Performance of a Modular Expandable AC-Couple PV Diesel Hybrid System in Thailand

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Abstract

This paper presents a study of the performance of a photovoltaic (PV) diesel hybrid system (PVHS) at the Energy Park of the School of Renewable Energy Technology (SERT), Naresuan University, Thailand. The system facility is a part of a cooperative program to develop PVHS in rural areas of Thailand. The implementation of the field test has successfully been done in the context of a research project. The PVHS installation based on the modular expandable AC-couple concept was developed by the Institut für Solare Energieversorgungstechnik (ISET), Germany. It has been proven to be an efficient operation for power supply systems. The evaluation of the system demonstrated that the final yield is about 3.46 kWh/kWp and the daily average energy produced by the diesel generator is 0.12 kWh/kW. The data shows the used energy produced by the PV is about 73%. The performance ratio of system is 64%.

Keywords: *Performance, PV diesel hybrid system, Modular expandable AC-couple*

1. Introduction

PV systems have been installed in Thailand by state agencies over the past 25 years. Electrification for rural areas by PV was first introduced in 1976 by the Ministry of Public Health and the Medical Volunteers Foundation to provide power to communication equipment in rural health stations. The next agencies that tried out PV technologies were the Electricity Generating Authority of Thailand (EGAT), the Telephone Organization of Thailand (TOT), the Ministry of Education (MOE), the Public Works Department (PWD) and Department of Alternative Energy Development and Efficiency (DEDE) [1]. The opportunity for PV in Thailand continues to be attractive, on the basis of strong government support and declining cost per watt peak installed. In addition, Thailand has fairly high solar energy potential (average 5 kWh/m^2.day) [2]. There are more than ten private companies in Thailand selling PV systems. At the end of 2009, the total capacity of PV systems installed in Thailand was estimated to be approximately 32 MW. Most of them (70%) are in remote areas and are for off-grid use, and the rest (30%) are for grid-connected systems. The types of PV applications vary base on the characteristics of the actual site, topography, climate and the needs of the user. PVHS is one application of PV that is suitable for a rural electrification system in remote areas or unelectrified villages. Presently in Thailand, only a small number of PVHS have been installed, but this trend is expected to increase in the future.

The modular expandable AC-couple PVHS in Thailand is installed at the Energy Park of the School of Renewable Energy Technology (SERT) at the Naresuan University in Phitsanulok. In the Energy Park around SERT various possibilities for the used of solar energy systems and other renewable energy systems are demonstrated. These can be examined by students and other interested people in order to fill the information gap regarding with Renewable Energies. As part of the Energy Park; PVHS, the demonstration of this power system has been installed and monitored. This monitored data has proved useful for validation of the hybrid system simulation tools being developed within the National Research Council of Thailand (NRCT) project [3,4]. In turn, these simulation tools, in combination with analysis of the data, have provided insight into the operation of the PVHS, and helped identify the strengths and weaknesses of the system. This paper presents an evaluation of the performance of this PVHS. The performance of the whole system is investigated. A discussion on the technical aspects has been presented and could be useful for future installations in Thailand.

2. PVHS descriptions

The PVHS is located at the Energy Park of SERT at the Naresuan University in Phitsanulok. Its coordinates are approximately latitude 16°47′N, longitude 100°16′E. The power system consists of the following components:

• A 2 kW PV array composed of one array. The array is mounted on the ground of the Energy Park. It contains 26 nominally 75 W BP Solar BP275 modules wired in 13 series 2 parallel strings. The array is oriented due south and at a 16º slope angle.

• A Honma 5GFLE 5 kW diesel genset.

• A battery bank of 30 cells in series with a nominal voltage of 60 V and capacity of 305 Ah. The cells are Exide OPzS 305.

• One grid-connected inverter. This a SMA Sunny Boy 1700E, 2.0 kW.

• A battery inverter, the SMA Sunny Island, 3.3 kW with 230 VAC output.

• Load breaker panels.

