Power System Protection
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Elements and Features of Protection Scheme
Lecture 02

Welcome, today in this session we will talk on the lecture 2, the introductory part.

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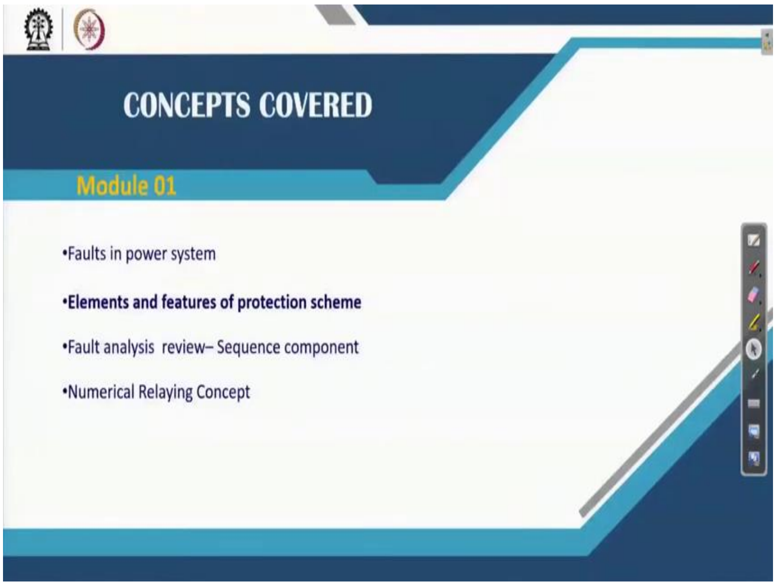

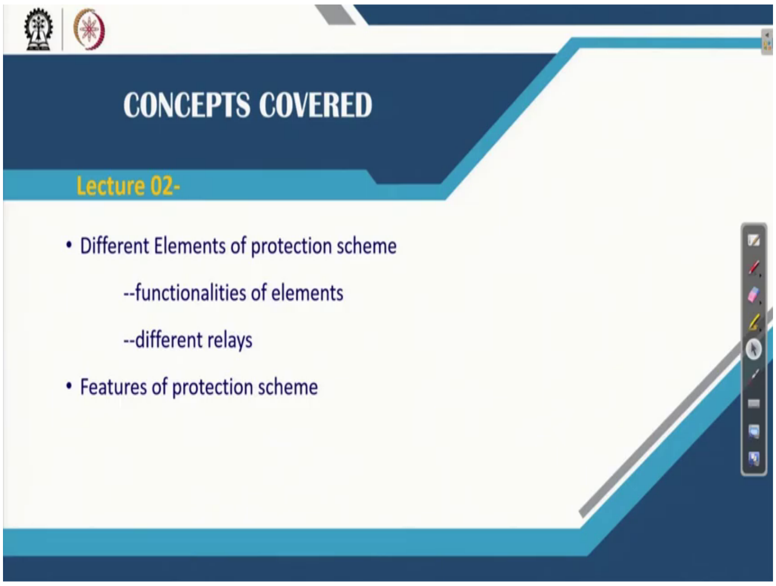

In this, we will talk on Elements and Features of Protection Scheme specifically we will address on the functionalities of different elements in their protection scheme, different relaying principles and their features on different protection schemes.

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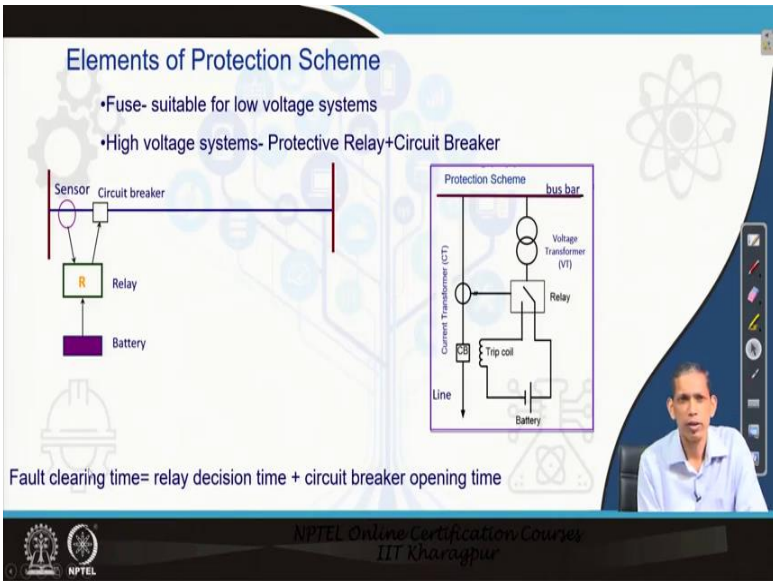

