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SAFETY AND RELIABILITY ANALYSIS OF ELECTRIC POWER STEERING SYSTEM USED IN AUTOMOBILES

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ABSTRACT

Now a days Electric Power Steering (EPS) systems are widely used in automobiles because they are more fuel-efficient and user-friendly compared with the traditional HPS systems. In EPS system, the electric motor runs on a battery and gives the movement of steering when driver turns the wheel, with the help of Electronic Control Unit (ECU) and Sensors. Therefore, EPS system is a safety-critical system since it affects vehicle stability and dynamics. A failure in electronic hardware or software results in an uncontrolled steering event that can be neither commanded nor stopped by vehicle's driver. In this paper, failure mode effects and criticality analysis and fault tree analysis techniques are developed and ISO 26262 have been employed to study the safety requirements of EPS.Criticality calculations for different failure modes are obtained, so that they can be used to reduce the number of failures to improve future design aspects. To control these failures proper control methods are taken to improve the safety and reliability of EPS.

***Keywords: Electric Power Steering System, FMECA, FTA ,ISO-26262*.**

I. INTRODUCTION

In case of Electric Power Steering Systems (EPS) no fuel is used and less maintenance compared with the other Power Steering Systems, because of these EPS systems are widely used in recent years[1]. The EPS system works with the help of battery, as it consists of Permanent Magnet Synchronous Motor(PMSM),Electronic Control Unit(ECU),The EPS system works with the help of battery, as it consists Permanent Magnet Synchronous Motor(PMSM), Electronic Control Unit(ECU), Sensors and other mechanical components. The PMSM produces the required torque used to move the vehicle that is calculated by ECU with the help of sensors to steering column via gear.

The Electronic Control Unit in the EPS decides the direction of rotation and calculates the desired amount of torque based on sensor signals. The corresponding steering power is obtained by motor output. The ECU also controls the EPS operation. Like in Hydraulic Power Steering System(HPS),The EPS system is not having the power steering pump, hydraulic fluids, hoses thus it is energy-efficient and eco-friendly. The ECU also controls the EPS operation.

The researchers[2-5],have been studied about the EPS state space analysis, control logic, modelling techniques but the safety and reliability process has not been systematically explained. If any component in the EPS fails or any problem in program implementation thus causes to dangerous effects which are directly influence the driver’s safety. So the EPS system is not only guarantee that it performs satisfactorily, but also prevent the failures in the system if it is operated in any condition. Though EPS controls the vehicle stability and dynamics its safety is most important.ISO 26262[10], is a functional safety standard provides an approach to determine the Automotive Safety Integral Level(ASIL).

In this paper, the safety analysis of EPS using quantitative FTA,FMECA are developed and hardware requirements of ISO 26262 are explained. In EPS, the PMSM is used to generate the torque which is used to move the vehicle, Electronic Control Unit ECU calculates the amount torque generated with the help of torque and speed sensors and the ECU also controls the EPS.

II. FMECA

FMECA is a combination of FMEA and criticality analysis. In the year 1950 FMEA was introduced. FMEA is a deductive analysis that identifies and evaluates the failure of a product, effects of the failure and gives the actions that could reduce the failures. Mainly there are two types of FMEA,these are Design Failure Mode and Effects Analysis(DFMEA) and Process Failure Mode and Effects Analysis(PFMEA)[6].DFMEA is developed in the design stage and PFMEA studies the manufacturing and assembly process of a product.DFMEA focuses the component and subsystem level failures. In this paper, DFMEA is used for calculation of failure mode criticalities. There are many applications of DFMEA when it performs properly. In quality improvement DFMEA is beneficial. The familiar failure modes of EPS are identified as many as possible by past unknown failures.

2.1 Criticality Analysis: The criticality analysis(CA) is used to rank the each potential failure mode identified in the FMEA process, according to the influence of severity and the failure effect probability based on the available data. FMECA was the first systematic method, developed by the U.S. Military[6].The complete FMECA of EPS are given in the FMECA report shown in table1.The below information given in the FMEA worksheet shall be transferred to the Criticality Analysis worksheet:

- Identify Item function
- Identify failure
- Identify causes of failure
- Identify the effects of failure
- Actions that could taken
- Determine criticality

2.2 Failure probability/failure rate: Failure rate is given as the failure per operating time. It is given in hour, Million hour, Billion hour. The number of failures given in particular time is given as failure rate. For each failure mode given in FMEA calculate the failure rate of particular item. Here MIL-217, NPRD data sources are used in the calculation of failure rate [7].In this failure rates are taken as failure per million hours.

