



Faculty of Electrical Engineering

**IMPACT OF INTEGRATING SOLAR PV SYSTEM TO MALAYSIAN
LV NETWORK AND MITIGATION USING DISTRIBUTED BESS**

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Master of Science in Electrical Engineering

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NETWORK AND MITIGATION USING DISTRIBUTED BESS**

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Electrical
Engineering**

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2019

DECLARATION

I declare that this thesis entitled “Impact of Integrating Solar PV System to Malaysian LV Network and Mitigation Using Distributed BESS” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :.....

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Date :.....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature :

Supervisor Name : Profesor Madya Ir. Dr. Gan Chin Kim

Date :

DEDICATION

To my beloved mother, father and husband

ABSTRACT

The current high demand for energy and increase in greenhouse gas emission have resulted in Renewable Energy (RE) sources gaining a lot of attention in effort to sustain future energy needs. Sustainable Energy Development Authority (SEDA) data show that the most popular RE in Malaysia is solar Photovoltaic (PV) energy which has the highest installed capacity with 66.95% total installed RE. However, connection of RE into the existing distribution networks can contribute to several network problems such as voltage flicker, reverse power flow, power fluctuations in grids and unintended islanding. More specifically, solar PV system with high variability can lead to output power fluctuation. This may worsen the performance of the distribution network. In addition, it is important to maintain the flexibility and stability of the system even in the event of disturbances or sudden changes in PV generation. Thus, this research aims to investigate the impact of solar PV integration on the Malaysian distribution network under various PV integration scenarios and solar variability. Analytical method was applied to determine the Battery Energy Storage System (BESS) capacity with the aim of reducing the negative impacts of PV integration on the network. A real Malaysian network was modelled in OpenDSS software and was utilized as the reference network. It is also important to highlight that there are three scenarios in this research which indicate where the PV system was installed namely, randomly allocated PV system, concentrated PV system installation across two feeders, and unbalanced allocation of PV system. Real PV variability data obtained from weather station installed at UTeM were collected at 5-minute intervals and were utilized to study their impacts on network distribution. A corresponding size of distributed BESS was modelled to store the excessive energy during low demand and deliver it during high demand. The findings suggest that randomly allocated PV systems are suitable for PV installation in residential areas. In addition, the result for BESS installation during high PV penetration showed significant improvement on the net load profile, and this can assist utility providers to deliver more reliable power supply.

ABSTRAK

Pada masa ini, permintaan tenaga yang tinggi dan peningkatan pelepasan gas rumah hijau menjadikan sumber Tenaga Boleh Diperbaharui (RE) mendapat perhatian yang lebih untuk mengekalkan keperluan tenaga masa hadapan. Data daripada Pihak Berkuasa Pembangunan Tenaga Lestari (SEDA) menunjukkan RE yang paling terkenal di Malaysia adalah tenaga suria fotovoltan (PV) yang mempunyai kapasiti tertinggi dengan 66.95% daripada jumlah RE yang dipasang. Walau bagaimanapun, sambungan RE ke rangkaian pengagihan sedia ada boleh menyumbang kepada beberapa masalah rangkaian seperti kerlipan voltan, aliran kuasa terbalik, turun naik kuasa di dalam grid dan berlaku kawasan berpulau yang tidak diingini. Lebih khusus lagi, sistem PV suria dengan kepelbagaian yang tinggi boleh menyebabkan turun naik kuasa keluar. Ini mungkin akan memburukkan prestasi rangkaian pengagihan. Di samping itu, penting untuk mengekalkan kefleksibelan dan kestabilan sistem walaupun berlaku gangguan atau perubahan mendadak dalam penjanaan PV. Oleh itu, kajian ini bertujuan untuk mengkaji kesan integrasi PV suria terhadap rangkaian pengedaran Malaysia di bawah pelbagai senario integrasi PV dan keberubahan suria. Tambahan pula, kaedah analitikal telah digunakan untuk menentukan kapasiti Sistem Penyimpanan Tenaga Bateri (BESS) dengan tujuannya adalah untuk mengurangkan kesan negatif integrasi PV pada rangkaian. Dalam hal ini, rangkaian sebenar Malaysia dimodelkan dalam perisian OpenDSS dan digunakan sebagai rangkaian rujukan. Ia juga penting untuk diambil tahu bahawa terdapat tiga senario dalam kajian ini yang menunjukkan di mana sistem PV dipasang iaitu, sistem PV yang diperuntukkan secara rawak, pemasangan sistem PV tertumpu di dua peti pembekal, dan peruntukkan sistem PV yang tidak seimbang. Data keberubahan PV sebenar diperolehi dari stesen cuaca yang dipasang di UTeM dikumpulkan dalam jarak 5 minit dan ia digunakan untuk mengkaji kesannya kepada pengedaran rangkaian. Oleh itu, saiz BESS agihan yang sepadan dimodelkan untuk menyimpan tenaga yang berlebihan semasa permintaan yang rendah dan menyampaikannya semasa permintaan yang tinggi. Penemuan ini menunjukkan bahawa sistem PV yang diperuntukkan secara rawak adalah cara yang sesuai untuk memasang PV di kawasan kediaman. Di samping itu, keputusan yang ditunjukkan selepas pemasangan BESS semasa penembusan PV yang tinggi mempunyai peningkatan yang ketara dan ditunjukkan pada profil beban bersih yang boleh membantu pembekal utiliti untuk memberikan kuasa yang lebih dipercayai.

