Renewable Energy 36 (2011) 125–131

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

User acceptance of diesel/PV hybrid system in an island community

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ARTICLE INFO

Article history:
Received 25 January 2009
Accepted 7 June 2010
Available online 29 June 2010

Keywords:
PV hybrid system
Rural electrification
User satisfaction
Island electricity
Decentralized generation

ABSTRACT

This paper presents the results of a study conducted at a rural (island) community to understand the role of PV hybrid system installed on an island. Until 2004, most islanders had installed diesel generators in their homes to generate electricity, which was directly supplied to appliances or stored in the batteries for later use. A field survey was carried out to study the user satisfaction of the PV hybrid system in the island community. The attitude of islanders to the PV hybrid system was mostly positive. The islanders can use more electricity, the supply of which can meet the demand. A comparison of pollutions before and after installation of the PV hybrid system was made along with the interviews with the users. The data show that the users are highly satisfied with the PV hybrid system which can reduce environmental impact, especially air and noise pollutions. New opportunities as a result of access to electric service include studying and reading at night that were not possible earlier. All the islanders use the PV hybrid system and more importantly, no one found that the system made their life worse as compared to the earlier state of affairs.

1. Introduction

1.1. Role of renewable energy in rural electrification

After the oil crisis in the 1970s, utilization of renewable energy worldwide has increased considerably. In recent years, however, the environmental impacts due to the use of fossil fuel have become a major global concern. The population growth and increasing energy demand also pose greater stress on global energy supply and environment [1]. At the same time access to electricity and other modern energy services is also a serious concern.

Application of renewable energy technologies (RETs) for rural electrification has been increasing in recent years. Of the available RETs, photovoltaics (PV) is found to be promoted where it is uneconomical to extend the electric grid [2]. Rural electrification using off-grid renewable energy has emerged to be a suitable approach. Many programs have been implemented in various parts of the world – most of them are in the developing countries. Some studies show that these technologies can provide reliable and comparatively low cost electricity service [3,4]. In addition to supplying electricity to rural households, small industries, and other establishments, it also has the potential to reduce environmental pollution and create income generating activities [5].

1.2. PV hybrid system for rural electrification

The installed PV power reported by International Energy Agency (IEA) at the end of 2005 is 3.7 MW and 85% of this capacity has been by grid-connected application and the rest are by stand-alone systems in remote/rural areas. PV hybrid systems can be stand alone or in some instance is grid connected. PV hybrid systems provide a realistic alternative to diesel generators for electricity generation in off-grid areas. It has been demonstrated that hybrid energy system (renewable coupled with conventional energy sources) can significantly reduce the total life cycle cost of a stand-alone power supplies in many off-grid situations, while at the same time providing a reliable supply using a combination of energy sources [6].

PV hybrid systems have been installed across the world [7–11], and expanding renewable energy industry has now developed reliable and cost competitive systems using a variety of technologies. Though there are problems arising from an increased complexity of PV hybrid systems in comparison with single energy source [12], particularly, sizing and PV contribution to the load, application of PV hybrid system has the potential to meet the electricity needs of rural areas as these could provide electricity in a cost effective way. Earlier studies on PV hybrid systems have been focusing on modeling, system sizing and performance, while

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doi:10.1016/j.renene.2010.06.007

studies based on the experience in operating PV hybrid systems in the field are limited [13,14].

1.3. Social aspect addressed

The obstacle of PV and PV hybrid systems for electrification is due to the techniques of operation of the system. Research in the development of these systems focused on the performance analysis of demonstration systems and development of efficient power converters, such as bi-directional inverters, battery management unit (storage facilities), optimization of different sources of energy sources, etc. The user attitudes towards the hybrid system as the success of a renewable energy based rural electrification system are not generally available. A study has been carried out on a PV hybrid system installed in an island community to supply electricity to the villagers. This article presents the results of the study including how PV hybrid systems are perceived by users and their impressions on the system. Details regarding the survey carried out, questions asked and their responses are described.

2. Community background

Details regarding the community, earlier mode of electricity supply and a description of the installed PV hybrid system are discussed in this section.

2.1. Demographic profile

Kohjig is an island located in Chantaburi province on the eastern coast of Thailand (latitude 12°N, longitude 102°E) with a total area of 1.12 km^2. This site is located in the Gulf of Thailand, 4 km from the coast. The community has a population of 502 with 98 households.

The majority of the family primary income is derived from fisheries. A small number of families own land on the island with rubber plantations and some houses have small shops selling groceries to the local community. The occupation on the island is 80% fisheries, 12% rubber orchard, and 8% shops. Based on the field survey in November 2004, the average household income is 211,860 Baht/year.

2.2. Earlier mode of electricity supply

Electricity requirements of the island community were earlier (before September 2004) met by individual (household based) diesel generators (Fig. 1). Ninety-four diesel generators (capacities ranging from 5 to 20 hp) were used to supply electricity for lighting and operating TV during evening hours. Based on the survey before installation of the PV hybrid system (in 2002), typical household diesel consumption was about 5 L per night (including charging the battery).

The electrical load at the island was estimated based on the survey carried out in 2002, the island was estimated to have electricity requirements of 116 kWh/day [15]. The types, numbers capacity and the period of use in a day, of each electric appliance were used to calculate the daily electricity demand. Major electric appliances used are electric lamp, television and fan. More than 30% of electricity was consumed by electric light and about 25% of electricity was consumed by television. The islanders used electricity mostly during 4 h (18:00–22:00 h) in a day.

2.3. Lack of public infrastructure

The electricity supply to the public community infrastructure was lacking. For example,

- The community school had a 3 kW diesel generator, but this was rarely used as there was no budget for fuel and upkeeps. The teacher's residence relied on candles and kerosene lamps for lighting.
- Electricity for the health center was supplied by a 3 kW diesel generator, which consumed about 3 L per night. However, this system was also not in operation as there was no budget for repairs.
- There are two wooden jetties, approximately 100 m long and 1.5 m wide, but no lighting was equipped.

The temple was supplied electricity by an 8 kW diesel generator, which also provided street lighting adjacent to the temple and occasionally to the school.

2.4. PV hybrid system at Kohjig

The PV hybrid system was installed at Kohjig in September 2004 through the cooperation of King Mongkut's University Technology Thonburi (KMUTT), Kasetsart University and Mahidol University. The system installed consists of combinations of PV panels supplemented with battery storage system and a diesel generator. A design of the system was conducted using HOMER computerized assessment tool (version 2.19) developed by the National Renewable Energy Laboratory (NREL). The system is designed to match the pre-defined load and to minimize the operation of the diesel generator. The following assumptions have been made:

Fig. 1. Electricity supplied by diesel generators before the installation of the PV hybrid system.