Operation and Planning of Power Distribution Systems

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Power Distribution Networks: A brief overview
Lecture - 08
Brief overview of power distribution substation

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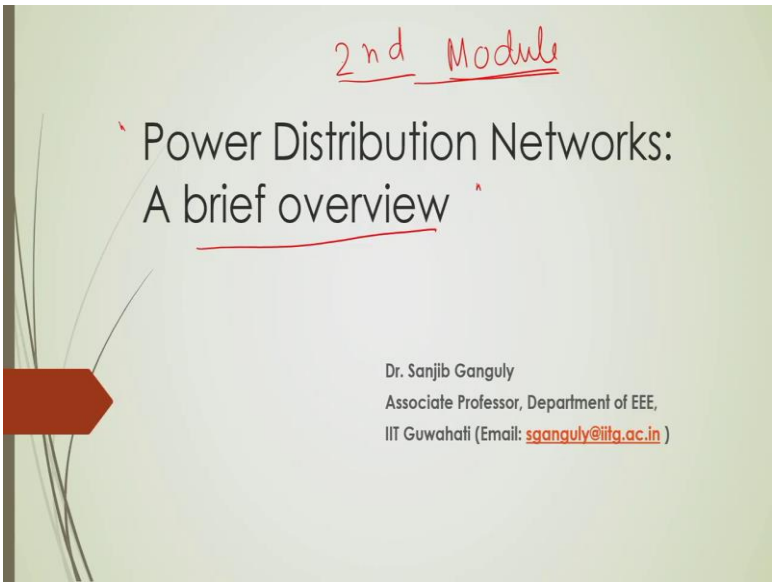

This is the 2nd module for this course and in this module, I will discuss a brief overview on power distribution networks; I will discuss different features of power distribution networks and also I will discuss some sort of analytical approaches for analyzing this operational features of power distribution networks, ok.

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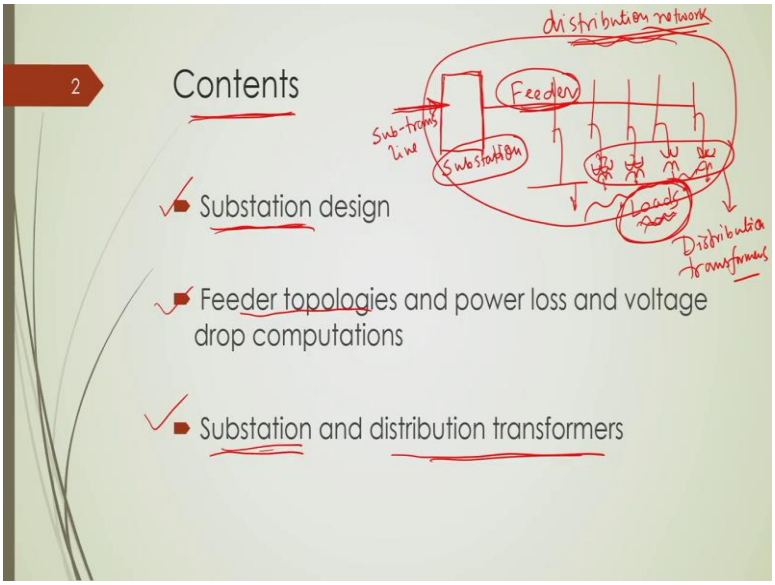

So, the contents of this particular module are, I will basically start with this substation ok, which is the first or starting point of a power distribution system; as you know our power distribution system starts from the substation. So, this substation you can either represent in a block or sometimes it is represented by a single bus.

So, this is our substation and this substation is connected usually with sub-transmission line; they feed power to the substation. So, power is fed to the substation by sub-transmission line, but we will not go for the discussion of the sub-transmission line.

We will start straight away from this substation and then we have this feeder which feeds the load to the customers, ok. So, in my first module, I discuss this loads what is electrical load, how can we model this load, what are the different features we have all these things.

Here we discuss this you know suppose these are all loads, ok. So, this are loads; these are laterals and these are our loads; so these all arrows are representing loads. Now, how this loads, what is load and how it can vary with time and what sort of indices or parameters we have to analyze this load already we discussed this.

