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Power System Monitoring with IoT Approach

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Abstract: The Internet of Things is an advanced technology and works very efficiently. By featuring the sensor devices which provide the measurement and calculation for the monitoring purpose, it's become powerful and able to control whilst monitor electrical practitioners in order to make a decision or evaluation. In this project, the objective of power system monitoring to develop a device with current and voltage sensor for measuring the voltage and current signal and compute the data that can easily access using internet of things platform. After that, the performance evaluation taking place for the devices with measurement tools to verify the data. Next, the component of the project is ESP32 development board that work for computing on value of the real power, apparent power, power factor, Root mean square of voltage and current. The input of the ESP32 development board is the voltage sensor and current sensor which sensing the voltage and current waveform for instantaneous waveform. From that, the error of the between measurement satisfying which had been below the 10% from the actual value from the measurement.

Keywords: Power System, Internet of Things, Power Monitoring

1. Introduction

With the uprising of the internet of things (IoT), everything is being progressively digitalized with the advanced technology with high skills group of organizations. This is giving more innovation and invention to be introduced every day and improvised through new research development. This technology can be referred to as the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence. IoT widely increases the interconnection between the bulk of information with human beings and other devices. This is due to rapid invention and technological advancement in order to work effectively [1]. Moreover, the eagerness the study Artificial Intelligence (AI) has a big idea to carry out more on IoT alongside big data analysis.

In this project, the understanding of power system theoretical is integrated with edge computing and using the IoT feature the flexibility of data monitoring. The power of a system shows the real consumption for the appliance usage and depends on the current flow that reflects on the load

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impedance. In Alternating Current (AC), the power is generated on the sinusoidal waveform generation between two waveforms which is the voltage signal current signal. From this, the instantaneous power is generated through the product between those signals. But the ideal load, the phase difference between signals is zero while when induction or capacitive is connected as load, the phase difference causes a small gap in either voltage leads to the current or vice versa called the power factor [2]. The power factor needs to monitor to ensure that the power system on the connected network loads at a standardized power factor.

The previous project related to power system monitoring with IoT has been developed. Faisal proposed a design system that is working out to manage and track the electrical energy consumption efficiently by monitoring with the AC-AC power adapter and current sensing that can be monitored-time through the Blynk interface [3]. Rozali monitors the energy consumption from the load using WeMos D1R1 with data logging into excel through Parallex Data Acquisition tools (PLX-DAQ) [4]. The interface of the monitoring is the energy consumption on the Blynk interface. Ansar has current monitoring and can manually isolate the Blynk interface [5]. The project mainly involves current sensing and voltage sensing which are used to measure the real power for monitoring purposes. Blynk interface establishes two ways of communication and having controlling and monitoring purposes.

2. Materials and Methods

The development of this project consists of two input signals which provide real-time voltage and current and they were two output displays on the Liquid Crystal Display (LCD) Screen and Blynk platform. The current signal waveform was sensed by the current sensor - ACS712 while the voltage waveform was sensed by the voltage sensor - ZMPT101B. The ESP32 development kits work as a microcontroller which is used to convert the analog to a digital signal and does the calculation for real power, apparent power, power factor, Root Mean Square (RMS) voltage and RMS current. All the data is transmitted by the application of the ESP32 WIFI module. The system block diagram is shown in Figure 1 as illustrated on the working project.

