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The potential of hybrid sufficiency energy system by wind and solar energy for a family-sized unit

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Abstract

We present a study of a combined system which produced electrical energy from both solar radiation via solar cells and wind energy from a wind turbine. A renewable hybrid energy system consists of two or more energy sources, a power conditioning equipment, a controller and an optional energy storage system. For wind energy, measurements of wind velocities at 4-5 m height were taken. After that, wind energy converted to the electrical energy was 200 W. However, the value of solar radiation from solar cells was taken at the optimum slope angle of collector which provided higher energy production for each 1 h during this application. Thus, data obtained from each system were used together for finding total energy. For these measurements, which would be used in calculation of wind energy, the average power of 1,200 Watts/day and the solar energy of 3,600 Watts/day were taken for a year between 2010 and 2011 in Sakon Nakorn. As a result, the energy of the combined system could support each other when one of them produces insufficient energy for a family-sized unit.

Keywords: Economic viability, Wind–solar hybrid energy system, Renewable energy, Life cycle cost, Green technology

1. Introduction

The energy is important for community of human life in Thailand, which the trend of energy is electricity expensive and trend of PV solar cell and wind power of Thailand less than cost. The forecast of energy needs for the years to come only confirm this trend, especially give demographic trends and development in some world regions, particularly in Asia. The alternative energy resources such as solar and wind have attracted energy sectors to generate power on a large scale. However, common drawback with solar and wind energy is their unpredictable nature, depending on weather and climatic changes. Standalone photovoltaic (PV) or wind energy systems do not produce unable energy for considerable portion of time during the year. The sizing optimization method can help to endorse the lowest investment with adequate and full use of the solar system, wind system and battery bank, so that the hybrid system can work at the optimum conditions in terms of investment and

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system power reliability requirement. The example result of alternative energy such as a sizing optimization of grid-independent hybrid photovoltaic/wind power generation system [1], a study on the performance and economy of integrated solar combined cycle systems [2] and a small hybrid solar-combined power system [3,4]. The hybrid system is popular for renewable system such as pneumatic hybridization of a diesel engine using compressed air storage for wind-diesel energy generation [5] and optimization of diesel engine performances for a hybrid wind diesel system with compressed air energy storage [6] and energy technology development [7,8]. In the world there are many results show the potential and management of solar power [9-11].

In this paper, a grid-independent hybrid PV/wind system optimization model utilizes the interactive optimization technique to follow the hybrid sufficiency energy system by wind and solar energy for a family sized. This paper consists of the introduction, the theory and hybrid energy, result and discussion and conclusion as well.

2. Theory and hybrid energy

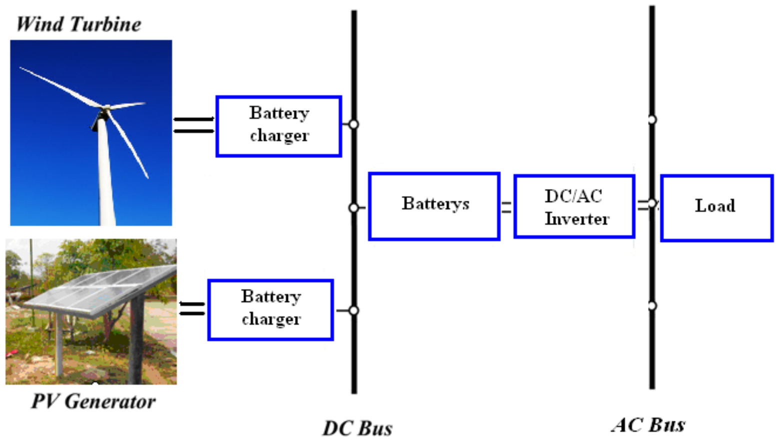

Fig. 1. shows the combination energy system for green energy house

Fig. 2. shows the setup on green energy house

The electricity from solar power and wind power system are shown in the Fig. 1. The system also receives (AC) electrical power systems producing electricity from solar energy and wind turbine combination system. When the hybrid energy generates DC power and battery charger into DC bus and keep the power in the battery bank. After the battery charging completed, the DC power is converted to AC power by DC/AC inverter for AC bus. The energy within the house is sent through the main power (AC bus) systems when the green energy house is not sufficient using combination power show in Fig. 2.

2.1 Quality factor

The quality factor (Q) is defined as the quotient of the real electric output energy measured at the system output (E_{load}), which is the system load (E_{demand}) and the theoretical output energy (E_{th}), which is defined as the output energy from the same system under ideal conditions, which is the Standard Test Conditions (STC).

$$Q = \frac{E_{Load}}{E_{th}} \tag{1}$$

Where Q is quality factor of the system , E_{Load} is real electric output energy [kWh] and E_{th} is theoretical output energy of the system [kWh] [9].

