Industrial Safety Engineering
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Lecture - 18
Common Cause Cut Sets

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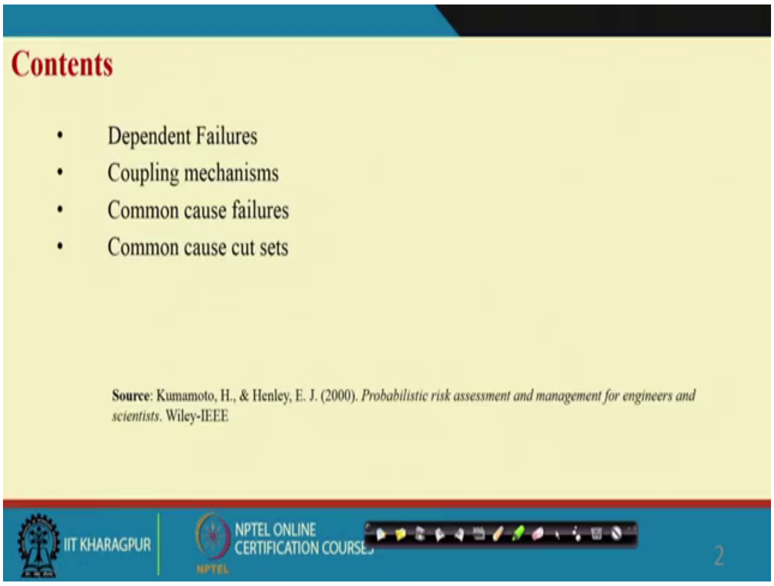

Hello, welcome, today we will discuss Common Cause Cut Sets. So, we will start with dependent failures then coupling mechanisms, common cause failures and common cause cut sets with reference to fault tree analysis.

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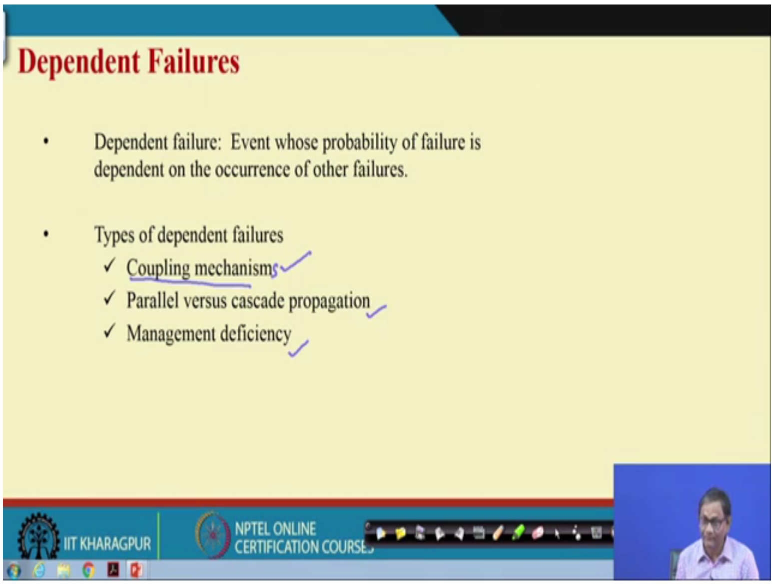

So, what is dependent failure? Event whose probability of failure is dependent on the occurrence of other failures, that is dependent failure, ok. So, we will discuss dependent failure and you will find out the causes of dependent failures and the types of dependent failures including the causes. So, you see that there are three types based on coupling mechanisms, parallel versus cascade propagation and management deficiency.

So, I have discussed parallel verses cascade propagation earlier in one lecture. Related to coupling mechanism we have not discussed. And management deficiency as you know, the management ultimately controls the work organization and, and starting from the day to day operation to big decisions everything are management oriented. So, any failure in management policy, management actions ultimately leads to failure of several components or several subsystem or even signal systems.

So, that is why the deficiency of management is always leading to failure of several components and with reference to fault tree that several basic events and then these are basically coming under dependent failure. So, we will be discussing next the coupling mechanism and then we will go for the common cause cut sets.

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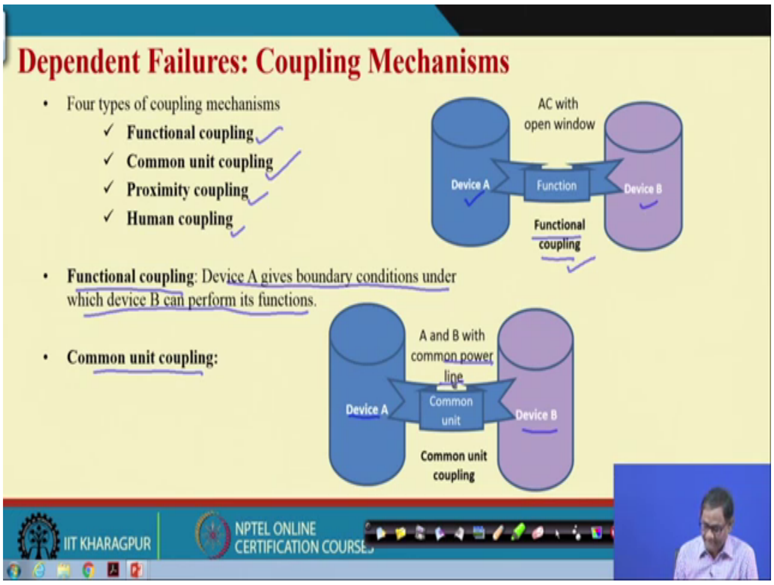

So, there are four types of coupling mechanism. Before starting this let me tell you that the lecture today we are presenting it is it has been taken from the book Probabilistic Risk Assessment by Kumamoto and Henley and almost all the slides, I prepared taking materials from that book. So, the students are therefore, requested to go through that book, the relevant portion and get understand that what is coupling mechanism. So, now under coupling mechanism there are functional coupling, common unit coupling, proximity coupling and human coupling.

Now, let us understand what is the functional coupling? Suppose, there are two devices which basically works when the window is for example, the AC with open window and this window is closed. Now, if AC is window is open then AC will not work. So, under such conditions that device A and device B will not work. In that case we can say that it is functional coupling; that means, the work of AC is required to will work only when the open window is closed.

