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Mobile Renewable House

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Abstract

International Center for Hydrogen Energy Technologies (ICHET) has implemented a demonstration project including photovoltaic/wind/fuel cell hybrid power system for a stand-alone mobile house. This concept shows that different renewable sources can be used simultaneously to power off-grid applications. The presented mobile house can produce up to 3.8 kW to provide sufficient power to cover the peak load. Photovoltaic and wind energy are used as primary sources and a fuel cell as backup power for the system. The power budgeting of the system is designed based on the local data of solar radiation and wind availability. Performance analysis, sizing of the various system components and modelling will be carried out as part of applied R&D program.

1 Introduction

Renewable energy technologies expected to be providing significant portion of the future energy need in the coming 20 to 50 years. However, due to the sporadic characteristics of natural resources, it has been a challenge to generate a highly reliable power with photovoltaic (PV) modules and/or wind turbines [1]. To overcome this limitation, using fuel cells as another energy source in a PV/wind/fuel cell hybrid power system may prove to be a feasible solution for stand-alone applications [2-4]. In addition, hydrogen and fuel cells enable storage and load-levelling during energy production and transportation applications. Integration of energy mix increases power availability option for highly critical applications regardless of location. This paper presents a demonstration of the use of a PV/wind/fuel cell hybrid power system to supply electricity to a mobile house. The demonstrated system shows that it is feasible to use hydrogen as an energy source with other renewable energy sources such as PV and wind energy. The hybrid power system was designed based on the data of solar radiation and wind availability in the city of Istanbul, Turkey. PV and wind energy are used as the main sources for the system and the fuel cell performs as a backup power source for the continuous generation of high quality power. The demonstration mobile house also indicates the capability of a hybrid power system which can be suitable for many other applications such as emergency vehicle, mobile clinics, mobile library and data centre.

2 Integrated System

A photovoltaic/wind/fuel cell hybrid power system for stand-alone applications is demonstrated with a mobile house. This concept shows that different renewable sources can be used simultaneously to power off-grid applications. The presented mobile house can produce sufficient power to cover the peak load. The system design was based on the

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results of load analysis and the study of the renewable resources available in Istanbul, Turkey. The system composed of a PV module (0.8 kW), a wind turbine (1 kW) and a PEM fuel cell (2 kW) was integrated and then mounted into the container with 3.8 kW maximum power capacities. The presented system uses PV and wind energy primarily and fuel cell energy as a secondary source for power generation. In figure 1, the energy production and demand is shown. Load scenario assumes that 4.8 kWh is used per day and calculations show that in December which Istanbul has the lowest sun irradiation, energy produced from PV panels is 2.203 kWh/day and energy produced from wind turbine is 2.177 kWh/day.

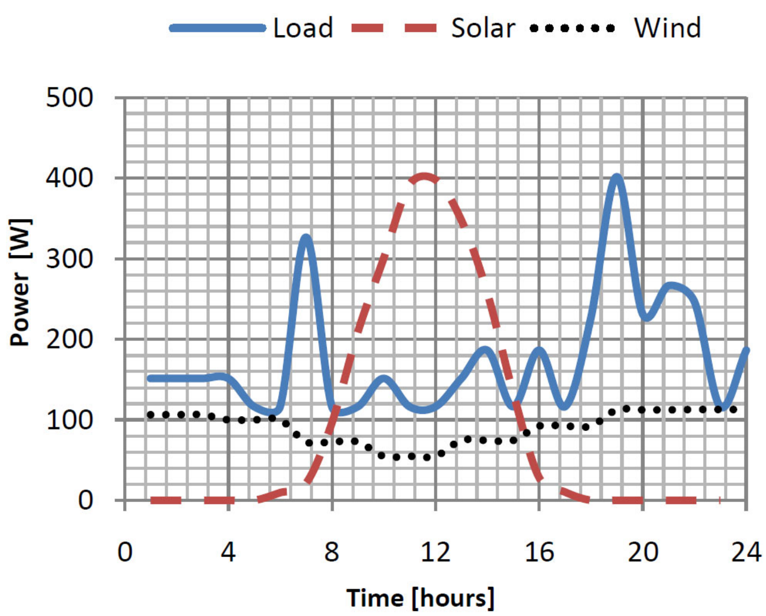

Figure 1: Energy production and demand relevance of mobile renewable energy house.

