Industrial Safety Engineering
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Lecture – 10
Failure Modes and Effects Analysis 9 (FMEA) – (Continue)

Hello last class we started Failure Mode and Effect Analysis, today will continue with the contents of today's presentation.

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We will revisit what we have discussed in last class first, and then I will give you another concept called how to select the important or significant failure modes. Then last class we have discussed about that bottom up approach for system breakdown. Today, I will give you the top down approach, then the parameters for risk priority number calculation that is probability, severity and detectability. So, those qualitative scales will be shown to you and then how you will document the total FMEA analysis that format will be given and finally, the calculated RPN will be used to prioritize the failure modes using prioritize analysis that we will discuss.

If you recall yesterdays that last lecture is what I have taken yesterday. That what I have told you that failure mode means the oh the component of a system fails. And then switch failure mode, motor failure mode, human failure mode and with reference to the

compressor system will different component failure mode we have seen. So, we are starting from that point.
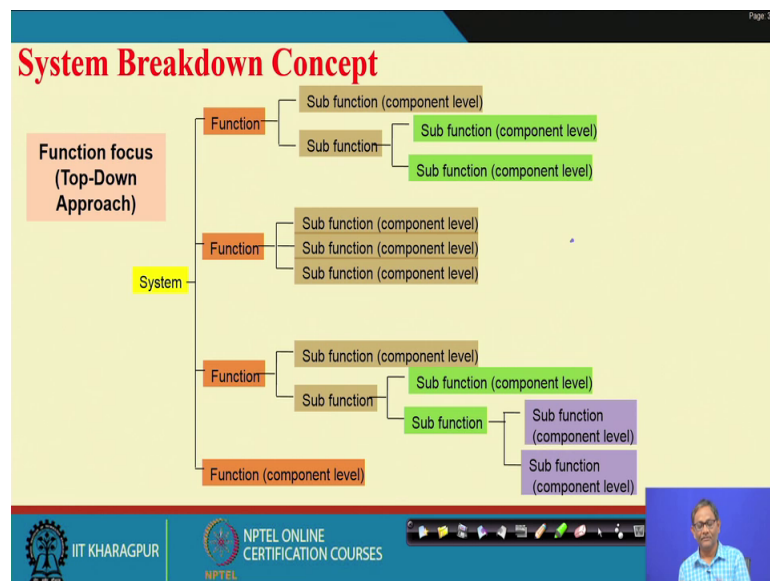
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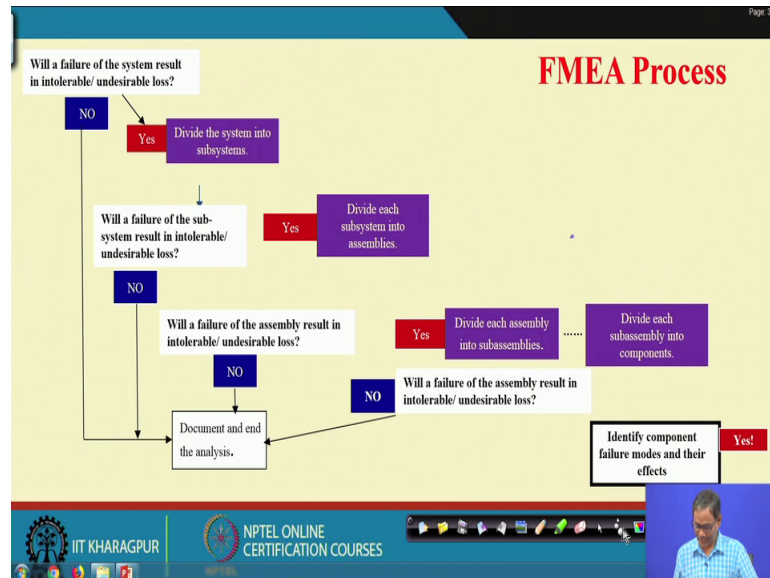
So, now so there can be multiple failure modes, a large number of failure modes will be there. So, will you go for failure mode and effect analysis of all the failure modes, or is there a way to decide that which are the failure modes or which are the component failure modes that will be important to consider for detailed FMEA analysis.
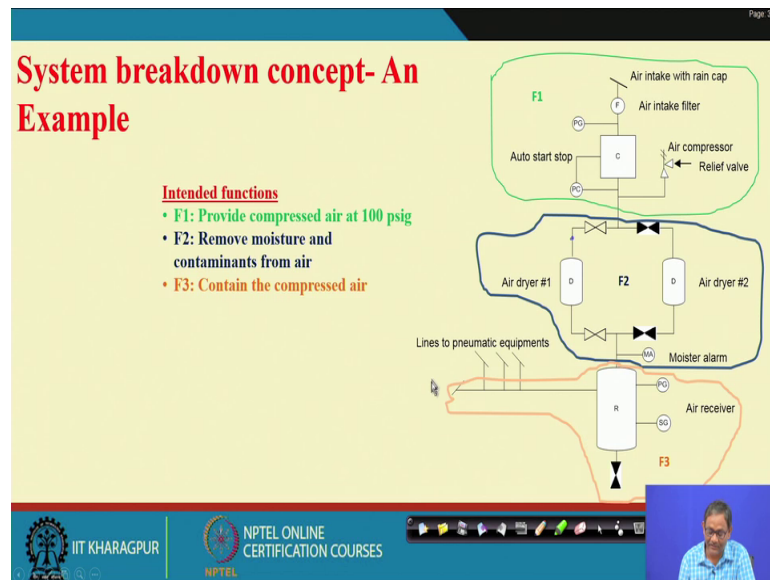
So, you put certain questions, questions are like this will a failure of the system result in intolerable or undesirable loss you have your big plant, big organization. You may you can divide it into the several system, then system to subsystem then up to compound level. Now, when you are talking about at a particular system, then when the if the failure of that system result in significant loss. Then that is basically the point of concern, if it is not forget it if it is yes then you divide the system into subsystems. And then you are again ask question will the will a failure of the subsystem result in intolerable undesirable loss.

