



Analysis of Grounding Issue in E-House Fabrication

Final Project

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Approval sheet

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Analysis of Grounding Issue in E-House Fabrication

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Abstract— The grounding system is a critical element in the fabrication of electrical house (E-house). Defects in this stage can reduce the reliability of the system, increase the potential for safety risks to personnel, and directly affect the quality of the final fabrication. This study uses a combination of Fishbone Diagrams and 5 Whys analyses to identify and investigate grounding-related issues during the fabrication process. The case study focuses on two major defects: Grounding resistance not good and Grounding not installed properly. A systematic analysis successfully identified the root causes, which were addressed through corrective actions. These included recalibrating the torque tools used for grounding bolt tightening and reinforcing the consistency of the internal inspection checklist monitoring process. These improvements were implemented continuously and effectively reduced grounding defects while improving installation performance. The structured approach offered by the Fishbone and 5 Whys methodologies supports the prioritization of improvement actions and provides clear technical guidance to minimize grounding-related risks. This contributes to enhanced overall fabrication quality.

Keywords: grounding system, E-House, fishbone diagram, 5 Why analysis, root cause analysis, fabrication quality, corrective actions

I. INTRODUCTION

The electrical house (E-house) is a prefabricated unit used as an electrical distribution and control center in industrial projects, such as those involving oil and gas, mining, and power plants.[1] A reliable grounding system is essential for protecting equipment and personnel from electrical disturbances, including leakage currents and overvoltage conditions.[2] However, grounding installation issues are frequently identified during the fabrication and inspection stages. These issues include grounding resistance that is not good, which is associated with increased contact resistance at bolted connections.[3] [4] Measurements using a ductor tester that exceed commonly referenced indicative micro-ohm ranges ($<50\text{--}200\ \mu\Omega$).[5] Other issues include grounding that is not installed properly and practices that do not comply with approved drawings and technical specifications. These deviations lead to noncompliance with grounding design standards. These nonconformities indicate

that the grounding installation process does not fully comply with quality requirements.[2]

This study uses the Fishbone Diagram (Ishikawa) and the 5 Whys analysis method, based on field observations, document review, and measurement data, to identify the root causes of these issues. The Fishbone Diagram identifies dominant contributing factors, and the 5 Why method traces underlying root causes to support effective corrective and preventive actions.[6]

II. METHOD

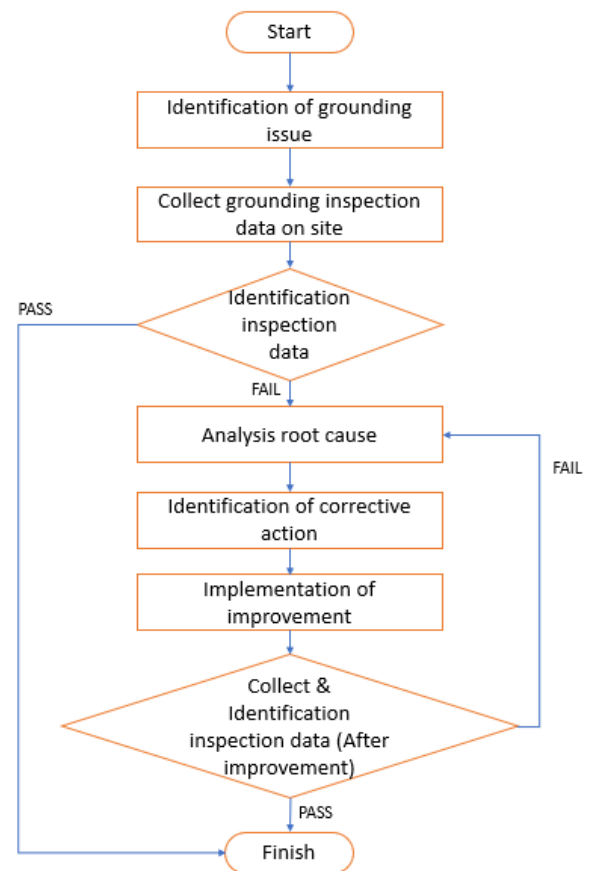


Figure 1. Flowchart Activity Analysis.

Figure 1. In completing the project “Analysis of Grounding Issue in E-House Fabrication”, a flow chart is needed to support the workflow to be carried out.