Now, we will discuss this part that, every basic overview of distribution networks. So, this distribution networks consist of many things and these loads are one of the stakeholders, ok. But apart from that, distribution network consists of substations; they consist of feeders and also they consist of this; because these loads they are getting power from a distribution transformer.

So, I will also discuss this distribution transformers. So, beyond every node, there is a distribution transformer from which this will alternatively represent this transformer like this. So, these are basically distribution transformers. So, if we go for this discussion of primary distribution network, firstly we need to discuss the substation, then this feeder topologies and feeder structure and also we need to discuss bit on distribution transformer and also substation transformer.

So, these are the different stakeholders of a typical power distribution network. Loads are also important stakeholders, but the detailed discussions of load characteristics and load management already is done in the module 1, ok.

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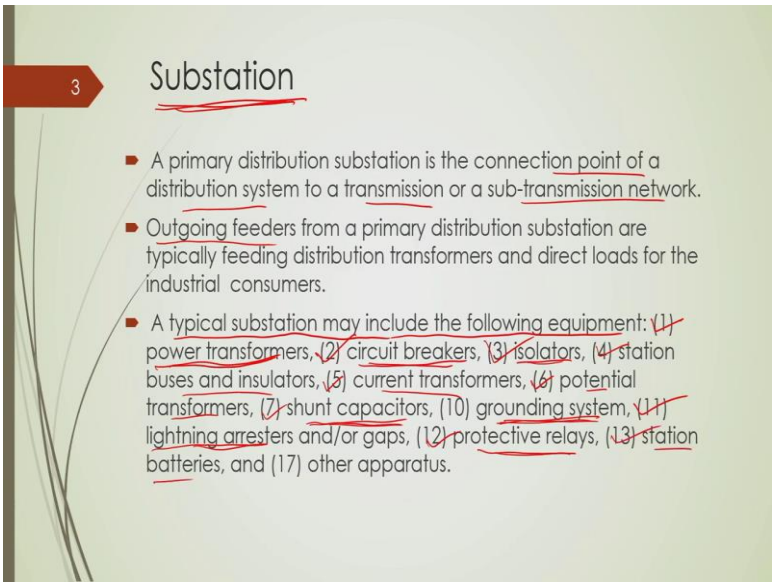

Let us start with the substation. Substation as I said, it is the connection point of a distribution system to a transmission or sub-transmission network, ok. So, from a sub-transmission network, we have this distribution substation from where our primary distribution network starts. We have many outgoing feeders as I discussed and we will try to analyze here in this particular module, the operational aspect of those feeders, ok.

But in this particular lecture, I will focus on typical substation design ok; typical different aspect or different equipment associated with a typical substation, ok. So, a substation consists of different electrical apparatus, which includes power transformer which is major stakeholder of a substation; then circuit breaker, see circuit breakers are

basically like switches that we use and they can operate all means during loading conditions and they can be also interrupted during faulty conditions.

So, you might be knowing like miniature circuit breaker which is there in your home. Then, we have isolators; then we have station buses and insulators; we have current transformers, potential transformers; these are for measuring and protection purposes. We also have shunt capacitor for providing reactive power compensator; I will come to this shunt capacitor in one of my modules.

Then, we will have this grounding system which is very very important for a particular substation; if you visit a substation, you will see that this grounding system which is an important thing and it is typically made of a very huge spaces underground, ok.

And then, we have this lightning arresters for protection against lightening; we have protective relays for protection purposes; we have batteries for emergency purposes and for providing the DC supply during particularly during emergency condition and also there are many other apparatus.

