A Smart Mobile PV-Wind Hybrid System Prototype for isolated electrification

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Abstract

This paper presents the design and construction of a Mobile PV-Wind-Battery-Diesel Hybrid System Prototype for isolated electrification. The system includes a real-time monitoring system and a control unit which can control all components automatically. The design uses a short calculation method and then simulated by Homer program. The mobile unit is considered as a mobility utility for remote areas therefore the unit is constructed in a container unit which can be able to be transferred comfortably. The design has the components as : PV 2 kWp, Wind turbine 1 kW, Battery 24 kWh, and Diesel Generator 5kW. From a long experiment, the system can operate as the design and it is working stably to supply power to the load. The paper will describe fully for the design, construction, monitored data, and analysis.

Key words: Mobile PV Hybrid, Control Hybrid Load Profile

1. Introduction

The PV hybrid system is described as a combined power unit of PV source and other mixed energy sources with conventional energy. The generator is considered as add-in conventional power source for this study. The design PV hybrid is also included a wind turbine for more renewable energy fraction. The hybrid system normally has been used for remote areas which demand below 30 kW. The PV hybrid system is typically designed to use solar energy for the main supply. The system will store the surplus energy from solar to the battery for night use and if the battery is not able to supply power then the generator is stared to supply power to the system and charge the battery at the same time. The generator will stop when the battery is full then the battery will be responsible for supplying power to load. The designed system operation can be described as:

1) During day time, energy from solar or from wind will supply to system and charge to battery at the same time. The Battery needs a Bi-directional inverter for the power flow to the AC bus system as shown in Fig.1.

2) During night time, the hybrid system will use energy from battery storage for the load and if the wind turbine can be able to produce energy, the wind energy can also supply power to the system at anytime.

3) If the battery can not supply power to the load, control unit will start the generator immediately to supply power to load and charge battery at the same time. However, if the battery if full and there is no demand load, the system will cut the wind turbine and PV from the system. For safety the wind turbine needs a dump load for such the case.

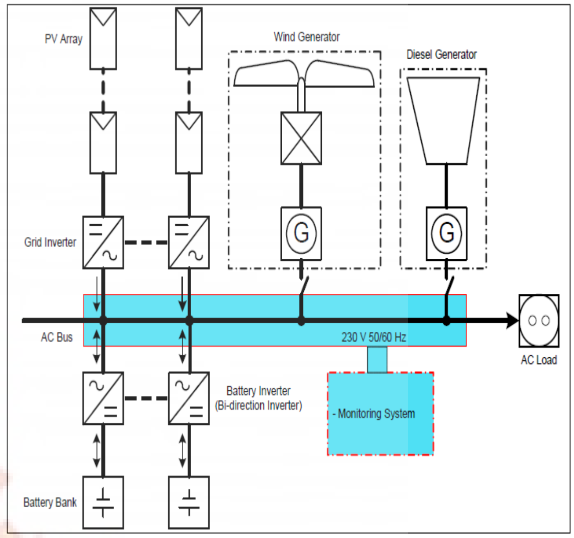

Figure.1: Proposed Hybrid system

From the purpose of this study, this design of PV mobile hybrid will cover all necessary features of mentioned PV hybrid system and moreover it will be designed to be able to transfer comfortably as a mobility unit.

2. The Principle of Design

As mentioned, the principle design of this mobile PV hybrid system will be considered at the stability of power supply. The real time monitoring system is also included for data analysis. For this study, we selected an example of load profile as shown in Figure 2. The selected load profile is a typical load in remote areas which has the peak load in the evening. The load normally includes the daily life electrical load without air conditioning system.