So, such things are functional coupling, the device A gives boundary condition under which device B perform its function. So, what is the boundary function for A? That window must be close then only AC will work. So, that type of coupling is known as functional coupling. So, you may find out situations where similar case, suppose two device that one device will give the boundary condition for the other to work, such situations will be known as functional coupling. For example, A make create boundaries of device B to work or B device B may create boundary of A to work. So, either of the two will ultimately talks about the functional company. Now, second one is common unit coupling. So, here what will happen? Here, because of this coupling mechanism in the first case functional coupling mechanism. So, failure of one device will depend on the others.

Now, common unit coupling, common unit coupling means suppose there are two unit device A and devise B. Now, both are connected to a common power line. So, what will happen if the power line disconnected or power line switch, power supply is switched off or power supply is disconnected? So, both the unit will fail to work. So; that means, they are coupled with a common power line which is low that is why if power is not available things will not work.

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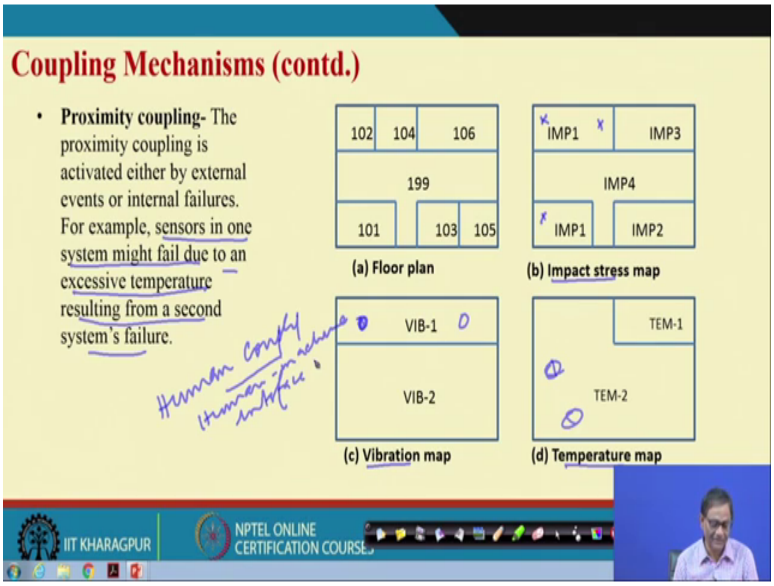

Now, come to the Proximity coupling. What is proximity coupling? Proximity coupling means that it sometime, it is basically related to the zone of influence. For example, you just think of this floor plan. So, there are few rooms and you see that we have given several maps, one is impact stress map, vibration map, temperature map. Now, these are the based on the floor plan, you see that this is the area or location where impact 1 is, is working, here impact 3, impact 4, impact 1, impact 2 like this. Similarly, this is the floor vibration 1 is affecting, this floor vibration type 2 is affecting and similarly that different temperature at this locations.

Now, come to the situation suppose there are different equipments and which are operating in this floor and if the equipment is impact susceptible then what will happen be impact 1, let it be. So, then the equipment suppose one equipment here another one, here another one here. So, because of this proximity to the impact source similarly, because of the proximity to the vibration or because of the proximity to the temperature, what will happen? Whatever the equipment which are susceptible, susceptible to this kind of stresses like the impact vibration or temperature. So, they will fail in the presence of this stresses.

So, then this is basically known as proximity coupling. The equipment fails because they are affected or exposed to particular type of stresses. So, the proximity coupling is activated either by external or internal failures. For example, sensors in one system might fail due to an excessive temperature resulting from a second system failure, ok. So, what does it mean? Suppose, here is an equipment sensor which is vibration dependent, if there is vibration the sensor will fail. Suppose there is another equipment which causes vibration and as a result this sensor is affected by that vibration, VIB vibration source one. So, this kind of coupling is known as proximity coupling.

So, when you develop fault tree and then you must understand that what are the equipment which are, which are affected by such common causes. So, another one is human coupling. So, as you know that human coupling basically human requires to do many things like operator operates machines, maintenance worker must do proper maintenance. So, that since there are human machine interface and it may so happen that human machine interface and it may so happen that, that one person is looking after 2 3 machines and if he makes mistake ultimately all the machines will be, will be under failure conditions.

So, that human coupling that is not is known as human coupling. So; that means, there are four kinds of coupling we have discussed, one is functional coupling, another one is your common unit coupling, then third one is proximity coupling and fourth one is human coupling. So, this coupling ultimately leads to dependent failures.

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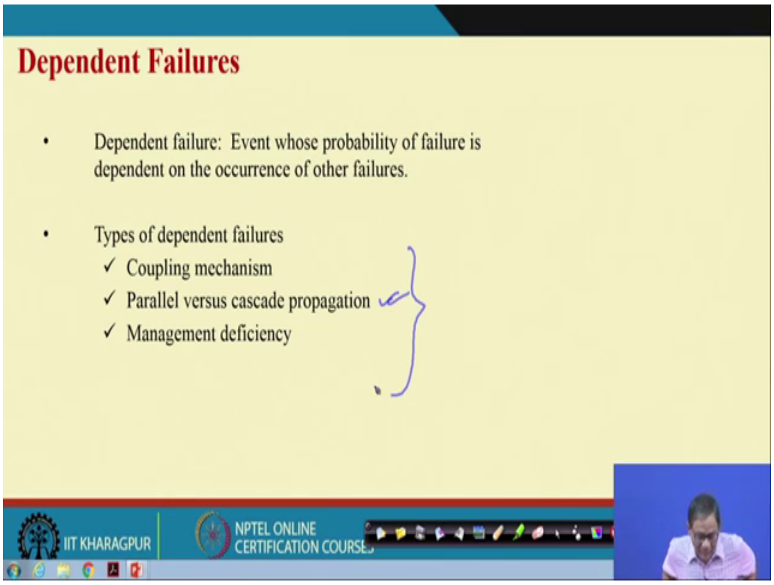

In addition what we have discussed, in addition you have seen that parallel or cascade propagation any unwanted accidents or incident what taken place, so that may propagate with cascading effects. So, what will happen, that also lead to failure of several equipment or components for such system. And management deficiency is another one, so, which is mostly hidden or latent in nature. But this, all this most of the time leads to common unit failure, common cause failures.

