

Reliability Analysis of Electric Vehicle Charging Station Using Risk-Based Inspection Method and Reliability Block Diagram

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Abstract - Due to the increasing market demand for electric vehicles, particularly electric cars, the infrastructure for electric vehicles is also being fulfilled. This research utilized two methods: Risk Based Inspection and Reliability Block Diagram. Through the Risk Based Inspection method, a Risk Priority Number was obtained which identifies critical points in the Electric Vehicle Charging Station (EVCS). The Block Diagram method established relationships between interconnected subsystems. The research findings indicate that the critical point of the EVCS lies within the Body subsystem. This discovery significantly contributes to raising awareness about EVCS, ensuring that stakeholders entering the EVCS business have a clearer understanding and knowledge of the system.

Keywords: EVCS, Risk Based Inspection, Reliability Block Diagram.

I. INTRODUCTION

In recent years, Indonesia has faced serious challenges related to air pollution. According to Law Number 23 Year 1997 on Environmental Management, air pollution is defined as the entry or presence of living organisms, substances, energy, or environmental changes caused by human activities or natural processes, leading to a decline in environmental quality to the extent that the environment no longer functions according to its original purpose [1]. Air pollution in Indonesia is prevalent in major cities such as the capital, Jakarta. According to the air quality research organization IQAir, the air pollution in the capital was once the highest in the world (IQAir, 2023) [2]. Air pollution is caused by various human activities such as production and transportation activities. Data from the Ministry of Environment and Forestry (MoEF, 2023) related to air quality improvement in the Greater Jakarta area indicates that the largest contributor to pollution in Jakarta is emissions from the transportation sector

at 44%, followed by the energy industry sector at 31%, the manufacturing industry sector at 10%, the residential sector at 14%, and the commercial sector at 1% [3].

To reduce emissions or combustion residues from motor vehicles, the use of fossil fuels in the transportation sector must be minimized or even replaced with other energy sources. One implementation of this is transitioning to electric vehicles (EVs)[4]. The electric vehicle industry has advanced due to the issuance of Presidential Regulation No. 55 of 2019 (PERPRES 55/2019) on the acceleration of the battery-based electric vehicle program. This regulation has boosted the adoption of electric vehicles in Indonesia [5]. In 2022 alone, the number of electric two wheelers (E2W) and electric four-wheelers (E4W) on the roads increased nearly fivefold and fourfold, respectively, compared to 2021 [6]. However, despite this significant growth in 2022, the adoption rate of electric vehicles is still far from meeting Indonesia's Nationally Determined Contribution (NDC) targets for reducing excessive carbon emissions [7].

If the availability of infrastructure that can support the sustainability of electric vehicles is ensured, public interest in switching to electric vehicles will increase rapidly. One of the supporting infrastructures is charging infrastructure for electric vehicles, thus a reliability analysis is necessary. Reliability is defined as the probability that a product will perform its intended function without failure, under specified conditions, for a certain period [8]. A common inspection method applied in the electrical industry, known as Risk-Based Inspection (RBI), has not yet been implemented at PT PLN. Therefore, the researcher proposes to the management of PT PLN to apply the RBI method in maintenance management, in addition to the existing time-based inspection and maintenance programs, with the hope that the RBI method can be an alternative solution for achieving efficiency in the maintenance of electric vehicle charging stations currently

installed at PT PLN locations. The points are the reasons that prompted the author to conduct this Final Project research.

II. MATERIALS AND METHODS OF RESEARCH

2.1 Electric Vehicle Supply Equipment (EVSE) Sub-system

Public Electric Vehicle Charging Stations (EVCS) are places where battery-powered electric motor vehicles can charge their batteries. In Indonesia, these facilities are known as Public Electric Vehicle Charging Stations (EVCS). The primary function of EVCS/SPKLU is to transfer electrical energy from the source to the electric vehicle's battery while ensuring that the power flow is appropriate and safe for the vehicle.