So, we know the usage of fuse that we use in our house wiring also so whenever there is a fault or a short circuit in the circuit, then the current becomes high and the fuse is blown out. So, in that case the faulted part becomes isolated from the rest and the rest of the circuit remains intact. Repair the faulted portion and then replace the fuse that circuit also can be restored.

Now, fuse is very comprehensive and easy to and a very cost effective solution for protection but it has limitation in terms of current interrupting capability and therefore it is not suitable for high voltage applications. In that case, circuit breaker and relays are being used, the tasks of circuit breaker is to isolate the circuit it provides a physical isolation of the faulted circuit.

Relay makes the command to the circuit breaker to be opened as and when required. Come to this circuit two buses connected through a transmission line and this line is to be protected by this protection arrangement. Here, we have the circuit breakers which is to be open in case of fault at any point in the line, this circuit breaker is being actuated by this relay. The relay takes signals of the system through this sensor and the relay and the circuit breaker are being actuated by this battery, the battery provides the required power to this arrangement.

Going into details of the circuit, if you see here this relay take signals from the voltage transformer, otherwise called as potential transformer and also from current transformer. So, using these signals the relay makes a decision regarding the fault in the line or not, and if decision is a trip decision, then this path will be closed. So once that is so, the battery supply the corresponding current to the trip coil and the trip coil opens the circuit breaker and thereby the corresponding fault can be successfully intervened. In this arrangement we see that there are two important components, the relay and the circuit breaker, the relay takes time for a decision, actuates the circuit breaker, and the circuit breaker opens. So in terms of time we have two aspects; relay decision time and the circuit breaker opening time.

Therefore, the time for fault clearing, from fault inception till the clearance of the fault equals to relay decision time plus the circuit breaker opening time. So, by a faster decision, we can clear the fault early. The circuit breaker also can intervene the fault at earlier, then also we can add the advantage of the clearing the fault early.

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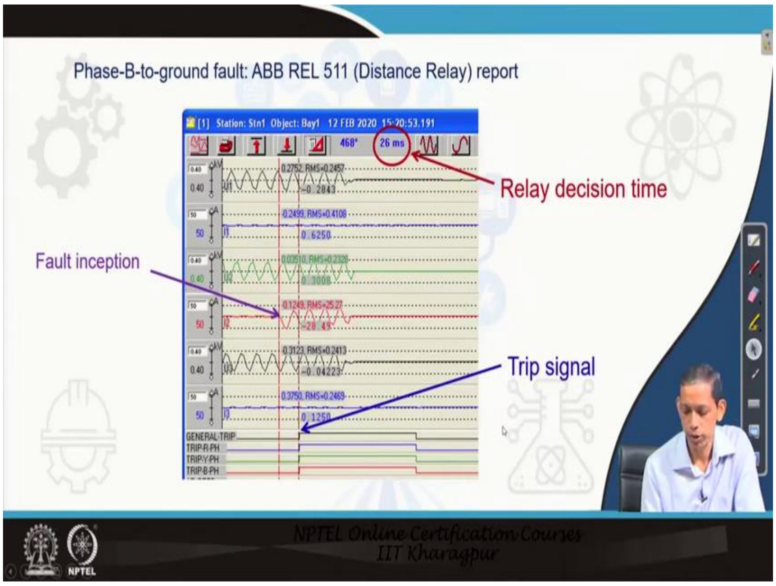

Now come to an example, on this aspect, so in a system there is a phase-B-to-ground fault and a relay that is numerical relay records the event. See in this case U_1, U_2 and U_3 are the voltages for the RYB phases, where I_1, I_2, I_3 are the corresponding currents. Now if you see the plots corresponding to I_1, I_2 and I_3, phase B current suddenly jumps up to a very high magnitude, this means that this is the inception of the fault and the fault continues.

Now this you see here that the relay trips. The trip signal of the relay is being actuated here, it becomes high and from the fault inception to the trip signal this time elapse you can say 26 millisecond. So the relay decision time from fault inceptions to the trip signal generation comes out to be 26 millisecond (ms) here for this 50 Hz system application.

