Analysis and Improvement of Work Methods to Reduce Wiring and Assembly Defects on Motor Starter Panels at PT Feen Marine

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Received on dd-mm-yyyy | *Revised on dd-mm-yyyy* | *Accepted on dd-mm-yyyy*

***Abstract*— The quality of electrical panel products is essential to ensure the safety, reliability, and performance of electrical systems, particularly in industrial and marine applications. In practice, variations in work methods, inconsistent task execution, and limited compliance with Standard Operating Procedures (SOPs) often contribute to defects in the electrical panel assembly process. These issues indicate that product quality problems are closely related to how work activities are performed at the operational level, not solely to final inspection results. This study aims to analyze the effectiveness of work method implementation in improving the quality of electrical panel products at PT Feen Marine in 2025. A qualitative descriptive approach is employed through direct observation of production activities, interviews with production personnel and supervisors, and analysis of production data, quality inspection records, and defect reports. The evaluation focuses on work method consistency, SOP compliance, and key quality indicators such as assembly neatness, installation accuracy, and defect occurrence. The results are expected to show that standardized work methods significantly reduce process variation and human error while improving product quality consistency.**

Keywords: Work Method, Standardized Work, Electrical Panel, Product Quality, Manufacturing Process

I. INTRODUCTION

Motor Starter Panels are essential electrical control systems used to operate, protect, and regulate electric motors in both industrial and marine applications. These panels contain critical components such as contactors, thermal overload relays, MCBs, push buttons, and terminal blocks, all of which play a direct role in motor reliability and operational safety. Due to the critical function of Motor Starter Panels, the accuracy and consistency of the assembly and wiring process are crucial in determining the overall quality and performance of the final product. [1]

However, several quality issues are still found during the production process of Motor Starter Panels at PT Feen Marine, particularly in the wiring and assembly stages. Field observations indicate recurring problems such as miswiring, weak crimping, improper cable routing, inconsistent cable labeling, and deviations from wiring diagrams. Similar wiring issues were also highlighted by [2]

who found that improper wiring and non-standard crimping are major contributors to defects in electrical panels. In addition, variations in work methods between operators further increase the inconsistency of wiring quality and raise the likelihood of defects [3]

II. METHOD

A. Research design

This study uses a qualitative descriptive research design to evaluate the effectiveness of standardized work method implementation in improving wiring quality on Motor Starter Panels at PT Feen Marine. The qualitative approach is chosen because the research focuses on observing work activities, understanding operator behavior, identifying work variations, and evaluating changes in wiring quality before and after the implementation of standardized work. Data are collected through direct observation, interviews, documentation analysis, and defect data review. These data are then analyzed using root cause analysis and comparative evaluation to determine how standardized work improves consistency and reduces wiring defects.

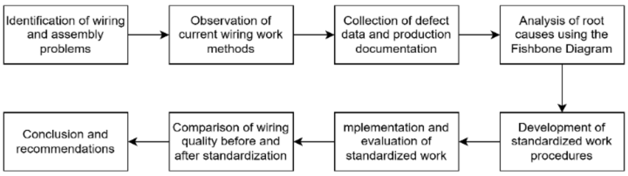


Figure 1. *Research Design*

B. Collection of error findings data

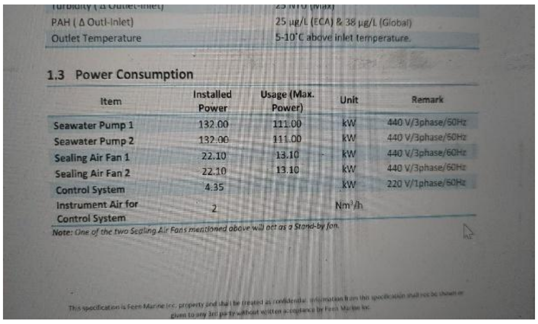
IThe following data were collected during the assembly of several motor starter panels, in which various types of errors were identified. These issues include a lack of attention to detail during assembly, insufficient checking and verification, limited understanding of wiring procedures, and the use of inadequate tools that do not fully support the assembly process

TABLE 1. DATA COLLECTION

Week	Total Panels	Total Number of Defect Types
1	1 panel	4
2	1 panel	2
3	1 panel	3
4	1 panel	3
5	1 panel	4
6	1 panel	2
7	1 panel	2
8	1 panel	3
9	1 panel	3
10	1 panel	4
Total	**10 panels**	**30 defect types**

C. *Motor starter panel specifications*

The motor starter panel analyzed in this research is used to control the **Sealing Air Fan** system installed in a marine application. The panel functions as the main control unit for starting, stopping, and protecting the electric motor while ensuring safe and reliable operation.



