A SMART METERING FOR ENERGY MANAGEMENT SYSTEM VIA GSM-SMS BASED PROTOCOL

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ABSTRACT

Energy resources and their management is one of the prime challenges to world especially developing countries like Malaysia where the significant contribution to energy generation is based on imported resources. In the mean time the elasticity curve is having a reasonable difference between growing demand and installation capacity. A study of local electricity structure shows that the individual user's consumption pattern is not a responsible one which leaves opportunity for policy makers to introduce new habit formation programmes like variable time pricing etc. This research model helps to create a better understanding and awareness towards the value and the importance of electrical energy, energy saving, promoting of smart energy management as well as an innovation towards further improvement to proven existing system. In this research a brief description about smart metering and the trends in meters from 'traditional' to 'smart' is provided. Feedback and its affect on a consumer's habit formation is a focus of literature. The system design consists of a cellular based power monitoring system using SMS protocol for data transmission. The designed system is compatible with all type of existing monitoring setups at consumer's end. The proposed monitoring system consist of a new energy calculation algorithm, offering electricity packages with a intelligent monitoring for daily power consumption connected to base-station via GSM network. In addition, the prototype designed aims to monitor the consumption records, send it periodically to the server to update to the relevant user profile, provide feedback alerts to the consumer on demand and also provide a better control to utility over individual user. With this proposed methodology, the end users are provided with proper awareness and they may plan their electrical consumption pattern. User are given plenty and incentives based on different time and consumption volume factors thus peak power consumption can be reduced and also wastage of electricity can be reduced until a specific level. The designed prototype proved to be a real-time and effective in individual data collection. It proved to be error free when compared to a manual metering data collection process. One of the most interesting features of the designed module "GSM-PRO" is that it doesn't need any replacement in currently existing monitoring systems. The intelligent pulse reading section of the meter made it compatible with both type of metering systems either it is an electromechanical meter or electronic one. Is also provided a wider control to utility over individual user in case of any fraud monitoring or supply interruption.

ABSTRAK

Sumber tenaga dan pengurusan adalah salah satu cabaran utama kepada dunia terutamanya negara-negara membangun seperti Malaysia apabila sumber-sumber yang diimport memberikan sumbangan yang signifikan kepada sumber tenaga.Sementara itu, keluk keanjalan mempunyai perbezaan yang ketara antara permintaan yang semakin meningkat dengan kapasiti pemasangan. Satu kajian setempat terhadap struktur elektrik menunjukkan bahawa pola penggunaan individu yang tidak bertanggungjawab apabila membiarkan penggubal polisi memperkenalkan program-program pembentukan baru seperti pembolehubah terhadap penentuan harga masa dan sebagainya. Model penyelidikan ini membantu untuk mewujudkan pemahaman yang lebih baik dan kesedaran terhadap nilai dan kepentingan tenaga elektrik, penjimatan tenaga, menggalakkan pengurusan tenaga secara bijak serta memandu inovasi ke arah penambahbaikan sistem yang tersedia ada. Dalam kajian ini, fokus literatur adalah penerangan ringkas terhadap 'Meter Smart' dan pola dalam meter daripada 'tradisional' kepada 'pintar' yang dapat memberikan maklum balas dan kesan ke atas pembentukan sikap pengguna. Reka bentuk sistem terdiri daripada sistem pemantauan berasaskan kuasa selular menggunakan protokol SMS untuk penghantaran data. Sistem yang direka bersesuaian dengan semua jenis susunan monitor yang tersedia ada pada pengguna terakhir. Sistem monitor yang dicadangkan terdiri daripada algoritma pengiraan tenaga baru, yang menawarkan pakej elektrik dengan pengawasan yang bijak bagi penggunaan kuasa harian yang disambungkan ke stesen pangkalan melalui rangkaian GSM. Di samping itu, prototaip yang direka bertujuan untuk memantau rekod penggunaan, menghantar secara berkala kepada stesen penerima untuk mengemas kini profil pengguna, memberi isyarat maklum balas kepada pengguna apabila diminta dan juga menyediakan kawalan yang lebih baik terhadap penggunaan individu. Dengan kaedah yang dicadangkan ini, pengguna diseberikan kesedaran yang betul dan mereka boleh merancang corak penggunaan elektrik mereka. Pengguna diberikan pelbagai insentif berdasarkan masa yang berbeza dan faktor penggunaan kuasa boleh dikurangkan dan juga pembaziran tenaga elektrik dapat dikurangkan sehingga tahap yang tertentu. Prototaip yang direka bentuk ini terbukti dapat menepati masa dan berkesan dalam pengumpulan data individu. Ia juga bebas daripada ralat jika dibandingkan dengan proses pengumpulan data pemeteran secara manual. Salah satu daripada ciri-ciri yang paling menarik dalam modul "GSM-Pro" ini adalah ia tidak memerlukan sebarang penggantian terhadap sistem pemantauan yang sudah tersedia ada. Nadi yang memberi bacaan kepada meter serasi dengan kedua-dua jenis sistem pemeteran sama ada meter elektromekanik atau elektronik. Ia juga menyediakan kawalan yang lebih luas terhadap penggunaan oleh pengguna untuk mengesan sebarang penipuan dalam monitor atau gangguan bekalan.

