# Critical Systems (CSCM13) Coursework Program Specification for

# Power Grid Energy Stabilizer Setzer System

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## Overview

The Power Grid Energy Stabilizer Setzer System is a program that is utilized by the renewable energy companies to stabilize their energy grid. It's critical that the grid is stable in order to give a constant influx of electricity to the buildings since some of the organizations need constant electricity to operate. This makes it a safety-critical system, and failure or malfunction may result in death or serious injury to people, loss or severe damage to equipment/property, environmental harm. The number one objective is to always have the energy to supply the demand.  Since this program is for renewable source energy, it can be that in a given day that there might not be enough energy. Hence alternative sources need to exist and be immediately accessible. Users will be able to make their own decision at certain points to decide when to buy energy from the non-renewable energy companies. This system is designed so it is fail-safe, meaning that at any point in time, that consumption of electricity can never be greater than the supply of energy. The system automatically buys energy from the non-renewable energy companies when supply isn't enough. The system gives status to help them make well-informed decisions. The refill system is partly automated. Wherever supply exceeds the consumption, then if the batteries are not at the maximum capacity already, they will be refilled with the remaining supply. If the batteries are at a critical level, the user is given the option to buy electricity from non-renewable energy companies. The sbattery is allowed to reach 0, but then whenever extra energy is required, the automatic purchase from non-renewable energy companies takes place. Since the company's objectives beyond the safety of the people are the safety of the environment, it's important to minimize the purchase from non-renewable energy companies. This is a challenging task to be able to provide safety to people always and, at the same time, minimize the impact on the environment.

The average home consumes about 11 kW per day, which makes it 0.13 watts per second, and in GW it's 0.000011. The power grid system has the capacity to supply over 3.2 million homes. The average energy consumption of 416,000 watts (416 kW) per second. The grid's maximum energy capacity is at 10,000 kW per second. The global variable for maximum capacity is set to 10,000 kW (*Maximum_Electricity_Possible*).

## System initialization

The System's first procedure to be executed is the ‘Init’, which initializes the global variables that are used throughout the system and the initialization of the Input/Output library. This procedure is only executed during the initialization of the system itself. Once the system has initialized and has executed the *Init* along with the *Print_Welcome* procedure that just prints a welcome message, it starts the loop that runs the rest of the system.

## Loop Invariant

At the start of the main loop that runs the system there loop invariant a loop invariant. That proves the properties of the loop and is a formal program verification. Once the program reaches the loop invariant, it checks two conditions that must hold true at the beginning of each iteration. The condition is that the consumption is less or equal to the supply else the system would fail. The second one is that the status of the battery reserve needs to be not active. At the end of every iteration, the status of the battery needs to be reset since the battery is not being used. These conditions then correspond with the post and preconditions in the *Energy_Stabilizerg_System* and *Refill_Reserve.* The Energy_Stabilizerg_System makes sure that the consumption never reaches a level higher than the supply. The *Refill_Reserve* is the procedure to be executed and resets the battery status.

## Measurement Inputs

In the program, there are several points where the user gives input. The first two inputs are the reading of the electrical measurements. After the loop invariant checks the condition, the next two procedures that get executed are the *Read_Consumption* and the *Read_Supply*. The Read_Consumption asks the user for the input of the current consumption level of electricity. Checks whether the input is a valid input by checking if it's in the electrical range by comparing it to the global variable *Electricity_Range*. Once validated, it stores the value in the global variable *Status_System_Type*.*Consumption_Measured*. The *Read_Supply* asks the user for the input of the current supply level of electricity. The verification of the range and storage of the variable is the same, except it stores the value in *Status_System_Type*.*Supplied_Measured.*

## Main logic

The main logic of the system lies in *the Energy_Stabilizerg_System* procedure. This procedure is what stabilizes the system to make sure the consumption never exceeds the supply. If the system doesn't have enough supply through its main source of renewable energy, it falls back to possibilities. The first that gets executed is that the battery reserves are used. If in the case, the batteries are enough to meet demand, then the last possibility is used, which is the purchase of electricity from non-renewable energy companies. This process is automated in order to make the system fail-safe. So humans can't interfere and somehow disallow the part of the process. Global variables are read from to get the readings in the procedure and to check the battery levels. Within the logic, new supply and the battery levels are adjusted in the global variables. The battery status is updated to active, in addition to an informative print out saying that the system is at a critical level and that automatic purchase will take place.