III. RESULT AND DISCUSSION

A. Fishbone Diagram

As shown at Figure 2. Fishbone Diagram, also known as an Ishikawa diagram, which is an analytical tool used to systematically identify and classify the various causes of quality problems. This method is also widely used to map organizational challenges to support tracing the root causes of problems. In this study, the fishbone diagram was used to categorize the primary causal factors and facilitate further analysis using the 5 Whys method to identify the root causes of grounding problems in a more structured method.[6] [7]

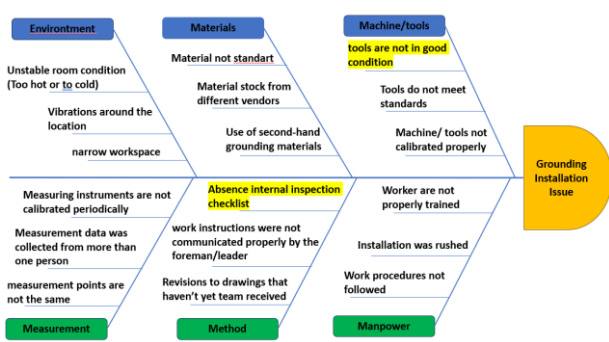


Figure 2. Fishbone Diagram

1. Material (No)

Material specifications are understood to be one of the factors affecting the performance of grounding systems, particularly with regard to electrical conductivity, the mechanical reliability of connections, and resistance to corrosion-related degradation. According to literature on grounding systems, selecting materials with adequate electrical and mechanical properties is important for maintaining the quality of grounding connections and ensuring their long-term reliability. [8][9]

However, based on field observations and visual inspections conducted during the fabrication stage, there were no indications of grounding material incompatibility that could be visually identified, such as physical damage or visible differences in specifications. Therefore, within the limitations of the visual inspection, material factors are not considered the primary cause of the grounding issues identified in this study.

2. Measurement (No)

The quality control team uses measuring instruments for grounding installation and verification activities that are practically included in the quality control system. According to literature in the fields of metrology and quality control, measuring instruments used for quality inspection and verification must undergo a calibration process to ensure the accuracy, consistency, and traceability of measurement results to recognized reference standards. Periodic calibration also detects shifts in instrument performance due to use, age, or environmental influences, thereby maintaining the reliability of inspection data.[10]

Based on the observed conditions, the same personnel took consistent measurements at the same points. No indications of measurement irregularities that could be attributed directly to errors in the instruments or measurement

methods were found. Therefore, measurement factors were not identified as the main cause of the analyzed grounding issues.

3. Machine/Tools (Yes)

A lack of proper contact pressure increases contact resistance, which reduces the reliability of the current conduction path in the grounding system.[11] Based on connection resistance measurement results from the E-House fabrication process, values exceeding the standard limit were identified, indicating mechanical connection issues. Theoretically, an increase in connection resistance is influenced by mechanical factors, particularly inaccurate bolt tightening torque, which results in suboptimal contact pressure in the connection area. [3] [4] Connection resistance measurements were carried out using a ductor tester (micro-ohmmeter), a low-resistance testing device commonly used to evaluate electrical connection quality due to its sensitivity to changes in connection mechanics.[12]

Results from the measurements correspond with mechanical connection theory, showing that grounding installation problems in this study are closely related to the reliability of work equipment, particularly the ability of torque wrenches to produce adequate contact pressure. Therefore, machine and tool factors were identified as the dominant contributors to the analyzed grounding problems.

4. Environment (No)

The long-term reliability of electrical installations and grounding systems can theoretically be affected by environmental conditions, including temperature, humidity, and mechanical vibration, particularly through their influence on material degradation and connection stability. According to electrical engineering literature, environmental factors must be considered when evaluating the performance of industrial electrical installations, especially substation and grounding system applications. [8] However, based on observations during the E-House fabrication stage, environmental parameters were within acceptable operational limits and showed no direct correlation with the identified grounding issues. Therefore, environmental factors were not classified as the dominant cause in this analysis.

5. People (No)

The literature widely recognizes human-related aspects, such as competence and training, as factors that can influence electrical safety outcomes. However, broader reviews on human factors in electrical work emphasize that frontline behavior and incidents are shaped by influences at multiple levels, including organizational, procedural, and environmental factors, rather than by individual failings alone. These reviews show that factors such as unclear procedures, inadequate verification systems, and a lack of effective controls influence execution performance and safety outcomes more than individual worker attributes do.[13] In this study, no objective evidence was found indicating that personnel competence was the primary cause of the observed grounding issues. Instead, the identified deviations were associated with ineffective verification and checklist control processes. Therefore, manpower-related factors were not

classified as dominant contributors to the grounding problem.