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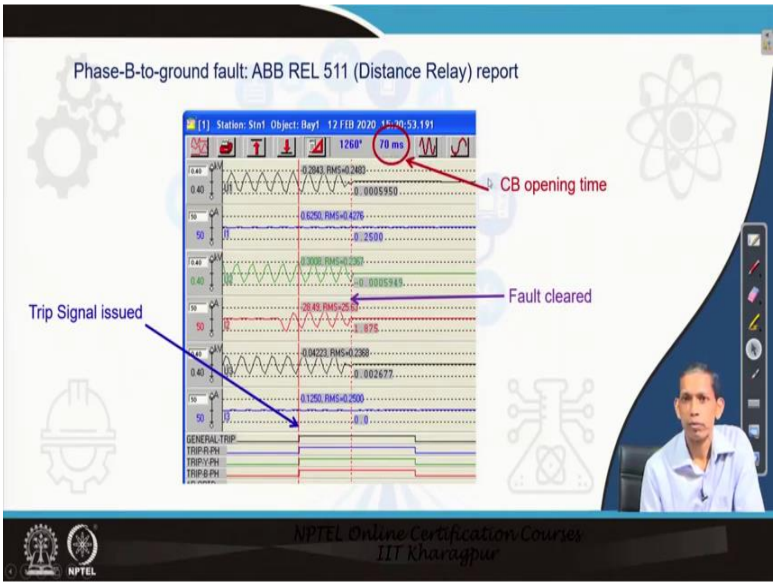

Now, following the trip signal, the circuit breaker starts opening and after sometime it successfully intervenes the fault. So you see here in that phase B where the fault current was high, now suddenly comes out to be 0, the fault is successfully intervened. Now following that you see here in the phase voltages also, the voltages also comes out to be 0, therefore the circuit breaker has successfully isolated the faulted part. So, this fault means the trip, trip circuit, relay trip command till the circuit breaker opening this is nothing but the circuit breaker opening time and that is what I can say in this case comes out to 70 ms time.

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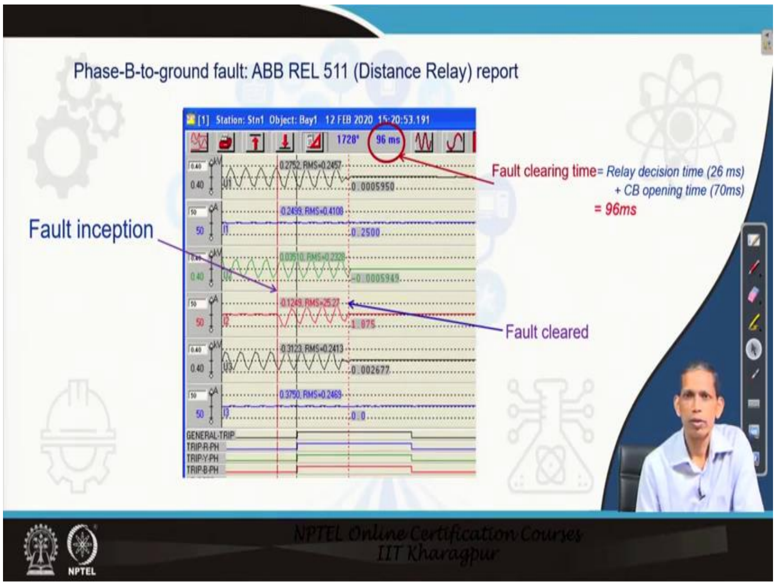

So in total we see from fault inception till the opening of the circuit breaker successfully. This total time is nothing but fault clearing time and the fault clearing time in this case comes out to be 26 ms for the relay decision time and 70 ms for the circuit breaker opening time: total is 96 ms. This 96 ms for the 50 Hz system, where each cycle consists of 20 ms, consequently 5 cycles corresponds to 100 millisecond, comes out to be less than 5 cycle period of time.

So we see that in this case that the fault clearing time is controlled by the relay decision time and the circuit breaker opening time. Circuit breaker gives us physical isolation, mechanical functioning actuated by the relay, so that takes 2-3 cycles and the rest period you can say that in general it taken by the relay decision time.

