**Risk and Reliability of Offshore Structures**
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Module - 03
Risk assessment and Reliability applications
Lecture - 12
Fault Tree analysis

Friends, welcome to the 12th lecture that is in module-3, where we are going to talk about one more method of risk assessment using fault tree analysis.

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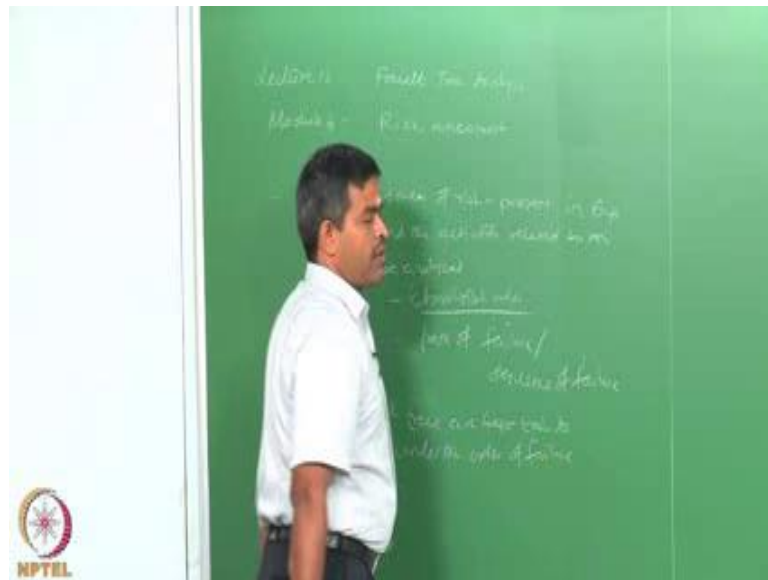
This is twelfth lecture in module 2, sorry module 3. Where we are focusing on risk assessment, fault tree and event trees are essentially very interesting methods of doing risk assessment. Different sources of risk of an engineering system, because we know engineering system has different sources of risk, present in engineering system and of course, the activities related to this, and the activities related to them. Need to be analyzed with one priority in mind, that is one should be able to identify them in chronological order.

So, may the risk assessment tool, whatever I apply if it is able to give me the order of failure as well, the path of failure in terms of it is sequence then the tool is going to be a very powerful in terms of implementing it for error mitigation or risk mitigation and risk

reduction techniques. So, my risk assessment tool should be able to give me the chronological order of failure, it should give me the path of failure or to better understand sequence of failure. So, to do this generally people do adopt logical trees understand the order of failure of any engineering system.

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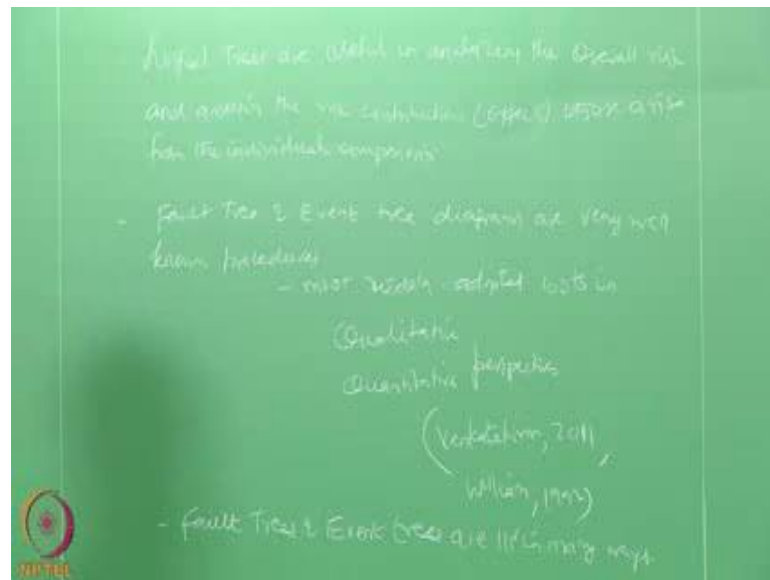
Logical trees are actually useful in analyzing the overall risk and assessing the risk contributions.