If no document and end the analysis, if yes then divide the subsystem into assembly each put similar question and in this manner you go on breaking down, like divide each subsystem into assemblies will failure of the assembly result anyway, then end. If it is yes divide each assembly to subassembly again if the if a subassembly will not result into any significant loss stop. And in this process you proceed and finally, divide each

subsystem into component and subcomponent to that that, those are the component you seal it and then further you component to part also that breaking up breaking down is require. So, that mean it is essentially, essentially those components which result into loss that loss may be at the subsystem level, at the component level, or at the system level. If a if any component failure has system level loss then it is very, very important component.

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So, last class the system breakdown concept we have disused with reference to bottom up approach; where the where so new that system subsystem sub subsystems and components two part you can go for functional approach. In case of function there will be system have different function and then different sub functions and then sub functions up to component level functions ok, that way you proceed.

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With reference to this I am not explaining this further, because you know this system we have explained is in last class with reference to this, what is the functional breakdown you see.

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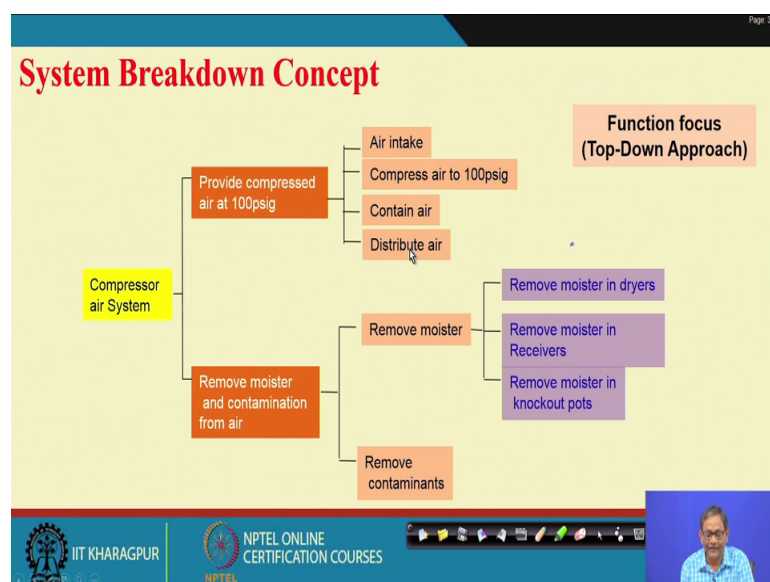
Compressed air system, what is the purpose of this compressor system provide compressed air at 100 psig remove moisture and contamination from air these are the two things to be done.

