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DETERMNATION OF WEIGHTED EFFICIENCY EQUATION FOR SB3000HF INVERTER

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DETERMINATION OF WEIGHTED EFFICIENCY EQUATION FOR SB3000HF INVERTER

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This report is submitted in Partial fulfilment of Requirement for the Degree of Bachelor in Electrical Engineering (Power Industry)

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ABSTRACT

System yield is a mechanism used to predict the Return of Investment before installed the solar PV and also to estimate the customer profit. Inverter efficiency is one of the important elements in order to calculate system yield. However, Peak inverter efficiency was used and it is inaccurate because it only occurs at ideal condition of Standard Test Condition and this condition rarely achieved so it's not reliable to use. Thus, a better representation is weighted efficiency such as European efficiency and California Energy Commission (CEC) efficiency because weighted efficiency takes into account the inverter will behave in complete daily profile of irradiance. Anyhow European efficiency is most suitable for medium irradiation region and CEC efficiency for high irradiation region. Tropical Climate is unique, hence, this project aimed at developing a Tropical efficiency equation according to IEC 61683 standards. To do so a one year irradiance, G and temperature, T data of Malaysia was used and simulated by using PV simulator on SB3000HF inverter. The result shows that the tropical efficiency match the real system yield and the best in terms of validation if compared to Euro efficiency and CEC efficiency. This project also suggests an alternative method to produce Tropical Efficiency equation that is by using Multiple Linear Regression. The correctness of the alternative method was justified since that Coefficient of determination with the conventional method gives a value of more than 0.9.

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ABSTRAK

Sistem hasil adalah satu mekanisme yang digunakan untuk meramalkan Return of Investment sebelum dipasang PV solar dan juga untuk menganggarkan keuntungan pelanggan. kecekapan penyongsang adalah salah satu elemen penting untuk mengira hasil sistem. Walau bagaimanapun, kecekapan inverter Peak telah digunakan dan ia tidak tepat kerana ia hanya berlaku pada keadaan yang ideal bagi Standard Keadaan Ujian dan keadaan ini jarang dicapai supaya ia tidak boleh dipercayai untuk digunakan. Oleh itu, perwakilan yang lebih baik berwajaran kecekapan seperti kecekapan Eropah dan kecekapan California Suruhanjaya Tenaga (CEC) kerana kecekapan wajaran mengambil kira inverter akan berkelakuan dalam profil harian lengkap sinaran. Bagaimanapun kecekapan Eropah adalah yang paling sesuai untuk rantau penyinaran sederhana dan kecekapan CEC bagi rantau penyinaran tinggi. Iklim tropika adalah unik, dengan itu, projek ini bertujuan membangunkan satu persamaan kecekapan tropika mengikut IEC 61.683 taraf. Untuk berbuat demikian yang sinaran satu tahun, G dan suhu, data T dari Malaysia telah digunakan dan simulasi dengan menggunakan PV simulator pada SB3000HF inverter. Hasilnya menunjukkan bahawa kecekapan tropika sepadan hasil sistem sebenar dan yang terbaik dari segi pengesahan jika dibandingkan dengan kecekapan Euro dan kecekapan CEC. Projek ini juga mencadangkan kaedah alternatif untuk menghasilkan persamaan Kecekapan Tropical iaitu dengan menggunakan Multiple Linear Regression. Ketepatan kaedah alternatif adalah wajar kerana yang Pekali penentuan dengan kaedah konvensional memberikan nilai lebih daripada 0.9.

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LIST OF ABBREVIATIONS

AC	-	Alternating current
BIPV	-	Building integrated photovoltaic
CO_2	-	Carbon Dioxide
FiT	-	Feed in Tariff
GCPV	-	Grid connected photovoltaic
MPPT	-	Maximum Power Point Tracker
PR	-	Performance ratio
PV	-	Photovoltaic
RM	-	Ringgit Malaysia
ROI	-	Return on investment
RSM	-	Response Surface Methodology
SEDA	-	Sustainable Energy Development Authority
STC	-	Standard Test Condition
S.Y	-	System Yield
TNB	-	Tenaga Nasional Berhad

