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Journal of
Electronics Technology Exploration

Homepage: https://shmpublisher.com/index.php/joetex
p-ISSN 3025-3470 | e-ISSN 3026-1066

Near Field Communication (NFC)-Based Prepaid Smart Power Meter

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Article Info

Article history:

Received Jun 6, 2024
Revised Jun 24, 2024
Accepted Jun 24, 2024

Keywords:

Electric consumption meter
PZEM-004T
Near field communication
Cos phi

ABSTRACT

An essential part of an electric energy service is an electrical power meter. Numerous customers have already expressed dissatisfaction over the electric meter's faulty readings. The development of an electrical power meter with an NFC reader is presented in this study. When an NFC card is successfully scanned by the NFC reader, the power meter is turned on and ready to deliver electricity. Before the electricity is automatically turned off, or when the credit is almost low, the display will show the alert. By experiment, PZEM 004T sensor use 3 loads, namely 60 W, 75 W and 100 W for testing current, voltage and cos phi and have error of 0 – 1.20%. In balance reduction with loads of 60 W, 75 W, and 100 W with a time gap of 5 and 10 minutes, there is an error reduction of 11.5 – 17.4%. Thus, this electricity meter with NFC reader is suitable for monitoring and controlling electricity usage.

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https://doi.org/10.52465/joetex.v2i1.374

1. INTRODUCTION

Generally, the management of energy resources has been a concern in many countries according to the supply of energy resources. Current research on individual electric consumption meters focuses on enhancing their accuracy, functionality, and integration with smart grid technologies. Innovations include the development of advanced metering infrastructure (AMI) that enables two-way communication between the meter and utility providers, facilitating better demand response and energy management [1], [2]. Additionally, researchers are exploring machine learning algorithms to predict consumption patterns and identify anomalies, aiding in the detection of energy theft and faulty appliances. Another significant area of study is the implementation of Internet of Things (IoT) technology to allow real-time monitoring and control of household energy usage, promoting energy efficiency and sustainability [3], [4]. These advancements aim to empower consumers with more precise data and greater control over their energy consumption, ultimately contributing to smarter and greener energy systems.

This issue has triggered researchers to investigate and develop the meters with various capability. In residential area, this individual electric consumption meter is able to control and monitor electric usage of rent house tenants for fairness [5]. Alvin et al. has develop IoT based electricity consumption meter using NodeMCU 8266 [6]. Several studies on this meter require college student boarding houses, in order to monitor accurately the usage of electricity. The support devices have been based on GSM, RFID, ZigBee, Wi-Max and Wi-Fi. to cover the measurement of the energy consumption [7]–[9].

The objective of this research is to develop embedded device using near field communication (NFC) in order to monitor and control tenants electricity usage. This device hopefully could be implemented for college students in residential boarding house. Eventually, electrical usage would be able to be controlled and monitored.

2. METHOD

This research use a current sensor to detect the electric source that flows to the load. The PZEM-004T module is a multifunctional sensor module that functions to measure power, voltage, current and energy contained in an electric current. This module is equipped with an integrated voltage sensor and current sensor. The measured value is then multiplied to calculate the active power. The PZEM-004T translates directly the data in machine language which can then be treated by an Arduino card or via serial TTL [10].

Functions and how to use the reset button on the module, long press the button for 5 seconds, and then release the button. Briefly press the reset button again, then the energy data will be cleared, and the reset operation completed. In use, this tool is specifically for indoor use and the installed load is not allowed to exceed the preset power. This module is a module that works in serial communication. Specification of this module is working in 80 ~ 260VAC, has power about 100A/22KWh, operation frequency of 45-65 Hz, and its accuracy of 1.0 grade.

Figure 1. PZEM004T module

In order to avoid wave interference from the same antenna, near-field communication (NFC) is a type of short-field wireless communication in which the antenna is shorter than the carrier signal waves. An antenna can produce an electric or magnetic field at close range, a short-range wavelength is not universally defined; for practical purposes, let's assume the wavelength is a quarter of a regular wavelength. However, this generated field is not caused by radio electromagnetic waves. For instance, if two small swivel antennas are near enough to one other, the magnetic field produced by a small spin antenna, often referred to as a magnetic spin, can be detected by them [11].

