



UNIVERSITI PUTRA MALAYSIA

***MODELLING OF STAND-ALONE HYBRID MICROGRID WITH
DEMAND- SIDE MANAGEMENT***

MOHAMMAD SEIFI

FK 2014 39



**MODELLING OF STAND-ALONE HYBRID MICROGRID WITH
DEMAND- SIDE MANAGEMENT**

By

MOHAMMAD SEIFI

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

May 2014

COPYRIGHT

All material contained within the thesis, including without limitation text, logos, icons, photographs, and all other artwork is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

MODELLING OF STAND-ALONE HYBRID MICROGRID WITH DEMAND-SIDE MANAGEMENT

By

MOHAMMAD SEIFI

May 2014

Chair: Azura Binti Che Soh, PhD
Faculty: Engineering

The future of power system will be highly influenced by Microgrid with renewable energy resources. Stand-alone Microgrid is widely proposed for any kind of grid-off community and rural electrification. Due to lack of established standards in Microgrid industry, designing a Microgrid seems ambiguous. The first part of this study tries to fill this gap by acquiring and addressing the relevant standards. The design starts by feasible study based on location and potential renewable energy resources. Based on load data, the supply capacity and storage backup are calculated. It was shown that solar and wind energy are suitable Renewable Energy Sources (RES) for tropical area such as Malaysia. In this study, solar energy, wind energy and battery backup are sized and modeled based on relevant standards. Three controllers are modeled and simulated for Maximum Power Point Tracking (MPPT), DC/DC converter and DC/AC inverters for proposed plant. Mathematical model of each individual elements of proposed Microgrid are modeled in MATLAB/Simulink software. The simulation results of main components are validated by manufacturer's datasheet. Due to uncertainty and intermittency in Renewable Energy (RE) Generation, a smart Demand Side Management (DSM) controller is proposed to smoothing demand control and increase system efficiency. The existing DSM functions are mostly suitable for utilities and grid-connected Microgrid. Proposed DSM is adjusted to meet vulnerable stand-alone system requirement. The simulation results show DSM controller will supply sensitive load longer and will increase system efficiency. Different scenarios for sun irradiance, wind speed and temperature are simulated to test DSM controller in different situation and the result shows DSM controller is successfully implemented. For future study, an intelligent load pattern recognition will improve the proposed DSM function for each load will be

recognized by DSM wherever they plugged in the supply. Finally, an experimental work on this study also is recommended.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk ijazah Master of Sains

**PEMODELAN HIBRID MIKROGRID BERDIRI SENDIRI DENGAN
PERMINTAAN DARI PENGURUSAN**

Oleh

MOHAMMAD SEIFI

May 2014

Pengerusi: Azura Binti Che Soh, PhD
Fakulti : Kejuruteraan

Masa depan sistem kuasa sangatlah dipengaruhi oleh grid mikro berserta sumber tenaga boleh diperbaharui. Grid mikro berdiri sendiri dicadangkan secara meluas bagi apa-apa jenis masyarakat grid-tutup dan elektrik luar bandar. Oleh kerana kekurangan piawai yang diiktiraf dalam industri grid mikro, mereka bentuk grid mikro masih kabur. Bahagian pertama kajian ini cuba untuk mengisi jurang ini dengan memperoleh dan menangani tahap yang ditetapkan. Reka bentuk ini bermula dengan kajian dilaksanakan berdasarkan lokasi dan potensi sumber tenaga boleh diperbaharui. Berdasarkan data beban, bekalan dan penyimpanan dikira. Ia menunjukkan bahawa solar dan tenaga angin sesuai sebagai sumber tenaga boleh diperbaharui (RES) bagi kawasan tropika seperti Malaysia. Tenaga solar tenaga angin, bateri sandaran dikenal pasti saiznya dan dimodelkan berdasarkan piawai. Tiga pengawal dimodelkan dan simulasi dijalankan untuk maksimum penjejakan kuasa titik (MPPT), penukar DC/DC dan pengawal tersongsang AC/DC bagi loji yang dicadangkan. Model matematik bagi setiap elemen di dalam cadangan grid mikro dimodelkan menggunakan perisian MATLAB/Simulink. Keputusan simulasi komponen utama disahkan oleh lembaran data dari pengeluaran. Disebabkan oleh ketidaktentuan dan ketidakteraturan dalam penjanaan tenaga boleh diperbaharui (RE), pengawal pintar permintaan dari pengurusan kawalan (DSM) dicadangkan untuk melicinkan kawalan permintaan dan kecekapan peningkatan sistem. Fungsi DSM sedia ada kebanyakannya sesuai untuk utiliti dan grid mikro grid-sambungan. DSM yang dicadangkan akan diselaraskan untuk memenuhi keperluan sistem yang berdiri sendiri terdedah. Keputusan simulasi menunjukkan DSM pengawal akan membekalkan beban sensitif lagi panjang dan akan meningkatkan kecekapan sistem.

