DEVELOPMENT OF INTERNET OF THINGS APPLICATION FOR DIGITAL ENERGY METER

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This report is submitted in partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering

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"I hereby declare that I have read through this report entitled "Development of Internet of Things Application for Digital Energy Meter" and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering"

Signature : …….

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Date : ……

I declared this report entitled “Development of Internet of Things Application for Digital Energy Meter” is the results of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …….

Author’s Name : LING SIONG NGIUNG

Date : ……

To my beloved mother and father

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ABSTRACT

The conventional analogue energy meter has the limitation in terms of real-time accessibility. In addition, issues of human error might have happened when a person obtain the data from the conventional energy meter. In contrast, digital smart meter represents a promising solution for monitoring of energy and consumption in real-time. Hence, the aim of this project is to develop a low-cost wireless-enabled Modbus module for digital energy meter with Internet of Things (IoTs) concepts. The concept IoT is implemented in this project. The real-time data from digital energy meter is obtained by using a universal Modbus protocol and the data were sent to the cloud through Internet. Firebase platform has been selected for users to visualise the data. The Arduino Nano act as main controller of this project and the ESP 8266Wi-Fi will transfer the data from digital energy meter and upload to cloud. This allows user to view the power consumption through clouds at anywhere and anytime. The system contains two inputs which are voltage and current. The output will be the real-time power consumption and transmitted to cloud for monitoring. With this project, smart meter and wireless-enabled universal module are installed in the building and connected through the internet. Users are able to view their power consumption easily by using cloud system. By using the obtained real-time data, the users able plan their actions and save cost.

ABSTRAK

Meter tenaga analog konvensional mempunyai batasan dari segi kebolehcapaian masa nyata. Di samping itu, isu-isu kesilapan manusia mungkin berlaku apabila seseorang memperoleh data dari meter tenaga konvensional. Smart Meter merupakan penyelesaian yang kukuh untuk memantau tenaga dalam masa nyata. Matlamat projek ini adalah untuk menghasilkan modul sejagat tanpa wayar dengan kos yang rendah untuk meter tenaga digital berasaskan konsep "Internet of Things" IoT. Konsep IoT digunakan di dalam projek ini. Data dari meter tenaga digital diperoleh dengan menggunakan protokol Modbus semesta dan menghantarnya ke "cloud" melalui Internet. Platform Firebse dipilih untuk membentangkan data untuk pengguna. Arduino Nano memainkan peranan sebagai pengawal utama dalam projek ini dan ESP 8266Wi-Fi akan memindahkan data dari meter tenaga digital dan dimuat naik ke "cloud". Aplikasi mudah alih juga dihasil untuk membolehkan pengguna melihat penggunaan kuasa mereka melalui telefon bimbit mereka di mana-mana dan bila-bila masa sahaja. Idea dan kaedah yang berbeza dikaji melalui kertas, jurnal dan buku yang dilakukan oleh penyelidik masa lalu. Sistem ini mengandungi dua input iaitu voltan dan arus. Output akan menjadi penggunaan kuasa masa nyata dan dihantar ke "cloud" untuk pemantauan. Dengan projek ini, meter pintar dan modul sejagat yang didayakan tanpa wayar dipasang di bangunan dan dihubungkan melalui internet. Pengguna dapat melihat penggunaan kuasa mereka dengan mudah melalui "cloud". Dengan menggunakan data sebenar masa nyata, pengguna dapat merancang tindakan mereka dan menjimatkan kos.

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IoT	-	Internet of Things
VT	-	Voltage Transformer
CT	-	Current Transformer
WSN	-	Wireless Sensor Network
RTU	-	Remote Terminal Unit
TCP	-	Transmission Control Protocol
TTL	-	Transistor - Transistor Logic

CHAPTER 1

INTRODUCTION

1.0 Introduction

Industrial Revolution 4.0 is a very timely topic in this globalization era given its huge potential impact and benefits toward manufacturing. The World Economic Forum's founder and chairman, Klaus Schwab states that Fourth Industrial Revolution changes the way how human work and live. The Internet of Things (IoT) industry is one of sector that crucial for embracing Industrial Revolution 4.0 in Malaysia. With Internet of Things (IoT), the communication skill such as speaking and writing will be improved [1]. The adoption of IoT technology in the industry has increasing. To stay competitive, many utility companies have turned to smart meter. The IoT-enabled devices are more efficient and ensure more accurate diagnostics and billing. With the help of IoT, consumers can be monitoring the energy consumption at anytime and anywhere.

