



Cairo University

**DESIGN AND EXPERIMENTAL IMPLEMENTATION
OF HOME AUTOMATION SYSTEM CONSIDERING
SMART GRID AND ENERGY MANAGEMENT
REQUIREMENTS**

By

Noha Moustafa Mahmmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE

**In
ELECTRICAL POWER AND MACHINES ENGINEERING**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
Year 2019

**DESIGN AND EXPERIMENTAL IMPLEMENTATION
OF HOME AUTOMATION SYSTEM CONSIDERING
SMART GRID AND ENERGY MANAGEMENT
REQUIREMENTS**

By
Noha Moustafa Mahmmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
ELECTRICAL POWER AND MACHINES ENGINEERING

Under the Supervision of

Prof. Dr. Ahmed Bahgat

Professor, Electrical Power Eng. Dept.
Faculty of Engineering, Cairo University

Prof. Dr. HASSAN RASHAD

Professor, Electrical Power Eng. Dept
Faculty of Engineering, Cairo University

Prof. Dr. AHMAD BESHEER

Professor of Renewable Energy , Environmental
Studies & Research Institute, University of Sadat

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2019**

DESIGN AND EXPERIMENTAL IMPLEMENTATION OF HOME AUTOMATION SYSTEM CONSIDERING SMART GRID AND ENERGY MANAGEMENT REQUIREMENTS

By
Noha Moustafa Mahmmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
ELECTRICAL POWER AND MACHINES ENGINEERING

Approved by the
Examining Committee

Prof. Dr. Ahmed Bahgat Gamal Bahgat, (Main Advisor)

Prof. Dr. Hassan Mohamed Rashad Emarah, (Advisor)

Prof. Dr. Mohamed Salah Elsobki , Internal Examiner

Prof. Dr. Abdel Ghany Mohamed Abdel Ghany, External Examiner

- Pro. Dr. in faculty of engineering- Helwan university

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2019

Engineer's Name: Noha Moustafa Mahmmoud
Date of Birth: 07/02/1990
Nationality: Egyptian
E-mail: Nohamoustafa15@outlook.com
Phone: 01113535024
Address: 6 st Mohamed salama, Ain shams
Registration Date: 1/10/2014
Awarding Date:/....../2019
Degree: Master of Science
Department: Electrical Power and Machines Engineering



Supervisors:

Prof. Dr. Ahmed Bahgat Gamal Bahgat
Prof. Dr. Hassan Mohamed Rashad
Prof. Dr./ Ahmad Hussein Besheer

Examiners:

Prof. DR. Abdelghani mohamed Abdelghani (External examiner)
Prof. DR. Mohamed Salah Elsob ki (Internal examiner)
Prof. DR. Ahmed Bahgat Gamal Bahgat (main advisor)
Prof. DR. Hassan Mohamed Rashad (advisor)

Title of Thesis:

**Design and Experimental Implementation of Home Automation System
Considering Smart Grid and Energy Management Requirements**

Key Words:

Home Automation; Smart Grid; Demand Response; HAN; HMI

Summary:

The thesis presents the development and laboratory application of the home automation system in terms of electrical power management and responding to the requirements of the smart grid. This includes the design of a range of communication interfaces between the system user through a smart display unit that enables the user to monitor the data on the use of electric power and make choices for loads and priorities. The user can also check the utility center signals for power pricing parameters and power reduction orders during peak hours. The user commands are executed by a PLC, and the controller also saves the data and sends it to the utility center, within the requirements of the smart grid. In addition to the implementation of a scheme for energy management within the home by controlling loads according to the priorities chosen by the user.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Noha Moustafa Mahmmoud

Date:

Signature:

Dedication

I dedicate this thesis to my family for their dedicated partnership for success in my life.

Acknowledgments

First I want to express my sincere gratitude and thankful to **my god** for helping me to finish this thesis and for responding my calls. I want to express my sincere gratitude to **Prof. Dr. Ahmed Bahget** for his support and his interest in the interest of his students more than themselves. I want to express my great thanks also to **Prof. Dr. Hassan Mohamed Rashad** for his help in my laboratory work. My great thanks go to **Prof. Dr. Ahmed** for his effort to attempt to adjustment my thesis. Finally I want to express my Deep gratitude to **Eng. Sarah El Fishawy** for her effort and support in laboratory work.