What we call as effects consequences those arise from the individual components fault tree and event tree diagrams are well known in literature or rather very well known procedures and most widely adopted both in qualitative and quantitative perspectives as said by Venkatakiran in 2011 and William in 1992. Interestingly fault trees and event trees are similar in many ways event trees are similar in many ways, choice of using either fault tree or event tree analysis depends more on preferences within the given industry choice of using fault tree analysis or event tree analysis depends on the preference within a given industry .

They do not depend on please understand this, the choice do not depend on the specific characteristics of the logical tree at all.

It is very important statement people generally get confused that event tree is, better than fault tree analysis and so on and so forth. Fault tree analysis can be applied only to a certain set of problems no logical trees in general can be applied to both qualitative and quantitative methods as prescribed by the researchers the choice purely and completely depends on what actually the industry wants. And what is the comfortable level of application to that industry; this was said very clearly by young and bum 2005. Now there is a significant difference between the 2 types of trees, let see what is that there is a significant difference between the two logical trees.

Let us say fault tree is more or less based on deductive logic, where as event tree is more or less based on inductive logic. So, let us make it very clear in physical terms, what do you mean by deductive logic? It means looking backwards inductive logic means looking forward this can be seen as a fundamental and significant difference between both the logical trees in practical applications. Generally a combination of fault and event tree is actually typically used in such combinations we have a specific role to be played by a fault tree and a specific role certainly to be played by a event tree.

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When both fault trees and event trees are combined to do risk analysis then which are very common practice then fault tree is used which is deductive logic is used to address the sequences of failure which may lead to events with consequences, where as event tree is used to represent the subsequent, evolution of the consequences including inducing the events consequences inducing events.

So, event tree looks into more breakup and more focused towards the consequences inducing events, where as fault tree if used in combination with event tree is generally required to address the sequence of failure, which is very important step in risk assessment. Now as an engineering perspective the intersection of a fault tree and event tree in reality is a very high matter of preference. So, if I have an intersection of fault tree and event tree then this is a high matter of preference in engineering performance when, you start combining the logical tree and event tree in a total analysis then one can also end up in small event tree with a large fault tree.
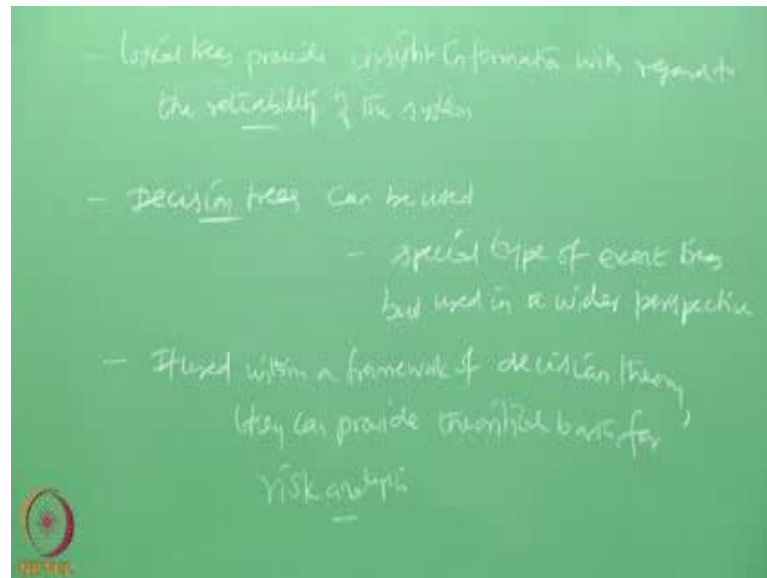
It can also happen vice-versa in certain problems this situation can occur during risk analysis in general logical trees, provide insight information with regard to the reliability of the system, alternatively as an higher order decision trees, can these are special type of event tree, but used in a wider perspective decision trees, if used within a framework within a framework of decision theory. They can provide theoretical basis for risk analysis detailed analysis of various types of logical trees actually has a preloaded condition what is the condition.
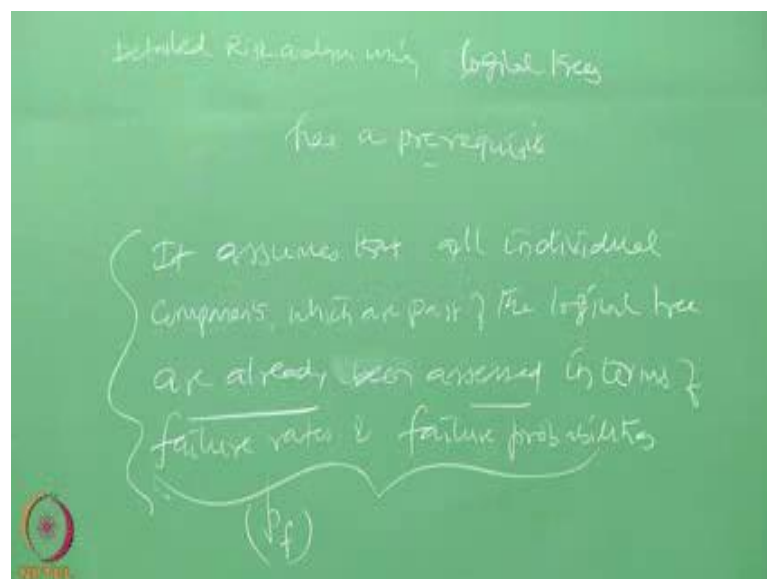
So, detailed analysis or detail risk analysis using logical trees has a prerequisite that is very important it assumes that all individual components, which are part of the logical tree, are already assessed in terms of failure rates and failure probabilities that is a very important statement here that is a very important statement here.

