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Techno-economic analysis of hybrid system for rural electrification in Cambodia

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Abstract

In developing countries, shortage of electricity is the main obstacle for economic and social development. In Cambodia, isolated grid diesel-based systems are used for rural electrification. However, due to the cost fluctuation and carbon dioxide emission of diesel fuel, alternative power generation scenarios are needed to consider. This paper aims to investigate the optimum scenario of a hybrid system for supplying electricity to one remote district in Cambodia. Hybrid Optimization Model for Electric Renewables (HOMER) is used as a tool for techno-economic analysis. Three scenarios are considered in this study: diesel-only; diesel/PV; and diesel/PV with battery system. Results show that diesel/PV with battery is the optimum solution. This hybrid system comprises 13% of solar PV penetration with cost of electricity (COE) of $0.377/kWh. The initial capital cost and total net present cost (NPC) are $2,260,000 and $16,661,344, respectively. Furthermore, this system can reduce almost 720 tons/year of carbon dioxide if compared with conventional diesel-only scenario. Sensitivity analysis with variation of parameters such as diesel prices, component costs, real interest rates, as well as demand loads are also performed in the study.

Keywords: rural electrification; hybrid system; HOMER.

1. Introduction

Shortage of electricity is the main obstacle for economic and social development in many developing countries. Cambodia is one of the countries in Southeast Asia which suffered by war over decades. All sectors were damaged

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especially power utility. After war, due to the financial constraint, government of Cambodia has encouraged private sectors to invest on the power infrastructure. As of 2015, total energy generation from independent power producers (IPPs) was about 4,422 GWh, which accounted for 98.5% of the total domestic energy generation. On the other hand, Electricité Du Cambodge)EDC), the only state-owned electricity utility, was contributed only 16.82 GWh or 0.37% of the generation [1]. In remote areas, isolated grid diesel-based systems are still used to generate electricity. Since abundant of renewable resources are available throughout the country, integrated the resources into the power generation is an alternative approach for rural electrification.

HOMER (Hybrid Optimization of Multiple Energy Resources) is an optimization software for hybrid energy simulation. It is developed by American National Renewable Energy Laboratory (NREL) which aims to help users access with wide range of renewable energy options, in terms of different technical and economic manner. It can evaluate the design issue in the planning and decision making for many rural electrification projects. Three main tasks can conduct in the program: simulation, optimization, and sensitivity analysis [2].

Reviews of literature show that many studies of hybrid energy generation have been conducted around the world, such as in Canada [3], United Arab Emirates[4], Iran [5], India [6], Nigeria [7], Malaysia[8], and Thailand [9]. However, the research of techno-economic analysis in Cambodia's rural electrification is still limited. One study of hybrid system has been found for the case study of Cambodia. Sou, et al. [10] proposed a model of PV/biomass hybrid system for one rural village in Cambodia. The findings show that 90% of energy demand can be supplied by biomass gasification system, 3% by solar PV, and the rest 7% by batteries. It was concluded that the system can give the village a self-sufficient energy supply from imported conventional fuel.

However, due to the declining of solar PV panel, fluctuation cost and carbon dioxide emission of diesel fuel, alternative power generation scenarios are needed to consider for rural electrification. This paper aims to investigate the optimum scenario of a hybrid system for supplying electricity to remote community in Cambodia. Hybrid Optimization Model for Electric Renewables (HOMER) is used as a tool for techno-economic analysis. Sensitivity analysis with the variation of parameters such as diesel prices, component costs, real interest rates, as well as demand loads are also performed in the study.

2. Methodology

2.1. PV panel

The output power from solar PV panels can be determined by using equation (1) and the specification of module [4]. In this study, the model of PV panel is Suntech STP280-24/Vd. De-rating factor is a scaling factor applied to the PV array power output to account for the loss of power output in real operating world [2]. Ground reflectance and de-rating factor is assumed as 20% and 0.80, respectively.

$$P_{PV} = Y_{PV} f_{PV} (\frac{\overline{G_T}}{G_{T,STC}})[1 + \alpha_P (T_C - T_{C,STC})] \quad (1)$$

where P_{PV} is the rated capacity of the PV array or the power output under standard test conditions in kW; f_{PV} is the PV de-rating factor; $\overline{G_T}$ is the solar radiation incident on the PV array (kW/m^2); $G_{T,STC}$ is the incident radiation at standard test conditions (STC); α_P is the temperature coefficient of power (%/°C) for the selected PV panel; T_C is the PV cell temperature (°C), and $T_{C,STC}$ is the PV cell temperature under standard test conditions at 25 °C.

2.2. Net Present Cost and capital recovery factor

The total net present cost (NPC) of a system is the present value of all the costs that it incurs over its lifetime, minus the present value of all the revenue that it earns over its lifetime. Capital recovery factor (CRF) is a ratio used to calculate the present value of an annuity. According to Cambodia's national bank report [11], the average nominal interest rate in 2015 was 12.3%, while the inflation rate from World Bank[12] was 1.2%. Therefore, in this study, real interest rate is chosen as 11% associate with the project life time of 25 years. NPC and CRF can be calculated by using Eqs. (2) and (3), respectively: