Faculty of Electrical Engineering

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

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A thesis submitted
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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 :…….

Name : Nur Izzati binti Zolkifri

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 peruntukan 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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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