Now, when we talk about compare provide compressed air these are the these are these are the sub function. So, function sub function intake air intake compress air, contain air, distribute air. So, air intake compress contain and distribute the difference you see intake here this one and then contain and distribute here. So, provide compressed air remove moisture contain compressed air so these two. So, you have broken down into subsystem level and then you see that provide compressed air will require first that you must have the compressed air, compressing and then this to be continent distribute. And removal of moisture is another function, where remove moisture and remove contaminants.

So, accordingly you see the differences are taken place ok. So, you may what you will do when you go for um FMEA analysis you may start with that suppose distribute air. During distributions what are the different ways this will fail that will be the failure mode functional failure mode.

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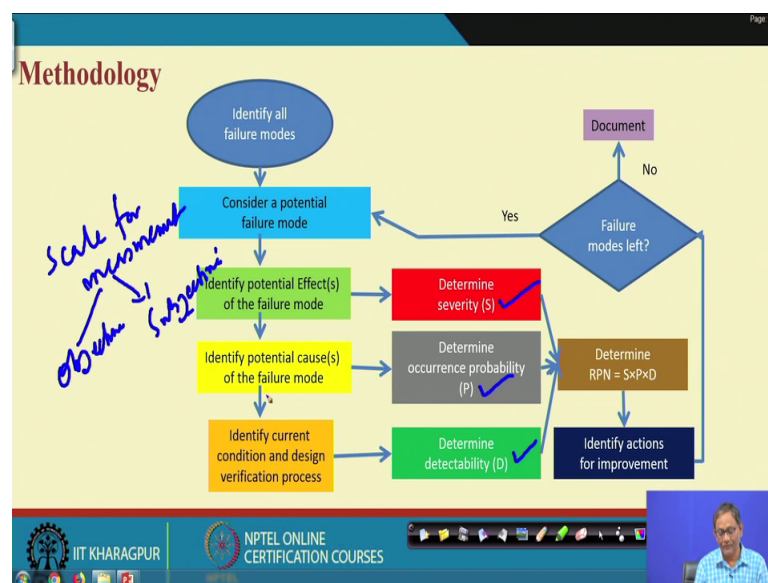
The methodology part I have discussed in last class, but today our primary focus is that how to find out the severity probability and detectability and calculation of RPN. So, what is required you require to have some scale. So, scale for measurement, scale for measurement it can be objective, it can be subjective.

So, we will see some subjective here, so what are those things? So, let us repeat it we will be providing you scale for measuring severity. Which is basically determined based on the effect of failure mode. We will be giving you scale for probability of occurrence

which will be determined by the potential causes of failure mode. And detectability of that failure modes that depending on the that design and current conditions and design verification process.

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I should not repeat this again this is compressor related failure modes, pipe related, failure modes, control, relief valve. We have considered only compressor subsystem and we are considering that bottom up approach that is hardware approach. So, how many failure if I we are interested only in this compressor and how many failure modes are there 1, 2, 3, 4, 5, 6, 7, failure modes ok. So, with reference to compressor we will show you all the calculation.

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Now, first one is the probability, so this probability we are giving you basically 10 point scale. And it is taken from a from a paper I think a which paper is this one I think in the reference you will get it.

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That basic FMEA, then Goodman manufacturability, Midwest that universities wheel write and Clark this one the third one, so we have taken from this. So, you can go through this and you find out something more. What is happening here we are saying that the probability of occurrence is having 10 different values means 10 point scale we are

using here 10 point scale. So, the it is basically in order of probability of occurrence, if it is one this is basically remote probability. If it is 10 certain probability, and in between the degree of occurrence the probability of occurrence is less; so, remote probability 1, low probability 2, moderate probability 4, 3 or 4 depending on the situation you have to give.

Moderate of a high probability 5 and 6, moderate high very high probability 8 and 7 failure is almost inevitable 9 and certain probability 10. So, these are all des subjective description, but you must have some reference. So, that you can how do put only 1 or 10 this is what is the failure with reference to potential failure rate it is given.

What it is given the one means failure almost never occurs, no one remember last failure. Low probability of occurrence failure occurs once per year or one in 1000 occurrence trials, failure occurs once in every 3 months or one in 500 trials. Failure occurs one in once per month or 1 in 100 once per month per week 150 every 3 to 4 days, 1 by 10 at least once a day 1 by 5. So, you must have this experience and when you are doing FMEA analysis for your system whenever you are considering component you see that: what is the failure rate, under which category it is falling.

