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THE COMPUTER GRAB HOLDING CONTROL SYSTEM ON A GSU (GRAB SHIP UNLOADER) CRANE

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Abstract
Grab Ship Unloader (GSU) is one of the main pieces of equipment in bulk material handling operations at industrial ports, where the reliability of the control system plays a crucial role in ensuring operational efficiency and safety. One of the critical subsystems in a GSU is the *grab holding* control system, which regulates the opening, holding, and closing processes of the grab during material handling. This internship report aims to analyze the grab holding control system of the GSU crane at PT Krakatau Bandar Samudra, with a particular focus on the Programmable Logic Controller (PLC)-based control logic and the implementation of ladder diagrams. The research methods include direct field observation, literature review, and discussions with field supervisors and academic advisors. The analysis focuses on the operating principles of the control system, operating modes (manual, automatic, and high-speed), safety interlocks, and the utilization of sensors such as encoders, load cells, and motor torque feedback. The results indicate that the grab holding control system is designed with a well-structured logic that processes position and torque signals to determine safe and stable *hold*, *close*, and *open* commands. The PLC ladder diagram plays a significant role in managing automatic cycles, speed control through ramp steps, and preventing motion conflicts. With this control system, grab operations on the GSU crane can be carried out more precisely, efficiently, and safely. This internship report is expected to serve as a reference for the development, maintenance, and improvement of GSU crane control systems in industrial port environments.

INTRODUCTION

In the port industry, bulk cargo handling operations from ships to land represent one of the most critical processes within the logistics chain, directly affecting operational efficiency, safety, and throughput capacity. Bulk materials such as coal, sand, iron ore, and other commodities are commonly handled using specialized equipment designed for high-capacity and continuous operations. One of the most widely applied machines for this purpose is the Grab Ship Unloader (GSU), a crane system equipped with a grab bucket that enables the extraction of bulk materials from vessels and their transfer to conveyor systems or other land-based transportation facilities [1], [2].

At PT Krakatau Bandar Samudra (PT KBS), a subsidiary of the Krakatau Steel Group responsible for managing industrial port operations in the Cilegon area, Banten, GSUs play a vital role in ensuring the reliability and efficiency of loading and unloading activities. The performance of a GSU is strongly influenced by its control system, particularly the grab holding control system, which regulates the opening, holding, and closing actions of the grab during material handling processes. This subsystem must operate with high stability, precision, and safety, as it has a direct impact on operational effectiveness, energy consumption, and occupational safety [3].

The performance of the grab holding mechanism is determined not only by mechanical and hydraulic components but also by the automatic control system that governs pressure regulation, actuator response speed, and holding duration. PLC-based control systems are widely implemented in industrial crane applications due to their reliability, flexibility, and ability to integrate multiple sensor inputs such as torque and position feedback [4], [5]. However, malfunctions in the grab holding control system may result in grab slippage, excessive energy usage, reduced productivity, and even workplace accidents [6].

As operational demands increase and equipment ages, various technical issues may arise, including unstable hydraulic pressure, delayed actuator response, and failures of control components such as solenoid valves and pressure sensors. These issues highlight the importance of conducting a comprehensive analysis of the grab holding control system to assess its current condition, evaluate performance limitations, and identify opportunities for system optimization and improvement [7], [8].

Therefore, this study aims to analyze the grab holding control system of a GSU crane operating at PT Krakatau Bandar Samudra through system observation, performance evaluation, constraint identification, and optimization analysis. The results of this study are expected to contribute to improved operational efficiency, extended equipment service life, and enhanced workplace safety in a sustainable manner.

