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SMART PV-H_2 GRID ENERGY COMPLEX

Розглянуто питання проектування, дослідження та експлуатаційної демонстрації фотоелектричного-водневого комплексу мережі електропостачання і його складових елементів для перетворення енергії відновлюваних джерел (сонячної) з нерівномірним надходженням в звичайні (якісні) електроенергетичні потоки. Стаціонарна система концентрування застосовується для зниження нерівномірності надходження сонячної енергії та підвищення ефективності фотоелектричного модуля. Водень як енергоносій і водневих паливних елементів є можливим варіантом для зберігання різних обсягів енергії протягом відносно тривалого часу з низькими втратами.

Introduction

Together with progressive depletion of traditional non-renewable sources of energy (fossils: coal, oil, natural gas etc.) the researches on seeking the renewable sources of energy are actively carried out all over the world. For the first time, the described below Energy Storage Solutions for Small and Medium-Sized Self-Sufficient Alternative Energy Objects configuration has been considered in [1] although similar schemes were well known and considered earlier. Nevertheless, the attempts of compiling renewable energy systems (namely the photovoltaic panels with concentrator) with electrolyzer, fuel cell and energy grid is at the early stage of research. This work focuses on the following targets: elaboration, design and optimization of the PV-H_2 SMART Grid energy complex configuration; manufacturing and assembling of constituent elements; creation of the specialized control system able to adapt, through a geolocalization module, to different geo-climate conditions. Thus, the novelty of our approach consists in the combination and advisable functional interaction of the constituent elements. The PV-H_2 complex was realised and tested both in laboratory as well in a standard work environment. The tests were conducted in Kharkiv, Ukraine in 2017. The obtained results in operational environment fit very well with laboratory ones. This verifies the PV-H_2 SMART Grid energy complex work potential.

PV-H_2 SMART Grid energy complex constituent elements description and operational peculiarities

The PV-H_2 complex consists of the following constituent elements, characterized by harmonized parameters: primary energy receivers - concentration photovoltaic energy farm; hydrogen and oxygen generator (electrolyzer); vessels for compressed gases SSS; fuel cell, grid invertor. The general complex scheme is shown in Fig. 1. The complex is provided by informational control system connected with separate elements by means of pipelines and sensors for gathering and processing working parameters data. The basic idea of renewable energy use consists in opportunity of “dirty” energy processing [2]. The irregular primary energy flow obtained from concentrated solar energy transformer (PV) is shared with the electrolyzer that is non-sensitive to the quality of received energy. This approach is preferable for creation of autonomous power plants with small and moderate power output for individuals. The elaborated PV-H_2 SMART Grid energy complex could be used as an autonomous hydrogen refill station for different kinds of hydrogen-feed vehicles [3, 4].

The SSS for compressed hydrogen are the simple gasbag type. Nevertheless, the foundations and experiments relatively to the possibility to store the hydrogen in binding state including the carbon nanostructures technology are considered and are presented. Moreover, the gamma-ray irradiation of carbone-nanostructures was conducted to modify the hydrogen sorption properties. The possibility to generate and concentrate the hydrogen in a compressed state, and to use as an ecologically pure secondary energy carrier is essential.

Photovoltaic static concentrator system (SCS). Designed SCS is able to concentrate solar energy with different efficiency during the year (see Fig. 2). Scientific and technological approaches of SCS were published in [5]. Fig. 3 performs the general view of ttemperatures distribution on the module surface after solar concentrator irradiation.