Excess energy is stored in batteries and when battery state of charge drops to 50%, PEM fuel cell starts to operate. The battery bank with 19.2 kWh capacity is used in the system to supply the transient power. When the minimum battery state of charge (50%) is taken into consideration, the efficient capacity becomes 9.6 kWh which is sufficient for 1.8 days of autonomy while hydrogen cylinders with a capacity of 8.2 kWh were used at the given conditions. Moreover, the hydrogen storage is sufficient for 0.8 day of autonomy on its own when losses occur in the system; hence, the total number of autonomy is 2.6 days. Since a multi-source hybrid power system increases energy availability, mobile house can be used regardless of location, especially in remote areas and in emergency situations such as natural disasters.

System Components: The hybrid power system of the mobile house consists of a 8x1 array of 100 W PV panels, a 1 kW wind turbine, and a 2 kW fuel cell. As shown in Figure 2, the block diagram of the system demonstrates the integrated components for power generation. In the following, each component of the system is presented and discussed.

For PV panels, Poly-Si PV modules were used to have better cost efficiency. The wind turbine, a Ventura 1000 from E-Sistem, generates 1 kW rated power with a permanent magnet synchronous generator. The wind turbine works in normal mode up to 20 m/s of wind speed, and after 20 m/s, the turbine activates a stall control system which enables electromagnetic regenerative brakes and lets the wind turbine generate power under the brake control. The turbine is installed on a foldable pole which has the height of 10 m from the ground. Although the turbines with permanent magnet synchronous generators are more expensive, they are more suitable for the mobile applications due to their compact and light structure. The Ventura 1000 is able to automatically change direction to face the predominant wind in order to generate as much power as possible.