## System Status

After executing the main logic of the system, the system status is printed out. In the *Print_Status* procedure, global variables are only read from. It prints the status of energy consumption, supply, battery reserve, and battery status. If the batteries are at a critical level, which is pegged at 50,000 watts (with maximum capacity to store up to 1,000 kW), then it gives a warning. In addition to informing on how much the battery will be refilled if there is supply left over.

## Final Execution

The final procedure that gets executed is *Refill_Reserve.* This procedure refills the battery reserve or gives the option to do so. If there is remaining supply after consumption and there is space to fill the energy reserves, the battery gets refilled with that supply here. Thereafter the procedure checks if the battery reserve energy levels are below the critical level; if they are, it asks the user to make a decision. It informs the user that the battery reserves are below the critical level and asks him if he wants to purchase from a non-renewable energy company. If the user chooses to do so, then the battery levels are put back above critical.

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**Scope and Boundries**

The electrical grid system consists of human-machine interfaces (HMIs), servers (SVs), energy boxes (EBs), intelligent electronic devices (IEDs) and Ethernet links. Including measurement units, protective relays and controllers, IEDs serving as interface devices between power and communication network. Each IED shall track, regulate and optimize the effective use of energy between generation and load. The commands received from HMIs also apply. Metering Infrastructures, such as EBs, are connected to electrical grid stabilizer systems to collect data on the energy usage of electricity grid stabilizer systems between various IED controllers and their respective power elements. Please note that each consumer is believed to be connected to one EB and, in the model, a general EB represents all related EBs. Through IED or EB is connected to a SW via an Ethernet communication which redirects data via the corresponding communication links. TA key SW gathers information and sends it to the corporate and control center from all points of the network.

| Compent | Functionality | Failure Mode(s) | Failure Cause(s) | SEVERITY (1 - 10) | Failure Effect | OCCURRENCE (1 - 10) | Detection method | DETECTION (1 - 10) | RPN |
|---|---|---|---|---|---|---|---|---|---|
| Human-Machine Interface (HMI) | Primary tool by which operators coordinate and control the grid | Power outage | Remote disconnection of power | 8 | HMI disconnection from the communication network; impossibility to monitor and/or control the grid in real-time by manual operation. No system monitoring; corrective and/or preventive manual commands are not properly executed, or can't even be impossible to execute. | 2 | Loss of power; HMI blackout | 1 | 16 |
| | | Operational failure | Poor communication between HMI and other cyber components | 6 | Impossibility to monitor and/or control the grid in real-time via manual operation; wrong control commands. No system monitoring; corrective and/or preventive manual commands are not properly executed, or can't even be impossible to execute. | 6 | Real-time monitoring | 6 | 216 |
| | | | Human error | 5 | | 8 | - | 6 | 240 |
| | | | Poor software design | 6 | | 7 | Software malfunctions detection; inability to execute manual actions | 6 | 252 |
| | | Security failure | Direct human intrusion: faulty commands (cyberattacks) | 6 | Loss of integrity. Ennergy systems applications run under inadvertent commands; inadvertent operations in the power system, which can lead to partial losses of energy; possible blackout. | 4 | Erroneous/illogical commands made without operator's consent; firewall block; attempt to pass the firewall | 8 | 192 |
| | | | Human Vengeance | 6 | | 3 | - | 8 | 144 |
| Server (SV) | Computing system platform used for various network communication applications / computer program or device that provides functionality for other programs or devices | Data overload | Lower storage capacity or unexpected large amount of data to storage | 4 | Large amount of data is lost; defective storage of data. Energy system applications are compromised. | 4 | SV has low data storage capacity | 2 | 32 |
| | | Hardware crash | Overheating and high humidity | 6 | Impossibility to access system's information. IT malfunction; Energy system applications fail or are compromised. | 4 | Temperature monitoring | 1 | 24 |
| | | | Hard drive crash | | | 4 | SV blackout | 1 | 0 |
| | | | Hardware sabotage | | | 2 | Physical surveillance | 1 | 0 |
| | | | Physical disaster (such as fire, earthquake, lightning or flooding) | | | 3 | Weather monitoring | 1 | 0 |
| | | Data errors | Software malfunction | 5 | Impossibility to access system's information. T malfunction; Eergy managemetn applications fail or are compromised | 5 | Unexpected behaviour | 3 | 75 |
| | | power outage | Remote disconnection of power | 6 | Impossibility to access system's information. Energy systems applications fail or are compromised | 3 | Loss of power | 1 | 18 |
| | | Security failure | Denial of service attack (DoS) | 5 | Loss of data integrity; deleted or corrupted data. Energy systems applications run under fallacious information; inadvertent operations in the power system; loss of integrity | 5 | Firewall block; attempt to pass the firewall; suspicious system behaviour | 3 | 75 |
| | | | Hacking for sensitive information | 6 | | 5 | Firewall block; attempt to pass the firewall; suspicious system behaviour | 8 | 240 |
| | | | Malicious software infection | 6 | | 5 | Firewall block; attempt to pass the firewall; suspicious system behaviour | 8 | 240 |

