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Light Mobility Applications towards Public Education and Research

Y. Ceviz, **M. Eroglu**, **T. Akfidan**, **S. Altinel**, **M. S. Yazici***, UNIDO-ICHET – International Centre for Hydrogen Energy Technologies, Turkey

Abstract

International Center for Hydrogen Energy Technologies (ICHET) has been implementing measures to demonstrate potential benefits of the "hydrogen and fuel cell systems" in developing countries. As part of applied R&D activities, various prototype vehicles (a small tri-wheel scooter, a four-passenger cart integrated with a 2 kW fuel cell, a mobile caravan with wind, solar and fuel cell power and a forklift with the necessary fuelling options and controls) were demonstrated utilizing hydrogen as fuel. Performance analysis, sizing of the various system components and modelling will be carried out as part of applied R&D program. A long-term objective of the projects is to push for use of fuel cell powered light mobile vehicles in public places and encourage local industry to manufacturer similar vehicles and explore market potential for such use. As a benefit of this activity, public awareness on applications of renewable and fuel cell technologies will increase and viability of such systems will be demonstrated to change public perception.

1 Introduction

Cleaner and more efficient energy systems and transportation means will be the choice of future under scenarios for climate change and energy supply limitations. The automotive industry is already in transition from internal combustion engines to batteries and fuel cells. Electricity and hydrogen can be produced from any primary energy carrier at high efficiencies. Hydrogen and fuel cells enable almost the same personal freedom, flexibility, and ease-of-use for energy and transportation.

The International Centre for Hydrogen Energy Technologies (ICHET) act as a bridge between developed and developing countries by spanning the gap between research and development organizations, innovative enterprises and the market place in order to stimulate appropriate applications of the hydrogen energy technologies and related industrial development [1-4]. The scope is worldwide with particular emphasis on the role of developing countries. Several demonstration projects have been implemented and some are discussed below.

2 Mobile Hydrogen Fuelling Station

This demonstration project intends realization of mobile refuelling for hydrogen fuelled facilities while stationary item will be aside [5]. All components required for a mobile hydrogen fuelling facility will be mounted onto a truck (figure 1) as an all-in-one system to

* Corresponding author, email: syazici@unido-ichet.org

provide fuel for our demonstration vehicles and to fill up hydrogen cylinders and metal hydride canisters. Small passenger cart, three wheeled scooter and mobile house require metal hydride canisters to be filled at low pressure values, while forklift needs approximately 200 bar filling pressure on the contrary. By accomplishing this project UNIDO-ICHET will gain mobile refuelling capability. In figure 1 process flow diagram is shown. Tap water stored in a tank is sent to the DI water unit; after the process water comes out of the unit with quality of min. ~2 Megohm-cm (0.5 μS/cm), it is pumped into the proton exchange membrane (PEM) electrolyser (1.5-4 bar); via electrolysis process ultrapure water is separated into hydrogen (99.9995% purity with water vapour <5ppm, N_2<2 ppm, O_2<1 ppm impurities) and oxygen. Hydrogen stored in a buffer tank with 100 l water volume at 14 bar; and then it is compressed up to 200 bar with 1 Nm^3/h capacity.

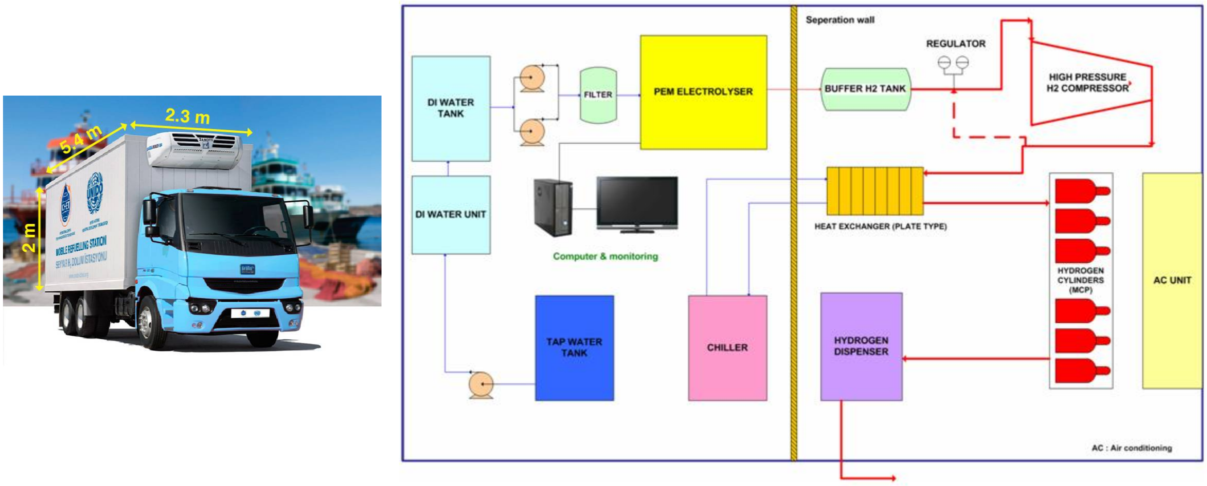

Figure 1: Mobile hydrogen fuelling station and process diagram.