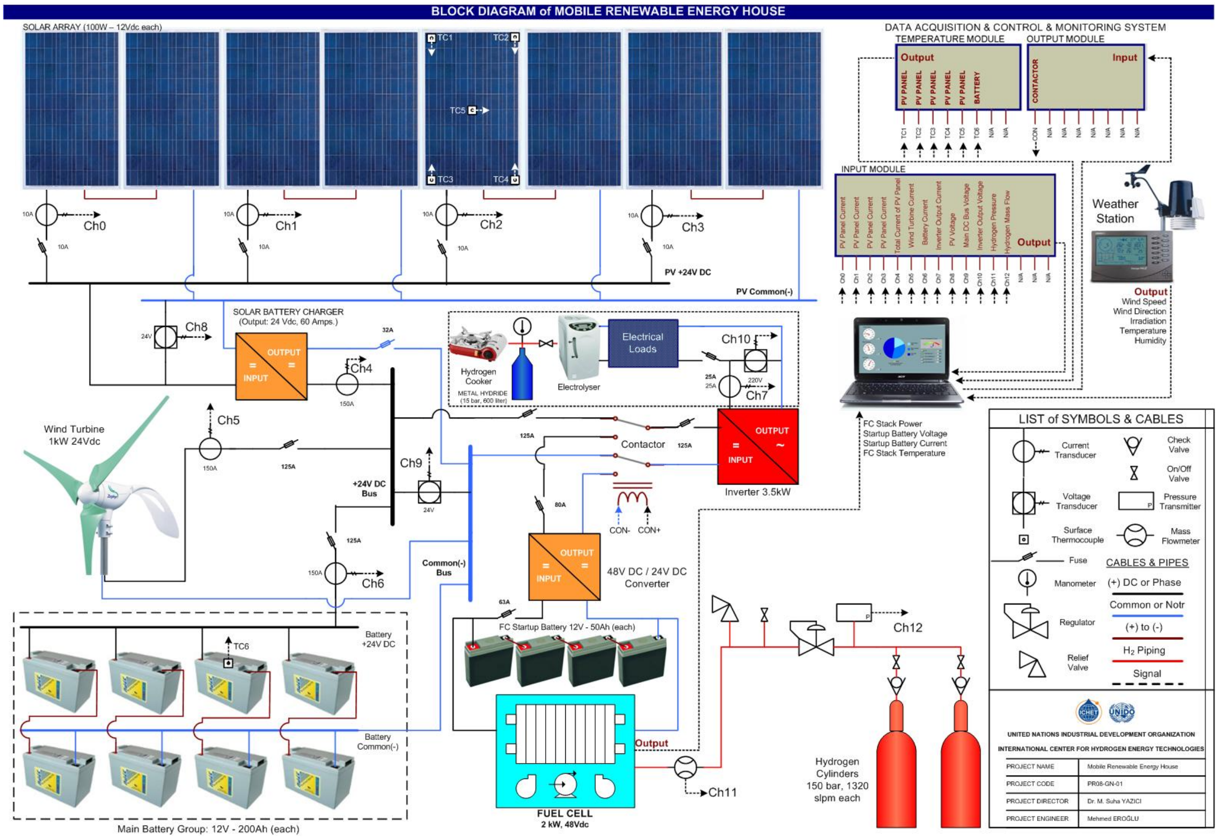

Figure 2: Block diagram of mobile renewable energy house.

A Jupiter B from FutureE is a PEM air-cooled fuel cell with 2 kW of rated power. Hydrogen is stored in two 10 litres tanks which are pressurized at 160 bar. PEM fuel cells with an air-cooled system are usually more suitable for mobile applications due to their low working temperatures and compact structure.

The battery bank consists of 8 gel type batteries of 200 Ah at 12 V. Sealed lead acid monoblock gelled electrolyte batteries are more tolerant of deep discharge, overcharge, and a high number of cycles. Due to their negligible gas emission, they are appropriate for residential usage. The sources and storage units are integrated on a single DC bus in order to make the system cost-effective. Having the same voltage level from the PV array and wind turbine allows both sources to be connected directly to the DC bus. Since the output of the PV module is unregulated, a 60 Amp rated Xantrex multifunction DC controller, which is capable of voltage regulation and three-stage battery charging, was used. The Ventura 1000 already has a rectifier with an internal regulator; hence, it gives an output of 24 V which is the same as the PV array. The fuel cell, which is used as backup power, has a 48 V output. Finally, a DC-DC converter was installed to convert the output of fuel cell to 24 V.

The battery bank with a capacity of 19.2 kWh is used in the system to supply the transient power. When the minimum battery state of charge (SOC) is taken into consideration, the usable capacity becomes 9.6 kWh which is the sufficient level for 2 days of autonomy. Hydrogen cylinders with a capacity of 8.2 kWh at the given conditions were used. Moreover, the hydrogen storage is sufficient for 0.9 day of autonomy when losses are taken into consideration; hence, the total number of autonomous days is 2.9 days. The startup battery group of the fuel cell prevents unnecessary switch-on when there is only a short term power demand. Since the battery group supplies the power without activating the fuel cell system, it ensures a smooth operation, allowing warm-up time in order to supply the necessary current for the future demand.

Figure 3: The mobile house with hybrid power system.

An automatic control system controls the energy flow and decides which energy source should supply load based on battery state of charge, hydrogen capacity, energy balance. Also control system starts and stops electrolyser when needed. For determining battery state of charge Amper-hour counting method was used with temperature and discharge, charge speed compensation. Collected data is shown to visitors on a LCD TV over an educational and simple graphical interface.

3 Conclusions

A demonstration of the PV/wind/fuel cell hybrid power system was presented. The hybrid power system increases power availability which is one of the key factors for many applications that need reliable power in remote locations. The mobile house, shown in Figure 3, demonstrates that hydrogen can function as an energy source with other renewable sources in order to generate highly reliable power.

The system was designed based on the results of a load analysis and a study of the renewable resources available in the city of Istanbul, Turkey. After the design, the components of the system were integrated; a PV module (800 W), a wind turbine (1 kW), and a fuel cell (2 kW) were installed to generate a maximum power of 3.8 kW. The presented system uses PV and wind energy as the primary energy sources and fuel cell energy as a secondary source for power generation.

Data collected from this study is being analyzed as an on-going project. With the collected data, a power analysis with MATLAB and LabVIEW will be conducted. For future work, the correlation between the parameters and energy production will be demonstrated to optimize the storage efficiency of the system.

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