Implementation of Microcontroller-Based Current Speed Monitoring System

Alvon Samuel Sinaga, Beni Satria

Abstract

The development of electrical technology and the Internet of Things (IoT) has driven the need for an accurate, real-time, and easily integrated electrical current monitoring system with digital systems. This research aims to implement a microcontroller-based current speed monitoring system by utilizing the PZEM-004T sensor and ESP8266 microcontroller. The system is designed to monitor electrical parameters such as voltage, current, pseudo-power, active power, reactive power, and electrical energy in real-time, as well as display data through the LCD and Blynk IoT app. The research methods used include literature studies, designing and prototyping, and testing systems. The test was carried out by comparing the sensor measurement results against standard measuring instruments on several load variations, namely lamps and electric drills. The test results showed that the PZEM-004T sensor had a good level of accuracy in voltage measurement with an average difference of 0.75%. Meanwhile, current measurements show an average difference of 17.65%, which is still acceptable for household-scale electrical energy monitoring applications. Power and energy tests show stable and consistent results under a wide range of load conditions. Based on the results of the research, it can be concluded that the microcontroller-based current speed monitoring system developed is able to work well and is suitable for use as an IoT-based electrical monitoring tool. This system has the potential to be further developed to improve accuracy and monitoring features according to user needs.

Keywords: Current Monitoring, Microcontroller, ESP8266, PZEM-004T, Internet of Things.

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Introduction

With technological developments in the field of industry and electrical systems require an accurate, fast, and integrated measurement and monitoring system with an automatic control system. One of the important parameters that needs to be monitored continuously is the speed of electric current. The speed of current has a direct influence on the performance of electrical and electronic equipment, especially in motor drive systems, power distribution, and electrical protection systems. Inaccurate monitoring can lead to decreased performance, increased energy consumption, and even damage to equipment (Rashid, 2014).

In industrial applications, current speed control and monitoring are essential to ensure the system is working according to predetermined specifications. In an electric motor system, for example, a change in current can indicate an overload, mechanical fault, or component failure. Therefore, real-time and precise current velocity information is needed to prevent premature breakdowns and improve system reliability (Chapman, 2012).

In general, the current speed monitoring system still uses many conventional analog instruments, such as analog amperemeters and basic oscilloscopes. Although these tools can still be used, conventional measurement methods have various limitations, including low accuracy, limitations in data recording, and reliance on human observation. In addition, analog systems are less flexible in terms of integration with computer-based control systems or modern industrial networks (Bolton, 2015). The use of microcontrollers in current speed monitoring systems allows for digital processing of sensor data with a higher level of accuracy than analog systems. The measurement data can be displayed directly through the LCD screen, sent to a computer, or stored in storage media for further analysis. In addition, microcontrollers also support the development of additional features such as alarm systems, current threshold setting and serial or network-based data communication (Barrett & Pack, 2012). The current sensor as the main component in this system functions to detect the amount of electric current flowing in a circuit. Modern current sensors, such as Hall effect-based sensors or resistor shunts, are able to provide outputs proportional to the measured current and are easy to integrate with microcontrollers. The combination of current sensors and microcontrollers allows the design of a monitoring system that is real-time, responsive, and flexible (Fraden, 2016).

In this study, the implementation of a microcontroller-based current speed monitoring system was carried out by utilizing a current sensor as a data acquisition device. The current data obtained will be processed by the microcontroller to determine the current speed in real-time, then displayed through an easy-to-understand user interface. The system is designed to be able to work continuously and provide accurate information to users. Thus, this research is expected to contribute to the development of flow speed monitoring technology that is more modern, applicative, and in accordance with current industrial needs (Ogata, 2010).

Literature Review

2.1 Monitoring System

A monitoring system is a system designed to observe, measure, and record certain parameters continuously or periodically to determine the condition of a system in real-time. In the field of electricity and industry, the monitoring system plays an important role in maintaining the stability and reliability of the system, because it is able to provide initial information if there is a deviation from normal conditions. Effective monitoring allows users to take corrective actions quickly so as to prevent greater damage and improve system operational efficiency (Bolton, 2015).

The development of digital technology has pushed the monitoring system to be more automated and integrated. Modern monitoring systems not only function as a measuring tool, but are also capable of storing data, displaying information visually, and connecting to automated control systems. (Ogata, 2010).

2.2 Electric Current and Current Velocity

An electric current is a flow of electrical charge that flows through a conductor due to a potential difference. Electrical current is measured in amperes and is one of the main parameters in the electrical system. The amount of current flowing in a circuit greatly affects the performance and safety of electrical equipment, so accurate and continuous monitoring is needed (Rashid, 2014).

The speed of current can be interpreted as the rate of change of electric current over time or the response of current to changes in load conditions. Information regarding current velocity is especially important in electric motor systems and power distribution systems, as sudden changes in current can indicate interference, overload, or component damage. (Chapman, 2012).