All individual components present as a part of the fault tree or logical tree, in general first need to be analyzed and assessed for each one of the failure rate and failure probability. Since I am saying each component is assessed independently and a prior to the fault tree for the rate of occurrence or probability of failure and rate of occurrence, we are taking about partly a reliability study here itself at component level let us try to explore more understanding towards fault tree analysis.

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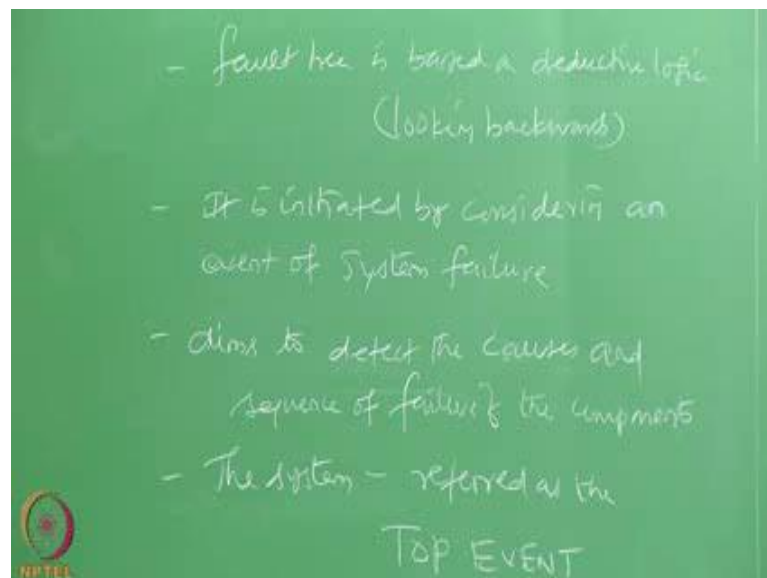
Let us say we already said that fault tree is based on deductive logic looking backwards.

It is initiated by considering an event of a system failure it aims to detect to detect the causes and sequence of failure of the components, which could overall lead to the system failure the system is then, the system which is being analyzed is in referred as a top event once the system which is being referred as top event is identified.

Then logical interrelation of sequence of component failures which, can lead to failure of the top event is represented through, what we call as logical gates fault tree is actually constructed like a tree structure top event at the top and basic events at the extremities.