The quality factor can be determined over any given time period. In most cases, a time period of one year is chosen to presize PV systems. The theoretical output energy (Eth) is defined as the energy output, which is produced by a PV array with an area of Aarray, the global radiation Eglob incident on a horizontal surface and efficiency η determined under STC:

$$E_{th} = \eta \cdot E_{glob} \cdot A_{array} \tag{2}$$

where E_{th} is theoretical output energy of array [kWh] , η is efficiency of the PV array [decimal], E_{glob} is global radiation [kWh/m^2] and A_{array} is area of the PV array [m^2]. It is often difficult to obtain values like the efficiencies from manufacturers. Besides, the area of the array is frequently unknown. However, the peak power measured under STC is normally given

(STC: I_{STC} = 1000 W/m^2; T_{STC} = 25 °C, AM = 1.5).

$$P_{peak} = \eta \cdot I_{STC} \cdot A_{array} \tag{3}$$

where *Ppeak* is peak power of the PV array [kWp], η is efficiency of the PV array [decimal] ISTC = global radiation under STC

[1 kW/m^2]

Aarray is area of the PV array [m^2] According to the equations (3) and (4) after substitution of η · A_{array}:

$$E_{th} = P_{peak} \cdot \frac{E_{glob}}{I_{STC}} \tag{4}$$

According to the equations (2) and (5) the quality factor can be found out:

$$Q = \frac{E_{Load}}{E_{glob} \cdot P_{peak}} \cdot I_{STC} \tag{5}$$

With the quality factor formula (6) and the empirical quality factors of existing systems it is practical to use this quality factor (Q) to pre-size the PV array [5].

2.2 Sizing of PV system

From the quality factor (Q) in *(6)* , the PV array can be sized accordingly:

$$P_{peak} = \frac{E_{Load} \cdot I_{STC}}{E_{glob} \cdot Q} \quad (6)$$

where P_{peak} is peak power of under STC [kWp], E_{load} is real electric output energy [kWh/a] ,I_{STC} is solar radiation under STC [1 kW/m^2], E_{glob} is annual global solar radiation [kWh/m^{2}a] and Q is quality factor of the system .

In the theory, supply and demand values are equivalent and the quality factor is therefore equal to one (Q = 1). A measured value of, for example, Q = 0.75 means that 75 % of the electric energy, which is converted from the incident solar energy, is used whereas 25 % of the electric energy is lost between the solar cell and the system output or it is not used [12].

2.3 Wind turbine system

The wind speed distributions for selected sites as well as the power output characteristic of the chosen wind turbine are the factors that have to be considered to determine the wind energy conversion system power output. Choosing a suitable model is very important for wind turbine power output simulations. The most simplified model to simulate the power output of a wind turbine can be described by [1]:

$$\mathrm{Pw(V)} = \begin{cases} \mathrm{P_R}\left[\left(\mathrm{V}^2 - \mathrm{V_C^2}\right)/\left(\mathrm{V_R^2} - \mathrm{V_C^2}\right)\right], \mathrm{V_C} \le \mathrm{V} \le \mathrm{V_R} \\ \mathrm{P_R}, \mathrm{V_R} \le \mathrm{V} \le \mathrm{V_P} \\ 0, \mathrm{Otherwise} \end{cases} \quad (7)$$

Where P_R is the rated electrical power; V_C is the cut-in wind speed; V_R is the rated wind speed and V_F is the cut-off wind speed. In this study, the adjustment of the wind profile for height is taken into account by using the power law that has been recognized as a useful tool to model the vertical profile of wind speed. The equation can be described by [1].

$$\frac{V(H)}{V(H_{ref})} = \left(\frac{H}{H_{ref}}\right)^{\alpha} \quad (8)$$

Where V(H) is the wind speed at hub height H, m/s; $V(H_{ref})$ is the wind speed measured at the reference height H_{ref} ,m/s; α is the power law exponent. The determination of α becomes very important. The value of 1/7 is usually taken when there is no specific site data [12].

3. Result and Discussion

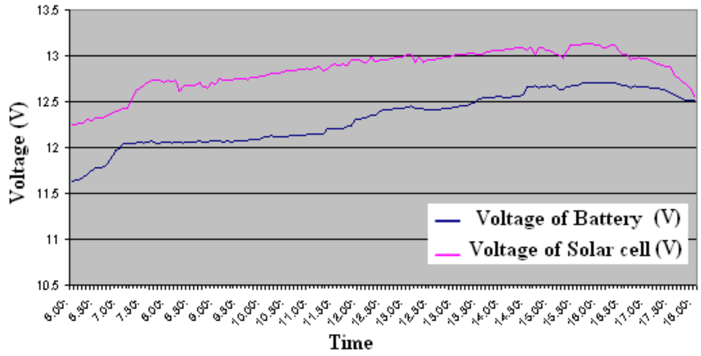

Fig. 3. shows the battery charge of wind turbine on 2 May 2012 in 06:00 am- 18.00 pm

The graph of Fig. 3 compares the battery voltage with the voltage of the solar cell to recharge the battery on May 2, 2012 at time: 06:00 to 19:30. The pressure increased from 11.63 V to 12.5 V of cycle. If the battery is not fully charge the system can be recharge the battery again on May 3, 2012, with a comparison between the voltages of the battery is shown in blue line. The voltage of solar cells shows a red line in this figure 3.