So, be careful when you are, you are developing fault tree and quantifying fault tree and as such you know that fault tree is one of the part of the bow tie. So, when you, you are interested to quantify the accident paths in bow tie. So, that time the common cause failures are very - very important and that has to be taken care of.

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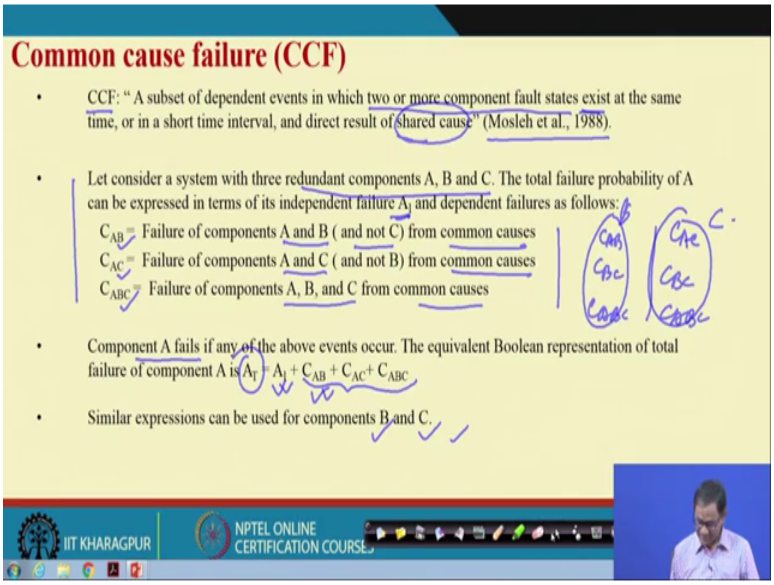

So, we will now discuss little elaborately, what is common cause failure? So, the definition given by Mosleh et al 1988; what is CCF? That common cause failure a subset of dependent events in which two or more component fault states exists, two or more components fault states exist at the same time or in short interval of time and direct result of shared cause.

So, whether it is because of coupling problem or it is because of your cascade or proposition problem or because of management deficiency problem. But when two or more component faults taken place given a shared cause, so, that is common cause. Example, you just think of three redundant component A B C, the total failure of probability A can be expressed in terms of their independent failure and dependent failures. So, for example, independent failure is definitely that A 1, probability of A 1, if you write in terms of probability. What are the dependents, say there are three components so; obviously, one will be A B, another will be A C and A B C is related to component A.

Because A and B that common failure, AC common failure and A B C, three component failure simultaneously. So, that is what is written as, that failure of component A and B, but not C from common mode shared cause, A C common cause, A B C from common cause, ok. Suppose, if you want to do this for B, then it will be C A B C B C, C A B C. If you want to do it for C then C A C, C B C, C A B C; so, these are the basically common failures, common failure events. So, then what will be the component as total failure. So, in terms of Boolean expression, you can write that the total failure of A will be the, the independent failure, common cause failures. So, you can do similar expression for B, similar expression for C, ok. So, this is: what is our definition of common cause failure.

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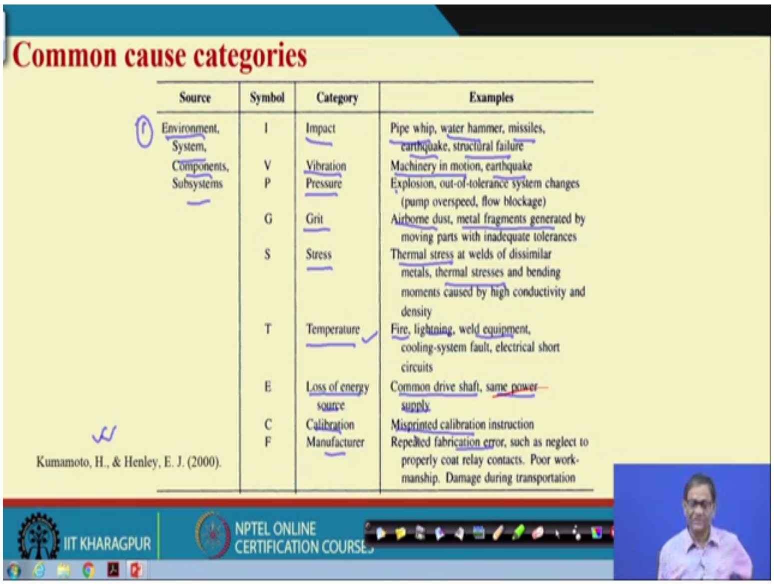

Now, what we will do? We will see what are the common cause categories in industrial situation or as such in any application, you will find out that there are different sources of common causes. In this slide and in the next slide, we will see all those sources, because if you know the sources you will be careful while developing fault tree and bow tie.

So, what we see, what is there? That is the, first one is your environment system component and subsystems and you see the symbol as well as the category. The categories are impact, vibration, pressure, grit, stress, temperature, loss of energy source, calibration, manufacturer. So, all are basically the source of common cause. So, there are some examples like impact, pipe, whip, water, hammer, missiles, earthquake structural failure, all those leads to impact category. Suppose, component or equipment susceptible all those impacts will be, will be failed simultaneously. So, that leads to common cause failure of those equipment or component.

Similarly, vibration machinery in motion will create vibration earthquake will vibration, pressure, explosion out of tolerance system changes pump, over-speed, etcetera, grit, airborne, dust metal fragments generated by moving parts with inadequate tolerances.

So, similarly stress, thermal stress, thermal stress and bending moments, temperature, fire lighting, welding equipment, cooling system fault, electrical short circuit, all those lead to temperature. Loss of energy sources common drive shaft same power supply or common power supply that also lead to your loss of energy source. Calibration you understand that misprinted calibration and manufacturer repeated fabrication error such as neglect to properly coat relay contacts poor workmanship and etcetera.

