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"ISLAND OPERATION" OF THE ELECTROLYZER SUPPLY SYSTEM

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ABSTRACT

The paper deals with the possibility of using the so-called "island operation" for feeding the electrolyser for the production of hydrogen. A series of 2000W photovoltaic panels is used for power generation in island operation. The electricity generated by the photovoltaic panels is then stored in accumulators for the time when we need it for hydrogen production

KEYWORDS: Elektrolyser, Hydrogen, Photovoltaic.

INTRODUCTION

Due to the increasing number of cars fueled by hydrogen fuel cells, there is a need to expand the number of hydrogen filling stations. Until now, the operation of petrol stations has relied on the supply of hydrogen from large industrial plants. In smaller petrol stations where there is a presumption of less hydrogen uptake, it is possible to use a hydrogen self-production system by meansofelectrolysers. The electricity required for the hydrogen production process in theelectrolysercanbeobtained directly from the public electric grid or by island operation, where the system would be fully tied to renewable energy sources. Last but not least, it is also possible to use a combined system whereby most of the time of operation, renewable energy sources would be used and, if necessary, the system would obtain additional energy from the public electric grid.

1. Island operation system

For the possibility of using the island operation system it is necessary to dispose of own power source. This energy can be obtained by converting solar, water, wind or geothermal energy.

The conversion of solar energy directly into electricity is done by means of photovoltaic panels, in the case of hydropower by small water turbines and wind energy uses wind turbines to transform energy. Electricity can also be generated by a cogeneration unit whose operation depends on the synthesis gas.

By properly combining these sources of energy together with storing them in accumulators, the system can be completely separated from the public electric grid (Fig. 1).

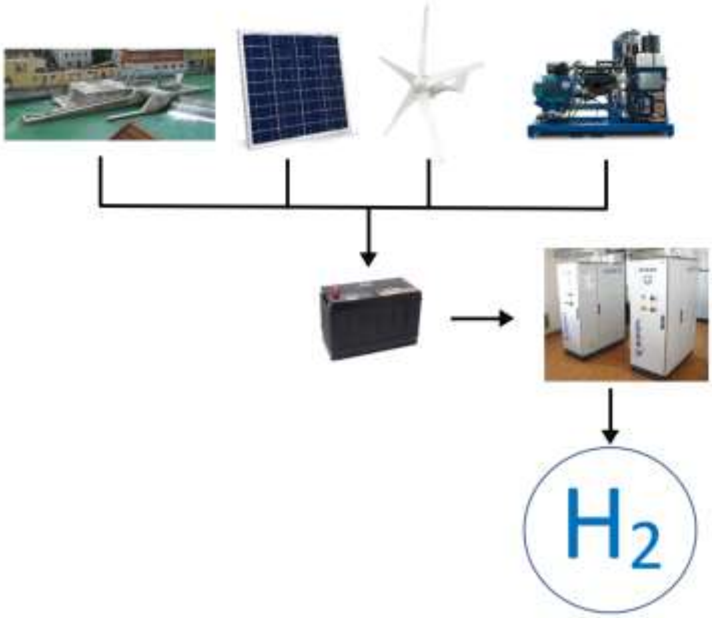

FIGURE 1 Scheme of "island" operations

The next step after the production and storage of electricity is its use to produce hydrogen in theelectrolyser. The process of producing hydrogen from water by means of electric power is governed by the equation:

$$2H_2O + 2e \rightarrow H_2 + 2OH^- \qquad (1)$$

$$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e \qquad (2)$$

For the amount of excreted hydrogen and oxygen is applies Faraday's law:

$$M_{H_2} = I.\frac{\tau}{2F} M_{O_2} = I.\frac{\tau}{4F} \qquad (3)$$

where I isthe current flowingthroughtheelectrolyzer (A), τ - duration of electrolysis (s), F - Faraday charge (96 487 C)

The minimum amount of energy that must be applied to theelectrolyzerelectrodes to spread 1 mole of water is determined by the ΔG value.

$$\Delta G = 2.F.E_{eql} \qquad (4)$$

whereE_{eql}istheequilibrium voltage of the oxygen-hydrogen cell at which the rate of electrode reactions is the same in both directions.

