

IOT-BASED POWER USAGE CONTROL SYSTEM FOR SMAW WELDING MACHINES AT UPT PKPTK, WEST KALIMANTAN PROVINCE

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ABSTRACT

This study analyzes electrical power consumption in welding processes and identifies factors contributing to energy inefficiency, including plate thickness, welding job type, arc height, welder skill level, and machine idle time. The results indicate that welding operations require relatively high electrical power and can lead to significant energy waste if not properly managed. For 8 mm plates, the routing welding job operates at an average current of 8–9 A, resulting in the lowest average power consumption of approximately 900 W. The filling job requires an average current of 15–16 A with a power consumption of about 1,900 W, while the capping job consumes approximately 1,800 W. For 10 mm plates, the routing job operates at 9–10 A with an average power consumption of 900 W, the filling job uses 17–18 A with a power consumption of approximately 2,500 W, and the capping job consumes around 2,300 W. These results confirm that increased plate thickness leads to higher electrical power consumption. In addition, welding arc height significantly influences power usage, where a higher arc increases power consumption. The welder's skill level also has a substantial impact on energy efficiency. Tests involving beginner students, skilled welders, and instructors show that beginners generate the highest energy waste due to longer preparation times and frequent rework, resulting in extended machine idle time. Recorded idle times were 89.20 minutes for beginner students, 61.47 minutes for skilled welders, and 29.33 minutes for instructors.

Keywords: *Welding Machine Power Consumption, Welding Machine Polarity, Energy Efficiency, Welding Machine Idle Time, Arc Height Variation.*

INTRODUCTION

In the industrial sector, particularly in engineering and vocational training environments such as the Welding Workshop of UPT PKPTK (Technical Implementation Unit for Job Training and Workforce Productivity) of West Kalimantan, the use of high-power electrical equipment such as welding machines is a primary requirement in training and production processes. Welding machines exhibit non-linear load characteristics and often cause disturbances in electrical power usage, including voltage fluctuations, harmonic distortion, and load imbalance. These disturbances can adversely affect other equipment connected to the system, accelerate equipment wear, and result in energy and financial losses [1].

Based on their operating principles, welding processes can be classified into three types: fusion welding, pressure welding, and brazing. Fusion welding is a method in which the materials to be joined are heated until they melt using a heat source [2]. This method is the most widely used, particularly electric arc and gas welding. Electric arc welding itself consists of several types, such as shielded electrode arc welding, TIG (Tungsten Inert Gas) welding, MIG (Metal Inert Gas) welding, CO₂ arc welding, gasless arc welding, and submerged arc welding. One example of shielded electrode arc welding is SMAW (Shielded Metal Arc Welding) [3].

SMAW is a welding process in which the base metal and electrode melt due to the heat generated by an electric arc between the electrode tip and the surface of the workpiece. This electric arc is produced by a welding machine. The electrode consists of a wire coated

with a protective material (flux), which melts together with the base metal during the welding process and then solidifies to form a welded joint. The molten metal from the electrode is transferred to the weld area in the form of liquid droplets carried by the arc current. The size of these molten droplets is influenced by the magnitude of the welding current, where higher currents produce finer droplets, while lower currents result in larger droplets. Finer metal droplets improve weldability and joint quality [4].

Unfortunately, in many training institutions, including the UPT PKPTK Workshop of West Kalimantan, real-time and historical power consumption monitoring systems are still limited. Monitoring is generally performed manually using conventional measuring instruments, which are only applied at certain times and can only be operated by experienced technicians. This condition makes early detection of electrical disturbances difficult and delays the implementation of preventive measures [5].

Recognizing the importance of energy efficiency, the President of the Republic of Indonesia has issued a mandate regarding energy-saving efforts in government institutions. Presidential Instruction (Inpres) Number 1 of 2025 regulates expenditure efficiency in the implementation of the State Budget (APBN) and Regional Budget (APBD) for 2025, emphasizing that public institutions are required to implement energy efficiency, particularly in electricity usage. This policy encourages government agencies to apply energy management principles, not only to reduce waste but also to support national programs aimed at reducing fossil energy consumption, lowering carbon emissions, and ensuring national energy sustainability [6].

