POWER AND ELECTRICITY BILL MONITORING ON SMART PHONE

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A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Control, Instrumentation and Automation)

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"I hereby declare that I have read through this report entitled "**POWER AND ELECTRICITY BILL MONITORING ON SMART PHONE**" and found that it fulfills the partial requirement for awarding the degree of Bachelor of Electrical Engineering (Control Automation and Instrumentation)".

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I declare that this report entitled "**POWER AND ELECTRICITY BILL MONITORING ON SMART PHONE**" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father

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ABSTRACT

This report aims to present a project on power and electricity bill monitoring on smart phone. This project is motivated by three problems. First, in commercial sectors the electricity bill can become very high and the Building Management Systems used to manage power consumption are expensive and prone to limitations in terms of power measurement and data logging. Second, in industrial sectors where there is a demand to monitor heavy machinery, it is necessary to have devices that can be easily installed and measure the usage. Third, devices that can monitor multiple AC power lines are crucial in countries like Malaysia where Net Metering Scheme is going to be implemented. To address these issues, this project tends to build a device that can measure multiple AC power lines such as power consumption and PV power generation simultaneously. Moreover, the proposed device needs to record the hourly, daily, monthly and yearly power usage so as to offer the optimal power management solution to the users in both industrial and residential areas. Lastly, the project needs to work based on the existing WLAN in the house to assess its easy installation. This project adopted a methodology with various steps to meet the objectives. A PCB was fabricated in a packaged design and the appropriate mobile apps was designed. The device was connected to two Current Transformers that are clamped on the AC power lines, measuring the electricity usage and PV power generation at the same time. In this project ESP 8266 was employed both as the microcontroller to perform decision making and as the WiFi transmitter to connect to the house WLAN router. EEPROM was used to data log the hourly, daily, monthly and yearly data of usage and generation. Smart phone showed the data saved by the EEPROM by communicating locally with the EPS 8266 via router. Multiple AC current measurement was performed by utilizing the multiplexer to route several data. The current measurements were based on RMS calculation in accordance with the methodology. The designed device successfully met the objectives of the project. Future researches need to consider integrating power factor measurement and cloud computing to make the instrument applicable to heavy machinery loads and usage in Demand Side Management.

ABSTRAK

Laporan ini bertujuan untuk mempersembahkan satu projek mengenai pengawasankuasa dan bil elektrik di telefon pintar. Projek ini dimotivasikan oleh tiga masalah.Pertama, dalam sektor komersial bil elektrik boleh menjadi sangat tinggi dan Building Management Systems biasa menguruskan penggunaan kuasa mahal dan cenderung kepada had dalam soal ukuran kuasa dan pengelogan data. Kedua, dalam sektor perindustrian di mana terdapat satu tuntutan memantau jentera berat, adalah perlu untuk mempunyai alat yang boleh dengan mudah dipasang dan mengukur penggunaan. Ketiga, alat yang boleh memantau talian kuasa AC berbilang genting di negara-negara seperti Malaysia di mana Net Metering Scheme akan dilaksanakan.Menangani isu-isu ini, projek ini cenderung untuk membina sebuah alat yang boleh mengukur talian kuasa AC berbilang seperti penggunaan kuasa dan penjanaan kuasaPV serentak. Tambahan pula, cadangan peranti perlu merekodkan setiap jam, setiap hari, setiap bulan dan penggunaan tenaga tahunan supaya dapat menawarkanpenyelesaian pengurusan kuasa yang optimum kepada pengguna dalam kedua-duakawasan perumahan dan perindustrian. Akhir sekali, projek perlu bekerja berdasarkan WLAN sedia ada di dalam rumah menilai pemasangan mudahnya. Projek inimengamalkan satu kaedah dengan pelbagai langkah untuk bertemu objektif. PCBdibina dalam satu reka dibungkus dan aplikasi mudah alih sesuai telah direka bentuk.Peranti disambungkan kepada dua Current Transformers yang mengapit talian kuasaAC, berukuran penggunaan elektrik dan penjanaan kuasa PV pada masa yang sama.Dalam projek ini ESP 8266 telah bekerja kedua-dua sebagai mikropengawalmenjalankan pembuatan keputusan dan sebagai pemancar WiFi disambungkan kepada rumah penghala WLAN. EEPROM digunakan untuk balak data setiap jam,setiap hari, setiap bulan dan data tahunan penggunaan dan generasi. Telefon pintarmenunjukkan data diselamatkan oleh EEPROM dengan berkomunikasi tempatandengan EPS 8266 melalui penghala. Ukuran terkini AC berbilang telah diusahakandengan