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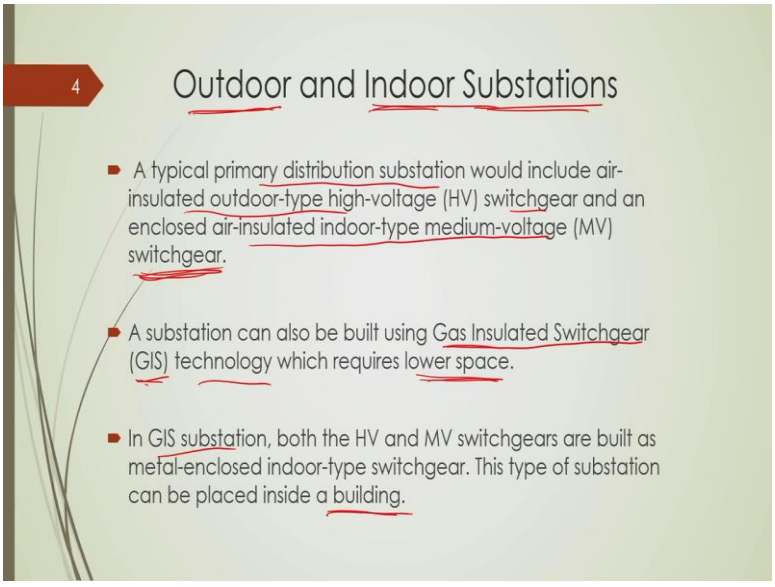

Now, there are two types of substations; one is called outdoor substation; one another is called indoor substation, ok. And typically a primary substation or distribution substation has a high voltage air insulated outdoor type of switchgear and enclosed air insulated indoor type of switchgear.

What is the purpose of this switchgear? Here all sort of switchings are done, ok. And there are some substations which are indoor substation and they are gas insulated switchgear. They use gas insulated or GIS technology ok, which will also require less space; they are very compact, ok. And that is why this GIS substation can be installed inside a building and which are normally used in a huge populated or dense populated metropolitan cities, ok.

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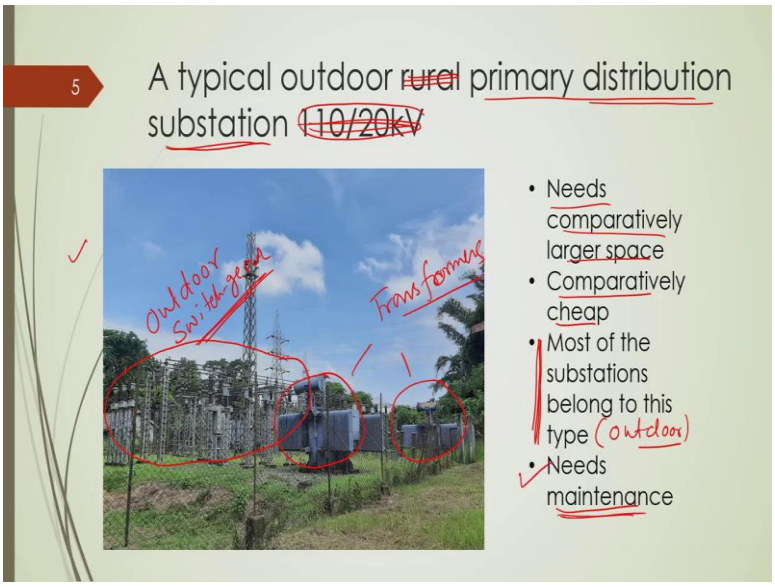

This is typical outdoor primary distribution substation; this is not rural; this is a typical primary distribution substation and its capacities also somewhat different, but it can have different capacity; for India normally this primary substation, primary feeder voltage level is 11 kV. So, this substation basically steps down this sub-transmission voltage level to the 11 kV primary distribution voltage level.

Now, this photo, these picture is basically substation of IIT Guwahati campus, ok. So, we have an outdoor distribution substation inside our campus, which has the transformers and also which has the outdoor switchgears. So, these are the transformers and this is outdoor switchgear, where all sort of switching operation is done.

And this outdoor switch gear needs comparatively large space; you can look at this; it is located in the open air; so it needs comparatively large space; it is comparatively cheaper, as well compared to this indoor substation. And most of the substations in the

world are of this sort of outdoor type; that this sort of outdoor substation, ok. And because it is exposed to the air, it needs considerable maintenance.

And if you look, if you visit any sort of such kind of substation, you will see there are some personnel; there are some engineers, who are responsible for the maintenance of all these equipment we have in a substation, which include this transformers, which include the switch gear; inside this switch gear there are many insulators, so this insulators need to be periodically cleaned and they need to be operated, ok. Similarly, you know all this insulators and all these systems need to be periodically maintained, ok.

