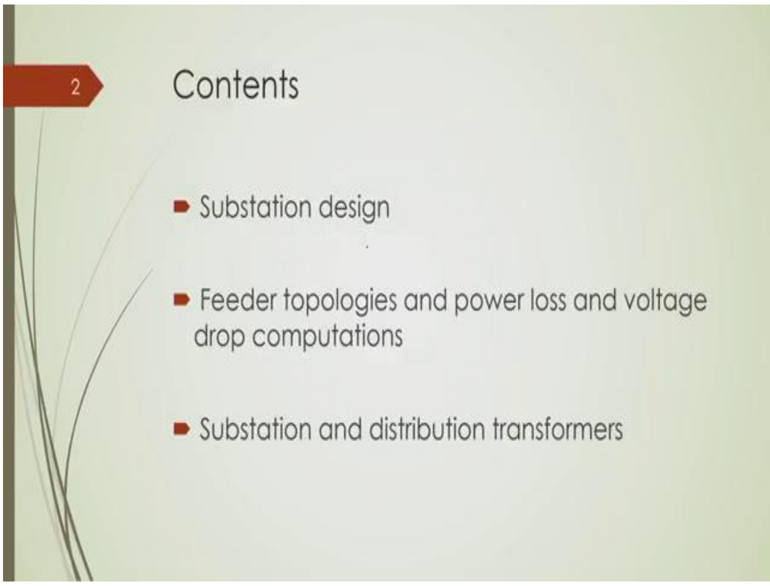

So, I talked about the substation design and I will continue to that, and then we will also discuss this feeder topologies, power losses, and voltage drop computations, ok.

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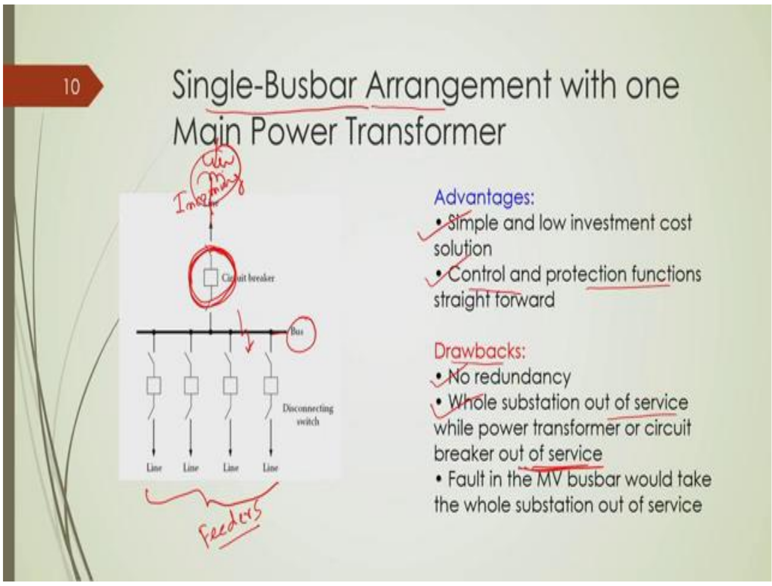

So, in my last lecture, I started discussion on different busbar arrangement systems which are used in a typical substation, outdoor type of substation, ok. And I discuss this simplest one that is Single Busbar Arrangement; Single Busbar Arrangement. This is a very simple system. We have a one incoming line; this is incoming line; this is incoming line, ok. And this is basically charging this bus, ok.

This is the bus from where these feeders, individual feeders are going out and they are basically supplying to the individual loads, ok. So, these are the individual feeder. So, these are these feeders, ok. And they are connected to the individual loads with distribution transformer which again transforms or steps down the voltage level to the utilization voltage level, ok.

So, this is a very simple type of busbar arrangement, single busbar arrangement, and this control and protection logic is very simple to devise for this type of arrangement, ok. But there is a drawback, like there is no redundancy. If there is any fault in any part of this incoming line or if I want to do maintenance for the circuit breaker then the whole circuit will be de-energized, and this whole circuit will be the out of service. So, none of the feeders will be energized because this bus will be de-energized, ok.

So, if we need any maintenance of that particular breaker, then we need to take the total outage of this substation and none of these feeders will be getting power or will be energized in that particular case. So, that is why there is no redundancy, whole substation will be out of service.

When there is any fault in power transformer, power transformer of course is connected somewhere here, if there is any fault in this power transformer or this incoming breaker, then obviously, the whole substation will be out of service, ok.

And also, if there is any fault in that particular busbar, then also all these feeders need to be taken outage. So, there is no other way possible, so that we can keep this feeders energized. There is no other possible option, so that we can keep these feeders energized, ok.

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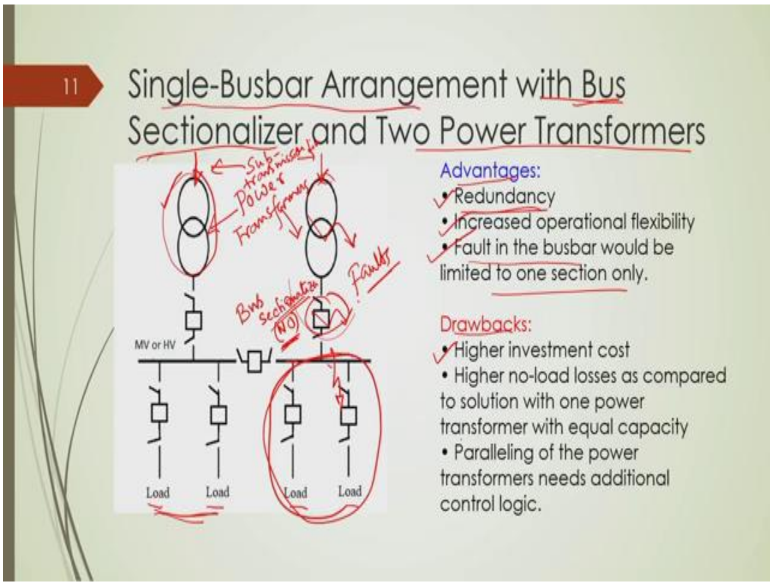

Now, in order to alleviate this, we have this single busbar arrangement with bus sectionalizer, ok. And there are two power transformers; this is one power transformer; this is another power transformer. These are two power transformers. And their functionalities are same; they are basically step down.