Figure 2. Near field communication (NFC) device

The ability of magnetic NFC to pass through conductors capable of reversing radio waves is one of its characteristics. Because NFC can only operate over a very small distance and is not always silent, many modern mobile phones use electric-field NFC (which operates at a frequency of 13.56 MHz and is connected with the 22.11 MHz band) for some particular connections. In order to effectively produce far-field, or send radio waves at this wavelength, an antenna needs to have a wavelength of at least one quarter of a meter. NFC can only be configured at "close-range" using the antenna's dimensional field, which includes length, width, and depth, if the antennas are only a few millimeters away. There won't be much energy released, which is necessary for the electromagnetic field to remain balanced.

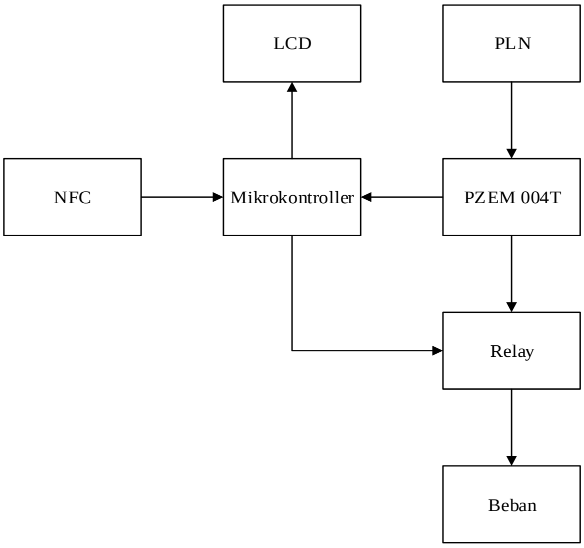

Figure 3. Schematic diagram of electric consumption meter

As shown in figure 3, microcontroller took place as main component to integrate the system by programming it. LCD is used as display to show the information to user, and this output device can be improved by advanced module such as for IoT technology, certainly depending on the microcontroller. As input device, PZEM-004T feed data as current magnitude in amperes.

3. RESULTS AND DISCUSSIONS

Figure 4 depicts developed system of individual electrical consumption meter. The system integrates each component as input and output devices using microcontroller as main organizer via its programming. The whole system is covered by a mica box which has connector for loads and electric source. MCB has been added as system fuse.

Figure 4. Individual electric consumption meter

A flowchart of the system is shown in figure 5. It starts with the initialization of the whole system, including NFC as the main input. The same code permits carrying on the process to activate the current sensor and relay. Using NFC, balance exhaust can be solved by adding some values in the power unit to the recent balance, so we can prolong the main source current. Figure 6 shows the experiment results of the developed system. Notably, the power values in watts (W) can actually be replaced by currency values in the real world.