2.3 Failure effect probability (β): Failure effect probability is the effect of probability for each failure mode given in the FMECA.The user has decided these values based on his judgement[8] according to the MIL-STD-1629.

2.4 Failure mode ratio (α): For a particular failure mode the percentage of part failure rate is given as the failure mode ratio[9].It is evaluated by the user. For each failure mode the failure mode ratio value is taken based on FMD-91.The sum of α values will be equal to unity when all failure modes of a component are considered. If failure mode data are not available, then α value should be taken based on user judgement[9].

2.5 FMECA of EPS

By studying the operation and working of EPS the familiar potential failure modes of EPS are analysed and the severity rankings are assigned based on its effects. If these causes of failures are controlled then take measures to prevent this, it will decrease the criticality number to lower level ,thus improves the safety of EPS.Now classify the every failure mode of EPS related to the system, subsystems and component level and calculate the criticality of each mode.

The five potential causes of EPS failure modes are:

- Failure of the Electronic Control Unit
- Failure of torque sensor and steering angle sensor
- Battery Failure
- EPS motor Failure
- Controller Area Network communication failure.

Coming to the each above category, each one is caused by subsystems and components. For example, the causes of EPS motor failure may be due to open circuit, short circuit, rotor fails and so on. Similarly the failure modes of each above category is subdivided into subsystem and component level failure modes, and calculate the criticality of each failure mode according to the given below equation. Based on this identify the highest critical failure mode and take measures to prevent this failure. The criticality of a failure mode is calculated by equation(1)

Criticality Number $C_m = \beta \alpha \lambda_p t$ (1)

where λ_p=part failure rate in million hour

t= operating time in hours

α=failure mode ratio

β=failure effect probability

III. FTA OF EPS

FTA was developed by Bell Telephone laboratories in 1962. FTA is a top-down deductive failure analysis method that gives the root causes of a failure[10].FTA is a combination of top undesired event, basic events and logic gates. The basic events are connected by logic gates that give logical expressions to inputs. The examples for logic gates are AND gate, OR gate, NOR gate, EX-OR gate etc.By developing the FTA of EPS system identify the critical components, fault paths and possible errors. In this paper, the quantitative FTA for EPS system are developed. In this the top undesired event is EPS failure. Then identify the events that are caused to steering failure. The EPS system consists of motor, power supply, ECU,torque and speed sensor and mechanical system. If any of these fails that could lead to EPS failure. In this paper consider the top undesired event "steering failure" to implement the quantitative FTA as given in Figure2.

By FTA identify the system weakness, causes leading to the EPS failure and prevent this by controlling the basic events thus improve the reliability of EPS. The Electric Power Steering System probability is 0.00045015 by the analysis of FTA.which is the failure probability of EPS system.

IV. ISO 26262

ISO 26262 is an international functional safety standard that is taken from the IEC 61508 standard. This standard is used for electric and electronic systems within road vehicles. ISO 26262 is having 9 parts which are helpful to achieve functional safety [10]. The overview of ISO 26262 is shown in fig1. Functional safety means the system operated correctly with respect to its inputs. It provides an approach to determine integrity levels that is "ASIL'(Automotive Safety Integral). ASIL is the last part of ISO 26262 and is categorised as ASIL A, ASIL B, ASIL C and ASIL D. In which ASIL D is the highest risk level. ISO 26262 gives a reference V model to conduct the different phases of product development process . Here in this paper the hazard and risk assessment of opposite steering is considered [11], and the corresponding ASIL is calculated. When this hazard occurs the driver will not able to move in correct direction. Due to this the loss of steering control exists which lead to accidents, so the severity is high. The causes for opposite steering are failure of sensor, Controller Area Network failure and ECU failure. ASIL is determined in this case, by severity, controllability; probability of exposure, that is obtained as ASIL D.ASIL D is the highest risk level, so specific safety goal should be determined to prevent this. And the hardware requirements of EPS failure metrics are calculated and are obtained as ASIL-D by failure analysis.

