UNIVERSITI PUTRA MALAYSIA

SOFTWARE DEVELOPMENT FOR ON-LINE ENERGY MONITORING AND CONTROL SYSTEM THROUGH THE WEB

MOHD AMRAN BIN MOHD RADZI

FK 2002 87

SOFTWARE DEVELOPMENT FOR ON-LINE ENERGY MONITORING AND CONTROL SYSTEM THROUGH THE WEB

By

MOHD AMRAN BIN MOHD RADZI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of Requirements for the Degree of Master of Science

September 2002

UPM

In the memory,

My father, Allahyarham Mohd Radzi Bin Jaafar

My brother, Allahyarham Anuar Bin Mohd Radzi

Special dedication to,

My mother, Che'e Buang Binti Haron

My sister, Che'e Azliza Binti Mohd Radzi

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

SOFTWARE DEVELOPMENT FOR ON-LINE ENERGY MONITORING AND CONTROL SYSTEM THROUGH THE WEB

By

MOHD AMRAN BIN MOHD RADZI

September 2002

Chairman: **Associate Professor Norman Mariun, Ph.D.,P.Eng**

Faculty: **Engineering**

In Malaysia, the demand for energy continues to grow, while supplies remain constant (at best) and cost increases. The cost of increasing the energy supply in Malaysia is significant in such areas as construction of added electrical generation capacity, the cost of source energy materials, and the cost of transporting energy materials. By curbing the use of energy, the impact of increasing demand can be delayed. Furthermore, the reduction of energy use will counter the increasing cost per unit.

There is a great potential for reducing the cost of electrical energy usage through introduction and application of Energy Management and Control System (EMCS). The EMCS consists of instrumentation control devices for data collection, monitoring and analyzing, and personal computers for automatic control system, which is primarily used to control the electrical demand of the user. The increasing use of internet application in information technology has given the option for this

system to be developed for being connected to the internet. Internet and web based application are the current features available in this system.

This research concentrated on the design and development of software that could be used as an on-line energy monitoring and control system through the web. By using this software, the measurement data from the loads was obtained through monitoring process. To implement energy saving program totally, the system would allow the user to control appliances manually or automatically.

The firmware was developed to operate the microcontroller as input and output function. At the same time, graphical user interfaces (GUIs) were developed and integrated as big software used in the computer where the loads would be connected. Besides that, the web pages have been developed and hosted by the web server so that it could be accessed through the internet. As an interfacing file, the database could link the GUIs and the web pages. The instrumentation devices such as sensor and relay units were connected between the microcontroller and actual loads.

The software was tested by connecting it to the two types of the loads such as lighting and air conditioning system. The monitoring and control has been successfully implemented through this software. At the same time, the testing was carried out by running the web site of the system through internet. The monitoring and control was successfully carried out through the web site.

Abstrak tesis yang dikemukakan kepada Senat Unjiversiti Putra Malaysia sebagai memenuhi keperluan unuk ijazah Master Sains.

PEMBANGUNAN PERISIAN UNTUK SISTEM PEMANTAUAN DAN KAWALAN TALIAN TENAGA MELALUI WEB

Oleh

MOHD AMRAN BIN MOHD RADZI

September 2002

Pengerusi: **Profesor Madya Norman Mariun, Ph.D., P.Eng**

Fakulti: **Kejuruteraan**

Di Malaysia, permintaan terhadap tenaga bertambah meningkat, sedangkan bekalannya masih tidak berubah dan kos terus meningkat. Peningkatan kos bagi bekalan tenaga di Malaysia sangat tinggi dalam sesetengah bidang sejajar dengan pembinaan bagi penambahan kapasiti penjanaan elektrik, kos bahan sumber tenaga, dan kos mengangkut sumber tenaga. Dengan mengurangkan penggunaan tenaga, kesan kepada peningkatan permintaannya dapat dikurangkan. Tambahan pula, pengurangan penggunaan tenaga akan mengatasi masalah peningkatan kos per unit.

Didapati terdapat potensi yang besar untuk mengurangkan kos penggunaaan tenaga elektrik melalui pengenalan dan penggunaan Sistem Pengurusan dan Pengawalan Tenaga (SPPT). SPPT mengandungi peralatan instrumentasi kawalan untuk pengumpulan, pengawasan dan analisa data, dan komputer peribadi untuk sistem kawalan automatik, yang digunakan untuk mengawal permintaan elektrik daripada pengguna. Peningkatan penggunaan Internet dalam teknologi maklumat telah memberi pilihan untuk sistem ini dibangunkan untuk disambungkan ke internet.