This voltage can be expressed numerically at temperature 298 K:

$$E_{eql} = \frac{G_{298K}}{2.F} = \frac{237\ 000}{2\ .96\ 487} = 1{,}229\ V \qquad (5)$$

However, at this voltage, the amount of hydrogen obtained from the electrolysis process is zero and therefore it is necessary to increase the voltage at the electrodes. By increasing the voltages on the electrodes, the resistance generated by the gas elimination and the ohmic resistance of the cell are overcome. Accordingly, it is best to use the formula to calculate:

$$\Delta G = 2.F.E \qquad (6)$$

where E is the voltage of the electrolysis cell (V), where:

$$E = E_{eql} + \eta_{cat} + \eta_{anod} + \sum R\ .I \qquad (7)$$

whereη_{cat}, η_{anod} – activation voltage on electrodes (V), ΣR – total cell resistance (Ω).

The activation voltage at individual electrodesis given by theTafelequation:

$$\eta_{act} = a + b \,.\log i \qquad (8)$$

where a, b are constants whose value depends on the material properties of the electrodes, the temperature and the pressure of the gases excluded attheelectrodes, i - currentdensity - units (A)

During electrolysis, it is also necessary to evacuate the generated gas from the electrode surface, since its accumulation on the electrode surface may be manifested as a concentration voltage. This can be avoided by circulating an electrolyte around the electrodes, thereby releasing gas from the electrode surface.

Fortheelectrolyser, itisalso necessary to take into account the heat balance, as this is an important value of the thermoneutral voltage of the cell:

$$E_{tn} = \frac{\Delta H_{298\,K}}{2\,.F} = 1{,}48\,V \qquad (9)$$

At this voltage, the operation of the electrolyzeris auto thermal, that is, all the energy that is supplied to theelectrolyzer in theform of electrical energy is used to maintain the isothermal course of the electrolysis. If the electrolyzer operates at a voltage lower than 1.48 volts, the electrolyzer takes heat from the environment, and if it works at a higher voltage, it transfers heat to the environment.

The calculation of the electrolyser efficiency is also associated with the value of the thermo nuclear voltage at T = 298 K. According to the IAHE() convention, the energy conversion efficiency of the supplied cell to hydrogen and oxygen is ΔH298 K. The for effectiveness is applied equation:

$$\eta_{el} = \frac{\Delta H_{298\,K}}{2\,.FE} = \frac{E_{tn}}{E} = \frac{1{,}48}{E} \qquad (10)$$

where E is the applied cell voltage (V)

The relationship implies that the efficiency is inversely proportional to the cell voltage, but for more efficient use of the fuel cell it is necessary to operate at the highest currentdensity, which of course requires a higher voltage on the fuel cell cells. From this, it can be concluded that the efficient operation of island operation depends significantly on the amount of current that we are able to supply to the fuel cell. In order to increase the current density, it is not appropriate to feed the electrolyzer directly from renewable sources but through an accumulator which is capable of generating a higher current density than the generator itself.

2. Measurement of electrolyser activity

An electrolyzerfrom H2 NITIDOR s.r.l. used in the experiment was connected in island operation with photo voltaic panels as a powersource and lead-acidbatteries. The installed power of the photo voltaic panels totaled a maximum of 2000W.