Besides, the traditional fossil fuel price is rising and it also causes negative impacts to the earth’s climate. It is important to explore new clean-energy sources or improve the energy efficiency in the consumer-side smart grids of various buildings. From a general survey [2], building is responsible for around 71% of the total electrical energy consumption, 40% of nonindustrial waste, 39% of the total energy usage, 38% of the total carbon dioxide emissions and 12% of water consumption. Smart energy meter is introduced as a solution for the problems. The main idea of smart meter is monitoring power consumption of buildings and increase the awareness of consumers on their electrical usages.

In this project, the purposed design will be able to send the data of energy consumption in buildings to a cloud through Internet of Things (IoT) in real time. Another purpose is allowing the consumers to log in to the platform to monitor the

energy consumption of buildings without going to each substation of the buildings at different places.

1.1 Problem Statement

Buildings are complex design and many factors can influence the total energy consumption in different building [3]. Without a probable way to monitor the real energy consumption, consumers lack alert to control and manage their energy usage. A lot of unnecessary energy is wasted and increase the monthly bill in buildings. Real-time monitoring helps industries to customize their plan to reduce the energy waste [4].

During 2016, about 300,000 houses in the Melaka will replace their traditional meter to a smart meter, an electronic device that records consumption of electric energy in intervals of an hour or less and communicates the information at least daily back to the utility for monitoring and billing. [5] A traditional meter is difficult and not convenient to assess or obtain the energy usage from time to time. Consumers need to go to the energy room of the building to obtain the data and perform an analysis. This takes time and special authority to access the energy room. Besides, issues of human error might have happened when obtain the data.

A wireless digital energy meter would offer greater convenience to the meter reading task [5]. Installation of smart meter is possible to obtain the consumed energy and analysis the data at anywhere. The features help in monitoring the energy consumption at customer sides. Customers also able to view their data through web page or Android application. However, the installation of smart meter system is very costly. This is not affordable for low income urban consumer.

IoT features have been implemented to some of the existing meter. However, specific software is required according to the brand of smart meter to analysis and monitor the usage. The software does not come with the smart meter when the consumers buy the smart meter. Different smart meters install at buildings will cause the consumers need to buy different software to operate with it. In terms of cost, consumers need to spend extra money to utilize installed smart meter. This problem

can be overcome by adding on a Modbus communication protocol instead of buying the software.

1.2 Objective

The objectives of this project can be listed as follows:

1) To implement and develop a low-cost wireless-enabled universal module for digital energy meter with IoTs concepts.
2) To obtain the value of current, voltage and power factor from digital energy meter through Modbus protocol and calculate the total power consumption.
3) To create a real-time platform to collect energy consumption data from different buildings.

1.3 Scopes

This project focuses on the daily monitoring of the power consumption among the residential houses supplied with single phase system located at Bukit Beruang, Melaka. A digital energy meter with IoT is installed in a few houses near Bukit Beruang residential area. Arduino Nano acts as the main system and communicate with the other subsystems from Transistor - Transistor Logic (TTL) to RS 485 Modbus. The parameters such as voltage, current and power factor are obtained though Modbus Remote Terminal Unit (RTU) protocol. The power consumption is calculated in Arduino Nano and compared with the reading from Mikro digital power meter DPM 380. The real-time power consumption will be uploaded to Firebase platform for the monitoring of real time data consumption of Bukit Beruang residential area. Modbus module produced is limited to the connection of one subsystem only. Besides, the storing of data depends wholly on the availability of internet connection. When there is no internet connection, the data will not be uploaded to cloud system.

1.4 Outline of Project

There are five chapters in this report which includes introduction, literature review, methodology, results and discussion, and ends with conclusion and recommendation.

