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Photovoltaic systems for Malaysian islands: Effects of interest rates, diesel prices and load sizes

K.Y. Lau [a, *], C.W. Tan [b], A.H.M. Yatim [b]

[a] Institute of High Voltage and High Current, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
[b] Power Electronics and Drives Research Group, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

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ABSTRACT

Standalone diesel systems have been widely used on Malaysian islands due to the isolated locations of the islands. Nevertheless, the high diesel prices and the high cost of transporting diesel to islands cause the use of standalone diesel systems to be uneconomical. This study analyzes the feasibility of implementing PV (photovoltaic) systems as alternatives to standalone diesel systems by considering the effects of annual real interest rates, diesel prices and load sizes, using the HOMER (hybrid optimization of multiple energy resources) software. The results indicate that, at the ordinary diesel price of $ 0.61/L, low interest rates (0–3%) are desirable for the implementation of hybrid PV/diesel with battery systems over standalone diesel systems, regardless of the load sizes. Although different load sizes may affect the decisions on the implementation of PV systems at higher interest rates (6–9%), these effects become less pronounced as the price of diesel increases to $ 1.22/L or higher. Also, under high diesel prices, the choice of optimal system configurations obtained for small load sizes should be applicable for larger load sizes, albeit with different component ratings. Although the current study is intended for Malaysian islands, the findings can be generalized for other places with similar solar radiation levels.

1. Introduction

Malaysia, blessed with abundant natural resources, is surrounded by plenty of islands. According to the Department of Survey and Mapping, Malaysia, the country has a total of 878 islands [1]. The largest island of Malaysia comprises the states of Sabah and Sarawak, located at the Borneo – the third largest island in the world, shared with Brunei and Indonesia. Nevertheless, a vast number of Malaysian islands consists of minor islands (below 200 km^2) [2], and these minor islands are normally powered by standalone diesel systems due to their isolated locations from the central energy generation and distribution networks.

The use of standalone diesel systems on Malaysian islands did not raised much concern until the sudden surge of crude oil price worldwide, such as the one experienced in June 2008, which resulted in a massive increase of diesel prices in Malaysia. In that particular month, diesel prices rose $ 0.30/L and peaked at $ 0.78/L (based on the currency exchange rate of $ 1.00 = MYR 3.30) [3]. Although the prices eased to $ 0.61/L as of September 2014, the much higher diesel prices as compared with the past ($ 0.21/L as of October 2000) raises questions on the practicality of utilizing standalone diesel systems, especially in the long run.

In addition, the difficulties in transporting diesel to isolated islands add up the overall cost to the already burdened diesel price. For example, Perhentian Island, Tioman Island and Redang Island are located about 20 km, 32 km and 45 km off the coasts, respectively [4,5], and the distance could extend as far as 300 km off the coast for the case of Layang–Layang Island [6]. Considering the transportation costs, higher diesel prices on the islands as compared with ordinary consumer prices is inevitable, such as those also reported for remote villages [7,8]. These disfavored situations become more sophisticated during monsoon seasons, where high tides and rough seas may cause not only further increases in diesel prices due to the risks involved, but also disruption to the supply of diesel to the islands. Alternatives to standalone diesel systems are therefore crucial in securing continuous yet economical supply of electricity to the islands.

Being gifted with abundant sunshine, hence solar radiation, Malaysia has a huge potential in generating electricity using solar energy – a clean, reliable yet renewable energy source of power [9].

* Corresponding author.
E-mail address: kwanyiew@fke.utm.my (K.Y. Lau).

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According to Sarawak Energy [10], Malaysia received annual average daily solar radiation between 4.21 kWh/m^2/d and 5.56 kWh/m^2/d, and these numbers are considered appropriate for the installation of solar energy systems [11]. In fact, solar energy systems have been used to power residential and commercial areas in Malaysia, albeit not widely practiced. It is noteworthy that solar energy systems can be divided into two main categories: solar thermal application and PV (photovoltaic) technologies. Solar thermal is a technology where the heat from solar energy is harnessed for heating purposes, but we will focus on the latter, where the PV effects consist of the direct transformation of the solar radiation into direct current electricity via solar PV materials without the intermediate production of heat [12].

PV technology was introduced in Malaysia as early as 1980s to provide electricity for communication towers, oil and gas facilities, consumer electronics and some rural systems [13] – these were mainly standalone PV systems. The first implementations of grid-connected PV systems in Malaysia were made possible between 1998 and 2001 via the six pilot PV installation projects initiated by Tenaga Nasional Berhad (TNB) – the largest electricity utility company in Malaysia. These include the PV systems installed on the rooftops of the College of Engineering, Universiti Tenaga Nasional (3.15 kW), a BP petrol station along the KESAS highway (8 kW), the Solar Energy Research Park at Universiti Kebangsaan Malaysia (5.5 kW), and public residences in Port Dickson (3.15 kW), Shah Alam (3.24 kW) and Subang Jaya (2.8 kW) [14]. Although the installations and operations of these PV systems were not without challenges, they provided valuable first-hand practical experience for Malaysian on the use of PV that, as of 2005, there were about 470 kW on-grid and 3 MW off-grid PV systems installed in Malaysia [15].