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LIST OF SYMBOLS

V_d	Actual instantaneous line voltage
A	Ampere (unit of current)
I	Current
K_i	current proportionality constant
$	Dollars
K_d	Digitization constant
Hz	hertz (unit of frequency)
mA	Milli-ampere
Ω	Ohm (Unit of resistance)
%	percentage
Rms	Root Mean Square
F_s	Sampling Frequency
Sec	second (Unit of time)
∑	Summation
Tx/Rx	Transmit/ Receive
μF	unit of capacitance
V	Volts (unit of voltage)
V	Voltage

LIST OF ABBREVIATIONS

AMI	Advanced Metering Infrastructure
AC	Alternating current
ADC	Analogue to digital converter
API	Application programming interface
AMR	Automatic meter reading
CMOS	Complementary metal–oxide–semiconductor
CT	Current Transformer
DSM	Demand side management
DSL	Digital subscriber line
DC	Direct Current
DG	Distributed Generation
EU	European Union
GPRS	General Packet Radio Service
GSM	Global system for Mobile communication
GUI	Graphic user interface
IC	Integrated Circuit
ISI	Inter symbol interface
KWh	Kilo watt hour
LED	Light Emitting Diode
LCD	Liquid Crystal Display
MW	Mega Watt
Mtoe	Million ton of oil equivalent
Maxis/DG	Mobile operators in Malaysia
NAN	Neighborhood Area network
PIC	A type of micro controller family
PLC	Power Line carrier
PPCOM	PLC Power-Controlled Outlet Module
RTC	Real Time Clock
RS 232	Recommended Standard232
RM	Ringgit Malaysia (Currency of Malaysia)
SMS	Short message service

SSGC	Sichuan South Gas Compressor Co., Ltd
SMSC	Short Message Service Center
SDK	Software development kit
TNB	Tenaga National Berhad
TTL	Transistor-Transistor Logic
USART	Universal Synchronous Asynchronous Receiver Transmitter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Since 19th century the monitoring of electricity is performed using electromechanical meters or electrical meters. Even though these meter are a master art of engineering designed a hundred of years ago measuring in kWh but still they are not capable to measure new rates structures i.e. variable time pricing and are unable to provide awareness to user about his consumption pattern. In traditional monitoring, human labor i.e. a line man plays a significant role in collecting and managing field data. However, due to the size increase of consumption areas, this conventional practice is considered time consuming and labor intensive. Around 2500 linemen and other supporting staff are required for this manual data collection process. This process always has chances of human error. The current metering system in Malaysia is not capable to measure variable time price and it is gradually replaced by digital or smart meters.

