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Solar home with energy management by frugal discharge

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Abstract

This paper presents Energy Management for a Solar Home at the Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien). The solar home comprises of power sources from a solar system, a battery system, and a transmission line system. Electricity rate is different depending on the energy source and electricity consumption period. The solar home system equipment are connected on SMA Sunny Home Manager to collect and display data via a website. Data analyses of solar home from July to December 2015 were divided into 2 cases; a home without solar system and the solar home with energy management by Frugal discharge. It was found that, a solar home with energy management by Frugal discharge can save the electricity bill by 24,820 baht per year. If the electricity is sold back to a transmission line system, a solar home with energy management by Frugal discharge can increase revenues by 12,497 baht per year. On economic analysis at interest rate of 10% per year, a solar home with energy management by Frugal discharge has a payback period of 16 years, the NPV value is negative, the B/C Ratio lower than 1 and the IRR of 2.96%.

Keywords: solar home, energy management, frugal discharge

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1. Introduction

Solar energy is not only a good alternative energy source for remote areas. At present, solar energy systems are integrated in houses and buildings along with transmission line system. The Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) support the production of electricity from solar installation on the roof under the solar rooftop project. The solar rooftop project has a goal to enhance green community policy and encourage generating electricity through solar systems for home appliances and sell electricity back to the to the grid lines. The solar systems can save electricity bill because the solar system can generate electricity for use in homes during the daytime and provide extra income from selling back the electricity to the grid lines [1, 2].

However, the production of electricity from solar energy depends on the nature of the solar intensity and the ambient temperature. Therefore, proper energy management system is needed to optimize the supply and demand of energy generated by solar systems. Home-owners need to analyze the data and calculate the amount of electricity produced from solar cells at different time in order to manage the energy available and optimize its uses for electrical loads in a household [3, 4].

The most important strategies of management are; Battery cyclic charge strategy; consisting in both maximizing the battery operation to feed the loads and using the diesel for recharging it. Load following strategy; consisting in using the diesel only to comply with the load, while the battery is recharge only by the photovoltaic system. Frugal battery discharge strategy; consisting in optimizing both the fuel consumption and the battery wear by determining the starting and stopping of the diesel generator at a certain power level [5].

For this study, energy management techniques were applied to for a Solar Home at the Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien). The solar home comprised of power sources from a solar system, a battery system, and a transmission line system. Data analysis is divided into two cases, the home without solar system and the solar home with energy management by Frugal discharge technique. The objective of the project is to compare the benefit of a house without a solar system and a house with a solar system with energy management by frugal discharge technique.

2. Materials and methods

The solar home at the Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien) used in this study is shown in Figure 1.

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Figure 1 Solar home at rural electrification learning center, King Mongkut's University of Technology Thonburi (Bangkuntien)

2.1 Solar Home system

The schematic of the solar home is shown in Figure 2. The solar home are equipped with six parts.

A) Photovoltaic (PV) system: convert solar energy into electrical energy.
B) Battery system: serving as an energy storage.
C) Inverter:
   - SMA Sunny Boy: converts direct current (DC) power from solar modules to alternating current (AC) for electrical loads and grid lines.
   - SMA Sunny Island: change DC from the battery into AC to power for electrical loads, and from AC to DC for battery charging.
D) Communication device: communicate among devices in the system and connected to Internet for monitoring and managing home appliances.
E) Control Devices: control the use of electrical load at the scheduled time, and measure electricity consumption of electrical devices connected to it.
F) Electrical loads:

2.2 Electricity Rate

Electricity has different electricity rate depending on the energy source and electricity consumption period.

2.2.1 Electricity rate of transmission line system

MEA priced electricity bills based on the time of use (TOU) [6].

- Electricity prices at 09.00 - 22.00 (On peak) is 5.2674 baht/unit.
- Electricity prices at 22.00 - 09.00 (Off peak) is 2.1827 baht/unit.
- Feed-in tariff for residential houses less than 10 kw_p is 6.96 baht/unit.

2.2.2 Electricity tariff of battery system

Battery system is the energy storage system of solar home. The electricity rate of battery system contains electricity rate of energy stored in the battery and the wear rate of the battery. Battery wear rate can be calculated by the following equation [7].

$$\text{Battery wear cost} = \frac{\text{Battery cost}}{\text{Equivalent Full Cycles}} \quad (1)$$

Battery cost is the capital cost and replacement cost of battery. Equivalent Full Cycles is the number of chargeï discharge cycles at the given Depth of Discharge

2.2.3 Electricity rate of solar system

Solar Home at the Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien) has a total capacity of 3.88 kW_p. The electricity rate of the solar system can be calculated by the following equation [8].

$$\text{Cost of Energy} = \frac{\text{Initial system cost}}{\text{Electrical energy generated} \times \text{Systems Life time}} \quad (2)$$

Initial system cost is sum of investment cost, operations cost and maintenance cost. Electrical energy generated is sum of electrical energy generated duration of the study period (Unit/year). Systems Life time is life time of a system (year).