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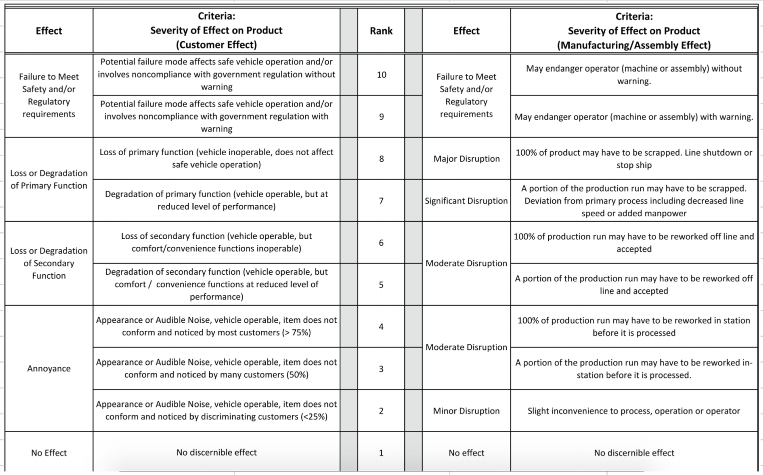
|---|---|---|---|---|---|---|---|---|---|
| Network link | Physical component responsible for assuring a message is sent from one network node to another node (local distances) | Cross talk (overload) | Excessive traffic/ congestion of packets | 4 | Delays in data communication; corrupted signal. Deterioration of communication network performance; Deterioration of communication network performance; energy system applications are compromised | 3 | Deterioration in communication network performance | 5 | 60 |
| | | Network link integrity defect | Manufacturing imperfection | 5 | Delays in data communication; no data transmission. Energy system applications are compromised (non-optimal asset management); decrease in communication network performance | 4 | Electrical test and quality assessment | 5 | 100 |
| | | | RJ45 degradation | 5 | | 3 | Visual inspection | 5 | 75 |
| | | | Incorrect installation | 5 | | 4 | nspection after installation | 5 | 100 |
| | | Network link breakdown | External damage (accidents) | 5 | Cable break; loss of communication between cyber-equipment. applications are compromised (non-optimal asset management); decrease in communication network performance | 5 | No communication | 5 | 125 |
| Energy Box (EB) | Electronic device used to record and communicate electric energy consumption for monitoring and controlling purposes | Communication Error | Poor signal with SV | 2 | Defective or even no transmission of data. energy system applications run under lack of information (non-optimal asset management); inadvertent operations in the power system | 4 | Inability to get EB reading | 4 | 32 |
| | | Power consumption misreading | Manual manipulation | 8 | Incorrect data acquisition. applications run under lack of information (non-optimal asset management); loss of efficiency; loss of power quality | 4 | Record of abrupt drop in power supply; comparison between registered and expected load diagrams | 6 | 192 |
| | | | Significant measurement error, or even inability to measure power consumption | 8 | | 4 | Comparison between registered and expected load diagrams | 4 | 128 |
| | | Operation failure | Improper EB programming and parameterization | 7 | Incorrect data acquisition, or even no data acquisition. Energy system applications run under lack of information (non-optimal asset management); inadvertent operations in the power system | 5 | Comparison between registered and expected load diagrams | 5 | 175 |
| | | | Erroneous installation | 7 | Incorrect data acquisition, or even no data acquisition. Energy system applications run under lack of information (non-optimal asset management); inadvertent operations in the power system | 5 | EB test and quality assessment | 4 | 140 |
| | | | Power supply failure | 7 | No data acquisition. Energy system applications run under lack of information (non-optimal asset management); inadvertent operations in the power system | 5 | - | 2 | 70 |
