Power System Protection
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Lecture 01
Faults in Power System

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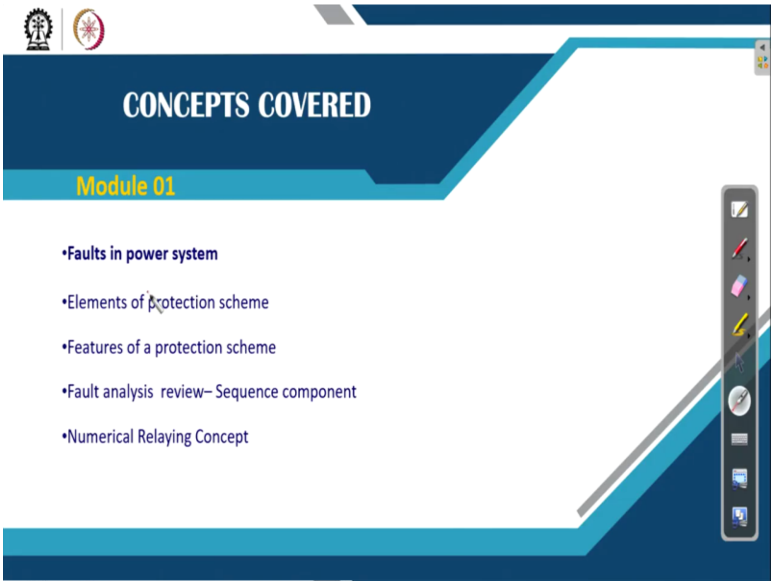

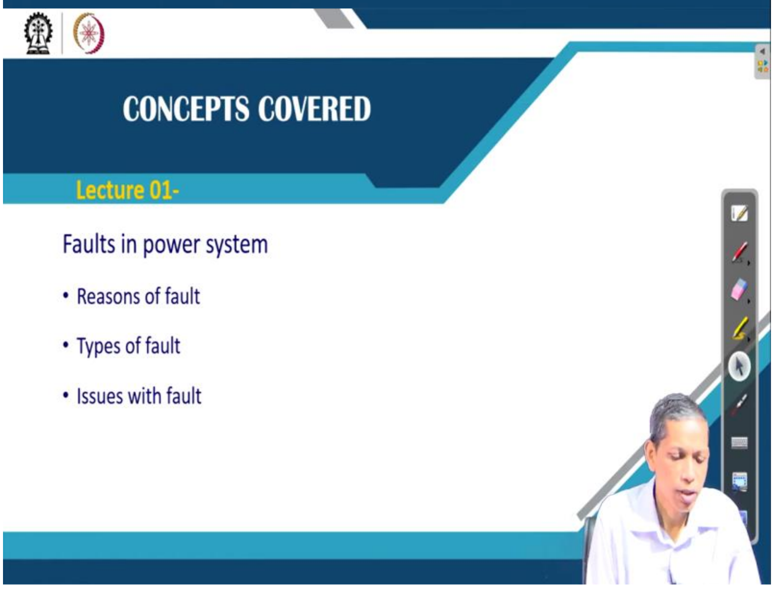

Welcome to the Power System Protection course. In the first module we will have the introduction on the concept of numerical relaying. In module 1, we will have few things on faults in power system. And then the elements of protection scheme, features of a protection scheme. We will have the fault analysis where we will take a review on this. This will help in designing the different power system schemes.

And then in overall, we will have a picture on the concept of numerical relaying. In first lecture, we will bring the concept of a power system, how a fault happens to be there, what are the different reasons therein. And we will classify the different faults. And then what are the related issues in power system operation to manage the fault.

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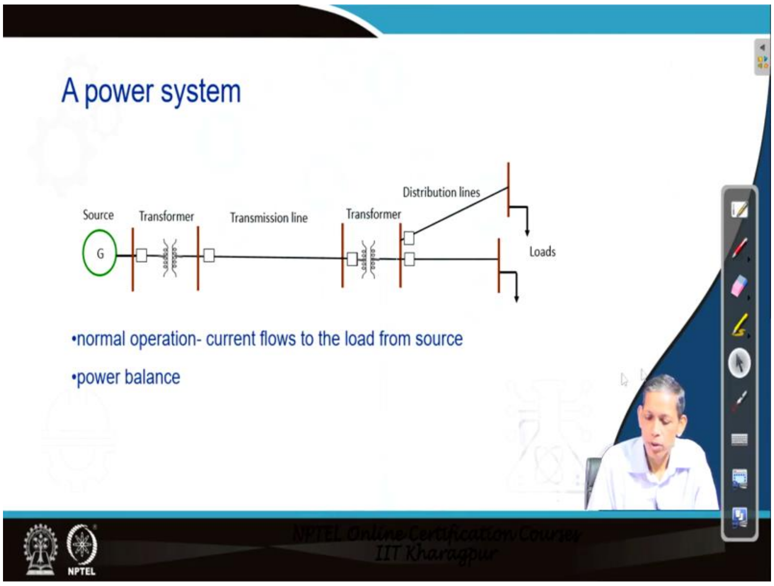