METHODS

The research methodology describes the approaches used to obtain data, both directly from field activities and from relevant literature sources. This methodology serves as a supporting framework for the analysis and discussion presented in this study. The research methods applied are as follows:

1. **Observation Method**
   The observation method was conducted to collect research data through direct and indirect field observations of the Grab Ship Unloader (GSU) crane at PT Krakatau Bandar Samudra. Following the field observations, systematic monitoring and analysis were performed on the research object to understand the operational characteristics and control system behavior of the grab holding mechanism.
2. **Literature Review Method**
   The literature review method involved collecting and examining reference materials from various written sources, such as scientific articles, academic journals, technical manuals, and research reports that are directly related to the issues discussed in this study. This method supports the theoretical foundation and comparative analysis of the grab holding control system.
3. **Discussion Method**
   Function of Computer in the GSU Grab Holding Control System

   The discussion method was carried out through technical discussions with field supervisors (Electric Cigading 1 Supervisor) who possess in-depth knowledge of the equipment and systems under study, as well as with academic supervisors responsible for guiding the research. This method was used to validate observations, clarify system operations, and strengthen the analytical results on figure 1

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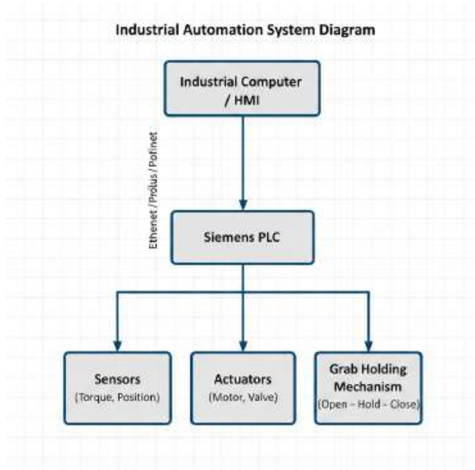

Figure 1. Function of computer in the GSU Grab Holding Control System

In the GSU grab holding control system, the computer functions as a supervisory and configuration unit that supports the PLC-based control architecture. The computer is typically implemented as an industrial PC or Human–Machine Interface (HMI) station and is connected to the Siemens PLC via industrial communication protocols such as Profinet or Profibus.

The primary function of the computer is to configure, monitor, and adjust control parameters used by the PLC. Through specialized software, the operator or engineer can set key control parameters, including torque thresholds, holding time, ramp coefficients, and mode selection (manual, automatic, or high-speed). These parameters are then transmitted to the PLC, which executes real-time control logic based on ladder diagram programming.

In addition, the computer provides real-time visualization of system states, such as grab position, motor torque, cycle status, and fault conditions. This visualization enables operators to supervise crane operations more effectively and respond quickly to abnormal conditions. The computer also serves as a data logging and diagnostic tool, storing historical operational data that can be used for performance analysis, troubleshooting, and preventive maintenance.

Unlike the PLC, which is responsible for deterministic and real-time control execution, the computer does not directly control actuators. Instead, it operates at the supervisory level, ensuring flexibility, system transparency, and ease of control system tuning. The integration of a computer with the PLC-based grab holding system enhances operational efficiency, system reliability, and safety in GSU crane operations at PT Krakatau Bandar Samudra.

RESULT AND DISCUSSION

The GSU crane is operated to transfer bulk materials from vessels to conveyor systems. One of the critical components in this system is the grab, which is controlled by a PLC-based system to automatically open and close based on position and torque signals. To implement grab holding control on the GSU crane (Grab Ship Unloader Crane), a PLC-based control system is required, and the controller used in this system is a Siemens PLC. The resulting PLC ladder program is described in the following sections.

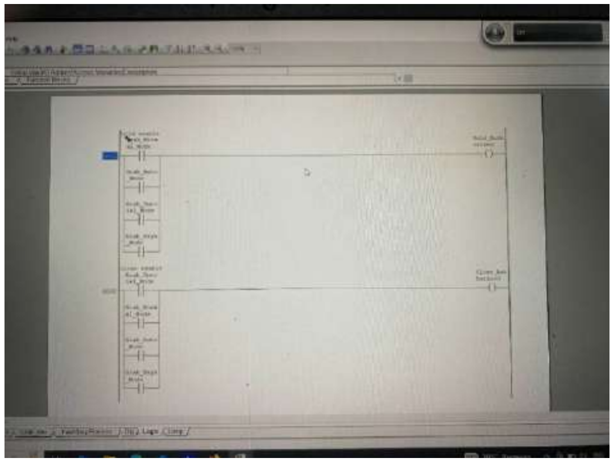

Figure 2. Ladder Diagram 1

Figure 2 illustrates the ladder logic that determines whether the system is in an authorized or unauthorized state to execute hold or close commands. Authorization can be obtained when one of the operating modes—Grab_Normal, Auto_Mode, Special_Mode, or High_Mode—is active. If any of these modes is enabled, the system allows the execution of Hold_Authorized and Close_Authorized commands.