So, here we have this sub-transmission line; here we have the sub transmission line, sub transmission line, ok. Then, we have this power transformer which steps down the voltage to the distribution level voltage; then we have this circuit breaker each to energize these two buses.

So, here basically there is only one bus and this bus is sectionalized with another breaker which is called bus sectionalizer. So, this breaker is basically bus sectionalizer, ok. And this breaker is normally open. So, this breaker is normally open, so that this is will be acted as an individual bus and this also will be acted as an individual bus, ok.

Now, as compared to this previous arrangement that is single busbar system, you can see here we are having only one bus, which is splitted into two parts by using this bus sectionalizer. And this bus sectionalizer is normally open switch; that means initially it will be kept off, ok.

Now, what is the advantage of this? We have off course, higher redundancy meaning that if there is any fault in this transformer or in this breaker, then of course, we can disconnect this circuit breaker and we can isolate this unit from the service. At this condition we can switch on this breaker; we can turn on this breaker; we can first turn on the isolator; then we make this breaker through or we will make this breaker through.

And then we can supply, thereby you can see if we make this breaker through; that means, this bus is getting connected with that bus, and then if this rating of the power transformer permits you can supply all these feeders connected to the bus from this particular transformer. This means that we can bring power through this transformer through this bus sectionalizer to that feeder, this feeder provided that the total load demand of this feeders along with the total load demand of this feeder, i.e., summation of all this load demand of all these feeders do not exceed transformer rating, ok. So, under this condition you can keep this feeders energized. So, that is what the advantage. That is why it is having better reliability, ok, better of operational flexibility.

So, if there is any sort of fault happens in this power transformer or in this breaker, if any sort of faults occur then you can isolate either this section or that section, and go for maintenance, and thereby you keep this bus sectionalizer on and you make the circuit, so that you can bring power from the other transformer, ok. So, that is why, fault in the busbar would be limited to one section only, ok.

Now, there is another advantage, i.e., if there is any busbar fault; busbar fault means if there is any fault in that either of this bus of this bus or this bus, suppose there is any fault in this bus then only this portion of the feeders or these many feeders whoever are connected to that particular bus will be affected. But here all other feeders which are connected to the other bus will never get affected.

On the contrary, you can see here, since we have a single busbar arrangement, if there is any fault in this particular busbar, all the feeders will be affected, they will be having outage, ok. So, this is one of the advantages. But off-course, this drawback is that if you have some advantage, this will be the cost of something else; so here we have this higher investment cost.

We have difficult in paralleling this power transformer, particularly devising the control logic is concerned. We also have higher no load losses as compared to one transformer because two transformer means there would be more amount of no load losses add up this no load losses, so that would be obviously, higher, ok.

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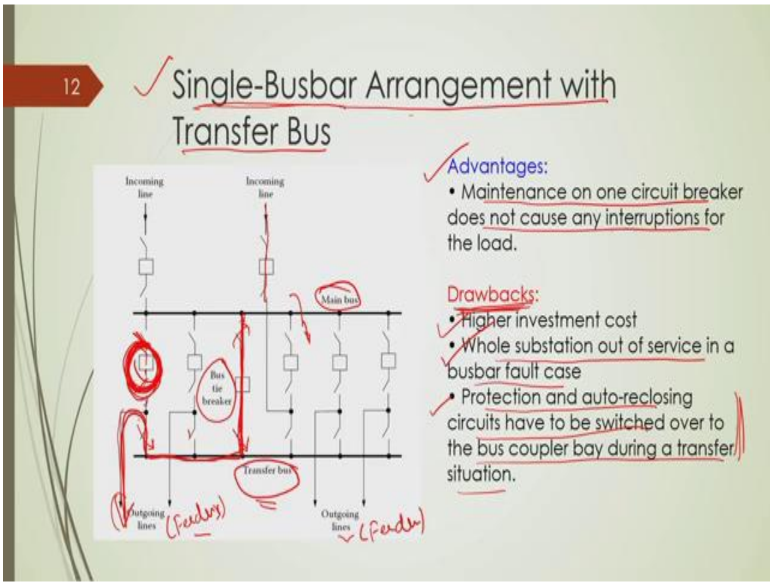

Now, we have another scheme that is called single busbar arrangement with a transfer bus. So, here we have one bus that is main bus, ok and all the feeders are connected to the main bus with a circuit breaker, ok. So, these are the incomers to charge this particular main bus. And there is another bus which is called transfer bus, which is normally not energized, which is normally de-energized, ok.

Now, these are the outgoing feeders, and these are the circuit breakers of the corresponding feeders. So, normally these circuit breakers are kept on or the circuit breaker makes this circuit; and these feeders they get supplied through this path, ok. So, similarly this feeder, this is one outgoing feeder or this is one outgoing feeder, this is also outgoing feeder. So, they get energized through their corresponding circuit breaker like this.

So, this feeder is getting energized through the circuit breaker, this feeder is getting energized through the circuit breaker and so on, ok. So, under normal condition that is how these feeders are energized, ok. Now, there is another bus which is as I said this transfer bus. Now, what is the role of this transfer bus?

This transfer bus is only used if you need any sort of maintenance required of any particular feeder breaker. Suppose, for this particular feeder, this is the circuit breaker which makes the circuit and I need to have any maintenance of that breaker. I need to off this breaker. Then, you need not to de-energize the whole feeder, ok. You even that case also you can keep this power supply of the corresponding feeder intact.

In fact, in the previous two schemes, there is no option. Suppose, if they we need to have any sort of maintenance required of that feeder, we have to simply de-energize this feeder loads and then you need to do a maintenance, and thereby this during this times this loads will be out of service, ok.

But, in fact, in previous schemes also, if I need to have any maintenance of that feeder, we do not have any option left to keep this feeder loads energized, ok. But, here, in this particular arrangement, that is single busbar arrangement with transfer bus, even if we need any maintenance required for this particular feeder, we can keep that feeder energized. How? In that case, we will isolate this circuit with these isolators and there is a bus tie breaker, which is basically used to charge this transfer bus from the main bus.

