OPERATIONAL EXPERIENCE FROM THE RES2H2 WIND-HYDROGEN PLANT IN GREECE

E. Varkaraki, E. Zoulias, E. Stamatakis
Centre for Renewable Energy Sources,
19th km. Marathonos Av., 19009 Pikermi, Greece
evarkara@cres.gr

INTRODUCTION

The simultaneous production of green electricity and green hydrogen fuel is an interesting option for wind farm owners. The hydrogen production rate may be optimised for different situations, according to the electricity export conditions available.

A wind-hydrogen experimental plant has been constructed in the wind park of the Centre for Renewable Energy Sources (CRES) in Keratea, Greece, in the frame of the European project "RES2H2" (ENK5-CT-2001-536). The plant is composed of a 25 kW water electrolyser, metal hydride tanks filled with a $LaNi_5$-type alloy and a hydrogen compressor for filling hydrogen cylinders, all powered by a 500 kW synchronous wind turbine. It has been in operation for over two years now.

The advanced alkaline electrolyser produces 0.45 kg/h hydrogen directly at 2 MPa pressure, which is compressed up to 22 MPa in a single stage, with an additional 10% energy loss. A small hydrogen buffer accommodates the flow variations between the electrolyser and the compressor. The electrolytic hydrogen may be also stored in six metal hydride tanks with a total capacity of 3.6 kg hydrogen. The utilities comprise an air compressor and drier to supply instrument air to the pneumatic valves, a water boiler to supply hot water to the metal hydride tanks for hydrogen desorption and a water chiller for the cooling water circuit, all supplied by wind energy.

Hydrogen is occasionally used to supply experimental hydrogen vehicles, either based on fuel cells or modified internal combustion engine. In the absence of a permanent hydrogen "user", and in order to avoid venting the produced hydrogen, the plant is only operated discontinuously. The installation of a fuel cell with heat cogeneration capability is foreseen for the near future, in order to supply electricity to the grid in low wind regimes.

OPERATING MODES OF THE WIND-HYDROGEN SYSTEM

The different electrical loads of the system, namely the hydrogen compressor, power conditioning unit, air compressor and drier, water boiler with circulating pump, and water chiller, require a fixed amount of power, which cannot be varied according to the availability of wind. Among the plant's components, only the electrolyzer can withstand the rapid variations of wind power.

The highest data acquisition rate available, which is generally applied, is one set of measurements every second. The set of measurements is composed of 21 variables for the hydrogen system plus one for the power output of the wind turbine. Only the temperature and pressure of the metal hydride tanks are registered every 10 seconds, due to their relative inertia. Additional data processed by the wind turbine's own control and monitoring system are recorded for 10-minute intervals.

There are three main modes of automatic plant operation. In the first one, the electrolyser supplies hydrogen to the metal hydride tanks and the hydrogen compressor does not operate. In the second one, the electrolyser supplies hydrogen to the compressor, filling the high pressure cylinders. In the third, hydrogen from the metal hydride tanks is compressed in the high pressure cylinders. The automatic operation is stopped when the high pressure filling station is full. The hydrogen discharge is performed manually, through a pressure regulator.

RESULTS & DISCUSSION

The overall efficiency of the system, from the electrical energy of the wind turbine to the high heating value of the hydrogen stored varies from 50% to 70%, according to the operating conditions. The electrolyser efficiency and some preliminary results, regarding the plant operation and performance, have been presented elsewhere (Varkaraki *et al*, 2006). The efficiency of the diaphragm compressor increases with higher inlet pressures and depends on the final storage pressure.

The performance of the metal hydride tanks under real conditions and their potential for the purification of electrolytic hydrogen are actually under investigation. The metal hydride tanks are supplied with hydrogen of "electrolytic purity", as produced in the alkaline electrolyser, without additional purification. The oxygen content in hydrogen is around 0.2% and the hydrogen is saturated with water vapour at the operating pressure, which corresponds to an atmospheric dew point of circa +12°C. The system has only been subject to a dozen of charging/discharging cycles, and no decrease of the storage capacity was detected so far.

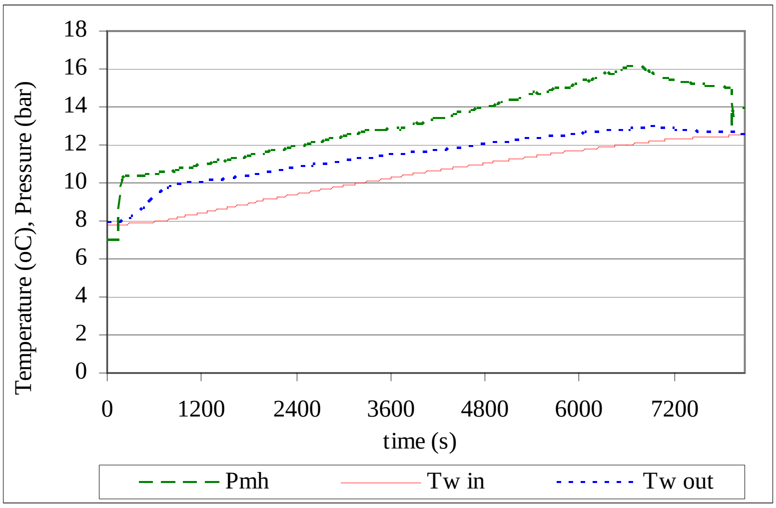

Fig. 1: Filling of the Metal Hydride Tanks under steady flow without external cooling

In order to avoid the energetic losses due to the external cooling of the metal hydride tanks, the hydrides may be allowed to form at low rate. An example is shown in Figure

1, where the pressure and temperature increase during charging with hydrogen.

