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Experimental stand for the study of energy conversion and storage

Stand experimental pentru studiul conversiei și stocării energiei

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Abstract: *This paper presents an experimental stand for the study of energy conversion and storage. The hybrid system has as component elements: water- water heat pump, the supply system of the heat pump with flow control, storage tank of the waste water discharged from a water-water heat pump, compressed air storage tank, compressor, Pelton turbine, photovoltaic system for electricity supply of the system, automation system, load resistance, wattmeter. With the help of the experimental stand were determined: the running idling characteristic of the electric generator at different simulated turbine drop and the operating characteristic under load. Thus, the efficiency of the system has been demonstrated by increasing the Coefficient of Performance (COP) of the heat pump.*

Keywords: *conversion, storage energy, hybrid system, electricity, COP.*

Rezumat: *Această lucrare prezintă un stand experimental pentru studiul conversiei și stocării energiei. Sistemul hibrid are ca și elemente componente: pompă de căldură apă-apă, sistem de alimentare pompă de căldură cu reglajul debitului, rezervor de stocare a apei reziduale evacuate de la o pompă de căldură apă-apă, rezervor de stocare aer comprimat, compresor, turbină Pelton, sistem fotovoltaic pentru alimentarea cu energie electrică a sistemului, sistem de automatizare, rezistență de sarcină, wattmetru. Cu ajutorul standului experimental au fost determinate: caracteristica de mers în gol a generatorului electric la diferite căderi simulate, ale turbinei și caracteristica de funcționare în sarcină. Astfel, s-a demonstrat eficența sistemului prin creșterea COP al pompei de căldură.*

Cuvinte cheie: *conversie, stocarea energiei, sistem hibrid, electricitate, COP.*

1. Introduction

The effects of climate change have gradually caused human societies to use renewable energy sources to reduce greenhouse gas emissions.

As a result of establishing maximum permitted values for greenhouse gas emissions released into the atmosphere, for the period 2020-2029, for energy security - as a basic condition of sustainable development, it is necessary to efficiently integrate the renewable energy sources, which to gradually replace conventional resources [1], [2].

The model of the three pillars, Economy - Ecology - Society, is the key to sustainable development [3], [4].

Even though, the renewable energy sources could satisfy most of the total energy demand, their intermittent nature brings an instability between the production and the demand for energy for a day or even an hour. Figure 1.

Schematically illustrates the difference between energy production and consumption within 24 hours [5].

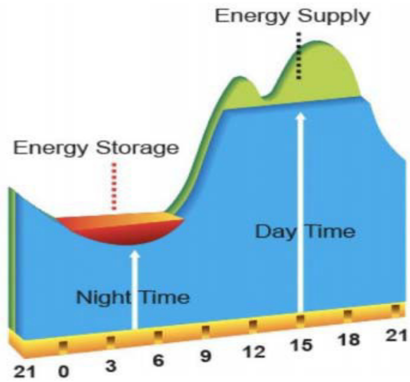

Figure 1. Variation of the load curve during a day

It can be observed that in the 9-18 hour interval, the basic production can be largely ensured by the photovoltaic systems, being necessary to provide a fast reaction energy source capable of providing the peaks of load. These sources are represented by storage systems that can accumulate energy during the night (from wind, tidal) when consumption is low, or during the day (on days with maximum sun from photovoltaic systems and/or other systems). The interest of the researchers, motivated by the energy policies regarding the promotion of microturbines, which, unlike the turbines of medium and large power, have a reduced effect on the environment [1, 2, 6, 7, 8]

So, the solution of the problems raised by the use of renewable sources is the storage of energy. In this way, energy availability can be ensured when needed.

2. Storage systems

If the use of distributed generation represents more than twelve percent of the energy production, then the problem of energy compensation will arise in the local network or in the whole system that can be solved by storing energy. In fact, it is not possible to achieve the direct storage of electricity, since it is necessary to convert it into other forms of energy.

Energy storage systems must be able to store the energy produced under favorable climatic conditions and return it to cover peak loads during the daytime or when production of renewable systems is not possible.

Possible solutions for storage systems include:

➢ ***Mechanical storage***:

- *the storage based on Pomped Hydro* - is a technology confirmed with long storage period, high efficiency and relatively low cost per unit of energy [6]

- *the storage with Compressed Air* - it is largely similar to the operation of pumped hydroelectric plants, but during periods of surplus power, this technology produces compressed air that it injects into underground caverns. To return the stored energy, the pressurized air is heated and expanded into an expansion turbine unit and generator that converts rotational kinetic energy into electricity [6].

- *storage with flywheel*- The technology uses electric motors to engages a flywheel to spin at high speed, so that the electrical power is transformed into mechanical power and stored, and when necessary, the flywheel command an electric generator [9].