CHAPTER 1

INTRODUCTION

Nowadays, the world has been suffered from energy crisis. Energy crisis occurs due to the world's demand on the limited natural resources. Energy sources have been consumed for power generation of power plants. Before 1980's, Malaysia Government energy sector are mainly dependent on fossil fuels such as coal, oil and natural gas [1]. However, the usage of fossil fuels has contribute negative environment impact such as greenhouse gas problem and carbon dioxide emission [2]. Moreover, these natural resources are in limited supply and diminishing as demand rises. Due to the crisis, government has give incentives and concern to make the use of renewable resources as alternative energy to overcome the global problem. The energy crisis is something that is getting worse despite the many efforts and measures undertaken [3].

Renewable energy source has become a necessary energy sources and play a crucial role in achieving the goal of sustainable development [4]. Hence, it is also as important role to reduce the CO_2 emission that contributes by the fossil fuels [5]. Renewable energy sources are natural processes that are continuously renewed. This energy resource includes wind energy, hydro power, solar power energy and biomass energy which are producing clean and environmental friendly. Firstly, wind energy is energy resources that have zero emission and without fuel cost which is constantly distributes the energy. Hydropower energy is one of sources energy which uses energy of moving water to generate electricity [6]. Besides that, its process so environmentally way to gain electricity by the flowing water and has no any chemical or fuel cost. The process of hydropower based on simple concept. The flowing water turns the turbine works and its spin the generator so its produce the electricity [7]. While biomass energy is energy produced from plant materials such as wood and waste wood, leaves of plants, and agricultural waste. Its generate electrical power by burning biomass and the process will generate the emission likes the fossil fuels However, burning of fossil fuels has captured the carbon dioxide emission out the air. Besides, renewable energy sources are providing good solution to overcome the energy crisis [8]. However, due to Malaysia is located at the equatorial region and highly potential to receive good level of sunshine throughout the year, making it ideal place for application of solar energy.

Today, Solar Photovoltaic (PV) energy has become the most demand of energy sources among renewable sources. It is expected that it will the most important and significant renewable energy source until 2040 [9]. It is one of the renewable green energy that generates electricity in very clean, quiet, and re-usable. Moreover, solar power also generates great optimism energy in researchers [10]. Figure 1.1 shows the amount of energy produced by PV inverter depends on the sunlight produced. When the sunlight strikes directly to the solar, conversion of light into electricity occurred at the atomic level. The solar cell captured the neutron and generates electricity. Also, Solar Photovoltaic (PV) offers no noise and their operation cost is low. This is because PV modules absorbs the radiation from sun and converts them into electricity.

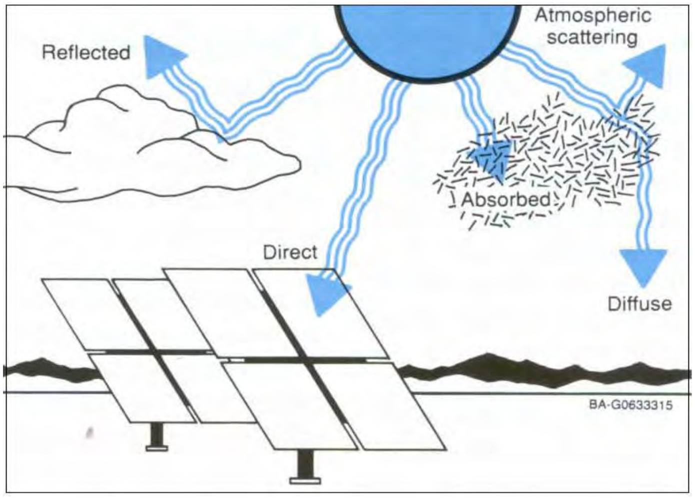

Figure 1. 1: How solar PV generates energy from the sun

However, solar photovoltaic (PV) energy is one of among renewable sources that promising the alternatives for the composition of a new energy in the world nowadays. It is expected that solar photovoltaic (PV) will be the important of renewable energy sources to the world until 2040 [9] . The conversion of solar energy to electrical energy shows that PV cells have better efficiency, longer lifespan and cheaper than others.