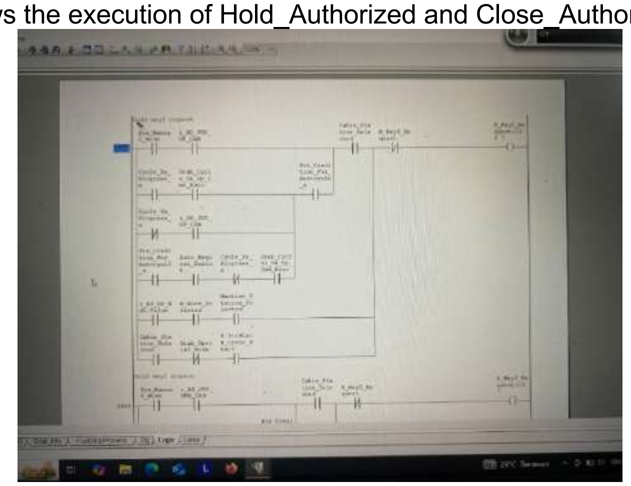

Figure 3: Ladder Diagram 2

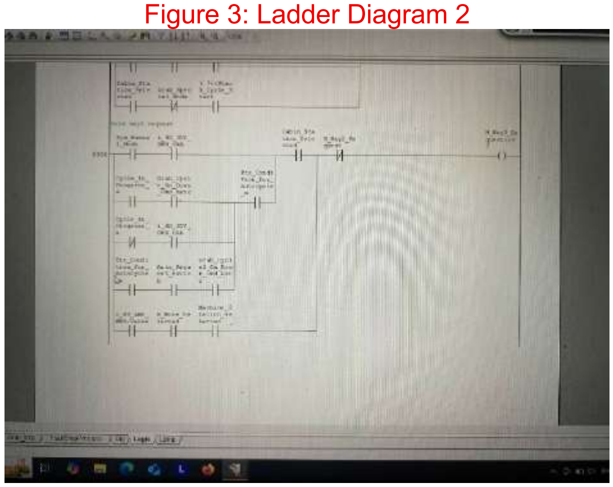

Figure 4. Ladder Diagram 3

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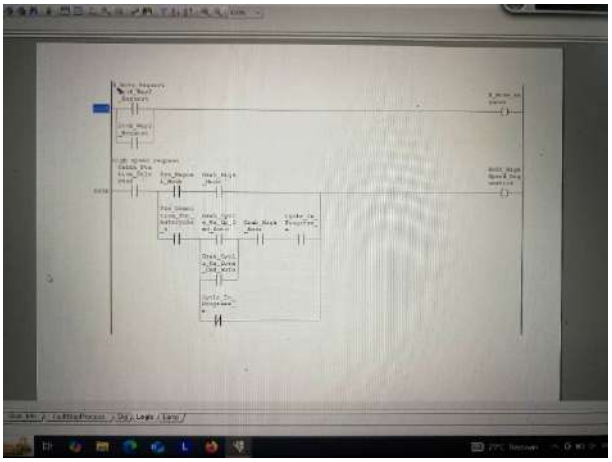

Figure 5. Ladder Diagram 4

Figures 2, 3, 4 and 5 show the ladder logic used to select between automatic and manual operation modes by separating the close and hold logic according to the selected mode. Manual mode is used when the operator needs to directly control the basic crane functions from the control panel, such as during initial setup, maintenance activities, or when sensor malfunctions occur.