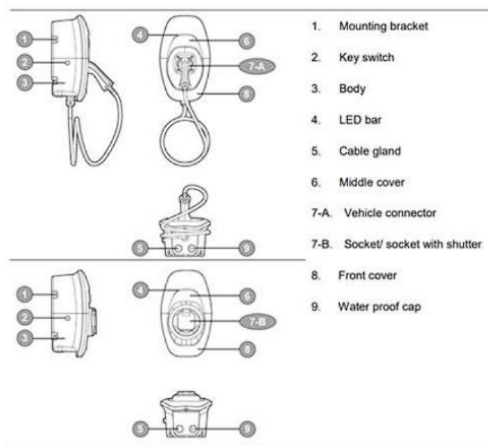


Figure 1: EVCS Sub-system

2.2 Risk Based Inspection

Risk-based inspection is a management tool to identify and prioritize risks associated with systems at various levels, and to present inspection plans based on calculated risks. RBI provides a modeling process to control reliability, safety, and health aspects, ensuring maintenance in technical performance and project cost. This inspection identifies risk sources and prioritizes equipment based on risk levels [9].

Risk-Based Inspection (RBI) is used to support decision-makers in managing this inspection intervention program. The basic principle of RBI is quite simple: after determining the risk target by the user (acceptable risk), the inspection program is designed to prevent risk levels higher than specified, thereby avoiding unwanted failures [10].

The result of RBI will generate a Risk Priority Number as presented in Table 1.

Table 1: Risk Priority Number

Component	Severity	Occurrence	Detection	RPN
Surge Protection	10	2	6	120
AC Isolation Circuit Breaker	10	2	6	120
Charging Cable & Connector	8	8	1	64
Auxiliary Power Supply	8	2	4	64
AC Charging Controller	8	2	4	64
Energy Measurement	6	2	4	48
Residual Current Monitor	6	2	4	48
Wired & Wireless Connectivity	5	8	3	120
Display & LED Indicator	2	8	3	48
Radio Frequency Identification	2	2	3	12
Temperature Measurement	8	2	4	64

From the table, it is found that the components with the highest values are wired & wireless connectivity, surged protection, and circuit breaker.



Figure 2: Wired and Wireless Connectivity



Figure 3: Surge Protection

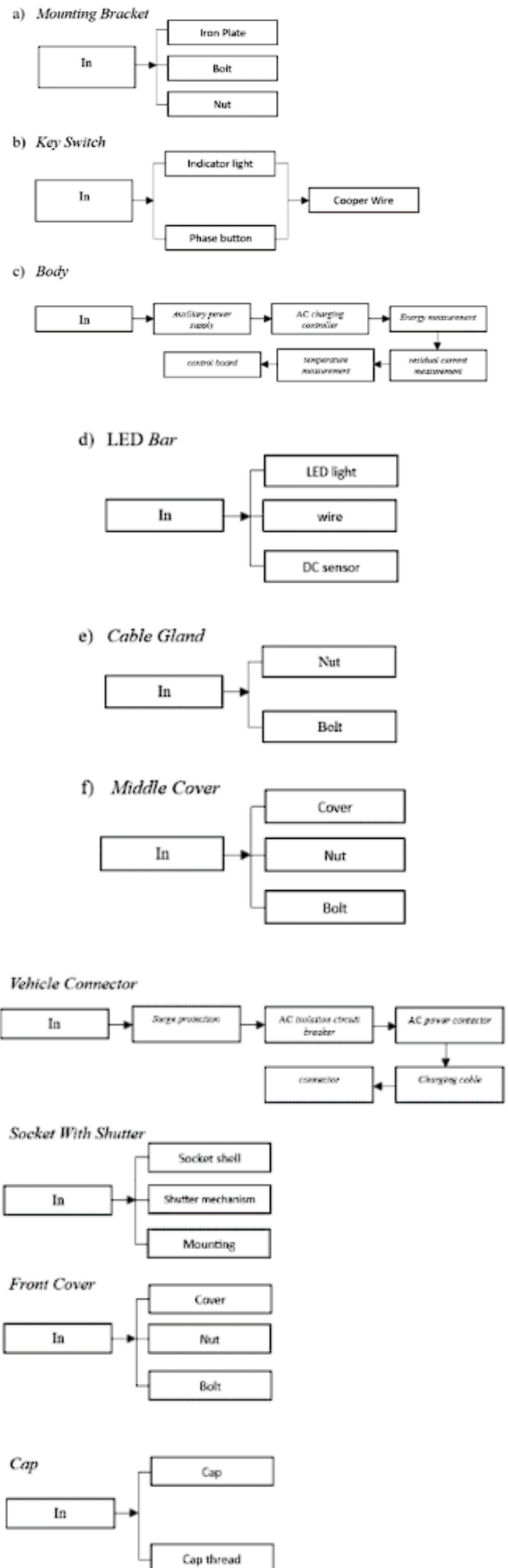


Figure 4: AC Installation Circuit Breaker

2.3 Reliability Block Diagram

The steps in creating a reliability block diagram for EVCS are crucial because they can be used to understand the dependency of each component from one subsystem to another within the EVCS system. By knowing the relationship of each component, the level of risk can be determined to prioritize repairs or maintenance. Priority focus is given to components with the highest risk levels based on critical analysis calculations.

