Development of design monitoring and electricity tokens top-up system in two-ways energy meters based on IoT (Internet of Things)

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Abstract. This study aims to develop a design of monitoring and electric token top up system of the two-way energy meter based on Internet of Things (IoT) which can be monitored in real-time using a low cost android application. The design of system was developed using ATMEGA1284P-AU as controller, Quectel M95 module to access internet protocol (IP), MODBUS RTU protocol through RS485 serial as a communication link between kWh meter and modem, and MQTT as the main communication protocol allowing the system to communicate with internet. The MQTT protocol was used to transmit data from the modem to the cloud server. After the development process, the system was then tested to find out the value of the delay between the appearance of the android application and LCD kWh meter. From a hundred times of experiment, the average value of delay, i.e. 1.81 s was resulted. By using the development of this system, it is expected to be an alternative solution for prepaid kWh meter users in managing electric top-up token automatically, practically and can be monitored remotely.

1. Introduction

Advances in technology, computers, and telecommunications is currently supporting the development of internet technology. Now, various devices can be interconnected via the internet using the IoT (Internet of Things) technologies [1]. One of the devices applied the technology of the IoT is energy meters. The device is able to record and transmit data from a device to the providers as well as users of electrical energy to the monitoring function etc. [2].

Has developed a network that enables two-way communication between the providers and users of electric energy in the system of smart grid [3]. Along with developments in Smart Grid Distribution System (SDG), application of two-way Energy Meter becomes very important [4].

Charging system electric token on prepaid meters kWh currently belongs to the less effective, because customers have to input vouchers token to the kWh meter manually. Although there has been a system that uses the mechanism of monitoring and charging the electric token via SMS, but it’s quite expensive for once message. Therefore, this research suggests technology kWh meters with two-way communication based on IoT to facilitate customers in top-up electricity token with cheaper cost and no longer need to input vouchers token on the keypad of electricity meter.
2. Device Description

2.1. ATMEGA1284P-AU
Microcontroller Advance Virtual RISC (AVR) is a microcontroller made by the Atmel company. This type of microcontroller is many used by electronic equipment developers. ATmega1284P is a low-power 8-bit CMOS microcontroller based on RISC’s enhanced AVR architecture. By executing strong instructions in one clock cycle, ATmega1284P achieves throughput close to 1 MIPS per MHz allowing system designers to optimize power consumption compared to processing speed [5].

2.2. Module Quectel M95
Quectel M95 is one of the smallest GSM / GPRS Quad-band modules in the LCC castellation package with ultra-low power consumption and extended temperature range. This Quectel M95 modem uses SMT (Surface Mounted Technology), with a low profile and small LCC packages that makes applications of M95 connectivity becoming a reliable, and easily embedded in low-volume applications [6].

2.3. ModBus
ModBus is a message protocol application layer that provides client/server communication between devices connected to various types of buses or networks. ModBus usually runs over RS 232, RS 442 point to point or RS 485 to multi-point links [7].

Modbus is a standardized protocol for interconnecting industrial machines where modbus provides client-server communication between various devices connected to different network types. Modbus communicates through a request and reply protocol by providing a service in the form of a function code [8].

3. Research Methods
This research uses descriptive and experiment (trial) methods. With descriptive method, author will explain study of literature related to this research. But for experiment method, author will design systems and implement IoT device on kWh meters with real-time data monitoring system and interfacing for automatic electric token charging based on IoT. Development of IoT device includes designing the system to be implemented on the interface module originally used for sending data via SMS, then build the system with additional software created in cooperation with PT. SMC Co.-Design, and do a test in order to know the reliability of the system have been made, and the last step is analyzing the results.

3.1. Block Diagram Tool
The whole of the tool will be tested this consists of kWh meter two way, ATMEGA 1284, module Quectel M95, serial communication RS485, power supply and the load.

![Figure 1. Tool Block Diagram](image-url)
Figure 1. shown 2W – energy meter with the module as a unit of processing that helps the system to be able to communicate with the user via SMS that was originally created by PT. SMC co. Design. But with the focus of the design and manufacture of IoT Device on this research, is to develop the design of the module for communication system through an existing SMS into a device that can communicate with the user through the internet. ATMEGA1284P-AU as a microcontroller that has dual port serial communication, which serves to process data from the two-way Energy Meters and then sent to the module Quectel M95.

Module Quectel M95 as GSM modem is used to access the IP protocol and also a device that serves to receive the signal and data from a microcontroller that will then be sent to the cloud. Serial communication RS485 communication serve as a liaison between the kWh meters with interface module /IoT device that uses MODBUS RTU Protocol. In the block tool diagram there is a power supply so that the whole series can run as appropriate. Next in order for communication from the interface module can be connected to the internet that is using the MQTT Protocol, message delivery protocol that uses the mechanism of publish/subscribe. MQTT protocol uses a bit energy compared to the other protocols, and can work well in environments that have limited bandwidth.