As the Malaysia economy sector is recovered from the financial and economic re-session, resurgence in energy demand is expected. Within the last three years, the energy generating capacity (increases according to the energy demand) has increased almost 20%, from 13,000 MW in the year 2000 to 15,500 MW in the year 2003. The energy generating capacity is further expected to increase to 22,000 MW by the year 2010 (Thaddeus J, 2002). In order to meet the increasing demand, energy supply infrastructure will be needed to develop continuously and at the same time being very capital intensive. Consequently, this will impose tremendous pressure on the natural resources, particularly for developing countries like Malaysia. At the same time, it is

clear that the current patterns of growth cannot extend indefinitely into the future (Abdul Rehman, 2004).

An overview of local energy statistics shows that the major contribution of electricity generation is from thermal plants mainly depending on imported coal. This year the price for import of coal will be near to 1000M $ which is 3 times greater than 2006 that was 316M. Coal, one of the most common fuel sources for power station has also experienced a sharp increase in price recently. The average coal price has moved up from USD49.90 per metric ton in 2005 to USD53.50 per metric ton in 2006. Approximately 70% to 80% of TNB's coal requirements are purchased from third parties. This imposes a high fuel cost for TNB with the increasing use of coal. The balance of TNB's coal requirement is sourced from its own coal mine in Kalimantan, Indonesia (Ceic, 2006).

With a projected average economic growth rate of 7.5% per year in the 2001–2005 periods, resource-rich Malaysia would have to cater for the 7.8% yearly increase in final energy demand. Total primary energy supply is projected to grow at an average of 7.2% per year in the same period (EPU, 2001a). The main sources of commercial energy supply in 1999 amounting to 37.2 million tones oil equivalent (Mtoe) were derived from crude oil and petroleum products (48.5%) followed by natural gas (41.8%), coal and coke (5.2%) and hydro (4.5%). In the 1990–1999 periods, the share of crude oil and petroleum products in the total primary energy supply declined while that of natural gas increased indicating a successful reduction from the overall dependence on crude oil and petroleum products (MECMM, 2000 and Ambun, 2000).

The use of electrical energy immensely increased in recent years and the demand of this will rather increase in an accelerated fashion in coming future. From 1991 to 2003 the demand and consumption intensity of electricity in Malaysia has increased in a regular fashion as shown in Figure1.1, but the rate of increasing demand is higher than the supply making unbalanced elasticity curve (EPU, 2001b; IEO, 2004 and UK Trade, 2003). Study of same trends from 2000 – 2010 clearly indicates a threat that needed to be managed and to produce balance between demand and supply in future, especially when country is strongly depending on imported resources and

limited resources of gas. Considerable trends are taken by government in term of energy efficiency, green and alternative energy but yet management in term of elasticity between demand and supply (short term management) of peak load is still an area needed to be explored widely.