With the advancement of Internet of Things (IoT) technology, it is now possible to develop low-cost, portable power consumption monitoring systems integrated with internet connectivity. By utilizing voltage and current sensors and microcontrollers such as the ESP32 with built-in WiFi connectivity, power usage data can be transmitted in real time to web-based monitoring platforms or mobile applications. In addition to data visualization, the system can also issue alerts when anomalies in electrical parameters are detected, allowing corrective actions to be taken promptly [7].

The implementation of an IoT-based power consumption monitoring system in the UPT PKPTK Workshop of West Kalimantan is highly relevant as an innovative approach to improving energy efficiency and workplace safety. Moreover, this system can serve as a practical learning medium for trainees to understand the importance of energy management and digital electrical measurement techniques. Therefore, this research not only provides a technical solution but also contributes to educational aspects and workforce competency development. Research on monitoring systems has become increasingly popular due to the need to improve efficiency in voltage and current utilization, particularly in welding machines. A previous study by Adlian Jefiza et al. (2022) developed a voltage and current monitoring system for welding machines; however, the study focused on FCAW welding and was limited to monitoring purposes only. The method applied in this research was a Multi-Layer Perceptron (MLP) [8].

A similar study was conducted by Sudarman et al. (2025), who performed research using GTAW welding. The method employed was non-destructive testing (NDT), which resulted in a production efficiency improvement of up to 30%. This significant increase was attributed to faster welding processes and reduced production defects [9].

Another related study by Nurul Ulfatin et al. (2024) discussed the implementation of low-voltage sensors to optimize welding machine usage, aiming to support small and medium enterprises (SMEs) in accelerating and improving production. Based on experiments involving 20 operators and employees, the results showed a significant improvement in welding performance [10].

Furthermore, research conducted by Roberth M. Ratlalan (2023) examined improvements in SMAW welding machine quality to enhance production output and energy efficiency. The quality improvement was achieved by analyzing individual risk scores, with the results indicating that all evaluated parameters were classified at a medium risk level [11].

Subsequent research by Edy Subowo and Dede Fadillah (2024) focused on the development of an Internet of Things (IoT)-based system for welding machines using voltage and current sensors to enable remote monitoring. However, a limitation of this study was the absence of an integrated protection system [12].

METHODOLOGY

This research applies an experimental methodology to analyze and control electrical power usage in three-phase welding machines. The system utilizes three-phase electrical power from the main supply as the input source. Key electrical parameters measured in this study include voltage, current, power, power factor, frequency, active power, and reactive power. These parameters are acquired using PZEM-004T power measurement modules installed on each phase.

Measurement data from the sensors are transmitted to an ESP32 microcontroller, which functions as the main data processing and control unit. The ESP32 is programmed to process the measured electrical parameters and to implement control logic based on predefined operational thresholds. The control strategy enables automatic shutdown of the welding machine during idle conditions and when abnormal electrical behavior is detected, such as voltage drops, excessive current, or system malfunctions.

The processed data are transmitted to an Internet of Things (IoT) platform via wireless communication, allowing real-time monitoring and historical data logging. In addition, key parameters are displayed locally on an LCD to provide immediate feedback to operators. This methodology allows continuous supervision of power usage, supports early fault detection, and contributes to improved energy efficiency and operational safety in welding machine applications.

RESULTS AND DISCUSSION

The power usage control system for SMAW welding machines at UPT PKPTK begins with evaluating the outcomes of this research through a series of tests and experiments to assess system performance based on several tested parameters. The evaluated parameters include voltage, current, and power for each phase (R, S, and T). In addition, tests are conducted to determine the electrical energy cost required for each welding job, evaluate the effectiveness of the protection system during overload conditions, and analyze suitable welding schedules. The scheduling analysis is performed to determine whether welding jobs can be executed simultaneously or alternately in order to prevent excessive power consumption.

The testing process is carried out in one of the welding booths that has been modified with the developed system. The system consists of multiple PZEM-004T sensors integrated with an ESP32 microcontroller. The microcontroller is also connected to an Internet of Things (IoT) platform, namely Adafruit IO, enabling real-time monitoring of welding machine power usage.

Furthermore, the system is designed to automatically deactivate the welding machine after 1 minutes of idle time to prevent unnecessary energy consumption, considering that the idle power consumption of the machine reaches approximately 60 W. The implemented system and the welding setup used in this study are illustrated in Figure 1.