Component grouping is necessary to determine the circuits present in the reliability block diagram. Here are the 9 sections of an EVCS along with the components within them.



III. RESULTS AND DISCUSSIONS

3.1 Risk Level Justification Results Based on Risk Priority Number

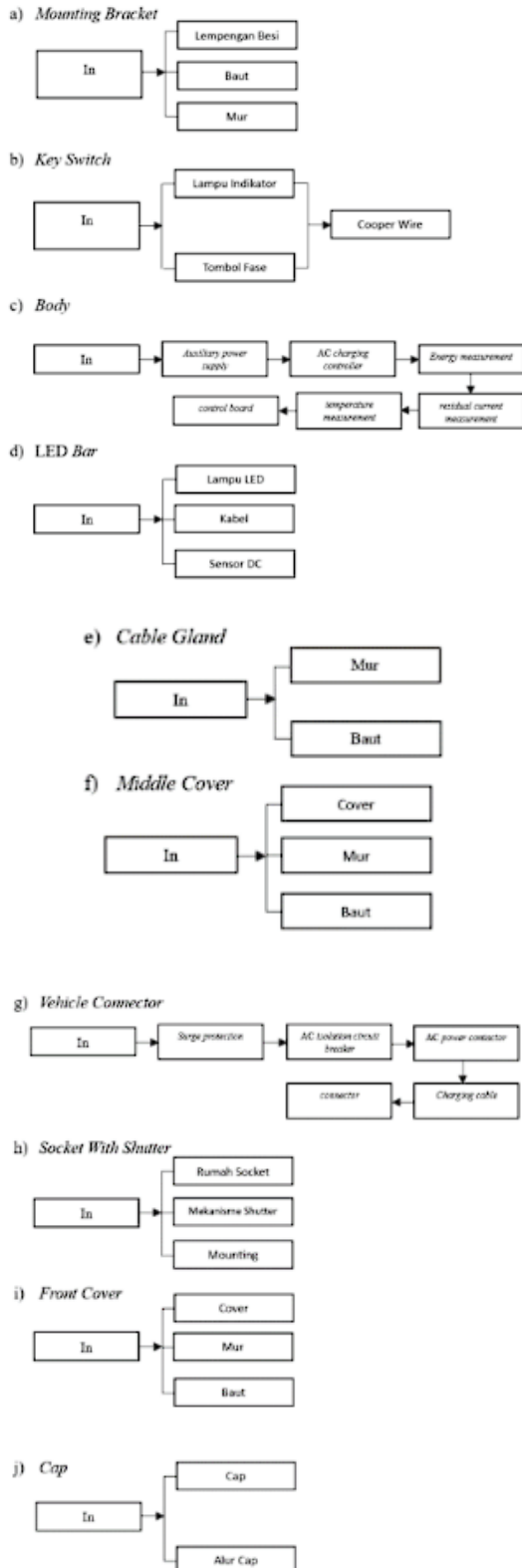
According by RPN calculation the result obtained Probability of Failure as shown in Table 2 below.