Table of Contents

DISCLAIMER.....	I
DEDICATION.....	II
ACKNOWLEDGMENTS	III
TABLE OF CONTENTS.....	IV
LIST OF TABLES	VI
LIST OF FIGURES	VII
NOMENCLATURE	IX
ABSTRACT	X
CHAPTER 1 : INTRODUCTION	1
1.1. DEFINITION OF HOME AUTOMATION SYSTEM.....	1
1.2. COMPONENTS OF HOME AUTOMATION SYSTEM	2
1.3. SMART GRID AND SMART METER.....	3
1.3.1. Smart Grid	3
1.3.2. Smart Meter	5
1.3.2.1. Components of Smart Meter.....	6
1.4. UTILITY CENTER (SCADA).....	7
1.4.1. SCADA system	7
1.5. DEMAND SIDE MANAGEMENT	8
1.5.1. Demand Response	9
1.6. HOME ENERGY MANAGEMENT SYSTEM	10
1.7. HUMAN MACHINE INTERFACE	11
1.7.1. Home Automation System user interfaces	11
1.8. THESIS OBJECTIVES	13
1.9. THESIS STRUCTURE.....	13
CHAPTER 2 : DESIGN OF HOME AUTOMATION SYSTEM.....	15
2.1. INTRODUCTION	15
2.2. SMART METERING	15
2.3. HOME AREA NETWORK	16
2.4. PLC AND CONTROLLER	17
2.4.1. Billing Segments	17
2.4.2. Scheduler:	18
2.4.3. Priority:	19
2.4.4. Bill limitation:	21
2.5. HMI:	22

2.5.1.	Main Display:	23
2.5.2.	Power Meter Readings :	25
2.5.3.	Trends:.....	25
2.5.4.	Alarm.....	26
2.5.5.	Billing and Billing Segments:.....	27
2.5.6.	Priority.....	27
2.5.7.	Scheduling loads:.....	28
2.5.8.	Bill limitation:	29
2.6.	DEMAND RESPONSE	30
2.7.	LOADS AS APPLIANCES:.....	32
CHAPTER 3 : SOFTWARE CONFIGURATION		33
3.1.	INTRODUCTION	33
3.2.	HMI SETTING AND DISPLAYS HIERARCHY	33
3.2.1.	Communication Between PLC and HMI.....	33
3.3.	VARIABLES USED IN PLC AND HMI.....	35
3.3.1.	Alarm configuration	39
3.3.2.	Trend Configuration	40
3.4.	SETTING OF PM	42
3.5.	MODEM:.....	42
CHAPTER 4 : RESULTS AND DISCUSSION.....		47
4.1.	INTRODUCTION	47
4.2.	CASE STUDY: DAILY LOAD CURVE.....	47
4.3.	DEMAND RESPONSE	48
4.3.1.	Accepting Demand response	48
4.3.2.	Refusing DR	53
4.4.	LOAD PRIORITIES:	55
4.5.	SCHEDULING	56
4.6.	ON/OFF LOADS	57
4.7.	MONITORING	58
4.8.	ENERGY CONSUMPTION: BILL.....	59
4.8.1.	Bill and Bill Segment Runtime.....	59
4.8.2.	Bill limitation.....	59
4.9.	ALARM.....	60
CHAPTER 5 : CONCLUSION AND FUTURE WORK.....		61
5.1.	CONCLUSION:	61
5.2.	FUTURE WORKS:	61
REFERENCES		62