So, what we will do? We will make this you know bus tie breaker on. Basically, this bus tie breaker is normally off, but whenever we need any maintenance required the corresponding feeder circuit breaker, we need to energize this transfer bus through this bus tie breaker. And prior to that we need to switch on this isolator, and thereby we can transfer the power of that particular feeder through this path, through this path.

See, if this is the circuit breaker corresponding to that particular feeder; this circuit breaker is under maintenance till that particular feeder is getting supplied through this transfer bus and tie breaker arrangement, ok. And that is what the advantage of this particular scheme.

So, individual feeder's circuit breaker can go for maintenance, but that does not interrupt that loads connected to that particular feeder, ok. So, this is what the advantage is. So, maintenance on one circuit breaker does not cause any interruption. But, there are drawbacks.

As I said, whenever you make some sophisticated arrangement you need to pay more; so, higher investment cost, and full substation would be out of service in case of busbar fault. If there is any fault in the main bus there is no other way to keep this circuit energized. So, whole substation will be out of service.

Also, protection and auto reclosing circuits have to be switched over to the bus coupler way during a transfer situation. So, this protection is bit complicated as compared to the simplest form of the protection scheme which is the single busbar scheme, ok.

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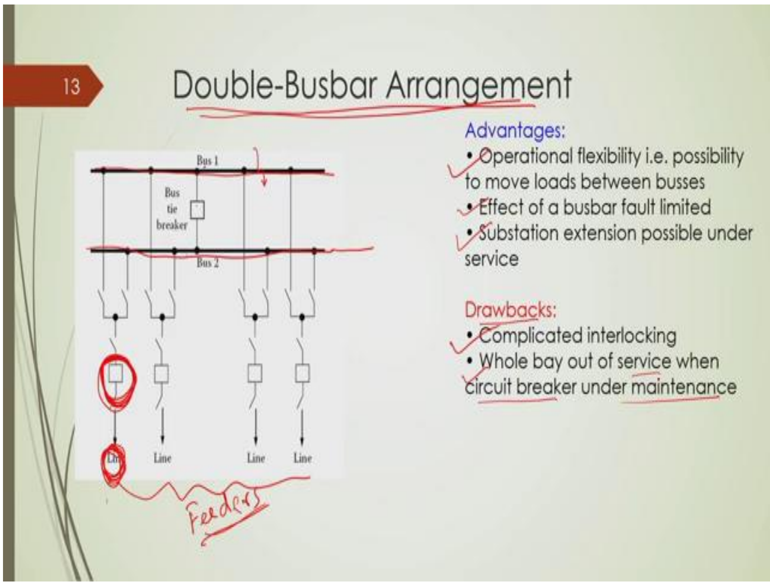

Now, next is double busbar scheme; double busbar arrangement. Here, we have two buses, one is bus 1 and another is bus 2, ok. Here, we have two buses; instead of a single main bus we have two main buses, ok.

Now, these are these outgoing feeders which are connected to the different loads. Now, any of these feeders, can be connected to any of these buses, ok.

So, when you will connect this particular feeder to this bus 1, then you simply switch on the isolators first, ok and then used to make the circuit by this charging the circuit breaker, and thereby you get power from this bus 1, ok. So, this is very simple. And also, in similar way, you can get the power from the bus 2.

In that case, prior to the switching of the circuit breaker you have to switch on this isolators, and then you would make the circuit through this charging this breaker and then this feeder will be connected to bus 2 and it will get power from the bus 2, ok. So, this is somewhat simple arrangement, but we have two busbars for that. And there is a bus tie breaker which connects these two busbar, ok.

The advantage is that we have operational flexibility; effect of a particular busbar is limited; if there is any fault in any busbar then you can get the power from the other bus and substation extension is also possible under service, ok. So, you can go for this extension for another feeder through this any of the buses keeping that bus uncharged; ok, keeping the bus uncharged.

But there are drawbacks like complicated interlocking system and whole bay will be out of service when circuit breaker is under maintenance. That means, that problem which was there for single busbar arrangement or you know busbar with bus sectionalizer arrangement here also that problem is there. If you need to have any sort of maintenance required for that particular breaker then of course, there is no other way to keep the feeder corresponding feeder energized.

So, if I need to go for maintenance of that particular circuit breaker, I have to definitely keep this line uncharged, ok. I need to you know power curtailment of all these loads connected to that particular feeder, but during that maintenance period, ok. So, there is no other way that this feeder will get supply from other options during this maintenance period of that particular breaker, ok. This is one of the disadvantages.

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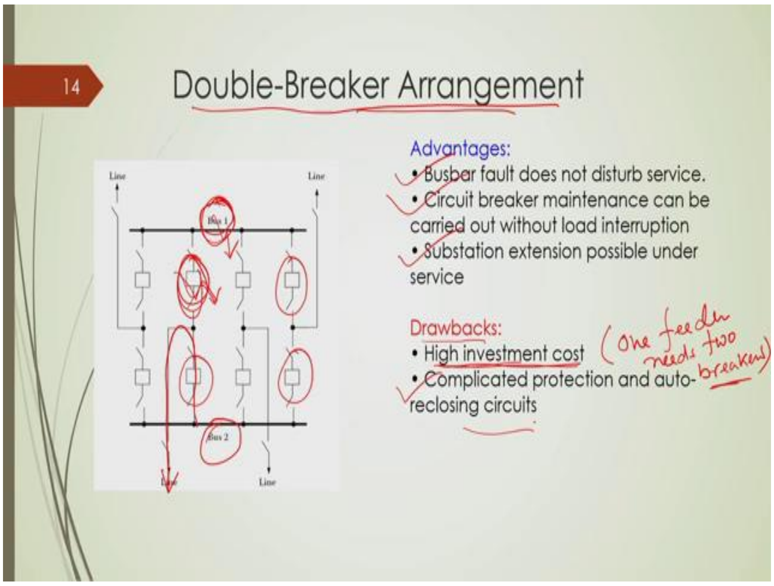

Now, we have double breaker arrangement, ok. In that case, we have two breakers to make one feeder; that means, this particular feeder is either can be energized with this breaker or can be that breaker, and this can be energized either by this bus or by that bus.