Table 2: Probability of Failure

Component (Assy/Sub-Assy/part)	Function	Normal Condition	Testing
Surge Protection	Protecting against sudden electrical surges	Voltage 396 V-400 V	Inputting abnormal voltage surges
AC Isolation Circuit Breaker	Protecting circuit breaker circuits from electrical leakage or short circuits	No leakage current from the circuit breaker	Using module sensor PZEM-004T
Charging Cable & Connector	Powering electric vehicles from the power source	Current flows according to specifications with no defects in the connector cables fitting and loading when connected to the car port	The current is tested with a multimeter at the connector terminal
Auxiliary Power Supply	Providing lower and stable DC voltage from the main AC supply.	Voltage converted from AC to DC	The current is tested with a multimeter at the connector terminals
AC Charging Controller	Controlling and monitoring the electric vehicle charging process	Observation of the duration of the charging time	Timer
Energy Measurement	Monitoring the amount of energy passing through and tracking the energy consumed by the connected electrical circuit using energy measurement	Showing changes when different inputs are provided	Observations from a monitor or temperature measurement
Residual Current Monitor	Monitoring the electric current entering and exiting through the electrical circuit	Showing consistent changes when different inputs are provided	Observations from a monitor or temperature measurements
Wired & Wireless Connectivity	Providing information to the operator (wired) and to the user (wireless)	Can connect via UTP cable and connect to the Chagres in PLN application	Handphone dan PC
Display & LED Indicator	Allows EV charging station users to monitor charging progress in real-time and provides important information such as voltage and current levels	All statuses are illuminated and provide accurate figures	Look at EVCS Display Monitor
Radio Frequency Identification	Allows users to start charging sessions by swiping an RFID card	The card can be identified properly Using EVCS	Using EVCS
Temperature Measurement	Showing several indications or symptoms of abnormalities occurring in the EV charging system	Temperature indicators turn on	Temperature display in EVCS

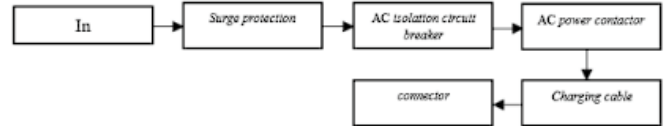
3.2 Reliability Block Diagram arrangements

Based on the 9 subsystems that have been described, a study and testing have been conducted regarding the interrelationship of components within each subsystem, and these relationships are explained in the following diagram.

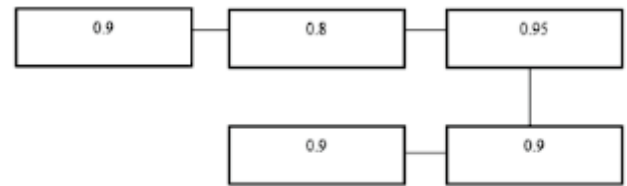


3.2.1 Reliability Calculation Based on Diagram above then

This Calculation focuses on the reliability of the vehicle connector subsystem.



The value of R knows as follows



Thus, the reliability system calculation is as follows:

$$\text{System} = 0,9 \cdot 0,8 \cdot 0,95 \cdot 0,9 \cdot 0,9 = 0,55404$$

3.3 RBI in Body Sub-system


In this subsystem, one example that will be used for testing is the AC Charging Controller. Its function is to regulate the electric current flowing to the vehicle and adjust to the battery capacity and electrical power source. The testing method is based on time:

Check Car Specification

Check EVCS Specification

Do Time Calculation

Example Wuling Air EV



Battery capacity 26,7 kWh

In this case, EVCS specification as follows :

Charging Output	Single-phase: 1.7 kW	Single-phase: 7.4 kW
Normal Power	Three-phase: 11 kW	Three-phase: 22 kW

Thus, time needed :

$$t_{\text{Charging}}(\text{hour}) = \frac{\text{Battery capacity (kWh)}}{\text{Charging Output EVCS (kW)}}$$

$$t_{\text{Charging}}(\text{hour}) = \frac{26,7 \text{ kWh}}{22 \text{ kW}} = 1,21 \text{ Hours or } 72,6 \text{ minutes}$$

Once the ideal charging time is determined, it can be matched with Table 2 of the probability of failure so that issues can be efficiently identified.

IV. CONCLUSION

Based on this research, critical components in the EV charging station have been identified. A RPN (Risk Priority Number) table has been established, enabling Risk Level

Justification mapping. The reliability for the critical component in the EV charging station, specifically in the vehicle connector subsystem, has been determined to be 0.55404.

ACKNOWLEDGEMENT

The authors would like to thank the Electrical Analysis and Engineering Measurement Reliability Laboratories of Diponegoro University for providing the equipment used for data collection in this research.

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Citation of this Article:

Falih Setiawan, Gunawan Dwi Haryadi, Ismoyo Haryanto, Toni Prahasto, Achmad Widodo, & Ojo Kurdi. (2024). Reliability Analysis of Electric Vehicle Charging Station Using Risk-Based Inspection Method and Reliability Block Diagram. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(9), 290-296. Article DOI <https://doi.org/10.47001/IRJIET/2024.809035>
