UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

FEASIBILITY STUDIES AND SYSTEM PERFORMANCE OF 2 MW SOLAR PV PLANT AT UTeM

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In partial fulfilment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

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DECLARATION

I declare that this dissertation entitle “Feasibility Studies and System Performance of 2 MW Solar PV Plant at UTeM” is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ....

Name : …..

Date : ....

APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality for the award of Master of Electrical Engineering (Industrial Power).

Signature	:	....
Supervisor Name	:	…..
Date	:	....

DEDICATION

To my family who has supported me significantly, a special feeling of gratitude to my great parents Zohdi Abunima and Najwa Alswerke who have supported me through my life. I will always appreciate their sacrifices for me. Their encouragement had a main role in achieving my goals and wishes throughout my career. I am extremely proud of them.

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To my beloved country, Palestine, which has a special place in my heart. I don't forget my hero people who fights for freedom. I also dedicate this work to the 2142 martyrs who were killed in the last war in 2014.

ABSTRACT

Photovoltaic (PV) is becoming increasingly important as one of the most promising source of renewable energy to tackle climate change challenge. Four PV systems were installed in UTeM, namely polycrystalline, thin film, HIT, and monocrystalline with total capacity of 23.88 kW. In this regard, this research aims to evaluate the complete electrical design of a 2 MW grid-connected solar PV plant located in UTeM, Melaka. To achieve this, a site survey was carried out to inspect the installation site condition as well as the distance to the possible interconnection point. In addition, meteorological parameters were obtained from Meteonorm software. The existing PV systems in UTeM were used to export actual meteorological data at the proposed site. Subsequently, the PV modules orientation, array sizing, and cable sizing were determined based on the data obtained. Inverters and transformers for this PV plant were proposed and studied. The research highlights the key factors that affect the performance of solar PV power systems. Furthermore, the performance ratio and specific yield of the proposed plant were calculated to verify the plant design validity. Economic viability was also analyzed based on the system performance. It take into account the Feed-in Tariff (FiT) scheme. Financial models of the project were assessed and expressed as levelized cost of energy, simple pay back, internal rate of return, and present value of the net profit. The key findings suggest that the project has economic and environmental value which is socially beneficial to the community in Melaka state. The proposed solar PV plant is expected to generate an annual energy of approximately 2,395 MWh, with return on investment of 13.7%. Therefore, the proposed 2 MW solar PV power plant is technically and economically feasible.

ABSTRAK

Fotovolta (FV) menjadi semakin penting sebagai salah satu sumber tenaga boleh diperbaharui yang paling meyakinkan untuk menangani cabaran perubahan iklim. Empat sistem FV dipasang di UTeM iaitu Polycrystalline, Thin Film, HIT dan Monocrystalline dengan jumlah kapasiti sebanyak 23.88kW. Oleh yang demikian, kajian ini bertujuan untuk menilai rekabentuk elektrik lengkap loji kuasa 2 MW solar FV tersambung grid yang bertempat di UTeM Melaka. Untuk mencapai matlamat ini, kaji selidik tapak telah dilakukan untuk meninjau keadaan lokasi pemasangan serta jarak ke titik sambungan yang berkemungkinan. Di samping itu, data meteorological boleh diperolehi dari perisian Meteonorm. Sistem FV yang sedia ada di UTeM digunakan untuk mengambil data meteorologi di tapak. Seterusnya, orientasi modul FV, saiz kumpulan FV dan saiz kabel ditentukan berdasarkan data yang diperolehi. penyongsang dan alatubah yang digunakan untuk loji FV ini adalah dicadangkan dan seterusnya dikaji. Kajian ini memperlihatkan faktor-faktor utama yang memberi kesan kepada prestasi sistem kuasa solar FV. Selain itu, nisbah prestasi dan hasil spesifik loji yang dicadangkan akan dikira untuk mengesahkan kesahihan rekabentuk loji. Skema Feed-in Tariff (FiT) juga turut dianalisa. Model kewangan projek akan dinilai dan dinyatakan sebagai penyeragaman kos tenaga, pembayaran kembali, kadar pulangan dalaman dan nilai terkini untung bersih. Penemuan penting dalam kajian ini mencadangkan bahawa projek ini mempunyai nilai ekonomi dan alam sekitar yang secara sosialnya memberi manfaat kepada masyarakat di negeri Melaka. Loji solar FV yang dicadangkan ini dijangka akan menjana tenaga tahunan sebanyak kira-kira 2,395 MWj, dengan pulangan pelaburan sebanyak 13.7%. Oleh yang demikian, cadangan pembinaan loji kuasa 2 MW solar FV ini adalah sesuai dilaksanakan setelah mengambilkira faktor teknikal dan juga ekonomi.