Aplikasi internet and sistem berteraskan web adalah cirri-ciri terbaru yang terdapat dalam sistem ini.

Penyelidikan ini telah menumpukan kepada reka bentuk dan pembangunan perisian yang boleh digunakan sebagai sistem pengawasan dan pengawalan tenaga secara talian terus melalui web. Dengan menggunakan perisiaan ini, data pengukuran daripada beban-beban diperolehi melalui proses pemantauan. Bagi melaksanakan program penjimatan tenaga sepenuhnya, sistem ini membenarkan pengguna untuk mengawal pengunaan tenaga secara manual atau automatik.

Program telah dibangunkan untuk mengoperasikan pegawal mikro sebagai fungsi masukan dan keluaran. Pada masa yang sama, antara muka grafik pengguna telah juga dibangunkan dan diintegrasikan sebagai perisian besar untuk digunakan dalam komputer di mana beban-beban disambungkan. Selain itu, muka-muka web telah dibangunkan dan dikendalikan melalui pembekal web supaya ia boleh diakses melalui internet. Sebagai fail antara muka, pengkalan data boleh menghubungkan antara muka grafik pengguna dan muka web. Peranti-peranti instrumentasi seperti pengesan dan geganti telah disambungkan antara pengawal mikro dan beban-beban sebenar.

Perisian ini telah diuji dengan menyambungkannya kepada dua jenis beban iaitu sistem lampu dan penghawa dingin. Pemantauan dan kawalan telah berjaya dijalankan melalui perisian ini. Pada masa yang sama, pengujian telah dijalankan dengan mengaktifkan laman web sistem ini melalui internet. Pemantauan dan kawalan telah berjaya dilakukan melalui laman web.

ACKNOWLEDGEMENTS

First and foremost, the researcher would like to express his most sincere gratitude to his supervisor, Prof. Madya Ir. Dr. Norman Mariun for his invaluable guidance, advice, and patience throughout the duration of completing this research. Without his untiring guidance, the author could not complete his work successfully.

The researcher would also like to take this opportunity to extend his indebtedness to all the supervisory committee members, Dr. Senan Mahmod, Dr. Samsul Bahari Mohd Noor and Dr. Abdul Razak Mohd Jim for their guidance and advice. The profound appreciation must also be expressed to Mr. Hasrol Akram Md Desa for his consultant and advice in the software development.

Last but not least, special thanks and appreciation are forwarded to all for their constructive suggestions, supports and encouragement.

The thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

NORMAN MARIUN, Ph.D., P.Eng.
Associate Professor,
Faculty of Engineering,
Universiti Putra Malaysia.
(Chairman)

SENAN MAHMOD, Ph.D.
Faculty of Engineering,
Universiti Putra Malaysia.
(Member)

SAMSUL BAHARI MOHD NOOR, Ph.D.
Faculty of Engineering,
Universiti Putra Malaysia.
(Member)

ABDUL RAZAK MOHAMED JIM, Ph.D.
No. 9, Jalan Nilam 1/5, Subang High-Tech Industrial Park,
40400 Shah Alam, Selangor
(Member)

AINI IDERIS, Ph.D.
Professor / Dean,
School of Graduate Studies,
Universiti Putra Malaysia.

Date:

TABLE OF CONTENTS

		Page
DEDICATION		ii
ABSTRACT		iii
ABSTRAK		v
ACKNOWLEDGEMENTS		vii
APPROVAL SHEETS		viii
DECLRATION		x
LIST OF TABLES		xiii
LIST OF FIGURES		xiv
LIST OF ABBREVIATION		xvii
CHAPTER		
1	INTRODUCTION	
1.1	Background	1
1.2	Objective	4
1.3	Scope of Work	5
2	LITERATURE REVIEW	
2.1	Energy Efficiency in Malaysia	7
2.2	Energy Management and Control System (EMCS)	9
2.2.1	Background	10
2.2.2	Benefits of EMCS	11
2.2.3	EMCS Configurations	12
2.2.4	Current States of Art in EMCS	15
2.3	Graphical User Interface (GUI)	17
2.3.1	Visual Basic	17
2.3.2	The Development of GUI	18
2.3.3	Error handling	19
2.4	Internet	19
2.5	World Wide Web (WWW)	20
2.5.1	Active Server Pages (ASP)	22
2.5.2	The Development of Web	24
2.5.3	Web Server	25
2.6	Database	27
2.7	Microcontroller	28
2.7.1	Motorola MC68HC11	29
2.7.2	Programming the Microcontroller	30
2.7.3	Small C Compiler	31
2.7.4	Serial Communications	32
2.8	Sensors and Instrumentation	34
2.9	Internet and Web-Based System	36
2.10	Summary	39