Figure 1. Welding Tools

Figure 1 shows the physical appearance of the installed device in the welding booth used for the experiment. The panel box is equipped with a lighting system to illuminate the welder's workspace and is fitted with a three-phase socket for the three-phase welding machine. The system is integrated with an Internet of Things (IoT) application, namely Adafruit IO, enabling remote monitoring.

The measured values obtained from the sensors are transmitted and displayed on the Adafruit IO platform. The user interface of the Adafruit IO dashboard is presented in Figure 2.

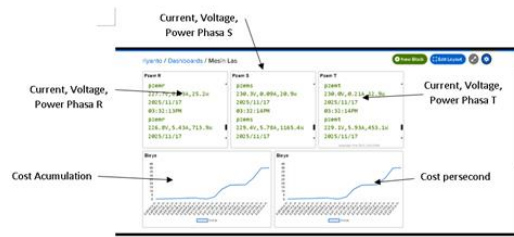


Figure 2. Adafruit IO

Figure 2 presents the Adafruit IO interface used in this study. To establish communication with the designed device, a specific authentication token is required. The token used in this research is generated by Adafruit IO and is random in nature. After successful connection to the device, access to sensor data requires linking the defined variables on Adafruit IO to the corresponding elements on the user interface. The Adafruit IO dashboard allows real-time data access, with response delays that may vary depending on the amount of data being transmitted.

Idle testing was conducted to prevent unnecessary energy consumption. An idle timeout of 1 minute was implemented, after which the system automatically shuts down. The test was performed by observing and measuring the time required for the system to deactivate after entering an idle condition. The recorded data show that before the idle timeout is reached, the power consumption on phases R, S, and T remains relatively stable. Phase R consumes approximately 38 W, phase S ranges between 21–28 W, and phase T is around 14 W. This indicates that the welding machine is in an idle state but still drawing standby power.

After the idle duration of 1 minute is exceeded, the system successfully performs an automatic shutdown. This is clearly indicated at 09:16:21 UTC and 09:16:31 UTC, where the power consumption on all three phases drops to 0.0 W. These results confirm that the idle control mechanism functions correctly according to the system design.

The comparison of power consumption is presented in Figure 6 to illustrate the difference in power usage between 8 mm and 10 mm plates during the routing welding job.

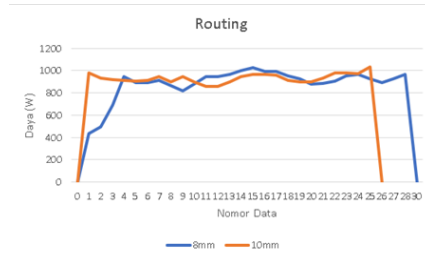


Figure 3. Routing

Figure 3 shows that the power consumption during the routing welding job for the 10 mm plate is higher than that for the 8 mm plate. In the initial stage of the routing test, the welding machine is turned on and operated at a stable current of 55 A under continuous conditions. The polarity used in this process is DCEN (Direct Current Electrode Negative).

The comparison of power consumption is presented in Figure 7 to illustrate the difference in power usage between 8 mm and 10 mm plates during the filling welding job.

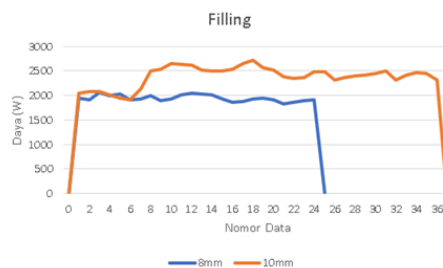


Figure 4. Filling

As shown in Figure 4, the job filling welding process begins by turning on the equipment, followed by welding using a current of 100 A for the 8 mm plate and 120 A for the 10 mm plate. This difference in current is applied to achieve better welding penetration. The results indicate that the power consumption during the job filling process for the 10 mm plate is higher than that of the 8 mm plate. In addition to the difference in current usage, this condition is also caused by the greater amount of electrode deposition required for the 10 mm plate, which consequently demands more power and longer welding time compared to the 8 mm plate.

The comparison of power consumption is presented in Figure 8 to illustrate the difference in power usage between 8 mm and 10 mm plates during the routing welding job.