Simulasi bagi senario yang berbeza untuk sinaran matahari, kelajuan angin dan suhu dilakukan untuk menguji pengawal DSM dalam keadaan yang berbeza dan hasilnya menunjukkan pengawal DSM berjaya dilaksanakan. Untuk kajian masa depan, pengecaman corak beban pintar akan meningkatkan fungsi DSM yang dicadangkan untuk setiap beban akan diiktiraf oleh DSM di mana sahaja mereka dipasang bekalan. Akhir sekali, kerja eksperimen kajian ini juga adalah disyorkan.



ACKNOWLEDGMENTS

I would like to express my sincere appreciation and gratitude to my supervisor Dr. Azura for the useful comments, remarks and engagement through the learning process of this master thesis.

I would also like to thank my committee members, Dr. Izzri and Dr. Khair for serving as my committee members by valuable comments and brilliant suggestions.

I would like to thank UPM staff especially in engineering faculty, GSO, Library and Hospital for their supporting.

I also express my sincere appreciation to UPM for research grant scheme as below:
"Research University Grant Scheme, RUGS, No. Project: 05-02-12-1906RU, Project Title: An Intelligent Load Control System for Autonomous Microgrid Based on Solar and Wind Energy"

A special thanks to my family. Words cannot express how grateful I am to my wife Soheila for all of the sacrifices that you have made on my behalf. Thanks to my son Arash and my daughter Sara for the special happiness, they brought to us.



© COPYRIGHT UPM

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

Azura Binti Che Soh, PhD

Senior Lecturer
Engineering faculty
Universiti Putra Malaysia
(Chariman)

Mohd Khair Bin Hassan, PhD

Senior Lecturer
Engineering faculty
Universiti Putra Malaysia
(Member)

Noor Izzri Bin Abdul Wahab, PhD

Senior Lecturer
Engineering faculty
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby declare that:

- This thesis is my original work;
- Quotations, illustrations and citations, have been duly referenced;
- This thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- Intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- Written permission must be obtained from supervisor and the office of Deputy Vice Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceeding, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- There is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: Mohammad Seifi, GS31812

Declaration by Members of Supervisory Committee

This is to confirm that:

- The research conducted and writing of thesis was under our supervision;
- Supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of
Chairman of
Supervisory
Committee: Dr. Azura Binti Che Soh

Signature: _____
Name of
Member of
Supervisory
Committee: Dr. Mohd Khair Bin Hassan

Signature: _____
Name of
Member of
Supervisory
Committee: Dr. Noor Izzri Bin Abdul Wahab

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	iii
ACKNOWLEDGMENTS	v
APPROVAL	vi
DECLARATION	viii
LIST OF TABLES	xiv
LIST OF FIGURES	xv
LIST OF SYMBOLS	xix
LIST OF ABBREVIATIONS	xx
CHAPTER	
1 INTRODUCTION	1
1.1 Power system and Distributed Generation	1
1.2 Microgrid and renewable energy sources	2
1.2.1 Microgrid concept	2
1.2.2 Microgrid system size	3
1.2.3 Voltage Sourced Converters (VSC)	4
1.2.4 Renewable Energy	4
1.3 Research outline and description	6
1.4 Problem statement	8
1.5 Objectives	9
1.6 Thesis construction	10
2 LITERATURE REVIEW	11
2.1 Microgrid concept	11
2.1.1 Microgrid and renewable energy resources	11
2.1.2 Microgrid vs. Power system	11
2.1.3 Hybrid Microgrid	12
2.1.4 Microgrid architecture and configuration	12
2.1.5 Relevant standards	14
2.1.5.1 IEEE 1547	14
2.1.5.2 IEEE 1562	15
2.1.5.3 IEEE 1361 and IEEE 1013	15
2.1.5.4 UL 1741	15
2.1.5.5 IEEE 929	15
2.1.5.6 IEC 61400 families	16
2.2 Power electronic converters in Microgrid	17
2.2.1 DC/DC converter	17
2.2.2 DC/AC Converter	17
2.3 Microgrid control strategies	18
2.3.1 Centralized and de-centralized control	18