So, these are the things which are available in this book also. And please go through because these are the information which you require together before doing any kind of fault tree or bow tie analysis. The examples are just to give you an, an hint that what are, what do mean by impact or what do you mean by the different common cause categories. So, there may be more examples, there can be more categories, if you found please, note it down.

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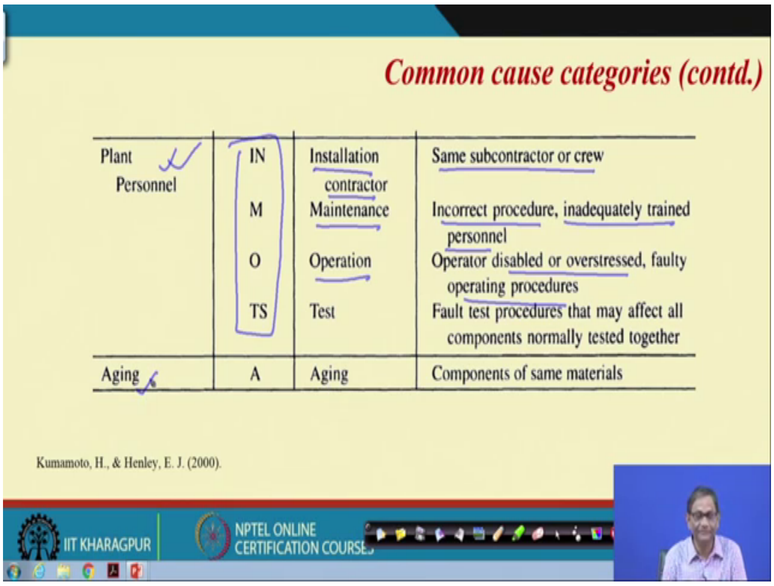

Then plant personnel will also lead to common causes like installation contractor, maintenance and operation so; that means, the human coupling will be a problematic one under this situation. So, human may create problem and then ultimately that will lead to common cause. For example, installation contractors same contractor or crew so and, and incompetent contractor let it be, always do some kind of mistake. So, that will lead to failures. Incorrect procedure maintenance, incorrect procedure inadequately trained personnel, if you follow incorrect procedure, so, you will follow it for several identical components which are which will be used in a particular systems. And then that incorrect maintenance ultimately leads to failure of all those components which, where maintained. Similarly, operation operator disabled or overstressed faulty operating procedure and test. So, these are the things which are basically operator plant personnel dependent or human dependent.

Then another one is basically aging which basically component of same materials. So, there are identical parts, so, made of same material. And what will happen, their life span will be also similar, it is quite likely that at a certain period of time all them will fail. So, that also leads to common cause failure. So, that is known as aging, ok. So, these are the sources of common cause failure. We explained that what are the different categories? One is environment system component, subsystem that is one source, second source personnel and third one is the aging, it is a component itself.

If you can relate to that P S C concept, that primary secondary and command you will, you have seen there that that failure, that aging is basically related to the design part, primary failure part. Plant personnel we have explained there that they will cause problem. And at the same time let us discuss with a fault tree example.

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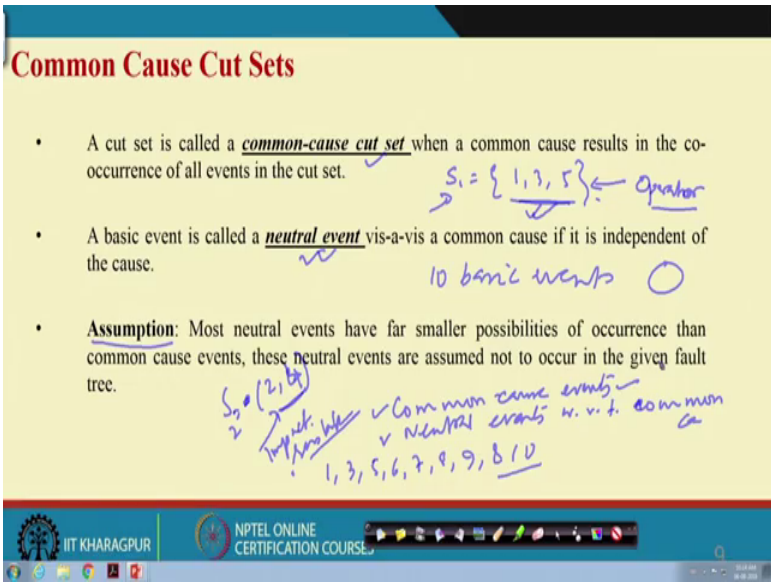

So, how can you develop cut sets? So, in order to develop common cause cut sets, you please, remember few things. One is the common cause cut set and neutral event and common cause event. So, a cut set is called a common cause cut sets, when common cause result in the co occurrence of all event in the cut set. So, our, our topic is common cause cut set. What is common cause cut set? You, you already know what is cut set, suppose S 1 is a cut sets and it is basically 1 3 and 5, these are the basic events.

So, we will say this is common cause cut set, when common cause result in co occurrence of all events in the cut sets. So, may there may be one common cause, let it be the vibration which result in failure of all those three, that is 1 3 and 5 these components and the event 1 and there and 5, these 3 events occur because of that vibration or it may be your operator error. So, operator or it may be impact or it may be something else, maybe aging also. So, when you get a cut set and where all the events are caused by a common cause, then this is known as common cause cut set.

So, a we will talk about neutral event, a basic event is called a neutral event vis a vis a common cause event, if it is independent of the cause. You develop fault tree, you will find out that in that fault tree it is not the fault tree, maybe there will be suppose 10 basic events, 10 basic events suppose 1, 3, 5 are caused by common cause then 2, 4, 6, 7, 8, 9, 10 they are not caused by common cause. So, then they will be called neutral event. Obviously, with, with reference to the common cause because here I say this is basically operator your human is the problem. So, operator maintenance is the issue because of poor maintenance all three fails then the common cause is poor maintenance and there are 10 basic events.