The concept of powering islands using renewable energy is not entirely new and has been analyzed on many islands worldwide [16–18], including Malaysia [19,20]. As far as we were aware, most of the investigations were intended for specific islands, hence specific load sizes and interest rates. In this paper, we analyze the potential implementation of PV systems on nonspecific islands across Malaysia, using the NREL (National Renewable Energy Laboratory's) HOMER software. The use of non-specific islands enables us to vary the effects of annual real interest rates, diesel prices and load sizes, and determine their consequences in replacing or at least, reducing the sole dependence on diesel systems. This, we hope, will serve as a basis for policy makers in judging the feasibility of implementing renewable energy systems on islands in Malaysia before embarking more detailed analyses on an intended island.

2. Background information

2.1. HOMER software

HOMER is a computer model that assists the design of renewable micropower systems and facilitates the comparison of power generation technologies based on technical and economic merits [21]. The design options are available for both off-grid and grid-connected, small-scale or large-scale power systems. It was originally developed by the United State (US) National Renewable Energy Laboratory, but now licensed to HOMER Energy.

There are three main tasks that HOMER performs: simulation, optimization and sensitivity analysis. In the simulation process, HOMER models the performance of a micropower system and determines its technical feasibility and life-cycle cost. In the optimization process, HOMER simulates various system configurations to come out with the optimal system configuration – the one that satisfies the technical constraints at the lowest total NPC (net present cost). In the sensitivity analysis process, HOMER performs multiple optimizations under a range of input assumptions to account for changes or uncertainties in the model inputs. More information on HOMER software can be found in the literature [12].

2.2. Solar radiation

According to Sarawak Energy [10], Malaysia's annual average daily solar radiation ranges between 4.21 kWh/m^2/d and 5.56 kWh/m^2/d, with the highest solar radiation estimated at 6.8 kWh/m^2/d in August and November while the least solar radiation estimated at 0.61 kWh/m^2/d in December; the reported data are in line with the data provided by Malaysian Meteorological Department [22]. Although the numbers may be different for islands, comparisons of solar radiation data obtained from the NASA (National Aeronautics and Space Administrative) Langley Research Center Atmospheric Science Data Center Surface Meteorological and Solar Energy (SSE) web portal [23] show that the above numbers are appropriate for Malaysian islands. For example, the average solar radiation data for selected islands of different locations across Malaysia, such as Pangkor Island (4.2200 °N, 100.5550 °E), Redang Island (5.7750 °N, 103.0150 °E), Tioman Island (2.8167 °N, 104.1833 °E), Lankayan Island (6.5000 °N, 117.9167 °E) and Sipadan Island (4.1147 °N, 118.6288 °E) were found to be 5.11 kWh/m^2/d, 5.07 kWh/m^2/d, 5.21 kWh/m^2/d, 5.12 kWh/m^2/d and 4.98 kWh/m^2/d, respectively. Since these data do not vary significantly, a representative set of daily radiation data (and the clearness index) assuming the latitude 5° 46′ and the longitude 103° 0′ was generated using HOMER (see Fig. 1). This led to scaled annual average solar radiation of 5.16 kWh/m^2/d.

It is noteworthy that solar radiation data from ground stations are more accurate than satellite-derived values, but measurement uncertainties from calibration drift, operational uncertainties, or data gaps are often unknown for ground site data sets, even if they are available [23]. Moreover, ground station data are normally based on a one-year period. Since solar radiation is a random variable, similar with the case of wind speed, long-term meteorological data are desirable to describe the solar energy potential of the sites [24]. In this case, the data obtained from the SSE databases are reasonable, in which the SSE estimates were based on a 22-year period, and were compared with ground site data on a global basis. Also, according to NASA [23], the satellite and modeled based products have been shown to be accurate in providing reliable solar and meteorological resource data over regions where surface measurements are sparse or nonexistent.

Since measured hourly solar radiation data are seldom available, HOMER has to generate synthetic hourly solar data from monthly

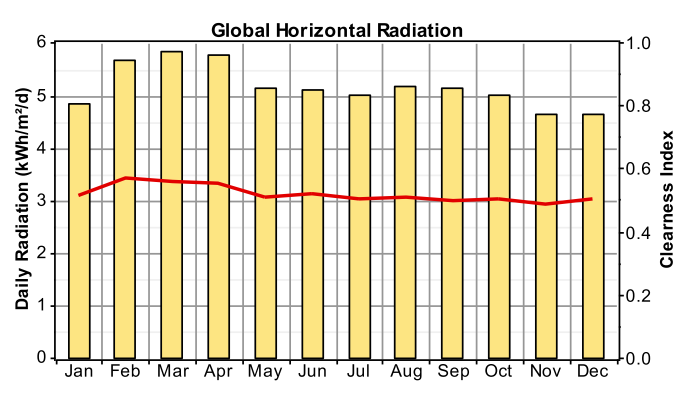

Fig. 1. Solar radiation data.