In fact, in previous one we had only one breaker to energize of one particular feeder from these two buses, ok. But here to energize this particular feeder we have two options: we have two circuit breakers, one can be connected to this bus 2; another can get to power from the bus 1, ok.

Now, here the advantage is that if there is any fault in this busbar or any fault in that particular circuit breaker, then during that time this particular feeders, they will definitely get power from this bus to through this particular breakers, ok. So, there is no problem at all.

So, breaker maintenance is not a problem; busbar fault is not a problem for this particular arrangement, ok. So, busbar fault is not a problem; breaker maintenance is not a problem, and substation extension is also a possible by keeping one bus uncharged; you can go for extension of that particular bus connected to new feeders, ok.

But again, these drawbacks are high investment cost which is obvious that one feeder needs two breakers. This is primarily because one feeder needs two breakers, ok. So obviously, this will increase the cost. Previous all this example you can see, one feeder corresponds to one particular circuit breaker, here also one breaker corresponding to one particular circuit breaker, but of course, we have an additional bus tie breaker.

Here also one feeder is connected to one particular breaker, ok. But here one feeder is connected to two breakers, one is this one is that, one is this one is that. So, obviously, the cost will be increased and also protection system would be complicated.

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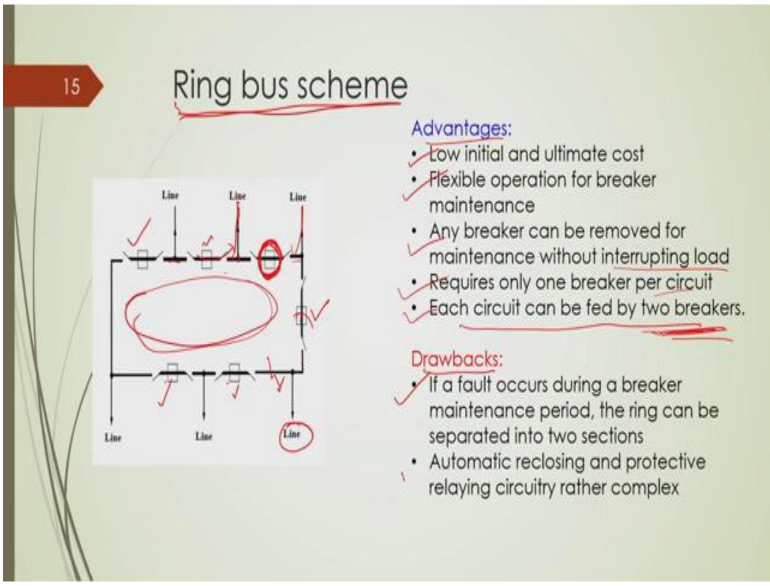

There is another system called ring bus system, which creates a ring; which creates a ring with a number of circuit breakers connected like this, this is one breaker, this is another breaker, this is another breaker and so on. Now, here all these lines are connected in this particular section like this, ok, in like this arrangement that is why it is called a ring breaker. And one particular line can be energized from either of this breaker or by making this breaker, ok so, this is possible.

And here also if you have, if you need maintenance of any sort of breaker then simply this there will be no interruption of any feeders. So, I need to do the maintenance of that feeder, of that breaker. So, I could simply disconnect this feeder, and this will not interrupt the whole circuit because this will just break the loop and this will keep all the lines energized, ok. So, that is what the advantage.

So, here low initial cost is there, but flexible operation of the breaker maintenance is possible. Any breaker can be moved for maintenance without interrupting any load as I was talking about. It requires only one breaker for circuit, but, due to this ring arrangement as if they are connected to two breakers side by side. And each circuit is fed by two breakers.

And due to this arrangement, you know, you can see that we have as many breakers as the lines; 1, 2, 3, 4, 5, 6 breakers are used for this 6 lines. But due to this loop connection only, each circuit can be fed by two breakers, ok. So, here it is not the fact that we have two breakers corresponding to one particular feeder. But still due to that particular arrangement one feeder can get supply from two breakers, ok.

Now, what are the drawbacks? If a fault occurs during this breaker maintenance period, that means, suppose if we are going for maintenance of that particular breaker at that particular instant there is any fault in any bus or may be in any breaker or we need some urgent maintenance of another breaker, then it would be difficult to keep the some of the feeders energized.

So, but this situation is obviously, somewhat rare situation that you can understand. So, this is one thing, and also another thing is that complicated protection arrangement.

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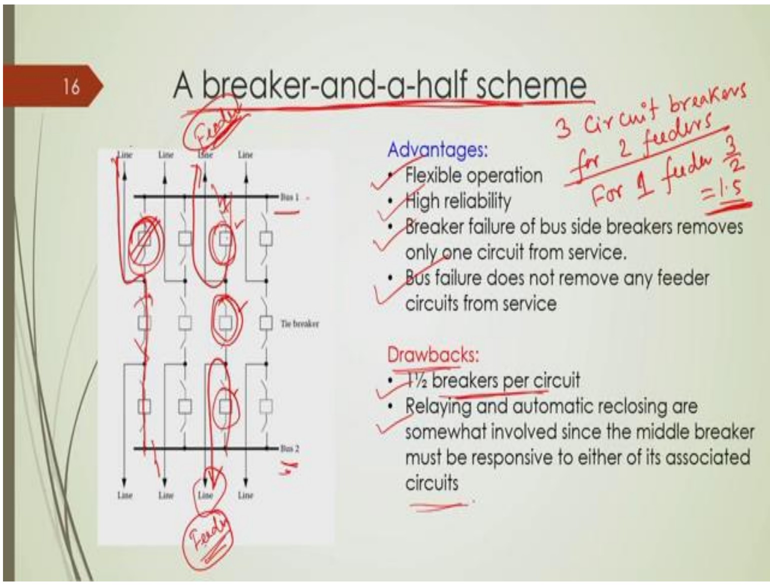

Now, finally, we have another popular scheme which is called breaker and a half scheme; breaker and a half. This is very popular, and this is used in many of the substations in India, ok. What is that scheme? In that scheme, you can see we have 3 breakers corresponding to two lines that means, this is one particular feeder; suppose this is feeder and this is another particular feeder, ok.