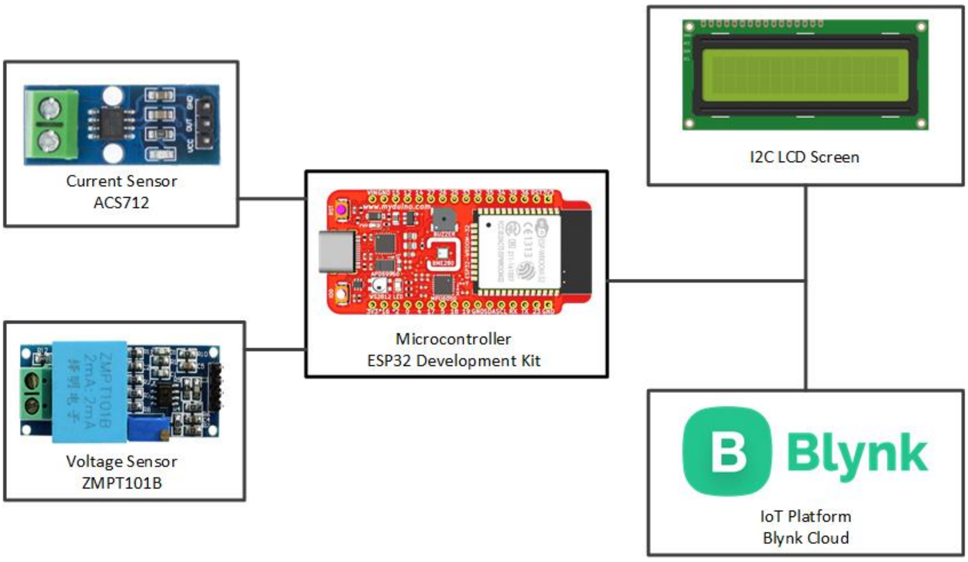

Figure 1: Power monitoring block diagram

The illustration of the working system is shown in Figure 2 the sensor connected to the AC supply line can measure the voltage current and send it into the microcontroller and display it on the LCD and Blynk Interface. At beginning of a sense of current, the current sensor is wired in series with the AC supply line and measures the instantaneous current while the voltage sensor measures the potential difference by tapping in parallel with the AC supply. Both measurements took place in the microcontroller, ESP32 Development kit and computed the real power, apparent power, power factor, RMS voltage and RMS current. The value of data that have been computed was sent for display purpose on two options, which are for LCD display and upload for the Blynk cloud interfacing. In the LCD, there are parameters shown which are RMS current, power factor and a real power. While in the Blynk Interface either in web-based or android/iOS application displaying the RMS current, RMS Voltage, Real power, and power factor.

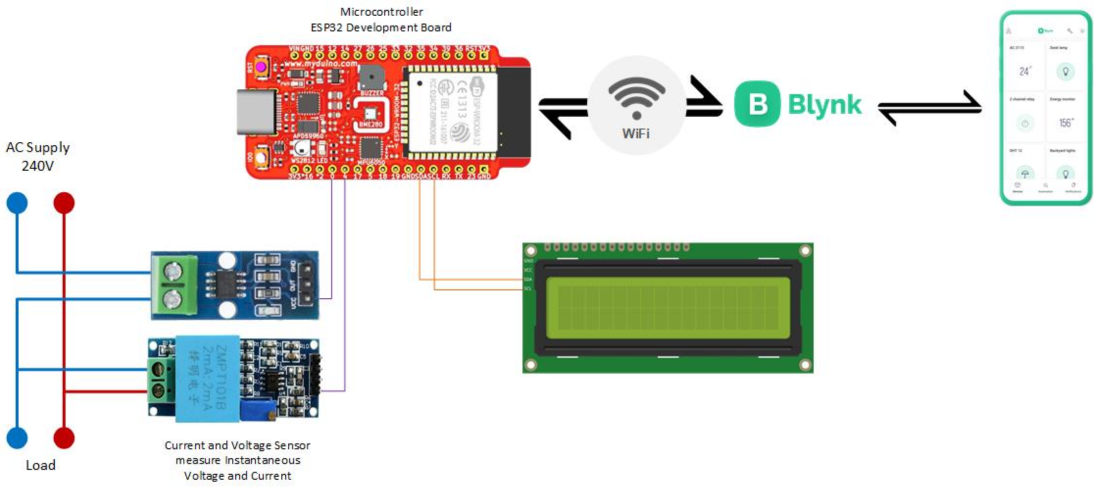

Figure 2: Flow working of the power system monitoring

In the digital, calculation of the RMS voltage and current using the method approach average of the total sample values. From the digital perspective, the RMS voltage or current is the square-rooted average value that is derived from the summation of the squared of each sample value. While RMS power or known as apparent power is the multiplication of the RMS voltage and RMS current. Figure 3 illustrated the value of the RMS voltage and current from the sample value and obtains the apparent power in analog to digital conversion.