PAH (Δ Outl-Inlet)	25 µg/L (ECA) & 38 µg/L (Global)
Outlet Temperature	5-10°C above inlet temperature.

1.3 Power Consumption

Item	Installed Power	Usage (Max. Power)	Unit	Remark
Seawater Pump 1	132.00	111.00	kW	440 V/3phase/60Hz
Seawater Pump 2	132.00	111.00	kW	440 V/3phase/60Hz
Sealing Air Fan 1	22.10	13.10	kW	440 V/3phase/60Hz
Sealing Air Fan 2	22.10	13.10	kW	440 V/3phase/60Hz
Control System	4.35		kW	220 V/1phase/60Hz
Instrument Air for Control System	2		Nm³/h	

Note: One of the two Sealing Air Fans mentioned above will act as a Stand-by fan.

Figure 2. *Motor starter panel specifications*

Based on the technical specification provided by PT Feen Marine, the Sealing Air Fan motor starter panel has the specifications shown in Table 2

TABLE 2. Motor starter panel specification

Parameter	Specification
Equipment	Sealing Air Fan Motor Starter Panel
Number of Motors	2 Units (1 Duty + 1 Standby)
Installed Motor Power	22.10 kW each
Maximum Operating Power	13.10 kW each
Rated Voltage	440 VAC
Phase	3 Phase
Frequency	60 Hz
Control System Power Supply	220 VAC, 1 Phase, 60 Hz
Control System Power	4.35 kW
Instrument Air Requirement	2 Nm^3/h
Operating Mode	One fan operates as Duty, while the other remains Standby

D. *Cable specifications*

The Motor Starter Panel uses several cable sizes according to the electrical load and function of each circuit. Selecting the appropriate cable size is important to ensure safe current carrying capacity, minimize voltage drop, and maintain reliable operation of the panel.

TABLE 3. Cable specifications

No.	Cable Size (mm^2)	Application / Location	Function	Reason for Selection
1.	6 mm^2	Main power circuit (Incoming power, Main Switch, Contactor, Overload Relay, Motor Output)	Carries the main current used to supply power to the Sealing Air Fan motor.	Selected because the main power circuit carries the highest current. The larger conductor reduces voltage drop, minimizes heat generation, and ensures safe and reliable motor operation.
2.	2.5 mm^2	Auxiliary power circuit (MCB, Control Transformer, Internal Power Distribution)	Supplies electrical power to auxiliary components and internal power distribution.	Used for medium-current circuits where a smaller cable than the main power cable is sufficient while maintaining adequate current-carrying capacity and electrical safety.
3.	0.75 mm^2	Control circuit (Relay, Terminal Block, Push Button, Indicator Lamp, Control Wiring)	Transmits control signals and low-current electrical power between control devices.	Selected because control circuits require only a small current. The smaller cable size simplifies wiring, improves panel neatness, and reduces installation cost while maintaining reliable operation.

Note: Cable selection is based on the expected load current, current-carrying capacity (ampacity), and industrial wiring practices in accordance with IEC 60204-1 and IEC 60364 to ensure electrical safety and reliable panel operation.