menggunakan pemultipleks kepada laluan beberapa data. Ukuran terkiniberasaskan pengiraan RMS sejajar dengan kaedah. Peranti bercorak be rjaya memenuhi objektif projek itu. Masa depan menyelidik keperluan mempertimbangkanmenyepadukan ukuran faktor kuasa dan pengkomputeran awan untuk membuat alatboleh digunakan kepada muatan-muatan jentera berat dan penggunaan dalam Demand Side Management.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DSM	-	Demand Side Management
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
HTTP	-	Hyper Text Transfer Protocol
I^2C	-	Inter Integrated Circuit
IoT	-	Internet of Things
IP	-	Internet Protocol
KWh	-	Kilo Watt Hour
LCOE	-	Levelized Cost of Electricity
MD	-	Maximum Demand
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PLC	-	Power Line Communication
PV	-	Photo Voltaic
RTC	-	Real Time Clock
SCL	-	Serial Clock
SCT	-	Split Core Transformer
SDA	-	Serial Data
SEDA	-	Sustainable Energy Development Authority Malaysia
TNB	-	Tenaga Nasional Berhad
WLAN	-	Wireless Local Area Network
WPA	-	WiFi Protected Access
GPIO	-	General Purpose Input Output

LIST OF SYMBOLS

A	-	Ampere
KB	-	Kilo Bytes
Kb	-	Kilo bits
KWh	-	Kilo Watt Hour
V	-	Volts
ms	-	Milliseconds
Hz	-	Hertz
ADC	-	Analogue to digital conversion

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will initially present an overview on electricity distribution systems and techniques utilized for energy efficiency on smart grids. Next, the motivation behind this research will be explained in the context of problem statement and objectives. The research scope, structure and contribution constitute the other parts of Chapter 1.

1.2 Project Background

In this part an overview will be proposed on the price of electricity bill and tariffs that exist in Malaysia for the commercial sectors. Afterwards, the factors that affect the amount of benefit or losses to the utility will be explained. Later, this amount of profit or loss will be examined in relation to the usage of non-reliable resources in producing electricity. In the next stage, the modern techniques employed in smart grids such as Distributed Generation (DG) and Feed In Tariff (FIT) and Demand Side Management (DSM) [1-3] will be discussed in this section.

Building electricity bill and energy monitoring systems have been an interested topic for researcher to make. Having this system will help customers to monitor the day to day power consumption and electricity bill. Knowing this information helps customers to use power more wisely and reducing the electricity bill. From the other side, giving the information to the users can be beneficial in a sense that they will be informed of the power consumption in the house. In many modern smart metering systems, this feature is included as it sends the measured power directly to the utility and the utility can reveal the information for each house. However, in many countries that this type of smart metering is not installed yet, they cannot monitor the day to day electricity bill. In this project, a system is introduced to monitor the day to day electricity bill, energy consumption and power of the house on the smart phone.

The purpose is to build this simple device and keep it as simply and costly as possible that it can be used easily by all the classes of society. This will help all the houses to use power more wisely while being informed about the daily, monthly and yearly power consumption.

The rates for the commercial users in Malaysia can be illustrated in Table 1.1. This shows that the Maximum Demand (MD) plays a huge role on the amount of electric bill issued especially for the commercial customers. MD is the amount of highest power consumption that has occurred through a month. Reducing the maximum demand can be an essential help to the users as the rate is seen to be 30.3 RM/KW. Moreover, the consumed KWh in the peak period has a key role in the electricity bill. This can be seen to be 45.1 RM/KWh for the Tariff C2 of the medium voltage.

Table 1.1: Current rates of Commercial Tariff in Malaysia [4]

Tariff Category	Current Rates (1 Jan 2014)
Tariff B_ Low voltage Commercial Tariff	
For the first 200 Kwh (1-200kWh) per month	43.5 sen/KWh
For the next kWh (201 kWh onwards) per month	50.9 sen/kWh
The minimum monthly charge is RM7.20	
TARIFF C1 - MEDIUM VOLTAGE GENERAL COMMERCIAL TARIFF	
For each kilowatt of maximum demand per month	30.3 RM/kW
For all kWh	36.5 sen/kWh
The minimum monthly charge is RM600.00	
TARIFF C2 - MEDIUM VOLTAGE PEAK/OFF-PEAK COMMERCIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	45.1 RM/kW
For all kWh during the peak period	36.5 sen/kWh
For all kWh during the off-peak period	22.4 sen/kWh
The minimum monthly charge is RM600.00	

Different methods of electrical power generation will result in different costs for the grid. It includes the parameters such as initial capital, discount rate, as continuous operation, fuel, and maintenance. This type of calculation assists policy makers, researchers and others to guide discussions and decision making [5]. According to Energy Information Administration (EIA), the residential monthly electrical bill consumption was $110.21 in 2013. As reported by NAHB tabulations of Bureau of Labor Statistics (BLS) electric bill accounts for almost 9% of the expenditure in the house that makes it the highest among the house bills [6].