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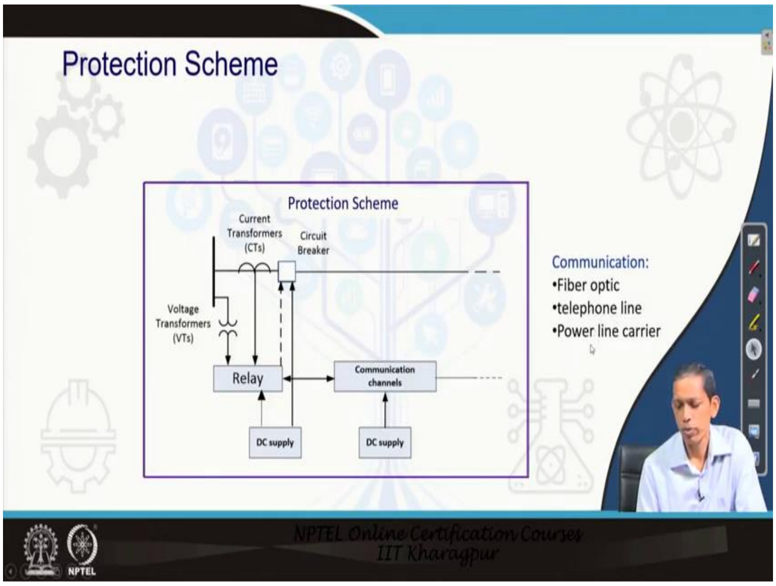

Going more into this protection scheme, we have breaker, we have the relay actuated by the DC supply we have sensors voltage transformers and the current transformers. In addition to that, today numerical relays are having a facility to communicate the information to other relays or any substation devices or they can also receive information from other relays also to have a better decision making for the protection.

So, this communication helps in total system protections perspective much better, and that is why the decision process becomes more improved one. The different communication facilities that can be incorporated in such a protection scheme can be dedicated fibre optic, can be telephone line or also can be a power line carrier communication based approach or so.

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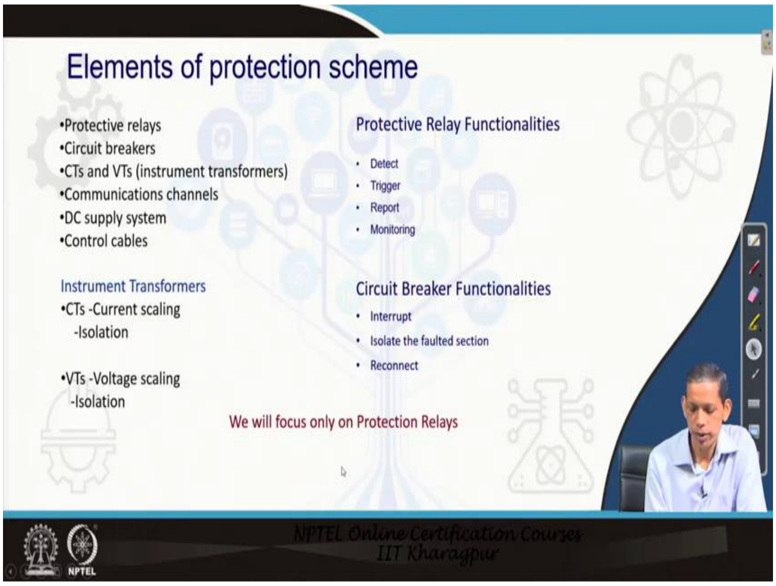

So, we say that there are different elements in a protection schemes like relays, breaker, sensors, communication channel, DC supply systems and the control cables connecting to such devices in a protection scheme. The instrument transformer are the sensors, basically we have two types that are current transformers and the voltage transformer. Current transformers scale down the current to a suitable level because relay is a small signal device to make it more cost-effective and this provides you can say that a magnetic isolation from the high voltage system; voltage transformer similar to that scale down the voltage to a lower voltage level compatible to the relay and then also we can say that a galvanic isolation is being provided by the VT from the high voltage system.

The different functionalities of these elements in the protection system, the relay detects the fault, makes a decision, triggers the trip circuit which commands the circuit breaker, it can store information on the fault aspect voltage current samples and it can have a reporting which can be very useful for the fault diagnosis and further analysis following a fault. It can continuously monitor voltage current and other things which can be also useful in metering purpose also. Similarly, circuit breaker interrupts the faulted path successfully where current can be very high during that period of time. It isolates the faulted section, it provides a physical isolation. So thereby I can say that the damage and the safety perspective are being can be addressed.

