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Economic viability of high temperature electrolysis integration with renewable sources for a power to gas solution

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Abstract

High temperature electrolysis as Proton Ceramic Electrolyzer Cells (PCEC) technology have a great potential within the scope of the Energy Transition and the Climate Change. These technologies can facilitate the transition in several important ways, as they can enable integration of Variable Renewable Energy (VRE) into the grid, improve the network flexibility and connectivity with bio-methane or syngas blending in built pipelines, conquer CO_2 sequestration, increase the energy efficiency and decrease the volatility of the needed raw materials.
The integration of solar PV and wind power into the grid will allow the network to remain clean, raising the share of renewables in the energetic mix and decreasing carbon emission so that the climate change may be mitigated. The economic viability of integrating PV and wind with PCEC electrolyzer has been analyzed through calculating operating cost of electrolyzer system in the Project "Electra" .

Introduction:

ELECTRA is a project of the FCH JU (EU FP7) with project title "High temperature electrolyzer with novel proton ceramic tubular modules of superior efficiency, robustness, and lifetime economy". The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° 621244.
One of the task of this project is to analyze the possibility of integration of this technology with renewable energy sources through process simulations and techno-economic analysis.

The operating cost of system integrated with PV/Wind energy sources has been evaluated and electricity requirements of system for 1.35 MW PCEC electrolyzer has been derived from simulations.

PCEC technology developed in "Electra" exhibits attractive features like:

- Production of dry hydrogen directly.
- Production of syngas in the so-called co-ionic co-electrolysis mode with H_2O and CO_2 as reactants.
- PCEC has higher efficiency than low temperature electrolyzer technologies.
- Multi-tubular PCEC electrolyzer module designed in the project has possibilities to monitor and replace individual tubes.

Process simulation of proton ceramic electrolyzer system:

Process simulation of system of 1.35 MW Electrolyzer has been carried out in Aspen Plus. The process flow diagram for electrolyzer system is given in Figure 1 indicating that electricity is required by electrolyzer, superheater and evaporator. The specifications for the electrolyzer are given in Table 1.

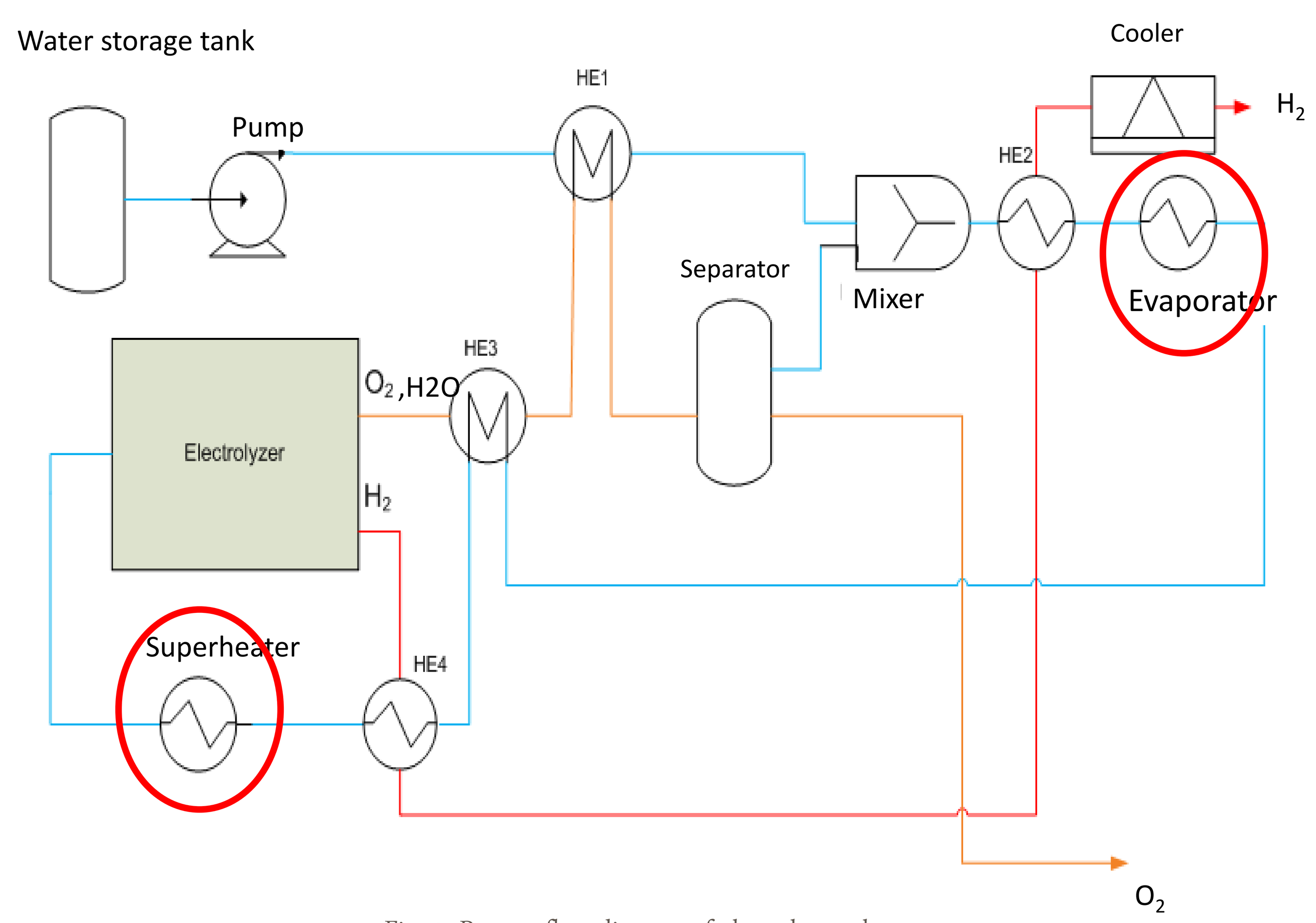

Fig. 1. Process flow diagram of electrolyzer plant

Specifications	
Sweep	No sweep gas
Air at the anode inlet	No air
Steam flow to electrolyzer	5.45 mole/s
Operating pressure	20 bar
Steam utilization	60%
Operating mode	Thermoneutral
Tª at anode/cathode inlet and outlet	700ºC

