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Stand-alone Energy System Applicable for Islands

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Abstract

A small-scale stand-alone renewable hydrogen energy system has been installed at the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split. The system consists of a wind turbine (1.4 kW), PV panels (1.6 kW), batteries (8 kWh), electrolyzer (2.4 kW), hydrogen storage, fuel cell (1.2 kW), DC/DC inverter (1.2 kW), control unit and programmable DC load. Electrolyzer can operate directly on variable power produced from renewable energy. It can deliver hydrogen at pressures up to 30 bar, so no hydrogen compressor is used. The purpose of this system is to study and optimize control strategies for energy management.

If the system needs to satisfy not only power demand but also heating and cooling, an air-source heat pump may be added to the system. In that case the system also includes heat recovery from the fuel cell and from the heat pump when working in the cooling regime. The system may be sized to satisfy daily power, domestic hot water and space heating and cooling needs of a single family house in a Mediterranean climate throughout year. In addition, the system may be sized to generate additional hydrogen fuel which may be used to power a vehicle or a boat.

As, the system is fully scalable it can be sized for a house, a village or an entire island, providing complete energy independence.

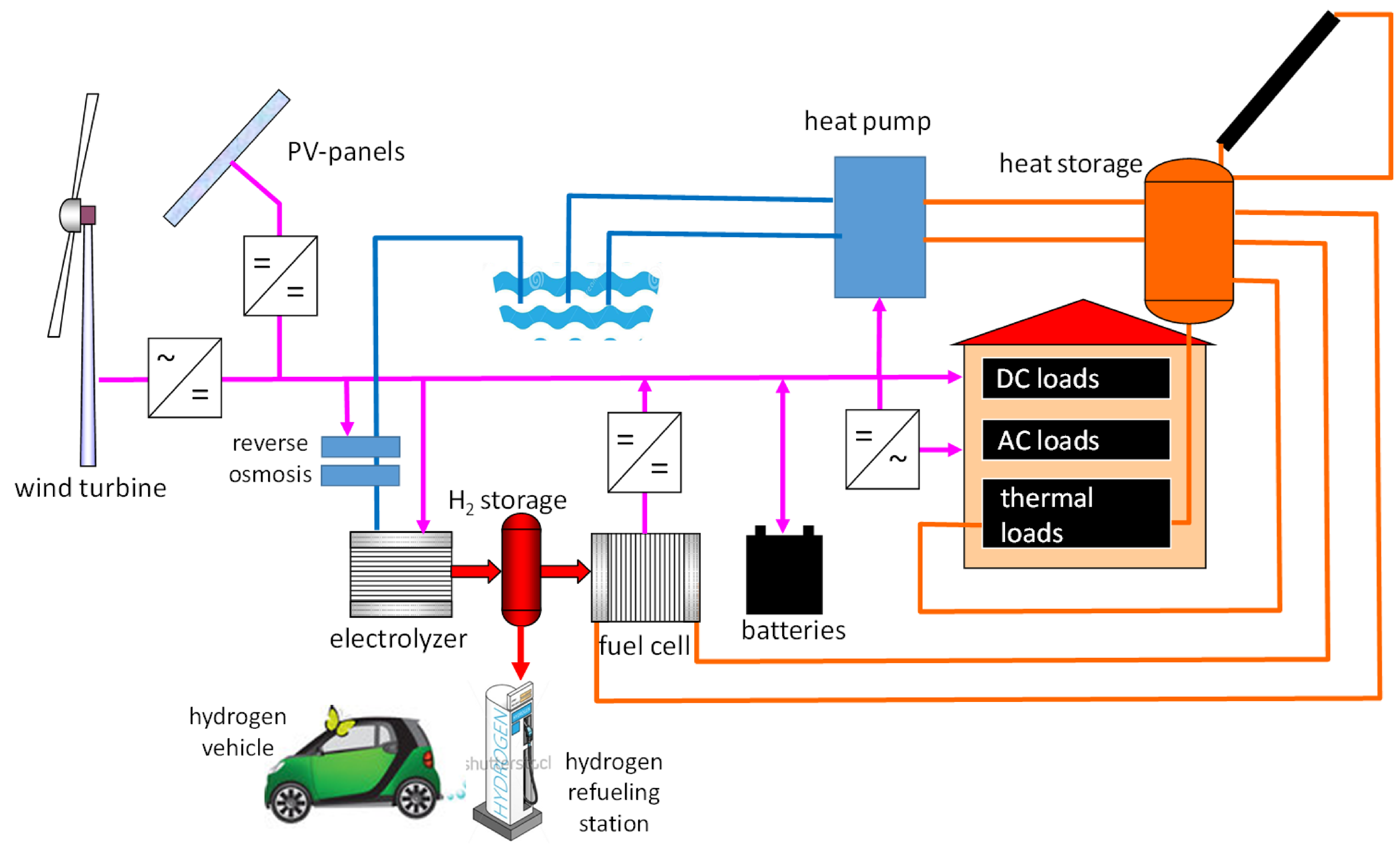

Fig. 3. Model of a stand-alone hydrogen energy system with added thermal subsystem

Stand-alone Hydrogen Energy System

Fig. 1. Stand-alone hydrogen energy system

Each of the components has its own operating characteristics:

- For the **PV panels (1)**, it is the current vs. voltage curves for different solar irradiations.
- For the **wind turbine (2)**, it is the power vs. wind speed curve.
- For the **hydrogen storage (4)**, it is the tank capacity and hydrogen tank replenishment.
- The **polarization curves** (voltage vs. current density) for the **electrolyzer (3)** and the **fuel cells (5)** were provided by a manufacturer and the **efficiency vs. power curves was calculated**. The minimum input power for electrolyzer was set at 20% of the rated power and minimum output power for the fuel cells was set at 10% as a safety boundary.
- The **battery bank (6)** has a significant role in such system as it is used as a short-term energy storage. Over-discharge of the battery should be avoided to protect the battery. There fore, the **low limit of SoC_{BAT} was set at 20% as a safety boundary.**
- The input weather data, sun irradiation and wind speed, used in this study were acquired from Croatian Meteorological and Hydrological service, station Split - Marjan. The **end-user load (7)** is defined as a constant load of 350 W over a year period.