Now, what are basic events basic events are those events for which the failure probability are available, most importantly. Why the term basic the term basic comes because these failure probabilities of basic events does not or do not let us say, do not require further bisection. So, you know totally about the failure scheme of an event, what are the causes? What are the effects? What is the probability of the failure? What is the rate of occurrence of that failure? You know everything about that event? If we have an event in a given tree or structure which is going to cause failure of the overall system or the top event then we call those events as basic events these basic events will now, put at the extremities of the tree and the treetop will be started with a top event sometimes events are differentiated into initiating and enabling events.
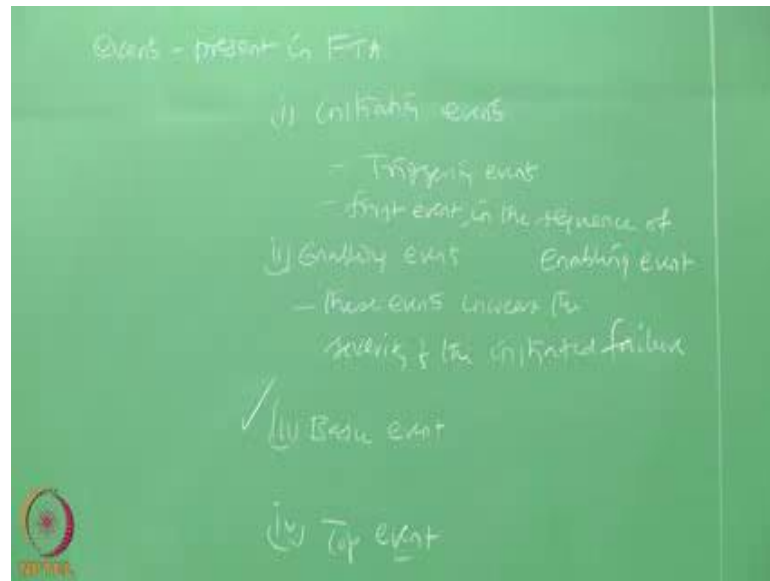
Events present in the fault tree analysis are identified as initiating events and enabling events, we have already seen the basic event, we have already seen the top event top events is actually the system which is being analyzed for it is failure initiating events, otherwise called as triggering events they are always the first event in a sequence of enabling events in the sequence of enabling event. Enabling events are those which will increase the severity of the initiated failure these events increase the severity of the initiated failure therefore; fault tree essentially is a Boolean logical diagram.
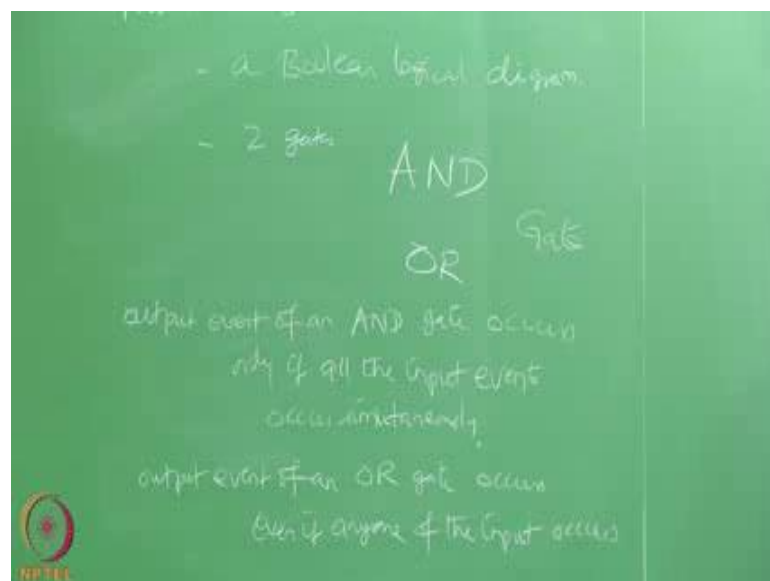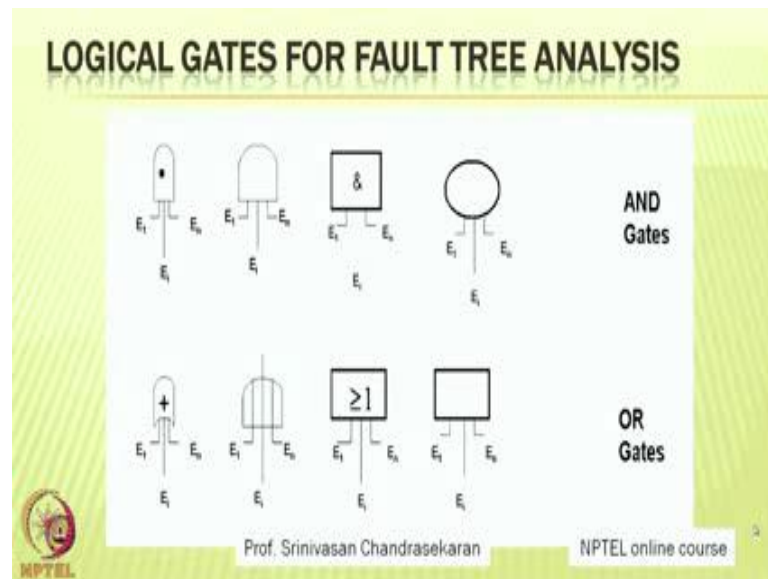
It has got primarily two gates which are called logical gates, the AND gate, the OR gate output event of an end gate occurs only if all the input events occur simultaneously.