| | | 'Catastrophic' failure (burning, melting or explosion) | Temperature stress | 9 | Degradation of surrounding smart meter components; personnel injuries or death. Energy system Degradation of surrounding smart meter components; personnel injuries or death | 3 | Temperature monitoring | 1 | 27 |
| | | Security failure | Hacking for personnel sensitive information or faulty information injection (cyberattack) | 7 | Loss of data integrity. Energy management applications are based on fallacious information | 5 | Detection method | 8 | 280 |
| | | Communication | Damaged transducers | 6 | Incorrect data processing due to erroneous or incomplete data acquisition; inadequate processing of data; inability to communicate with control center unit. Corrupted communications; Energy systems applications fail or are compromised (non-optimal asset management); decrease in communication network performance. | 4 | Inability to establish communication with IED | 3 | 72 |
| | | | Poor communication between IED and remaining network | 6 | | 4 | | 6 | 144 |
| | | | Signal processing error (corrupted data) | 6 | | 4 | | 4 | 96 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Intelligent Electronic Device (IED) | Interface device responsible for collecting data from the electrical equipment and receiving and applying a control command from the operator | Communication failure | Network | 6 | Communication network becomes unavailable to redirect the important data for the system operation; large volume of data saturating the network capacity; major consumption of processor computation resources. Corrupted communications; Energy systems applications fail or are compromised (non-optimal asset management); decrease in communication network performance | 4 | Inability to establish communication with IED | 5 | 120 |
| | | Monitoring failure | I/O port damage | 6 | No power component status monitoring. Energy system applications fail or are compromised (non-optimal asset management); | 3 | Loss of data | 3 | 54 |
| | | | Significant measurement error | 8 | Error in monitoring power components. eergy system applications fail or are compromised (non-optimal asset management); | 3 | Incongruous or corrupted data | 2 | 48 |
| | | Control failure | Inability to apply control commands | 7 | Inability to control power system operation. Energy system applications fail or are compromised; | 4 | Operational test | 1 | 28 |
| | | | Inability to apply control commands | 7 | | 3 | Operational test | 1 | 21 |
| | | Power outage | Remote disconnection of power | 8 | Remote disconnection of power. Energy system applications fail or are compromised; loss of control in the downstream network area; | 3 | Loss of power | 1 | 24 |
| | | Security failure | Hacking for personnel sensitive information | 6 | Loss of integrity. energy system applications run under fallacious information; loss of integrity; | 5 | Firewall block; attempt to pass the firewall; existence of corrupted data | 8 | 240 |
| | | | Faulty information injection (cyberattack) | 6 | | 5 | | 8 | 240 |