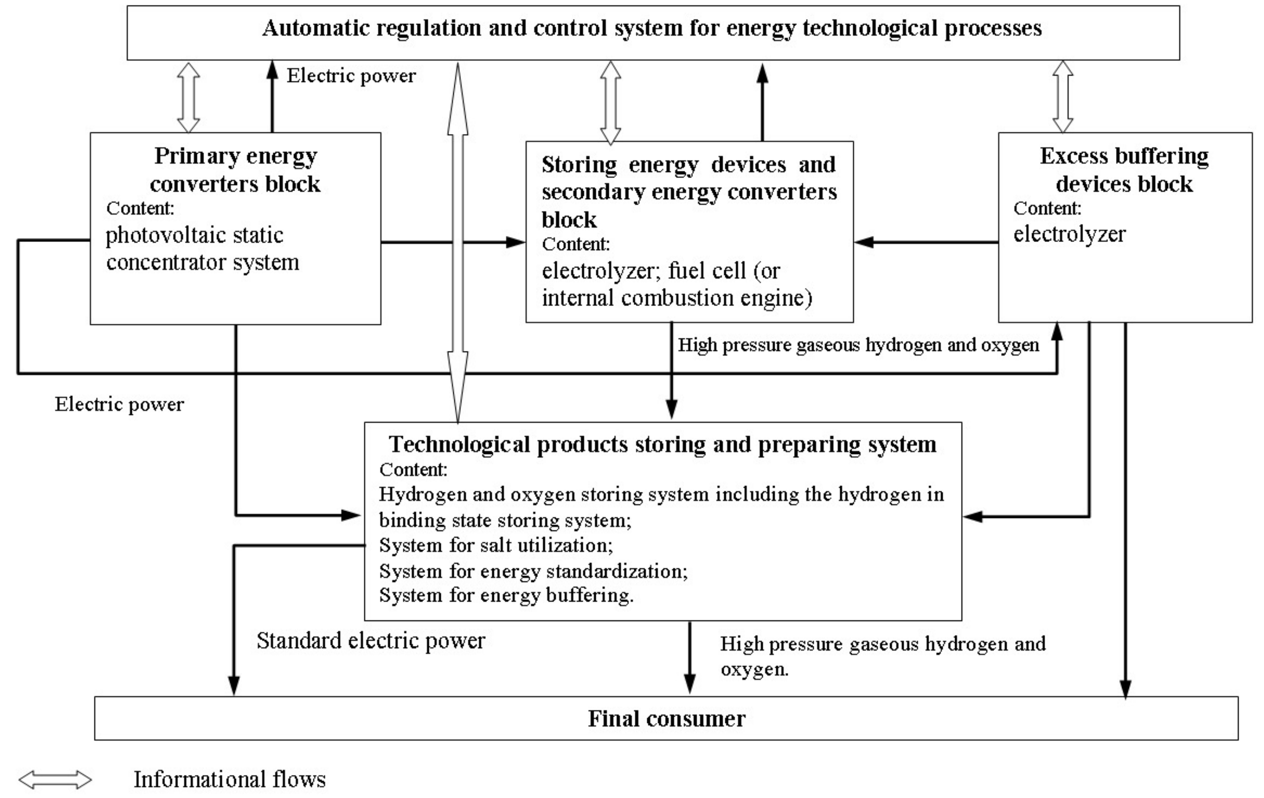


Fig. 1. Photovoltaic-hydrogen SMART Grid energy complex schematic diagram

Photovoltaic transformer. The solar energy receiver, operating in calm conditions, was included into PV-H_2 SMART Grid energy complex scheme. Produced by firm "SOLARWATT" photovoltaic transformer with nominal power 30 W is shown on Fig. 4. Solar battery consist of 20 such monocrystalline modules (panels).

Electrolyzer. The consumed non-steady primary energy is delivered to the electrolyzer to decay the water on to hydrogen and oxygen. The electrolyzer with active elements and original scheme and consumed power ~ 0.5 kW was used in the project. The operating pressure about 15 MPa provides the hydrogen and oxygen generation directly in compressed state [6]. The electrolysis cycle operational mode is based on the time sharing between hydrogen and oxygen emanation. This is achieved by the use of electro-active electrodes that can store hydrogen or oxygen in accordance with their capacity. In a second time, fur-

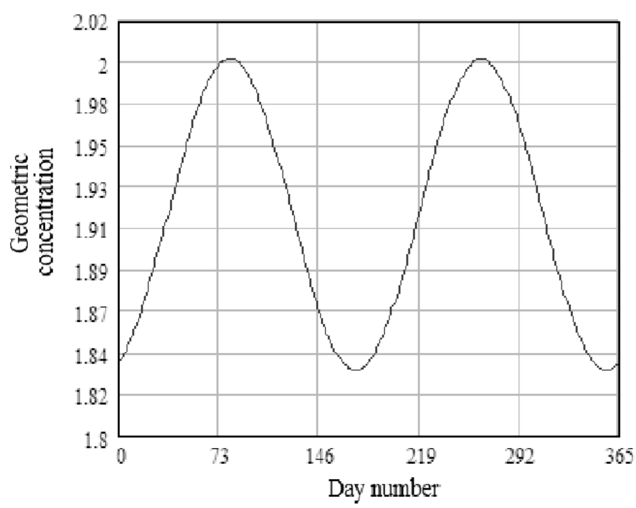


Fig. 2. Geometric concentration factor during the year for the Kharkiv

ther hydrogen and oxygen emanation was stored in the next part of the cycle. The switch from one of the component receiving to it emanation can be realized by electrodes pole switching. The cycle duration is determined by the electrochemical capacity and output of the active-electrodes.