Circuit breaker can be it needs to be reconnected to restore that line after the fault being cleared, so circuit breakers makes and breaks a circuit. There are different types of circuit breakers available like air brake, SF6 sulphur hexafluoride circuit breaker, vacuum circuit breaker depending upon the medium of insulation. However, in this course will only confined to protective relays and its different application perspective.

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These elements combinely provide a protection scheme, a protection scheme has different features which need to be looked into for a reliable operation of the protection scheme. The first important point is the reliability, it must be reliable, the protection scheme must be reliable otherwise at times it may fail, which implies a dangerous situation and which will lead to destruction in a system. It should be accurate, say a protection scheme for one line, takes a decision for a fault in another line, so that is a malfunction situation inaccurate or improper you can say that decision situation, so that is undesirable.

Therefore, a protection system should be as accurate as possible. Fastness, speed is essential otherwise, may lead to damage. Any system any element may fail at times, so protection scheme for a power system may also fail, so in that case you can see that the whole protection scheme should have a backup arrangement also.

Power system is dynamic, system condition changes always. The relay should adapt to that system condition and during all such situations or so it should function accurately, properly reliably. Today's numerical relays have this capability of recording data for further analysis, it can integrate other relays in the system or in the substation through dedicated communication system. A relay should draw minimum power from the battery, the burden to this sensors: CTs and PTs should be as low as possible; otherwise, it will be a lossy system.

As compared to the power system cost, the cost of the protection scheme is concern from implementation point of view, relay engineers are also concerned about maintenance of such protection scheme, calibration, setting aspect; it should be as simple as possible. Technology changes and with numerical technology, computer based technology is changing very fast, so the life cycle of the relay is a concern for the decision on the protection schemes to be implemented for an application in power system.

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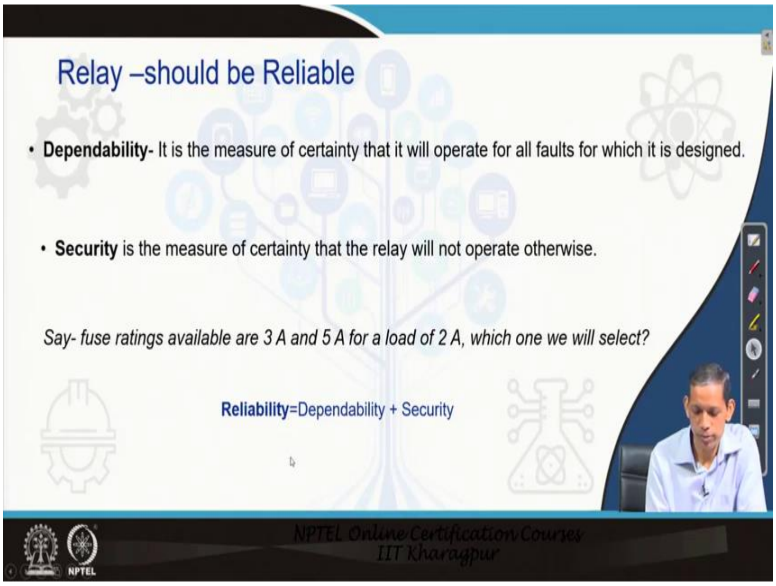

Relay should be reliable, reliable implies two aspects, first one is on dependability, it is a measure of certainty that relay operates for all faults for which it is designed, that implies whenever a fault is there in a line, a corresponding relay must take a decision; otherwise, the fault will continue which will be detrimental. The other aspect is the security that is a measure of certainty that the relay will not operate otherwise; the relay which is protecting a line should not operate during normal loading condition or if the fault is beyond the line.

So, it means that, say for example to clarify on this: a 2 Ampere (A) load is there full load, that is a device load draws 2 A full load current and we have to two ratings of fuse: 3 Ampere or 5 ampere. Now we have to select out of these two, say for 3 A, if we select 3 A, for this load any fault happens to be there, the fuse will take care, but if there will be momentary overload in this circuit, then there is a chance that this 3 A fuse will be blown out which is undesirable.

Now, if you select 5 A, then that undesirable tripping for overload can be avoided better way, but with 5 A many faults which will have a lesser amount of current, not significant amount of current may not be detected and fuse may not be blow out, so that becomes a challenging. So, in this perspective when you pick up 3 A, dependability is high, but security is less.