Output event of an OR gate occurs even if any one of the input occurs friends please pay attention to the image shown on the screen now.

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Which shows logical gates which are commonly used in fault tree analysis in that different shapes of fault tree gates which are being used these are nothing, but the and gates these are different geometric shapes which are being used which can indicate or gates. So, please understand for an, and gate the output will always happen only if all input events occur where as for an OR gate the output will be successful even if anyone input occurs.

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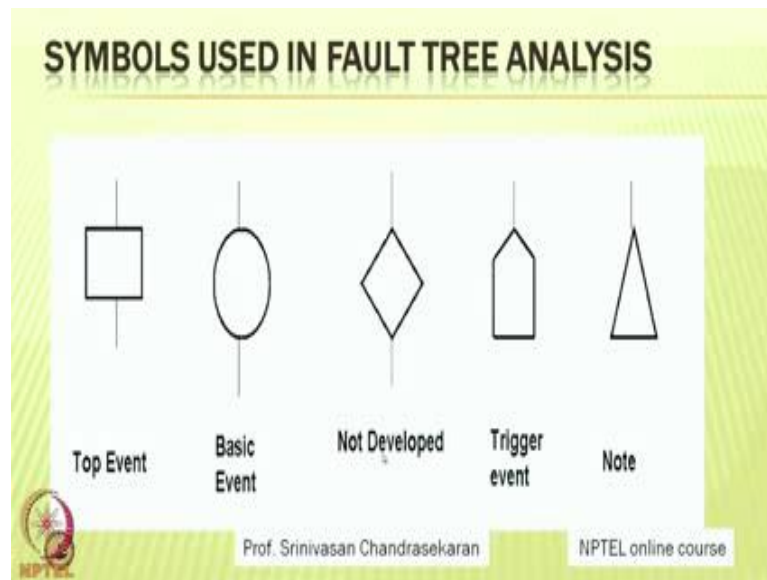
We also use standard symbols in fault tree, analysis please pay attention to the symbols used in the fault tree analysis on the screen a top event. Generally represented by a rectangle or a square the basic event which we already know, the probability information of failure which is indicated by an ellipse with major axis along the fault tree the event, which is not developed or indicated as not developed event is indicated as a doubtful event with a rhombus where as a triggering event which is called as an initiating event is always indicated by a figure shown here and if you want to write any note related to any specific event you can always write the note using a triangular box as shown here in the fault tree analysis.

As I said these gates and trees can be combined to form a typical fault tree analysis please pay attention to a symbol or a to a typical fault tree analysis, which connects the logical gates of different order the OR gate and the AND gate with different types of events like initiating event.

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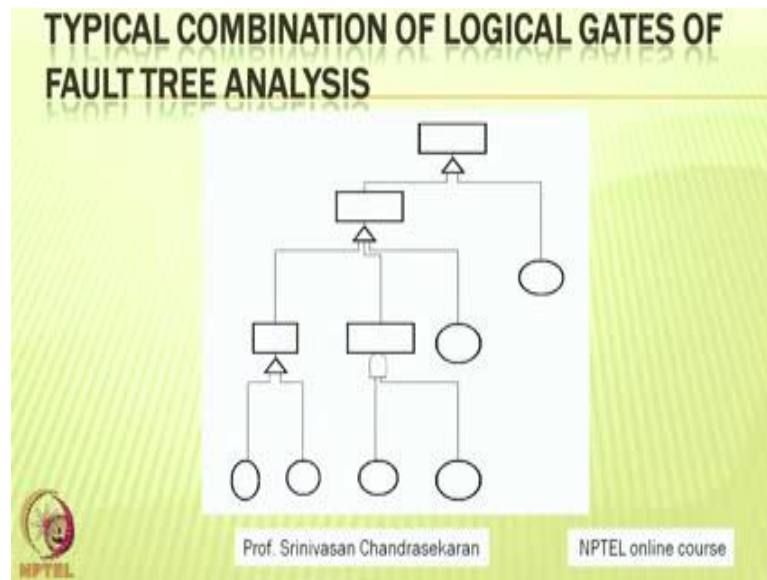
Basic event nodes etcetera and terminating events or triggering, events which indicates here please understand, all the events which are being used as components in the fault tree are analyzed independently a prior to making a logic tree. Whose probability of failure consequences and effects of failure are known a prior in advance, before we do a logical tree. So, please note that the fault tree comprises of and gate represents a parallel system.

