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OPTIMUM SIZING OF GRID CONNECTED PHOTOVOLTAIC SYSTEM UNDER TROPICAL CONDITION

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2017

“I hereby declare that I have read through this report entitle “Optimum Sizing of Grid Connected Photovoltaic (GCPV) System under Tropical Condition” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : ………………………………………………

Supervisor’s Name : Azhan bin Ab Rahman

Date : 2 June 2017

OPTIMUM SIZING OF GRID CONNECTED PHOTOVOLTAIC (GCPV) SYSTEM UNDER TROPICAL CONDITION

WAN NUR SYAHIRAH BT WAN MOHD KAMIL

A Report submitted in partial fulfilment of the requirements for the degree of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declared that this report entitle "Optimum Sizing of Grid Connected Photovoltaic (GCPV) System under Tropical Condition" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………………

Name : Wan Nur Syahirah bt Wan Mohd Kamil

Date : 2 June 2017

BISMILLAHIRRAHMANIRRAHIM

In the name of Allah, the most Beneficent, the most Merciful

My humble effort in which I dedicate to my sweet and loving Father and Mother

Wan Mohd Kamil bin Wan Ibrahim and Zainon bt Omar

Whose affection, love, encouragement and prays of days and night enables me to complete the writing of these thesis successfully

Along with hard working and respected

Supervisor

And not to forget, all my fellow friends

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ABSTRACT

Initial investment for Photovoltaic system is expensive. Therefore, meticulous planning on the financial investment is needed. Usually, 60% from the total installation PV system cost went to solar panel and around 15% to 20% goes to the inverter. Currently, there are still no written standard or guidelines available yet on the optimum sizing between the solar panel and the inverter. Therefore, this research aims to determine the most optimum sizing ratio between solar panel and the inverter. To do so, an average of one year tilted irradiance and back panel temperature data are collected. Then, the collected data is simulated by PV simulator which is set at different sizing ratio which are 1:0.7, 1:0.8, 1:0.9, 1:1, 1.1.1, 1:1.2. The results show that the most optimum sizing ratio between solar panel and inverter is at 1:0.8. In terms of financial impact, this ratio shows that it saves cost around 4% for each 4kW system and will be greater if the PV system is expanded up to GigaWatts of size. Furthermore, this ratio also has the highest efficiency if compared to other ratios. When compare to 1:1 ratio, 1:0.8 ratio is higher in efficiency at 0.68%. This is due to the finding that at 20% smaller size than the panel, the inverter operated the closes to its full potential under tropical climate condition.

ABSTRAK

Pelaburan awal untuk sistem photovoltaic adalah mahal. Oleh itu, perancangan yang teliti terhadap kos pelaburan adalah diperlukan. Kebiasaannya, 60% daripada jumlah kos pemasangan sistem PV terdiri daripada panel dan kira-kira 15% hingga 20% terdiri daripada penyongsang. Sehingga kini, tiada garis panduan mahupun standard bertulis bagi nisbah optimum antara solar panel dan juga penyongsang. Oleh itu, kajian ini bertujuan untuk menentukan nisbah optimum diantara panel solar dan penyongsang. Untuk berbuat demikian, purata setahun bagi sinaran condong dan suhu belakang panel dikumpulkan. Kemudian, data yang dikumpul disimulasikan dengan simulator PV yang ditetapkan pada nisbah saiz yang berbeza iaitu 1:0.7, 1:0.8, 1:0.9, 1:1, 1:1.1, 1:1.2. Keputusan menunjukkan bahawa nisbah saiz yang paling optimum antara panel solar dan penyongsang adalah pada nisbah 1:0.8. Dari segi kesan kewangan, nisbah ini menunjukkan bahawa ia dapat menjimatkan kos kira-kira 4% bagi setiap sistem 4kW dan akan lebih tinggi penjimatan jika sistem PV dibesarkan sehinggan saiz gigawatt. Tambahan pula, nisbah ini juga mempunyai kecekapan tertinggi jika dibandingkan dengan nisbah yang lain. Apabila dibandingkan dengan nisbah 1:1, kecekapan nisbah 1:0.8 adalah 0.68% lebih tinggi. Ini adalah kerana keputusan bahawa pada saiz 20% lebih kecil daripada panel, penyongsang akan beroperasi pada tahap hampir maksimum keadaan iklim tropika.