List of Tables

Table 3.1: Variable Tages.....	36
--------------------------------	----

List of Figures

Fig. 1.1: Home Automation System Components.....	3
Fig.1.2: Smart Home By Using Smart Meter	4
Fig.1.3: Purpose Of Smart Grid Infrastructure	5
Fig. 1.4: Block Diagram of SM	6
Fig.1.5: SCADA Architecture	8
Fig.1.6: Types Of DR	10
Fig. 1.7: HAS User Interface For C4yourself.....	12
Fig. 1.8: HAS User Interface For Designed Integration.....	12
Fig. 1.9: HAS User Interface	13
Fig.2.1: Software, Hardware System and Data Flow For The Proposed HAS With SG15	
Fig. 2.2: HAN Communication Network Layout	16
Fig. 2.3: PLC Program Design	17
Fig. 2.4: Billing Segments Block Diagram in PLC	18
Fig. 2.5: Flow Chart Of Scheduler In PLC Program	19
Fig. 2.6: PRIORITIES FLOW CHART	20
Fig. 2.7: DEFAULT PRIORITY FLOW CHART	21
Fig. 2.8: HMI Display Design	22
Fig. 2.9: Main Panel In HMI	23
Fig. 2.10: Login Panel In HMI	24
Fig. 2.11: Registration Panel	24
Fig. 2.12: PM Readings	25
Fig. 2.13: Power Trend	26
Fig. 2.14: Alarm Panel.....	27
Fig. 2.15: Billing.....	27
Fig. 2.16: Choosing Priorities and Accepting DR	28
Fig. 2.17: Scheduling Load 1 (Washing Machine).....	29
Fig. 2.18: Bill Limitation.....	30
Fig.2.19: HMI Interface Screen For Accepting DR	31
Fig.2.20: HMI Interface Screen For Refusing DR	31
Fig. 2.21: Resistive Used For Appliances Emulation.....	32
Fig.3.1: Add A New Driver In HMI.....	33
Fig.3.2: Select the Type Of The New Driver	34
Fig.3.3: IP Address of the PLC M340	34
Fig.3.4: IP Address Of HMI To Transfer Data	35
Fig. 3.5 Alarms And Events Button	39
Fig. 3.6 Create A New Alarm Group	39
Fig. 3.7: All Alarms Of The System.....	40
Fig. 3.8: Data Logging Button In HMI program	41
Fig. 3.9: New Logging Group In HMI	41
Fig. 3.10: Logging Groups	41
Fig. 3.11: Variables of DR Logging Group.....	41
Fig.3.12: Setup Communication in PM710	42
Fig. 3.13: Point to Point Network.....	42
FIG. 3.14: Configuration Of Remote Network	43
Fig. 3.15: Writing IP Address Of Remote Network.....	44

Fig. 3.16: Configuration Of Access Point Network	45
Fig. 3.17: Writing Address IP Of Access Point.....	46
Fig. 4.1: Daily Load Curve.....	47
Fig.4.2: HMI Interface Screen for Accepting DR In Runtime	48
Fig. 4.3: Cutoff All Loads To Achieve DR	49
Fig. 4.4: Loads Priorities For Cutting Off DR.....	49
Fig. 4.5: Load Curve without Applying DR.....	50
Fig. 4.6: Load Curve with Applying DR.....	50
Fig. 4.7: Enhanced Load Curve with Applying DR	50
Fig.4.8: Load Priorities for Curtailing Loads Shape2	51
Fig. 4.9: Load Curve with Applying DR (Curtail Load3 As The Lowest Priority)	51
Fig.4.10: Load Curve with Applying DR (Curtail Load2 as The Lowest Priority)	52
Fig. 4.11: Load Curve with Applying DR (Curtail Load2 as the Lowest Priority).....	52
Fig.4.12: HMI Interface Screen for Refusing DR In Runtime	54
Fig.4.13: Refusing DR Trend in Runtime	54
Fig. 4.14: Priority Selection in HMI.....	55
Fig.4.15: Scheduling Panel in Runtime for Washing Machine	56
Fig.4.16: Power Trend Showing Scheduling Of Washing Machine At 11/7/2019 In 12:26 PM	56
Fig. 4.17: Current Trend Showing Scheduling Of Washing Machine at 11/7/2019 In 12:26 PM	57
Fig. 4.18: Closing Load1 (Washing Machine) Using ON/OFF Loads Panel in HMI....	57
Fig. 4.19: Closing Load1 (Washing Machine) Using ON/OFF loads Panel in Power Trend.....	58
Fig. 4.20: Closing Load1 (Washing Machine) Using ON/OFF Loads Panel in Power Trend.....	58
Fig. 4.21: Runtime PM Readings	58
Fig. 4.22: Runtime PM Readings	59
Fig. 4.23: Bill Limitation Panel in HMI	59
Fig. 4.24: Curtailing All Loads by Using Bill Limitation Panel	60
Fig.4.25: Alarm for Curtailing Load1 and Load3	60

Nomenclature

A

ADC	Analogue to Digital Converter
AMI	Advanced Metering Infrastructure

C

CPP	Critical Peak Pricing
-----	-----------------------

D

DR	Demand Response
DTE	Data Terminal Equipment
DSM	Demand Side Management

E

EDS	Electrical Distribution System
-----	--------------------------------

H

HAN	Home Area Network
HAS	Home Automation System
HEMS	Home Energy Management System
HMI	Human Machine Interface
HW	Hardware

I

ICT	Information and Communication Technology
-----	--

M

MDM	Meter Demand Management System
-----	--------------------------------

P

PM	Power Meter
PLC	Programmable Logic Control
PTR	Peak Time Rebate

R

RTP	Real Time Pricing
-----	-------------------

S

SG	Smart Grid
SM	Smart Meter
SW	Software
SCADA	Supervisory Control and Data Acquisition

T

TOU	Time of Use
-----	-------------

U

UC	Utility Center
----	----------------