If you find that it is basically that failure occurs once per month or 1 in hundred. So, you can put 6 or 5 depending on. That means, if you if you think that known it is higher side means this obviously, that 1 in 100 then 6 or you think that no it may be little less give it 5 because it is a subjective one. So, for a particular failure mode you will first find out what is the probability of occurrence it may be 6 so, failure mode 1 probability of occurrence if 66.

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Then what you require you just think the example here or compressor these are the failure modes 1, 2, 3, 4, 5, 6, 7 failure modes. Now what is the probability that external leak will occur, so we are giving it moderate. What is the probability that external rupture will occur one what is the probability that fails to start again moderate.

So, like this depending on the on the system knowledge, operation knowledge so, you are finding out that this probabilities with reference to this scale given. So, for all the failure modes reference to compressor their probability is now defined probability value is quantified now though subject it, but we are putting a numerical value: between 1 to 10.

Then effects what is effect, effect is a severity if a failure mode occurs what is going to happen to the system. So, here also with from the same reference we have taken 10 point scale one no danger to 10 extremely dangerous. In between slight danger, low to moderate danger, moderate danger dangerous very dangerous like this, then what is the description, description is given here.

That mean no danger mean failure causes no injury or and has no impact on the system ok. So, may be at the beginning you may eliminate some of the things while selecting that what are the modes we will consider, but even then something will remain. And in that case if you find that the thing is like this no danger put one like 10 failure could cause death of a customer. So, it is a fatality case, so you give it is a extremely dangerous put 10 in between you find out.

Sometimes what happen let it be may be 6 failure causes minor injury with some customer dissatisfaction and or major safety or system problems ok. So, need not be that it is it need not require you will follow this particular scale 10 point scale. There can be possibility that you may go four 5 point scale 1 2 3 5 4 5, because tens when you are using tens points scale. So, many combinations are there, so many minor differences will be there from one level to another level you may get confused. So, in that case it is it is better to go for 5 point scale if you find that the people the experts who are basically or the team members are more comfortable in 5 point scale then you take 5 point scale.

So, what will happen you have to that means, you are. So, much of that mean the breaking into a 10 different levels will not require ok. You may start with your slight danger, moderate danger, and then very dangerous extremely dangerous and then you are one may be the no danger. So, 5 5 point scale possible 3 point scale possible also 7 point scale possible also. So, you can create your own scale and give some severity as well as probability and detectability values.

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So, with reference to our example external leak does not produce compressed air at desired pressure and volume if there is external leak. So, this is the effect, so it is it is low to medium. So, we are giving four external rupture you see property damage injury and death is a huge one. So, effect is 10 like operates at degraded performance does not produce compressed air at desired pressure and volume like this. So, you see where it is 4 um, so you have to know that the occurrence of a mode what level of loss to the system is going to happen and accordingly you put the value from the 10 point scale given.

Then detectability, detectability case if the failure mode is easily detectable then what is the, what will be the value the value will be low. So, when you moved up when a detectability decreases then your risk increases. So, here detectability high this is detectability and this is risk detectability increases risk decreases detectability decreases risk increases. So, that is why what happened we have used the reverse scoring when detectability is almost certain you are putting the rating one when it is no chance or detection you are getting putting 10.

And in between similarly very high, high moderate remote very remote no chance like this and the description is given here. When no chance of detection there is no known mechanism for detecting the failure, like suppose you think of that any system when suppose different gases are used. There may be leakage of gas and you have no deta detector sensors put there which will ultimately give an alarm that there is a leakage. So, then what will happen the leakage will not be known, so that that kind of mechanism.

For example in the pressure tank system where the overpressure coordination's can be detected yes because alarm is there and pressure gauge is there, but suppose you think that there is no alarm no pressure gauge. What will happen that overpressure condition is not detected, which may ultimately lead to the tank rupture this is the extreme, extreme failure dangerous failure mode.

So, similarly one more certain there is automatic start up or constraint that prevent failure ok. It will not happen even if that that failure the system is such that that the failure is prevented. So, we have defined probability, we have defined severity and we have defined detectability. Now, extending for the system compressed air system external leak detectability high, rupture almost certain fails to start like this suppose operate degraded performance it is difficult to detect. So, accordingly the detectability ratings are given. So, then what happened it simply such that you have given P S and D it is known now P S D known now, what is P? P probability severity detectability now known.