Chapter one is the introduction of the project. In this chapter, research background, problem statement of research topic, objective of this research, scope and the outline of the project is stated. The aim of this chapter acts as introductory to research topic which is Smart Meter to help readers gain relevant initial understanding regarding the research.

Chapter two covers the literature review of the project. In this section, information about previous research published by other researchers on this topic or similar topic was discussed. All this information act as guidance for this research and give us an overview to how our research should be done.

Chapter three states the methodology of the research. In this chapter, the methods and technique used in this research is discussed. The synthesizing method and parameters and characterization techniques is listed in this section to give readers understanding of how the research is carried out.

Chapter four includes the result and discussion of the research. The results of the experiments and testing had been presented in this section. Discussion is done based on the results obtained from the experimental procedure. This section carries all the important findings of the whole research.

Chapter five is conclusion and recommendation. The conclusion had been done based on the whole findings of project. Relevant recommendation was included to make further improvement for the project.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Nowadays, the demand of energy in the form of electricity is increasing around the world due to global population increment. Electricity consumption is one of the major cost contributor in the commercial, industrial or household property. In fact, many people are concerned about reducing the intensity and cost of consuming electricity but are yet to find a suitable solution to it. Therefore, this project helps to develop a monitoring system for the electricity consumption in the household. This system will help users to have deeper understanding on the relation of the appliances they use in the household and the power consumption needed to fuel their daily routines. The challenges that are faced by the smart energy monitoring system is the number of data to be collected and uploaded to cloud is massive. There may be loss of data at certain period of time where server failure happens. Therefore, the design of energy monitoring system should be able to compensate the loss of data by allowing alternative ways for data storage.

2.1 Internet of Things (IoT)

Internet of Things (IoT) encompasses a set of technologies that enable a wide range of appliances, devices, and objects (or simply “things”) to interact and communicate among themselves using networking technologies. Most of the contents and information found on Internet is supplied by human being, whereas in IoT small devices are frequently the active element that provides the information. [6]

Nowadays, Internet is not only a network of computers. It has evolved into a network of devices of all types and sizes, vehicles, smartphones, home appliances, toys,

cameras, medical instruments and industrial systems. IoT make everything connected, communicating and sharing information to each other all the time as presented in Figure 2.1. Besides, IoT based application become a popular solution for real time problems. [7,8]

The integration of intelligent measuring devices in a city using the Internet of Things (IoT) allows the collection of all the data necessary to become a smart city.

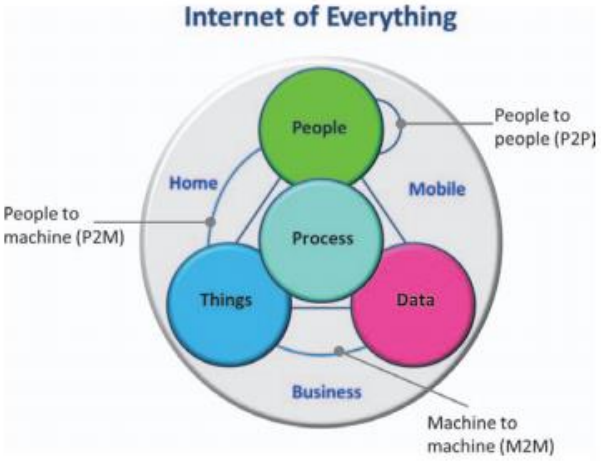

Figure 2.1: Internet of Everything [7]

2.2 Smart Meter Concept

A smart meter is usually an electric meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to utility for monitoring and billing purposes. Smart meter provide parameter like voltage, current and energy consumption in real time to the utility or to the end user. In addition, these data allow understanding spending habits, improving network efficiency, and contributing to electricity, water, or gas saving. With smart meters, the energy consumption can be managed and can be monitored in real time. Nowadays, several the smart meter can be bought in market and Internet of Things (IoT) is the way to communicate with them. [9,10] Figure 2.2 shows the existing smart meter in market.