Now, these two feeders can be kept energized by these 3 breakers, ok. So, that is why you know, so we need 3 circuit breakers for two feeders. So, for one feeder, for one feeder how many circuit breakers we require actually? It will be 3 by 2, it is a arithmetic, so that is 1.5. That is why it is called a breaker and half scheme, ok. So, we need 3 breakers to keep energization of two feeders, ok.

Now, generally you can understand that this tie breaker is kept off and there are two buses that is bus 1 and bus 2 and this particular feeder, it is getting supplied by this particular circuit breaker from bus 1 like this. Similarly, this particular feeder it is getting energized from bus 2 through this particular feeder, ok. This is under normal condition, ok.

But if there is any sort of fault for example, this there is a bus fault at this bus 1, ok, then also this particular feeder can be energized from this bus 2 via this particular tie breaker. In that case, you can bring power of that particular feeder through this route and you keep this feeder or line energized, ok. This is possible. And that is why in reliability point of view it is a better option, ok.

Similarly, if there is any busbar fault at bus 2, what we can do? We can keep this both the feeders which are connected here energized from this bus 1 by using this tie breaker, provided that this tie breaker's capacity does not exceed, ok. So, total power flow does not exceed the breaker capacity. So, this you have to ensure, and then only it is possible to keep both the feeders energized under any sort of bus fault conditions.

Also, if there is any requirement of any maintenance of any of the breakers, for example, I need to have maintenance this particular breaker. So, I can put it de-energized, and in that case also by charging this tie breaker I can bring power corresponding to that feeder. So, busbar fault is not a problem. Breaker maintenance is not a problem, ok.

So, this will not create any problem for this particular scheme, ok, which is mentioned over here; flexible operation, higher reliability, breaker failure does not have any problem; busbar failure does not have any problem for any feeder, ok. But the drawback is again we need one and half breakers per circuit. So, for feeder we need 1.5 breakers, more than one breaker which is more costly, ok. Also, this, as I said many times that protection arrangement would be also complicated, ok.

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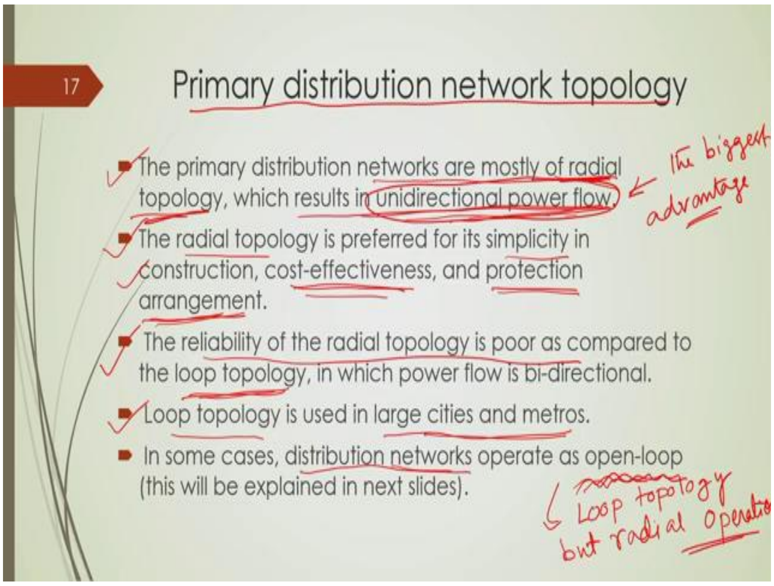

Now, we will come to this, primary distribution network topology. So, from this point onward we are slowly moving away from the substation. So far, my discussion was limited to the substation only. So, as I said, substation is our gateway; substation is our feeding point or it is the beginning of a distribution network, ok from where you know distribution network starts, ok. So, I discussed about whatever is required for the substation, ok.

Now, here in the successive slides, I will discuss basically some aspect of primary distribution feeders, ok. The primary distribution networks are mostly of radial, ok which results in unidirectional flow of power. So, it is of radial, how what do you mean by this radial topology? I will come to that in my next slide, ok.

Now, why this radial topology is preferred? Because of this advantage that unidirectional flow of power. This is the biggest advantage; this is the biggest advantage, and due to which you know we choose radial operation of primary distribution network, even if you have the flexibility of keeping it in loop, ok. Because this unidirectional flow of power, it makes this come protection coordination very easy, very uncomplicated, ok.

Now, this radial topology is preferred for its simplicity in construction, cost-effectiveness, and protection arrangement. So, these are the advantages of this radial topology, ok. So, it is the simplest form of this network. And it is preferred particularly in distribution networks for the simplicity in construction, cost-effectiveness; it is for economy; it is the best option; and also, the less complicated protection, in fact, very simple protection arrangement, ok.

But the reliability is poor for this you know radial topology as compared to the loop topology. I will come to that. I will have some single line diagram in which I will explain why it is so, ok. And loop topology is only used for large cities and metropolitan cities which demand a more reliable power.

But mostly in rural areas and most part of the country distribution networks, even if small cities and even if cities also you know we have radial distribution network, radial topology of distribution network. And sometimes, this distribution networks as I said, even they are having loop topology, but they are operating as open loop, ok.

So, why they are operating as open loop? Because open loop means that it is eventually a radial network, ok. So, even though you have the flexibility of this loop topology it is operated as radial, ok. So, this is called open loop configuration, ok. Open loop configuration means loop topology, loop topology, but radial operation, ok.