3 METHODOLOGY
3.1 System Design 40
3.2 The Selection of Building 42
3.3 Programming the Microcontroller 43
3.3.1 Programming Development 44
3.4 Graphical User Interface (GUI) 46
3.4.1 The Development of the GUI 48
3.4.2 Error Handling 52
3.5 Web Site 53
3.5.1 The Development of the Web Pages 53
3.6 Database 57
3.7 Web Server 58
3.8 Software Integration 59
3.9 Security Feature on the Web Site 60
3.10 Hardware Development 60
3.10.1 Movement Sensor 61
3.10.2 Temperature Sensor 66
3.10.3 Optocoupler Circuit for Relay Operation 67

4. RESULTS AND DISCUSSION
4.1 Graphical User Interface 69
4.2 Web Site 79
4.3 The Effect of Additional Security Feature to the Web Site 90
4.4 Movement Sensor 91
4.5 Temperature Sensor 92
4.6 Relay 94

5 CONCLUSION
5.1 Conclusion 95
5.2 Recommendations 96

REFERENCES 97

APPENDICES
Appendix A: Programming for Microcontroller 100
Appendix B: Programming for the Development of GUIs 101
Appendix C: Programming for the Development of Web Pages 102
Appendix D: Datasheet of Movement Sensor 103
Appendix E: Datasheet of Temperature Sensor 107
Appendix F: Datasheet of Optocoupler 121

BIODATA OF THE AUTHOR 130

LIST OF TABLES

	Page
Table 1: Total Electrical Energy Efficiency Market in Malaysia	9
Table 2: The three types of syntax available in the ASP	24
Table 3: Pin assignment for D type 9-pin connector	34
Table 4: The output of the temperature sensor unit	93

LIST OF FIGURES

	Page
Figure 1: Electricity consumption in Malaysia according to categories of consumers	7
Figure 2: Electricity consumers in Malaysia according to categories	8
Figure 3: Centrally controlled EMCS (a) Star Network (b) Common bus network	13
Figure 4: Distributed control EMCS star network	14
Figure 5: D type 9-pin connector	33
Figure 6: The configuration of the dual-type infrared sensor	36
Figure 7: General overview of the system	41
Figure 8: Detail configuration at the site	41
Figure 9: The corridor of the selected building	42
Figure 10: The plan of Power Electronics Laboratory and its set up for monitoring and control of air conditioning and lighting	43
Figure 11: Flowchart of the program	45
Figure 12: The flow of the GUI for the overall system	46
Figure 13: "Personal Web Manager" interface	59
Figure 14: The configuration of the software integration	59
Figure 15: Block diagram of the movement sensor	61
Figure 16: Two-stage amplifier	62
Figure 17: Low cut-off frequency and high cut-off frequency of the band pass filter	63
Figure 18: The comparator window circuit	65
Figure 19: The 555 timer circuit	66
Figure 20: Temperature sensor circuit	67

Figure 21: The designed circuit from the combination of photodarlington optocoupler 68

Figure 22: "Start" GUI as the first GUI in this software 70

Figure 23: "Security" GUI that requires the user to enter his or her username and password 70

Figure 24: "Main" GUI as the main platform for next operation 71

Figure 25: Information available in "Building Information" GUI 72

Figure 26: "Corridor" GUI that was developed to run the monitoring and control action 73

Figure 27: The "Help" command to open the "Help" GUI 73

Figure 28: "Power Electronics Laboratory" GUI for the user to start implementing monitoring and control jobs at inside of the building 74

Figure 29: "Control Selection (Air Conditioning)" GUI for the user to select automatic or manual operation 75

Figure 30: "Control Status (Air Conditioning)" GUI that shows monitoring and control status in the automatic operation of the air conditioning 76

Figure 31: "Manual (Air Conditioning)" GUI for the user to control the air conditioning through manual control 76

Figure 32: "Control Selection (Lighting)" GUI for the user to select automatic or manual operation of lighting 77

Figure 33: "Automatic (Lighting)" GUI that showed the status of automatic operation of lighting 77

