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Hydrogen and fuel cell demonstrations in Turkey

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Abstract

As a non-profit UNIDO project funded 100% by the Turkish Ministry of Energy and Natural Resources, International Center for Hydrogen Energy Technologies (ICHET) has been implementing pilot demonstration projects, providing applied R&D funding; organizing workshops, education and training activities in Turkey and other developing countries to show potential benefits of "hydrogen and fuel cell systems". It is important to leap-frog developing countries to hydrogen for eliminating detrimental effect of fossil fuels. To achieve its mission, ICHET implements pilot demonstration projects in combination with renewable energy systems to encourage local industry to manufacture similar systems and explore market potential for such use. Support is provided to selected industrial partners in Turkey for developing products or for early demonstrations including a fuel cell forklift, a fuel cell boat, a fuel cell passenger cart with PV integrated roof-top, renewable integrated mobile house, fuel cell based UPS installations. As more and more systems demonstrated, public awareness on applications of hydrogen and fuel cell technologies will increase and viability of such systems will be realized to change public perception.

Hydrogen; fuel cells; demosntrations;

1. Introduction

Developing economies are heavily investing on alternative and renewable energy technologies to meet their future energy demand. Hydrogen together with renewable energy sources has been promoted as a potential solution to the climate change issue. Hydrogen can be made from a variety of domestic resources and compatibly used with electrochemical and combustion processes, making hydrogen

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superior to any other alternative fuels. Fuel cells, with their numerous possible applications, may actually be the main driver for the hydrogen economy when hydrogen infrastructure becomes available [1].
There has been growing worldwide interest in renewable hydrogen economy and fuel cell technology, as reflected in the dramatic increase in public and private sector funding. International partnerships are also emerging that provide the necessary infrastructure and coordinate multinational deployment programs. Transition to a hydrogen economy may be more beneficial for developing countries due to new economic opportunities for reducing poverty and the availability of dramatically cleaner renewable energy sources. Energy independence can truly be possible when each individual can produce their own energy. China, India, South Africa are setting serious demonstration projects to introduce hydrogen and fuel cell technologies [2]. Since 2004, International Center for Hydrogen Energy Technologies (ICHET) has been at forefront on hydrogen and fuel cell demonstrations in Turkey [2]. In order to make ways toward hydrogen economy and place hydrogen energy into proper perspective for its effective and efficient implementation, ICHET activities are designed to increase knowledge and awareness of society in whole.

2. Hydrogen and Fuel Cells in Turkey

Hydrogen and fuel cell research has started late in Turkey and it is still in infancy compare to developed countries. To achieve significant progress with hydrogen technologies, Turkey must develop and implement favorable policies that treat renewable and hydrogen energies as priority issues. Turkish Ministry of Energy has been supporting the International Centre for Hydrogen Energy Technologies (ICHET) through a trust fund administered by UNIDO to implement hydrogen and fuel cell demonstrations in Turkey and developing countries. ICHET has acted as a catalyst to involve Turkey in international hydrogen and fuel cell platforms. The Turkish Scientific and Technical Research Council, Marmara Research Centre (TUBITAK-MAM) has been working on new technology development with emphasis on fuel cell prototypes, gasification and reforming research. Several Turkish universities have engineering faculties with research programs on hydrogen and fuel cell subjects. However, companies involved with fuel cell research is very limited and restricted to only a few companies.

3. 'UNIDO-ICHET Effort on Hydrogen and Fuel Cells in Turkey

3.1 Demonstrations

ICHET has several national projects for various hydrogen and fuel cell technology demonstrations [3]. Universities, small and big companies, public entities have all been encouraged to participate in these projects for widespread acceptance of hydrogen technologies.

The Bozcaada island wind-solar-hydrogen facility aims to demonstrate electricity and hydrogen production with 30 kW wind power coupled with 20 kW PV panels. This on-grid set-up is ideal to demonstrate storage of excess electricity in the form of hydrogen (power to gas, gas to power). Hydrogen produced at 50 kW electrolyzer is utilized at a 35 kW genset and 20 kW fuel cell back-up power systems. This demonstration is helping learning process on renewable-hydrogen integration in the energy systems of islands.