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TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	viii
LIST OF FIGURES	x
LIST OF APPENDICES	xvi
LIST OF ABBREVIATIONS	xvii
LIST OF PUBLICATIONS	xviii
CHAPTER	
1. INTRODUCTION	1
1.1 Background	1
1.2 Problem statement	3
1.3 Research objectives	5
1.4 Research scope	5
1.5 Thesis outline	7
2. LITERATURE REVIEW	8
2.1 Introduction	8
2.2 Distribution network	9
2.3 Solar PV system	12
2.3.1 Grid-connected PV systems	13
2.3.2 PV penetration level	14
2.4 Solar irradiance	17
2.4.1 Solar variability	18
2.4.2 Solar variability classification	21
2.5 Impact of intermittent power source	23
2.5.1 Voltage fluctuation	23
2.5.2 Reverse power flow and overvoltage	23
2.5.3 Voltage flicker	24
2.5.4 Unintended islanding	25
2.5.5 Power fluctuation in grid	26
2.5.6 Grid frequency fluctuation	26
2.6 Methods to reduce intermittent power sources	27
2.6.1 Energy storage technologies	27
2.6.1.1 Battery energy storage	29
2.6.1.2 Capacitors and superconductive magnetic energy storage (SMES)	31
2.6.2 Reduction of active power by MPPT control and dump load	33
2.6.3 Fuel cell	34
2.6.4 Diesel generator	35
2.7 Summary	37

3. METHODOLOGY	39
3.1 Introduction	39
3.2 OpenDSS	40
3.2.1 Validation of OpenDSS with IEEE 4 bus test feeder	41
3.2.2 OpenDSS code for IEEE 4 bus test feeder	41
3.3 Network modelling	44
3.3.1 Transformer modelling	46
3.3.2 Demand modelling	47
3.3.3 Photovoltaic system modelling	48
3.4 Impact assessment method	52
3.4.1 Voltage fluctuation	53
3.4.2 Voltage unbalance	53
3.4.3 Network losses	54
3.4.4 Load factor	54
3.4.5 Variability index	56
3.5 Deterministic approach in assessing PV integration	56
3.5.1 Solar PV penetration levels	56
3.5.2 Solar PV system capacities	57
3.6 Case study	58
3.6.1 Simulation for the base case	59
3.6.2 Case study 1	60
3.6.2.1 Scenario 1: PV system randomly allocated across Feeders 1, 2 and 3	61
3.6.2.2 Scenario 2: Randomly allocated PV system concentrated across Feeder 1 and 2 only	62
3.6.2.3 Scenario 3: Imbalanced allocation of PV system at Feeders 1, 2 and 3	64
3.6.3 Case study 2	67
3.6.4 Case study 3	70
3.6.4.1 Proposed battery energy storage system method to reduce fluctuations	73
3.6.4.2 Proposed BESS sizing by utilized analytical method	74
3.6.4.3 State of charge (SoC) BESS	77
3.6.4.4 Scenario 1: PV and BESS are randomly allocated across Feeders 1, 2 and 3	79
3.6.4.5 Scenario 2: PV and BESS randomly allocated and concentrated across Feeder 1 and 2 only	80
3.6.4.6 Scenario 3: Imbalanced allocation of PV and BESS	81
3.7 Summary	82
4. RESULT AND DISCUSSION	84
4.1 Introduction	84
4.2 Base case study	84
4.2.1 Power demand profile	85
4.2.2 Voltage profiles	85
4.2.3 Network losses	86
4.2.4 Variability index and load factor	87
4.2.5 Voltage unbalance	88