	2.3.1.1	De-centralized control	18
	2.3.1.2	Centralized control	19
	2.3.2	Droop control	20
	2.3.3	PQ/VSI control	20
	2.3.4	Intelligent control system	21
	2.3.4.1	Fuzzy Logic Controller for inverter	22
2.4		Demand Side Management	22
	2.4.1	DSM functions (modules)	23
	2.4.2	Stand-alone Microgrid and DSM	24
	2.4.3	Direct Load Control and load shedding	25
	2.4.4	Tele-control technology required for MGCC-DSM	25
2.5		Renewable Energy Sources and rural electrification in Malaysia	26
	2.5.1	Renewable energy in Malaysia	26
	2.5.1.1	Sun irradiance	26
	2.5.1.2	Wind speed	27
	2.5.2	Rural electrification in Malaysia	27
	2.5.3	Load calculation	28
2.6		Conclusion	31
2.7		Summary	31
3		METHODOLOGY	33
	3.1	Introduction	33
	3.2	Description of case study	33
	3.3	Design and modeling stand-alone Microgrid	35
	3.3.1	Loads and cable sizing and modeling	36
	3.3.1.1	Load sizing and modeling	36
	3.3.1.2	Residential load	36
	3.3.1.3	Water house load	37
	3.3.1.4	MGCC room load	38
	3.3.1.5	All loads review	38
	3.3.2	Cable calculation	40
	3.3.3	PV system design and modeling	41
	3.3.3.1	Structure of photovoltaic	41
	3.3.3.2	PV system electrical characteristics	42
	3.3.3.3	PV models and equivalent circuits	43
	3.3.3.4	PV Simulink model	43
	3.3.3.5	MPPT Techniques	45
	3.3.3.6	PV sizing	48
	3.3.4	Wind energy and wind turbine model	50
	3.3.4.1	Wind turbine	50
	3.3.5	Battery sizing and modeling	53
	3.3.5.1	Battery model	53
	3.3.5.2	Battery capacity (Ah) calculation	54
	3.3.6	DC/DC converter	56
	3.3.6.1	DC/DC converter design	56
	3.3.6.2	DC to DC controller design	57
	3.3.7	Battery charger	59

3.3.8	DC/AC Inverters	59
3.3.8.1	Inverter design	59
3.3.8.2	Inverter state space model	61
3.3.8.3	Fuzzy Logic Controller (FLC) for inverter	64
3.3.9	Filter design	65
3.3.10	DC link Capacitor	66
3.4	Demand side management	67
3.4.1	Energy management and Demand side management strategy	68
3.4.2	Smart DSM controller modeling	71
3.4.2.1	Environment data	71
3.4.2.2	Load model in DSM	72
3.4.2.3	DSM model of PV	73
3.4.2.4	DSM model of wind turbine	74
3.4.2.5	DSM model of battery	75
3.4.2.6	DSM model of Supply (generation)	76
3.4.2.7	If condition block	77
3.4.2.8	Load switching subsystem for DSM	78
3.4.2.9	Remove chattering from DSM controller	79
3.5	Summary	79
4	RESULTS AND DISCUSSION	81
4.1	Introduction	81
4.2	Power stage simulation, results and discussion	82
4.2.1	PV simulation results	82
4.2.2	DC/DC converter Controller simulation results	84
4.2.3	Inverter simulation results	86
4.2.4	Filter simulation results	88
4.3	DSM controller simulation and results	88
4.4	Simulation scenarios	88
4.4.1	Solar powered operation	89
4.4.2	WT powered operation	89
4.4.3	PV+WT powered operation	90
4.4.4	Load simulation results	91
4.4.5	Sun irradiance, temperature and wind speed	92
4.5	DSM controller simulation results	94
4.5.1	Simulation results for three days sun and wind with fixed temperature	94
4.5.2	Simulation results for two days sun and wind with fixed temperature	96
4.5.3	Simulation results for partially shaded sun with fixed temperature	97
4.5.4	Simulation results for normal sun and no-wind with fixed temperature	98
4.5.5	Simulation results for normal sun and wind with variant temperature	99
4.5.6	Simulation results with demand response	100
4.5.7	Battery powered operation	102

4.5.8	Simulation result with and without DSM controller	102
4.5.9	Comparison between DSM controller and PI controller	105
4.5.10	Energy evaluation simulation	106
4.6	Summary	107
5	CONCLUSION AND FUTURE WORK	109
5.1	Conclusion	109
5.2	Contribution	111
5.3	Future work	111
5.4	Suggestion	112
	REFERENCES	113
	APPENDICES	
	Appendix A, Wind Speed Data For Mersing, Malaysia	122
	Appendix B, Typical Electrical Load Calculation Sheet	123
	Appendix C, Load Priority Table	124
	Appendix D, Cable Specification	125
	Appendix E, Ideality Factor For Different Type Of PV	125
	Appendix F, Matlab Scripts For Calculate Un-Known PV Parameters	126
	Appendix G, Simulink Model Of PV	128
	Appendix H, abc And dq0 Transformation	129
	Appendix I, Suntech PV Electrical Characteristics	130
	BIODATA OF STUDENT	131
	LIST OF PUBLICATIONS	132