When you pick up 5 A security is high, dependability is low, but reliability is a combination of dependability and security. In general, protection schemes are more inclined towards dependability; however, with today's numerical technology the overall reliability can be enhanced and when you make a decision on which protection scheme is to be incorporated in a system, the reliability is one of the important aspects on the decision process.

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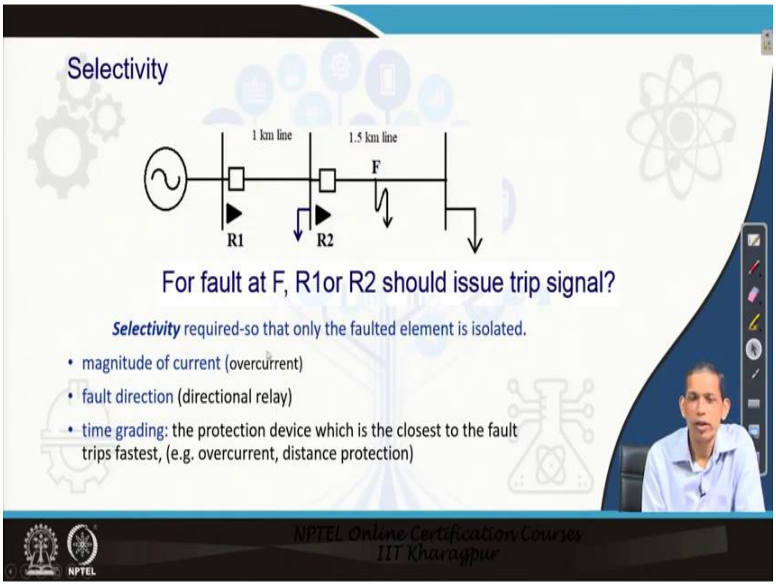

Now, on other aspects of protection scheme, let us see this circuit, substation source, we have two sections or line. And let us say that a fault happens to be at point F. Now, in this case, there is a clear mandate here that the relay should make a decision and trip the breaker so that this section can be isolated and the rest of the portions including this load can be made from this substation.

So, it means that for the fault at F the current through this R1 and R2 are will be both same; therefore, you can say that it becomes a challenge to R1 and R2 that which one should act first, but as you see the requirement is that R2 should act first for this case before the R1. So there is a perspective we call selectivity, it required with that the faulted element is isolated successfully and also reliably.

This selectivity you can say that is an important factor and this is being addressed by different features of a protection scheme. Magnitude of current, magnitude of current when the line sections becomes longer then the faults in different sections can be easily identified from the magnitude of current, but if the lines sections becomes smaller, like this: 1 kilometre here and 1.5 kilometre here. Then for fault in this section or fault in this sections will lead to similar level of current; therefore, we can say that distinction through simple magnitude may not be possible.

Faults can be discriminated also, whether the fault is with the left or to the right or call it upstream or downstream and that can be done through fault direction or through the directional relay. There is another option also, that is by time grading in case of overcurrent link principle or so. That this the relay R2 here should act fast as compared to the relay R1 for the fault at F. So, we can have a time grading principle embedded into the relay decision process then you can have a better selectivity solutions in that perspective

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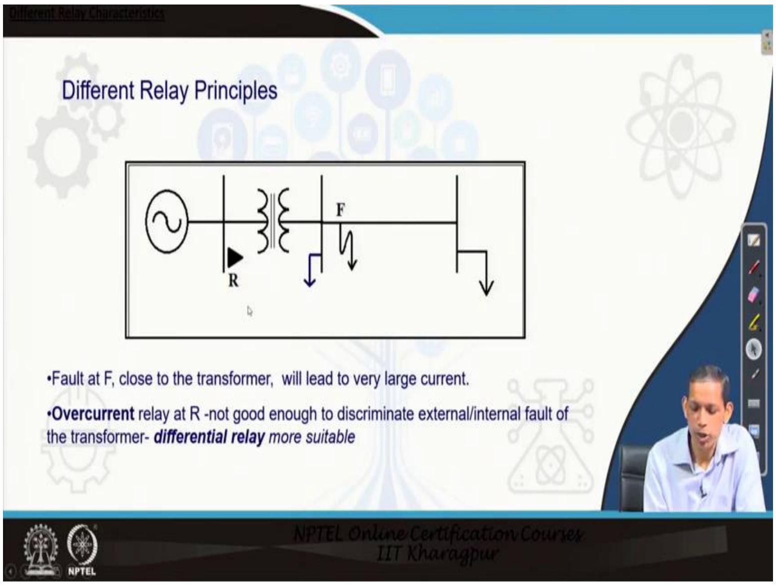

The other things that, see this circuit here, we have a transformer connecting to a source or substation and we have a line section. This fault happens to be closed to the transformer and we have relay protecting the transformer at R, then the relay using only the over current principle may not be able to distinguish whether the fault is in the inside the transformer or beyond the transformer.