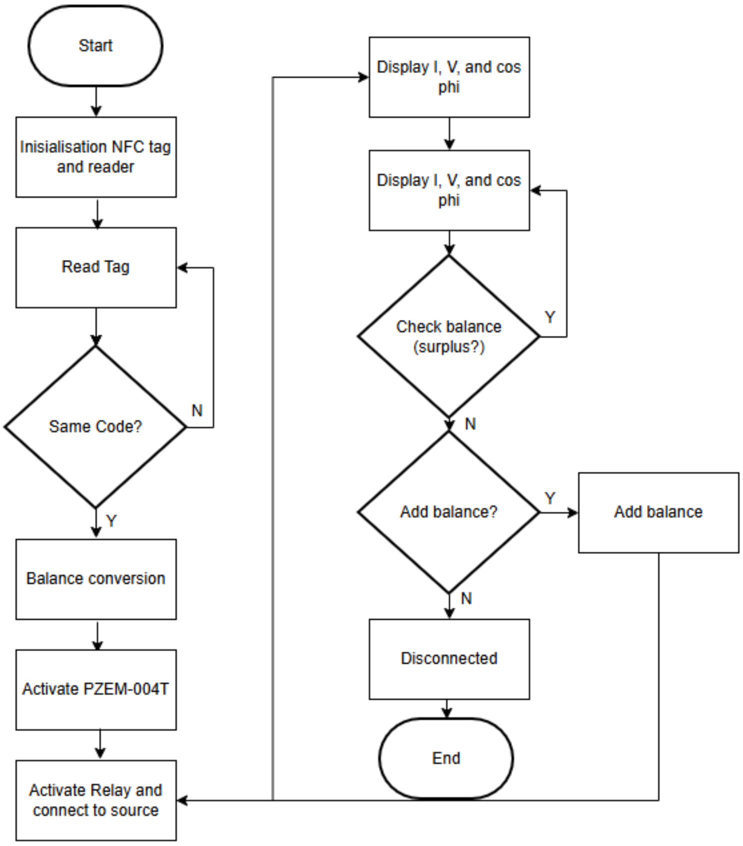

Figure 5. System flowchart

Figure 6. System test

As depicted in Table 1, by install a 60-W incandescent lamp load, the current reading on the energy meter is 0.262 A, and on the PZEM 004T sensor, the current is read at 0.26 A. The voltage reading on the energy meter is 204.5 V, and on the PZEM 004T sensor, it is 204.9 V. The cos phi reading on the energy meter and sensor is the same, which is 1.00. The energy meter reads 0.313 A of current when installed with a 75-watt incandescent light load, and the PZEM 004T sensor reads 0.31 A of current. The voltage is 202.2 V on the energy meter and 202.3 V on the PZEM 004T sensor. The energy meter and sensor both have the same cos phi value of 1.00. The current readings on the energy meter and PZEM 004T sensor are 0.415 and 0.41 A, respectively, when the energy meter is mounted with a 100 W incandescent light load. The PZEM 004T sensor reads 201.7 V, whereas the energy meter reads 201.5 V. The energy meter and sensor both display the same cos phi value of 1.00.

Table 1. Sensor PZEM 004T test

No	Load	Current		Voltage		Cos Phi	
		Energy Meter	Sensor PZEM 004T	Energy Meter	Sensor PZEM 004T	Energy Meter	Sensor PZEM 004T
1	60 Watt	0,262 A	0,26 A	204,5 V	204,9 V	1.00	1.00
	Error	0,76%		0,19%		0%	
2	75 Watt	0,313 A	0,31 A	202,2 V	202,3 V	1.00	1.00
	Error	0,95%		0,04%		0%	
3	100 Watt	0,415 A	0,41 A	201,5 V	201,7 V	1.00	1.00
	Error	1,20%		0,09%		0%	

Table 2 shows saving balance test in controller program. By testing, the balance data from 89.32 until 4994.99 W and then the source is disconnected, and the meter is turned back on, the minimum system memory successfully stores the last data in the form of balance reduction before the source is disconnected. It means the saving process in the system is reliable.

Table 2. Saving balance test

No	Balance	After turned off
1	89,32 Watt	89,32 Watt
2	152,67 Watt	152,67 Watt
3	963,87 Watt	963,87 Watt
4	1256,62 Watt	1256,62 Watt
5	4994,99 Watt	4994,99 Watt
Error	0%	

Furthermore, it is necessary to test for voucher addition mechanism. By experiment, it is observed that program work well. When we add the voucher based on previous value, then it will be added by the same value. We can see that data 1 until data 3, the value is not changed in addition.

Table 3. Voucher test

No	Nilai Voucher	Saldo Awal	Setelah Penambahan
1	1000 Watt	164,53 Watt	1164,39 Watt
2	2000 Watt	1146,46 Watt	3146,46 Watt
3	3000 Watt	88,58 Watt	3088,58 Watt

Eventually, the code of system is tested by its reduction mechanism and its effect on balance and power remains.By data of table 4, it shows errors presence of about 11.5 – 17,4%. Probably, it is caused by interference of current that flows in sensor. Temperature is an important element that can affect this smart meter system, causing errors in data reading [12].

Table 4. Balance reduction

No	Load	5 minutes		Energy Meter	10 minutes		Energy Meter
		Sstarting balance	Ending balance		Sstarting balance	Ending balance	
1	60 W	3057,16W	3052,80W	5Wh	3052,80 W	3044,09W	10Wh
	Error		12,8%			12,9%	
2	75 W	3044,09W	3038,78W	6Wh	3038,78 W	3028,27W	12Wh
	Error		11,5%			12,4%	
3	100W	3028,27W	3021,23W	8Wh	3021,23 W	3007,19W	17Wh
	Error		12%			17,4%	

4. CONCLUSION

In the reading of the PZEM 004T sensor using 3 loads, namely 60 Watt, 75 Watt and 100 Watt for testing current, voltage and cos phi there is an error of 0 – 1.20%. Comparison of sensors using energy meters. In balance storage with 5 attempts there are no errors or 0%. Balance storage is carried out by disconnecting the PLN source and equating it with the last balance before the PLN source is disconnected. In adding balance with 3 tries, there is 1 time inappropriate experiments. This is because when adding balance there is an attached load and when adding balance there is a calculated load. In balance reduction with loads of 60 Watt, 75 Watt, and 100 Watt with a time gap of 5 and 10 minutes, there is an error reduction of 11.5 – 17.4%.

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