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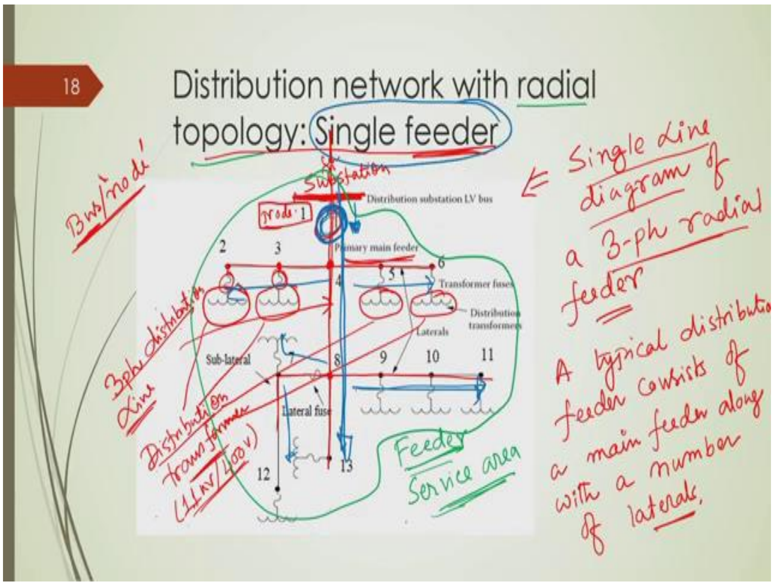

Now, this is the single line diagram of a single feeder radial topology. So, this is a single line diagram of a 3-phase radial feeder, ok. So, as I said that in power system in the very beginning, I mentioned that we analyze the circuit considering the single line diagram and this is a single line diagram although it is a 3-phase network; although it is a 3-phase circuit, ok.

So, here you can see, it is our gateway of this network. It is the beginning of our network that is the substation. And beyond that we have this power transformer; we have this power transformer, and we have the substation line; those things we will not consider particularly analyzing of this radial feeder. But we will start from this radial feeder analysis from the substation. Substation is our gateway that is the beginning you can say for a radial feeder, ok.

This is all, in fact, all other nodal point either we can consider them as a bus or node. So, in distribution system, generally this bus is not the terminology we use. We use node to represent different nodal point of a network, ok. So, this is substation. So, this is you can consider as node 1 or bus 1; both are having same meaning.

This is the circuit breaker which is making this feeder energized, ok. And then, this long line is basically a 3-phase distribution line. So, this is basically a 3-phase distribution line, either you know overhead line or underground cable whichever option is possible. So, this is basically 3-phase distribution lines, which is also called trunk feeder or main feeder, ok; which is also called trunk feeder and main feeder and it is connected to different nodal points with different lateral.

So, these are basically lateral feeders; so, this is one lateral; this is another lateral; similarly this is another lateral; this is another lateral and so on. So, if a typical distribution feeder consists of a main feeder along with a number of laterals; sometimes they are called lateral speeders, ok, a number of laterals. You can see this is the main feeder and these are the laterals, ok.

Now, these are the different other nodes, marked with node 2, node 3, node 4, node 5, node 6. Beyond which what we have? We have this distribution transformer; these are all distribution transformer and from where all these loads are getting supplied, ok. Now, these are the distribution transformer, ok.

These are the distribution transformer; distribution transformer whose primary responsibility is to convert this distribution voltage level to the utilization voltage level which is required by the customers. So, this distribution transformer convert, they step down further this distribution voltage level to the utilization voltage level.

In India you know, they convert this typical 11 kV distribution network to 400 volt utilization voltage. From where, if it is a single page customer, they will get 400 divided by route 3, that much of 220 volt single phase or maybe 400 volt 3-phase supply, ok. Now, this symbol shows, this symbol shows this fuse, ok which is the protection arrangement for this particular transformer.

If there is any fault beyond that this fuse may blown out, and isolate the distribution transformer, so that there will be no problem for the rest of the circuit to operate, ok. Now, one another important thing is that under this particular feeder this is basically the feeder, this is basically called feeder service area, and whoever customer is located under this particular service area the feeder should supply.

The feeder should supply to those customers. So, under this particular service area whichever loads are there, they are all connected to this particular feeder, ok. This is the traditional approach. And if you look at this radial topology then how this power will flow?

The power flow will be unidirectional; power will flow let us say starting from the substation to the individual distribution transformer and then we have this loads like this. So, power will flow uni-directionally starting from the substation towards the load, ok. So, everywhere you will get unidirectional flow of power; unidirectional flow of power, ok.

And you can see later on I will also analyze this type of feeder in more detail, that here of course, whatever current will flow that current will consist the power demand or load demand of all these loads connected. So, this particular breaker, it is experiencing the power flow which is sum of the all the power demand of all the customers who were connected to that, and apart from that we have also line losses.

Through this we have all these customers connected and this current which is flowing through this particular breaker which is summation of all these load current, but apart from that we have some losses. So, we need to consider.

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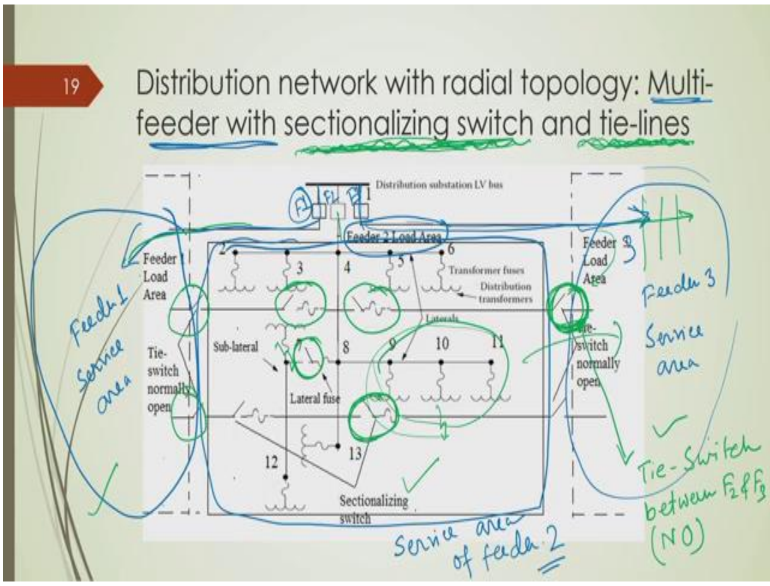

Now, this one is shown; it is a single feeder unit, ok. We in general as you have seen in the busbar arrangement, we have multiple number of feeders, typically in a under a particular distribution substation. So, here in this figure you can see multi-feeder distribution networks, multi-feeder distribution networks. So, this box is showing the service area of one particular feeder or this feeder 2, ok.