Let us consider a simple power system having a generator, a transformer, a transmission line and then distribution line feeding load connecting through a transformer. So in this case, most of the time in normal operation, current flows from the generator to the load. Now in case of a failure of any of the component in this system, there is disruption in power supply to the load and that creates problem in the reliability aspect of the supply system.

Such a scenario maybe we can think of a tree falling on a transmission line which results in a circuit to the ground and that leads to the fault current flowing from the generator to the ground through that path. That becomes an unwanted path for the current and that leads to problem in providing the power supply to the loads. So that becomes again challenging situation.

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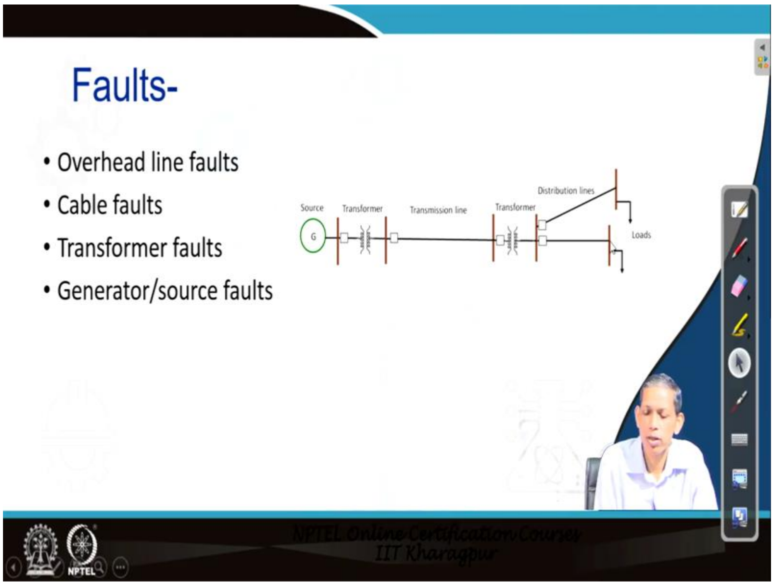

Now such a situation we call it faults. And this fault can be in any of the elements in the system. It can be overhead line. And if we have different cables connected in a systems, it can be in the cable also. Like cable joints are more vulnerable and also faults can be in any of the transformer.

It may be due to the insulation failure or it may be due to transformer problem during a lightening conditions and so. Faults can be internal to the generator also. So whenever a fault happens to be there in any of the system element, then that leads to disruption in power supply to the load, which is not desirable.

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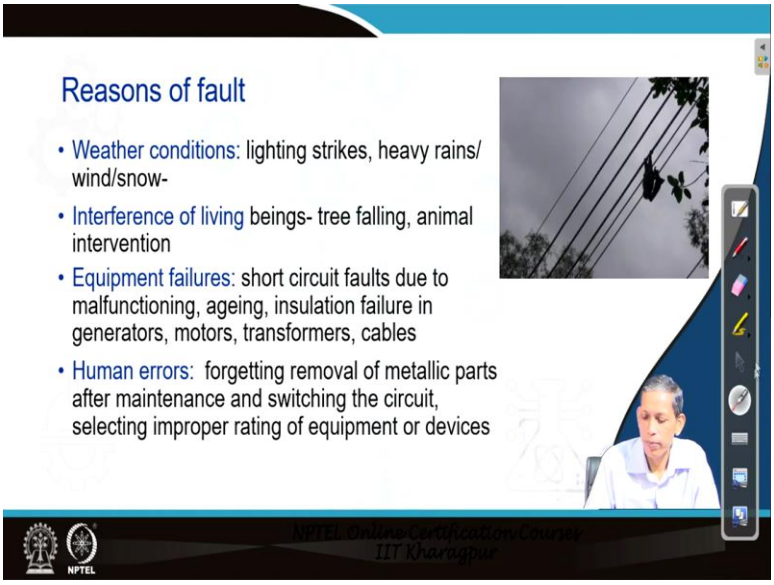

There are different reasons for fault. Let us categorize them. In that case, weather condition, bad weather condition like say a storm comes in an area snatches live power lines; that results in a fault situation, lightning strikes and then the lightning arrestor functions that becomes a momentary short circuit. Heavy rain condition or so may result in deterioration of the insulators and may lead to faults in the system. Another category about it, living beings interfering to the power supply system.