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LIST OF ABBREVIATIONS

AC	Alternative Current
BOS	Balance of System
DC	Direct Current
FF	Fill Factor
FiT	Feed in Tariff
HIT	Heterojunction with intrinsic Thin Layer
IRR	Internal Rate of Return
KNUST	Kwame Nkrumah University of Science and Technology
LBS	Pounds (Weight Unit)
LCOE	Levelized Cost of Energy
MGTC	Malaysia Green Technology Corporation
NOCT	Nominal Operating Cell Temperature
NPV	Net Present Value
PR	Performance Ratio
PV	Photovoltaic
RE	Renewable Energy
RM	Malaysian Ringgit
ROI	Return on Investment
SEDA	Sustainable Energy Development Authority Malaysia
SGB	Starkstrom Gerätebau (High Current Equipment Manufacturing)
SPD	Surge Protection Device

STC	Standard Test Conditions
T	Metric Ton
TNB	Tenaga National Berhad
UTeM	Universiti Teknikal Malaysia Melaka

LIST OF PUBLICATIONS

[1] Abunima, H., Gan, C. K. and Nawawi, N., 2014. Preliminary Evaluation of 2 MW Solar PV Farm in Melaka. Power and Energy Conversion Symposium (PECS 2014). Melaka, 12 May 2014, UTeM.

CHAPTER 1

INTRODUCTION

1.1 Research Background

In recent years, the risks of traditional power resources have become more severe, which affect our lives. Matters such as depletion of natural sources, increase of the ratio of CO_2 in the air and climate change have made the need of new alternative sources of power more urgent than before. Most of the attentions now are directed toward renewable energy such as solar energy and wind energy. The average solar radiation which reaches earth's atmosphere is 1366 watts per square meter, and has an average solar power of 173000 TW striking the earth. Since sunshine is scattered and reflected after penetrating the atmosphere, the average solar radiation on the sea level on a clear day is approximately 1000 watts per square meter (Chen, & Kai, 2012). According to the consultation firm Enerdata, the world electricity consumption in 2013 was around 20,000 TWh (Enerdata, 2014). Approximately, 20000 TWh is needed to satisfy the world electricity demand which needs 36.5 billion PV panels with 15% efficiency, which occupies a land area of approximately 20 million acre.

Solar power has significant features which make it attractive as research subject for alternative energy. Although the cost of installing solar power system is greater than that of traditional power plant, the operating and maintenance costs of solar power plant are much less than that of traditional power generation. Moreover, solar power is environmentally friendly. As a result, many governments in the world have defined the exploitation of solar energy in a large scale, with the intention of identifying incentive program to guarantee continuous growth of the solar power in their country. For example, solar power production in Europe has gained more attention than in other countries. In 2007, the European Union set a target that 6% of the European Union electricity requirement will be produced using solar power by 2020, to meet the demand of 84.4 GW (Pearsal, 2011). The most productive country of solar power is Germany, which produces a major portion of its energy demand using solar power; and already met 6% of electricity consumption in 2012. At certain hours in 2012, the solar power plants contributed 40% of the power demand in Germany. Germany sets the target to reach the expected capacity of solar power in 2020 around 51.75 GW, meeting 7.4% of power needs (Appen *et al.*, 2013).

The peak electricity demand in west Malaysia is approximately 16,562 MW, in which 45.5% of the total energy is generated by TNB is using fuel gas, followed by coal at about 40.5%, and hydropower at around 11.7% and distillates 2.0% (TNB 2013).