Table. 1. Specifications of electrolyzer system

Results

The main stream results from process simulation are summarized in Table 2. The total energy requirement by the system is 1.69 MW which include electricity consumption by electrolyzer, pump, superheater and evaporator. This electricity requirement can be fulfilled by wind or PV sources. The operating cost of electrolyzer has been calculated using wind and PV as an energy sources and has been compared with grid. The operating cost includes the sum of cost of water and electricity consumption per kg.

Figure 2 shows the operating costs (€/kg) of hydrogen production using different electricity sources (grid, wind and PV) for Spain, France and Norway countries. If operating costs are compared, then it is found that the operating cost is lower using wind electricity. Moreover there is cost variations observed among countries due to amount of availability of electricity resources (wind, PV).

Stream results	
Steam in	0.1635 kg/s
H_2	0.01098 kg/s
Power to electrolyzer	1.352 MW
Pump	253 W
Electricity consumption for superheating	0.0398 MW
Electricity consumption for vaporization	0.308 MW
Electrolyzer electric efficiency	3.074 kWhe/Nm^3
Plant electric efficiency	3.87 kWhe/Nm^3

Table. 2. Main stream results for assuming electricity as main energy source

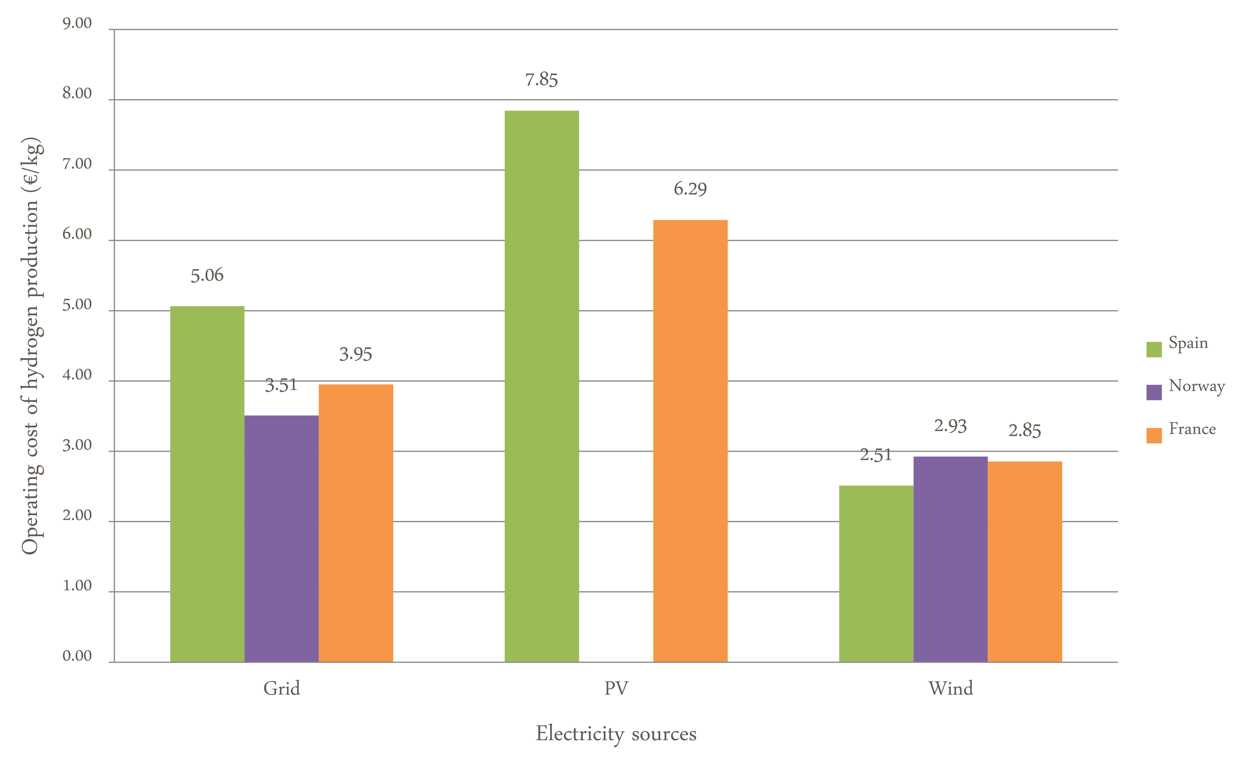

Fig. 2. Operating cost of hydrogen production using different electricity sources in Spain, Norway and France

Discussion

The challenges of producing hydrogen from renewable energy are capital cost of electrolyzer and electricity cost for operation. Prices differ from one location to another for photovoltaic and wind electricity. However photovoltaic electricity cost is coming down every year due to reduction in capital cost of photovoltaic and that will bring down the hydrogen production cost further. Wind is going to be competitive with PV in terms of price [1]. The results obtained from PCEC system will be compared with Solid Oxide Electrolyzer Cells (SOEC) technologies.

References

[1] Millborow, D., Onshore wind is more competitive than ever, Wind power monthly, January 2015

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