TABLE 1. Electrolyser parameters

		Unit
Electrolyte	solution KOH	
Concentration KOH	25-30	%
Amount of electrolyte	15	l
Adjustable power range	20-100	%
Maximum working temperature	80	°C
Location	vovnútri	
Room temperature min-max	5-40	°C
Equipment dimensions	1200/600/1850	mm
Weight of the device	500	kg
Water consumption at full power	0,45	l/h
Volume of inner tray	3,5	l

The measurement was carriedout in there gion of Košice, where according to FIG. 2, it can be determined that the amount of incident solar radiation during the year is around 1300 kWh · m-2. The electricity produced was stored in lead-acid batteries with a total capacity of 500 Ah. When the equipmentis in operation, the electricity is transferred through converters from DC to AC. The converted electricity then drives the entireis land operation, including the control systems and the electrolyzer.

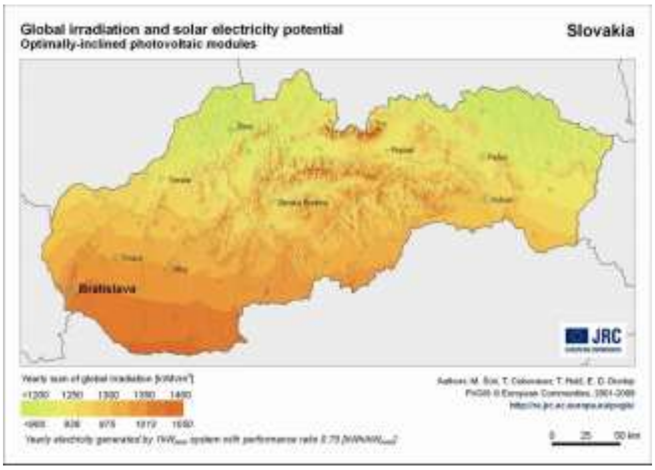

FIGURE 2 Global irradiation and solar electricity potential

During the measurement, the performance characteristics of the electrolyzer were periodically varied to determine its overall efficiency under various load conditions. Thanks to the island operation measuring devices, not only the overall power requirements but also the bipolar electrolyzer itself, the whole electrolyzer and the whole system with the analyzer were monitored. The hydrogen produced was further stored in metal hydride containers.

The results of several measurements were averaged and the dependence of the amount of produced hydrogen on performance was generated.

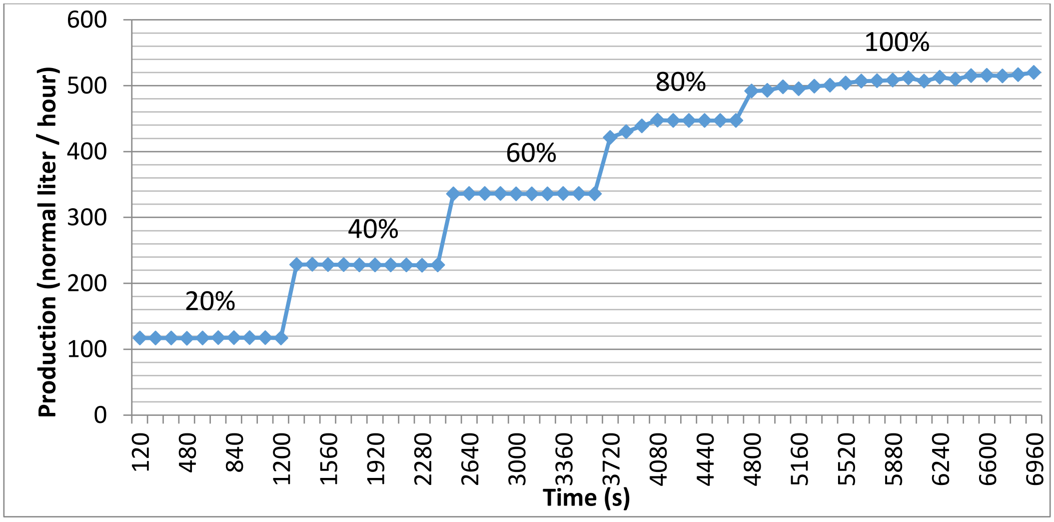

FIGURE 3 Dependence of hydrogen production on performance

The efficiency of the bipolar electrolyzer, the whole electrolyzer and the island operation were also evaluated.