6. Method (Yes)

The reliability of grounding systems depends on proper installation methods and process control. Good electrical installation practices emphasize structured work procedures, systematic inspections, and consistent technical documentation. Inconsistencies in work method implementation can lead to discrepancies between the design and actual installation conditions.[8]

This study found that the grounding installation did not fully follow the design drawings, particularly in the connection of conductors to the earthing bar. This discrepancy has the potential to complicate the inspection and maintenance process because the cable routing and labeling are not in line with the technical documentation.[14] Therefore, the method factor was identified as one of the dominant causes of the grounding problems analyzed.

Table 1. Fishbone Table

No	Factor	Potential	Contributor (Yes/No)
1	Material	- Material not standart	No
		- Material stock from different vendors	No
		- Use of second-hand grounding materials	No
2	Measurement	- measurement points are not the same	No
		- Measurement data was collected from more than one person	No
		-Measuring instruments are not calibrated periodically	No
3	Machine / Tools	- Tools are not in good condition	Yes
		- Tools do not meet standards	No
		- Machine/ tools not calibrated properly	No
4	Enviroment	- Unstable room condition (Too hot or to cold)	No
		-Vibrations around the location	No
		- Narrow workspace	No
5	Manpower	- Worker are not properly trained	No
		- Installation was rushed	No
		- Work procedures not followed	No
6	Method	- No internal inspection checklist	Yes
		-work instructions were not communicated properly by the foreman/leader	No
		-Revisions to drawings that haven't yet team received	No

Based on the verification results on Table 1, the author concludes that Grounding issue are caused by Two factors, namely Machine/tools factors and method factors.

B. 5 Why

The 5 Whys method is a root cause analysis technique that uses repeated questioning to identify the underlying causes of a problem. The analysis begins with defining the main problem, with each answer serving as the basis for the next "why" question. This step-by-step approach helps uncover indirect cause-and-effect relationships, enabling more systematic and accurate identification of root causes of problems.[7]

C. Data analysis in 5 why

1. Grounding resistance not good

Problem	Grounding resistance not good
Why ?	Why is the grounding resistance not good?
	Because the bolt connection to the earthing bar is not strong enough.
Why ?	Why is the bolt connection to the earthing bar not strong enough?
	Because the bolt was not tightened properly.
Why ?	Why was the bolt not tightened properly?
	because the torque on the tool used is not matched
Why ?	Because the torque applied using the tool was not appropriate.
	Because the torque tool was in poor condition.
Why ?	Why was the torque tool in poor condition?
	Because the tool has been used continuously, resulting in deviation and reduced accuracy.
Root Cause	Because the tool has been used continuously, resulting in deviation and reduced accuracy.

Figure 3. 5 Why grounding resistance not good

The grounding problem in this study was indicated by grounding resistance values that did not meet the required standards. Ductor tester is a specialized instrument used in electrical protection and maintenance to evaluate the quality of metallic bonding and grounding connections. The device measures extremely low resistance values, typically in the micro-ohm range, by injecting a high test current through the conductor and detecting the resulting voltage drop. The measurement principle ensures high accuracy, as even small resistance increases caused by corrosion, oxidation, or insufficient torque can significantly affect grounding performance. [15] Figure 3. A 5 Whys analysis revealed that suboptimal bolt connections on the earthing bar caused this condition. These connections increased contact resistance and disrupted the current conduction path to the grounding system. The bolts were not tightened to the appropriate preload force due to inaccurate torque values being applied, resulting in weak connections.

Torque wrenches are limited because the torque they deliver can deviate from the set value when used repeatedly in the field. Over time, mechanical wear, friction changes, and variations in the tool mechanism can cause the actual torque applied to decrease in accuracy and consistency. Even with calibration, repeated use in real conditions can lead to significant deviations in the delivered torque, creating uncertainty in achieving the required preload force on a bolt connection. Such variability in torque output undermines the reliability of torque-based tightening methods for ensuring consistent preload in grounding connections.[16]

Based on the results of this analysis, it can be concluded that the grounding problems in this study were primarily caused by factors related to the machine/tools used. Notably,

the reliability of torque tools in ensuring the quality of mechanical grounding connections.