Tree falling like a bat here touching the phased conductors and momentarily that becomes a short circuit. And then the system does not have a longer period of intervention there. We can have equipment failures like the different generators, transformers due to ageing or insulation degradation; this failure may be due to internal or external agency like lightening or any other thing.

Human errors, in this case maintenance crew people sometimes forget removal of metallic parts from the phase conductors and then if we restore the supply, then that becomes resulting in dead short circuit. Further, you can have improper rating of any equipment or device and that may result in, you can say that fault or circuit in a system. During such situations the current may be pretty high and resulting in detrimental situation.

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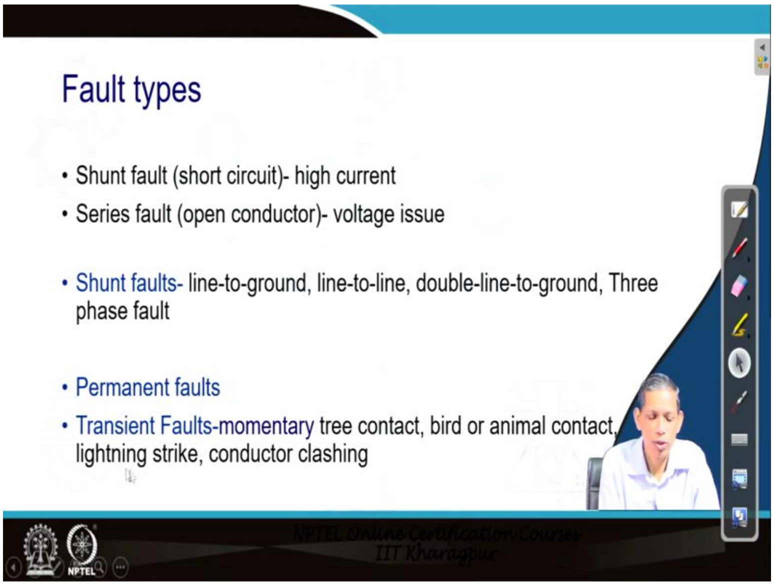

Faults can be categorized into different types. In one way, we can call shunt fault or series fault. Shunt fault is, the short circuited path or unwanted path through which the current flows. That results in very high current, but series faults are the situation of open conductor like a cable joint having problem. At the joint point there is an opening. So therefore, that results in, you can say that no available voltage supply to the load end.

Shunt faults can be further classified into line-to-ground or called phase-to-ground fault, can be line-to-line fault, can be double-line-to-ground fault, three phase fault. Furthermore, three phase fault involved with ground. So, shunt faults can be also simply categorized into fault involved with ground and fault not involving ground.

Permanent faults, we can categorize into permanent faults, a dead circuit. There is another category called transient faults and like a tree touching and then coming back, and a bird or animal intervention that becomes a momentary circuit in the system. Lightning strikes, and that is a nothing but a period of microsecond only.

And during that time the lightning arrester functions and again the system becomes normal. But sometimes the lightning strikes and the insulators gets damaged. That result in the permanent fault. So an event we can say that maybe resulting into a permanent fault or temporary fault. Most of the faults are however transitory in nature and they in particular over a line. But in case of a cable, faults are permanent in nature.

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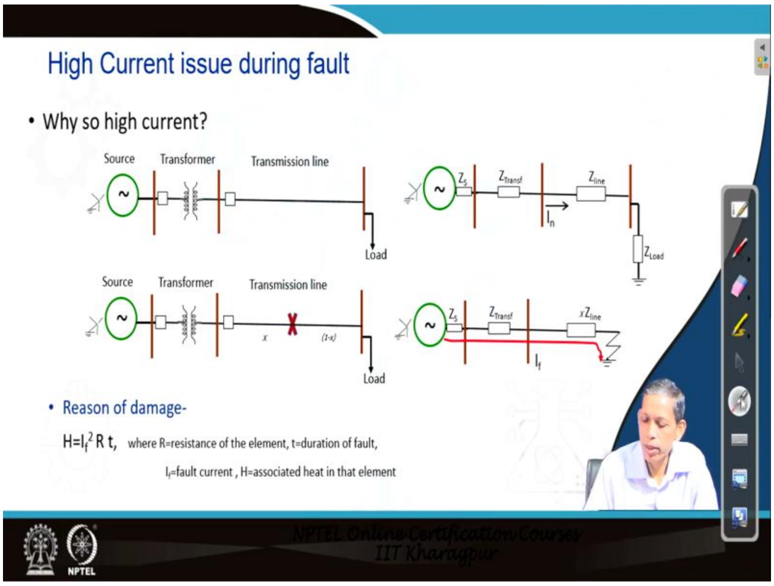