• A 3000 W variable load simulator, the variable load possible to operate a load from 10 – 3000 W and controlled by the timer system for loads profile setting.

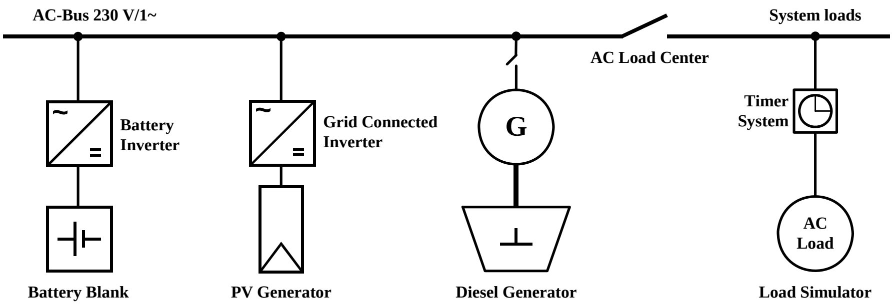

Fig. 1. Schematic of a Photovoltaic Diesel Hybrid System.

The components in a modular expandable AC-couple concept were developed by the ISET [5,6] shown schematically in Fig. 1. The arrays charge the battery and supply the AC loads through the grid- connected inverter. The battery supplies the AC loads when there is insufficient sunshine. Current from the battery and the array passes through the inverter to supply the AC loads, except on those rare occasions when the genset operates; then the current flows in the opposite direction, with power in excess of the AC loads being converted to DC by the battery inverter, there by charging the batteries. The genset operates under automatic control. It is turned on and off by an internal controller of the battery inverter. The system provides power to various loads as set by a timer system. The load profile is set instead of real load from rural area of Thailand [3].

3. Monitoring system

This power system has been monitored since April, 2003 by a set of sensors and monitoring systems that record a number of key variables at 15-min intervals during one day. The data loggers are a Sunny Boy Control (SBC) for electrical parameters and Delphin topmessage for solar radiation and temperature parameters. In the monitoring system, the following parameters measured:

Parameter	Data Logger	Device	Unit
• Meteorological parameters:			
Irradiance on plane of PV array	Delphin	Kipp & Zonen CM11	W/m2
Ambient temperature	Delphin	PT 100	°C
Module temperature	Delphin	PT 100	°C
Battery temperature	SBC	PT 100	°C
• Electrical parameters:			
AC energy of load simulator	Delphin	kWh transducer	kWh
AC power of load simulator	Delphin	AC power transducer	W
AC power of genset	Delphin	AC power transducer	W
PV DC and AC voltages	SBC	SBC	V
PV DC and AC currents	SBC	SBC	A
AC power	SBC	SBC	W
Cumulated AC energy supplied to grid	SBC	SBC	kWh
Daily AC energy production	SBC	SBC	kWh
Errors and warnings reported by the inverter	SBC	SBC	-
Grid voltage	SBC	SBC	V
Grid current	SBC	SBC	A
Grid frequency	SBC	SBC	Hz
Battery voltage	SBC	SBC	V
Battery current	SBC	SBC	A
Battery power in/out	SBC	SBC	W
SOC battery	SBC	SBC	%

4. System performance analysis of PVHS

4.1 Solar radiation availability

The sunshine on the PV array surface is the principal source of energy in the PVHS. It is interesting; to examine the solar resources that were measured at the site. These measurements were taken by a tilted mounted pyranometer. Fig. 2 shows the average daily radiation on a tilted surface of the PV array as measured.

