THE IMPACT OF PV LOCATION ON VOLTAGE PROFILE AND LINE LOSSES

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Dedicated to my beloved parents

Zainol Bin Ahmad and Zabidah binti Wahab

Siblings

Zakiah Binti Zainol

Zuraida Binti Zainol

and

All my friends in MEP programme and lecturers

for their support, encouragement

and

motivation through my journey of education

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ABSTRACT

In Malaysia, the most attracted renewable energy is Photovoltaic (PV) source since Malaysia having high exposure to the sun's rays through most days. Besides that, it considered being important in improving the security of energy supplies by decreasing the dependency on imported fossil fuel and reducing the emission of greenhouse gases. However, several factors like capacity and location of PV must be considered while planning the electric system also the location of PV can help reducing system losses. Too much power injected into the power system may cause voltage problem. This research proposed an index to optimize the location of PV by considering voltage profile and system losses. The proposed index is tested on modified 30 bus system. The result showed that the lowest index represent the optimal location of PV location. The combination of two or three PV generations at the optimal location help to improved the voltage profile and reduced system losses. However, the installation of PV at the random location showed less improvement in voltage profile and also in reduce system losses.

ABSTRAK

Di Malaysia, tenaga boleh diperbaharui yang paling mendapat perhatian adalah daripada sumber Photovoltaic (PV) memandangkan Malaysia terdedah kepada sinaran cahaya matahari yang tinggi hampir sepanjang hari. Selain daripada itu, ia dianggap penting dalam meningkatkan kawalan bekalan tenaga dengan mengurangkan kebergantungan kepada bahan api fosil yang di import serta mengurangkan pembebasan gas rumah hijau. Walaubagaimanapun, beberapa faktor seperti kapasiti dan lokasi PV perlu dipertimbangkan ketika merancang sistem elektrik memandangkan lokasi PV dapat membantu mengurangkan kehilangan kuasa dalam sistem. Terlalu banyak kuasa yang dibekalkan ke dalam sistem kuasa akan meyebabkan masalah voltan. Kajian ini mencadangkan index dalam mengoptimumkan lokasi PV dengan mengambil kira profil voltan dan juga kehilangan kuasa dalam sistem. Index yang dicadangkan ini diuji pada sistem 30 bas yang telah diubahsuai. Hasil menunjukkan bahawa index terendah mewakili lokasi PV yang paling optimum.Gabungan dua atau tiga penjana PV di lokasi yang optimum membantu memperbaiki profil voltan dan mengurangkan kehilangan kuasa dalam sistem. Walaubagaimanapun, pemasangan PV di lokasi secara rawak menunjukkan kurangnya peningkatan dalam profil voltan dan juga kehilangan kuasa dalam sistem.

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LIST OF ABBREVIATIONS

PV	-	Photovoltaic
RE	-	Renewable energy
Mid-scale	-	Medium scale
SREP	-	Small Renewable Energy Power Programme
TNB	-	Tenaga Nasional Berhad
TNB-ES	-	TNB Energy Service
KMB	-	Kumpulan Melaka Berhad
NPG	-	Nasional power grid
VLSPV	-	Very large scale PV
DG	-	Distributed generation
PD	-	Protection device
LV	-	Low voltage
MV	-	Medium voltage
SWIS	-	South-West Interconnected System
V PII	-	Voltage profile improvement index
Vmin	-	Minimum voltage
Vmax	-	Maximum voltage
Vnom	-	Nominal voltage
VP	-	Voltage profile
P	-	Power
V	-	Voltage
MW	-	Mega Watt
LLRI	-	Line losses reduction index
IVR	-	Voltage regulation index
I_{Ai}	-	Per-unit current in distribution line i

I_{Li}	-	Per-unit line current in distribution line I without DG
R_i	-	Line resistance for line i (pu/km)
D_i	-	i^{th} distribution line length (km)
M	-	Number of lines in the distribution system
BI	-	Distributed generation benefit index