Figure 34: "Manual (Lighting)" GUI for the user to implement manual action 78

Figure 35: "Help" GUI that could help the user to run software properly 78

Figure 36: The "Warning" GUI 79

Figure 37: "Start" page as the first page appeared in the web site 80

Figure 38: "Security" page for the user to enter his or her username and password 80

Figure 39: Web page appears after successfully entered to the system 81

Figure 40: "Main" page with two frames 81

Figure 41: "Building" page showed some information about the monitored and controlled building 83

Figure 42: "Corridor" page for monitoring and control jobs at corridor of the building 83

Figure 43: "Plan" frame that is divided into two more frames 84

Figure 44: The frame that shows the monitoring and control status of the loads 85

Figure 45: The automatic or manual operation can be selected through this page 86

Figure 46: This web page allows the user to determine the setting values of temperature sensors 86

Figure 47: All the temperature values and current operation status is shown in this page 87

Figure 48: "Manual (Air Conditioning)" page 87

Figure 49: The page where the user can select whether to run automatic or manual operation 88

Figure 50: The page for the user to select the set time for automatic operation 89

Figure 51: "Automatic (Air Conditioning)" page that shows the setting and current time together with operation status of lighting 89

Figure 52: The page for implementing manual control 90

Figure 53: This response page will inform the user that the web site is already opened at another place or internet browser 91

Figure 54: The outputs from oscilloscope connected to the output of the window comparator and the timer 92

Figure 55:The configuration of connecting two pins of port E to the circuit 93

LIST OF ABBREVIATION

ALU	Arithmetic Logic Unit
ASD	Adjustable Speed Drive
ASP	Active Server Pages
CGI	Common Gateway Interface
CPU	Central Processing Unit
DBMS	Database Management System
DCE	Data Communications Equipment
DDR	Data Direction Register
DTE	Data Terminal Equipment
EMCS	Energy Management and Control System
ESMS	Energy Saving Management System
FTP	File Transfer Protocol
GUI	Graphical User Interface
HCMOS	High-density Metal-Oxide Semiconductor
HTML	HyperText Markup Language
HTTP	HyperText Transport Protocol
HVAC	Heating, Ventilation, and Air Conditioning
IDC	Internet Database Connector
IDE	Integrated Development Environment
IIS	Internet Information Server
ISAPI	Internet Server Application Programming Interface
OOP	Object Oriented Programming
PWS	Personal Web Server
RAM	Random Access Memory

ROM	Read Only Memory
RTD	Resistance Temperature Detector
SCADA	Supervisory Control and Data Acquisition
SGML	Standard Generalized Markup Language
SPPT	Sistem Pengurusan dan Pengawalan Tenaga
SSL	Secure Sockets Layer
TCP/IP	Transmission Control Protocol
URL	Uniform Resource Locator
WAIS	Wide Area Information System
WWW	World Wide Web
WYSIWYG	What You See Is What You Get

CHAPTER 1

INTRODUCTION

1.1 Background

In Malaysia, the demand for energy continues to grow, while supplies remain constant (at best) and the cost increases. As our country is experiencing rapid industrial growth, additional consumers requires more housing, transportation facilities and other services. This increasing industry escalates projected energy demands. The cost of increasing the energy supply in Malaysia is significant in such areas as construction of added electrical generation capacity, the cost of source energy materials, and the cost of transporting energy materials to and within a state. By curbing the use of energy, the impact of increasing demand can be delayed. Therefore, by using less energy, the existing supply will accommodate other users in the expanding Malaysian population. Furthermore, the reduction of energy use will counter the increasing cost per unit.

There is great potential for reducing the cost of electrical energy usage through introduction and application of energy management. It is obvious that if costs are to be minimized, usage of the electricity energy has to be monitored more accurately and carefully. The best way to implement this approach is by introducing energy management. Energy management can be defined in many ways. First, energy management can also be described as the judicious and effective use of energy to maximize profits (minimize costs) and to enhance competitive positions [1]. In other definition, energy management means ensuring that users get all the energy

necessary, when and where it is needed, and of the quality requested, supplied at the lowest cost. In other definition, Energy management is implemented due to losses or energy waste occurred in our daily life.

Computerized energy management is a method to conserve and managing the energy used in commercial, industrial and large residential complexes [1]. A system that implements this concept is known as an Energy Monitoring and Control System (EMCS). In this system, two main elements or parts are involved. The first part is monitoring where the reading of some parameters such as voltage, current, frequency, phase angle, power factor, KWh and temperature will be considered. The second part is control where this part is implemented to save the electrical energy usage through automatic or manual operation of the loads.