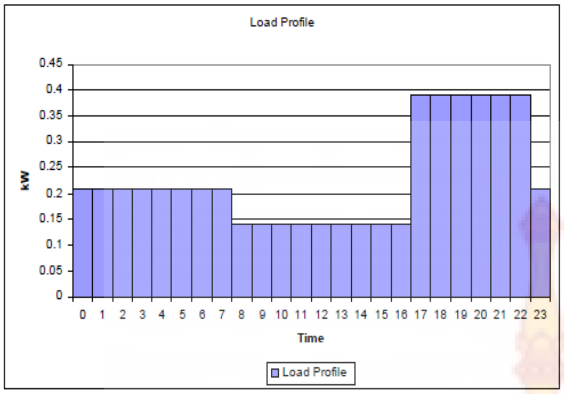

Figure.2: Selected loads for the design

After having the load profile, the capacity of the solar cell, P_{peak}, can be calculated by using a short method [1] as followings.

$$Q = \frac{E_{el}}{E_{th}} \quad (1)$$

$$E_{th} = \eta \cdot E_{glob} \cdot A_{array} \quad (2)$$

$$P_{peak} = \eta \cdot I_{STC} \cdot A_{array} \quad (3)$$

$$E_{th} = P_{peak} \times \frac{E_{glob}}{I_{STC}} \quad (4)$$

$$Q = \frac{E_{el}}{E_{glob} \times P_{peak}} \times I_{STC} \quad (5)$$

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

When: P_{peak} = peak power of the PV array under STC [kW_p]

E_{el} = real electric output energy of the system [kWh/a]

I_{STC} = incident solar radiation under STC [1 kW/m^2]

E_{glob} = annual global solar radiation [kWh/m^{2}a]

Q = quality factor of the system

E_{th} = theoretical output energy of the system [kWh/a]

η = efficiency of the PV array [decimal]

A_{array} = area of the PV array [m^2]

The equation (6) is used to calculate the PV capacity. The quality factor, Q , is defined as in table 1.

Table 1 Shows quality factor of the system for the design of PV system [1]

Component/System	*Q*
PV module (Crystalline)	0.85…0.95
PV array	0.80…0.90
PV system (Grid-connected)	0.60…0.75
PV system (Stand-alone)	0.10…0.40
Hybrid system (PV/Diesel)	0.40…0.60

The battery capacity is calculated by (7) [1].

$$CB = 10 \times P_{peak} \quad (7)$$

When: P_{peak} = peak power of the PV array under STC [kWp]

CB = battery capacity [kWh]

Therefore the calculation can be done as following by having the E_{glob} in Thailand as 5 kWh/m^{2}d and the load from the load profile is 5.97 kWh/d.

$$P_{peak} = \frac{5.97kWh/d \times 1kW/m^2}{5kW/m^2d \times 0.6}$$

$$= 1.99kW$$

Then we have the capacity of PV as 1.99 kWp. And therefore the battery capacity is then 19.9 kWh. Once the capacity of the battery is obtained, the level of battery voltage can be selected depending on the level of load consumption. The proposed voltage level selected the voltage level of battery 24 volts. When all the values have been obtained, simulation must be done for analysis of the design. The simulation for this study is a well known Homer program. The designed system under homer is shown as in figure 3.

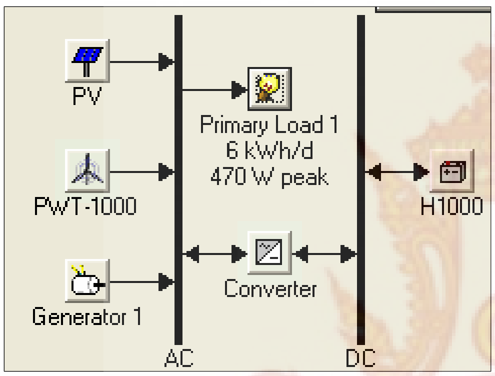

Figure.3: Simulation of the designed system

From the analysis of simulation, we select the capacity of the system components as:

PV = 2 kWp
Diesel Generator = 5 kW
Wind Turbine = 1 kW
Battery = 20 kWh

The result of simulation shows that the designed system can supply power stably with out energy shortage as in Figure 4. Therefore the designed system is selected for the smart mobile Hybrid system.