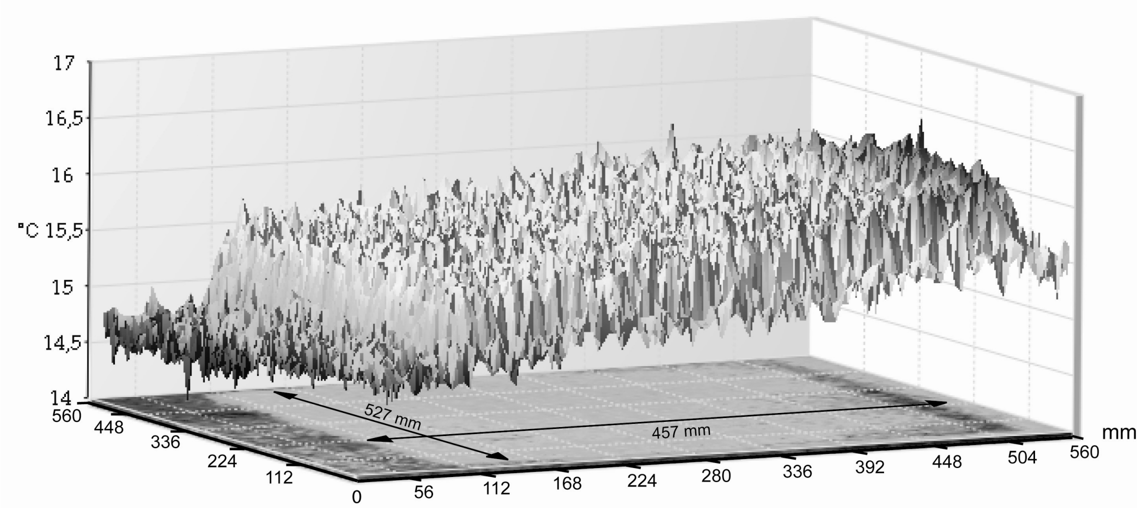
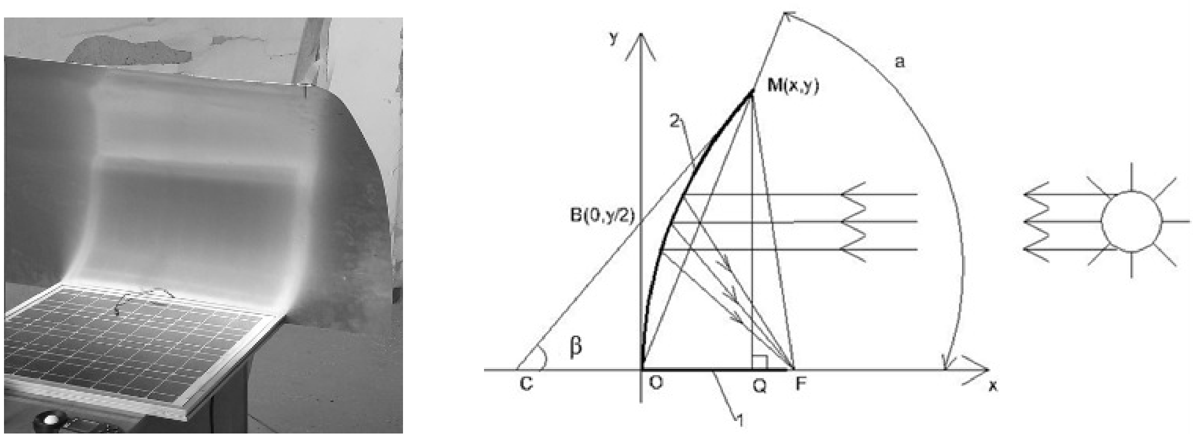


Fig. 3. Temperature distribution on the module surface

The tests were conducted at the levels of 25, 50, 75 and 100 percent of maximum power consumption. The maximum power of high-pressure electrolyzer was ~ 450 W (voltage was up to 0.200 kV, and current consequently up to 2.2 A). The demonstrated output of hydrogen was 0.52 m^3 and oxygen – 0.26 m^3. The content of oxygen additives in hydrogen was at the level of 0.04–0.06 volume percent and hydrogen additives in oxygen was 0.08–0.1 volume percent correspondingly. The duration of electrolyzer system adaptation to the energy income differences (electrolyzer dynamical property) was about 60–180 s. Electrolyzer has the unique properties and after the improving the it could demonstrate the ability to reversible operational mode. The simplest vessel type of SSS for compressed gases has been used.