Figure 2.2: Siemens meter, Schneider meter and Mikro meter

2.3 Energy Monitoring

An energy monitoring system is a system used to show the energy consumption by a domestic, industrial and agricultural. Various real-time parameters such as current, voltage, power, and energy can be obtained based on electricity consumption. Sensing elements such as voltage transformer and current transformer is used to sense the voltage and current consume by load.

2.4 Review of Previous Related Work

Samarth Pandit [11] states that present scenario the world is facing energy crisis such as energy tampered. This paper proposes a smart energy meter using Internet of Things (IoT) to monitor energy consumption in domestic level through two-way communication between utility and customers. In addition, this system able to cut down the energy supply if customers fail to pay the bill or tampering occurs. Once the bill is paid the energy supply is reconnected. This device can notify the customer and utility at the event of meter tampering. IoT act as the main method of communication between energy meter and the web server. The data collected from the sensor is stored on cloud for monitoring. The real-time data is displayed on the webpage for customers and utility to monitor and plan their actions.

Based on Rashmi M. N. [12], this paper proposes a remotely monitored energy meter with help of WiFi, server and android application. This meter is used to view

live data consumption and sight energy expended points of interest on daily or monthly. The total consumption is collected by using an ARM Cortex M4 microcontroller and upload to server through wireless modules. The descriptive bill is generated at customer premises with more accuracy data and details. Besides, relay is installed to cooperate with microcontroller to disconnect the power supply just by a tap in android application.

Based on Arati Kurde [13], the paper aim is to design a device to measure and report the energy use or receive control input form the network for a building. ACS712 current is used to measuring the current and voltage to perform analysis on energy consumption. This paper also focuses on improve the accuracy of disaggregation algorithm by ON/OFF events with smart meter to calculate the energy consumption. Users can access or monitor the data since IoT platform is used to receive the information and store the real-time data in cloud server and web hosting. Energy monitoring can increase the awareness of energy consumption among users.

Aneesh P Kunjappy [14], monitoring and controlling of energy consumption is very important nowadays. However, there are still many exist problems such as difficultly in construction, poor real time, no quick two-way communication and etc for current energy meter reading system. This paper introduces a IoT Based Smart Energy Meter for Home Management System. Current and voltage is measured at load through a sensor and power calculation is performed before the data is upload to IoT platform. Users not only can monitor the information from cloud but also can obtained the calculated power consumption unit by SMS through GSM module. In addition, a user kit (portable wattmeter) is purposed. It helps users to monitor power consumption details of a device on will.

Win Hlaing [15], Internet of things (IoT) concept is good solution for solving the growing issue of power and energy management. IoT's energy monitoring is designed to overcome human error and cost reducing in energy consumption with more efficiency for the power system. A low cost wireless sensor network and protocol for smart energy and web application is proposed in this paper. Challenges of energy efficiency and manageability is overcome by this system. This meter able to view parameter such as current, voltage, power and energy. All this information will display on websites through existing server by using ESP 8266 as a WiFi module.

Sanket Thakare [16], currently power generated is contributed by fossil fuel and it might get exhausted within 20 years. Energy monitoring and conservation holds prime become very important. Internet of Things (IoT) allows the energy meter to upload the power consumption at device level to sever for monitoring and establish remote control of any appliance. A potable smart home energy meter for residence is introduced. The sensing of signal happens at 20ms. Through IoT, the power consumption by various electrical device which had been calculated can be upload to a home energy monitoring website. Users can monitor the power consumption of electrical appliances at home and take further step to control the usage.

Anmar Arif [17], the electricity demand in Saudi Arabia is increasing and smart meter can decrease the overall energy consumption. This paper presents the development of a GSM and ZigBee based smart meter. GSM and ZigBee protocol are used as wireless communication. Development of this meter provided a two-way and real-time communication between consumers and the provider. The receiver uses GSM network to send the consumption information to user through SMS. A webpage and Android app are developed foe customers to view their real-time energy consumption. Nowadays, users can manually be reading and monitoring their electricity meters by using a smart phone. With this information, people able to manage their usage and save both energy and money.