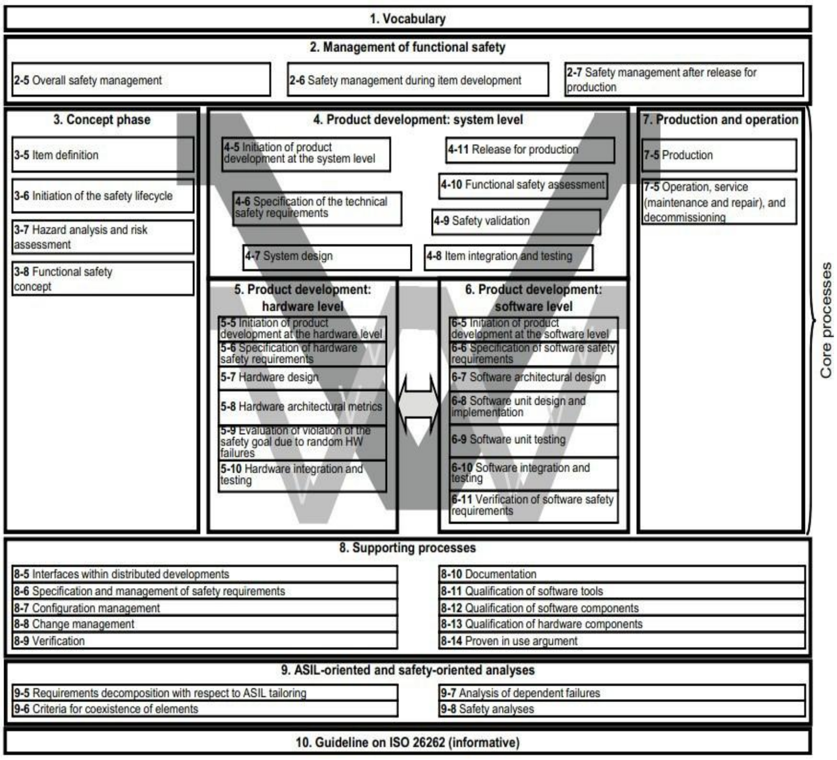

Fig1.overview of ISO 26262

Table 1: FMECA worksheet of EPS

Item	*Failure mode*	*Failure cause*	*Severity*	*Failure mode ratio (α)*	*Failure effect probability*	*Failure rate(λ) in FMH(NPRD)*	*Operating time t in hours*	*Criticality*	*Effects*
Permanent Magnet Synchronous Motor	Motor winding short circuit	Motor inner winding insulation fails	catastrophic	0.31	1	148.235	1	45.95285	Motor damaged due to excessive current
	Motor winding open circuit	Excessive current at winding terminals	Critical	0.28	1	148.235	1	41.505798	Motor may be cutoff by the ECU ,the motor become generator
	Motor fails to start	Power supply failure or connections wrong	catastrophic	0.23	1	148.235	1	34.09405	No output
	Motor fails to run	Insufficient voltage To be operated	Major	0.18	1	148.235	1	26.685	No output
Sensor	False response	Faulty sensor	Critical	0.15	1	113.402	1	17.0103	Incorrect output
	Fault tolerance	Sensor signal incorrect	Critical	0.68	1	113.402	1	77.11336	Incorrect output
	Sensor open	Power supply failure or connections wrong	Major	0.12	1	113.402	1	13.60824	No output
	Sensor short	Short circuit of connectors	Major	0.05	1	113.402	1	5.6701	No output
Power supply	No output	No power	catastrophic	0.52	1	4.195	1	2.1814	No output
	Incorrect out put	Due to connections of capacitors and resistors mismatch	Major	0.48	1	4.195	1	1.88775	Incorrect output
ECU	Slow Transfer of data	Delay in communication between ECU and CAN	Major	0.79	1	0.02415	1	0.01907	Delay in output

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		communication.							
Transistor	Transistor open	Terminals get opened	Minor	0.61	1	5.55	1	3.3855	Incorrect output
	Transistor short	Terminals get shorted	Major	0.39	1	5.55	1	2.1645	Incorrect output
Diode	Short mode	Diode get over heated	Minor	0.49	1	0.000316	1	0.0005484	No output
	Open mode	Terminals are opened	Minor	0.51	1	0.000316	1	0.000474	No output
Resistor	Open	Terminals get opened	Minor	0.54	1	0.00066	1	0.0003564	Incorrect output
	Short mode	Terminals get shorted	Minor	0.46	1	0.00066	1	0.0003036	Incorrect output
Capacitor	Short mode	Capacitor get over heated	Major	0.54	1	0.012	1	0.0648	No output
	Open mode	Terminals are opened	Minor	0.46	1	0.012	1	0.00552	No output