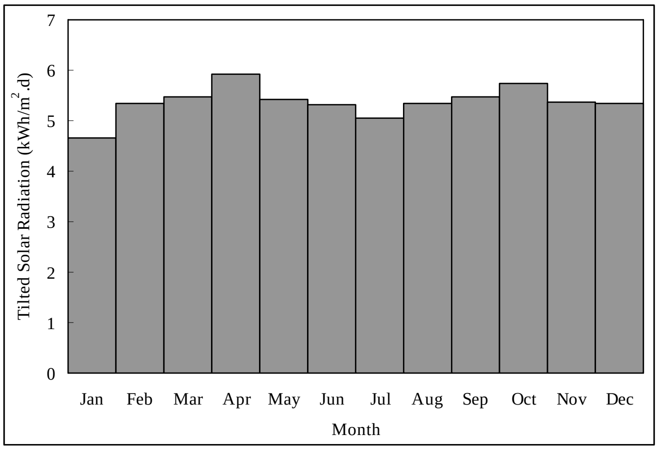

Fig. 2. Average daily radiation on the plane of the array.

4.2 Temperature

With a climate moderated by the tropical zone, the temperature in the PVHS site is not very different throughout the year, as seen in Fig. 3. During the summer (March - June) the site is quite hot, and during the winter (November – February) the site is not very cold. The battery temperature was also monitored, and Fig. 3 shows that the thermal mass of the battery, along with the insulated battery enclosure, is large enough to dampen the diurnal temperature cycles. Thus the battery tends to stay slightly closed to a moving average of the ambient temperature, due to heat gains caused by battery inefficiency. The maximum module temperature measured at the back of the PV module was about 60 – 65 °C. The average daytime (9.00 am – 3.00 pm) module temperature is show in the Fig.3.

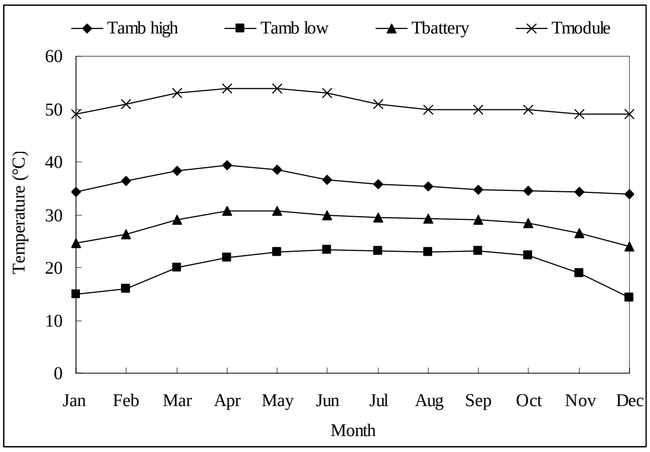

Fig. 3. Average daily temperature of ambient (Tamb), battery (Tbattery) and module (Tmodule).

4.3 Power from PV array

A certain portion of the incident light on the PV modules is converted into electricity. When the battery is fully charges with no load demand, the grid-connected inverter disconnects the arrays from the system, causing the output current to drop to zero. Thus, it is impossible to measure the output of the array that is available in use when the battery is full. This is shown in Fig. 4. The energy produced by PV array is in correspondence with the load profile and solar radiation. The low energy in January and February are caused new PVHS control settings and repair, the system stops operation for a few weeks, and in July a new load profile setting and are often causes of low PV energy.

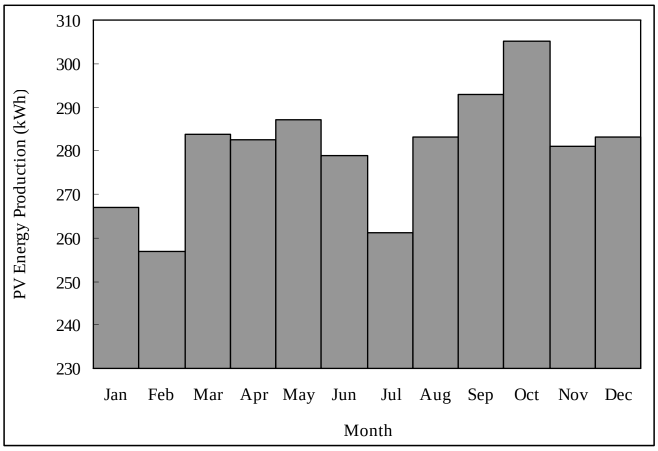

Fig. 4. Monthly PV energy production.