1.1 Motivation

Solar photovoltaic (PV) has set foot in Malaysia since 1980s with the purpose of providing electricity to rural areas. In 1998, an initiative given by Tenaga Nasional Berhad (TNB) to set up the grid connected PV system for national power utility which was inspired by the success of Japanese Sunshine Programs [6]. Solar Photovoltaic (PV) system is one of the most numerous throughout the Earth's surface and very simple of implementations. However, to ensure the system efficient, secure and environmentally sustainable supplies energy, Malaysia was developed National Energy Policy in 1979.

National Energy Policy was developed with long term objectives and guidelines to ensure efficient, secure and clean supplies energy. Not just that, it is the main policy in Malaysia in governs energy sector under Prime Minister's Department [7]. Development of national energy policy has opened up advantages of opportunities to renewable energy conservation. This growth enables of secure, affordable and reliable electricity sector in Malaysia.

However, National Renewable Energy Policy and Action Plan (2009) have a vision to enhance the utilization of indigenous renewable energy resources to contribute towards national electricity supply and sustainable socioeconomic development in Malaysia. By then, it has attracted many users towards renewable energy especially solar photovoltaic energy. Besides that, the Feed-in Tariff (FiT) has been implementing by Sustainable Energy Development Authority (SEDA) set quality prices for electricity generated from the renewable sources. It is crucial in ensuring the Mechanism Fit-in Tariff successfully implemented in Malaysia. Among of the main function of SEDA are to encourages and implementation of national policies for renewable energy. SEDA also monitor and review the Feed-in Tariff system so that it is compatible with the requirements of time and economy.

The introduction of Feed-in Tariff mechanism gives a good investment of renewable energy by the private sector or individuals. SEDA will constantly monitor the progress of each developer to make sure their project successfully. Figure 1.2 shows the fixed rate to the electricity for community for every kilowatt hour (kWh) of electricity generated and exported to the grid. The rate is provided under Fit as an incentive to the community to join of renewable green and clean energy. This rate is provided at a premium over the electricity rate that TNB (Tenaga Nasional Bhd) will pay for it according the latest rate. TNB will pay the current price for each day.

Description of Qualifying Renewable Energy Installation	FiT Rates (RM per kWh)
(a) Basic FiT rates having installed capacity of :	01-JAN-2016 ▼
(i) up to and including 4kW	0.8249
(ii) above 4kW and up to and including 24kW	0.8048
(iii) above 24kW and up to and including 72kW	0.6139
(i) up to and including 4kW	0.9166
(ii) above 4kW and up to and including 24kW	0.8942
(iii) above 24kW and up to and including 72kW	0.7646
(i) up to and including 4kW	0.9166
(ii) above 4kW and up to and including 24kW	0.8942
(iii) above 24kW and up to and including 72kW	0.7222
(i) up to and including 4kW	1.0184
(ii) above 4kW and up to and including 24kW	0.9936

Figure 1. 2: Fit rates for Solar PV (community) by SEDA [7]

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For example, the seller generates a power of 4kW for every day while the current price according to FiT is 0.8249 RM/kWh and according to a study by the SEDA, an average "peak sun hours" ranging about 4-6 hours per day for good production and t is average about 5 hours per day only. So it will be calculated as the following:

Power generate = 4kW

Current rate RM/kWh = RM 0.8249

Peak Sun Hours = 5 hours

= (Power generate x Rate RM/kWh x Peak Sun Hour)

$1\text{ kW} \times 4 \times 0.8249\text{ RM/kWh} \times 5\text{h}$ = RM 16.498/ day

So, for 30 day it will be RM 16.498 X 30 = RM 494.94/month

Since the FiT rate is higher than normally rate of electricity of TNB, it makes senses that this is a good investment since we can make some profit of selling the electricity generated from our PV panels to TNB.