As shown in Figures 4.3 and 4.4, the ladder logic indicates that the Sys_Manual_Mode signal is activated by the operator to switch control from the automatic system. In this mode, the operator can use the joystick signals (CL_JOY_UP_CAB and CL_JOY_DOWN_CAB) to manually open and close the grab. Safety interlocks are implemented through Cycle_In_Progress and Pre_Condition_For_Autocycle logic to prevent conflicts during mode transitions. Even in manual mode, the system verifies Machine_Station_Selected and Cabin_Station_Selected to prevent operation from an incorrect station.

Automatic mode is designed to accelerate and optimize bulk material handling processes by enabling repetitive operations without direct operator intervention. As shown in Figure 4.2, the Sys_Auto_Mode signal becomes active when Pre_Condition_For_Autocycle, Auto_Request_Switch, and Cycle_In_Progress conditions are satisfied. The PLC program then controls the open–hold–close grab cycle (Grab_Cycle_On_Open_Cmd_Auto and Grab_Cycle_On_Close_Cmd_Auto) based on torque and position sensor feedback. When the Grab_High_Mode condition is satisfied, the system activates the HighSpeed_Request signal to accelerate operation. The entire cycle is controlled and reset using Stack_Cycle_Start, Stack_Cycle_End, and Stack_Cycle_Bit logic.

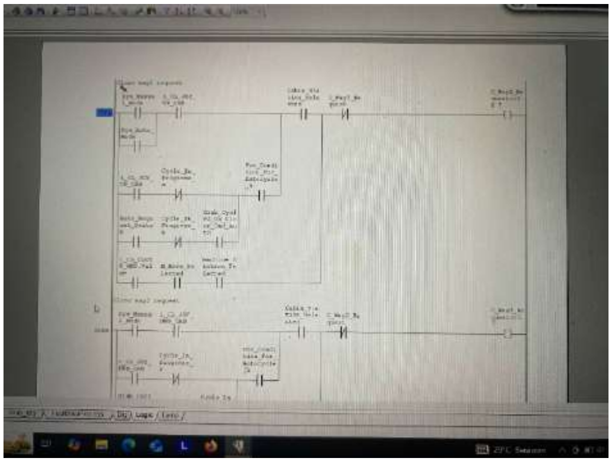

Figure 6. Ladder Diagram 5

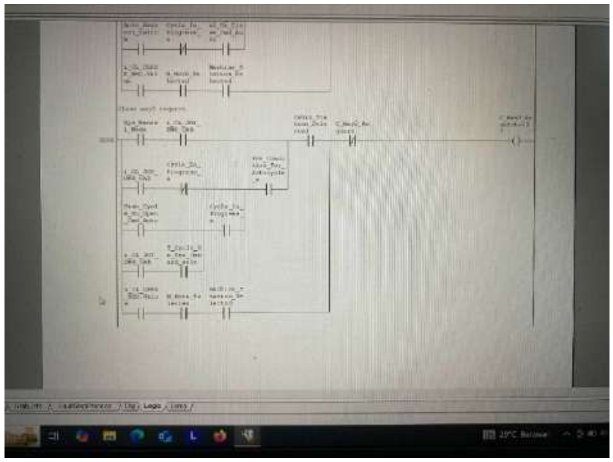

Figure 7. Ladder Diagram 6

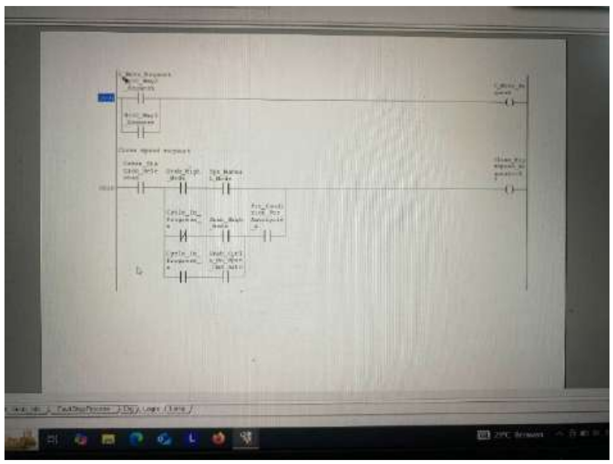

Figure 8. Ladder Diagram 7

Figures 6, 7, and 8 demonstrate how the PLC regulates motion requests through ladder logic to determine movement paths (Way2 and Way3), direction, and speed based on the operating mode and crane status. Motion requests are used to activate control signals for motors or actuators that drive the grab in specific directions at appropriate speeds.