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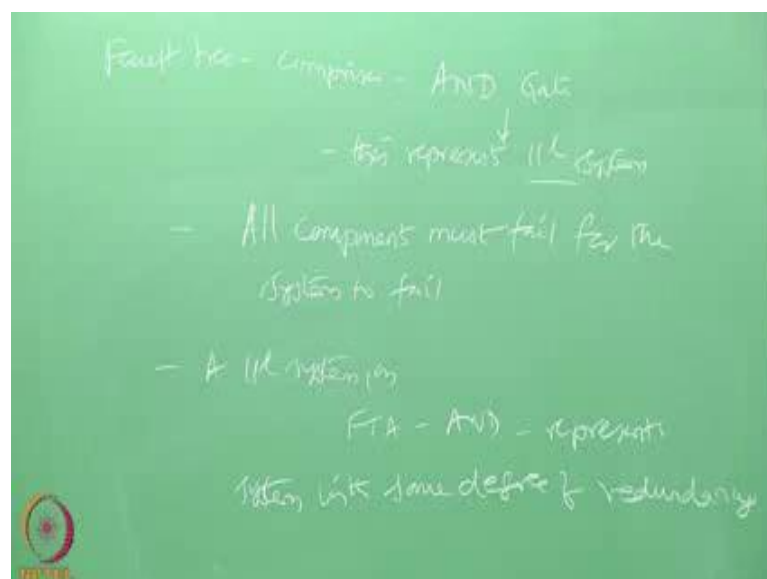
If I have a fault tree which comprises and gate this represents a parallel system we have

already seen system in parallel system in series in earlier module lectures as well.

What does it mean is very interestingly all components must fail for the system to fail that is the condition in a parallel system? So, all components must fail for the system to fail that is the condition for a parallel system. It means indirectly when, you are connecting events through an AND gate the output of the and gate, will occur only when all events connected to and gate will fail because fault tree consisting and gate is similar to a parallel system such a system thus represents some degree of redundancy. So, a parallel system or a fault tree analysis using and gate represents system with some degree of redundancy because the system will consider to be failed only, when all events connected to the and gate have to fail.

Even if one function is not failing then, we will not accept that the system failure has happened. So, that gives me some degree of redundancy in the overall system, alternatively let us look at the fault tree which is compressing an OR gate.

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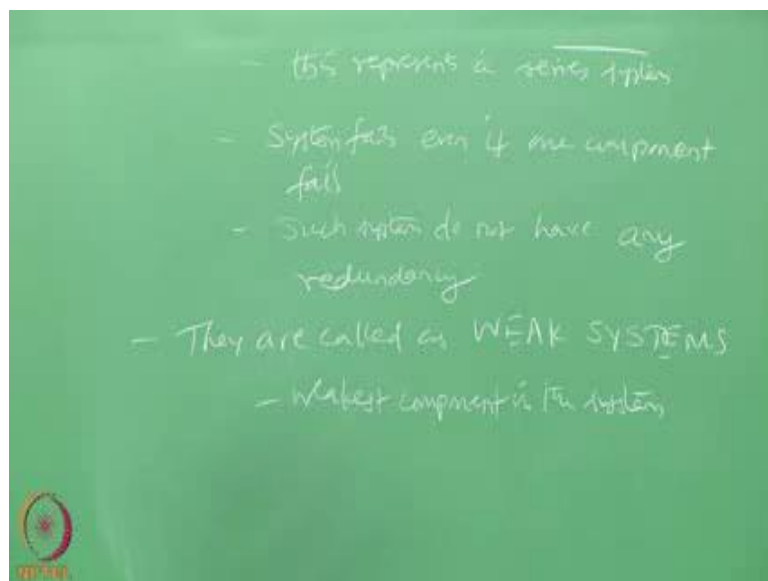
Let us take fault tree compressing, an or gate this represents a system in series what does it mean in that sense it fails as soon as any one component fails, that is important system fails even if one component fails. So, therefore, such systems do not have any redundancy. Therefore, they are called as weak systems because they consist of weakest component in the system, one can also do a block diagram for system reliability using an AND gate and an OR gate please pay attention to the block diagrams shown on the

screen now.