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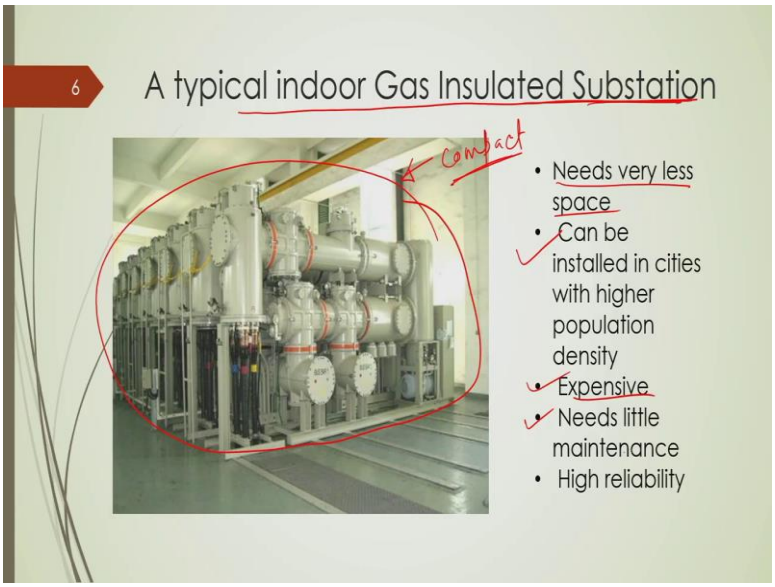

Now, this is a typical indoor gas insulated substation, which use GIS technology. This is a very compact technology, which can be installed in a small building. So, that is why they need very less space; they can be installed in a densely populated cities and that is why you know they are expensive, ok. And they are maintenance free; they need little maintenance and they are of high reliability.

So, they do not get exposed to the atmosphere. So, there is no problem if there is a huge storm or severe rain; there is no such problem. So, they are somewhat maintenance free, as well. Now, the question is in order to design a primary distribution network, the first question is, where do we place a substation, which is very important ok, where do we place a substation.

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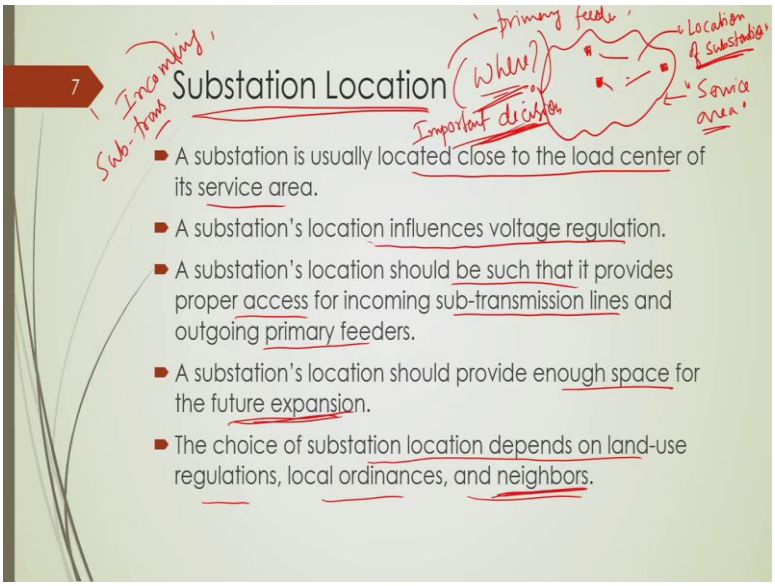

So, substation location is an important factor; usually it is located close to the load center in a service area, ok. Suppose this is the arbitrarily service area for a utility, then utility needs to choose that where it should place the substation, inside the center or near to the periphery or where.

So, the location of substation itself is basically a important decision,; it is an important decision and often it is basically decided based upon certain optimization approach; where do we place a substation, inside a service area, at exactly center of the service area, or at the periphery or where?

So, where should we place this substation? It is an important decision. So, this is an important decision, where is an important decision, ok. Now, apart from that what would be the capacity of the substation that is also an important decision; basically substation capacity depends upon that how many transformers you have and what are the capacities of the individual transformers, ok.

So, substation location influences also voltage regulations. So, if you have a substation far away located; if you have a substation located far away from a particular load or customers, then these customers will definitely experience some problem, some voltage problem ok, particularly during peak load condition.