In this logic, C_Move_Request represents the command to close the grab, H_Move_Request represents the command to hold the grab position, C_Way2_Request and H_Way2_Request represent movement requests through Way2, while C_Way3_Request and H_Way3_Request represent movement requests through Way3. The HighSpeed_Request signal enables high-speed operation mode.

The PLC only activates movement signals when operational conditions are satisfied. The grab must be in a valid mode (e.g., Auto Cycle active and Cabin Station selected), there must be no conflict between movement paths (Way2 and Way3 cannot be active simultaneously), the grab must not be in fault or bypass status, and the system must be in Cycle_In_Progress or the correct pre-condition state. For example, C_Way2_Request is activated only when Grab_High_Mode, Cycle_In_Progress, and Auto_Mode are active, while C_Way3_Request remains inactive. This logic ensures that grab movement occurs in only one direction at a time and prevents logical conflicts.

The system is designed to avoid overlapping movement paths. For instance, C_Way3_Request cannot be activated if C_Way2_Request is already active, and H_Move_Request or C_Move_Request are also conditioned to prevent simultaneous activation without system authorization. This approach is essential in crane control systems, as incorrect grab movement direction may cause workplace accidents or material damage.

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Figures 4.6 and 4.7 also illustrate the logic for activating the HighSpeed_Request signal. This signal is enabled only when Grab_High_Mode is manually activated by the operator, no fault conditions are present, the grab is in a position that permits high-speed operation, and the system is not transitioning between manual and automatic modes.

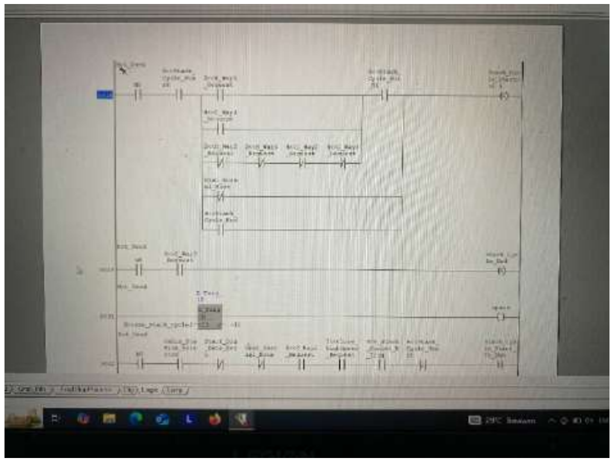

Figure 9. Ladder Diagram 8

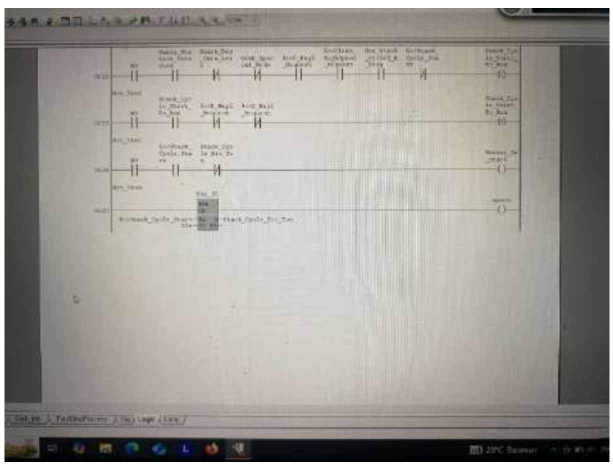

Figure 10. Ladder Diagram 9

Figures 9 and 10 show how the PLC processes initial trigger signals and preconditions to execute the automatic stacking cycle. The stacking cycle consists of a sequence of automatic commands that manage mode selection (auto/manual), cycle trigger signals from operators or sensors, and the activation of cycle bits to execute the grab open–hold–close logic.