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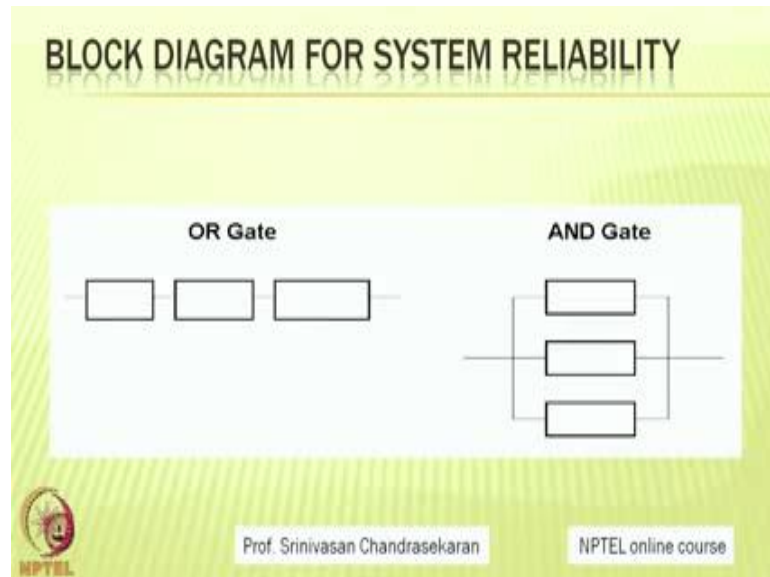
Either using an or gate nor an and gate interestingly, we have already learnt the probabilities of failure of system in parallel system in series, and combination using the weakest links etcetera we have already found out the equivalent system which can replace the failure modes of a parallel or a system in series. We found out probability of failure I will recollect back those discussions and try to and try to write this rule as we already know.

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Now, according to probability theory probability of an event for an and gate is given by p is equal to I equals one to n p I that for an or gate is, given by probability equals to 1 minus pi equals 1 to n, 1 minus p I equation number 1. Where n is the number of events connected to the gate p I are the probabilities of failure of the events, which are already known it is assumed that these events are independent to each other that is an assumption therefore, the failure modes of such systems will be defined.

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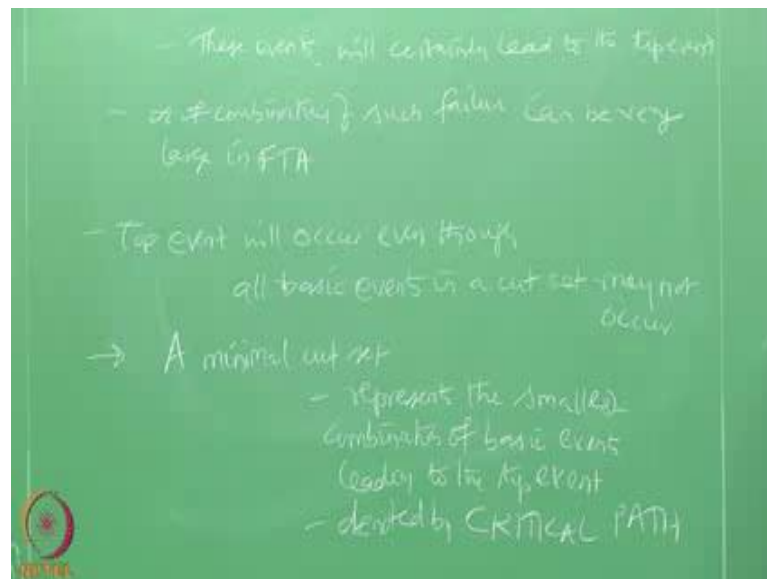
Now, by cut sets and path sets we already discussed about this in the probability of failure in the first modules, which is going to the combination of basic events because basic events the properties probability of failure occurrence causes effect total information are known to me.