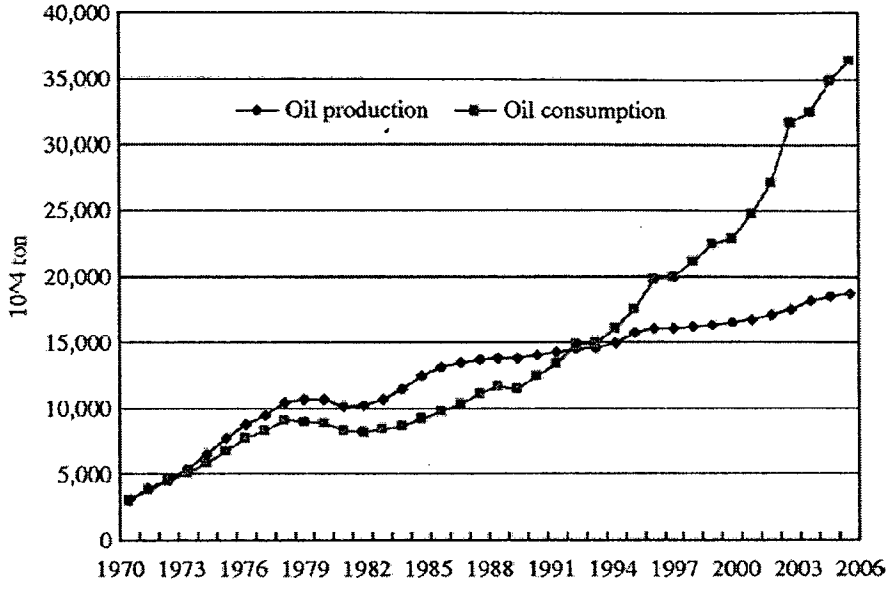

Figure 1.1: A comparison between oil production and consumption (IEO)

Figure 1.2 shows that the projected energy demand for Malaysia in the 2009-2020 and estimated values for 2020 (Thaddeus, 2002 and UK Trade, 2003). It can be seen that the energy demand in Malaysia increases rapidly as the energy demand increase almost 20% within the last 3 years (from 1999 to 2002). The recent electricity demand in Malaysia has crossed 18,000MW. In order to meet the increasing demand of energy in Malaysia, a major challenge facing the power industry will be having an effective and sustainable energy policy.

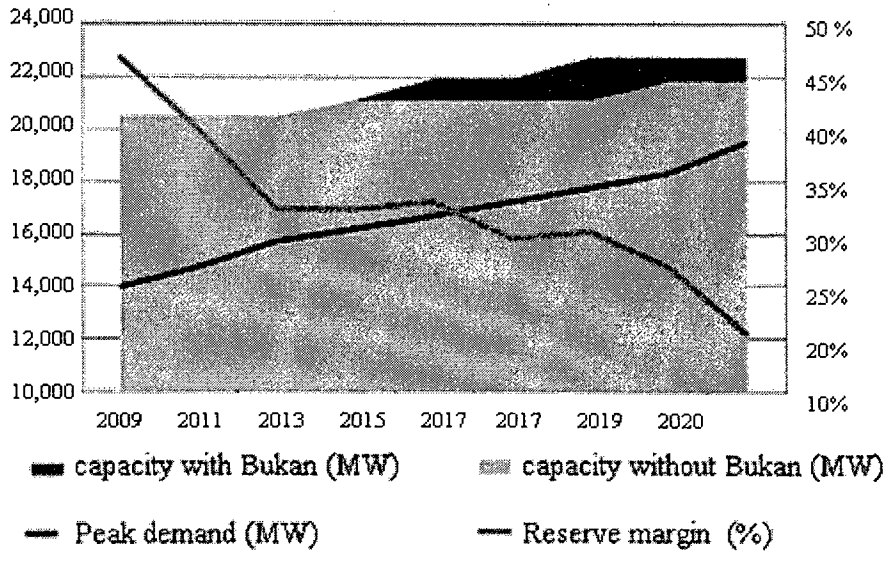

Figure 1.2: A forecast of Malaysia Energy demand and supply (Ceic, 2006)

1.2 THE UNWANTED ELECTRICITY PEAK

The dramatically increase local energy statistics shows that the demand can't be fulfilled blindly as energy resources will be one of the major issues in future worst than as it is now for some countries including developing countries even. The available energy resources needed to be managed on short and long term basis. The peak electricity in afternoon is one of the common problems that add up to the existing problems. Meanwhile the growing demand for new power plants in a situation where generation is already depending mainly on importing coal is a serious issue to be addressed. Generation of power plants is directly related to the peak energy demand and a solution to this issue can result in reduction of this demand for time being at least; i.e. delaying the urgent installation of a power station.