So, then with reference to the operators maintenance problem then 1, 3, 5 are common cause events, but rest of the seven events they will be neutral event. So, please remember one is with reference to basic events, there will be common cause events, there will be neutral events with reference to common cause. For example, we say for operator is the common cause and these are the common cause event. Maybe there is another cut set which is basically 2 and 3, so or 2 and 4, let it be 2 and 4 which may be impact prone, impact susceptible, impact susceptible.

Now, if we say that this is also common cause cut set where 2 and 4 both the event occur because of common cause impact and then with reference to this impact 2, 4 is the common cause events, but another 1, 3, 5, 6, 7, 8, 9 and 10, they are neutral event. So, that mean you have to understand common cause event and neutral event with reference to the common cause, ok. Now, let us understand one assumption here, most neutral events have far smaller probabilities of occurrence than common cause events, these neutral events are assumed not to occur in a in the given fault tree. So, I will see little later that given a fault tree there will be few important thing one is common cause.

Then when you say common cause so, there will be common cause events related to that common cause and neutral event which are not related to that common cause. Then the assumption is all the neutral events have far smaller probabilities of occurrence compared to the common cause events. So, in basically understanding the or while deriving the common cause cut set the assumption is that you put 0 value for the neutral event, 0 probability value for the neutral event; that means, assumed that those things are not occurring, ok. So, this particular assumption will be using while we will be deriving common cause cut sets.

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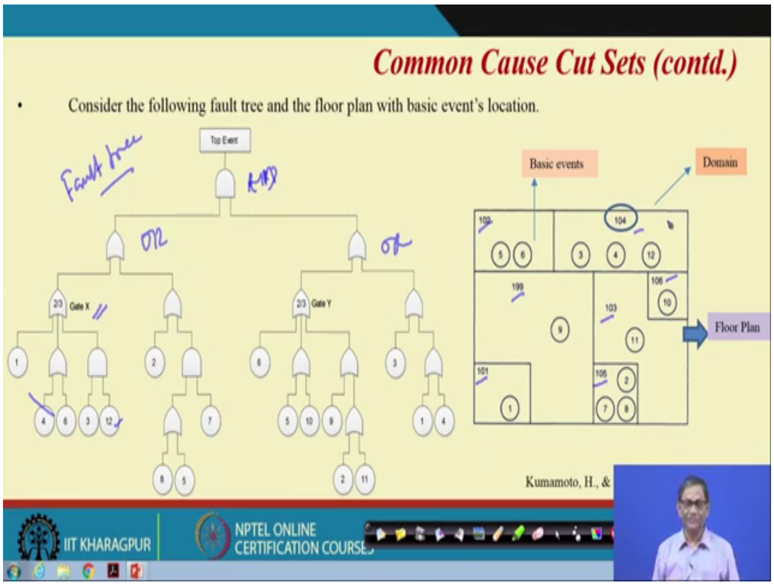

So, let us see this our fault tree, this is our fault tree. So, this and gate, or gate or gate then this is voting gate like this. Now, here how many events are there basic events? So, you see 1, 2 to I think 12 basic events are there, 1, 2 this is 12 yes, 2 basic events are there. So, let the, this is fault tree for a system and, and all the basic event related equipment and component are situated in a particular floor and this is our floor plane. So, if you see the floor plan, now you see that there are different rooms 102, 104, 190, 199, 103, 16 105, 101 and you see that 5 and 6 these two basic, these two equipment or component related to event 5 and 6 located here, these are 3 4 12 located here, 9 located here only this is basically the floor plan.

Now, as you have seen earlier in the proximity coupling, we have shown you that that different locations of the floor is susceptible or affected by different kind of stresses or common causes. For example, impact, for example, operators problem, for example, vibration, for example, temperature.

So, that mean one is the equipment or component relating to basic events another one is the common cause, another one is the domain means the common cause has its own domain. For example, there are some common cause whose domain maybe 104 and then and that domain maybe the, there are some equipment or some events which can be affected by that common cause, but there are some events which are, which are not affected by those common causes. So, this situation will arise and this situation in summary it is given in this table.

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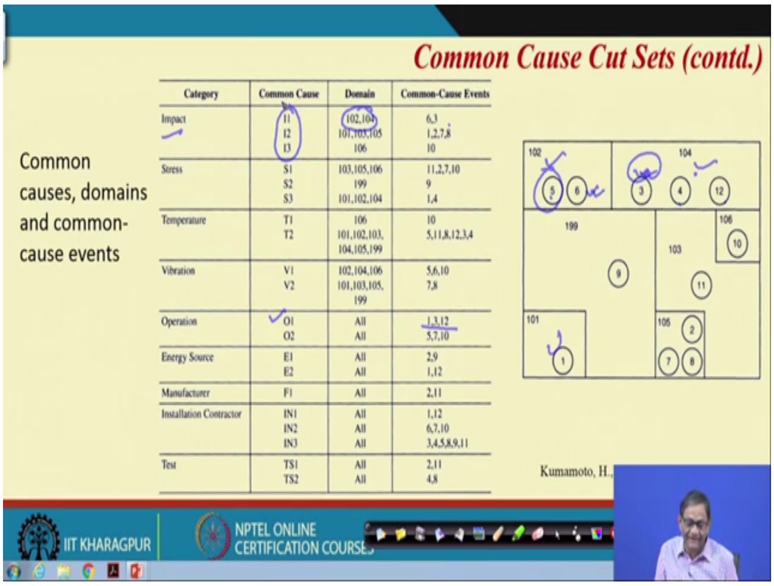

What it given in this table, you see that impact then the common cause, impact 1, impact 2, impact 3 and then the domain. So, impact 1 domain is 102, 104; so, this and these two rooms. But there are events which are impact which, which are caused by I 1, impact 1 are 6 and 3. So, that mean in 102, the equipment whose basic event we are saying or component basic event we are saying 6, this is affected by impact 1 and as well as 3 which, which is situated in 104 room affected by impact 1. But even though, even though the domain is for impact 1 is these two rooms, but 5, 4 and 12 are not affected by impact 1 because they are not susceptible to impact 1.