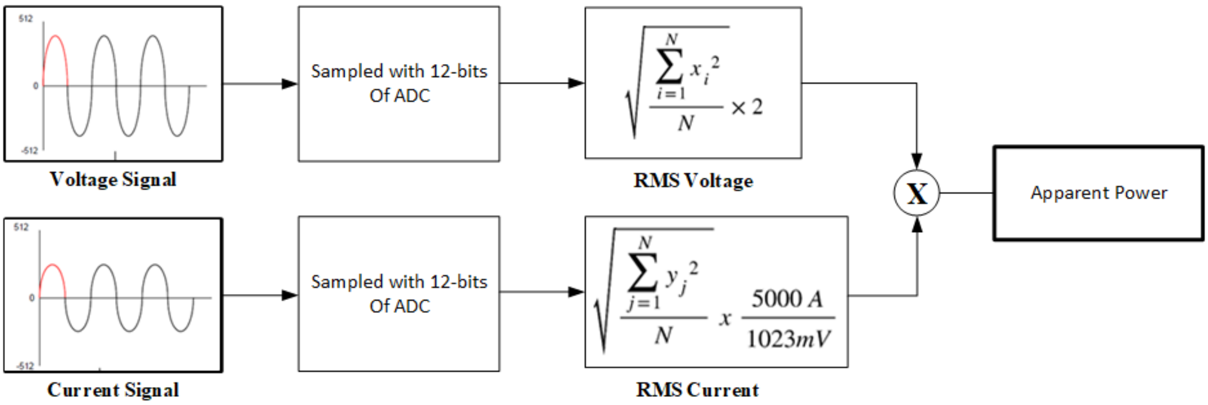

Figure 3: Block Diagram of Apparent Power computing

The instantaneous power was the averaged value derived from the summation of instantaneous current times voltage sample value. There was one precaution to verify the reading of conversion which the level of bits conversion needs to be maximum referenced to the ratio of the sensor. Figure 4 shows the mathematical programming for computing the real power.

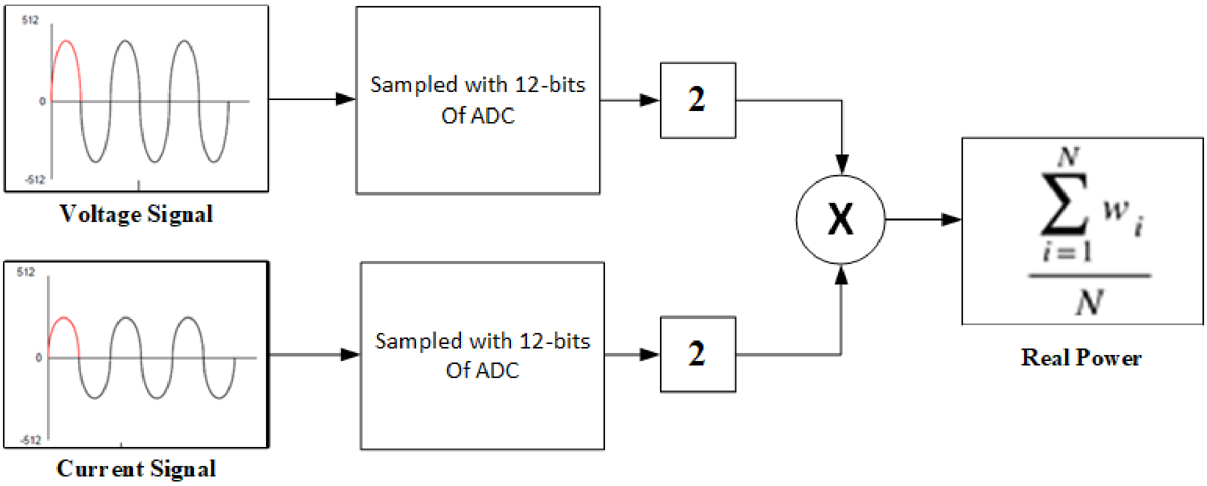

Figure 4: Block Diagram of Real Power computing

The power factor or cos θ is the ratio of real power and apparent power. This equation 1 shows that the power factor featuring change on real power and reactive power the angle deviation is directly proportional with the reactive power and inversely proportional to the real power.

$$\cos\theta = \frac{Real\ Power}{Apparent\ Power} \quad (1)$$

For measuring the power factor in this project, the method phase difference between voltage signal and current signal on an oscilloscope. Figure 5 shows the screenshot of the phase angle calculation on an oscilloscope for the load profile.