Apart from the above statement, reducing the power consumption can reduce the losses on the distribution network. This will help the utility to generate less for an amount of generated power. This will have effect on the network so that the distribution system will not get hot or damaged through time.

The cost of generating electricity is called Levelized Energy Cost (LEC) that is the life-time cost of present amount of power generation [7-9]. Thus, this cost is the amount of profit that the electrical utility should receive just to surpass the amount of asset that has been used to generate electricity. LEC can be calculated using the total amount of asset being used over the life time divided by the lifetime amount of electricity produced [10-14]. The Levelized Cost Of Electricity (LCOE) is given by Equation 1:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^2}}{\sum_{T=1}^{n} \frac{E_t}{(1+r)^2}} = \frac{total\ cost\ over\ lifetime}{total\ electricity\ produced\ over\ lifetime} \tag{1.1}$$

where:

I_t : The initial investment in the year t (RM)

M_t : The amount of money spent on maintenance in the year t (RM)

F_t : The amount of fuel consumption in the year t (RM)

E_t : The amount of electricity generation in the year t (KWh)

r : discount rate

n : The expected lifetime of the power station (years)

The unit of LCOE is or RM/KWh or RM/MWh that is Killo-Watt hour or Mega-Watt hour that calculated over the life time of the power station that is typically between 20 to 40 years [15].

As stated above, reduction in the consumed power has a direct relation with the sum of costs over lifetime of the distribution network grid. As the consumed power increases, the losses in the network increases. This will definitely have some drawbacks on the network as it reduces the life time of the network [16].

The other effects of consumed power reduction is on the requirement of the maintenance on the grid. As the power consumption decreases, the amount of cost required for the maintenance will also decrease. As the Power consumption increases, the losses in the distribution network will also increase [17]. This has a drawback on the distribution system as the temperature on the cables increases exponentially.

The other impact of reduction in the power consumption is on the saving of natural resources such as oil, natural gas and coil. This is clearly shown in Figure 1.1. As it is observed, the demand increases the generation cost that will involve the natural resources into the grid. The rise in the energy demand will change the type of energy used to supply the power from the power plant. In the low consumption period, the renewable energies such as wind power and solar power is used. This will include the green portion in the generation. As the power increases, the Nuclear energy is increased that is also a fixed portion of the power generation. However, by increasing the power consumption, the natural resources come into play taking larger portions of the consumed power. This will introduce non-reliable resources into the generation plant and will increase the cost of generation.