2.3 Frugal Discharge

Frugal Discharge method was applied to control the discharge of batteries such that the battery was discharged to supply the loads at the optimal period. Barley's study frugal discharge operation for control battery discharge

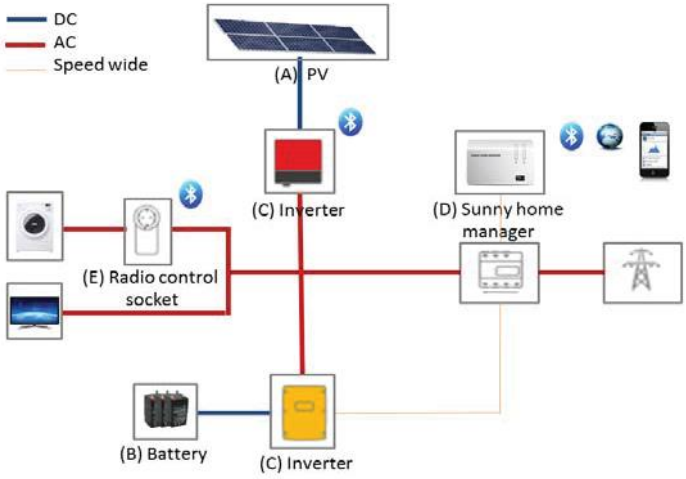

Figure 2 Solar home system components

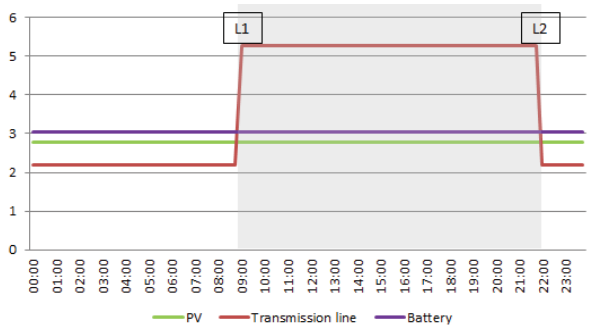

Figure 3 Electricity rate for three different sources: PV, transmission line, and battery

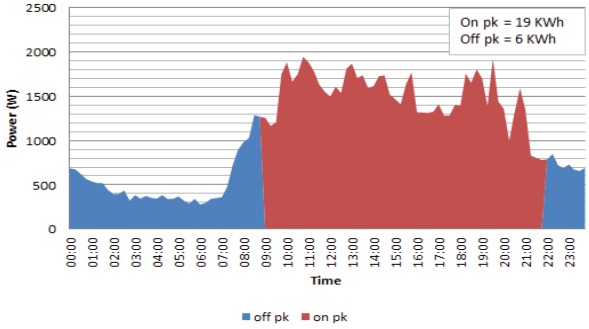

Figure 4 Power consumption in the home without solar system

in wind diesel systems. The methods is based on critical load. If the net load is higher than the critical load, it is cheap to run the generator set [9]. In this study, frugal discharge methods is based on electricity rate. If electricity rate is higher battery wear cost, it is cheap to discharge battery.

In Figure 3, electricity rate for the transmission line, battery, and PV systems were compared. It is observed that the electricity rate for the transmission line is higher than that of the PV and battery system between 9.00 ï 22.00 hr., therefore, battery was discharged to provide energy for electrical loads from L1 to L2. Charging of the battery occurred between 22.00 ï 9.00 hr., when the electricity rate of the transmission line is low.

3. Results

Results of Solar Home at Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien) were divided into three parts: home without solar systems, solar home with energy management by frugal discharge, and economic analysis of the solar home.

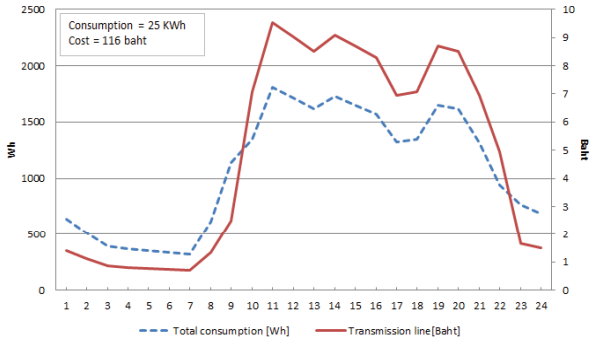

Figure 5 Consumptions and costs of energy at home without solar systems

3.1 Home without solar systems

In this case, the solar home used energy by transmission lines only. It can be divided into two periods. At 9:00 to 22:00 (on peak), the electricity rate is 5.2674

Table 1 Income and expenses for the solar home between July-December 2015

Expense/income	Home without solar systems	Solar Home with Energy Management by the frugal discharge
Expense from all energy sources	4.49 baht/unit	2.89 baht/unit
Expense from transmission line	4.49 baht/unit	1.09 baht/unit
Income from electricity sell back	0 baht/day	34 baht/day