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AC	-	Alternating Current
BIPV	-	Building Integrated Photovoltaic
BOS	-	Balance of System
CCC	-	China Compulsory Code
CSP	-	Concentrated Solar Power
DC	-	Direct Current
FiT	-	Feed-in-Tariff
GCPV	-	Grid Connected Photovoltaic
HIT	-	Heterojunction with Intrinsic Thin-layer
MPPT	-	Maximum Power Point Tracking
NEC	-	National Electrical Code
PV	-	Photovoltaic
ROI	-	Return of Investment
RTD	-	Real Time Display
SAPV	-	Stand Alone Photovoltaic
SEDA	-	Sustainable Energy Development Authority
SPD	-	Surge Protection Device
STC	-	Standard Test Condition

CHAPTER 1

INTRODUCTION

1.0 Introduction

By 2050, electrical energy supplies are targeted to multiply with a specific end goal to take care of energy demand of all household [1]. Fossil fuel sources like normal gas, coal, hydro and oil are some of the constrained normal sources which are expected to deplete in the future. Day by day, fossil fuel looked for from place to another. In the event that this procedure is proceeds with, these sources will become less and exclusive [2]. Based on Figure 1.1, According to National Energy Policy (1979), Malaysia aims to have a safe and ecological feasible supply as well as effective and clean use of energy in the future [3]. In order to fulfil this energy policy, in the year 1999 Malaysia has adopted the Five-Fuel Diversification Strategy as shown in Figure 1.1. This strategy adds a new source which is a renewable energy. The goal of this policy is to empower the use of renewable energy and to have a proficient and clean usage of energy [3] [4] .

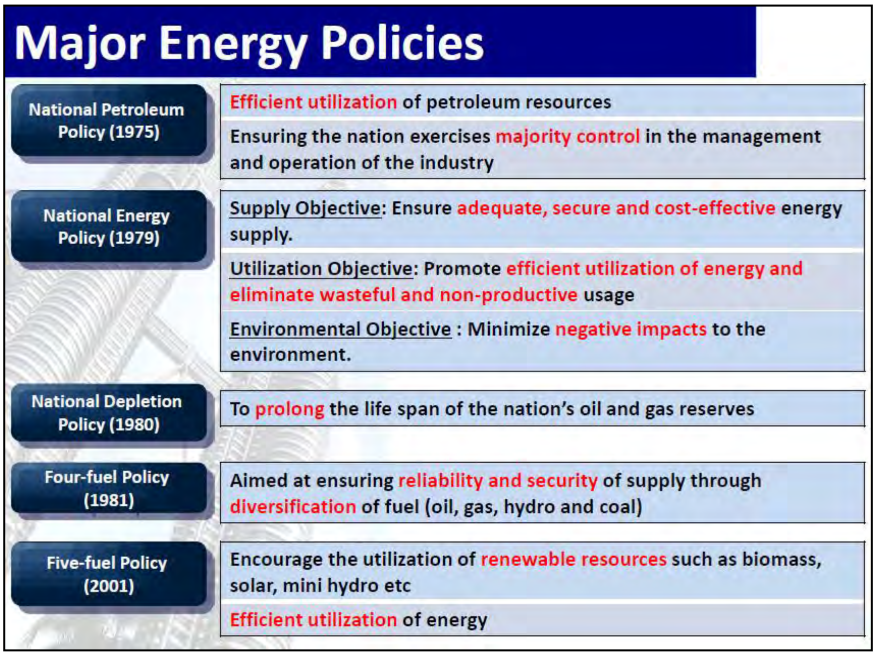

Figure 1.1: Energy Policies in Peninsular Malaysia and Sabah by KETTHA [3]