To initiate the stacking cycle, several conditions must be satisfied, as shown in Figure 4.9. The Cabin_Station_Selected signal must be active, indicating control from the crane cabin; Grab_Special_Mode or Auto_Mode must be active, indicating the selection of automatic or special operation mode; Pre_Stack_Cycle2_Trig must be active as an initial trigger signal; and Cycle_In_Progress must be inactive, indicating that the previous cycle has been completed. When all conditions are met, the Stack_Cycle_Start_To_Run bit is set, marking the system's readiness to execute the automatic cycle.

Figure 4.8 also includes the TON_55 timer block with Stack_Cycle_Bit_Ton as its input. This ON-delay timer introduces a delay before the cycle is fully executed. The delay prevents the system from immediately executing open or close commands after the start signal and allows sufficient time for the PLC to read sensor status, torque values, and the last known grab position. After the delay elapses, the Cycle_In_Progress bit becomes active, and the automatic logic (such as Cmd_Auto_Close and Cmd_Hold) is executed sequentially by the PLC. After a cycle is completed, the operator can trigger the next stacking cycle, allowing the system to operate repeatedly in a loop until the unloading process is fully completed.

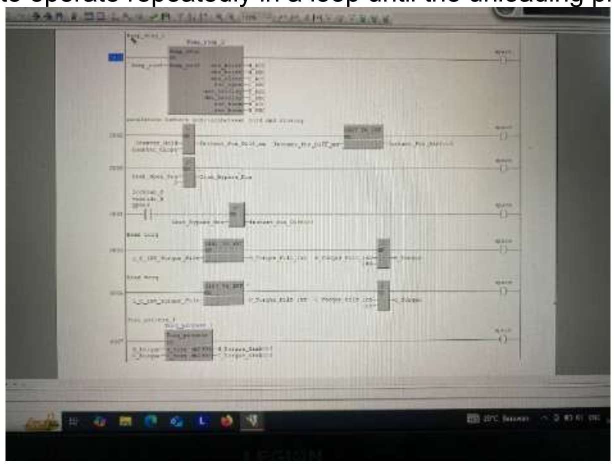

Figure 11. Ladder Diagram 10

Figure 11 presents the initial stage of the grab motion control process, which involves two critical aspects: the ramp step and torque filtering. The ramp step regulates grab acceleration and deceleration, while the torque filter processes motor torque values to provide reliable inputs for the PLC decision logic related to grab opening, holding, and closing. This stage is crucial for ensuring stable and accurate input data for the main PLC logic.

The ramp step is used to control the speed transition of the grab during movement. Its purpose is to prevent sudden movements or shock loads, provide smoother and more controlled motion, and adjust speed based on load torque and position. The ladder diagram shows the use of Ramp_step_2 and Ramp_coef functions to calculate the position difference (Instant_Pos_Diff) between the current and previous positions. This value is used to assess the actual grab movement, whether it is too fast, too slow, or stationary. The resulting calculation determines when the grab is permitted to close, hold, or reopen.

The PLC continuously reads torque values from the hoist motor (i_H_Torque) and trolley motor (i_C_Torque). However, torque sensor signals may be affected by noise due to load variation or vibration. To address this issue, filtering functions are applied, such as DINT_TO_INT for data type conversion and ABS(i_H_Torque) to ensure that torque values remain positive. The filtered torque values are then compared with predefined threshold limits to determine whether the grab is loaded or empty. High torque values indicate that the grab is likely carrying material, allowing the system to execute the hold command and subsequently the close command. Conversely, low torque values indicate an empty grab, causing the system to wait until a load is detected.

Key logic signals include Grab_Open_Pos, Grab_Bypass_Bos, and Instant_Pos_Diff. Grab_Open_Pos indicates whether the grab is fully open, Grab_Bypass_Bos acts as an interlock to bypass the automatic closing system when activated, and Instant_Pos_Diff represents the actual position change used to detect whether the grab is moving or stationary. When the grab position is stable and the torque value exceeds the threshold, the PLC activates the Hold_Authorized logic and prepares the Close Command for the next cycle stage.