Similarly, if you consider O 1, see what a domain is basically operation, domain will be all the rooms everywhere operation takes place. And, if you see that which are the basic events that are affected by operation problem that are 1, 3 and 5; so, 1, 3 and 5 and 5. So, let me few things very important things are there first is common cause, what is the domain, it is affecting and what are the events that will be caused by that common cause, these things you have to keep in mind.

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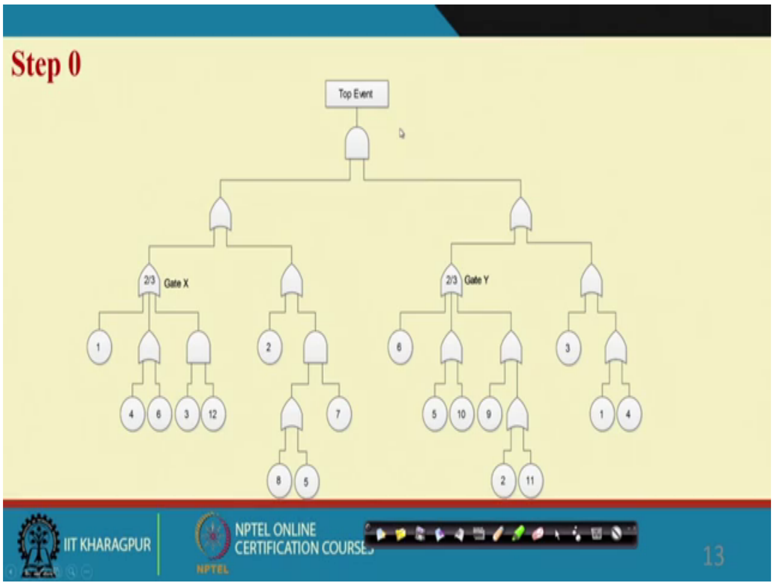

Now, let us take this example, this example that this is our top event and you all know that that voting gate can be represented equivalently using and, and or gate. So, our step 0 is, this is our fault tree and the common cause map is give also common cause that domain and common cause events it is given the along with floor plan. So, with reference to these, we want to create, we want to development common cause cut sets. So, what does it mean? You will develop C C F for I 1, CCF for I 2, CCF for I 3. Similarly, CCF for any of the common causes, CCF common cause that cut sheets we will develop common cause failure cut sets.

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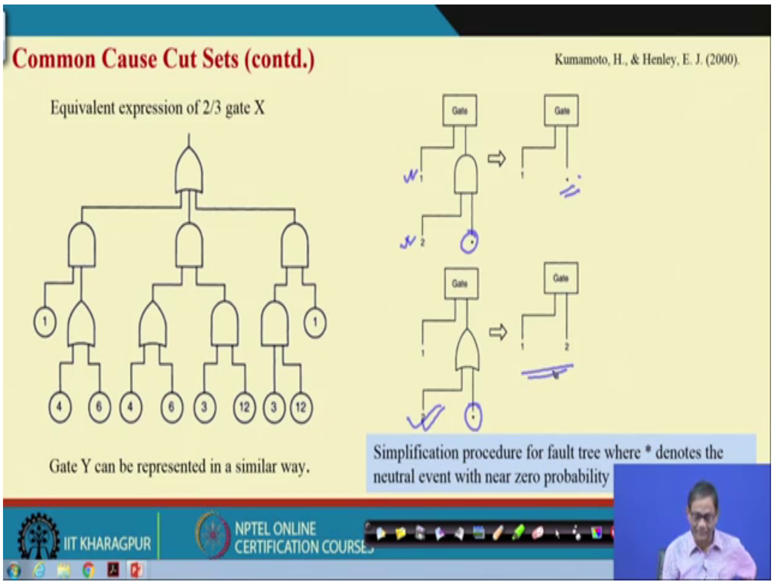

So, what we are taking we are taking example of this fault tree and all of you know that voting gates can be represented like this. Now, assumption is that neutral event probability will be far, far less than the common cause event probability. Hence, there will be, there will be simplification. What is the simplification here? Simplification is gate dependent. For example, we are we are basically saying that star this denotes the neutral event, this is our neutral event so, this is our neutral event.

Now, so, that mean this is a common cause event. Now, common cause event and neutral event are inputs to and gate. So, what will be the resultant simplification base because of the assumption, because of the assumption the resultant signification will be here, the neutral event will be there because of and gate as this probability is far, far low. So, ultimately this with this common cause will not have such affect. So, ultimately it will be dominated by this neutral event probability.

So, your the upper gate will be will gate inputs of 1 which was already there and the neutral event, ok. But, but if it is or gate it will be just reverse because any one of the two can cause that of event to occur. So, as a result here it will be dominated by your common cause, because the neutral event probability is far low. So, it will be dominated by 2, 2 means the common cause. So, accordingly the simplification of this gate will be like this. So, if adobe these two simplification in the in the fault tree given to us; so, what

I mean to say, now you will with reference to a particular common cause you will be able to simplify it, .

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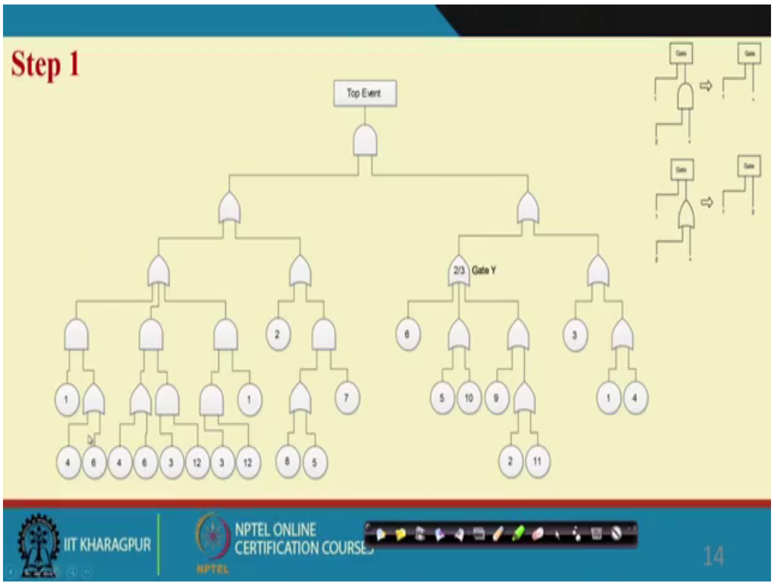

So, let us do step 0, this is the, this is the fault tree. Now, step 1, step 1 basically we are making the common cause cut set with reference to O 1, that is operation 1 in a common cause. So, ultimately what happen if you go you see that this is the first, this is our tree 0 tree then equivalent and, and or combination tree, then the then the and, and or gate simplification based on the assumptions.