- ***Electrochemical storage:***

- batteries with internal storage (eg Pb, NiCd, Li-ion)
- batteries with external storage:
- primary batteries with external regeneration (eg Zn- air)
- gas storage (electrolyser, combustion cells)
- torage with liquid electrodes (eg redox with vanadium)

- ***Electrical Storage***:

- superconducting coils
- capacitors (different technologies)

Storage should not only be seen at the level of the national energy systems (SEN), but also at the level of the distribution operators for supplying in remote areas and prosumers . At the prosumers level, the surplus of energy can also be stored in the form of thermal energy for heating/cooling in order to increase the degree of thermal comfort.

3. Description of the experimental stand

Starting from the fact that any technical system evacuates in the external environment a certain fraction of the useful energy, as lost energy, the experimental installation (Figure 2) highlights ways of converting and storing energy. The experimental stand was created in the "Energy Conversion" Laboratory of the Polytechnic University of Timisoara. Water discharged from the primary circuit of a water-to-water heat pump is fed into the R1 storage tank to be distributed to a small Pelton turbine (Figure 3) on which a DC generator is mounted. Thus, the potential energy of the waste water will be converted into kinetic energy of rotation and then into electrical energy.

Figure 2. Experimental installation Figure 3. Pelton turbine

The inlet of the water in the turbine is done by means of the solenoid valve mounted at the exit of the storage tank R_1. For adjusting the flow rates and pressure on the nozzles, two adjusting valves have been mounted. In order the establish operating regimes that ensure the coverage of the load peaks, the turbine drop is simulated by increasing the pressure in the water storage tank using the compressed air stored in the R_2 tank. The air pressure introduced into the water storage tank is regulated by means of a compressed air pressure regulator. The stored compressed air is produced using a compressor. A photovoltaic system with two panels, was designed to supply the compressor with electricity.

3. Results and discussions

The potential energy of the waste water, stored in the R1 storage tank, is transferred to the Pelton microturbine at a pressure of 1.5bar, equivalent to a fall 15mWC level.

In order to highlight the efficiency of the system, we recorded the operating parameters of the heat pump and determined its COP. The amount of heat supplied by the heat pump was measured with a Multical 402 thermal energy meter, and for the electricity consumed by the heat pump and the feedwater pump an electronic wattmeter was used. Thus, a COP of 3.49 was obtained. The proposed hybrid system produces electricity throughout the operation of the heat pump which results in a COP exceeding 3.49. The generator idle operation is illustrated in Figure 4.

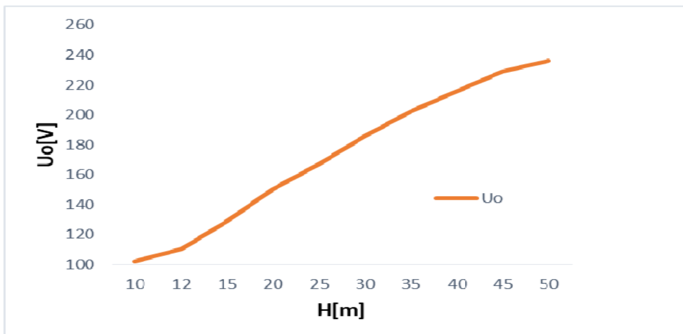

Figure 4. The running idling characteristic of the electric generator

To determine the maximum power output of the electric generator (Figure 5.), tests were performed on different turbine drops. For the considered turbine drops, in Table 1 is presented the flow rate and electrical generator efficiency.

Table 1.

The electrical generator efficiency

H [m]	Q [l/h]	η [%]
15	2556	31
20	3204	31
25	3348	32
30	3412	36
35	3528	38
40	3924	40
45	4212	43

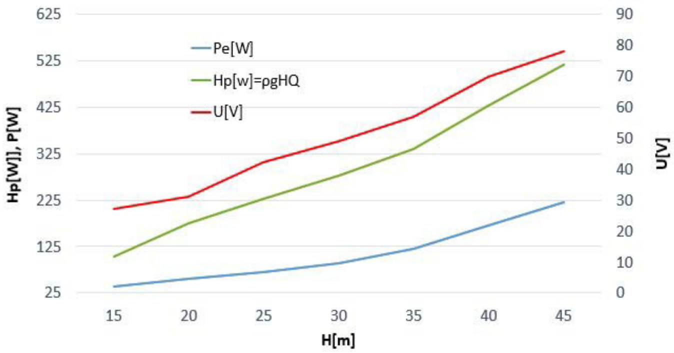

Figure 5. The maximum power output of the electric generator

4. Concluzii

Hydraulic energy conversion systems are robust systems, have very low inertia, require relatively low maintenance and have service life of over 50 years. Microturbines integrated in recovery systems are sometimes the only solution for the electricity supply to small consumers, but especially a solution for covering peak loads.

It has been experimentally determined that the yield of the Pelton microturbine used is between 30-50%

By integrating the microturbine into the outlet circuit of the water-water heat pump, at the available pressure of the 1.5bar supply pump, the equivalent of a 15 mWC drop, 40W can be recovered, resulting in a COP increase to 3.57. If a 45m drop is assured, the COP of the heat pump can reach 3.99.

Proposing a hybrid system, the experimental installation is a necessary tool for the study of energy conversion and storage and is an open topic for further research.

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