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A mobile off-grid platform powered with photovoltaic/wind/battery/fuel cell hybrid power systems

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ARTICLE INFO

Article history:
Received 17 October 2012
Received in revised form
1 March 2013
Accepted 2 April 2013
Available online 6 May 2013

Keywords:
Hydrogen
Caravan
Renewable
Hybrid
Fuel cell

ABSTRACT

Cross utilization of photovoltaic/wind/battery/fuel cell hybrid-power-system has been demonstrated to power an off-grid mobile living space. This concept shows that different renewable energy sources can be used simultaneously to power off-grid applications together with battery and hydrogen energy storage options. Photovoltaic (PV) and wind energy are used as primary sources and a fuel cell is used as backup power. A total of 2.7 kW energy production (wind and PV panels) along with 1.2 kW fuel cell power is supported with 17.2 kWh battery and 15 kWh hydrogen storage capacities. Supply/demand scenarios are prepared based on wind and solar data for Istanbul. Primary energy sources supply load and charge batteries. When there is energy excess, it is used to electrolyse water for hydrogen production, which in turn can either be used to power fuel cells or burnt as fuel by the hydrogen cooker. Power-to-gas and gas-to-power schemes are effectively utilized and shown in this study. Power demand by the installed equipment is supplied by batteries if no renewable energy is available. If there is high demand beyond battery capacity, fuel cell supplies energy in parallel. Automatic and manual controllable hydraulic systems are designed and installed to increase the photovoltaic efficiency by vertical axis control, to lift up & down wind turbine and to prevent vibrations on vehicle. Automatic control, data acquisition, monitoring, telemetry hardware and software are established. In order to increase public awareness of renewable energy sources and its applications, system has been demonstrated in various exhibitions, conferences, energy forums, universities, governmental and nongovernmental organizations in Turkey, Austria, United Arab Emirates and Romania.

1. Introduction

Providing reliable, environmentally friendly, and affordable energy has been a goal for many countries. The rising consumption of energy and decreasing accessibility of natural resources are increasing the cost of electricity. In addition, greenhouse gases are becoming a threat to the natural ecosystem. Therefore, renewable energy systems have been considered as future alternatives.

Solar radiation and wind are considered the most preferred renewable energy sources for their availability and inexhaustibility [1]. However, due to the intermittent characteristics of natural resources, it has been a challenge to continuously generate a highly reliable power with photovoltaic (PV) modules

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0360-3199/$ – see front matter
http://dx.doi.org/10.1016/j.ijhydene.2013.04.025

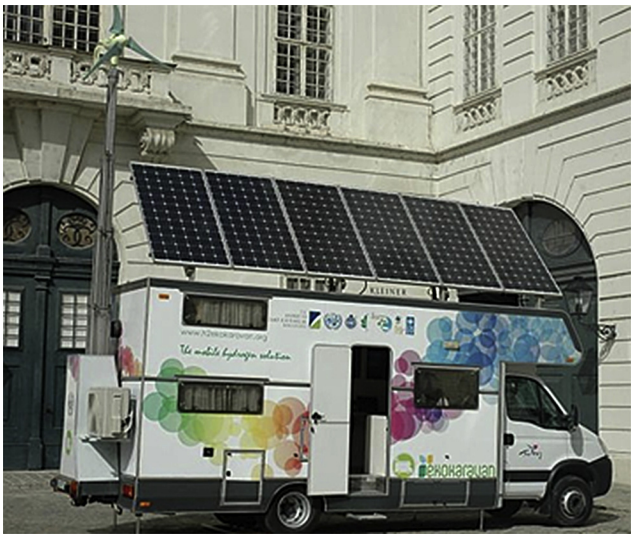

Fig. 1 – Exterior of H_2Ekokaravan.

and/or wind turbines [2]. Power-to-gas and gas-to-power conversions are best option for energy storage, efficiency and sustainability. Hydrogen can be effectively produced and stored when there is excess energy available and utilized through fuel cells when there is need for excess electricity. Studies were conducted using a fuel cell as another energy source to overcome this problem and simulated results showed that a PV/wind/fuel cell hybrid power system may be a feasible solution for stand-alone applications [3–6]. Since a multi-source hybrid power system increases energy availability significantly, it becomes advantageous for practical applications that need highly reliable power regardless of time and location [7,8].