4.3	Case Study 1: Impacts of location of PV integration under one typical clear day	88
4.3.1	Scenario 1: PV system randomly allocated across Feeders 1, 2 and 3	89
4.3.1.1	Network losses in Scenario 1	89
4.3.1.2	Voltage unbalance in Scenario 1	90
4.3.1.3	Variability index and load factor	91
4.3.2	Scenario 2: PV system randomly allocated and concentrated across Feeder 1 and 2 only	92
4.3.2.1	Network losses in Scenario 2	92
4.3.2.2	Voltage unbalance in Scenario 2	93
4.3.2.3	Variability index and load factor	94
4.3.3	Scenario 3: Unbalanced allocation of PV system	95
4.3.3.1	Network losses in Scenario 3	96
4.3.3.2	Voltage unbalance in Scenario 3	96
4.3.3.3	Variability index and load factor	97
4.3.3.4	Summary of case study 1	98
4.4	Case study 2: Impact of weather conditions on network performance on LV	100
4.4.1	Scenario 1: PV system randomly allocated across Feeders 1, 2 and 3	100
4.4.1.1	Network losses	101
4.4.1.2	Voltage unbalance	102
4.4.1.3	Variability index	105
4.4.1.4	Load factor	106
4.4.2	Scenario 2: PV system randomly allocated and concentrated across Feeders 1 and 2 only	107
4.4.2.1	Network losses	107
4.4.2.2	Voltage unbalance	109
4.4.2.3	Variability index	111
4.4.2.4	Load factor	112
4.4.3	Scenario 3: Imbalanced allocation of PV system	113
4.4.3.1	Network losses	113
4.4.3.2	Voltage unbalance	114
4.4.3.3	Variability index	116
4.4.3.4	Load factor	117
4.4.3.5	Summary of case study 2	119
4.5	Case Study 3: Impact of BESS in the network	123
4.5.1	Integration of Battery Energy Storage System (BESS) on the network	123
4.5.2	Scenario 1: PV and BESS are randomly allocated across Feeders 1, 2 and 3	127
4.5.2.1	Variability index after BESS installation Scenario 1	127
4.5.2.2	Load factor after BESS installation in Scenario 1	128
4.5.2.3	Network losses after BESS installation Scenario 1	129
4.5.2.4	Voltage unbalance after BESS installation Scenario 1	130
4.5.3	Scenario 2: PV and BESS are randomly allocated and concentrated across Feeders 1 and 2 only	135