Referring to Figure 1.3(also refer to annex 1) it can be seen that the difference between base load and the peak load in afternoon is 5000 MW. According to Goswami (2009) the generation is planned considering the peak load not the base line load. So the utility in Malaysia should prepare a generation not only for the baseline load but should prepare for the peak load that is 13500MW. It clearly shows that peak will be creating demand meeting problems for new power plants.

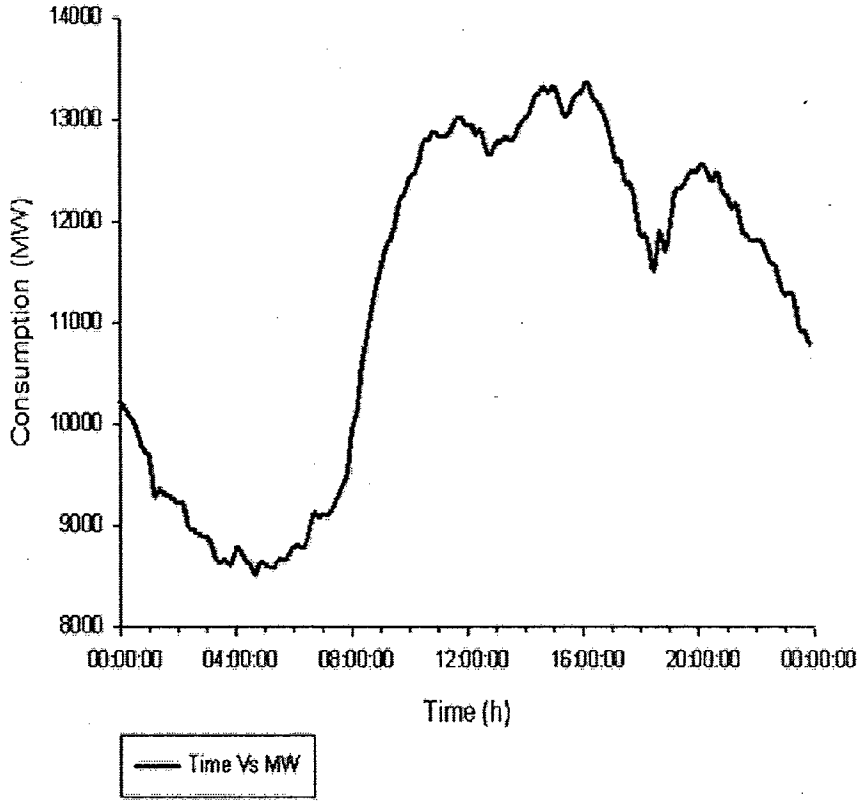

Figure 1.3: Overall system peak recorded at NLDC (Refer to annex1)

In residential or domestic sector, electricity demand is driven by the growing number of households and as well as the development in household income distribution. A study in 1998 estimated that an average family in low cost house spends about RM 65 (about US$17) per month, while the electricity in the medium cost house is approximately RM 110 (US$30) per month, and in a bungalow can go up to RM 350 (US$92) per month (Taylor, 2008 and Woodward, 1996). The electricity consumption per household depends very much on family size, living habits, number and age of electrical appliances and their hour of use. Wise use of electricity, as well as the use of efficient appliances will reduce energy, hence the electricity bills. This gives a space to researchers to design some sort of mechanism to change the user habits of electricity consumption and manage the available resources wisely.

1.2.1 User Awareness is a Key to Resolve Peak Load Demand

One of the main solutions of getting out this peak problem is to provide the awareness to user for his actual consumption in real time. The feedback of real consumption will surely result in change of habit to use electricity, depending on defined variable time pricing. Shifting the peak load to the areas of off load is a solution suggested by a number of researchers (Zachariadis et al., 2007; Narayan et al., 2007; Mark, 2007; Ziramba, 2008; Roula, 2010 and Hussain et al., 2011). This shifting is long term process which is performed by implementing an embedded system design that monitors user's consumption pattern, apply a variable time pricing in real time environment and provide a feedback to user about it consumption graph. The embedded systems design considers the systems characteristics and restrictions that are fundamental for an efficient system function. As a result, low power design of communication intensive real-time embedded systems must consider the environment and application constraints to optimize the system's design, such as real-time responsiveness and intensive execution of communication tasks. In these systems, the response time is as important as the correctness of the outputs. A real-time system does not have necessarily to be fast; it must simply produce correct responses within a definite time limit. A real-time embedded system usually monitors on the environment where the embedded system is installed, and if it does not respond in time to a request, the result can be disastrous (Wolfing, 1999).