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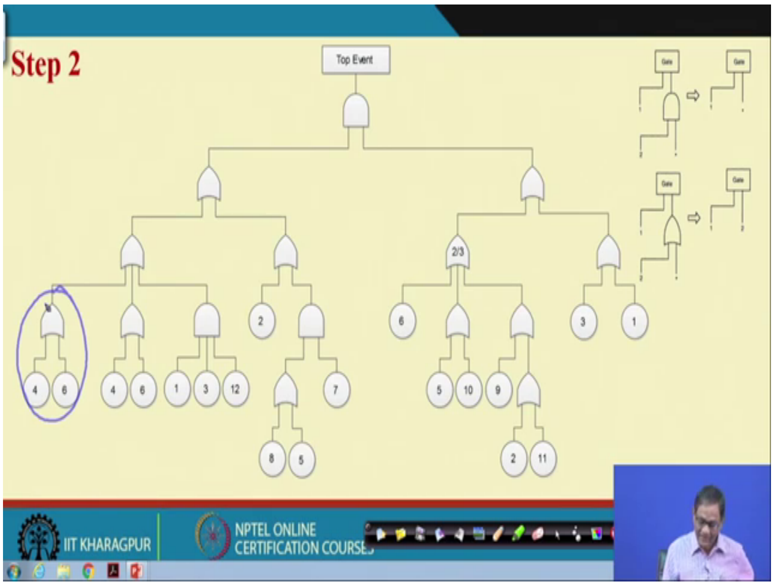

So, it these three ultimately leads to these. You see just, I explain one, this one, this is 4 and 6, how it is becoming 4 and 6? You see with reference to O 1, 1, 3, 12 is the common, common cause events, 4, 6 not common cause this is neutral. This is the and gate when there is and gate so, what will happen ultimately the neutral event will be there the common cause event will have insignificant role. So, 1 is the common cause 4, 6 is the neutral. So, this, this ultimately using this simplification, you are getting 4, 6 here.

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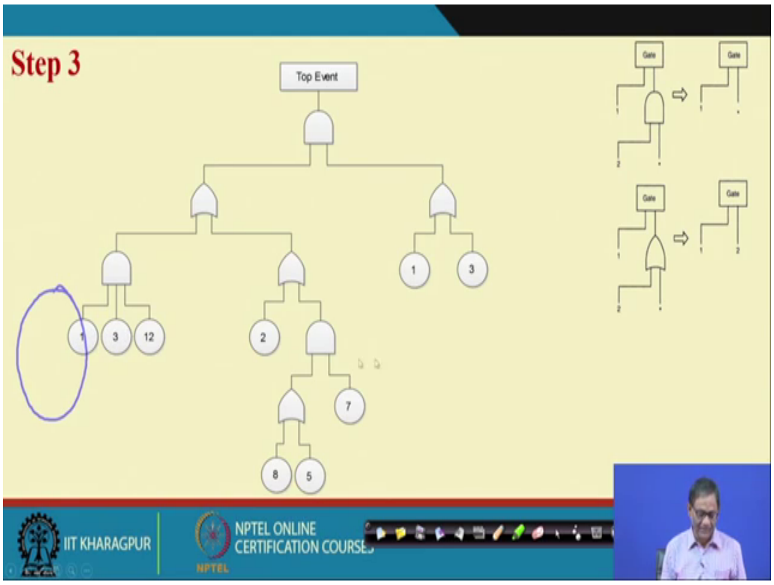

In this manner you simplify, if you simplify, this is step 2, then step 3, you see what happened 1, 3, 12 is coming 1, 3, 12. Now, this is our, this is and 4, 6 neutral, 4, 6 neutral 1, 3 to 12 is the 12 is the common, it is or gate when it is or gate. So, ultimately the neutral your common events will become significant. So, neutral event will be neglected. So, 4, 6 will be neglected 1, 3, 12 be there, will be there. So, as a result next step 1, 3, 12 be there.

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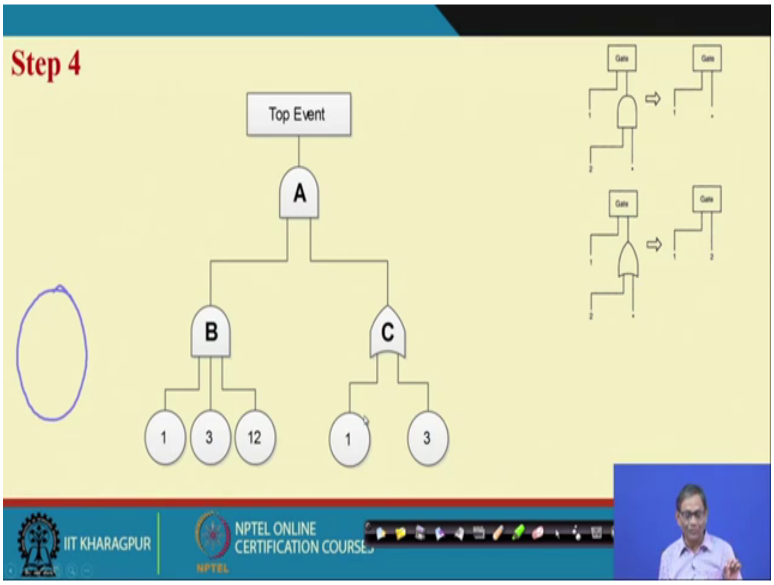

So, in this manner if you continue, so, ultimately you will get with reference to O 1, this is the result, this is the resultant fault tree; now, 1, 3, 12 and 1, 3.