Now, you what do you require you require to compute RPN, what is RPN? RPN is probably times severity times detectability. So, RPN is something like this RP N is like this so you will you will buy if it is probability. So, with increase in RPN a probability RPN increases with increase in severity RPN also increases, but with increase in detectability RPN is decreasing that is why we have used reverse, reverse scoring here.

Here if it is almost of a certain you are giving 10 here also 10, but here you will be given 1. So, so for different failure modes probability severity detectability given you multiply 4 into 4 into 4 is 64 10, 7 into 4 28 112 30 180 168. So, whose RPN is maximum here operates at degraded performance which is 160. So, if you do not calculate RPN, if you simply think that these are the failure mode where you should concentrate. Then obviously, you will first say that this is the place to be concentrated because it is a huge severity, but when you have seen the probability that the chance is very less because the design is with high safety factor it is designed. So, probability is less so that means, it is already taken care of.

And as a result the RPN value is low, but when we talk about that operates at degraded performance, if severity is comparatively low, but its probability is high and detectability is also low. So, that the that means, probability high probability with low detectability creates maximum problem here. And as a result is RPN is RPN is more that means, ultimately loss to the system because of this failure mode is much more compared to others, so your efforts actions require here ok. Another one operates too long that is also a issue third one is the fails off while running an issue and external leak also an issue because these are having high RPN values.

So, you know how to calculate RPN, now how what is the documentation the documentation part is important, see that you have to point out that failure mode and effect for what system subsystem and component level what level you are doing. Then you describe it suppose you have taken let it be compound level. Then you write down the name of the component or subsystem level name the num name of the subsystem and write down the comments.

Usually FMEA at the component level we do when we go for say the hardware um based breakup breakdown that is bottom up approach, but if you go by functional case then may be what will happen a subsystem function also you can take and accordingly you give comments. But that functional breaking down although require some a sometimes, but it is difficult to find out the failure modes and the other parameters ok.

So, then you just you just you see that there are eleven different items that is to be filled up; the component which whatever you have chosen either component sub subsystem. What function it will perform and then what are the failure modes there can be many failure modes. You have seen the compressor system is performed what is the function compress the air to the desired pressure. Then what are the failure mode there are 7 failure modes for every failure mode failure mode one what is the effect what are the causes and what are the current control you have to write. And then accordingly P S D will be written and RPN value will be calculated and that is what we have seen ok.

And then you require corrective actions, if suppose RPN is just for operates at degraded performance that RPN we have found out that is 168. And we also found out the detectability 7 this one 6 and this one 4. Now, your recommended action will be where what is the recommended action you want to reduce you reduce it to your values, it is possible if you if you reduce this value this value or this value which one is maximum here 7. So, it may so, happen if you know the current controls then if you when if you have the system knowledge, design knowledge you may find out that the there can be a possibility of putting a sensor or some kind of inspection scheme.

So, that the detectability part that it is operating at lower performance can be improved may be it can be improved with three. So, that is what is the recommendation what you should do. So, that detectability will be improved similarly this you may required to improved it to three, so what you should do? So, that the probability of occurrence will be less, so then 3 into 4 into 3 then this will be 3 into 4 12 into 3 36 so RPN value will be reduced.

So, by corrective action means this, your action may be hardware, software, human ware or may be administrative may be engineering control and this can be triggered to probably reducing probability reducing severity or improving detectability. So, these are the clues now where you should focus you focus on where the value is high. That there is a possibility for improving, if you find that no there is no possibility that the detectability can be improved then it will remain 7.

Then it may be possible that probability three and may be severity can be finally, reduced to 2 something like this. So, by recommended action we means preventive and mitigative. Preventive actions what will happen it will say it will improve the probability means reduce the probability of occurrence. Mitigative actions reduce the severity of occurrence and detectability, detectability part is primarily in the preventive side. So, it will help you in detecting the fail it is it is it will help you in detecting the failure mode occurs. So that means, it is in the mitigative side failure mode has occurred immediately take actions.

So, the action then you find out the action now where the action if action taken then this value will change, now 6 change to 3 4 remain 4 and 7 change to 3, so your final RPN is 36. So, you can add another something like remarks here whether this is taken place

suppose it is closed that means, this action has been identified and action has been taken accordingly this reduction is achieved and it is closed ok. So, this is basically the purpose, so when the for your own system there will be several component and several failure modes it is a big list will be prepared.