Use of a PV/wind/fuel cell hybrid-power-system, which is independent from grid, and produce clean and sustainable energy and gas, to supply electricity to equipments in a caravan is described in the following sections. PV and wind energy are used as the primary energy sources for the system and the fuel cell performs as a backup power for the continuous generation of high quality power.

2. Discussions

H_2EkoKaravan, as shown in Fig. 1, includes a bathroom, a bedroom, a kitchen and an office type living room. Electrical equipments such as air conditioner, LED TVs, home theatre, 3G Modem, refrigerator, microwave oven, hair dryer, coffee machine, lighting, water boiler, hydrogen cooker etc. are included to form a modern living facility (Fig. 2).

In this study, H_2Ekokaravan is integrated with hybrid energy technologies and auxiliary components such as PV panels, wind turbine, electrolyser, fuel cell, batteries, electronics, mechanics, hydraulics, control and software. Wind and PV are the primary power sources of the system, and an FC-electrolyser combination is used as a backup and a long-term storage system [7,9]. In H_2Ekokaravan, solar panels and wind generator supply electricity directly to the electrical equipments. Excess energy is stored in the batteries. When the batteries are charged to an optimum level, excess energy is used to electrolyse water for hydrogen production, which in turn can either be used to power fuel cells or burnt as fuel by the hydrogen cooker. Automatic control, data acquisition, monitoring, telemetry hardware and software are implemented. Various sensors and transducers are installed to acquire data and control energy flow & mechanical actuators. Automatic and manual controllable hydraulic systems are designed and installed to increase the photovoltaic efficiency by vertical axis control, to lift up & down wind turbine and to prevent vibrations on vehicle.

In Fig. 3, various applications of H_2Ekokaravan are shown. H_2Ekokaravan can be designed to function as an electricity source for mobile medical centre for remote areas, or as an emergency response vehicle, relief coordination hub or communication centre under circumstances where power from the grid is unavailable.

2.1. *Simulation/experiment*

Design of the hybrid power system is based on the data of solar radiation and wind availability in the city of Istanbul, Turkey. A renewable energy analysis software "HOGA" is used to dimension the components of H_2Ekokaravan by providing inputs such as load profile, solar, wind data, equipment options, numbers, prices, control strategy etc. Daily load profile is close to a studio apartment with an air conditioner. Total daily consumption is assumed to be 4.5 kWh for simulation and an energy consumption value is assigned for each hour. Air conditioner, the most energy-consuming device, is assumed to be running 8 h a day that corresponds to 4 kWh per day energy usage. Istanbul's monthly solar irradiation and hourly wind data is taken from Turkish State Meteorological

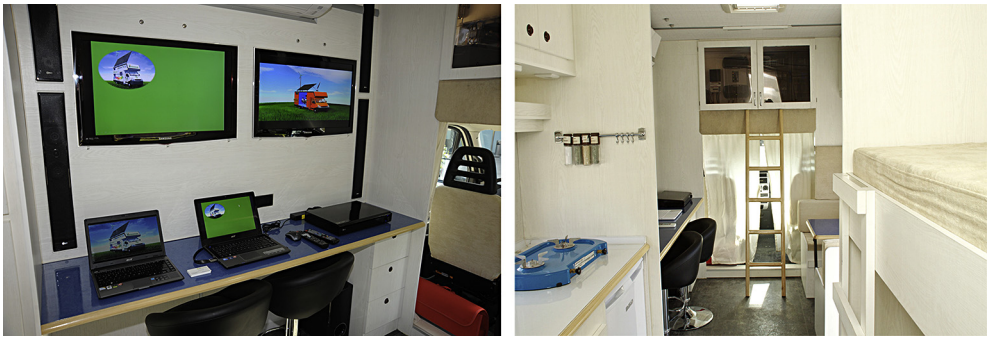

Fig. 2 – Interior of H_2Ekokaravan.