Fuel cell. In order to generate the conventional (standard) electricity from the stored secondary energy carrier - hydrogen, a fuel cell with power 0.4 kW was used. Hydrogen/air fuel cell is shown on Fig. 5.



a) b)

Fig. 4. Solar panel (1) with total installed capacity 30W and SCS (2):
a) – photo of panel with concentrator; b) – schematic drawing

Main obtained results and recorded parameters

The operation of such complexes demands of their adaptation to the geo-climate conditions of region of use and this adaptation are provided by the specialized control system. The control system provides the distribution of energy supply from SCS to the secondary capacitors and energy transformers. The regulation and control system for PV-H_2 SMART Grid energy complex realizes the rational electrical energy distribution from the primary energy converters to the external consumers and for energy storing and buffering. The recommendations for PV-H_2 SMART Grid energy complex efficiency increasing are registered as control system's SOFTWARE and corresponded to the concrete geo-climate conditions. As the result of project implementation assembled PV-H_2 SMART Grid energy complex as whole unit has been tested and parameters for control system tuning was presented for possible customers.

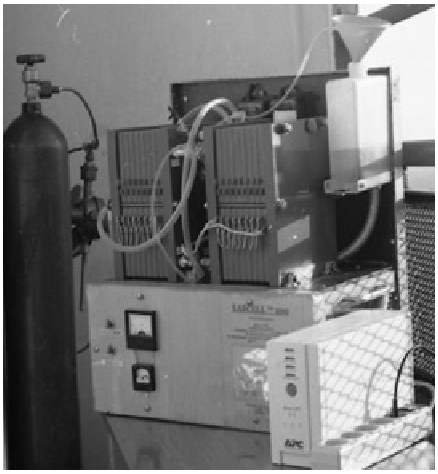


Fig. 5. Hydrogen/air fuel cell with power 0.4 kW

The control system destination provides the main working processes of energy output in automatic regime and in regime of manual control. There are following control system functions:

- "stand by" control of PV-H_2 SMART Grid energy complex main constituent elements;
- forming of rational PV-H_2 SMART Grid energy complex configuration in dependence upon actual state of energy sources and PV-H_2 SMART Grid energy complex aggregates and analysis of possibility of any working process implementation;
- switching in/off of PV-H_2 SMART Grid energy complex elements;
- keeping of PV-H_2 SMART Grid energy complex elements working parameters at different regimes in accordance with requirements of energy consumption/transformation technology;
- recording of working parameters data on floppy discs;
- switching off PV-H_2 SMART Grid energy complex aggregates in cases of energy consumption reducing down to minimal values.

The results of development and natural testing (2017 in Kharkiv, Ukraine) of the Energy-Technological Complex allow generalizing over the input/output characteristics:

- Stationary silicon solar battery 0.6 kW(177 V, 3.4 A), efficiency of energy transformation is 15%.
- High-pressure electrolyzer – 0.450–0.5 kW (200 V, 2.2 A) of consumed power and with specific energy consumption ~ 4.9 kW/m^3 of hydrogen showed the efficiency about 0.9.
- Storage/supply system for hydrogen (with 0.04–0.06 vol. % of oxygen as additives) and oxygen (with 0.08–0.1 vol. % of hydrogen as additives) in cylinders right at high pressure (15.0 MPa).
- Fuel cell – consumes H_2 – 270 liter/h, air – 1500 liter/h at 0–80 C, produces electricity 150–400 W (15–20 V, 10–20 A), efficiency ~ 0.5.
- The automatic control system was done and the control parameters were controlled.

The total demonstrated PV-H_2 SMART Grid energy complex efficiency is about 25–26 percent. The duration of PV-H_2 SMART Grid energy complex recoupment could be estimated as ~ 5–6 years correspondingly with high ecological indexes. The propositions for further commercialization of the system due to project implementation results and characteristics for the PV-H_2 SMART Grid energy complex should be oriented on the markets of Italy, USA, Mexico, Israel and Asia or Near East Countries. On the base of light climate inherent to the number of climate zones (Kharkov region, Crimea, Asian countries) the typical diagrams of energy exchange can be created. In accordance with this diagram, the permissible operational modes for constituent elements will be defined and work orders for their improving will be determined.

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