Now coming to the issues related to fault, so we say that shunt fault results in large current. Series fault results in voltage issue. So our focus here henceforth onward will be on large current issue, that is shunt fault issue. In case of shunt fault, we see that the current becomes pretty high. Let us come to a system representing a small system like this. A source, a transformer connecting a transmission line.

So for this case the normal power flow will be from the source to the load and we have taken the equivalent of this system in terms of this corresponding Thevenin voltage and the impedance. Impedances like source impedance, transformer impedance and the Z line and the Z load. In this case, the corresponding load current will be encountering only Z_S, Z_{Line}, and the Z_{Load}.

Typically, we see that the Z_{Load} is much higher than the Z_{Line} or Z_{Transf} or Z_S from the consideration of the efficiency, consideration of the voltage regulation and so. In that case, this normal current I_n will be controlled by this summation of these impedances Z_S, $Z_{Transf,}$ Z_{Line} and Z_{load}, where Z_{load} is much higher than the other impedances.

Now next we will consider that the fault happens to be there in the transmission line due to the free falling or so. Then the corresponding current which will be flowing to this path, to becomes like this. Let us say we designate it by If. So in this case, the corresponding fall encounters Zs, $Z_{Transf,}$ and the xZ_{Line}.

And we can say that the corresponding impedance of this path is much smaller than what we see in case of earlier case, which is the normal current flows. So this leads to the I_f becomes several times as compared to the I_n and that leads to the large current issue in case of the fault.

So such a large current is detrimental to the system and may lead to damage of different system elements in the power system. And the reason of damage, the factors which leads to damage is governed by this relation, $H=I_f^2 Rt$. Where, I_f is the fault current which is several times that of the normal current. R is the resistance of the element which we are concerned and t is the duration of the fault. Now you see here, the more the H, the heat in that element, the possibility of damage of that element becomes more and more. So we see here that the time is also a factor here. More the time in fault events in the system, the associated heat becomes more and the possibility of damage of that equipment becomes more and more.

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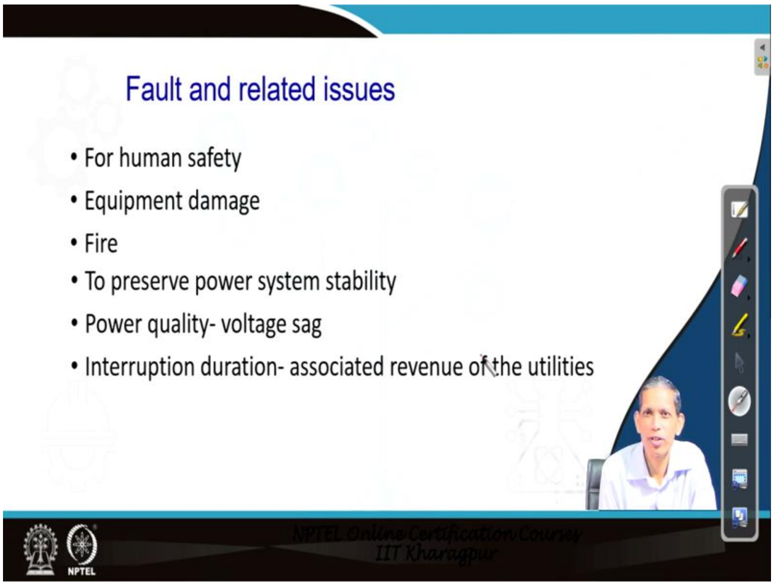

So we see that this fault leads to large current and there is a possibility of damage in the system. It is not only limited to that, it has other aspects also. Like a livewire falling on the ground leads to ground voltage pretty high, and then that has implications to the human safety. And this equipment damage as we have already addressed due to the large current in that path, so that leads to damage of the equipment.

But it has associated financial implications and also a replacement of any component like transformers or so takes lot of time. Not only that in case of a large current and associated heat like in a substation we can think of a transformer having in trouble, transformer contains inflammable oil and that may lead to fire and this we can say that very peculiar situations to handle with, to handle.