Renewable energy advancements can deliver reasonable and clean energy from their sources. Renewable sources which are commonly used are biomass which includes wood waste, municipal solid waste and biogas, hydropower, geothermal, wind and solar [5]. Solar energy is the most famous renewable energy among others in Malaysia. There are two main types of solar energy namely photovoltaic (PV) and concentrated solar power (CSP). Malaysia is likely the most acquainted with photovoltaic which is used by panels. For CSP innovations, regularly it will be utilized as a part of the vast power plant and is not proper for private utilize [6]. The reason why people are attracted to solar compared to other renewable sources is because it is free from pollution and placed near to the equator. As Malaysia is close to the equator, it receives 4,000 to 5,000 watt-per hour per square metre per day which is equivalent to sufficient energy from the sun to generate 11 years' worth of electricity.

1.1 Motivation

The motivation of this research is to make sure the customers who are interested to invest in solar energy to get the correct Return of Investment (ROI) for their investment. This research aims to reduce the installation cost of the solar system in addition to maintain the system efficiency. FITs is the one of the strategies to advance more prominent utilization of renewable energy in Malaysia. This strategy also allows user to sell the sources generated by renewable energy to the power utilities at a fixed premium price [7]. Figure 1.2 shows the simple operation of Feed-in Tariff in residential. First and foremost the solar panel generates DC electricity from the sunlight, and then the inverter converts DC-AC electricity for the own use. Besides, the meter is used to measure the amount of electricity generated from the solar system. The system is connected to utility grid to export the energy generated from the solar system [8].

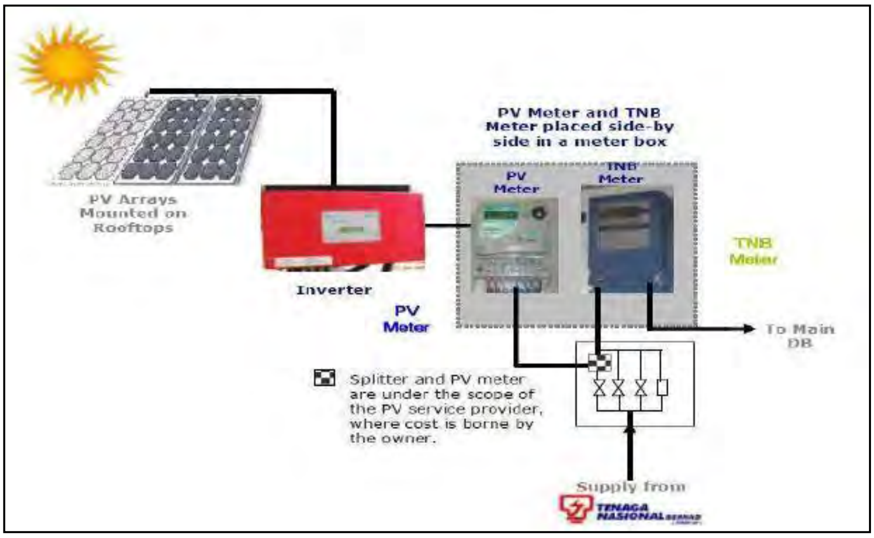

Figure 1.2: Simple Operation Using Feed-In Tariff in Residential [9]

By utilizing FITs, the client can make profits as well as making the investment. This is because if client is eligible to produce renewable energy, the energy is allowed to be sold to national security grid [10]. Figure 1.3 below shows the Feed-In Tariff rates for solar PV in 2013 and 2014 provided by Sustainable Energy Development Authority Malaysia (SEDA). By installing 4kW capacity of solar system, the income is generated as shown below:

INCOME = (RM 1.0411 + RM 0.2201+ RM 0.2116+ RM 0.0300+ RM 0.0100) × 4kW × 4.5 hour × 30 days = RM 816.912 per month (1.1)

This program is known as the world's best strategy to implement the quick improvement of renewable energy besides creating an expansive and growing base of jobs and salary for the people involved.