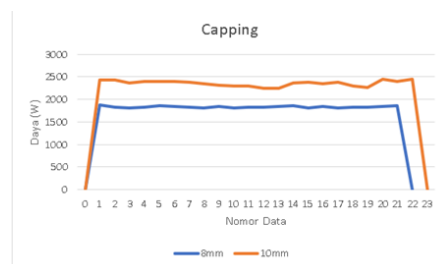


Figure 5. Capping

As shown in Figure 5, the power consumption during the job capping process for the 10 mm plate is higher than that of the 8 mm plate. The difference in the graph is caused by the use of different welding currents, where the 10 mm plate uses a current of 120 A and the 8 mm plate uses 100 A, resulting in different levels of power consumption.

Based on several data sets obtained, it can be observed that plate thickness significantly affects the power consumption of the welding machine. Therefore, it can be concluded that the thicker the plate, the greater the energy consumption required.

To observe the comparison of each job performed, Figures 9 and 10 present a comparison of power consumption for each job, from the initial condition until the system reaches a stable power level.

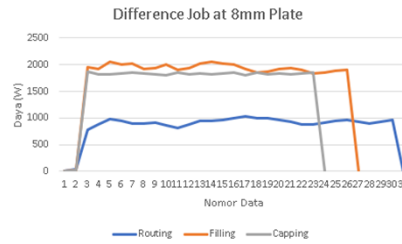


Figure 6. Different Job 8mm plate

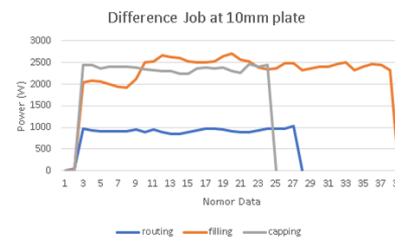


Figure 7. Different Job 10mm plate

Based on the graphs above, it is observed that the power consumption characteristics for 8 mm and 10 mm plates vary for each job. During the routing job, a welding current of 55 A is used, resulting in a stable power consumption of approximately 1000 W.

In contrast, during the filling and capping jobs, different currents are applied, namely 100 A for the 8 mm plate and 120 A for the 10 mm plate. Consequently, the filling process exhibits longer and more fluctuating power consumption, while the capping process shows a more stable power usage of approximately 1800 W for the 8 mm plate and 2300 W for the 10 mm plate.

The testing conducted by beginner students to evaluate the response of the energy-saving system. The testing duration was 2 hours, during which the experiment was carried out twice, using a welding machine with the system and without the system. The results of the testing are presented in Figure 8.

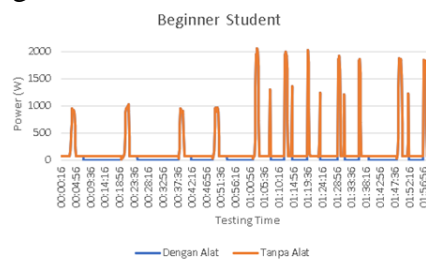


Figure 8. Beginner Student

Figure 8 shows the system response, which exhibits a significant amount of idle time. This occurs because beginner students still have many limitations in performing welding operations, resulting in less optimal welding quality. As a result, the total energy consumption recorded was 119,730.2 watts when using the system and 151,843.9 watts without the system.

In terms of cost, the energy usage corresponds to IDR 1,110.52 with the system and IDR 1,408.38 without the system, indicating a cost saving of IDR 297.86 when the system is applied. Furthermore, the welding machine without the system experienced 89.20 minutes of idle operation, which represents a significant potential source of energy waste during idle conditions.

The testing conducted by skilled students to evaluate the response of the energy-saving system. The testing duration was 2 hours, during which the experiment was carried out twice, using a welding machine with the system and without the system. The results of the testing are presented in Figure 9.

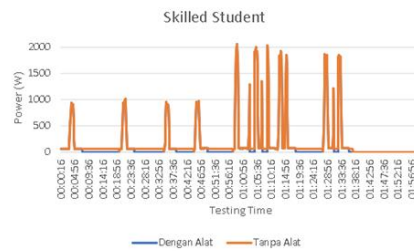


Figure 9. Skilled Student

Figure 9 illustrates the system response, which still shows a considerable amount of idle time. This occurs because skilled students already possess sufficient welding management abilities, allowing them to perform welding tasks more efficiently. The total power consumption recorded was 119,730.2 watts when using the system and 141,862.4 watts without the system.