E. *Applicable Standard*

The assembly and wiring process of Motor Starter Panels must comply with internationally recognized electrical standards to ensure safety, reliability, consistency, and product quality. In addition to international

TABLE 4. Applicable standard

Standard Title	Title / Scope	Application in This Research
IEC 61439-1	Low-voltage Switchgear and Controlgear Assemblies – General Rules	Used as the primary reference for the design, assembly, and verification of low-voltage electrical panels.
IEC 60204-1	Safety of Machinery – Electrical Equipment of Machines	Provides requirements for electrical wiring, protection, grounding, and safety of control panels.
IEC 60445	Basic and Safety Principles for Man–Machine Interface, Marking and Identification	Used as the reference for conductor color identification, terminal marking, and equipment labeling.
IEC 60364	Low-voltage Electrical Installations	Used as a guideline for cable selection, current-carrying capacity, and electrical installation practices.
Company SOP	PT Feen Marine Work Instruction	Used as the internal guideline for wiring sequence, component installation, inspection, and quality control during panel assembly.

F. *Fishbone*

The Fishbone diagram (also called the Ishikawa diagram) is a tool for identifying the root causes of quality problems. It was named after Kaoru Ishikawa, a Japanese quality control statistician, the man who pioneered the use of this chart in the 1960's (Juran, 1999). Fishbone (Ishikawa) diagram mainly represents a model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. The structure provided by the diagram helps team members think in a very systematic way. Some of the benefits of constructing a Fishbone diagram are that it helps determine the root causes of a problem or quality characteristic using a structured approach, encourages group participation and utilizes group knowledge of the process, identifies areas where data should be collected for further study (Basic Tools for Process Improvement, 2009).[4]

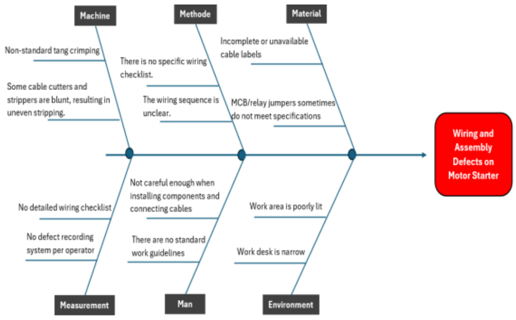


Figure 3. Fishbone diagram

III. RESULT AND DISCUSSION

A. *Fishbone Diagram wiring and assembly defect*

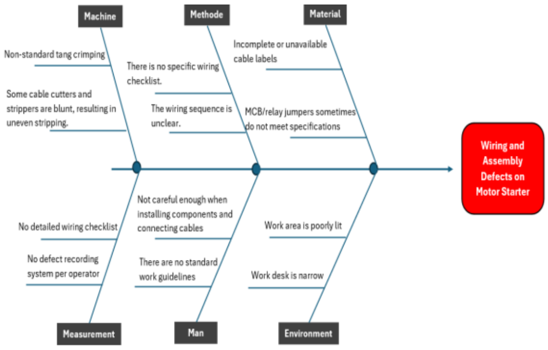


Figure 4. *Fishbone Diagram wiring and assembly defect*

Based on **Figure 4**, the authors used the Fishbone Diagram as a tool to identify the possible root causes of wiring and assembly defects in the Motor Starter Panel production process at PT Feen Marine.

TABLE 5 FISHBONE TABLE

Factor	Potential Cause	Observation	Status
Machine	Non-standard tang crimping	Crimping results are inconsistent and may cause loose connections.	NO
	Some cable cutters and strippers are blunt, resulting in uneven stripping.	Cable insulation is not stripped cleanly and may cause damage, increasing the risk of defects.	NO
Method	There is no specific wiring checklist.	Operators do not have a structured work guideline, leading to variations in output.	CAUSE
	The wiring sequence is unclear.	Cable installation is not performed in a clear order, causing confusion and potential mistakes.	CAUSE
Material	Incomplete or unavailable cable labels	Cables are difficult to identify, slowing the process and increasing the risk of wrong connections.	NO
	MCB/relay jumpers sometimes do not meet specifications	Material inconsistency leads to unreliable connection quality.	NO
Measurement	No detailed wiring checklist	There is no reference to verify each wiring step.	NO
	No defect recording system per operator	Root cause analysis is difficult because there is no record of who performed the work.	NO
Man	Not careful enough when installing components and connecting cables	Installation errors are found in several points due to lack of attention to detail.	CAUSE
	There are no standard work guidelines	Operators rely on personal habits instead of standardized procedures.	CAUSE
Environment	Work area is poorly lit	Poor lighting makes it difficult for operators to see cable and connector	NO

		details.	
	Work desk is narrow	Limited workspace makes it difficult for operators to arrange cables and components.	NO