2. Grounding not installed properly

Problem	Grounding not installed Properly
Why ?	Why was the grounding not installed properly?
	Because the installation did not follow the drawing and specifications.
Why ?	Why did the installation not follow the drawing and specifications?
	Because the workers failed to correctly interpret the drawing.
Why ?	Why did the workers fail to interpret the drawing correctly?
	Because the verification or checklist process was not conducted after installation.
Why ?	Why was the verification or checklist process not conducted?
	Because there was no control or monitoring to ensure the checklist was properly implemented.
Why ?	Why was there no control or monitoring over the checklist implementation?
	Because the control system for checklist implementation was not running effectively.
Root Cause	Because the control system for checklist implementation was not running effectively.

Figure 4. 5 Why grounding not installed properly

The problem with this 5 Whys analysis is that the grounding cable installation does not comply with the working drawings or technical specifications. The location and route of the installation should follow the established design. Discrepancies between the design and the actual conditions in the field can lead to differences in the grounding configuration. This complicates the process of verifying and evaluating the system as a whole and has the potential to affect the safety of grounding systems in substations and E-houses.[2] This situation occurred because the installation did not fully adhere to the approved drawings, and there was no adequate post-installation verification process or checklist. According to the literature, consistency between the design and implementation of grounding installations is an important work method for ensuring that the grounding system functions effectively and safely. [2]

Therefore, this problem is influenced more by work method factors and weak installation control systems than by individual worker errors.

1) Data collection

Data were collected by observing and recording grounding issues that occurred during the Inspection E-House fabrication process over a three-week period

Table 2. Data Collection Grounding issue before action

Inspection Time (Module XYZ)	Total Units (Point)	Total Grounding Issue (Point)	Type of Issue		
			Grounding not installed properly (Point)	Grounding resistance not good (Point)	% Issue
1 st Week of Oct 2024 (Substation A)	60	26	6	20	43,33%
2 nd Week of Oct 2024 (Substation B)	60	23	8	15	38,33%
3 rd Week of Oct 2024 (Substation C)	30	22	6	16	73,33%
Total	150	71	20	51	47,33%

Table 2. shown grounding data was collected on the XYZ module during three observation periods representing different locations: Substation A during the 1st week, Substation B during the 2nd week, and Substation C during the 3rd week. The data were obtained through grounding connection measurements from electrical equipment and systems (e.g. electrical panels (LV, MV, and MCC), switchgear, fire alarm panels, lighting systems, HVAC, and cable tray systems). All of these systems were bonded to the main grounding bar. During the 1st week at Substation A, 26 problematic points (43.33%) were found out of 60 grounding

points inspected. These consisted of six grounding points that were not installed correctly and 20 points with poor grounding resistance. During the 2nd week at Substation B, 23 problematic points (38.33%) were identified out of 60 points, consisting of eight grounding points that were not installed correctly and 15 points with poor grounding resistance. During the 3rd week at Substation C, 30 grounding points were inspected, and 22 problematic points (73.33%) were found. Of these, six were not installed correctly, and 16 did not meet the grounding resistance criteria. Overall, out of a total of 150 grounding points inspected on the XYZ module, there were 71 problematic points with an issue percentage of 47.33%. This data indicates that the majority of grounding problems identified are related to grounding resistance values that do not meet the required criteria, thus forming the basis for further analysis using the Fishbone Diagram and 5 Whys methods before corrective action is taken.

2) Identify causes

Grounding issues are mainly caused by two factors: poor grounding connection quality and incorrect installation practices. Insufficiently tightening bolts causes poor contact on the grounding bar, increasing contact resistance. This condition is influenced by torque tools whose performance decreases with continuous use, resulting in inaccurate torque application.

Additionally, grounding installations often deviate from design drawings and specifications. Limited verification after installation and ineffective control of checklist implementation allow installation errors to go undetected.

3) Process Improvement

After identifying the root causes, corrective improvements were implemented. A third-party calibration vendor recalibrated the torque tools used for grounding installation to restore measurement accuracy and ensure compliance with applicable standards. These tools were only reused after meeting the required tolerance limits.

Additionally, a post-installation grounding checklist was implemented as a control mechanism. The assigned technician carried out the installation, and then completed a post-installation checklist. A supervisor then verified the checklist to ensure compliance with the design drawings and technical specifications. This verification process served as a control mechanism to confirm that the implemented improvements were properly applied. After implementing corrective improvements, follow-up data was collected during the next grounding installations to evaluate the improvements' effectiveness.

4) Monitoring after Implementation

Data was collected after corrective action was taken by recording the number of Issue in E-house Fabrication over the course of three weeks, from the first week of March to the third week of March 2025.

