

**AUTOMATED DEMAND RESPONSE FOR A COMMERCIAL
BUILDING: A MODEL DESIGN AND PILOT STUDY**

C.T.J. Fernando

(159303B)

Degree of Master of Science in Electrical Engineering

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

October 2018

**AUTOMATED DEMAND RESPONSE FOR A COMMERCIAL
BUILDING: A MODEL DESIGN AND PILOT STUDY**

C.T.J. Fernando

(159303B)

Dissertation submitted in partial fulfillment of the requirements for the

Degree Master of Science in Electrical Engineering

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

October 2018

DECLARATION OF THE CANDIDATE & SUPERVISOR

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date:

The above candidate has carried out research for the Masters Dissertation under our supervision.

Signature of the supervisor:

Date

Dr. P.S.N. De Silva

Signature of the supervisor:

Date

Dr. W.D.A.S. Rodrigo

ABSTRACT

The inherent intermittency of non-conventional renewable resources has been the major impediment in admitting renewable resources to the traditional Electricity Grid. The flexibility of loads in the power system are disregarded in such analysis. The traditional Utility and Customer model is now subjected to change with active customer participation from demand side.

With the growing renewable share in the Energy mix, power industry will require more capacity and inertia to have a better control over the power quality. Automated Demand Response is the cutting edge technology which enables the grid to use load flexibility in counteracting the NCRE intermittency.

This project pilots the possibility of mitigating the rooftop solar intermittency of a building with air conditioning loads which has an inherent flexibility as DR resources. A building-wide Home Area Network is implemented together with short term solar prediction and a central controller with dynamic dispatch algorithm.

Results from the pilot project are presented to demonstrate as how the solar transients are mitigated at the Point of Common Coupling (PCC) with an eye on benefits and impacts on the participants.

ACKNOWLEDGEMENT

It is my great pleasures to express gratitude to all those who have helped me in completing my research project.

First I would like to express my sincere gratitude to my supervisor Dr. Narendra De Silva for providing the concept and for his continuous guidance and support throughout the period.

Also, my sincere gratitude goes to Dr. Asanka Rodrigo for his guidance and support from the very beginning to the end.

My sincere thanks goes to my immediate supervisor, LECO system development manager Mr. S.D.C Gunawardana and all my colleagues at Lanka electricity company private limited who helped me in many ways during this period.

Last but not least I would express my heartiest gratitude to my family, for helping to complete this work in difficult circumstances.

Table of Contents

ABSTRACT	II
ACKNOWLEDGEMENT	III
TABLE OF CONTENTS	IV
LIST OF FIGURES	VI
LIST OF TABLES	VII
1. INTRODUCTION	1
1.1 BACKGROUND	1
1.2 SMART GRIDS.....	1
1.2.1 <i>Smart Grid Concept</i>	1
1.2.2 <i>Renewable Energy Sources and Demand Response (DR)</i>	2
1.2.3 <i>Automated Demand Response (ADR)</i>	3
1.2.4 <i>Applications of ADR</i>	3
1.3 SRI LANKAN DISTRIBUTION NETWORK	4
1.3.1 <i>Overview of the Network</i>	4
1.3.2 <i>Upcoming Challenges</i>	4
1.3.3 <i>Customer Participation</i>	5
2. PROJECT OVERVIEW	7
2.1 SCOPE OF THE PROJECT	7
2.2 RESEARCH OBJECTIVE	7
2.3 METHODOLOGY	8
2.3 CAPACITY OF THE ADR PORTAL.....	8
3. LITERATURE REVIEW	9
3.1 PREVIOUS RESEARCH WORKS	9
3.2 ADR ARCHITECTURE	9
3.3 SELECTION OF PARTICIPATING LOADS	10
3.4 BEHAVIOUR OF LOADS AND MODELING THE EVENTS	11
3.5 COMMUNICATION METHODS	12
3.6 CASE STUDIES	12
4. DESIGN OF THE ADR ARCHITECTURE	13
4.1 ADR ARCHITECTURE.....	13
4.2 ADR MODEL.....	14
4.2.1 <i>Participating Loads and their dispatching methods</i>	15

4.2.2 Behavior of Solar Transients.....	16
4.2.3 Net Power Consumption of a building with a Solar panel.....	16
4.2.4 Communication Method	19
4.2.5 Central Controller – ADR Algorithm	20
5. IMPLEMENTATION OF THE ADR MODEL	23
5.1 HARDWARE DEVELOPMENT.....	23
5.1.1 Individual Load Controllers – Plug and Play	23
5.1.2 Energy meters	24
5.2 WiFi COMMUNICATION NETWORK.....	24
5.3 SOFTWARE APPLICATION DEVELOPMENT	25
5.3.1 ADR Software application	25
5.3.2 Firmware of the WiFi module.....	27
6. PILOT PROJECT AND ITS RESULTS.....	28
6.1 THE PILOT PROJECT	28
6.1.1 The participated commercial building and the loads	28
6.1.2 Dispatch rules maintained for the building	28
6.2 THE PILOT PROJECT - RESPONSE OF ADR APPLICATION.....	29
7. DISCUSSION	35
7.1 RESPONSE OF THE APPLICATION - HIGHLIGHTS.....	35
8. CONCLUSION	36
8.1 LIMITATIONS OF THE ADR APPLICATION	36
8.2 CUSTOMER PARTICIPATION	37
8.2.1 encourage participation in ADR portals in a financial manner	38
8.2.2 measuring the optimal RE penetration level.....	38
8.3 FUTURE WORKS.....	38
REFERENCES.....	39
APPENDIX 01	40
APPENDIX 02	42

LIST OF FIGURES

Figure 1.1: Conceptual Model of Smart Grid. From Automated Demand Response for Smart Buildings and Micro grids [1].....	2
Figure 3.1: System Architecture of typical ADR [1].....	10
Figure 3.2: PL Architecture [3].....	10
Figure 3.3: Behavior of heat pumps with reference [4].....	12
Figure 4.1: Typical Electricity Use of an Office Building.....	14
Figure 4.2: ADR model.....	15
Figure 4.3: Sample Air Conditioner Load Profiles.....	15
Figure 4.4: Sample solar curves.....	16
Figure 4.5: Different types of buildings and their load profiles.....	17
Figure 4.6: Normal Load Profile of the building without Solar integration.....	18
Figure 4.7: Net Power consumption of the building with Solar integration.....	18
Figure 4.8: Load Profile seen from the Grid for a building with Solar Integration.....	19
Figure 4.9: Primary Selection of Loads using Knapsack Algorithm.....	21
Figure 5.1: Arrangement of the Load Controller Module.....	23
Figure 5.2: Load Controller Module.....	23
Figure 5.3: The driver circuit of the latching relay.....	24
Figure 5.4: ESP8266 WiFi Module.....	25
Figure 5.5: Simplified Flowchart for the ADR algorithm.....	27
Figure 6.1: Day 1 - Solar Power Generation.....	31
Figure 6.2: Day 1 - Total Consumption of the building.....	32
Figure 6.3: Day 2 - Solar Power Generation.....	33
Figure 6.4: Day 2 - Total Consumption of the building.....	34
Figure 8.1: Variation of the size of an ADR event with maximum possible time duration....	37

LIST OF TABLES

Table 1.1: Demand response program types in the 2012 FERC Survey3

Table 4.1: Electricity use of selected buildings 13

Table 9.1: Participating Loads for the Pilot Project.....40

Table 9.2: Load Profile data for Day 142

Table 9.3: Event log for Day 1.....51