3.2. Series Interface Module
In this research there are a number of basic blocks in the series interface module that was created, namely:
1. Quectel M95 Module
   Quectel M95 is one module GSM/GPRS Quad-band in the smallest package castellations LCC with the consumption of ultra-low power and an extended temperature range. This is a series of Quectel modem power supply with the M95 voltage 3.3 V single-4.6 V, with the normal voltage 4.0 V.

2. Battery Charger
   Battery charger is the most important part of the minimum system, because without battery charger the rest of the series will not be able to walk properly. This is a series of Battery Charger on designing on this research. The power used by 5 volts DC, the power supply used to power the microcontroller.

3. RS485 Port
   Serial communication is a communication data transmission is done alternately or one by one. This system was supported by ICS RS-485 communication for serialization. This is a series of port RS-485. Serial communication port is bidirectional and can transmit data i.e. 1.2 km or (4000ft), and has a slightly so that more save pins and wires when compared to parallel communication.

4. Controller
   On this research of controlling devices made using microcontroller AVR output, i.e. the ATMEGA 1284P-AU. This is a series of controller ATMEGA 1284-AU. This microcontroller has a function to process data from the kWh Meter is then sent to the modem Quectel M95.

3.3. Working Principles
The working principle of the monitoring system power consumption of electricity and the automatic electric token charging based on IoT is described using a block diagram in Figure 2 was intended.
Figure 2. Block Diagram of the Working Principle of Two-way Energy Meters

Figure 2 indicates that the system design monitoring and charging the electric token on the two-way Energy Meters using systems of MQTT Protocol. Seen that the system design is divided into two parts, namely the section on client 1 and client 2, with broker MQTT as the Centre of Exchange data. On the design of this system, both the client acts as a publisher as well as a subscriber.

Publisher on client 1 on duty for sending/publish data kWh meters form the value of electric power consumption and also the response the request token delivery of electricity through android applications, while the subscriber in client 1 on duty to receive the electric token input/requested by client 2. While the publisher on client 2 was tasked to publish/Sending token power corresponds to the amount of input, and sends the request monitoring kWh meters, while the subscriber on client 2 on duty to receive data from the kWh meter.

3.4. Testing Interface Module
Testing is divided into two parts, namely monitoring testing energy meters to know electrical energy consumption, as well as testing the charging system of the electric token automatically. As for the block diagram testing the charging system of the electric token can be done with two events, namely the input token code with electrical simulation system, which is testing the system through android applications, as well as with the input token by keypad on kWh meters.

Figure 3. Electricity Token Charging System Scheme

Figure 3 is the scheme of the system to be tested on this research to know comparison delay charging electric tokens between input directly on the kWh meter, with input via simulation systems/android applications.

4. Implementation and testing
Following implementation of the draft featured hardware interface module for automatic charging system of electric token based on IoT.
Description of Figure 4 as follows:

- a. ATMEGA1284P-AU Microcontroller
- b. Quectel Modem Module M95
- c. RS-485 Converter
- d. Battery Charger
- e. Power Supply
- f. Antenna
- g. Terminal AC
- h. on/off Switch.
- i. Connector RS-485

From Figure 4, seen physical form of the implementation design of hardware interface module for automatic electric token charging system based on IoT using the ATMEGA 1284P-AU, module Quectel RS485 port, M95, and power supply. While in Figure 5, seen that the device have been installed so that the battery system still run if there is no supply of electricity.

ATMEGA 1284P-AU as the central control of the system function to process and transmit data from the kWh meter towards the module Quectel M95. Module Quectel M95 serves as a GSM modem that is used to access the IP protocol and is also a device that serves to receive the signal and data from a microcontroller that will then be sent to the cloud. While port RS485 with MODBUS RTU Protocol
serves as a liaison between the kWh meters with communication *interface* modules, and *power supply* so the whole series can run as appropriate.

![KWh meter](image)

**Figure 6.** KWh two-way meter Meisys Power brand type of 200/201

This research use two-way kWh meters with Meisys Power brand type of 200/201 to facilitate testing research as shown in Figure 10.

5. Result and Discussion

A. Testing Simulation System

This test aims to test whether the system can work as expected, and also to know the performance of the system are made. In Table 1, described as an experiment done N followed by a number as an ordinal number description of the experiment. The table can be seen in the comparison of the value of the *delay* generated against the response is displayed on the LCD and the android application kWh meters with electric token delivery testing as much as 100 times the experiment. Z1 Android application response or kWh meter to show the display the token status information sent has a value of *delay* which vary.