To determine the primary causes of wiring and assembly defects, each potential cause identified in the Fishbone Diagram was verified through direct observation during the Motor Starter Panel assembly process. The verification results indicate that only the verified causes were considered the main contributors to the defects. The summary of the verification results is presented below:

1) *Machine*
   - N/A
2) *Method*
   - Operators do not have a structured work guideline, leading to variations in output.
   - Cable installation is not performed in a clear order, causing confusion and potential mistakes
3) *Material*
   - N/A
4) *Measurement*
   - N/A
5) *Man*
   - Installation errors are found in several points due to lack of attention to detail.
   - Operators rely on personal habits instead of standardized procedures.
6) *Environment*
   - N/A

B. *Electrical drawing verification*

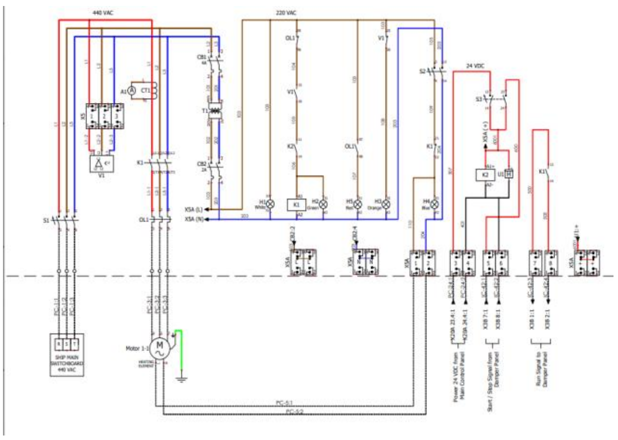


Figure 5. *Electrical Drawing*

Electrical drawing verification was conducted to ensure that the Motor Starter Panel assembly complied with the approved electrical drawing. The verification process involved comparing the electrical drawing with the actual panel to confirm the correctness of component installation, wiring connections, terminal numbering, and cable identification. The verified electrical drawing used as the reference during this study is shown in **Figure 5**

C. *Development of Standardized Work*

Based on the results of the Fishbone analysis and electrical drawing verification, standardized work instructions were developed to improve consistency during the Motor Starter Panel assembly process. The standardized work provides a systematic sequence of activities, ensuring that each operator follows the same assembly and wiring procedures. The developed work instructions for operators and quality control are presented in the following tables.

TABLE *6*. Work Instruction For Operator

Operator name: date of work: completion date: panel type: panel serial number:				
NO	**Type of process**	**all done**	**not yet**	**description**
1	Prepare all components and drawings.			
2	Check the completeness of the components and their specifications.			
3	Assemble all components onto the panel.			
4	Ensure that all components are installed correctly and completely.			
5	After all components are complete, begin wiring the panel.			
6	After completing the wiring, perform a re-inspection.			

TABLE 7. Work Instruction For Quality control

NO	Check item	pass	Fail	Remarks
1	All required components are installed			
2	All components have the correct identification (Tag No.)			
3	All installed cables have the correct cable markings			
4	All installed cables have cable lugs and are properly tightened			
5	All installed terminal blocks are numbered			
6	All installed terminal blocks have the correct label name			
7	Cable wiring uses the correct color codes			
8	All installed terminal blocks have the correct color			
9	There are no loose terminations			
10	MCB jumper connections are correct and tight			

D. Comparison Between Drawing and Actual Panel

After completing the electrical drawing verification, a comparison was conducted between the approved electrical drawing and the actual Motor Starter Panel assembly. This comparison was performed to identify any discrepancies in component installation, wiring connections, cable numbering, and terminal identification. The comparison results are presented in the following figures.