2.3 Current Sensor

A current sensor is a device used to detect and measure the amount of electric current flowing through a circuit. These sensors work by converting the current into other electrical signals, such as voltage or digital signals, which can then be processed by the control system. The use of current sensors allows the measurement process to be carried out automatically and continuously without the need for human intervention (Fraden, 2016). In a microcontroller-based monitoring system, the current sensor plays a key component in the data acquisition process. Commonly used current sensors include resistor-shunt-based sensors and Hall effect-based sensors. (Bolton, 2015).

2.4 Microcontroller

A microcontroller is a minicomputer system that is integrated into a single chip and consists of a central processing unit, memory, and input-output devices. Microcontrollers are widely used in embedded systems because they have a small size, low power consumption, and sufficient processing capabilities for various control and monitoring applications (Malvino & Brown, 2016).

In a current speed monitoring system, the microcontroller functions as a data processing center. The microcontroller receives signals from the current sensor, performs data processing, and displays the measurement results in the form of information that is easy for the user to understand. (Barrett & Pack, 2012).

2.5 Microcontroller-Based Current Speed Monitoring System

A microcontroller-based current speed monitoring system is a system that integrates a current sensor and a microcontroller to monitor electric current in real-time. The system is designed to automatically measure, process and display current velocity data with a higher level of accuracy than conventional methods. The use of microcontrollers allows the system to work independently and continuously without the need for manual processing (Ogata, 2010).

The main advantage of microcontroller-based monitoring systems lies in their flexibility and ease of development. This system can be developed with additional features such as historical data storage, graph display, and integration with automatic control systems. With this capability, microcontroller-based current speed monitoring systems are very suitable to be applied in modern industrial environments that require reliable and efficient monitoring systems (Barrett & Pack, 2012).

Research Methodology

This research uses an experimental method with a research and development approach, namely through the stages of software design and hardware design. The developed system is designed to support the drying process of agricultural products with Arduino microcontroller-based automation, thereby reducing dependence on weather and increasing drying efficiency.

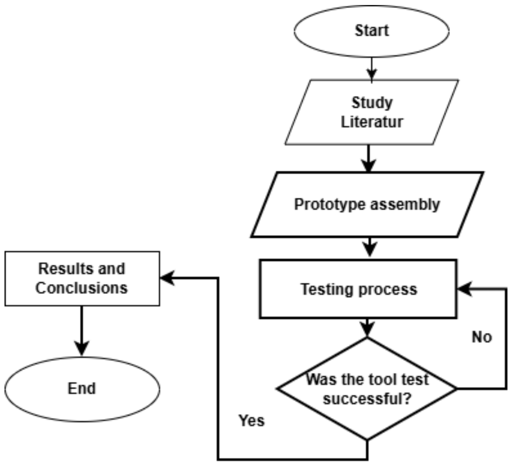

Figure 1. flowchart

Flowchart Description

1) Start
   Research begins.
2) Literature Study
   Collect and study references related to current speed monitoring systems, current sensors, and microcontrollers as the basis for system design.
3) Create Prototype
   Design and prototype microcontroller-based current velocity monitoring systems, including hardware and software.
4) Testing Process
   Conducting tests on prototypes to determine the performance of the system in monitoring the flow speed.
5) Is Testing Successful?
   Determine whether the test results are in accordance with the objectives and specifications of the system.
6) YesIf the test is successful, the study proceeds to the stage of analysis of results and drawing of conclusions.
7) NoIf the test has not been successful, the prototype is repaired and the test is repeated.
8) Results and Conclusion
   Analyze the test results and draw up research conclusions.
9) Finish
   The research is complete.

Results

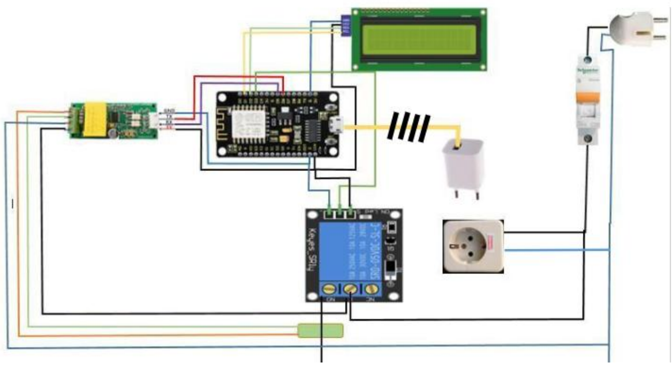

Figure 2. A series of current monitoring systems

4.1 Discussion of the Results of the Implementation of the Tool

Based on the results of the implementation, the IoT-based current and power speed monitoring system has been successfully realized in an X6 box with dimensions of 18.5 cm × 11.5 cm × 6.5 cm. The placement of all components in the box is carried out in a structured manner so as to support space efficiency, ease of maintenance, and system stability. A 16×2 LCD with I2C module is installed at the top of the box to make it easier for users to monitor data directly, while two output holes are provided as power supply lines to ESP8266 and output lines for PZEM-004T sensors. This physical design indicates that the system has been designed with both functional and ergonomic aspects in mind.