1.2 Problem Statement

Inverter efficiency is one of the elements that have a crucial influence on the Performance Ratio of Photovoltaic (PV) plant and System Yield (S.Y) calculation to predict the Return of Investment for install PV. It can be simply that the higher the efficiency of the Photovoltaic (PV) inverters, the higher the Performance Ratio (P.R). The performance ratio is used commonly to access the quality installation on a daily, monthly or annually reported. It can be expressed in percentage by using this formula:

$$PR = \frac{Y_F}{Y_R} \tag{1.1}$$

While for the System yield, it is calculated by the following equation:

$$\mathrm{SY} = \mathrm{P_{array}} \times \mathrm{PSH_{period}} \times \mathrm{No\ of\ Days} \times \mathrm{Error} \times \mathrm{n_{inv}} \tag{1.2}$$

Where,

SY= PV yield of system (kWh)

Parray = power of the inverter

PSH_{period} = PSH value for the for the specified tilt angle over the period of interest

n_{inv}= inverter efficiency

The equation above shows that, inaccurate inverter efficiency value use will lead to inaccurate system yield, hence lead to misleading Return on Investment hence reduce the customer profit. Estimating the performance is very important to ensure the shortest Return on Investment (ROI). So, to ensure the shortest return-on-investment (ROI) as well as extending the lifetime of the system in good condition, estimating of the system performance is crucial and need to be considered [13]. The validity of existing efficiency formula is not accurate and not every country can use that formula. It is important because each country is very wide and there diverse climates between the states [9].

Furthermore, general rule of thumb in Europe where even 1% difference in inverter efficiency will lead 10% difference in price of Photovoltaic (PV) inverters. Even small differences of efficiency, it has a very large impact on the current price and at the same time affects the buyers [11]. For example, an inverter A with efficiency 94% would need to be 20% cheaper than inverter B with efficiency 96%. Its mean if inverter B cost about RM 10000, so inverter A should be RM 8000 only.

Besides that, different climate produce the different irradiation reading [12]. Climate determines the rate of degradation of the panel and the effect of temperature on efficiency. Also, Irradiation profile benchmark to irradiation region such as Europe regarded as benchmark for countries with medium irradiation level whereas California is regarded as benchmark for countries with high irradiance level. But there is no benchmarking yet for tropical climate. Thus, tropical climate should have its own PV inverter weighted efficiency equation. Since that climatic condition is known to have an effect on PV system performance, the research could be done in tropical climate.

1.3 Objectives

i. To determine the weighted efficiency equation of SB3000HF inverter by using a conventional method i.e. IEC 61683 standards as guideline.

ii. To determine the weighted efficiency equation of SB3000HF inverter by using an alternative scientific approach i.e. Multiple Linear Regression method.

iii. To compare the accuracy of the alternative with the conventional method

1.4 Scope

i. The inverter under study will only involve with the SB300HF.

ii. The raw data of irradiance for the simulation work will be gathered from UTeM's dedicated weather station from January 2014 to December 2014 of 5 minute sampling size.

iii. The Multiple Linear Regression method will be implemented by using MATLAB software.

iv. The accuracy of the alternative and conventional approach will be compared with R square method.

CHAPTER 2

LITERATURE REVIEW

2.1 PV System Configurations

There are two main configurations of PV system which are Grid-Connected Photovoltaic (GCPV) and Stand-Alone Photovoltaic (SAPV). Both configurations have their advantage and disadvantage in their application and uses. However, Stand-Alone Photovoltaic (SAPV) is preferable to be installed at rural area and in developing countries where the population is scattered. This system used the batteries and not connected to the power grid to store the power that generate by solar panel. In general, this system is an independent system and cannot maintain the energy supply when there is no enough sunlight unless energy storage is used. This system is much expansive than grid connected system since it used batteries.

While the Grid connected photovoltaic (GCPV) power system is actually a photovoltaic (PV) system which is connected to a utility grid. However, it is connected and supply power to a large independent grid. The panel of the grid is connected to inverter and main distribution for a complete system. Figure 2.1 shows the grid connected PV power system. In China, the solar PV will play as important role in power generation for their future energy supplied [13]. Grid-connected PV system usually applied conventional grid electricity is readily available in town or urban area [14]. There are two main types that related in grid connected photovoltaic system which are building integrated PV (BIPV) systems and terrestrial PV system. The generated electric power must be consumed within milliseconds of being generated at the scale of the entire interconnected electric power grid Not just that, GCPV system continued to be fastest growing in technology which is able to generate power with a 55% increase in cumulative installed capacity from 2.0 GW in 2004 to 3.1 GW [13].