Recently, solar power has been given more attention in Malaysia, which can be seen from the government subsidies and incentives dedicated to encourage PV installation. Malaysian government aimed for a significant step toward enhancing renewable energy in 2011 by issuing Renewable Energy Act 2011 (Tam, 2013). The Sustainable Energy Development Authority Malaysia (SEDA) was established under this Act to promote, stimulate, facilitate and develop sustainable energy. Some recommendations have been introduced such as policies of laws, promoting sustainable energy by introducing Feed-in Tariff law, and carrying out related researches, assessments, and studies. At the end of 2012, the total renewable energy capacity connected to the Malaysia grid was 98.52 MW, in which 25 MW of them was produced by solar power (SEDA Report, 2012). The target for SEDA is a total expected renewable energy (RE) capacity of 2,065 MW by 2020, in which 175 MW of it will be produced by solar power. The expected targets of Renewable Energy development in Malaysia by 2050 are shown in Figure 1.1 (SEDA Action Plan, 2008).

The rising number of the MW-scale PV plant installations throughout the world has necessitate the development of methodology and techniques for the design of efficient PV plants. The PV plant design can significantly affect the performance of the harvested solar energy and the system's technical lifetime. Inaccurate design of solar plant may negatively affect the output power of the plant and pose danger to the solar plant equipment.

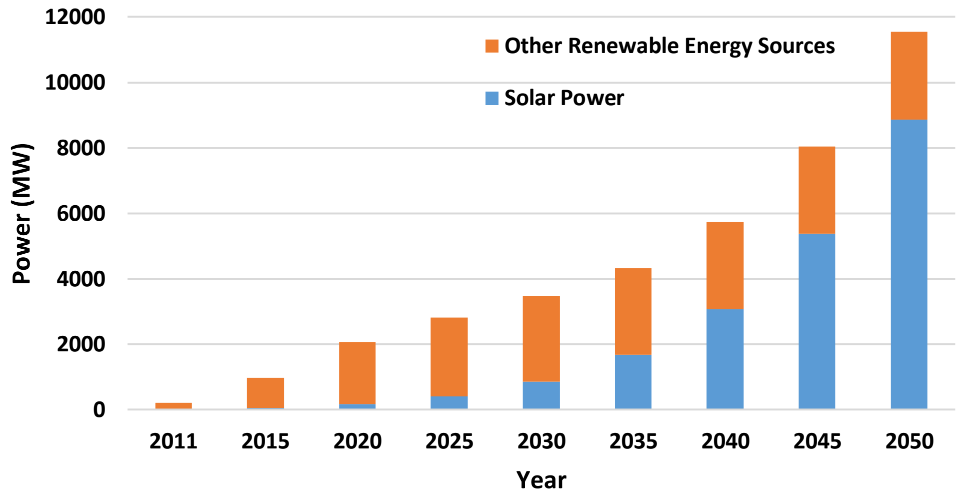

Figure 1.1 : The Expected Target of Renewable Energy Development by 2050

The PV applications can be divided generally into two categories; off-grid applications and grid-connected. Off-grid PV system is a system that is not connected with the utility grid, and it is considered a stand-alone system. This system normally contains storage unit to supply energy when needed, and it is used in small-scale applications.

Grid-connected PV system is a system that is connected to the utility power grid, and it supplies the power directly into the grid, so any onsite load is fed by combination of power generated by the PV system and the utility power grid. Grid-connected system does not require storage unit because no extra power after feeding the public grid (Kumi, & Hammond, 2013). The produced energy from the solar power system can be sold to the main grid under economic system which is normally called Feed-in Tariff. In this research, grid-connected system has been evaluated and verified of its possibility of achieving its target.

This dissertation presents evaluation and analysis on a 2 MW solar PV plant located in Melaka. Two types of PV module technology were considered, namely poly-crystalline and thin film modules. The study was conducted considering that the location of the plant (Melaka) has coordinates of 2.3° North latitude, 102.3° East longitude, and at altitude around