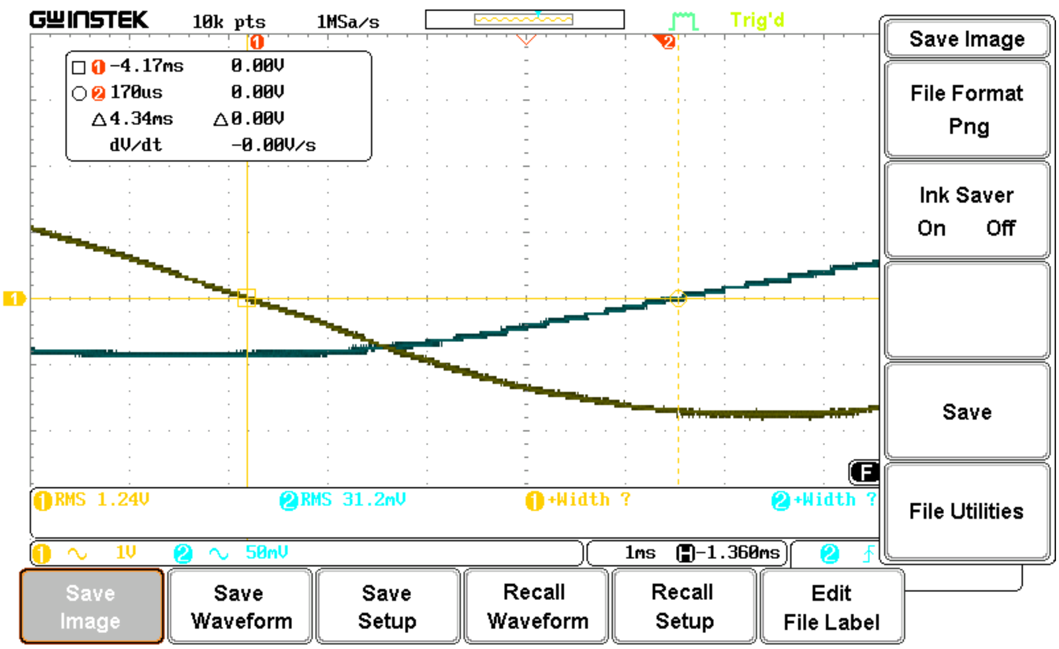

Figure 5: The phase difference between voltage and current signal

On that, the time difference between phase change from each signal was determining the phase angle for power factor calculation. By that, the power factor be determined by the equation 2 [6].

$$Phase\ Angle, \varphi = Time\ Different, \Delta t\ x\ Frequency, f\ x\ 360° \quad (2)$$

3. Results and Discussion

In this project, the data will obtain from the AC power supply from the socket. Before the data was taken, the calibration of the sensor needed to carry out by clamp meter and oscilloscope value. Figure 6, shows the power system monitoring consisting of various parts such as an AC supply socket, and two power socket outlets in parallel. The measuring method is by tapping the differential probe at the terminal block which has the incoming power supply while the current sensing by the clamp probe had been clamped at the current through the wire on the output of the current sensor. The evaluation was tested on three load profiles on inductive load with different real power outputs.

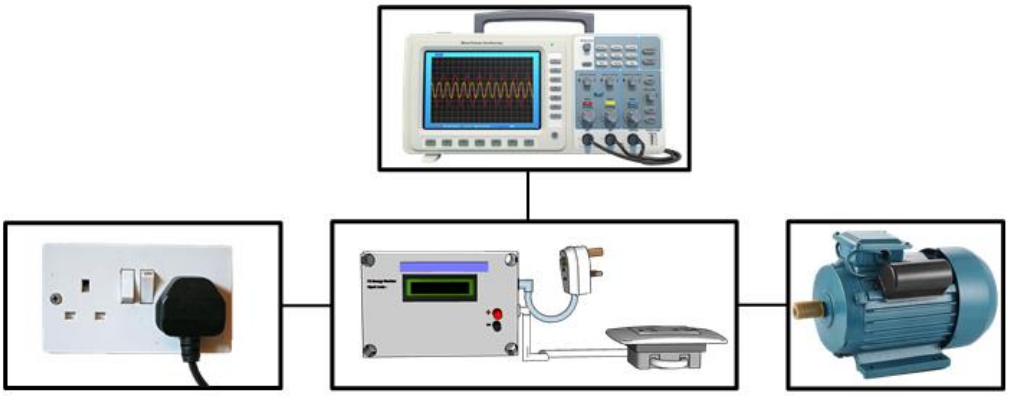

Figure 6: Block diagram of power monitoring load test

On this Load monitoring profile 1, a single-phase induction motor has acting as the load device for testing the power factor and real power usage. The specification of the single-phase induction motor is extracted as shown in Table 1.

Table 1: Specification of Single-Phase Induction Motor

Parameters	Data Obtain
$\cos\theta$	0.65
Real Power	0.37kW
Maximum Speed	1400RPM
Operating frequency	50Hz
Voltage	240v
Nominal Current	3.82A

Result of the oscilloscope on load profile 1 which has measured the RMS value for both signals as result in Table 2. In this, the power factor was determined by the phase difference between voltage and current. The factor is calculated using the formula of phase angle change as stated in equation 2.