Also substation location should be such that it provides proper access to the incoming sub-transmission line and outgoing primary feeders; because as you know substation is basically connected; it connects incomings, incoming sub transmission line to the primary feeder. So, it is a junction between these two so that you should have a proper access that, you can bring; you should locate a substation such that you bring these sub-transmission lines and also you can take your primary feeders out, ok. And this will not be possible if you have some important facilities at the neighborhood of this substation.

For example, if there is a school complex or may be a college; so bringing a high voltage sub-transmission line there would be difficult. So, sometimes even though we decide this location of substation or we decide this decision that, where should we place substation through an optimization problem or by solving by an optimization problem; the optimal locations may not be a feasible location, because it needs a lot of social issues to take care.

So, substation location should provide enough space also for future expansion; because as you know for meeting this future load demand, we need to extend the substation capacity and in order to do so, we need to have proper expansion.

The choice of substation location also depends on various activities like land regulations, local ordinance and neighbors. Neighbor is an important factor; so we cannot arbitrarily place it anywhere, where with some you know local important buildings are situated.

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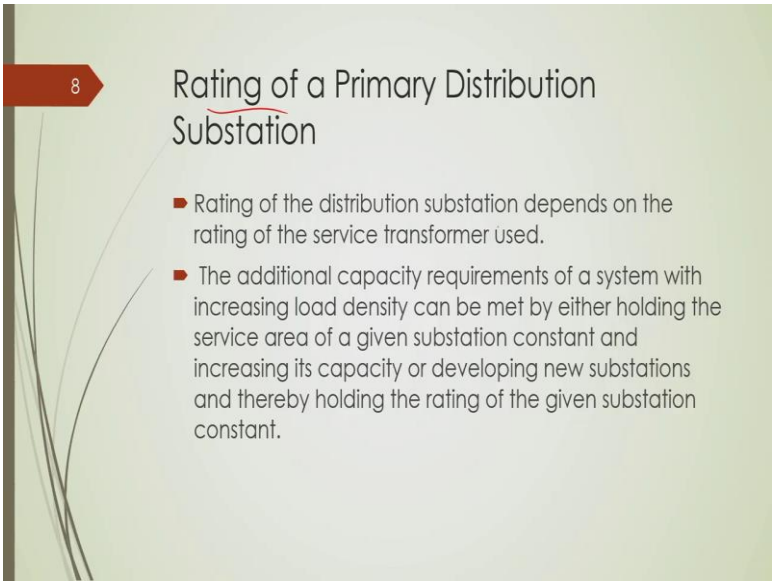

Now, rating of the substation depends, as I said, based upon the service transformer that you have; but off-course, some additional capacity requirement, you can increase the capacity of the substation in future by installing additional transformers.

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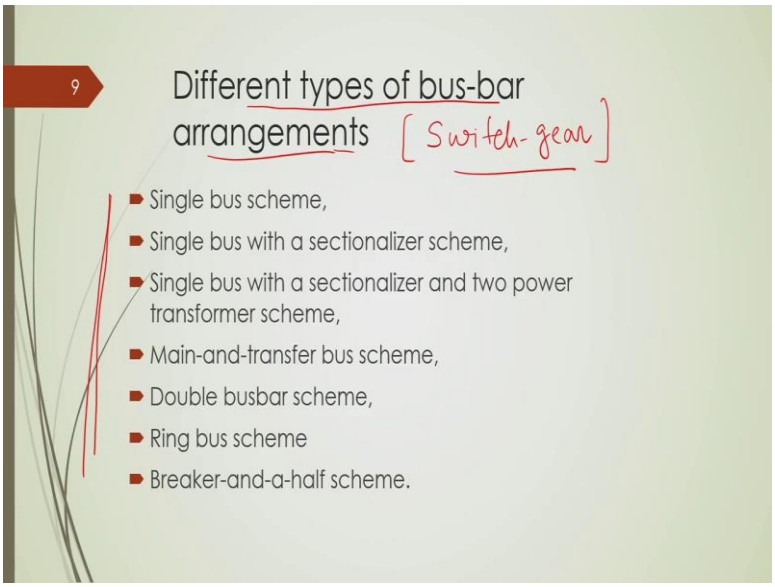

These are the different types of bus bar arrangement, ok. So, we have different bus bar scheme to design a substations, which is very important; that how do you do? This is basically an arrangement for designing the switch gear or this bus bar arrangement or switch gear arrangement we can call, switch gear arrangement and there are different schemes.