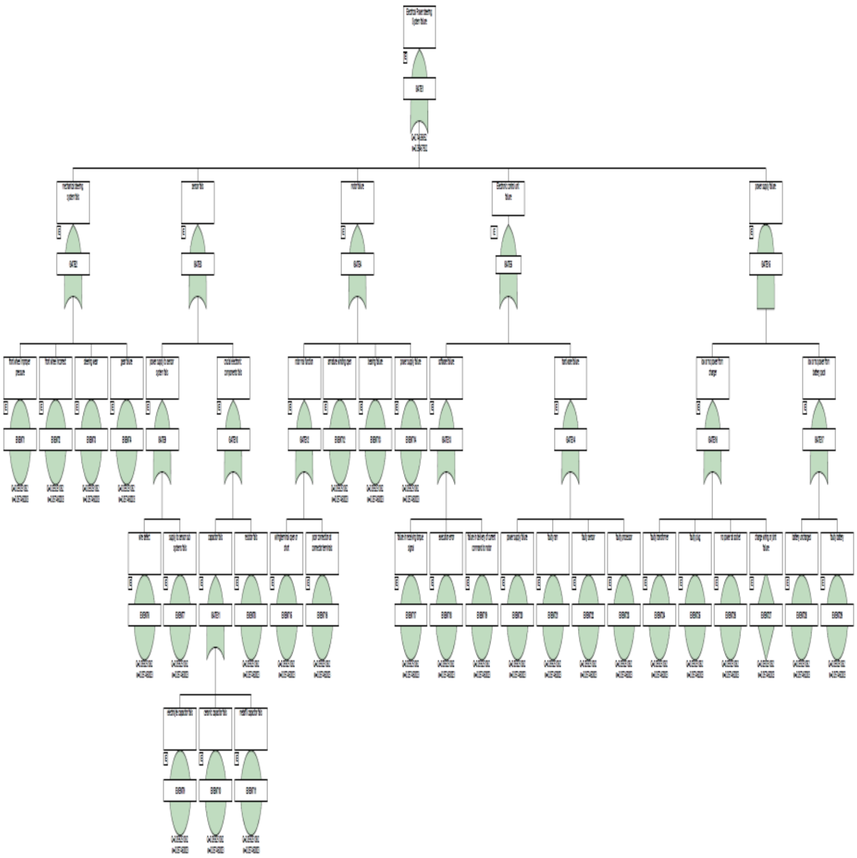

Fig2.FTA of EPS

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VI. CONCLUSION

The main content of this paper is to improve safety and reliability of EPS. In this paper FMECA and quantitative FTA of EPS system are developed. By using FMECA and FTA identify the failure causes and weakness of the system. so that these potential failures can then be designed out, which decreases the system failures and improves reliability. By FMECA the most critical component is motor, then measures should be taken to lower the criticality level and improve the system reliability and safety. By using the FTA the EPS probability, failure rate is calculated, this helps the EPS system weak nodes and gives maintainability information thus focus efforts on improving reliability and safety of EPS. And also the safety requirements of ISO26262 are explained using FTA and FMECA.

REFERENCES

[1] Rajiv Dey, "Electronic Power Assisted Steering System" International Journal of Engineering and Innovative Technology(IJEIT) Volume 1, Issue 3, March 2012.

[2] F.Bolourchi and C. Etienne, "Active damping controls algorithm for an electric power steering application," In Automotive Technology & Automation, pp. 807-816, 1997.

[3] J. H. Kim and J. B. Song, "Control logic for an electric power steering system using assist motor,"Mechatronics, vol. 12, no. 3, pp. 447- 459,2002.

[4] C. H. Hu, "Modelling and simulation of automotive electric power steering system,"In Intelligent.InformationTechnology Application, Second International Symposium, vol. 3, no. 2, pp. 436-439, 2008.

[5] D. Mahendra, "Modelling and analysis of power steering system, "International Journal of Electric and Hybrid Vehicles, vol. 4, no. 8 pp.2911-2915, 2010.

[6] MIL-STD-1629A, 1980

[7] Reliability Prediction of ElectronicEquipment, Department of Defence , MIL-HDBK217F, Dec. 1991.

[8] FMD-91,Reliability Analysis Centre,1990.

[9] W. E. Vesely and N. H. Roberts, Fault Tree Handbook. Nuclear Regulatory Commission.

[10] ISO 26262, Road Vehicles-Functional Safety, 2011.

[11] P. O. Jacob, "Design & safety considerations for electric power steering (EPS) systems based on automotive safety integrity levels," SAE Technical Paper, 2010.