The prospect of implementing PV/diesel hybrid energy systems for rural electrification in eastern part of Malaysia

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Abstract— **In this study, an optimized design of a PV-diesel hybrid renewable energy system has been proposed to electrify remote locations in the eastern part of Malaysia, which are located far away from the grid. First, a brief review of energy status in the eastern part of Malaysia has been conducted, and then an illustration of the various electrification plans for remote locations in Sarawak has also been carried out. A review for a number of studies, each of them analyzing a certain configuration of a hybrid renewable energy system, has been also conducted. These studies were directed to supply certain applications located in remote areas. For the purpose of analysis and optimization, HOMER has been used where meteorological measured data for a few of Sarawak's remote locations have been utilized as inputs. The load profile being taken into account is for a typical household in these remote areas. Besides, the main scenario where the hybrid system consisted of PV panels and diesel generator as energy sources and battery bank as a storage media, HOMER has been also used to evaluate other scenarios. One of these scenarios is a standalone scenario, where the system consists of PV panels and a battery bank without backup source, whereas the other scenario is the diesel-alone system. It was found that the optimized scenario is a combination of various sources with a cost of energy (COE) production equal 0.214 $/kWh. In addition, a sensitivity analysis has been carried out to evaluate the effect of change of certain parameters on the COE production. Although the analysis in this study has been carried out for a location in Sarawak, the results can be generalized for any location with the same climatic conditions.**

Keywords— Hybrid system; Photovoltaic; Diesel generator; Battery bank; Renewable energy

I. INTRODUCTION

Finding adequate supply of clean and sustainable energy for remote areas is challenging. The global energy strategies have changed due to changes in energy prices, increasing energy consumption, and environmental concerns [1-4]. Renewable sources, such as solar, biomass, and wind, will be salient in the future in the implementation of combined energy technologies[5]. Hybrid Energy System (HES), as the name suggests, incorporate more than one type of power source [6-9]. Modern HES designed for village/rural electrification may appropriately combine almost all kinds of available renewable power sources. When several types of renewables are available, optimization is carried out to benefit from the best mix of available energy and reduction on the capital cost [10-16].

A. Renewable energy trends in eastern part of Malaysia-Sarawak

On average, Malaysia receives daily solar irradiation in the range 4.21 to 5.56 kWh/m^2, with around 12 hours of daily sunshine. Sarawak receives an average daily solar radiation equal to about 5.04 kWh/m^2 [17-18]. This makes the potential for using solar energy for electrification purposes very high.

In Malaysia, installation of PV systems has been expanded for remote areas, as PV systems offer clean, environmental friendly and secure energy [16, 19]. It has a simple operation, longer lifetime, high reliability, as well as low operation and maintenance costs [19]. These features make PV technology a viable solution for energy production for different applications. The wind energy potential in Malaysia is relatively low. The remote island, the east coast of Peninsular, and the north west of Sarawak and Sabah region have higher potentials for wind energy where a small number of turbines were installed [20-21]. There are around 50 rivers in Sarawak and Sabah combined. The average annual rainfall in Malaysia is around 2000 mm, and this makes the potential of hydropower in Malaysia in general, and in Sarawak in particular, quite high. The hydro power sources can be commercially utilized on a large scale in Malaysia [21].

B. Electrification plans for remote locations in Sarawak

In Malaysia, especially in Sarawak, there are still many remote villages without access to electricity. Referring to the Tenth Malaysia Plan, the percentage of the remote villages without electrification coverage was about 33% in 2009 [6]. It is very difficult and very expensive to extend the grid to these remote locations. Furthermore, around 809 schools are not full-time electrified, where most of them are located in both Sarawak and Sabah [21]. Malaysia target to reduce the uncovered locations drastically in both Sarawak and Sabah, and the focus will be on increasing renewable energy shares [6]. The government of Malaysia (through seventh to ninth Malaysia Plans) encourages the development of renewable energy applications; it has funded about 176 research projects for this purpose [22-23].