Table 3. Data Collection Grounding issue after action

Inspection Time (Module XYY)	Total Units (Point)	Total Grounding Issue (Point)	Type of Issue		
			Grounding not installed properly (Point)	Grounding resistance not good (Point)	% Issue
1 st Week of Mar 2025 (Substation A)	40	8	2	6	20,00%
2 nd Week of Mar 2025 (Substation B)	50	10	2	8	20,00%
3 rd Week of Mar 2025 (Substation C)	30	5	0	5	16,67%
Total	120	23	4	19	19,17%

Table 3 shows that data was collected on the XYY module during three observation periods representing different locations: Substation A during the 1st week, Substation B during the 2nd week, and Substation C during the 3rd week. corrective actions were implemented, grounding issues decreased across all inspection periods. The highest percentage of grounding issues was observed in the 1st and 2nd weeks of March 2025 at 20.00%, while the lowest percentage occurred in the 3rd week at 16.67%. The overall grounding issue rate after improvement was 19.17%, indicating a significant reduction compared to the condition before corrective action and demonstrating improved grounding installation quality.

5) Comparison before and after implementation

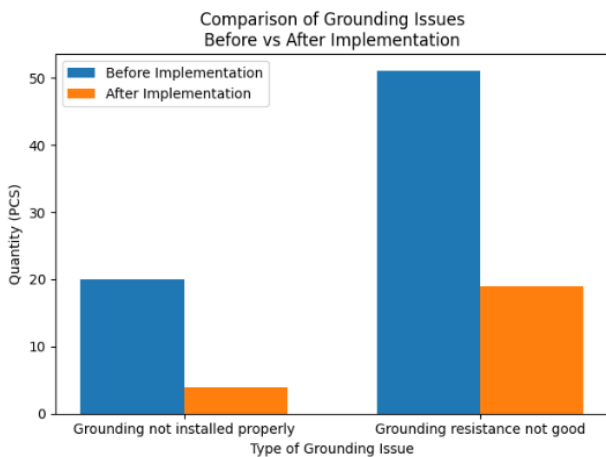


Figure 5. Comparison of grounding issue before vs after

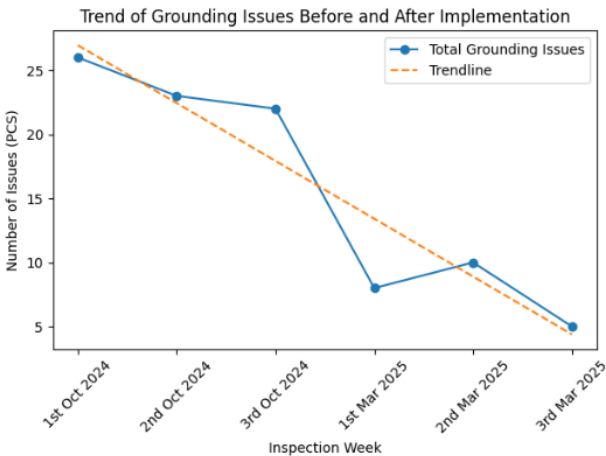


Figure 6. Trendline of grounding issue

All inspections were carried out using the same criteria by the same personnel with the same equipment so the results could be directly compared. As Figures 3 and 4 show, there was a significant reduction in grounding issues after corrective actions were implemented. Improperly installed grounding and inadequate grounding resistance decreased significantly, indicating improved installation quality and connection reliability. The downward trend across inspection periods confirms that the implemented actions effectively addressed the dominant root causes. Thus, the corrective actions effectively reduced grounding issues and improved the overall quality of the grounding system during the E-

House fabrication process.

IV. Conclusion

The study, "Analysis of Grounding Issues in E-House Fabrication," yielded three key findings. First, the Fishbone Diagram and 5 Whys methods successfully identified and analyzed the main causes of grounding problems. These problems were primarily due to unreliable torque tools and an absence of a structured, post-installation inspection and checklist control process. Second, grounding resistance measurements using a ductor tester revealed elevated contact resistance values. These values were linked to insufficient contact pressure, which was caused by improper bolt tightening. This finding confirms that mechanical connection quality is critical to grounding system performance. Third, the author improved the grounding installation process by recalibrating torque tools, implementing a standardized checklist, and monitoring post-installation effectively. These corrective actions reduced grounding issues and enhanced the reliability of the E-House grounding system. The study provides clear recommendations for minimizing grounding issues and improving installation quality through systematic root cause analysis.

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Attachment

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