Several simulation graphs were obtained during the operational analysis of the GSU crane, illustrating system performance under various operating conditions.

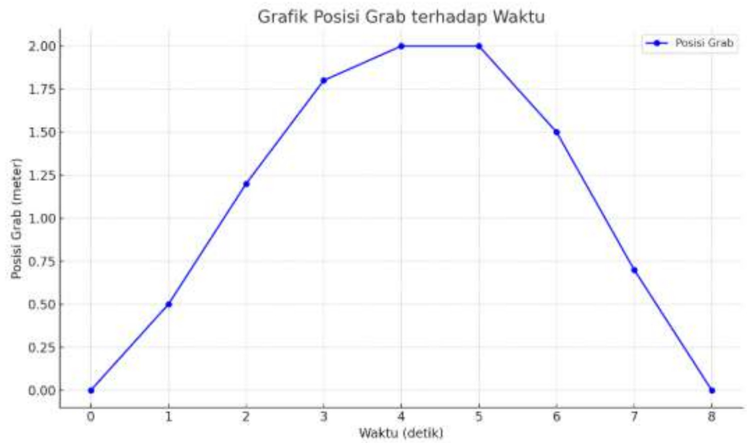

Figure 12. Position Variation of the Grab with Respect to Time

Table 1. Grab Position Variation with Respect to Time

Time (Second)	Grab Position (meter)
0	0
1	0,5
2	1,2
3	1,8
4	2,0
5	2,0
6	1,5
7	0,7
8	0

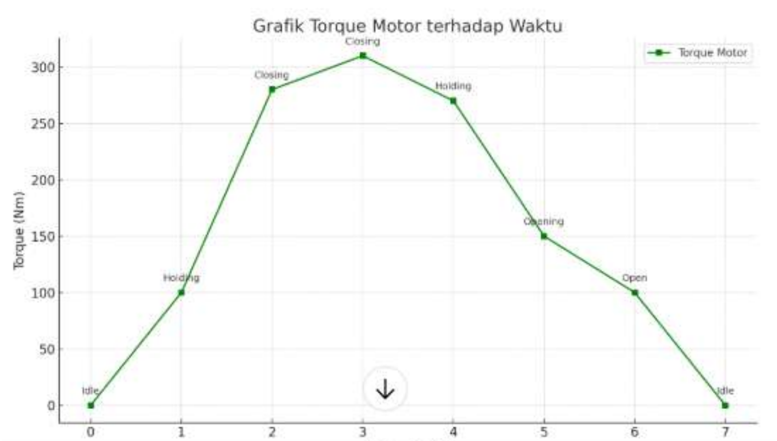

Figure 13 Motor Torque Variation with Respect to Time

Table 2. Motor Torque Variation with Respect to Time

Time (Second)	Torque Motor (Nm)	Grab status
0	0	Idle
1	100	Holding
2	280	Closing
3	310	Closing
4	270	Holding
5	150	Opening

6	100	Open
7	0	Idle

CONCLUSION

Based on the results of robust regression analysis on poverty data from 154 regencies/cities in the Sumatra region, it can be concluded that the Least Trimmed Squares (LTS) method demonstrates superior performance compared to Ordinary Least Squares (OLS) and M-Estimation methods in handling data containing outliers, achieving the smallest Mean Squared Error (MSE) of 0.909 and an R-squared value of 53.37%. All four predictor variables used (Labor Force Participation Rate/LFPR, Human Development Index/HDI, Percentage of Population with Access to Safe Drinking Water, and GRDP) significantly influence poverty levels at the 10% significance level. The DFFITS method successfully identified 10 observations as outliers out of 154 total observations using a cutoff value of 0.3603, and classical assumption tests revealed that residuals in the OLS model were not normally distributed (p-value = 0.0171), indicating the necessity of using robust regression methods. The LTS method is more recommended for poverty data analysis containing outliers due to its breakdown point of up to 50%, making it more resistant to the influence of extreme observations and producing models that are more representative of the actual data structure.

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