Md.Masudur Rahman [18], this paper proposes an Arduino and GSM based smart meter with aim to provide all required services remotely for metering and billing with high fidelity. Smart energy meter (SEM) is an electric device communicate with a wireless protocol to take a meter reading automatically. In additional, energy consumption in term of money, accurate data and a Smart Energy Report is provided by this system. The design able to obtain the real power by multiple the current and voltage signal and low-pass filtered. The overall cost of this project is high. This problem can be overcome by commercialize this meter, reduce the man-power for billing service and cut off service.

Prof. Yogesh Pingle [19], this paper explains how the design help in reduce the wastage and energy by using the electricity efficiently. This device will notify the users about the electricity usage at home by sending alert, suggestions, statistics, graph, etc. This device helps user to monitor consumed by its device and if the device is

malfunctioning it will consume large amount of energy. This project will upload the power consumption at cloud or mobile device through Internet of Things (IoT). Hence, users will alert on energy consumption at their home and decide his actions to reduce the cost.

Woong Hee Kim [20], this paper talks about smart energy management system for home and building with the combination of wireless sensor network and intelligent home way. This system enables the users to monitor his electricity usage and remote on/off control by providing tracking energy consumption, cost comparison, analysis and rule-based configuration to user's smart devices like smart phone and smart pads. Alarm will ring if a device consumer more electricity than usual. This paper focus on monitor and measure electricity usage at home in real-time.

Giri Prasad. S [21], energy crisis is the main problem faced by our society. Another issue is TNEB worker has to visit each house for measuring the power consumption and calculate the bill amount. Human error and bill delay might happen during this process. This paper proposes a IoT-based meter reading system to overcome the problems. Daily consumption report and cost are generated and upload to cloud in form of chart and gauge format. The consumers can monitor a real-time data through web portal.

Birendrakumar Sahani [22], the paper presents a method to modification existing meter into smart meter without replace it. This meter provides continuously monitor energy consumption. The cost is calculated based on per the blinking of LED and upload to web page for display. In additional, the ability for users to choose the threshold value on web page in added. If consumer reading is near to the set threshold value, a notification is send to customer by SMS through GSM to aware customer. Customer need to change the threshold value if not the meter will automatically get off.

Akshaya Ravishankar [23], this paper explains the implementation of low cost home energy monitoring system. An expensive home automatic system is not affordable for low income urban consumer. Aim of this paper is to design a low cost, open-source, non-intrusive residential energy monitoring system to continuously monitor the consumption over twenty-four-hour period. The measuring parameters such as voltage, current, real power and reactive power are logged into SD card. A

Liquid Crystal Display (LCD) is used to display the energy consumption over 24 hours. The recorded data over a period of time would enable the utility service provider to study the user behaviours pattern.

The next paper by Shang Wen Luan [24], point out the Smart Power Meter for AMI Based on ZigBee Communication. It is focusing on implement a ZigBee system into a power meter to monitor power consumption. In addition, this project also purposes an outage recording system. Voltage and current waveform are acquired by a data acquisition module and store in internal memory. A software of proposed rear-end processing system is designed to establish the power consumption and outage event database.

Himshekhar Das [25], electrical utilities are suffering from huge losses due to power theft, inadequate usage of energy, unpaid bills and distorted power quality. The paper proposes Smart Energy System for residential customer and smart switch board to curtail the need to upgrade to smart appliances. Besides, Virtual Instrumentation also introduced to perform In House Display (IHD) for Energy Management System (EMS) when connect to any computer. The energy consumption is calculated and transmits to the utility once in every hour. Data obtain also can be saved into SD card through Secure Digital (SD) card module reader.

Bharath P [26] states electricity is one of the basic requirement of human beings and wisely used for ` purposes. A low cost, single phase digital electricity metering system is proposed in the paper. The active power consumed is calculated according to number of pulses obtained and the bill can be generated at the customer's end. Since master station unit (MSU) has the complete data base of various credit card, customers able to pay the bill by using credit card at his place.

Table 2.1 shows the summary of the review of past project by the author, title of journal, the year published, presence of IoT, type of storage, type of wireless sensor network, presence of mobile app, microprocessor used and type of sensor used.