FiT Rates for Solar PV (21 years from FiT Commencement Date)

Description of Qualifying Renewable Energy Installation	FiT Rates (RM per kWh)	
(a) Basic FiT rates having installed capacity of :	2013	2014
(i) up to and including 4kW	1.1316	1.0411
(ii) above 4kW and up to and including 24kW	1.1040	1.0157
(iii) above 24kW and up to and including 72kW	0.9440	0.7552
(iv) above 72kW and up to and including 1MW	0.9120	0.7296
(v) above 1MW and up to and including 10MW	0.7600	0.6080
(vi) above 10MW and up to and including 30MW	0.6800	0.5440
(b) Bonus FiT rates having the following criteria (one or more) :	2013	2014
(i) use as installation in buildings or building structures	+0.2392	+0.2201
(ii) use as building materials	+0.2300	+0.2116
(iii) use of locally manufactured or assembled solar PV modules	+0.0300	+0.0300
(iv) use of locally manufactured or assembled solar inverters	+0.0100	+0.0100

Malaysia's Solar PV Feed-in Tariffs. *Source: SEDA*

Figure 1.3: Feed-In Tariff rates for solar PV on 2013 and 2014 [10].

1.2 Problem Statement

These days, the utilization of sun powered energy has increased. Still, not all individuals can possess this sunlight based PV framework because of its exorbitant establishment cost. The establishment of sunlight based PV framework is very costly toward the start. However, in the event that considering the benefit offered by Malaysia Feed-In Tariff program in the long term, the arrival must be ideal to the clients. According to thestar.com on 24 February 2014, the installation cost for complete system of 4kWp solar PV system costs around RM 40,000 compared to 50,000 to 60,000 on the year before 2014[11].

For a complete PV system, 60% from the total cost goes to the panel and around 15% to 20% goes to the inverter and the rest goes to Balance of system (BOS) which includes all other components that make the system provide the desired effect. Some of the examples of BOS are cables, breakers, protection device like SPD and fuses. The panel output power is not exactly the same to the output rated power. This is because photovoltaic PV system output depends on the environmental factors such as temperature and irradiance. The best condition to have a maximum output is at the Standard Test Condition (STC) in which the cell temperature is 25˚C, irradiance is 1000 W/m^2 and the air mass is 1.5 spectrums. In Malaysia climate, six out of more than 10 hours in a day receive direct sunlight with the irradiation between 800 W/m^2 and 1000 W/m^2 [12]. This is one of the factors which led the output of the panel, not to be at its maximum level. Since the panel output is not exactly the same to the rated output power, an inverter can undersize based on the panel output power. Under-sizing the inverter will not only result in the maximum performance of the system but can also reduce the cost [13]. Hence, the sizing ratio between panel and inverter needs to be optimized in order to deliver the maximum amount of energy at the lowest possible system cost.

Nowadays, in Malaysia there is no written standard for the optimum sizing between solar panel and inverter. Therefore, this research carries out a guideline so the optimum sizing ratio between solar panel and inverter can be achieved specifically for the requirement in the tropical condition.

1.3 Objectives

- To determine the average of one year profile of the tilted irradiance and back module temperature for Malaysia (to be used as raw data for GCPV system simulation).
- To perform simulations of GCPV system using DC Simulator to determine the optimum sizing ratio.
- To determine the most optimum sizing ratio of GCPV system between panels and inverters for the practice in the tropical climate condition.

1.4 Scope

- The study focuses on the optimum sizing of CGPV system under a tropical condition.
- The data sampling size used is based on five minutes average collected from the data in Malaysia from January to December 2014.
- The inverter tested is SB 3000HF and this experiment is carried out to determine the AC power, DC power and the efficiency.
- The tested ratios between panels and inverter in this experiment are 1:0.7, 1:0.8, 1:0.9, 1:10, 1:11 and 1:12.