Table 2: Result of Load measurement of Load Profile 1

Parameter	Measurement in Oscilloscope	Absolute value of data
RMS Voltage	1.23V	246V
RMS Current	31.7mV	3.17A
Phase Difference between V and I	4.34ms	78.12°
Calculated Real Power	159.02 W	
Measure Power Factor	0.2059	

From this measurement, the result compares with the Blynk value display on the smartphone and the oscilloscope result had been listed in Table 3.

Table 3: Error of percentage on load profile 1

Data Measured	Reading in Oscilloscope	Reading in Blynk	Error in percentage, %
Voltage, V	246	239	-2.85
Current, A	3.17	3.18	+0.32
Real Power, W	159.02	133.9	-15.79
Power Factor	0.2059	0.18	-12.58

On load profile 2, a single-phase induction motor and Commercial Stand fan were acting as the load device for testing the power factor and real power usage.

Table 4: Specification of Commercial Stand Fan

Parameters	Data Obtain
Real Power	65 W
Operating Frequency	50 Hz
Voltage	240 V

Result of the oscilloscope on load profile 2 which has measured the RMS value for both signals as result in Table 5. In this, the power factor was determined by the phase difference between voltage and current. The factor is calculated using the formula of phase angle change as stated in equation 2.

Table 5: Result of Load measurement of Load Profile 2

Parameter	Measurement in Oscilloscope	Absolute value of data
RMS Voltage	1.20 V	244 V
RMS Current	33.7 mV	3.32 A
Phase Difference between V and I	4.16 ms	74.88°
Calculated Real Power	213.84 W	
Measure Power Factor	0.2608	

From this measurement, the result compares with the Blynk value display on the smartphone and the oscilloscope result had been listed in Table 6.

Table 6: Error of percentage on load profile 1

Data Measured	Reading in Oscilloscope	Reading in Blynk	Error in percentage, %
Voltage, V	244	243	-0.41
Current, A	3.32	3.38	+1.81
Real Power, W	213.84	200.37	-6.30
Power Factor	0.26	0.24	-7.70

On load profile 3, a single-phase induction motor, industrial stand fan and commercial stand fan have acted as the load device for testing the power factor and real power usage. Table 7 list the specification of industrial stand fan.

Table 7: Specification of Industrial Stand Fan

Parameters	Data Obtain
Real Power	160 W
Maximum Speed	1350 RPM
Operating Frequency	50 Hz
Voltage	240 V
Nominal Current	0.7 A

Result of the oscilloscope on load profile 3 which has measured the RMS value for both signals as result in Table 8. In this, the power factor was determined by the phase difference between voltage and current. The factor is calculated using the formula of phase angle change as stated in equation 2.

Table 8: Result of Load measurement of Load Profile 3

Parameter	Measurement in Oscilloscope	Absolute value of data
RMS Voltage	1.20 V	244 V
RMS Current	34.2 mV	3.42 A
Phase Difference between V and I	3.58 ms	64.44°
Calculated Real Power	357.09 W	
Measure Power Factor	0.43	

From this measurement, the result compares with the Blynk value display on the smartphone and the oscilloscope result had been listed in Table 9.

Table 9: Error of percentage on load profile 1

Data Measured	Reading in Oscilloscope	Reading in Blynk	Error in percentage, %
Voltage, V	240	247	+2.92
Current, A	3.42	3.48	+1.75
Real Power, W	357.09	358.13	-0.29
Power Factor	0.43	0.43	0

The device template was created on the Blynk cloud which monitors processes through the Blynk application on smartphones. The application is available to download from any available application website or app store. Figure 7 shows the screenshot of the completed Blynk profile on this project. The profile is named Power System Monitoring. The interface of the profile provides a graph of the real power usage, RMS current, RMS Voltage, power factor and real power.

Figure 7: Interface of Power system Monitoring in Blynk Application

4. Conclusion

In conclusion, the design of a power monitoring system for electrical practitioner use can be produced. The prototype of the real-time electrical power monitoring system is developed and the performance evaluation of the real-time power has been carried out between the oscilloscope and IoT platform interface. Based on the finding and results, this project is able to apply to the daily usage of measurement for electricians. The voltage sensor and current sensor are used to measure the value and process by the ESP32 development board for computer the value of real power, apparent power, power factor and RMS voltage and current. With the integration of the system with Blynk through the WIFI module on the ESP32 chip, the Blynk application become an interface for visualizing the data value that had been computed by the ESP32 development board. The accuracy of the power factor and the real power is still under 2% and the percentage is acceptable in terms of accuracy and consistency for the measurement.

Acknowledgement

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