So that means that we require more different principles to have a better protection for the different elements and in this case for transformer a better protection scheme can be a differential relay principle using sensors at the both the sides of the element. So, what you see is that different elements and different systems may be requiring different relaying principles and, the fault behaviour of different elements in the systems may be different and their functionality may be different. Therefore, we need different relaying principle for better protection of the power system elements.

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In this perspective, we have numerous relaying principles available and based on that we have different relay available; time overcurrent relay, instantaneous overcurrent relay, directional overcurrent relay, distance relay, differential relay, frequency relay, under frequency relay, under frequency relaying and so many others. These relays are we can say have a device number like here, 51 for time overcurrent relay and 50 for instantaneous overcurrent relay, 21 for distance relay and so. These are in terms of IEEE standard and they are being widely used by the protection engineers.

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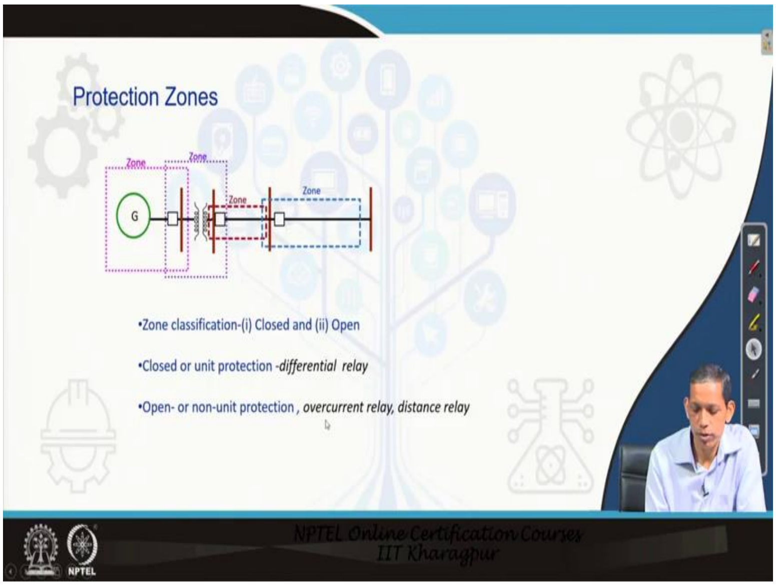

We have a different areas, sections allocated to different protection schemes, like the generator portion is being protected by an arrangement of the protection, the transformer being protected by another one, and these line sections can be protected by different protection schemes. So these protection regions are divided into different parts; you can say that as different zones, but note that these zones must be over lapping because not an inch of the section in the power system should be left out from the protection. Otherwise if a fault happens to be there, and the fault will continue and that will be detrimental to the system.

In this perspective the different zones can be classified into two categories, closed type or open type. Closed type is having sensors at both the ends; like differential relay and they are also called as unit protection scheme. Non-unit protection type otherwise also known as open type or open zone; you can say from the perspective that they can have sensor set only one side like the relaying principle applications to overcurrent and distance relay.

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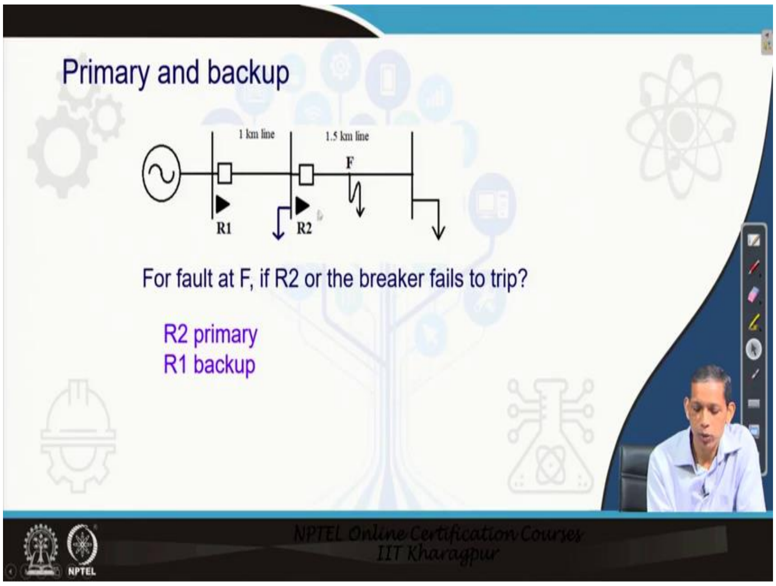