LIST OF SYMBOLS

$f(\hat{Y})$	-	Objective function in the optimization procedure
$g_i(\hat{Y})$	-	i^{th} inequality constraint
$h_i(\hat{Y})$	-	i^{th} equality constraint
N_e	-	Number of equality constraints in case of primal-dual interior point OPF
N_{ie}	-	Number of inequality constraints in case of primal-dual interior point OPF

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Since the beginning of power system development, the electricity is supplied to the consumer in a model of bulk-power transmission system. As the technologies in power system improved, the traditional power system operating model seems to appear some disadvantages in terms of security and market price issues. Energy derived from the sun, the wind, the earth's heat, water and the sea has the potential to meet the world's electricity needs many times over, even allowing for fluctuations in supply and demand [1]. Unlike the conventional energy sources for example coal and oil, solar energy is characterized as free-fuel energy and free for air pollution. Solar energy is growing at double-digit rates worldwide and it will continue to do so in coming years across all its different applications (residential, in small and large building or in power plant) due to the rising fuel prices [2].

Rooftops PV or small- scale PV system is becoming more popular in residential network due to the increasing price of electricity and as well as benefit from the incentive and rebate provided by authorities. To encourage more renewable and green energy generations within the residential and distribution network,

government and utilities has provided various schemes so that PV owner is able to sell their excess electricity during peak hours. At present, the mid-scale PV systems are in practical use and the number is expected increase time to time [4]. However, for very large-scale PV system, there are many problem need to be consider including generation cost, the large capacity transmission from distance, large-scale solar energy storage etc.

1.1.1 Photovoltaic (PV) in Malaysia

Malaysia has been active in efforts to encourage adoption of renewable energy as evidenced in the 8th Malaysia Plan and later [17]. Renewable energy (RE) was targeted as the 'fifth fuel' that supplied the energy demand in in this country. The Small Renewable Energy Power Programme (SREP) was launched to allow independent producers of renewable power to connect to the distribution network and gain compensation for their energy generation [17].

Looking at the variety of options available in term of renewable energy sources for example wind, the earth's heat and sea, solar photovoltaic (PV) is evidently suited in Malaysia’s situation which is having high exposure to the sun's rays through most days.

Malaysia’s power utility company Tenaga Nasional Berhad (TNB) is responsible to centralize the power generation, transmission and distribution. TNB has decided to develop 5MW PV generation and it will connect to grid. After considering a certain issues, TNB Energy Service Sdn Bhd (TNB-ES), a wholly-owned subsidiary of TNB have decided to build 5MW in three phases over 18 months, 2MW-2MW-1MW in that order. The expected cost to build the solar farm is

between RM60 million and RM70 million. It will be located in the administrative capital of Putrajaya where the TNB's cycle 625MW power plant is opened.

Besides that, Malacca and Negeri Sembilan also build solar farm and the capacity are 5MWp and 8MW respectively. In Malacca, the solar farm was built at Melaka World Solar Valley in the Rembia Industrial Area, Alor Gajah while in Negeri Sembilan the location of PV farm is located at Cypark Suria, Palam, Negeri Sembilan.

On March 21, 2012 Malaysia largest solar park with the most number of solar panels was developed on a safely closed landfill in Pajam,Negeri Sembilan. This project officially launched by Prime Minister, Y.A.B Dato' Seri Mohd Najib bin Tun Haji Abdul Razak and Cypark Resources Berhad was a companies that responsible to developed this project. The 8MW Solar Park commenced construction in September 2011 and was completed within a four months period on 31 December 2011[16]. Figure 1.1 shown CyPark's solar power plant under construction, next to Pajam landfill.

Figure 1.1 Cypark's solar plant under construction, next to the Pajam landfill

The solar park have been installed the large number of solar panels (31,824) in the large area (41.73 acres) to generate 8MW capacity connected into grid. Cypark started exporting its energy into grid system and selling it to TNB on 28 March 2012. As a prediction, the project with utility scale is capable of producing about 11,712MW of energy annually for the next 21 years with annual sales value of more than RM 11 millions. Besides that, additional 5MW solar have been installed progressively in 2012. Figure 1.2 shows Cypark's solar farm 8MW, Negeri Sembilan.