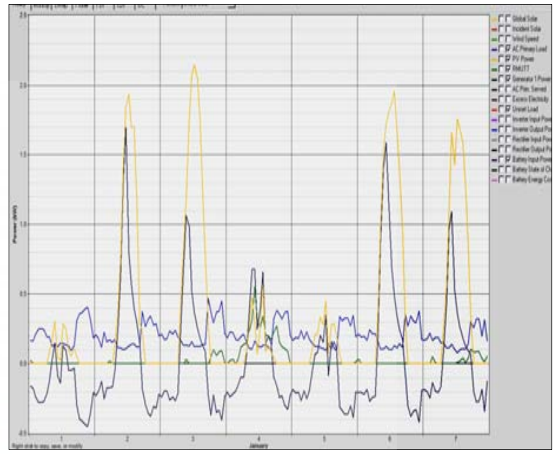

Figure.4: The simulation result

3. The Smart Mobile System Design

After having the components, next is to design the system diagram. The mobile PV hybrid system will be a mobility unit which can supply power to load in remote areas and will provide real time data to the operator for immediate action if the system is failed to operate, the designed system is shown in Figure 5. The system includes power diagram and communication diagram for monitoring.

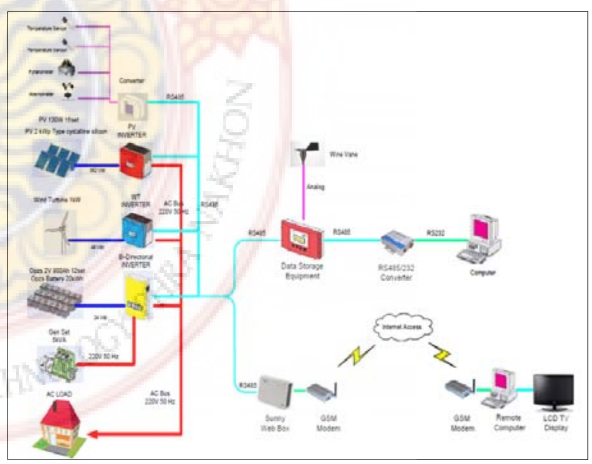

Figure.5: Diagram of designed system

After the system design, the mobile unit must be designed. In order to be a power mobility unit, the all components must be installed in a container unit and all components must be communicated with control unit for action. The container is divided in to 2 sections. The first section is for the inverters, control unit, and monitoring unit. The second section is for the battery and generator. The mobile unit is designed as shown in Figure 6.

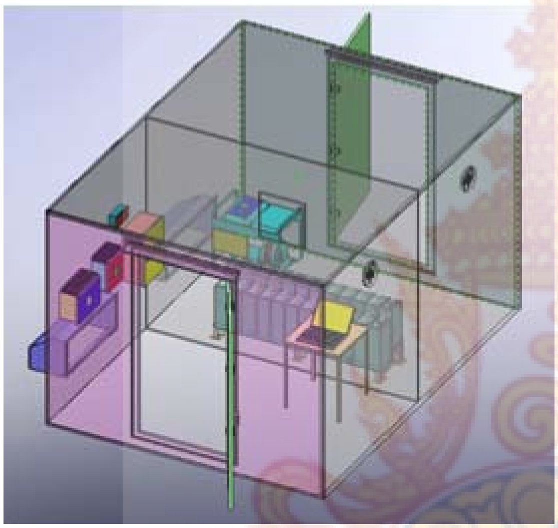

Figure.6: The design of internal Mobile Unit.

After having the mobile unit, the completed PV hybrid system can be designed, as mentioned for transfer ability, all components must be installed as a unit therefore the designed PV hybrid system is designed as shown in Figure 7. The system will be constructed accordingly to this designed and will be located for experiment at Rajamangala University of Technology Thanyaburi (RMUTT).