1.2.2 The Embedded System Design or Smart Metering Implementation

Smart meters which are actually embedded system designs with some new features added, attracted people's attention worldwide. Various countries began extensively the use of these metering units as early as 2006. The authorities have strong arguments that these meters will solve problem of peak load demand. Smart meters are standardizing and this interoperability will enable a greater roll out to other utilities in the US (Khurana, 2010). This is illustrated in Figure 1.4.

"43% of US Households will be served by an AMI meter by 2014".

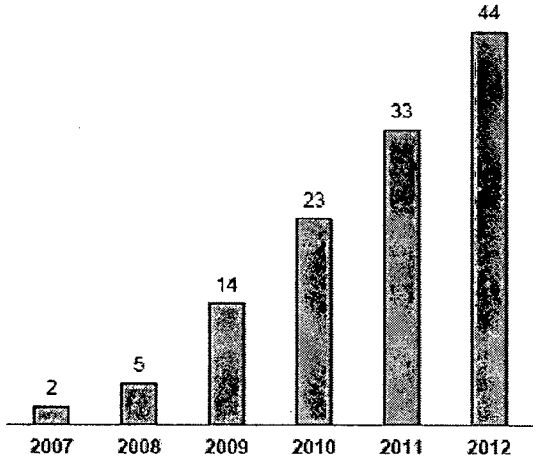

Figure 1.4: US Smart meters installations. 2007-2012(Source: Gerwan).

(The numbers along y-axis are in millions)

Business case for smart meters is driven by cost and labour savings and increased customer awareness resulting in lower energy consumption. Smart metering which is also termed as AMI (Advanced Metering Infrastructure) has following benefits;

i. AMI eliminates the need to manually read meters and the associated labor and travel costs; and

ii. Smart meters permit near "real time" pricing of energy and can raise awareness of the consumer to help.

1.2.3 Smart Metering in Asian Region

The trend change for smart metering also affected the Asian region. SSGC who is responsible for more than 80% of power networks in China announced huge investment in term of smart grid. Smart meters will be an integral part of these change programs. AMI which utilizes two-way communications to enable real-time monitoring and control of energy use in residential, commercial, and industrial buildings will be an important tool for utilities to accomplish their smart grid objectives. According to a new

forecast from Pike research group, China will represent more than three-quarters of the installed base of smart meters in Asia Pacific, and the government has declared plans to continue a large-scale meter deployment through at least 2020 (Ovel, 2011).

Singapore is also competing in this technology, the authorities signed a deal to shift to advance metering. ST Engineering's electronics arm, ST Electronics, on 13th Sep, 2010 announced that its subsidiary, Telematics Wireless Ltd has been awarded a contract worth US$21.5m (about S$29m) by Arad Technologies Ltd (Arad) to supply Automatic Meter Reading (AMR) radio transceivers for Arad's DIALOG 3G AMR solutions. The supply cooperation agreement between Arad and Telematics Wireless takes effect immediately and extends to 2015 (Business News, 2010).