4.5.3.1	Variability index after BESS installation Scenario 2	135
4.5.3.2	Load factor after BESS installation in Scenario 2	136
4.5.3.3	Network losses after BESS installation in Scenario 2	137
4.5.3.4	Voltage unbalance after BESS installation in Scenario 2	138
4.5.4	Scenario 3: Imbalanced allocation of PV and BESS	142
4.5.4.1	Variability index after BESS installation in Scenario 3	142
4.5.4.2	Load factor after BESS installation in Scenario 3	143
4.5.4.3	Network losses after BESS installation in Scenario 3	144
4.5.4.4	Voltage unbalance after BESS installation Scenario 3	145
4.6	Summary	149
5.	CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH	155
5.1	Introduction	155
5.2	Research contribution	155
5.2.1	Modelling of Malaysian LV distribution network and evaluation of the impact of solar integration on Malaysian distribution network	156
5.2.2	Identification of the corresponding size of BESS using analytical method	157
5.2.3	Evaluation of the performance of BESS in mitigating the impacts of solar PV integration	157
5.3	Significance of results	158
5.4	Recommendation for future works	159
	REFERENCES	161
	APPENDICES	179

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Percentage limit variation voltage fluctuation under normal conditions (TNB, 2011)	11
2.2	Characteristic of LV network in UK, EU and Malaysia (J.Wong et. al, 2011)	12
2.3	Type of PV penetration level in different study	15
2.4	Relationship between Clear Sky Index (CSI) and condition of sky	20
2.5	CI and VI daily variability conditions based on five categories (Trueblood et. al., 2013)	22
3.1	Voltage and current validation of OpenDSS 4-bus test feeders with IEEE test result	43
3.2	Cable type and sizes utilized in LV network in this study	45
3.3	Line code for each cable type modelled in OpenDSS	46
3.4	Power transformers technical data (Malaysia Transformer Manufacturing SDN BHD, 2009)	46
3.5	OpenDSS coding for transformer	47
3.6	Number of houses sorted by type for every feeder and the ADMD value	48
3.7	Details of UTeM's PV system	49
3.8	VI and LF value before and after BESS installation	79

3.9	Number of houses connected to PV system and BESS according to PV penetration level in Scenario 1	80
3.10	Number of houses connected to PV system and BESS according to PV penetration level in Scenario 2	81
3.11	Number of houses connected to PV system and BESS according to PV penetration level in Scenario 3	82
4.1	Energy consumption and network losses	87
4.2	Variability index and load factor result	87
4.3	Voltage unbalance	88
4.4	Network losses, voltage unbalance, variability index and load factor for Case study 1	99
4.5	Result of Scenario 1 in Case study 2	119
4.6	Result of Scenario 2 in Case study 2	121
4.7	Result of Scenario 3 in Case study 2	122
4.8	Summary on improvement of load factor, variability index, network losses, and voltage unbalance in Scenario 1	151
4.9	Summary on improvement of load factor, variability index, network losses, and voltage unbalance in Scenario 2	152
4.10	Summary on improvement of load factor, variability index, network losses, and voltage unbalance in Scenario 3	153

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	PV connected with dump load	34
2.2	PV, diesel generator hybrid system	36
3.1	IEEE 4 bus test feeder	41
3.2	OpenDSS coding for IEEE 4 bus test case Y-Y stepdown balanced	42
3.3	The single line diagram of LV distribution network feed by 500kVA distribution transformer located in Taman Impian Putra	45
3.4	Daily load profile of residential area with five-minute resolution (Busrah et. al., 2011)	48
3.5	Thin-film type rooftop PV system	49
3.6	Inverter room for data collection	50
3.7	PV generation profile in 5-min resolution during clear day	50
3.8	PV generation profile in 5-min resolution during overcast day	51
3.9	PV generation profile in 5-min resolution during moderate variability day	51
3.10	PV generation profile in 5-min resolution during mild variability day	52
3.11	PV generation profile in 5-min resolution during high variability day	52