Another promising fuel cell application that takes advantage of zero emission feature is waterborne applications. Fuel cell systems will be advantageous especially for small boat use on lakes and rivers whose pristine environments need to be preserved from green house gas emissions and oil contamination. ICHET is supporting four universities to construct boats measuring up to 7 m long and 3 m wide (Fig. 1). Each boat is integrated with an 8 kW fuel cell with receiving power from high pressure hydrogen stored on board. Students are utilizing their engineering knowledge on design, control, power

management and system integration. ICHET facility and engineers are used for hydrogen and fuel cell system integration.

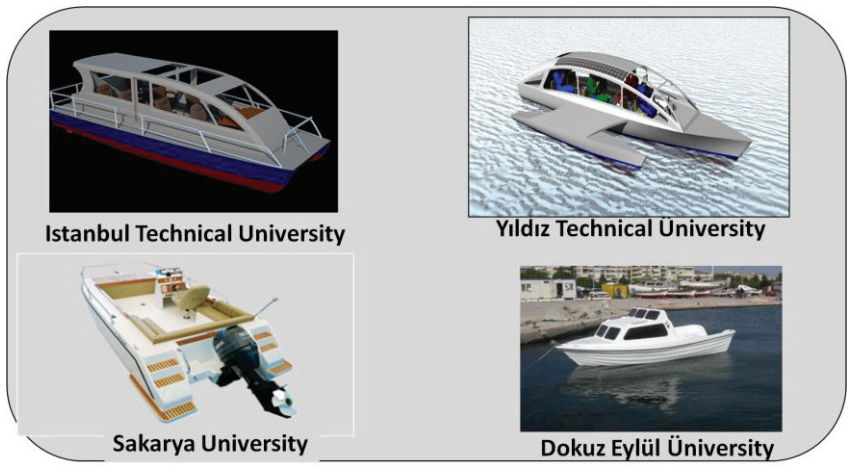

Fig. 1. Boats constructed by different universities

A hybrid bus powered by a hydrogen fuelled internal combustion engine (HICE) is in the manufacturing stage. The HICE will act as an electrical generator that charges on board batteries for powering an electrical drive system (Fig.2). Bus is expected to be operated by the local authority to carry passenger in the area where filling station is located.

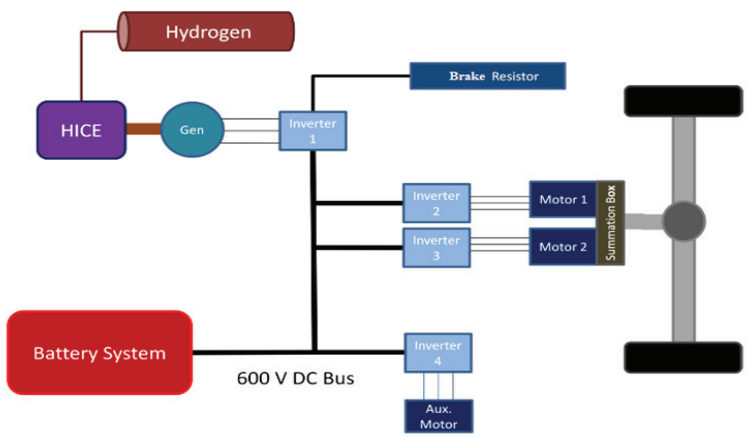

Fig. 2. Hybrid hydrogen engine-battery bus drive train

Hydrogen for the applications mentioned above will be provided through a hydrogen production, storage and refueling facility adjacent to the Golden Horn in Istanbul. System will provide about 50 kg/day hydrogen at 350 bar (for bus), 200 bar (boats) pressures and 100 kg storage capacity. This will be the first facility of its kind supplying both sea and land transport vehicles from the same refueling facility putting ICHET on the map for European network of filling stations. A smaller version of filling facility is

made operational by ICHET engineers for the purpose of providing fuel at 200 bars pressure to the various demonstration vehicles and for refilling low pressure metal hydride cylinders (Fig. 3). ICHET worked with a Turkish company for the production of a PEM electrolyzer with 5 litres/min production capacity in the 15-20 bars pressure range. Encouraging local companies in hydrogen production technologies, while at the same time, creating opportunities for market environment with a low cost electrolyzer is important.