The integration of the main components, namely the ESP8266 microcontroller, PZEM-004T sensor, 16×2 LCD, and 4-channel relay module, was successfully done. ESP8266 functions as a control center as well as a Wi-Fi communication medium, so that the measurement data can be sent and displayed in real-time through the Blynk IoT platform. Neat and systematic wiring plays a role in maintaining the stability of the connection between components and minimizing signal interference during the testing process. This shows that the monitoring system has been successfully implemented in accordance with the initial design.

4.2 Discussion of Voltage and Current Sensor Validity Testing

The results of the PZEM-004T sensor validity test for voltage measurement show a high level of accuracy. Based on test data on the load of 200 W lamps and 80 W floodlights, the voltage measurement difference between the sensor and the standard measuring instrument is in the range of 0.2% to 1.5%, with an average of 0.75%. This value indicates that the PZEM-004T sensor is very reliable in measuring electrical voltage and is suitable for use for monitoring systems.

In contrast to voltage measurement, the current test results show a relatively larger deviation. The percentage difference in current measurement ranges from 10.71% to 30.43%, with an average of 17.65%. This difference can be caused by several factors, such as the characteristics of the PZEM-004T current sensor, sensor tolerance, measurement resolution, as well as load fluctuations during the testing process. However, such deviation values are still acceptable for non-critical monitoring applications, especially in energy monitoring and power consumption in general.

Table 1. Voltage and Current Sensor Validity Test Results

Load	Measuring Instrument Voltage (V)	Sensor Voltage (V)	Voltage Difference (%)	Measuring Instrument Current (A)	Sensor Current (A)	Current Difference (%)
200 W Lamp	100.00	100.60	0,6	0,37	0,41	10,81
	150.00	150.20	0,2	0,45	0,50	10,41
	170.00	170.50	0,5	0,48	0,54	12,50
	220.00	221.20	1,2	0,56	0,62	10,71
Floodlight 80 W	100.00	100.20	0,2	0,18	0,23	27,70
	150.00	150.70	0,7	0,22	0,25	13,63
	170.00	171.10	1,1	0,23	0,30	30,43
	220.00	221.50	1,5	0,28	0,35	25,00
Average	–	–	0,75	–	–	17,65

Based on Table 2, (200 W Lamp Load and 80 W Floodlight) test results show that the PZEM-004T sensor has a good degree of accuracy in voltage measurement. The voltage measurement difference between the sensor and the standard measuring instrument is in the range of 0.2% to 1.5%, with an average value of 0.75%. This value indicates that the sensor is able to read the voltage with a relatively small error rate and is still within the measurement tolerance limit. However, in the current measurement, there is a larger difference than the voltage measurement. The percentage difference in flow ranges from 10.41% to 30.43%, with an average of 17.65%. This difference can be caused by sensor tolerances, load fluctuations, and limited current measurement resolution on the PZEM-004T sensor. However, the current measurement results are still acceptable for household-scale energy and electrical power monitoring applications.

Table 2. Power and Energy Test Results

Testing	Sensor Voltage (V)	Sensor Current (A)	Pseudo-Power (VA)	Active Power (W)	Reactive Power (VAR)	Energy (kWh)
1	231.6	0.44	101.3	87.1	14.2	0.08
2	231.4	0.44	101.3	87.2	14.2	0.08
3	231.5	0.44	101.3	87.2	14.2	0.08
4	231.5	0.44	101.3	86.9	14.2	0.08
5	231.6	0.44	101.3	87.1	14.2	0.08

Based on Table 3, (Load of 11 Lights) the results of the monitoring system test at the load of 11 lights showed a stable and consistent measurement value. The voltage read by the sensor is in the range of 231.4–231.6 V with a current of 0.44 A in each test. This shows that the system is capable of repeating measurements with almost the same results.
The calculation of the apparent power produced by the system showed a value of 101.3 VA, while the active power was in the range of 86.9–87.2 W and the reactive power was 14.2 VAR. In addition, the electrical energy recorded was 0.08 kWh in each test. The consistency of power and energy values shows that the microcontroller-based monitoring system is able to measure and calculate power and energy parameters well and can be used for continuous monitoring of electricity consumption.

Conclusion

Based on the results of the design, implementation, and testing of a microcontroller-based current speed monitoring system, it can be concluded that the system has been successfully realized and functions in accordance with the research objectives. The monitoring system is able to measure and display electrical parameters in the form of voltage, current, pseudo-power, active power, reactive power, and electrical energy in real-time through LCD and IoT applications.

The test results showed that the PZEM-004T sensor had a good level of accuracy in voltage measurement with an average difference of 0.75%. Although there is a considerable difference in current measurement with an average difference of 17.65%, this value is still acceptable for household-scale and non-critical electrical energy monitoring applications. In addition, the results of power and energy tests show stable and consistent values, so that the system is considered capable of monitoring power consumption and electrical energy well. Overall, the developed monitoring system is feasible to use as an IoT-based electricity monitoring tool and can be an alternative solution in monitoring electricity usage efficiently. This system also has the potential to be further developed to improve the accuracy of current measurement and expand monitoring features according to user needs.

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