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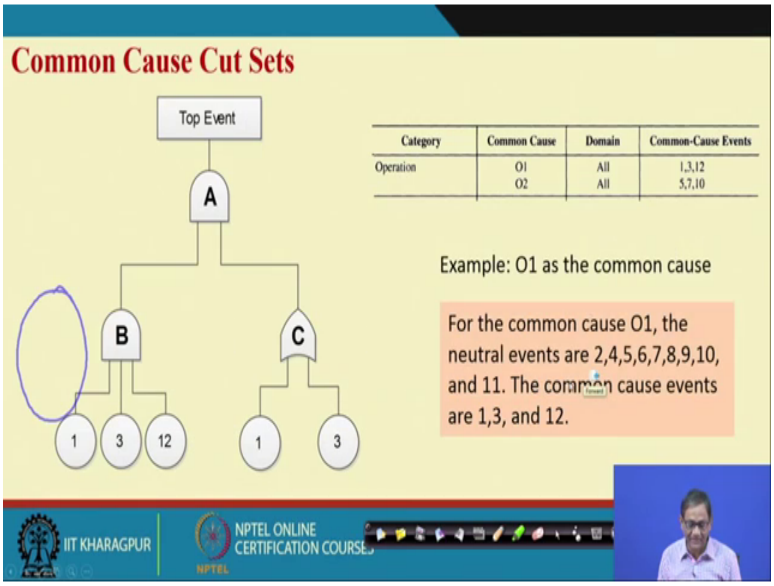

So, if you now use Mocus algorithm and develop the cuts sets so, if you now use Mocus algorithm and develop the cuts sets. So, you will ultimately get the cut set for O 1, will be the common cause events 1, 3 in the cut set for O 1 will be 1, 3 and 12.

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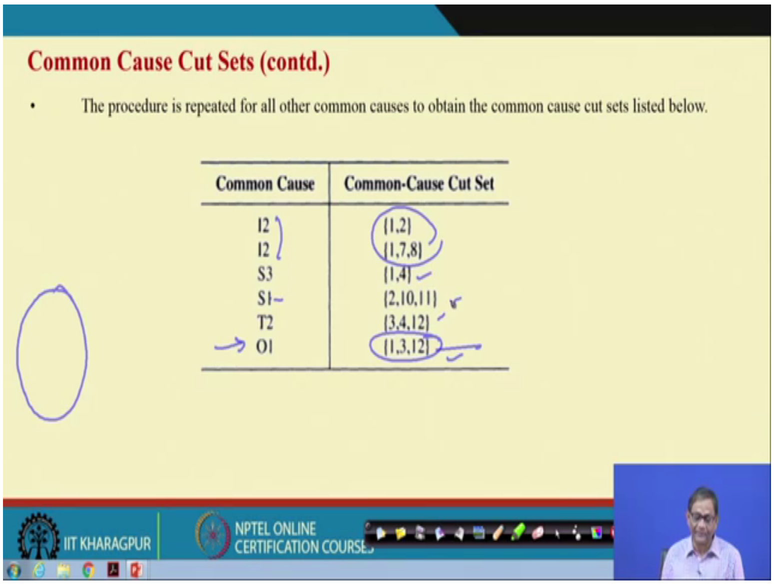

So, please practice, I am sure that you will be with reference to this tree, this is for O 1 you will and where ultimately 1, 3, 12, but the common cause. So, when you would, you use Mocus algorithm here. So, ultimately when you, ultimately when you simplify the final cut sets what you got, then you will be you will be leading to only this 1, 3, 12.

So, then what is the common cause cut set for common cause O 1, 1, 3, 12. Similarly for T 2, S 1, S 3, I 2. So, for I 2, you got two cut sets, S 3 you got one, S 1 one, T 2 one, ok. So, similarly I, I request you to check for O 2 and you see that whether you are going to get any common cause cuts sets or not; however, it is impossible you check it, ok.

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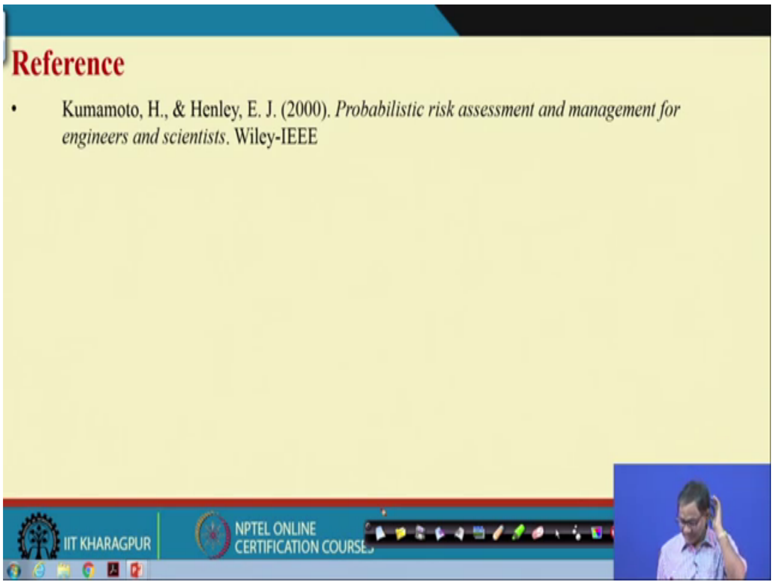

So, I hope that you understand the common cause, common cause cut set, common cause cut set let me repeat once more. That basically there will be some shared causes which, which cause many of the events to occur all those events given a shared cause is called common cause events. And when you want to find the common cause cut sets from my fault tree then you have to use the assumption that common cause neutral event cut probabilities are far less than the common cause probabilities. And then you for a fault tree you make the equivalent fault tree using and or gates, if it is needed.

Then for and or simplification whatever way we have explained here, you follow it. And finally, consider a particular common cause, simplify the fault tree with reference to that common cause and then later use the Mocus algorithm or (Refer Time: 39:40) algorithm with reference to that simplified fault tree. And whatever sets you will get that will be or whatever cut sets you will get that will be the common cause cut sets for that particular cause. And accordingly you have to find out all the common cause cut sets considering all the common causes that is applicable for your fault tree.

Thank you very much.