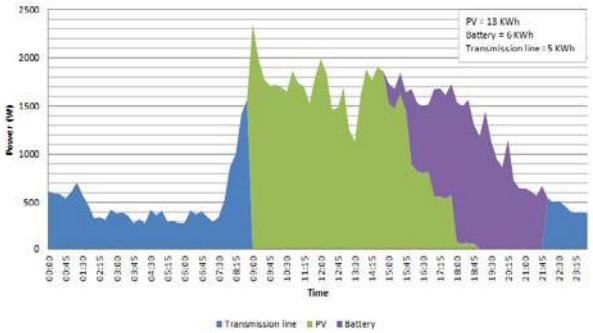

Figure 6 Power consumption in solar home with energy management by the frugal discharge

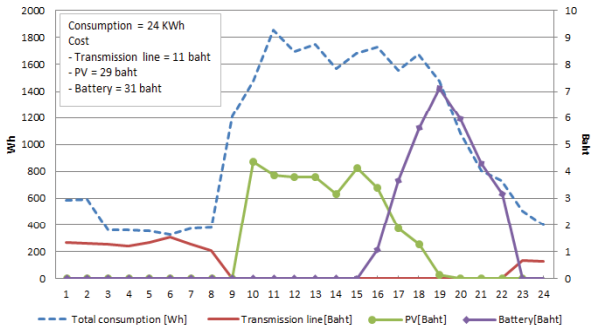

Figure 7 Daily energy consumptions and costs of energy at solar home with Energy Management by the frugal discharge

baht/unit. And at 22:00 to 9:00 (Off peak), the electricity rate is 2.1827 baht/unit. The electric home appliances consumed the most power between 10:00 to 20:00. A daily power consumption of the home without solar system is shown in Figure 4.

The energy consumptions and costs of energy at the home powered by transmission line and without a solar system are shown in Figure 5. It is shown clearly that the energy consumption is high during on - peak period, which made the cost of the electricity much higher between 9.00 ï 22.00 hr.

3.2 Solar Home with Energy Management by the frugal discharge.

In this case, the solar home used three sources of energy: transmission system, PV system and battery system. At 22:00 to 9:00 (Off-peak) the solar home used electricity from a transmission lines because the transmission lines electricity rate is the cheapest. During 9:00 to 22:00 (On-peak), where electricity rate is high, the solar home used electricity from the PV system. If energy from the PV system was not enough, electricity from the battery was connected. And when energy from battery was not enough, it used electricity from the transmission lines. The power consumption in the solar home with Energy Management by the frugal discharge is shown in Figure 6

After applying the energy management by frugal discharge technique, the cost of the electricity was calculated. The energy consumption and cost of energy at the solar home with energy management by the frugal discharge are shown in Figure 7. Between 9:00 to 15:00, the solar home was powered by the PV system only. During 15:00 to 22:00, the electricity rate by the transmission line was still at the on-peak rate and the PV could not provide enough energy, hence the battery became the main power source. After 22.00 until 9.00, the transmission lines was the main power supply because it was at the off-peak rate.

3.3 Economic Analysis

It was calculated that the home without solar systems had approximately 32,777 baht per year of electric bill. The solar home with energy management by the frugal discharge had approximately electricity bill from transmission line 7,957 baht per year while the electric bill from all energy sources was approximately 21,097 baht per year. And if the electricity was sold back to a transmission line system, Home owner of the solar home with energy management by Frugal discharge can receive approx. 12,497 baht per year in return. The income and expense for energy in the solar home is shown in Table1. From July to December 2015, the average electric bill for home without solar system was 4.49 bath/unit while for solar home with energy management by frugal discharge was 2.89 baht/unit. Home owner saved on the electric bill and at the same time earned 34 baht/day in selling back the electricity into the grid line.

On economic analysis at interest rate of 10% per year, a solar home with energy management by Frugal discharge has a payback period of 16 years, the NPV value is -185,224, the B/C Ratio is 0.65 and the 2.96% IRR.

4. Conclusions

At the Rural Electrification Learning Center, King Mongkut's University of Technology Thonburi (Bangkuntien), a solar home consisting of solar modules, batteries, inverters, communication devices, and monitoring systems were set up. The solar home were also connected to the transmission line. Data analyses of solar home from July to December 2015 were divided into two cases; a home without solar system and solar home with energy management by Frugal discharge. It was found that the solar home with energy management by Frugal discharge could save the electricity bill by 24,820 baht per year. If the electricity is sold back to a transmission line system, a solar home with energy management by Frugal discharge can receive 12,497 baht per year.

On economic analysis at the interest rate of 10% per year, the solar home with energy management by Frugal discharge had a payback period of 16 years, the NPV value is -185,224, the B/C Ratio is 0.65 and the 2.96% IRR.

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