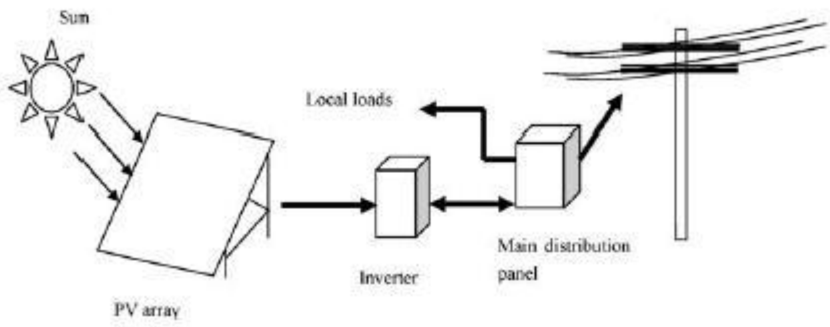

Figure 2. 1: Grid Connected PV power system [13]

Basically, grid-connected photovoltaic systems do not require battery system because it is connected to the grids which absorb the excess of electricity generated by the photovoltaic and export the electricity to the needed. Figure 2.2 shows the basic component of a grid-connected Photovoltaic (PV) system includes solar modules, metering, inverter and utility grid. The basic component of a grid-connected Photovoltaic (PV) system includes solar modules, metering, inverter and utility grid. Table 2.1 below shows the function of each component for GCPV system.

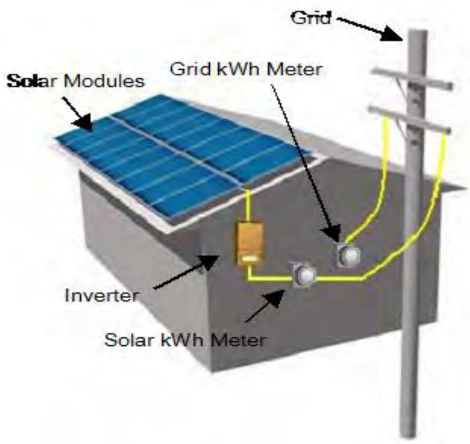

Figure 2. 2: The basic schematic GCPV system [15]

Table 2. 1: Specifications the basic component of the GCPV system

Component	Function
Solar photovoltaic Modules	Installed on the rooftop to generate DC power from sunlight
Inverter	DC power from the solar photovoltaic sent to the inverter and it is convert to alternating current (AC)
Metering	To record and monitor the PV electricity generated
Utility Grid	As interconnected network for delivering electricity from the supplier.

In general, the grid-connected Photovoltaic (PV) system can be categorized into two types which are Central grid connected PV system and Distributed grid PV system. The central grid system works when a large PV array is directly connected to the transmission line [14]. The range of this system installation can be as small as 50kWp up to 60MWp which has been succeed installed in Europe in recent years.

While distributed grid PV system is the system which is distributed through electricity grid. There are two types of distributed grid PV system which are commercial and residential system. Commercial system usually used more than 10kWp refers to those installed on factories, shopping centre and hospital and it is no excess power. While average residential is typically in range 4kWp – 5kWp refer to that installation on the rooftop. Basically, residential system is usually constructed as a Building Integrated Photovoltaic (BIPV) system because the PV modules is install as a part of the building itself. Moreover, GCPV system is a fastest technology in generating power with a 55% increase in cumulative installed capacity [13]

2.1.1 GCPV Inverter

Inverter technology is a key technology in which it has a security grid PV system. Inverter used to generate high-quality power to ac power with the low cost and it is a device which converts DC electrical energy into AC electrical energy [10]. The voltage generated from Photovoltaic (PV) array which is DC power is converted into AC power by using an inverter before delivered to the utility grid [16][14]. Inverter plays an important role in solar photovoltaic system. Hence, the inverters which used for GCPV system are diverse from other inverter that used in standalone PV system. It is also vary the output to match and synchronize with the utility AC, voltage and frequency. Besides that, output power from PV is varies according the meteorology of that location [17]. The grid inverter is different from a typical inverter because current drawn from the inverter is delivered to