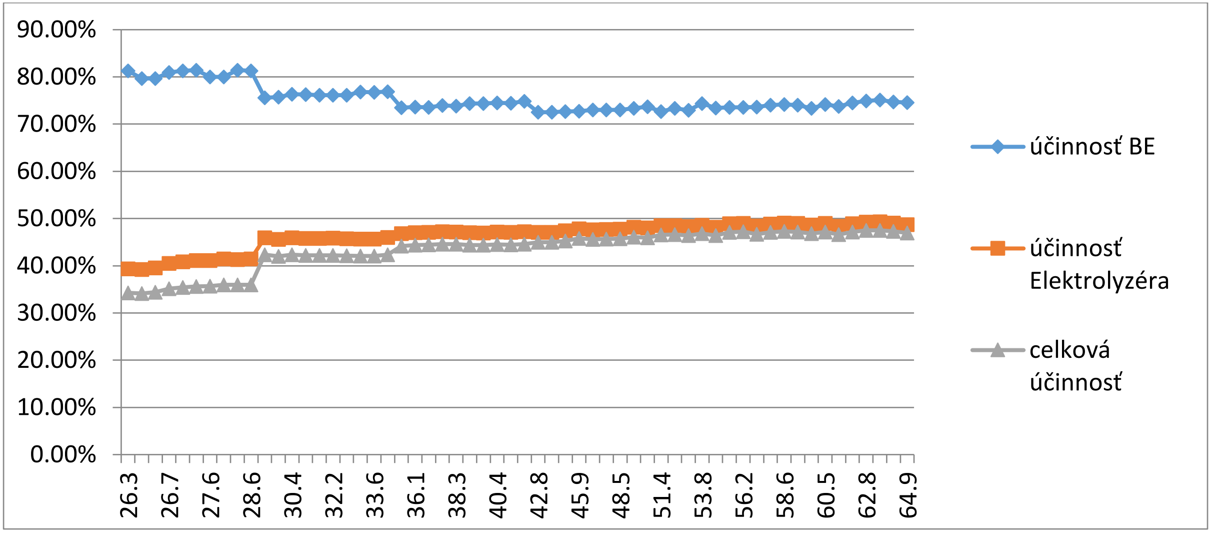

FIGURE 4 Dependent of electrolyzer efficiency

As can be seen from the graphical dependence of FIG. 4, the efficiency of the bipolar electrolyzer slightlydecreases with increasing power. The efficiency of the electrolyser as well as the overall efficiency of island operation with increasing power increases. This operation of the bipolar electrolyzer can be justified by increasing the amount of gas that is generated at the electrodes, preventing liquid access. Due to the gas layer that forms on the electrode surface, more work is needed to distribute the same amount of hydrogen, reducing the efficiency of the device (Fig. 4). However, overall efficiency increases due to an increase in hydrogen production despite a decrease in the efficiency of the bipolar electrolyzer.

From the measured data it can be determined that the fuel cell works best at 100% power, but its efficiency does not change significantly from 60% power. It is possible to observe the impact efficiency in the range of a few %, but when comparing the efficiency changes when switching from 20% to 40% and then when changing from 60% to 100%, the change in efficiency is significantly less.

CONCLUSION

The initial phase of the experiments suggests that the possibility of island operation of electrolysers could be one of the solutions to build hydrogen pumping stations in remote areas or in areas where high traffic density is not expected in the future and thus an increased need for hydrogen fueling. It has also been found that, due to the volatility of the performance of renewable energy sources, it is appropriate that the system is powered from at least two sources, combining more stable sources such as a small hydropower or cogeneration unit with sources such as solar or wind to provide a large amount of energy but provide the energy irregularly.

When comparing performance-related efficiency, it is also possible to determine that a given cell type can be operated in a power range from 60% to 100% and its efficiency will not change significantly in this range. This could make it possible to continuously control the amount of hydrogen produced in continuous operation without significant energy losses.

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