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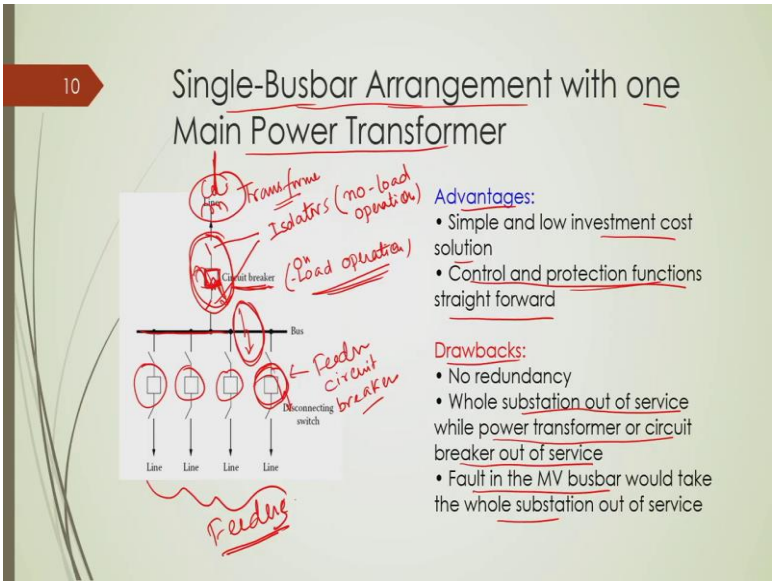

So, these schemes I will discuss here. So, first one is single bus bar arrangement scheme with one power transformer. So, here we have one power transformer. So, this is the transformer; this is inside the substation and beyond that we have this sub-transmission line. Then this symbol is basically, representing a circuit breaker, ok. As I said the main role of a circuit breaker like a switch; it can make the circuit energized and also it will be used to trip the circuit during any fault event, ok.

Now, with a circuit breaker, you have these switches, additional switches; these switches are called isolators, isolators. And these isolators are also switches; circuit breakers are also switches; then what is the difference? Circuit breakers can be operated at load conditions.

So, on load operation is possible; on load operation is possible. But isolators are always operated at no load condition; so no load operation. So, they are no-load operative switch and circuit breakers can be on-load operative switch.

And this arrangement is done in such a way that, we have one circuit breaker along with two isolators, ok. Now, what is the need of these isolators? when we have this circuit breakers? These isolators are basically used to isolate the circuit breaker from both side of the circuit so that if you have any need of maintenance of that particular circuit breaker, you can do so easily, ok.

So, this is the basic function of the isolator, ok. Now, for this particular scheme you can see; it is simple scheme with low investment cost solutions; it controls the protection function straight forward because why it is very simple scheme.

Because we have only one circuit breaker, which is connected to the transformer to this particular bus, from which these feeders are coming in, so, these are feeders; these are feeders, distribution feeders and they will go to this individual distribution transformer and they are connected with them.

So, here in this figure, we have four different feeders. Now, why it is so simple? Because you know we have one circuit breaker for this transformer to be connected with this particular bus ok, from which we have this four feeders coming out. Now, compared to the other schemes which I will discuss later on, this scheme is very simple and straight forward, ok.

And that is why its control and protection function is also straight forward. But the drawback is that, if there is any fault anywhere at this bus or at the circuit breaker, these circuit breakers are feeder circuit breaker, this circuit breaker are feeder circuit breaker, feeder circuit breaker.

So, if there is any fault in any of these devices, either in the bus or the circuit breaker or this feeder circuit breaker, total system will go out ok; not total system, if this fault occurs in this particular feeder, then of course these feeders will not be affected. But if there is a fault in this particular bus and this feeder, this circuit breaker, then total system will go out, total system will go out.

So, substation will be out of service, while power transformer or circuit breaker will be out of service or there is a fault in this bus bar. So, if there is a fault either in this transformer or this circuit breaker or in the bus happens, then total system will be out.

Thank you.