3.12	Load profile before and after installation of BESS	55
3.13	Percentage of 3kWp, 4kWp, and 5kWp PV system sizes installed in Malaysia, 2012-2016 (SEDA, 2016)	58
3.14	Flowchart of base case simulation	60
3.15	Flowchart of Scenario 1 for Case study 1	62
3.16	Flowchart of Scenario 2 for Case study 1	64
3.17	Flowchart of Scenario 3 for Case study 1	66
3.18	Clear day PV generation profile with 5-minute step size	68
3.19	Overcast day PV generation profile with 5-minute step size	69
3.20	Mild variability day PV generation profile with 5-minute step size	69
3.21	Moderate variability day PV generation profile with 5-minute step size	70
3.22	High variability day PV generation profile with 5-minute step size	70
3.23	Flowchart of PV and BESS integration in Case study 3	72
3.24	Battery power shape during 50% PV penetration level on clear day	74
3.25	(a) Load Factor (LF) based on battery size, (b) Variability Index (VI) based on battery size	76
3.26	Battery power shape during 75% PV penetration on clear day, high variability and mild variability	77
3.27	Load profile before and after battery installation with SoC battery status	79
4.1	Transformer loading of network	85
4.2	Voltage profile	86

4.3	Percentage of network losses for PV system randomly allocated across Feeders 1, 2 and 3	90
4.4	Voltage unbalance in Scenario 1	91
4.5	Variability Index and Load Factor in Scenario 1	92
4.6	Percentage of network losses for PV system randomly allocated and concentrated across Feeders 1 and 2 only	93
4.7	Voltage unbalance of Scenario 2	94
4.8	Variability Index and Load Factor Scenario 2	95
4.9	Percentage of network losses for unbalance PV system installation	96
4.10	Voltage unbalance of Scenario 3	97
4.11	Variability Index and Load Factor of Scenario 3	98
4.12	Network losses in five different PV variability for Scenario 1	102
4.13	Voltage unbalance at Feeder 1 in Scenario 1	104
4.14	Voltage unbalance at Feeder 2 in Scenario 1	104
4.15	Voltage unbalance at Feeder 3 in Scenario 1	105
4.16	Variability index of five different PV variabilities in Scenario 1	106
4.17	Load factor of five different PV variabilities in Scenario 1	107
4.18	Network losses of five different PV variabilities in Scenario 2	108
4.19	Voltage unbalance at Feeder 1 in Scenario 2	110
4.20	Voltage unbalance at Feeder 2 in Scenario 2	110
4.21	Voltage unbalance at Feeder 3 in Scenario 2	111
4.22	Variability index of five different PV variabilities in Scenario 2	112
4.23	Load factor of five different PV variabilities in Scenario 2	113
4.24	Network losses of five different PV variabilities in Scenario 3	114

4.25	Voltage unbalance at Feeder 1 of five different PV profiles in Scenario 3	115
4.26	Voltage unbalance at Feeder 2 with five different PV profiles in Scenario 3	116
4.27	Voltage unbalance at Feeder 3 with five different PV profiles in Scenario 3	116
4.28	Variability index of five different PV variabilities in Scenario 3	117
4.29	Load factor in five different PV variability for Scenario 3	118
4.30	Battery size from 5kWh to 30kWh tested on clear day	124
4.31	Battery size from 5kWh to 30kWh tested on overcast day	125
4.32	Battery size from 5kWh to 30kWh tested on moderate variability	125
4.33	Battery size from 5kWh to 30kWh tested on mild variability	126
4.34	Battery size from 5kWh to 30kWh tested on high variability	126
4.35	Variability index before and after BESS installation in Scenario 1	128
4.36	Load factor before and after BESS installation in Scenario 1	129
4.37	Network losses before and after BESS installation	130
4.38	Voltage unbalance during clear day before and after BESS installation in Scenario 1	132
4.39	Voltage unbalance during overcast day before and after BESS installation in Scenario 1	133
4.40	Voltage unbalance during moderate variability before and after BESS installation in Scenario 1	133
4.41	Voltage unbalance during mild variability before and after BESS installation in Scenario 1	134