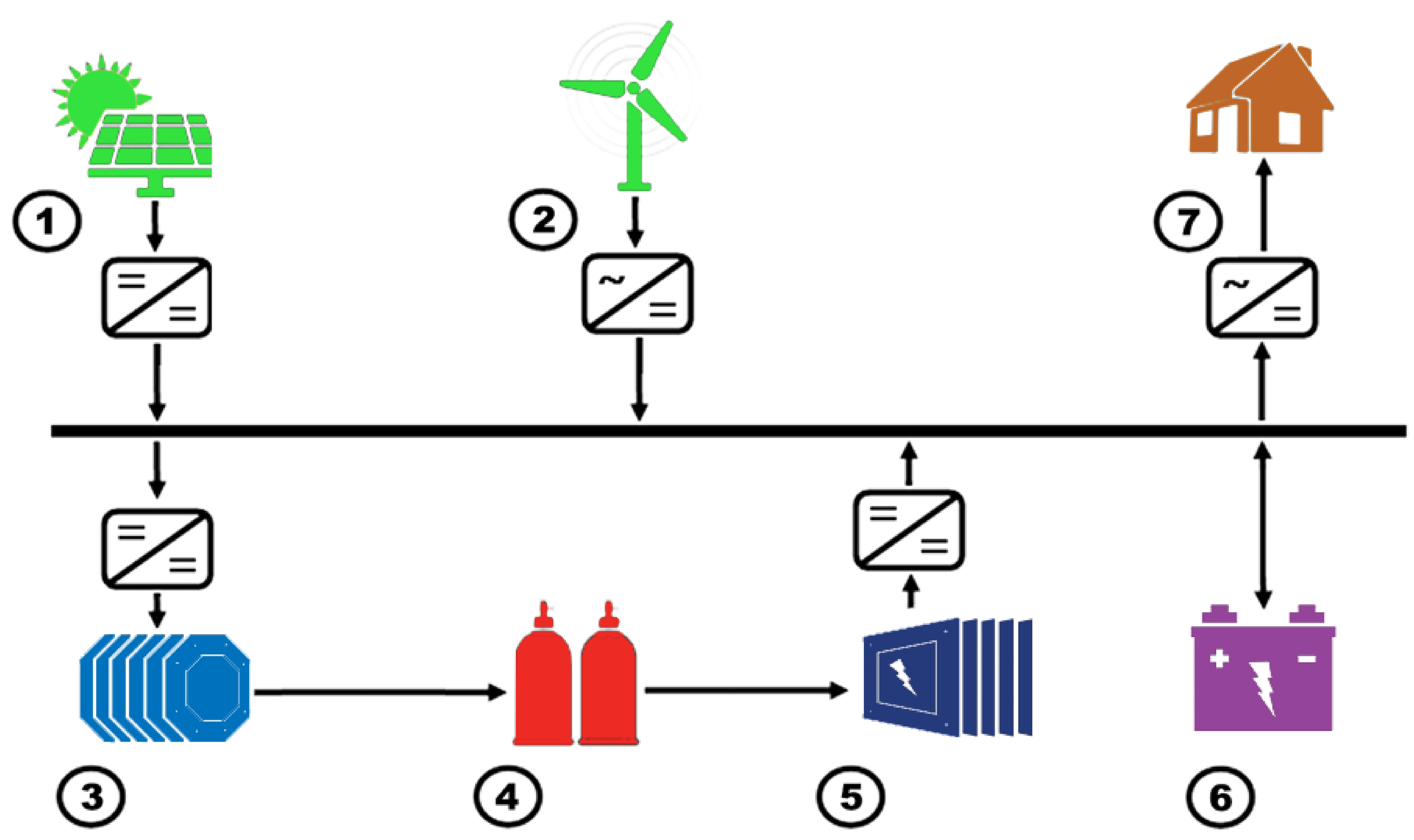

Fig. 2. Model of a stand-alone hydrogen energy system

Energy Management Strategy

The EMS operation, applied in this study, is based on switching the electrolyzer and the fuel cells on/off depending on SoC_{BAT}, where ELE_{up} and ELE_{low} control the electrolyzer, while FC_{up} and FC_{low} control the fuel cells. This is enabled by using a double hysteresis loop control scheme adopted from [1, 2]. The EMS can be described through following energy flow routes:

- If available, the load first draws power directly from the renewable energy source (PV and/or wind turbine). This energy route is the most efficient one and therefore has the highest priority. If the produced energy exceeds the end-user load demand, the excess energy is then used to charge the battery bank. When the battery is fully charged, the excess energy is used for the electrolysis process.
- When produced energy is insufficient for the end-user load, the battery will provide energy to compensate the difference. This is the second route by efficiency and priority.
- If SoC_{BAT} is equal or higher than ELE_{up}, excess energy or the battery will be used to supply the electrolyzer. The electrolyzer will be switched on until SoC_{BAT} drops below ELE_{low}. In this study, ELE_{low} is set at 80% and ELE_{up} at 95%.
- If SoC_{BAT} drops below FC_{low} the fuel cells will switch on and start supplying the end user load and the battery bank. The fuel cells will be switched on until SoC_{BAT} is higher than FC_{up}. During fuel cells operating time, the battery bank will not be able to supply, but only to receive energy from the system. In this study, FC_{up} is set at 40% and FC_{low} at 30%.

Conclusions

- The system installed at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture is sufficient for laboratory research and can be used to test the components durability.
- Islands are ideal polygons for stand-alone renewable energy systems and individual hydrogen energy technologies.
- With these type of stand-alone renewable energy systems, where hydrogen serves as energy storage medium and fuel, the island can become energy self-sufficient.

References

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[2] Ø. Ulleberg,.The importance of control strategies in PV–hydrogen systems“, Solar Energy 76, Institute for Energy Technology, Kjeller, Norway, 2003.

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