1.2.4 Malaysian Experience about Smart Metering

Malaysia being a developing country shows its interest towards adaptation of technologies. To adopt and change with changing technologies is a healthy approach to keep ourselves up dated. But if a careful analysis is not taken into consideration this change may result into draw backs rather than making some solid contribution and achievement. Malaysia in 2007 signed a deal with International metering supplier company for installation of a number of smart meters that was expected to be a move towards technology in metering infrastructure (AMI, 2007 and NTDW, 2007). There are no more details available that what actually happen to this deal later. But some reliable sources and authorities who were involved in this deal told that it didn't turn into an affective and healthy step. It was rolled back to Electromechanical Meters as the reliability of the newly installed metering system was the question. The communication mode and flow was also proven to be highly technical, less user friendly and it was not flexible to adopt any modification needed.

1.3 PROBLEM STATEMENT

The Malaysian experience with smart metering has raised a lot of issues. There are number of authorities' claim that the working of conventional electromechanical system is satisfactory and it no needs to be replaced. The second issue arises for

recycling or disposal of currently existing meters if Malaysia takes an initiative to replace the existing system with "Smart Meters". No doubt smart metering is a good solution but it is not the end. Few questions arise after this case study;

i. Installation of Smart Meters will cost a Billions of RM investment. How if this investment is not satisfactory as expected?
ii. The disposal of currently existing 1million meters (almost) is a question that can't be answered.
iii. The most important question that is a theme of this research also is "why don't we update our existing system and make it smart enough"? This way will surely save more than 60% of total possible expected investment and there is no question about reliability of the existing system. All the possible features of a smart meter can be included to this existing system.

The questions can't be simply skipped when improvement of the existing system can be a solution that may resolve all these questions. The issues of cost and reliability of the system will be solved automatically and the working of current system will remains the same.

1.4 RESEARCH OBJECTIVE

The objectives of this research are to;

i. Design of a real time power monitoring system
ii. Develop the variable time pricing through GSM SMS protocol
iii. Develop a periodic feedback to user about his electricity consumption details
iv. Conduct a pre-survey to know user's opinion and understanding about the user consumption pattern and proposed research design

1.5 HYPOTHESIS

An affective feedback and variable time pricing, comprising of penalties and incentives to user will help in a new habit formation along with modernization of current metering system.

1.6 SCOPE OF THE THESIS

This research is a bit different from the ordinary works done because it comprises of both social and technical sections. It start from making a feasibility report based upon a survey (Questionnaire), describing need of the system and public interest towards proposed system. Then it covers design aspects of both remote and master module. Application of embedded system in power monitoring using a cellular based network is core of this remote module. The real time monitoring section is included for live monitoring and pricing. The system also covers the software section and performing the calculations based upon a pre-defined time slot. Feedback mechanism is applied and the social implication of this system will be a change in consumption pattern of the consumer.

1.7 THESIS ORGANIZATION

The thesis is organized as follows. Chapter 1 highlights the background, problem statement and scope of the project. Chapter 2 is focusing on and contribution introduction about smart meters and related work towards smart metering. It also relates to the effect of feedback towards habit formation. Chapter 3 deals with methods and materials used to carry out the process. Chapter 4 is mostly about the results and data obtained through experimental process. The last chapter is the conclusions of the research work.

CHAPTER 2

SMART METERING AND ELECTRICITY DEMAND

2.1 INTRODUCTION

In this chapter a detailed description is explained what smart meters are all about. It also highlights working principle and parties involved in it. The details of ongoing projects on smart meters are also a part of this chapter. The second section of the chapter refers to a step by step change towards smart metering from traditional meters. Lastly, the chapter highlights the effect of feedback provided to user about its consumption pattern.

2.2 WHAT SMART METERING IS ALL ABOUT?

2.2.1 World is Turning to Smart Metering

Smart metering is without any doubt a topic that recently has attracted much attention. Many countries around the globe are already involved in projects with smart metering on a demonstration scale or larger. A variety of benefits are generally attributed to smart meters and these will be discussed in detail in this chapter. Many questions arise, even if we focus on smart metering for electricity use only that what are the exact functions of smart meters and what are the benefits? As the smart metering is a newly introduced term in last two decades, so what is the state of art of these smart meters now?