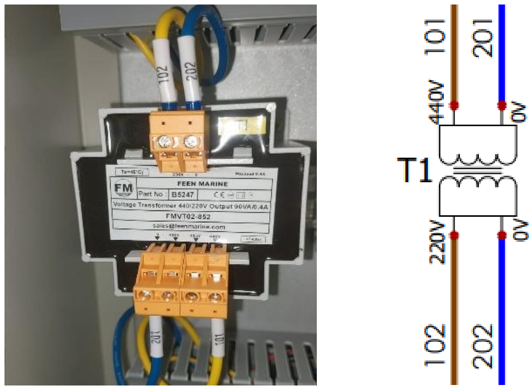


Figure 6. *Comparison Between Drawing and Actual Panel*

The following is an example of a comparison between the drawing and the actual results on the wiring panel; it shows that the actual results are in accordance with the drawing.

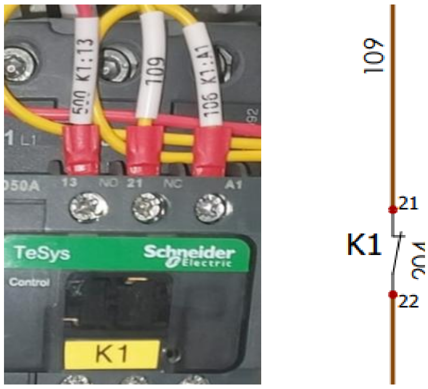


Figure 7. *Comparison Between Drawing and Actual Panel*

The following is an image showing the wire connected to the magnetic contactor (K1) at port 21—the yellow wire marked 109. This indicates that the wires installed on the component match the drawing.

E. Before and after comparison

After the implementation of standardized work, a comparison was conducted between the conditions before and after the improvement to evaluate the effectiveness of the developed work method. The comparison was based on the total number of defect types identified during the Motor Starter Panel assembly process. The comparison results demonstrate the impact of standardized work on reducing defects and improving the consistency of the assembly process.

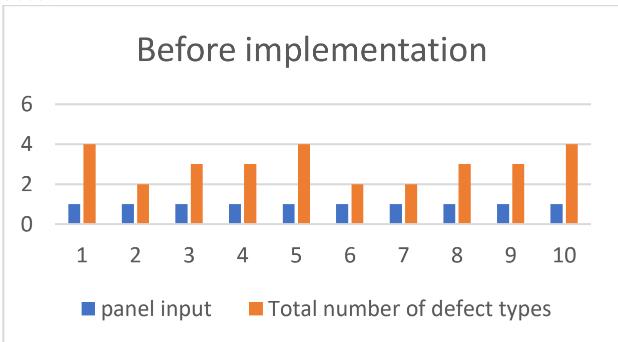


Figure 7. *Before implementation*

Before implementation, there were 30 types of defects on 10 panels

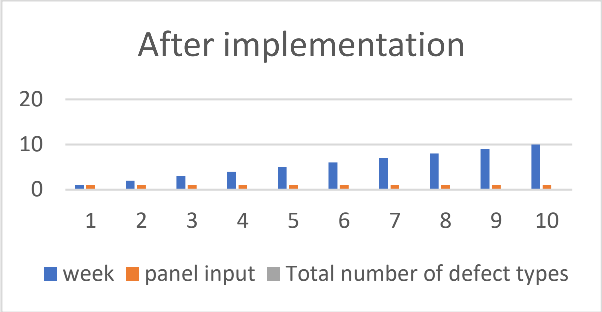


Figure 8. *After implementation*

After making the repairs, no defects were found.

IV. CONCLUSION

This study analyzed the root causes of wiring and assembly defects in the Motor Starter Panel production process at PT Feen Marine using the Fishbone Diagram. The analysis identified that the primary causes of the defects were related to the **Method** and **Man** factors, specifically the absence of structured work guidelines, unclear wiring sequences, lack of attention during assembly, and operators relying on personal work habits.

Based on these findings, standardized work instructions for operators and quality control were developed to establish a consistent assembly process. The implementation of standardized work improved the consistency of wiring activities and reduced variations during panel assembly.

Furthermore, the comparison of defect data before and after implementation showed that the standardized work effectively reduced wiring and assembly defects. Therefore, it can be concluded that the implementation of standardized work contributes to improving the quality and consistency of the Motor Starter Panel assembly process at PT Feen Marine.

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