So it has associated fire implications into that system also. The other issues which comes into, it is stability. We know that in normal situation there is a balance between power of the generating units to the load, but in case of a fault; because the output power decreases that from the any alternator, so thereby, the input power remaining constant during that period of fault. Then there is mismatch of power between input power to the generating power and that leads to speeding of the rotor.

And that creates the problem with the stability. If the fault remains for longer period and more than the critical clearing time, then system becomes unstable. So that the time becomes pretty important in case of that system. And note that in case of higher and higher voltage the level of fault current becomes more and more and therefore the corresponding time left, time available for we can say that clearing the fault, time less than critical clearing time becomes pretty challenging.

In case of a fault in any area or any element, the voltage at that point dips substantially and so also in that area a different buses also we will see, different lower magnitude of voltage. And that leads to functional, that leads to problem to the functionality of the different loads. So that becomes a power quality challenge and therefore, we can think that the smaller the period of the fault in the system, the better it is.

The interruption due to the fault in the system, any element that affects the functionality of the load also has revenue implications to the utilities. So lesser the number of faults in the system better it is.

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So in a power system operational perspective if we see into the fault, faults are inevitable. Yes, we can reduce the number of faults in a system by routine maintenance, preventive maintenance, for overhead line you can have vegetation issue that can be cleared in advance and so. But still faults are inevitable and which leads to life and disruption in power supply and also loss of property and so.

So that acts for a provision of adequate protection system, protection scheme for the reliable operation of power system and therefore, a protection scheme is an integral part of any power system. But we from the earlier discussion we can conclude that the power system, the faults in the power system must be cleared as early as possible to avoid possible damage, risk with life and stability perspective as well as from the power quality perspective.

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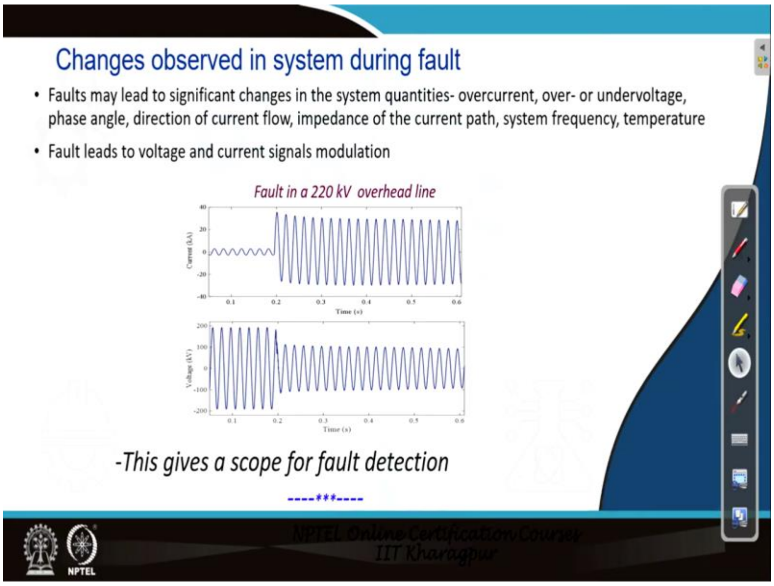

In case of a fault, what the changes you observe in the system is that the fault may lead to large amount of current also dip in voltage. Further changes are being noticed in terms of phase angle between voltage, current, direction of current flow in a grid, impedance of the current path becomes smaller. System frequency may change and temperature of different elements at a given instant of time may also change.

Fault leads to voltage and current signals, significant changes in there. Like consider a case, a 220 kV actual system in the grid. There is a fault in a 220 kV system. If we see this current pattern here, this is what normal functioning of the system and fault happens to be there at around 0.2 second. And the current increases significantly. So this is clear, you can say that the fault continues for this long duration of time.

And at the same time if you observe the voltage in the 220 kV systems, this is about the pre-fault situation, normal situation of voltage. Now whenever a fault happens to be there, the voltage goes down at that bus. And this shows clearly that there is a change in current, significant change in current during the fault and also change in voltage is also of significance.

So this gives a scope to identity the fault from the voltage, current signals. So in overall, in this lecture, we see that faults particularly short circuit faults leads to large amount of current and are detrimental to the system. If they remain for longer period of time, it leads to instability issue also, issue on the life safety, issue with damages to different elements and also to the voltage sag and other challenges.

So the fault should be cleared as early as possible. The faulted part should be isolated from the rest of the system so that the other part of the system remains intact and functions in as usual manner. So in the next class, we will see the perspective of fault, the mitigation strategy to fault which is a protection scheme. So what are the different basic elements in a protection scheme and what are the fundamental features such a protection scheme should have for a successful mitigation of any fault. Thank you.