4.4 Power from diesel genset

The yearly energy consumption of this system is 2,619 kWh, average daily energy consumption is 7.2 kWh and the energy produced by the diesel genset over the year is 227 kWh. Fig. 5 presents the diesel genset energy production for each month throughout the year.

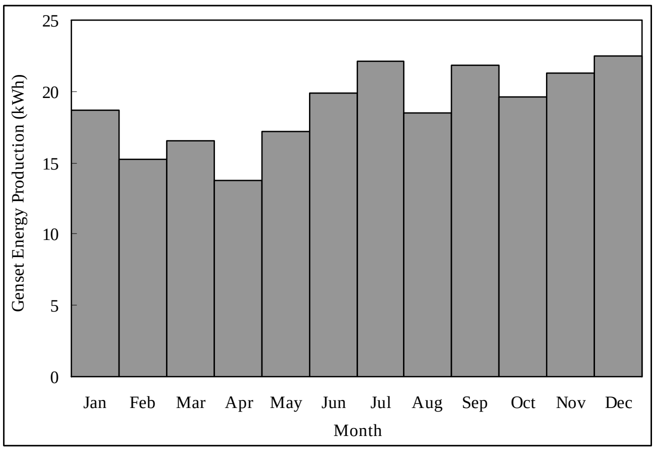

Fig. 5. Monthly diesel genset energy production.

4.5 Performance of PVHS

The PVHS system is fully monitored to assess both potential of PV technology in the Thailand climate and the performance of the system. The monitoring system was designed to meet the guidelines of IEC 61724 standard [7] and within the framework of the International Energy agency Photovoltaic power system (IEA PVPS) Program Task 2 [8-13].

During the monitored period, the PV system generated about 3,362 kWh. The efficiency of the PVHS is 7.09%. Normalized parameters Yf, LS, and LC, as defined in IEC 61724, are shown in Table 1. The final yield (Yf) in this system is equal to the daily energy production. System losses (LS) are due to losses in DC-to-AC energy conversion and cables. Capture losses (LC) are due to PV array losses. The final yield is 65%, capture losses are 12% and system losses are 23% in the total energy balance of the PVHS. The Performance Ratio (PR) of the PV system, as defined in IEC 61724, average at 0.64 for daily solar radiation level higher than 2.0 kWh/m^2. This is a relatively high value compared with other PV stand-alone systems. All performance indicator values from the monitor are high. One reason for this is the high uniformity of the irradiation profile throughout the year and the system testing making under controllable load conditions (timer variable load simulator). Thus there is a good match between PV produced and load demand, and the system performance results are probably higher than under real loads.

Table 1 Summary of the PVHS performance

Reference Yield (Yr) [kWh/kWp]	5.37
Array Yield (YA) [kWh/kWp]	4.72
Final Yield (Yf) [kWh/kWp]	3.46
Capture Losses (LC) [kWh/kWp]	0.65
System Losses (LS) [kWh/kWp]	1.26
Performance Ratio (PR)	0.64
Array Efficiency (ηA) [%]	10.41
Total Efficiency (ηPV) [%]	7.63

5. Conclusions

Data collected from the PVHS at the Energy Park around SERT in Naresuan University were very helpful for the NRCT project. These data were useful for identifying ways in which the system can be improved, for validating the hybrid system simulation tools, and for understanding better how Thailand PV systems are designed and operated. In general, the PVHS at SERT seems to be functioning well. The system components appear to be appropriately dimensioned and configured. The arrangements of the modular expandable AC-couple concept seem to be one of the appropriate PV techniques for rural electrification in Thailand. The high performance ratio shows the interest of this hybrid concept. For further work, the details of system components, reliability and the long term economics of the system need to be studied.

Acknowledgements

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