In real scale storage systems, there is generally no temperature indication inside the metal hydride tanks, but the water temperature may be measured at the inlet and outlet of the water-cooled system. Even when a temperature sensor is installed inside the tank, the measurements may not be representative of the whole storage system, due to the presence of gradients. In addition, the charging and discharging processes are non-equilibrium situations. The measurement of a “precise” Pressure-Composition-Temperature curve is therefore not possible in real systems. However, a qualitative relation between pressure and temperature for a given hydrogen content can be established by letting the metal hydride tank cool down slowly after a heating phase. The water temperature at the inlet and outlet are almost equal, and close to the hydride temperature. Such an example is shown in Figure 2, and may be repeated for several hydrogen compositions.

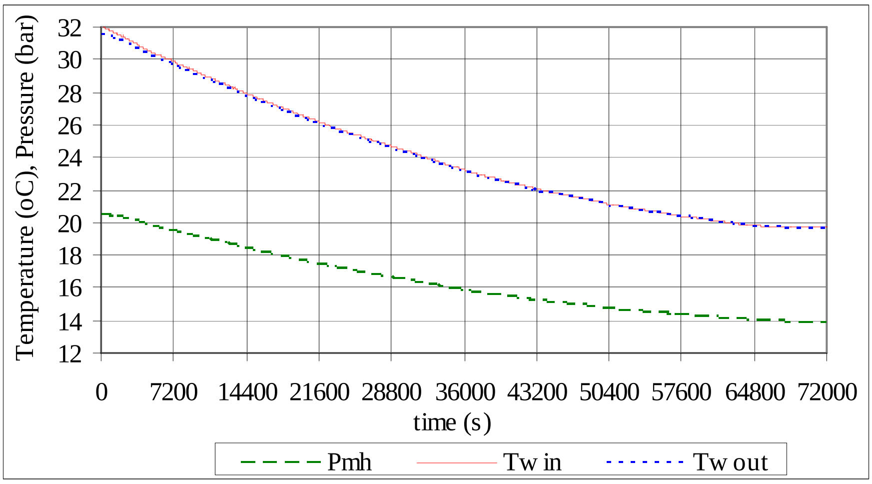

Fig. 2: Temperature and pressure evolution during slow cooling down of the Metal Hydride Tanks

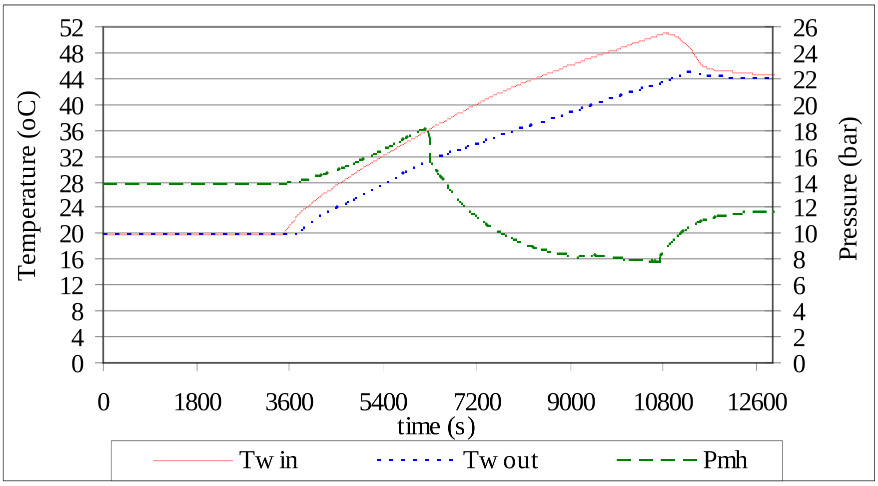

Fig. 3: Preheating and partial discharge of the Metal Hydride Tanks

A preheating phase is generally necessary prior to the discharge of the metal hydride tanks. During the discharge, heat is continuously supplied, but the pressure may not remain constant if the hydrogen discharge rate is fast. An example is shown in Figure 3, where the metal hydride pressure drops continuously during discharge, but increases again as soon as the discharge stops and comes closer to the “equilibrium” pressure.

CONCLUSION

The efficiency of wind-hydrogen systems may be enhanced by the appropriate sizing of the individual components, in relation with the modes of operation foreseen. Metal hydride tanks should be filled without external cooling to the extent possible and the heat supply during discharge should be optimised.

REFERENCES

Varkaraki E., Lymberopoulos N., Zoulias E., Kalyvas E., Christodoulou C., Karagiorgis G., Stolzenburg K., “Experiences from the operation of a wind-hydrogen pilot unit”, Proceedings, 16th WHEC, 13-16 June 2006, Lyon, France

BRIEF BIOGRAPHY OF PRESENTER

Dr. Elli Varkaraki is a chemical engineer, working in the Renewable Energy Sources & Hydrogen Technologies department of CRES since 2001. Before joining CRES, she has worked as a process engineer for ammonia and urea plants and hydrogen generators. Her research interests cover the fields of electrochemistry and catalysis and now focus on the hydrogen production through electrolysis and the optimised design of hydrogen systems coupled to renewables.