Finally hydrogen is stored in 12x1 parallel connected steel cylinders with 50 l standard water volume at 200 bar with 100 Nm^3 total storage capacity. All hydrogen cylinders bundled on a common frame are connected to a single manifold with a control valve and a pressure gauge. The manifold has one inlet and 200 bar outlet to supply fuel to mobile units, 200 bar outlet to fill in the hydrogen cylinders and 15 bar outlet to fill up the metal hydride canisters.

3 Mobile Renewable Energy House

A photovoltaic/wind/fuel cell hybrid power system for stand-alone applications is demonstrated with a mobile house [6]. 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 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 capacity. The presented system uses PV and wind energy primarily and fuel cell energy as a secondary source for power generation. In figure 2, the energy production and demand is shown. In figure 3 and 4, block diagram and electrical diagram of the energy system are shown respectively. Load scenario assumes that 4.8 kWh energy 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.

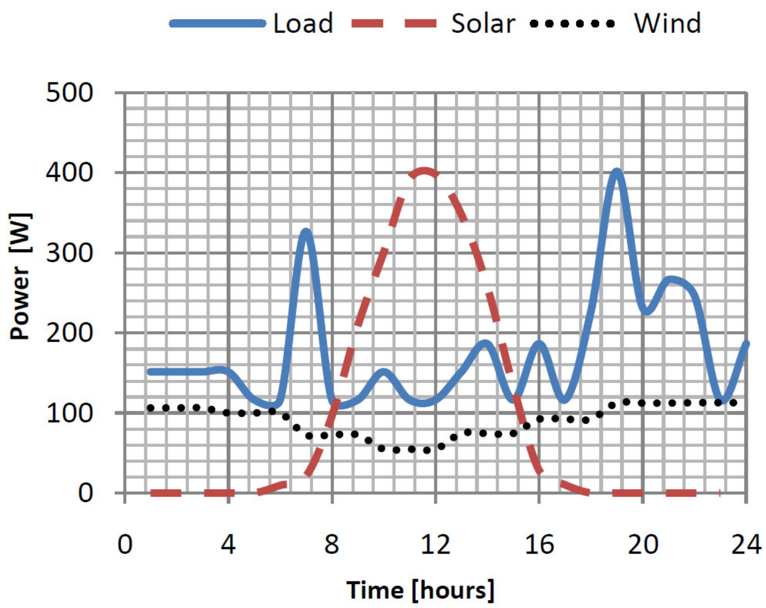

Figure 2: Energy production and demand relevance of mobile renewable energy house.

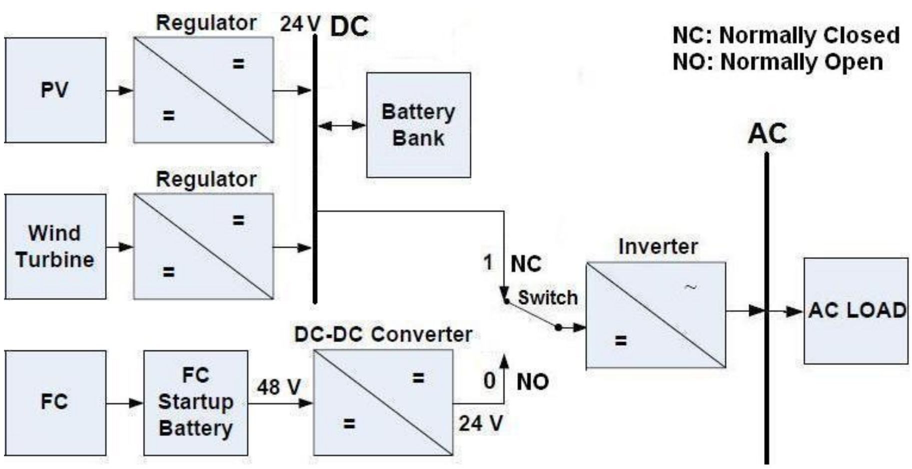

Figure 3: Block diagram of mobile renewable energy house.