These events which will be formed the part of cut sets will certainly lead to the top event. That is why in logical tree analysis; we say looking backwards interestingly the number of combinations of such failure can be very large in fault tree analysis. There can be several hundreds of logical tree with about 50 basic events. Therefore, it is important to note that the top event may still occur even though not all basic events in a cut set occur that is very, very important. So, a top event will occur even though all basic events in a cut set may not occur. Therefore, one should look for a minimal cut set, what is a minimal cut set. A minimal cut set is that, cut set which represents the smallest combination on basic events leading to the top event, which is also denoted by what we

call as a critical path top event will only occur if all the events fail in the minimal cut set that is very important.

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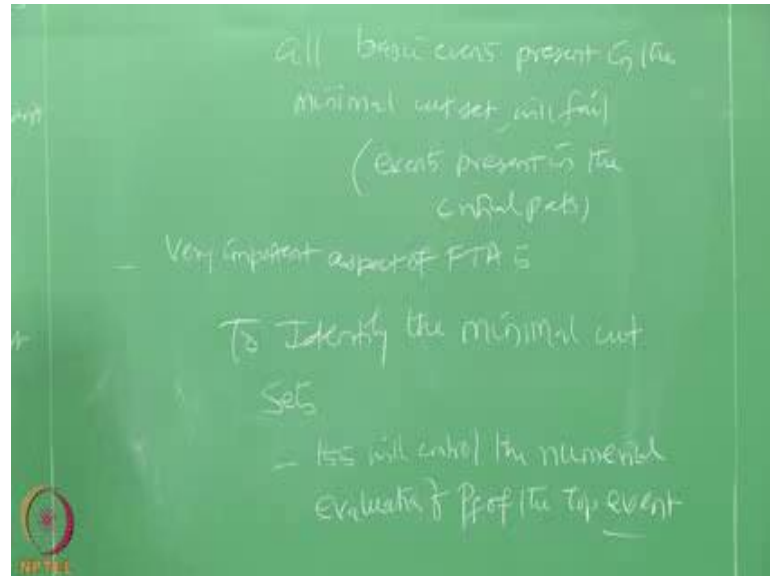
Therefore top event will occur only if all basic events present in the minimal cut set or events present in the critical path will fail. Therefore, an important aspect of fault tree analysis very important aspect of fault tree analysis is to identify the minimal cut sets because this will control the numerical evaluations of the probability of failure of the top event.

So, friends interestingly in this lecture we discussed about the basic ideas, which are being carried forward in one of the type of risk assessment, which is fault tree analysis or logical tree in general, we have discussed fault tree analysis and event tree analysis quickly logical trees can contain both fault trees and event trees generally a logical tree, is a combination of these 2, we have also discussed about various events various kinds of events, with all that we understand that all these events, which are logically connected should be independently analyzed a prior to the logical tree that the probability of failure consequences effects and rate of occurrence of these failure should be known in advance or beforehand before you do a risk assessment to a logical tree analysis.

Now, logical tree analysis can be further extended similar to the top the events connected using an AND gate and OR gate. So, one represents system in parallel one represents system in series system in parallel connected through and gate indicates that, system

failure will occur only when, all events connected to the and gate fail. Simultaneously therefore, such systems have high degree of redundancy they are called strong systems. Whereas systems connected using or gates indicate a system in series this mentions a very important statement that even. If one event fails it is going to lead to the failure of the overall system or the top event. Therefore, such systems are called weak link systems which should be avoided in the whole design. Therefore, logical tree analysis establishes a fact that your system is strong or weak in the basic form of risk assessment.

However; one can see very clearly here logical trees do not focus anything towards economic perspective. Therefore, in strict sense they may not be method of risk assessment. But; however, they quantify the risk and therefore, they also tell me about the probability of failure to some extent, they are higher than reliability studies to a larger extent they may not be matching in the economic perspective as that of a logical tree analysis which deals with the probability of failure. So, they may not give you the economic perspective of failure in terms of money involved or financial loss etcetera or asset loss and management; however, they are also classical methods of risk assessment applied to offshore structures.

Thank you very much.