4.42	Voltage unbalance during high variability before and after BESS installation in Scenario 1	134
4.43	Variability index before and after BESS installation	136
4.44	Load factor before and after BESS installation	137
4.45	Network losses before and after BESS installation	138
4.46	Voltage unbalance during clear day before and after BESS installation in Scenario 2	140
4.47	Voltage unbalance during overcast day before and after BESS installation in Scenario 2	140
4.48	Voltage unbalance during moderate variability before and after BESS installation in Scenario 2	141
4.49	Voltage unbalance during mild variability before and after BESS installation in Scenario 2	141
4.50	Voltage unbalance during high variability before and after BESS installation in Scenario 2	142
4.51	Variability index before and after BESS installation in Scenario 3	143
4.52	Load factor before and after BESS installation in Scenario 3	144
4.53	Network losses before and after BESS installation	145
4.54	Voltage unbalance during clear day before and after BESS installation in Scenario 3	147
4.55	Voltage unbalance during overcast day before and after BESS installation in Scenario 3	147
4.56	Voltage unbalance during moderate variability before and after BESS installation in Scenario 3	148

4.57	Voltage unbalance during mild variability before and after BESS installation in Scenario 3	148
4.58	Voltage unbalance during high variability before and after BESS installation in Scenario 3	149

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	IEEE 4-bus test feeder system	179
B	OpenDSS codes for IEEE 4-bus test feeder	183
C	OpenDSS codes for modelled network located in Port Dickson Malaysia	184

LIST OF ABBREVIATIONS

ADMD	-	After Diversity Maximum Demand
BESS	-	Battery Energy Storage System
CI	-	Clearness Index
DG	-	Distributed Generation
EPRI	-	Electrical Power Research Institute
FiT	-	Feed in Tariff
GHI	-	Global Horizontal Irradiance
LF	-	Load Factor
LSSS	-	Large Scale Solar Schemes
LV	-	Low Voltage
LVUR	-	Line Voltage Unbalanced Rate
MATLAB	-	Matrix Laboratory
MDS	-	Main Distribution Substation
MV	-	Medium Voltage
NEM	-	Net Energy Metering
OpenDSS	-	Open Distribution System Simulator
PV	-	Photovoltaic
SEDA	-	Sustainable Energy Development Authority Malaysia
VI	-	Variability Index

LIST OF PUBLICATIONS

Journal

Zolkifri, N. I., Gan, C. K., Meysam, S., 2019. Performance Analysis of Malaysian Low Voltage Distribution Network under Different Solar Variability Days. Indonesian Journal of Electrical Engineering and Computer Science, 13(3), pp. 1152-1160. (Scopus-indexed)

Conference

Zolkifri, N. I., Gan, C. K., Khamis, A., Baharin, K. A., and Lada., M. Y., 2017. Impacts of Residential Solar Photovoltaic Systems on Voltage Unbalance and Network Losses. TENCON 2017 - 2017 IEEE Region 10 Conference, Penang. pp. 2150-2155.

CHAPTER 1

INTRODUCTION

1.1 Background

Electricity generate from non-renewable energy such as fossil fuel, coal, petroleum, and natural gas are the main reason which lead to the serious negative impacts on environment. Global warming, greenhouse gas emission, and acid rain are the main harmful effect of non-renewable energy to the environment (Abdelaziz EA. et. al., 2011). In line with technology development, more electricity is needed to accommodate the global demand. This situation become worse if human heavily depending on non-renewable energy and more power plant are required to be built. Thus, high-income nation such as Germany, Japan, and U.S. itself have encourage their researcher to find more initiative way in reducing the use of non-renewable energy. Renewable energy (RE) such as solar energy, wind energy, and hydro energy become one of rising technology in reducing the dependency of fossil fuel energy (Mekhilef S. et. al., 2011).

In Malaysia, there are various type of renewable energy such as solar PV, biogas, biomass, and hydroelectric. Based on the statistic by Sustainable Energy Development Authority (SEDA) Malaysia, annual power generation in 2017 by solar PV increase 34.68% from 316831.39MWh to 426700.90MWh which is the biggest RE power generation compared to the others RE (SEDA, 2018). Generally, solar system connection was divided into two categories which are stand-alone PV system and grid-tied PV system. The power produced by stand-alone PV system is more on direct usage or to be stored in storage systems (Remli et. al., 2015). It differs from grid-tied PV system where the surplus power from PV