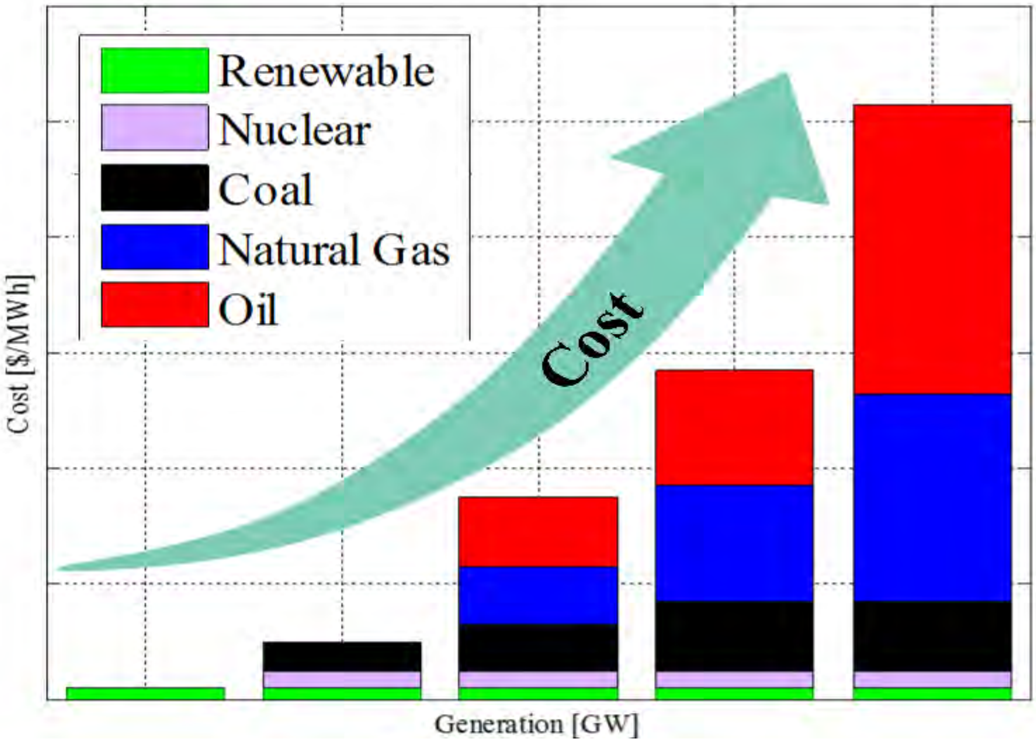

Figure 1.1: Cost of generation

In order to solve the problem of generation using non-reliable resources, new methods such as Distributed Generation (DG) comes into play [18-21]. These methods suggest the usage of renewable energies such as wind and solar power as local generation in every area that can contribute partially to the electricity grid. However, the main problem of the DG is that the renewable energies does not supply continuous amount of power. E.g.

the wind turbines supply power only if there is a wind and solar panels supply power only if there is sunshine.

To bring renewable energies into the grid in Malaysia, Feed in Tariff (FIT) [22-26] was introduced to encourage users to invest on generating solar power. Thus, the users would enjoy a reduction in their electricity bill. However, with the increasing number of users involving in the (FIT), the TNB faced the problem of excess power generation. This led to new plans such as Net Metering Scheme that is going to be implemented in Malaysia [27]. Under this scheme the users would be encouraged to use the excess power generation from their solar panels rather than importing it to the grid. The future houses in Malaysia require devices that can measure multiple AC power lines and monitor the data on the cloud so the best decision about consumption can be made.

In order to be able to actively participate in Net Metering Scheme, the user is required to be informed about the consumed power of the building and the generated power from the installed solar panel. Only by knowing this two at the same time, the user is able to make decision about the house power consumption. That is to say, Net Metering Scheme can be easily implemented if the user has the ability to instantaneously monitor the house power consumption and house solar power generation. Net Metering Scheme with Demand Side Management strategies are the future plans for Malaysian electricity distribution [27].

Currently, there is no implementation of DSM strategies in Malaysia such as Demand Response (DR). This plan sets up a DR pattern that determines the amount of power that utility can provide for the end-users. The user is then encouraged to participate in this plan by actively responding to the demand set by the utility. That is to say, if the DR pattern falls during the peak time then the user is required to lower the consumption. The utility will then provide a discount in electricity bill for the users who can actively participate in this type of program. DSM strategies can be more easily implemented if the user can monitor the house overall power consumption. This brings the need to have devices that are easily installed and can measure multiple AC power lines at the same time.

1.3 Problem Statement

In commercial sectors like hotels, universities or companies, the price of electricity bill can be very high. One of the methods to reduce the bill is the utilization of modern Building Management System. Currently, the devices to inform about the hourly and daily electricity usage are not popular because of their high cost and limitations in terms of power measurement.

In industrial sectors where the usage of heavy machinery loads is common, there exists a need for devices that can simply monitor the AC power. This has been done by expensive tools such as Supervisory Control and Data Acquisition System (SCADA). The disadvantage of this instrument is that if the user wishes to monitor only one load, he needs to buy one SCADA unit that is very expensive with unnecessary functions.

Lastly, in developing countries like Malaysia where the DSM techniques and Net Metering Scheme are going to be implemented, there exists a need for users to monitor and manage their power consumption with higher efficiency. This is achieved by knowing the power consumption in three phase or single phase and PV power generation simultaneously.

To solve the existing problems, it is necessary to have a device that can measure multiple AC power lines at the same time. To ensure the easy installation and mass production of the device, it needs to be as cost-effective as possible, requiring no external router to set up. Moreover, the device should have the ability to inform the users of the real time usage in terms of hourly and daily power consumption.

1.4 Objective

The research tends:

1) To build a device that can monitor two AC power lines simultaneously;

2) To build a device that can be connected to smart phones via the existing WLAN system in the house; and

3) To build a device along with mobile apps that can compute the daily, hourly, monthly and yearly usage (in RM) and generation (in KWh).

1.5 Scope

The scope of this project covers designing a system to data log the KWh power consumption on a microcontroller that can communicate with multiple clients using the existing Wireless Local Area Network (WLAN) in the buildings. At this stage the data is sent locally and the cloud programming is not included.

Moreover, measurements are based on the wire size of 10mm and it doesn't consider the high voltage applications where the wire size exceeds 10mm. This is because the used clamp sensor is only designed for the 10 mm wire cores.

The storage is done on an EEPROM with data being stored based on a 30 minutes interval. For usage pattern, the user can monitor the hourly usage during the current month and the daily usage throughout the year. However, only the hourly data of the current day and the daily data of the current month are available for generation pattern. Monthly and yearly data can be monitored both for usage pattern and generation pattern.

Finally, this project does not take into account the effect of voltage measurement and consequently the power factor measurements.