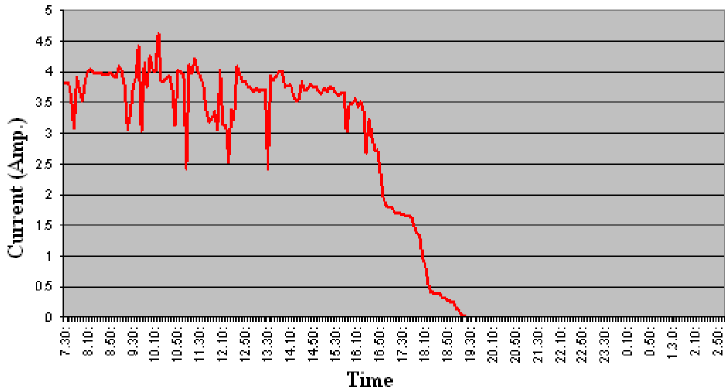

Fig. 4. shows the graph of electricity used to charge the battery and along with

In Fig. 4 shows the flow chart of the solar cell. The using and charging are at the same time. It can be seen that the flow chart should have changed over time. Since the flow is steady. The solar power changes, depending on the amount and intensity of sunlight. The current of charger shows the time at the charging time which is from 6:55 am. to 03:00 am. due to the darkness. We can also use renewable energy by electricity from wind energy to offset system.

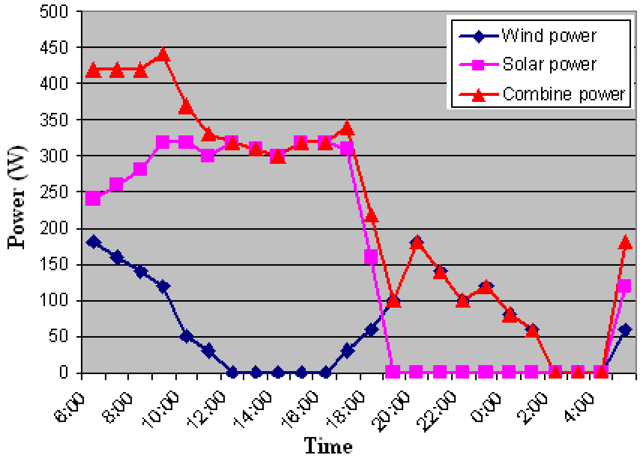

Fig. 5. shows the output power of wind turbine and solar cell power

The power of green energy house uses the charge from solar –wind energy for sufficiency energy per a day. In fig. 5 shows the relative the power and time of a day, which have 3 lines: the blue line shows the wind power in the morning and the wind turbine can generate the power between 50 -180 W in the midday and does it again from 6.00 pm. – 2.00 am. the following day; the pink line shows the solar power, which generates 250 - 320 W a day; the red line shows the combination power between 250 -300 W all day and all night . In the result shows the data on May 4, 2012.

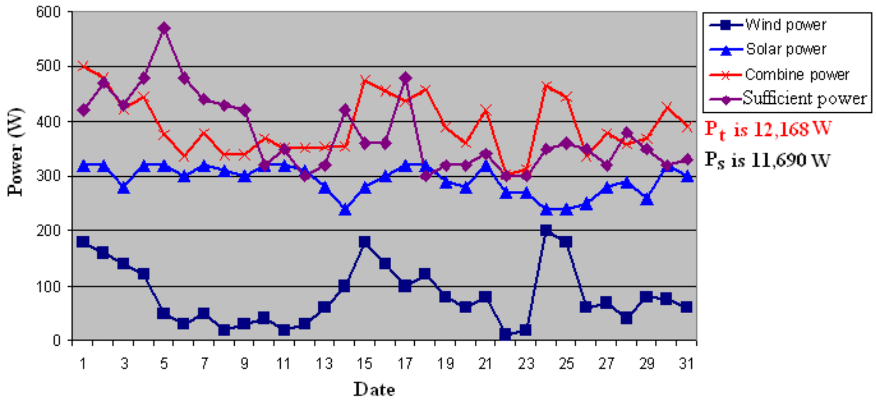

Fig. 6. shows the sufficiency power for a family on July 2012 in Sakon-Nakorn of Thailand

Fig. 6 shows the average power in July 2012, which the energy is at the optimum power for a family per month. The total value of combined power (Pt) is 12.168 kW/month, which is enough for 4 persons or a family. The reference for sufficiency power (Ps) is 11.690 kW/month which shows (magenta line) in figure 6. The wind energy is alternative power because the wind speed in Sakon-nakorn province, is low less than 4 m/sec. In this paper, we have purposes the sufficiency power for a family with the green power for communities of compromise of Thai people.

4. Conclusions

This paper presents the effective of hybrid power system for sufficiency power for a family- sized unit in Sakon-Nakorn province of Thailand, which can generate the power potential at 500 Watts-hours. The powerful of design is based on a family of 4 persons and the using of the green power sufficiency is 400-500 Watts per day. The total wind-solar power within a month is 12 kW and the family consume 11.96 kW, which is enough to a family-size unit. In near future, the free electricity (green energy) could be popular in Thailand much more than today.

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