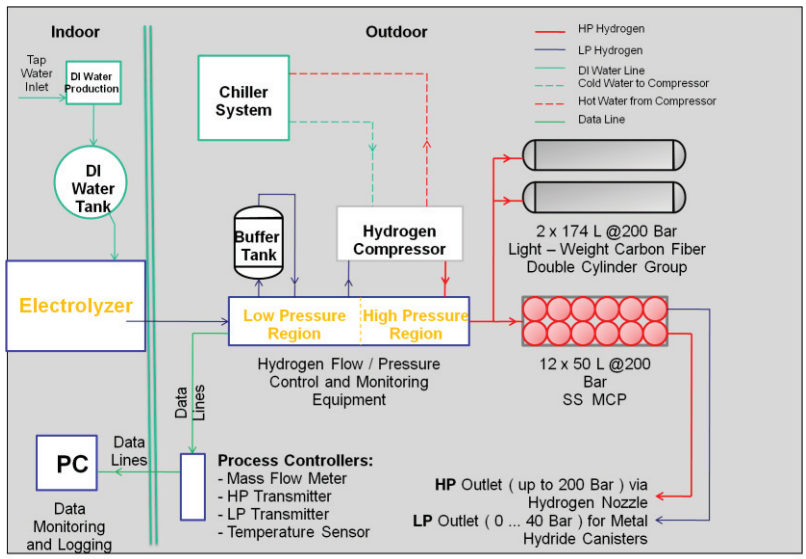

Fig. 3. Schematics of small filling point at ICHET facility

In Figure 4a, class 1 forklift built with an 8 kW fuel cell is shown. It has 1.6 kg hydrogen storage capacity and carrying capacity of up to 1.5 tons. It is refilled from small filling point at ICHET facility with commercial refueling nozzles (Fig. 4b). Replacing existing battery technology in forklifts will increase productivity by reducing refueling times and reduce cost by eliminating additional batteries and forklifts. The European Commission is financing production of 10 fuel cell forklifts (FC FLT) with required hydrogen refueling infrastructure at sites in Turkey, the United Kingdom and Spain. Each deployment site is representative of one of the market segments for early commercialization including: airports; light logistics; and industry. Real time data will be gathered with fuel cells fuelled by different hydrogen supply scheme, such as trailer delivered, on-site reforming and by product.

Fig. 4 (a) Fuel cell forklift and (b) filling process with portable nozzle

Fuel cell based un-interruptible power supply (UPS) systems are considered as an early commercial opportunity for market penetration of fuel cells [3]. ICHET has installed two back-up power systems with 5 kW power capacity in locations of commercial activity (Istanbul Ferry Headquarters and Ankara OSTIM Industrial Region) (Fig. 5a). In continuation of this project with partners from manufacturers, suppliers, end users and R&D centers, the European Commission is financing four additional units in Turkey, two being considered as telecommunication application (Fig.5b). This demonstration project will involve benchmarking of units with extensive field trials at sites selected by end users in Italy, Switzerland and Turkey allowing lifecycle cost analyses to be undertaken for the determination of the real economic value in comparison with existing battery and diesel generator based technologies.

(a) (b)

Fig. 5. Fuel cell back-up power systems in (a) daily operations and (b) telecommunications towers

Hydrogen should be considered an essential component of the majority of renewable energy systems. In order to promote power to gas scheme where excess electricity is converted to gas for later conversion, multi-source hybrid power system (photovoltaic/wind/fuel cell/battery) for stand-alone applications is developed and demonstrated by ICHET engineers (Fig. 6). In this vehicle, batteries are being used to store some of the excess energy produced by the solar panels (1.7 kW) and wind turbine (1 kW) which in normal use feed DC power directly to the inverter [4]. Any excess power is used to electrolyze water for hydrogen production which in turn be used to power a fuel cell or burnt as fuel in the stove. The system, with 34 kWh storage-capacity, has many potential uses including off-grid power supply, emergency response vehicle, medical facility and communication center etc.