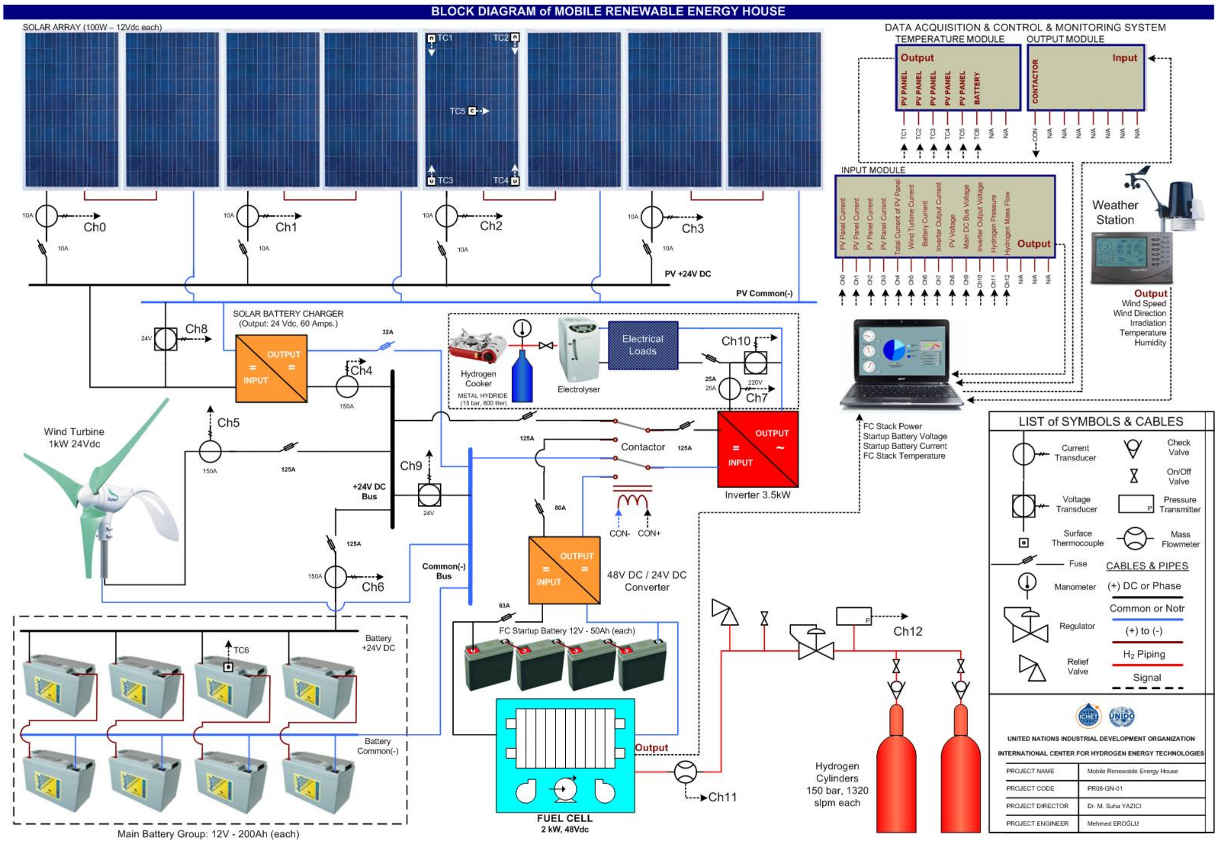

Figure 4: Electrical diagram of mobile renewable energy house.

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 8.159 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.

4 Fuel Cell Passenger Cart Project

One of UNIDO-ICHET's demonstration projects is the Electrical Passenger Cart which is mainly powered by PEM fuel cell system [7]. Passenger carts, commonly used in airports and public sites to facilitate the movement of elderly and disabled people, are generally powered by battery packs. Fuel cell passenger cart prototype demonstrates that hydrogen fuel cells can be advantageously integrated into such mobile units. The Fuel Cell Passenger Cart project achieved by UNIDO-ICHET is a good model for the approach mentioned above (Figure 5). The passenger cart has a 2 kW fuel cell as main electrical power source and 1.5 kW battery group as auxiliary power unit. The hydrogen fuel cell unit generates electricity for electric motor and other electrical equipment of the cart. Batteries can be charged by plug-in or 0.36 kW solar panels. The passenger cart mostly uses electrical energy which comes from the fuel cell unit; but there are some exceptions to use the battery next to the fuel cell system. If the energy generated by fuel cell drops or motor needs power instantly (>2 kW), then the battery group supplies the electric motor next to the fuel cell system; and thus possible damage to fuel cell stack is prevented by means of battery group. The fuel cell unit is supplied by six metal hydride canisters with 3600 standard litres storage capacity of hydrogen gas (99.99% purity) at 17 bar.