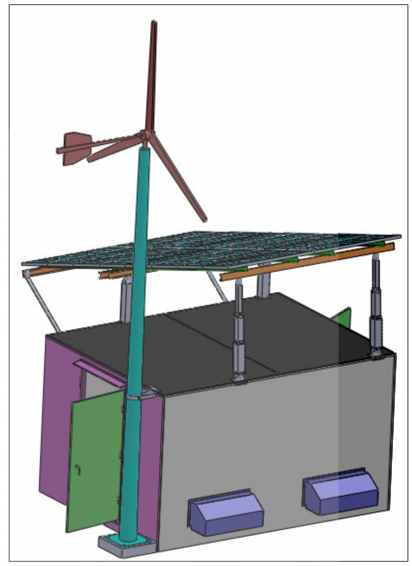

Figure.7: Drawing of the completed designed Mobile Hybrid System

4. Experiment and Analysis

The designed Mobile PV-Wind-Battery-Diesel Hybrid System Prototype for isolated electrification can be now constructed. The construction is done very hardly because this is a first prototype, there has no an example before in Thailand. The construction is shown as in Figure 8.

Figure.8: Construction of the designed Mobile Hybrid System

Figure 9 shows the finished complete mobile PV hybrid system. The system includes various measuring system for analysis such as radiation meter, temperature sensor, and anemometer. The all control unit and communication unit are installed in the container room as shown in Figure 10. The automatic load controller is installed to supply power to the load for experiment. The experiment carries out very interesting results.

Figure.9: The completed construction of designed Mobile Hybrid System at RMUTT

Figure.10: Installation of control and monitoring Unit

For performance analysis of the system, we set up the experiment by a simulation load connected to the system. The data storage with monitoring system is used for the data collection. The results show that hybrid system can supply the real Electric energy to load as it was designed. The system is working stably and can deliver the power to the load without energy shortage and moreover the system has enough power form PV therefore the generator is not started during the experiment. The results are shown as in Figures 11. From the sesult, this can besure that the system design is correctly and the smart mobile PV-Wind-Diesel system can be used for the remote electrification.

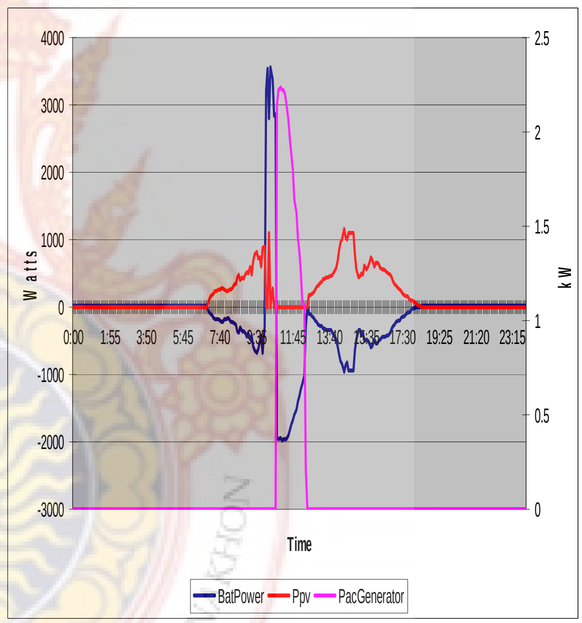

Figure.11: Performance of the Smart Mobile Hybrid System

5. Conclusions

The paper presents a method of design for Smart PV-Wind Hybrid system which is very short and useful for the design. The system design after the calculation is simulated by Homer program for system optimization. The result of the calculation is confirmed the design. The system is working stable and can supply the power to the selected load without energy shortage. After the design, the system is constructed accordingly to the design. The mobile unit is built exclusively for the remote electrification and can be moved very comfortable therefore the mobile is constructed within a unit. After the finished construction, the smart mobile is used to supply power to the load for experiment. After a long experiment by using an automatic load controller unit, the system is able to supply the power to the load continuously. The results show that the system is working stably as it is designed. The system can automatically observe the battery and will start the generator when the battery is low. However during the experiment, the system can deliver the power to the load without starting generator this because the PV can produce electrical power enough for the load. This can be sure that the smart mobile is correctly designed and can be used for remote electrification.

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