This one is basically this feeder 1 and which is going out and this is another feeder, ok. So, this is feeder 3 actually, this is feeder 3 and this is feeder 1. So, this is feeder F 1, this is F 2, this is F 3. And F 1 represents this feeder 1 which serves this load, ok. Feeder 2 is not shown in that particular figure.

Similarly, this feeder 3 which is used to serve the power demand of the load which is connected at the right hand side. So, this is the service area of feeder 3. So, feeder 3 service area is not shown here. Similarly, here this is the service area of feeder 1. And this rectangular box is representing the service area of feeder 2, ok.

Now, we have two important concepts here which are basically this sectionalizer or sectionalizing switch and tie lines. So, these are two important concepts one need to understand, their usefulness, ok. So, here we have these 3 feeders and these are the 3 service areas. This is service area feeder 1, this is service area feeder 2, and this is service area feeder 3.

Now, inside the service area we have as you can see a number of laterals connected to the main; this is the main feeder; this is the main feeder, which is connected to a number of laterals and number of nodal points, number of nodes etcetera. And also, each node is associated with one particular distribution transformer which is basically provided the utilization voltage of the loads, ok.

Now, as I said we have an important concept at this point one is sectionalizing switch, another is tie line. Now, what is the function of sectionalizing switch? These are the sectionalizing switches. This is one sectionalizer; this is another sectionalizer, ok; this is another sectionalizer. So, sectionalizer basically sectionalizes the whole circuit into different sections, ok.

A typical feeder for example, this feeder is having number of sections, ok. So, what is the role of the sectionalizer switch? They are normally closed switch and they are like isolators. They do not operate on-load condition, rather they operate off-load condition, ok. So, what is the function of the sectionalizer?

This sectionalizer can be operated if there any fault in that particular section. For example, if there is any fault in this particular section, then we can open this particular sectionalizer or if there is any fault in this particular section, we can open this sectionalizer and thereby we can remove this faulty part from the circuit, and we can keep the circuit energized again. And then this faulty part would be under maintenance, ok.

Now, this is the basic function of the sectionalizer; they sectionalize a particular feeder into number of sections; they are normally closed switch; they are like isolators; they are operated off load conditions. And whenever there is any fault corresponding to that particular sectionalizer, we can disconnect this sectionalizer, thereby disconnecting this faulty part from the circuit and rest of the circuit can be energized, thereby they improve the reliability, ok. So, this you have to understand.

Similarly, this tie lines, they basically provide some tie from one feeder to another feeder. So, this tie line is making a tie of this feeder 2 to feeder 3. So, this is a tie line or tie switch between this F 2 and F 3. Similarly, these two are the tie switches between F 1 and F 2. They are normally off-switch, they are normally open switch, n o switch, ok. So, they are normally open. And when they are normally open, they are both the feeders are operated in radial. If you close that then probably radiality will be lost, ok.

Now, what is the usefulness of this tie line? If there is any fault in any sort of any particular feeder of this F 2, ok any section of this F 2, then sometimes it is not possible to keep the rest of the part energized, even though you have this option of sectionalizer, ok.

So, under this condition, we will keep this tie switches on and we can bring power via this feeder 3 or alternatively in that arrangement we are connecting some of the loads of this feeder 2 to feeder 3, ok. And thereby we are keeping this loads energized, ok.

So, tie switch will be operated when there is not possible by operation of the sectionalizer to keep most of the part of the circuit remain healthy, ok. During that time you can get, you can connect some of the sections of one feeder to the another feeder through this tie line arrangement, ok. So, during this my discussion on reliability in module 3, I will discuss this in more detail.

But the basic purpose of both the switches are: one is normally closed switch, and another is normally open switch; they will be operated to improve the reliability of the circuit or reliability of the network, ok.

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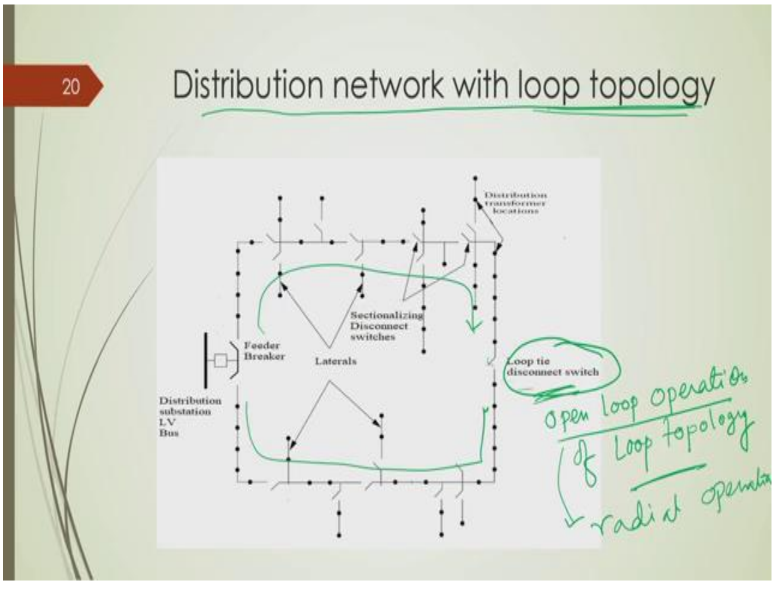

This is another possible network topology which is loop topology and there are some switches like loop tie disconnect switch. If you connect this then only this will be operated as loop. But if you disconnect this, then this part will be operated as radial; this part is also operated as radial. But if you connect this loop switch, they will be operated this loop. So, that is basically the slope tie disconnect switch is for open loop operation of loop topology, open loop operation of loop topology, ok.

So, the basic function of this loop tie disconnect switch is for open loop operation of loop topology; they are normally open switch and if you close it then this can be operated in the loop condition. Now, why they are normally open switch? Because to have a radial operation. So, open loop operation is nothing, but a radial operation. You can see, if this loop tie switch is kept off, it is open then this part will be open; you know this will be operated in radial; this part will be operated in radial, ok.