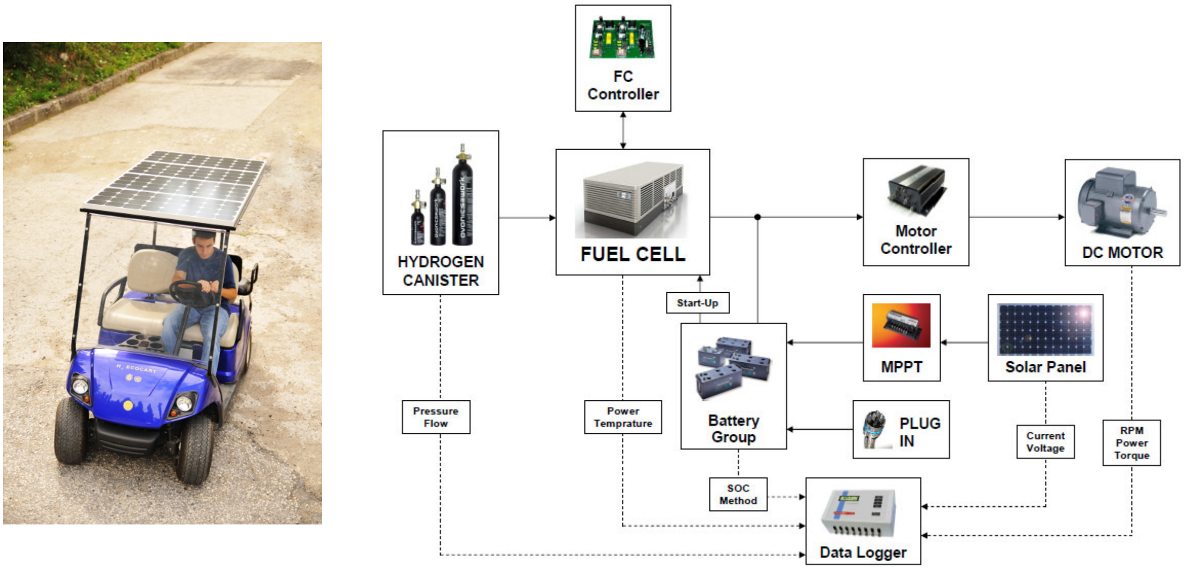

Figure 5: Fuel cell passenger cart and system block diagram.

Further aim of this project is to test fuel cell passenger cart on a circuit and to collect scientific data from the system. The data will be used to simulate dynamic model of the fuel cell passenger cart based on analysis programs. Following the simulation, results will be reviewed and the system optimization will be carried out for performance enhancement.

5 The Fuel Cell Forklift

The fuel cell forklift project intends to demonstrate the conversion of forklift powering technology from diesel engine or conventional lead-acid batteries to environmentally friendly PEM fuel cell [8]. The design and prototype phases of this project have been carried out jointly by ICHET and Cumitas, a Turkish forklift manufacturer. The hydrogen fuel cell forklift is based on the vehicle retrofitted by Cumitas and integrated by ICHET (figure 6). This 1.5 tons capacity forklift comprises an 8 kW PEM fuel cell power pack and a hydrogen storage tank. It is served by hydrogen refuelling facilities purchased from a local hydrogen distribution company, consisting of a nozzle connected to a manifold of 15 pressurized hydrogen cylinders linked in parallel. Preliminary tests have demonstrated both improved overall performance and an extended run time between fills, which together significantly increase the forklift’s productivity. Moreover, if the hydrogen is produced from a renewable energy source, the overall carbon footprint of the forklift is drastically reduced. As a unique item for technology demonstration, the hydrogen forklift is being exhibited in public events, fairs and clean energy shows throughout Istanbul as part of UNIDO-ICHET's endeavour to raise awareness and acceptance of hydrogen energy technologies.

Figure 6: Fuel cell forklift and hydrogen filling.

6 Conclusions

ICHET has several demonstration projects to promote eco-friendly hydrogen and fuel cell technologies in developing countries for them to adopt such technologies in early stage. With these initiatives, ICHET is committed to raise awareness and acceptance of hydrogen energy technologies in commercial applications. Fuel cell forklift is a relevant demonstration prototype as competitive as diesel or battery systems. Fuel cell passenger cart could be an alternative as a mobile unit for e-mobility in industrial plants or short commutes. Mobile renewable energy house is a promising prototype for system demonstration for various purposes such as disaster response unit, medical room or remote mission house. Mobile Hydrogen Fuelling Station project will give mobile refuelling capability for hydrogen vehicles and mobile units.

Acknowledgements

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