Table 1. Comparison of *delay* against the response is displayed on the LCD and the android application kWh meter

| No | Token Code                  | Display on Android Application Delay (Second) | Display on LCD kWh meter Delay (Second) | Delay (Second) |
|----|-----------------------------|-----------------------------------------------|----------------------------------------|----------------|
| 1  | 6298 4851 4531 0787 1738    | 2.05                                          | 4.21                                   | 2.16           |
| 2  | 3257 2795 6498 3961 2899    | 2.4                                           | 3.54                                   | 1.14           |
| 3  | 4980 5978 4250 7893 0424    | 2.02                                          | 4.15                                   | 2.13           |
| 4  | 6978 8951 9293 5701 9232    | 2.57                                          | 4.41                                   | 1.84           |
| 5  | 6929 0985 5944 9623 4648    | 2.55                                          | 4.32                                   | 1.77           |
| …  | …                           | …                                             | …                                      | …              |
| 95 | 6919 0367 0182 8779 2259    | 0.86                                          | 2.71                                   | 1.85           |
| 96 | 0978 1013 6974 7372 0890    | 0.76                                          | 2.59                                   | 1.83           |
| 97 | 2310 8869 4923 0298 4774    | 0.64                                          | 2.57                                   | 1.93           |
| 98 | 5992 0618 3991 2385 1545    | 0.48                                          | 2.19                                   | 1.71           |
| 99 | 1044 9628 1281 4315 5735    | 0.28                                          | 2.83                                   | 2.55           |
| 100| 1151 7388 5610 7798 0829    | 0.38                                          | 2.89                                   | 2.51           |

Average 1.5477 3.3637 1.816
Than one hundred times the experiment was done as shown table 1. the obtained average value of delay between displayed on android applications with the kWh meter displayed on the LCD of 1.81 seconds. Figure 7. shows the process of charging voucher electricity on two-way communication systems.

![Figure 7](image)

**Figure 7.** The process of charging the voucher system on electric two-way communication.

Publish /subscribe in Figure 7 is a message exchange patterns in network communications where the sender of data called the publisher and the receiver of the data referred to by the subscriber. The delivery of the data on the MQTT based on topic, this topic later which will determine the message from the publisher should be sent on subscriber which this topic and can be hierarchical. MQTT topics have a string data type and for the difference hierarchy or level of topics used punctuation "."

If the system starts from the request data on Android Apps form monitoring data at kWh meters nor the request token to add electric recharging balance kWh automatically, then Android Apps (client 2) can referred to as a client who did publish requests against client 2W- energy meter (client 1), which is the exchange of messages in the communication network between two passes broker as intermediary first. In the meantime because client 1 is in the same topic with client 2, then it will receive the request/subscribe request form data monitoring at kWh meters or request of electric token charging.

Because the request is sent to client 2 is already up, client 1 will then send the data processing results/publish a response in the form of the results of monitoring as well as charging electric token response form whether the token was success or failed to input). Next client 2 will receive a response/subscribe respond from client 1 through brokers, and get the monitoring data on kWh meters as well as the response to the request of charging the electric token had previously been inputted.

Token inputted at the research made by using STS Simulator. The result code of the token that is created on the Simulator STS can be termed as a special local token as token test. Transfer Standard Specification (STS) was developed as the specifications of Eskom. The STS can be defined as the secure message protocol that enables secure information flow between the CDU (Credit Dispensing Unit) and meters. The CDU is the unit that serves generate code token for electricity prepaid. The information is carried between the CDU and the meter in the encryption protocol into a fixed length value is referred to as a token. Meanwhile the image of making token using the STS test process simulator for the system shown in Figure 8.
Applications for the electric token automatically charging and monitoring must be created specifically to run on smartphones that system operations are open platforms which support MQTT system. However, in this study, android applications used are still not connected directly to the broker. Android applications make requests to the server in advance with HTTP, then the server is receiving and processing the data request and send it with MQTT Protocol towards broker (publish request). The Server used in the study was made with the platform of nodeJS.

The next process, kWh meters will receive data request/subscribe request from the server, and then prepare it and send you a reply response/publish respond towards the brokerage. After that the server will immediately receive a response/subscribe respond, and this response is sent the server towards android applications.

The server also serves to do generate electrical pulses in the form token also do rating entity, i.e. change credit value pulses into electric power unit and the result of this process is called quota. This quota will be sent prepaid server to the kWh meter.

6. Conclusion
The system is built on this final project goes according to scenario testing and function properly and can be used to find out the remaining credits kWh, kWh meter stand, voltage and electric current and can do charging token power automatically via smartphone.

The results of the implementation of the field shows that the system of interfacing on kWh meters 2 of directions is able to carry out the charging electric token automatically by utilizing the MQTT Protocol through a IoT. In this study, android applications and kWh meters with the IoT device act as a publisher or subscribe to send or receive data in the form of monitoring or top up request token electricity.
Than one hundred times the experiments conducted obtained rating average delay between displayed on android applications with the kWh meter displayed on the LCD is 1.81 seconds. Overall system interfacing can be implemented as a system which can potentially be used as an alternative solution to users customers of prepaid meters kWh in electricity token charging handle from a distance in automatically without input vouchers manually on a keypad in kWh meters with cheaper cost.

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