These results indicate that the application of the system is able to reduce electrical energy consumption compared to operation without the system, even though the difference in welding skill levels is not significant. In terms of cost, the energy usage corresponds to IDR 555.26 with the system and IDR 657.90 without the system, resulting in a cost saving of IDR 102.63.

Furthermore, the welding machine operated 61.47 minutes in idle condition when the system was not applied, which represents a potential source of energy waste during idle operation.

The testing conducted by instructor to evaluate the response of the energy-saving system. The testing duration was 2 hours, during which the experiment was carried out twice, using a welding machine with the system and without the system. The results of the testing are presented in Figure 10.

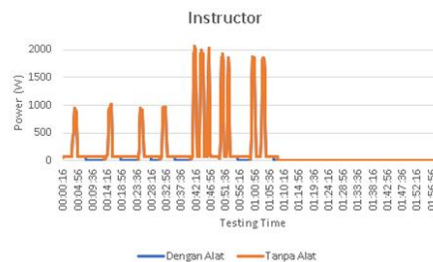


Figure 10. Instructor

Figure 10 shows that the system response exhibits a relatively small amount of idle time, as the instructor has extensive experience in managing both working time and electrical power consumption, thereby reducing unnecessary operation of the welding machine. The total power consumption recorded was 118,616.3 watts with the system and 129,176 watts without the system.

These results demonstrate that the implementation of the system is able to reduce electrical energy consumption compared to operation without the system. In terms of cost, the energy usage corresponds to IDR 550.09 with the system and IDR 599.06 without the system, resulting in a cost saving of IDR 48.97.

Furthermore, the welding machine operated in an idle condition for 29.33 minutes when the system was not applied, which represents a potential source of energy waste

during idle operation.

It was found that the height of the welding arc significantly affects power consumption. With an ideal arc distance, the welding power consumption can be reduced by up to 3,419.6 W. This result demonstrates that the welder's skill level has a substantial influence on the electrical power consumed during welding operations.

Under an ideal electrode angle, the increase in welding machine power occurs gradually. At a moderate angle, a high power surge appears at the initial stage, while at a larger (farther) angle, the power surge becomes more pronounced and occurs over a wider range.

CONCLUSION

This study found that welding processes consume a significant amount of electrical power, while considerable energy waste occurs due to idle conditions, plate thickness, welder skill level, and improper scheduling. For 8 mm plates, the routing process used an average welding current of 8–9 A, resulting in the lowest power consumption at approximately 900 W. The filling process required an average current of 15–16 A with a power consumption of about 1,900 W, while the capping process used a similar current range with an average power consumption of 1,800 W. For 10 mm plates, routing required an average current of 9–10 A with power consumption around 900 W, whereas filling and capping required higher currents of 17–18 A and 16–17 A, resulting in power consumption of approximately 2,500 W and 2,300 W, respectively. These results indicate that increased plate thickness leads to higher electrical power consumption during welding.

In addition to plate thickness, welding power consumption is strongly influenced by welder skill, particularly the height of the welding arc. Variations in arc height result in noticeable differences in power usage, where a higher arc distance leads to increased electrical power consumption. Tests conducted on beginner students, skilled students, and instructors showed significant differences in energy efficiency. Beginner students experienced the highest energy waste due to frequent preparation and rework, which caused extended idle periods. The recorded idle times were 89.20 minutes for beginners, 61.47 minutes for skilled students, and 29.33 minutes for instructors, indicating that welder experience plays a crucial role in reducing idle-related energy losses.

Based on the experimental results, the implementation of the monitoring and power control system achieved an electricity cost saving of Rp 297.86 for every 2 hours of welding operation for beginner students. Assuming an 8-hour daily welding operation, the total cost saving reaches Rp 1,191.44 per welding booth per day. When applied to 16 welding booths used by beginner students, the total daily electricity cost saving amounts to Rp 19,063.04. Furthermore, with a 30-day operational period, the system has the potential to generate electricity cost savings of up to Rp 571,891.20 per month. These findings demonstrate that the proposed system effectively reduces energy waste caused by excessive idle time and is economically feasible for improving the operational efficiency of welding activities.

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