Figure 1.2 Cypark's 8MW solar farm, Negeri Sembilan

In 2012, Kumpulan Melaka Berhad (KMB), which is wholly owned by Chief Minister Incorporated invested about RM46 million to build first solar farm in order to achieve the target to become a Green Technology City State in 2020. Solar photovoltaic (PV) farm has been built at Melaka World Solar Valley in the Rembia Industrial Area and the PV installation covered about 7,248.43 hectares. Figure 1.3 shows the launching of Melaka's first solar PV farm in 2012. The first solar farm capacity is 5MWp and the construction was divided in to 3 phases which are:

Phase 1: 1.3MW constructed in December 2012 and completed in April 2013
Phase 2: 1.22MW constructed in January 2013 and completed in May 2013
Phase 3: 2.48MW constructed in February 2013 and completed in August 2013

All the power generated from PV farm has been sold to Tenaga Nasional Berhad (TNB) and the electricity was channelled directly into national power grid (NPG).

Figure 1.3 Launching of Melaka's first solar PV farm in 2012 by Malacca Chief Minister, Datuk Seri Mohd Ali Rustam

In this year, Kumpulan Melaka Bhd already invested approximately RM20 million to build and operate its second solar farm. For second solar farm, the power that will be generated is 2MWp sprawled on 2.8 hectares

1.2 Problem Statement

The year 2012 brought improved access to modern energy services through the use of renewable [5]. Installation of renewable electricity in rural areas has increased with greater affordability, improved knowledge about local renewable resources, and more sophisticated technology applications.

Nonetheless, the lack of proper and precise study on network performance in solar based conditions brings unpredictability to network performance and characteristic. It happened in urban network whenever the integration of PV technology is accelerated. From research and analysis, the connection of PV systems to utility grids may cause several operational problems for distribution networks [6]. The severity of these problems directly depends on the location of the PV installation. The possible effect that PV may impose on distribution systems is fluctuation of voltage profile. Besides that, the impact of location also may drop the power capacity due to losses during transmitted.

1.3 Objectives

The objectives of this project are:

- To analyse the impact of PV location on system voltage profile and losses.
- To propose an index to determine the optimal location of PV generation in the system that considers the voltage profile and losses.

1.4 Significant of Study

Renewable energy already plays a major role in the energy mix in many countries around the world. In year 2012, prices for renewable energy technologies, primarily wind and solar, continued to fall making renewable increasing mainstream and competitive with conventional energy sources.

In the European Union, almost 70% of additions to electric capacity in 2012 generated from renewable energy, mostly from solar PV and wind power. In 2011 (the latest year for which data are available), renewable met 20.6% of the region's electricity consumption and 13.4% of gross final energy consumption [5].

Access to modern energy enables people to live better lives in good environment. To produce good power quality and also safety to utility and consumer, the impact of PV location in term of voltage profile and losses need to be study.

1.5 Scope of Project

For this project, the analysis is using the modified IEEE 30 bus system. PowerWorld 17 simulation software is used for analysis. The PV generation capacity injected is fixed to 10MWp and the system considered for medium voltage connected to grid. An index will be developed to determine the optimal location for PV installation that considers voltage profile and system losses.

1.6 Structure Organisation

This report is included of six chapters. The chapters are:

Chapter 1: Introduction about Photovoltaic (PV) power generation in general and Malaysia in specific.

Chapter 2: Literature Review which is review of journals, conference papers and thesis that related to topic of this research.

Chapter 3: Methodology explains about the steps had been taken to get voltage profile and losses from the simulation. From the result, index performances are developed and have been tested.

Chapter 4: Result and discussion which is represent the result of simulation and data have been analysis to see the performance.

Chapter 5: Conclusion and recommendations included the summaries of whole project and the recommended for future work.

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