In EMCS, this system consists of instrumentation and control devices for data collection, monitoring, analysing and control. They will be connected to personal computers for allowing of automatic control, especially to control the electrical demand of the user.

This system offers the advantages of high reliability operation, better utilisation of human and mechanical resources and reduction of operating cost. By applying this technology, the development of monitoring and controlling system can be simplified so that it can be applied in more space and applications.

However, in a large operation, the computerized system still needs a lot of human resources. Although the controlling part can be done automatically, at least one

operator is needed to take care of the system especially in the monitoring part of the loads. So, the cost will increase again and this system will not be popular among the users. To solve this problem, application of communication technology will be used as a part of the developed system. In this case, the system is being upgraded by introducing a new approach of monitoring and control of the energy usage, on-line method. In the on-line method or application, data sending and receiving by using modem or other types of network will enhance the capability to monitor and control the energy usage.

Nowadays, Internet is widely used for communication purpose. Due to increasing use of Internet application in information technology era, there is a possibility to develop a monitoring and control system that can be connected to the Internet. Besides that, by applying the technology described above, the monitoring and control can be done remotely, from anywhere in the world. This technology is implemented so that the system can function as a centralized monitoring and control system. In other words, the development of monitoring and control system that uses the computerized system with on-line capability can help to enhance the performance of this system.

Electrical energy is the most important and critical resource for economic growth and human comforts [3]. It has become an essential part of daily lifestyle. It must be available and adequate to the consumer in any amount that one may require from minute to minute. Modern industry especially that uses a lot of machines is almost entirely depends on electrical energy for its operation. So, it is important to develop a good energy management system or program so that the electrical energy can be used at optimum level.

1.2 Objective

The aim of this research is to design and develop software that can be used as an on-line energy monitoring and control system through the web. By using this software, the user can get data from the loads through monitoring process. At the same time, the system can allow the user to implement control action to the loads manually or automatically. Since the system will be based on the on-line method, this research has a target to develop the system that can monitor and control the loads at the dedicated building through on-line method.

The detail objectives of this research are:

i. To study the concept of energy management. The study covers its definition, explanation and application to the existing system.

ii. To study the scenario of energy usage and application in Malaysia especially electrical energy. All the related issues are included in this study. Besides that, the study of energy efficiency will become a part of this research.

iii. To study the current state of art of energy management and control system available in the research area and market. This study includes the latest technology or system used, the principal method applied in the system and the current states or specifications of the other latest technology related to the development of this system.

iv. To design and develop software of the system. In this research, four mains part are developed: graphical user interfaces for the computer at

the site, database for recording all the data, web pages for on-line application and interfacing program for running the controller.

v. To design and construct hardware of the system. This includes the development of sensor and relay circuits connected between the loads and the controller.

vi. To test the system through the computer at the loads site. The testing covers the implementation of monitoring and control action through the developed software.

vii. To activate the web server so that all the developed web pages will be accessible through the internet.

viii. To access the web site through the computer at the other place and start to do monitoring and control.

1.3 Scope of Work

This research began with the study of the basic concept or idea of the energy management. All data that show the energy level usage in Malaysia has been studied since this research concentrates on the development of product suitable for Malaysia environment. Besides that, the energy efficiency that also plays an important role in energy management was also considered as one of the main factor to be studied. The study also covered the current application of communication technology especially internet. After that, the study continued with the components used in the system. These include the latest technology used and how the components will be integrated to the other related technology especially in the computer and communication field.

After completing the study, the next process was to design the software and hardware. All the design includes the configuration of the system, how the system is connected and the most important thing how it can applied in the actual situation.

This work concentrates more on the design and development of software part since the main objective of this research is to develop the software. The software available in the market and suitable for developing the needed software has been studied. For the software applied at the load sites, the graphical user interfaces (GUIs) have been developed.

The database was created to be as a recorded platform for all the data obtained from monitoring and control. The web pages were developed to be site application. To be accessible through internet, they were hosted by the web server.

The next stage was to develop a program for running the controller. The written program must be comfortable with the loads specifications and the developed software. The controller acts as interfacing medium between loads and computer at the load site. The controller structure and its operation were studied.

The simple hardware was developed to connect the system to the loads. It includes the sensors and relays. The testing has been done to make sure the developed system can fully operate. The testing included the implementation of monitoring and control action of the system.