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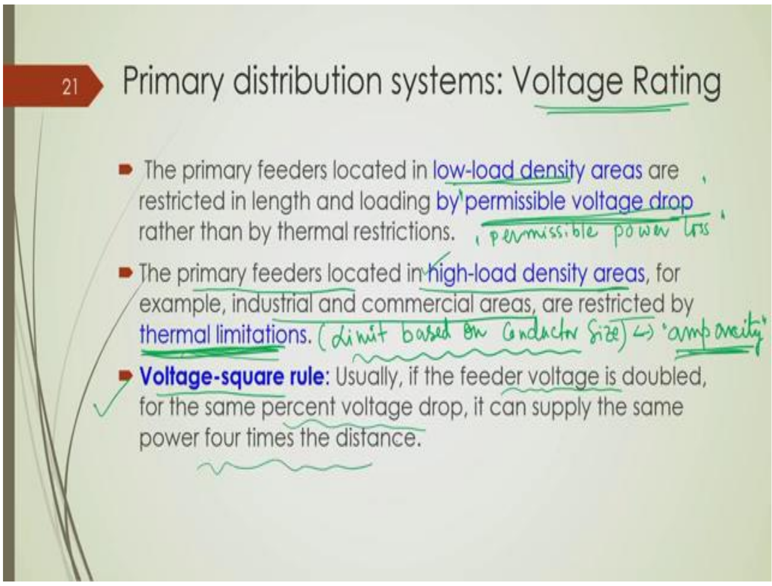

Now, next we will go for some important concepts like voltages, voltage rating of this primary distribution network. How do we decide that what should be the voltage rating of a typical distribution network? Should we go for 11 kv? Should we go for 22 kv or more? Ok. That basically depends on the two important factors, one is permissible voltage drop and also one is permissible power loss, permissible power loss, ok.

So, these are two important limiting criteria for deciding that what should be the length of the feeder and what should be the voltage rating of the feeder. Normally, we keep 11 kV; a higher voltage distribution network is also possible which needs some more investment, ok. This will be costlier, ok.

Normally, in power primary feeders located in high load density areas, for example, industrial and commercial areas in large cities or metropolitan cities; they are restricted by thermal limitation. What do you mean by thermal limitation? This thermal limitation is basically this, a limit of the particular distribution line based on the conductor size. This thermal limitation is the limit based on conductor size, ok.

So, there is one limit based on the conductor size that every conductor has some current carrying capacity; sometimes we call its ampacity; sometimes we call it ampacity; a ampacity means amp correspond to Ampere then capacity that is called ampacity limit.

So, this is basically decided upon the size of that particular conductor. And for high load density areas;,this limiting factor is their thermal limit because in those distribution networks this distribution lines are heavily loaded.

They carry more amount of current, so, that the limiting criteria is the thermal limit that is the ampacity limit. But for rural areas where we have low load density, this rural areas where each of the line is not much loaded, in those areas the limiting criteria are permissible voltage drop, ok, permissible voltage drop, ok.

Now, there is a thumb rule which is called voltage square rule; that means if you go for increase in the voltage, then keeping the same voltage drop as a criteria, you can provide the you can make the circuit 4 times longer; 4 times longer, ok. So, I have an example here, ok.

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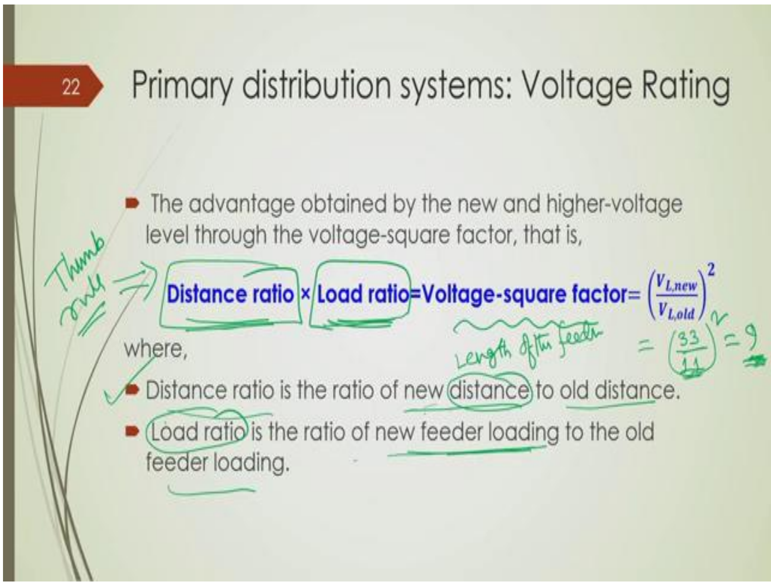

So, this is a thumb rule, although this is a thumb rule which is basically distance ratio multiplied by load ratio is voltage square factor. So, if you go for 11 kV, if you go for upgradation of 11 kV to 33 kV; that means, here in the numerator will be 33, denominator will be 11, so this will be square, so that means, 9. So, 9 would be the you know distance ratio multiplied by load ratio.

Now, what is distance ratio? Distance ratio is basically ratio of the new distance to the old distance. That means this distance stands for the length of the feeder; length of the feeder, ok. So, this distance ratio is basically the ratio of the length of the feeder for a new voltage level network and old voltage level network. Similarly, load ratio is also the ratio of the new feeder loading to the old feeder loading, ok.

Now, if you keep this load ratio same, load ratio 1; that means, I want to keep this number of loads same for new feeder which is having of 11 kV sorry 33 kV, similar to this 11 kV network, then as if you can increase the length of the feeder to 9 times as compared to the 11 kV network, ok.

So, keeping this load ratio same; load ratio same means I will keep the same loading, same amount of load for 11 kV network and upgraded 33 kV network. Under that condition, you can have the flexibility to increase the feeder length to the 9 times of the actual length of the feeder.

Similarly, if we keep the distance ratio constant, meaning that I will keep the length of the feeder constant for both the cases, one is 11 kV another is 33 kV, ok, and in that condition I can supply 9 times more load as compared to the 11 kV network in 33 kV network, ok. So, this is a thumb rule. One should understand how this voltage upgradation will impact this whole circuit operation, ok.

So, with this I will stop today.

Thank you.