Now see this network, source or substation, feeding to two line sections and a fault in the second line. In this case R2 relay should actuate the breaker, and let us think of a situation when the relay R2 fails, or the breaker fails to open, or the communication between R2 and the breaker or the battery you can say that supply fails at this point. That means that the fault will continue and that will lead to damage in the system and issue that life security and so.

Therefore, in case of failure of any protection schemes there must be a backup, so in this case of fault we can say that R2 is the primary and the backup should be provided by R1 and the corresponding circuit breaker arrangement perspective.

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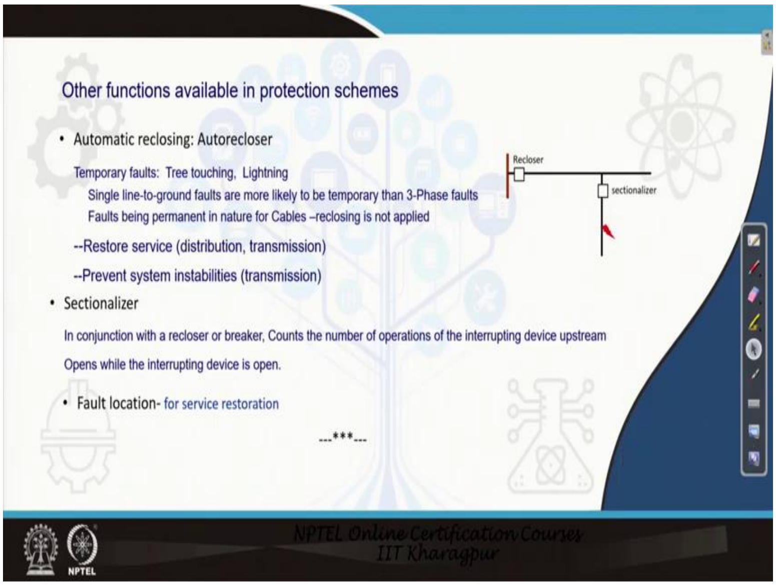

The other functions which are available in protection schemes, like you see here in this example we have a fault in this lateral and then we have a recloser arrangement. Now what the recloser does is that because in an overhead line most of the faults are transitory in nature they remain for some time and they vanish.

Therefore, the recloser what it does that, whenever it finds a fault, it opens and again recloses after sometime; by that time if the corresponding fault has vanished, the full system supply can be restored automatically. So this kind of trials it makes two- three times, and by that time if the fault has vanished, then the system has been completely restored.

And if the fault is permanent, then recloser finally opens the circuit and thereby whole system can be without supply. The advantage of the recloser is that because most of the faults are transitory in nature therefore the restoration becomes automatic in most of the cases and also it helps in stability or so. But recloser is meaningful, purposeful because most of the transitory faults are single to line ground faults but if faults happens to be three phase faults, then they are mostly permanent.

So therefore, the recloser should able to distinguish these two. Further, in case of cable faults, those are permanent in nature so recloser should not be used in that case. The other thing you can say that if the fault being permanent and in that case the recloser opens; then the whole network supply is being affected.

Now, what we see here if the fault is permanent and if we add a sectionalizer which counts the number of reclosing, number of operation of the recloser and if the corresponding current through this branch is high, then this sectionalizer opens the circuit when the recloser was in the open condition that successfully isolates this portion. Thereby we can say that rest of the network still remains intact. In addition to the protection scheme this also helps in the fault location perspective which can pinpoint that where the fault has occurred and accordingly you can say that the maintenance crew can restore the service as early as possible.

So, through this lesson, we see the different elements of a protection scheme, and their features; also selectivity, reliability, zones of protection and so in terms of that. In the next lesson, we will address on the review on the fault analysis which will be very useful in developing the different relaying principle or so. Thank you.