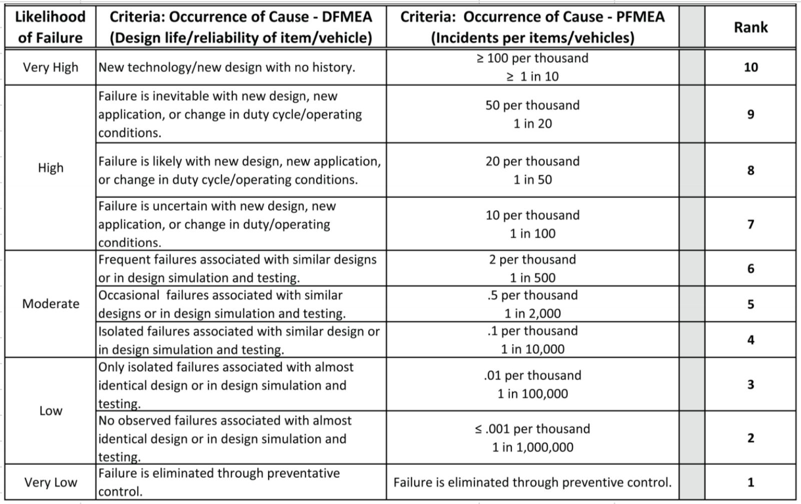
Severity Criteria



| Effect | Criteria: Severity of Effect on Product (Customer Effect) | Rank | Effect | Criteria: Severity of Effect on Product (Manufacturing/Assembly Effect) |
|---|---|---|---|---|
| Failure to Meet Safety and/or Regulatory requirements | Potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning | 10 | Failure to Meet Safety and/or Regulatory requirements | May endanger operator (machine or assembly) without warning. |
| | Potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning | 9 | | May endanger operator (machine or assembly) with warning. |
| Loss or Degradation of Primary Function | Loss of primary function (vehicle inoperable, does not affect safe vehicle operation) | 8 | Major Disruption | 100% of product may have to be scrapped. Line shutdown or stop ship |
| | Degradation of primary function (vehicle operable, but at reduced level of performance) | 7 | Significant Disruption | A portion of the production run may have to be scrapped. Deviation from primary process including decreased line speed or added manpower |
| Loss or Degradation of Secondary Function | Loss of secondary function (vehicle operable, but comfort/convenience functions inoperable) | 6 | Moderate Disruption | 100% of production run may have to be reworked off line and accepted |
| | Degradation of secondary function (vehicle operable, but comfort / convenience functions at reduced level of performance) | 5 | | A portion of the production run may have to be reworked off line and accepted |
| Annoyance | Appearance or Audible Noise, vehicle operable, item does not conform and noticed by most customers (> 75%) | 4 | Moderate Disruption | 100% of production run may have to be reworked in station before it is processed |
| | Appearance or Audible Noise, vehicle operable, item does not conform and noticed by many customers (50%) | 3 | | A portion of the production run may have to be reworked in-station before it is processed. |
| | Appearance or Audible Noise, vehicle operable, item does not conform and noticed by discriminating customers (<25%) | 2 | Minor Disruption | Slight inconvenience to process, operation or operator |
| No Effect | No discernible effect | 1 | No effect | No discernible effect |

Figure 1 - Severity Criteria [FMAE20]

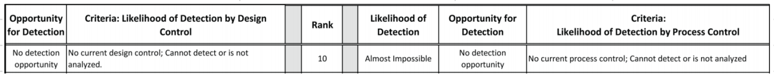
Occurance Criteria



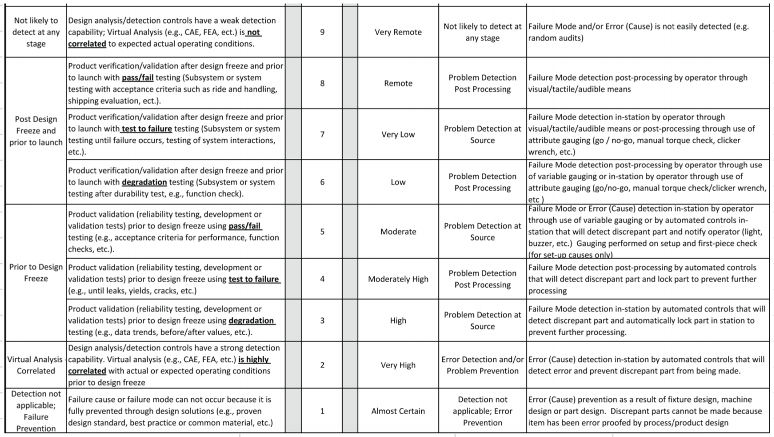
| Likelihood of Failure | Criteria: Occurrence of Cause - DFMEA (Design life/reliability of item/vehicle) | Criteria: Occurrence of Cause - PFMEA (Incidents per items/vehicles) | Rank |
|---|---|---|---|
| Very High | New technology/new design with no history. | ≥ 100 per thousand<br>≥ 1 in 10 | **10** |
| High | Failure is inevitable with new design, new application, or change in duty cycle/operating conditions. | 50 per thousand<br>1 in 20 | **9** |
| | Failure is likely with new design, new application, or change in duty cycle/operating conditions. | 20 per thousand<br>1 in 50 | **8** |
| | Failure is uncertain with new design, new application, or change in duty/operating conditions. | 10 per thousand<br>1 in 100 | **7** |
| Moderate | Frequent failures associated with similar designs or in design simulation and testing. | 2 per thousand<br>1 in 500 | **6** |
| | Occasional failures associated with similar designs or in design simulation and testing. | .5 per thousand<br>1 in 2,000 | **5** |
| | Isolated failures associated with similar design or in design simulation and testing. | .1 per thousand<br>1 in 10,000 | **4** |
| Low | Only isolated failures associated with almost identical design or in design simulation and testing. | .01 per thousand<br>1 in 100,000 | **3** |
| | No observed failures associated with almost identical design or in design simulation and testing. | ≤ .001 per thousand<br>1 in 1,000,000 | **2** |
| Very Low | Failure is eliminated through preventative control. | Failure is eliminated through preventive control. | **1** |