Fig. 6. Renewable-fuel cell energy demonstration mobile unit

Demonstration projects by themselves are great learning platforms to solve problems with real world applications. System diagnostics were carried out constantly to seamlessly integrate fuel cell power plant, converters, rectifiers and hydrogen supply system. System integration knowledge is utilized to identify problems. Projects lead to development of the data acquisition and monitoring system plus implementation of automatic controls for power management. Automatic controls are designed and installed to optimize the production and storage efficiency of the systems. Demonstration projects implemented in Turkey and abroad have always relied on support provided by engineers or M.S. and Ph.D. students for system integrations, maintenance, data acquisition and analysis.

3.2. R&D Support:

ICHET, university and industry partnerships are utilized to take R&D stage development into prototyping and eventually advancing towards commercial product introduction. Support of several universities in Turkey (METU, NU, EU, IU, SDU, GU, YU, AU) helped several M.S. and Ph.D. students to gain expertise on their subject field and helping capacity building in Turkey. Projects with multi-partner involvement under university coordination are routinely implemented to turn academic R&D programs and expertise into product development and industrial commercialization.

Two such active projects are 3 kW fuel cell systems and 3 kW CHP systems development in Turkey. Both consortiums consist of partners from academia, industry and R&D organizations, each having individual expertise in the areas of catalysts, membranes, system assembly, electronics and control systems. In the final part of the project, the consortium is expected to provide plans for developing the prototype to a pre-production level. This type of technology is expected to be very viable and cost effective for applications in developing world in the future. While supporting external activities on fuel cell development, ICHET engineers focus on utilizing their mechanical and control engineering knowledge to develop fuel cell integrated system. Figure 7 shows system diagram for integration of 1,5 kW air cooled stack with other necessary components, control box and user interface. Next stage in the development is to improve capabilities in air and water cooled-stack system development.

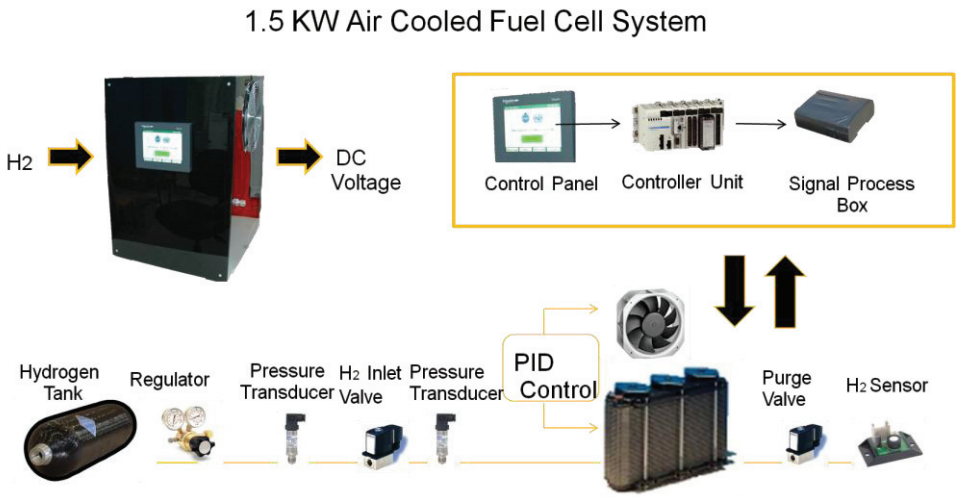

Fig. 7. Stack to system integration components

4. Conclusions

ICHET is promoting hydrogen and fuel cell energy technologies for social and economic benefits. Turkey has not been at the forefront of fuel cell development. In order to close the gap, ICHET's demonstrations and permanent research capabilities including fuel cell testing; hydrogen production and storage facilities offer a wide range of hydrogen energy related facilities to Turkish universities and industry. However, the most significant impact will come from educating the public about hydrogen energy and its future role. This eventually will create sufficient momentum to influence policies, accelerate public interest in hydrogen technologies, lead to the creation of a technology network for competitive advantage, and unlock the energy potential of Turkey. A "National Hydrogen Energy Roadmap" would encourage nationwide involvement. It is believed having Regulations, Codes and Standards (RC&S) in place together with Government subsidies and tax incentives will encourage foreign companies to consider Turkey for mass production.

Acknowledgements

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