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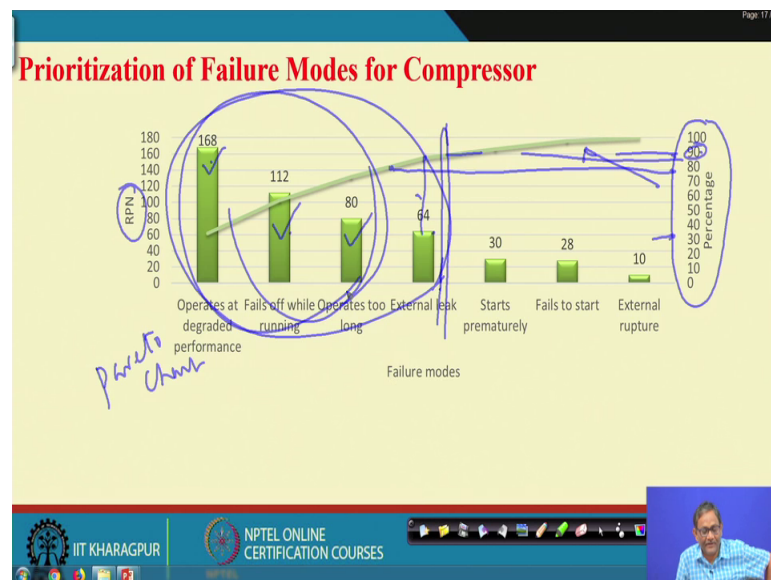
Now, another important issue is that as I told you that where to concentrate that prioritization of failure mode. So, that mean once you calculated the RPN you can do this kind of bar chart. So, here 168 112 like this in decreasing order of RPN, and then you create a queuemility value chart and then what will happen it will ultimately gives you that what is the this one actually this you have to see this one in order to understand this. So, here although RPN value is although it is said, but from percentage wise we will be interested in 80 percent cases suppose 80 percent is this. So that means, this 3 failure modes these 3 failure modes are having 80 percent of the overall tot total risk RPN values.

So, your concentration will be first here and here may be here followed by here followed by here ok. Someone may say that this is also high value suppose if we want to consider this. Suppose, if we consider then it is basically 30 percent it is thirty percent case, if we consider this what will happen you are doing like this. So, 90 percent suppose you want to see the 90 percent cases then this will also be considered.

So, that is what is the use of this chart so, this chart the queuemility value chart this one percentage chart known as Pareto chart. So, that mean here we are what we are saying although there are 7 failure modes, but 3 failure modes are creating 80 percent of the problem when risk issues from the risk point of view this three mailure failure modes are contributing to 80 percent of the risk ok. Where risk is RPN risk priory number so I hope that you got failure mode and effect analysis.

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So, you just see just we capitulate first is what I am say that that you must have system knowledge, design knowledge, hazard knowledge and other knowledge with experience. Then there will be system breakdown is important there will be why either hardware approach or software approach. So, it is usual hardware approach or functional approach, functional approach hardware approach. Then hardware approach is easier one it will ultimately leads to component level for every component you find out the failure mode, so find out failure modes.

Now, whether the component failure is important or not there is a process given to you. So, the from that process you may ignore some of the components or system or subsystem. And then what happened once you have the failure modes the probability, severity and detectability you find out this will be found out if you have the system knowledge, design knowledge, hazard knowledge.

So, what happen probability actually from the cause it basically if you know the causes of failure occurrence of failure mode then it will help you in finding probability; Severity from effect point of view and it detectability that, whether you are able to detect the failure mode or not. Then everything can be quantified, but it is and it is a practice level issue and you cannot wait for quantification. So, better quant, so what you do you will use subjective quant scale subjective scale is used. So, then the subjective scale 10 points scale can be used 5 7 point can be used 5 point 3 point, but usually either 5 point scale or 10 point scale are used use this scale.

And then what you do what you do find out the compute RPN, and based on RPN then you prioritize RPN and then you take you take action, action on priority basis. And documentation is important because after action taken your RPN value should be n property document ok, now FMEA can be designed FMEA can be process FMEA can be operational. So, FMEA can be used in different time, so it is very powerful, powerful, but simple technique to understand, but it require team game to complete it ok.

Thank you very much.