Figure 2 - Occurance Criteria [FMAE20]

Detectability Criteria



| Opportunity for Detection | Criteria: Likelihood of Detection by Design Control | Rank | Likelihood of Detection | Opportunity for Detection | Criteria: Likelihood of Detection by Process Control |
|---|---|---|---|---|---|
| No detection opportunity | No current design control; Cannot detect or is not analyzed. | 10 | Almost Impossible | No detection opportunity | No current process control; Cannot detect or is not analyzed |



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Not likely to detect at any stage | Design analysis/detection controls have a weak detection capability; Virtual Analysis (e.g., CAE, FEA, ect.) is **not correlated** to expected actual operating conditions. | | 9 | | Very Remote | Not likely to detect at any stage | Failure Mode and/or Error (Cause) is not easily detected (e.g. random audits) |
| Post Design Freeze and prior to launch | Product verification/validation after design freeze and prior to launch with **pass/fail** testing (Subsystem or system testing with acceptance criteria such as ride and handling, shipping evaluation, ect.). | | 8 | | Remote | Problem Detection Post Processing | Failure Mode detection post-processing by operator through visual/tactile/audible means |
| | Product verification/validation after design freeze and prior to launch with **test to failure** testing (Subsystem or system testing until failure occurs, testing of system interactions, etc.). | | 7 | | Very Low | Problem Detection at Source | Failure Mode detection in-station by operator through visual/tactile/audible means or post-processing through use of attribute gauging (go / no-go, manual torque check, clicker wrench, etc.) |
| | Product verification/validation after design freeze and prior to launch with **degradation** testing (Subsystem or system testing after durability test, e.g., function check). | | 6 | | Low | Problem Detection Post Processing | Failure Mode detection post-processing by operator through use of variable gauging or in-station by operator through use of attribute gauging (go/no-go, manual torque check/clicker wrench, etc ) |
| Prior to Design Freeze | Product validation (reliability testing, development or validation tests) prior to design freeze using **pass/fail** testing (e.g., acceptance criteria for performance, function checks, etc.). | | 5 | | Moderate | Problem Detection at Source | Failure Mode or Error (Cause) detection in-station by operator through use of variable gauging or by automated controls in-station that will detect discrepant part and notify operator (light, buzzer, etc.) Gauging performed on setup and first-piece check (for set-up causes only) |
| | Product validation (reliability testing, development or validation tests) prior to design freeze using **test to failure** (e.g., until leaks, yields, cracks, etc.) | | 4 | | Moderately High | Problem Detection Post Processing | Failure Mode detection post-processing by automated controls that will detect discrepant part and lock part to prevent further processing |
| | Product validation (reliability testing, development or validation tests) prior to design freeze using **degradation** testing (e.g., data trends, before/after values, etc.). | | 3 | | High | Problem Detection at Source | Failure Mode detection in-station by automated controls that will detect discrepant part and automatically lock part in station to prevent further processing. |
| Virtual Analysis Correlated | Design analysis/detection controls have a strong detection capability. Virtual analysis (e.g., CAE, FEA, etc.) **is highly correlated** with actual or expected operating conditions prior to design freeze | | 2 | | Very High | Error Detection and/or Problem Prevention | Error (Cause) detection in-station by automated controls that will detect error and prevent discrepant part from being made. |
| Detection not applicable; Failure Prevention | Failure cause or failure mode can not occur because it is fully prevented through design solutions (e.g., proven design standard, best practice or common material, etc.) | | 1 | | Almost Certain | Detection not applicable; Error Prevention | Error (Cause) prevention as a result of fixture design, machine design or part design. Discrepant parts cannot be made because item has been error proofed by process/product design |

Figure 2 - Detectability Criteria [FMAE20]

## Bibliograhy

[FMAE20] Retrieved on April 20th from https://quality-one.com/fmea/