PILOT PROJECT ON «GREEN» HYDROGEN GENERATION AT THE TERRITORY OF TURKMENISTAN

Aganiyaz Jumayev,
Candidate of Science, Vice Rector,
State Energy Institute of Turkmenistan

Atageldi Kakabayev,
Principal of the financial and economic secondary
vocational school of Mary region

Abstract

This paper recommends the production of the «green» hydrogen at the territory of Turkmenistan. The electrical energy required for the production of «green» hydrogen is generated by a photovoltaic solar station. Current work presents a modelling project, which consists of electric power source – photovoltaic solar station (PVS) with a capacity of 100 MW, system of generation of hydrogen (electrolyzer with a capacity 50 MW) and the system of freshening – installation of the reverse osmosis with an output of 80 tons water a day.

Keywords: photovoltaic solar station, electrolyser, hydrogen energy, a reverse osmosis unit.

Introduction

Accomplishments of the goals of Paris agreement on climate; reduce of the greenhouse vapors' emissions and the decrease of carbonic fuel consumption - serve as a stimulus of hydrogen energy development. Hydrogen used for accumulation, conservation and transportation of the energy and at the same time provides a great potential for the development of low carbonic economy that in turn reduces man (anthropgennic) impact on climate change.

Advantages of hydrogen are the followings:

– non-emission of carbonic dioxide as an energy carrier use;

– high power intensity (duty) (three times higher in comparison with natural gas);

– production potentiality from varios sources including water, hydrocarbons and organic materials.

It is expected that key role in the process of energy system's (energy transition) global transformation, first of all related with decarbonization and low carbonic development (progress), would play «green» hydrogen. In addition, «green» hydrogen considered not only as an energy carrier for the final consumption, but also as a mean for energy storage and accumulation as well as load equilibrium (balancing) of power grids (taking into account the instability use of electric energy and its generation from alternating (variable) renewable energy sources) (ECE, Energy, 2022).

Road map, on the development of the international cooperation in the field of the hydrogen energy for 2022-2023 years, was adopted by the decree of the President of Turkmenistan on January 28, 2022. Within the scope of this road map, it is planned to realize 18 projects and activities, particularly, to work out the national strategy for the development of the hydrogen energy in Turkmenistan (Ýol Kartasy, 2022).

Researches and methods. Objectives of pilot project:

– Analyse current condition and perspectives of the hydrogen energy development;

– examine the opportunities of the realization of the pilot project on generation of hydrogen at the territory of Turkmenistan;

– choose an appropriate place for the project construction;
– consider the use of the renewable sources to provide unit's consumers with electricity;
– investigate existing methods of generation of hydrogen and choose the apt one to apply at the territory of Turkmenistan;
– calculate electric energy capacity, produced by the chosen source and consumed elements in generation of hydrogen system;
– set a cost for pilot project realization and determine a term of its recoupment (payback).

Turkmenistan has a huge potential for the generation of hydrogen production. Pilot project considers the construction of the two photovoltaic solar station (PVS) s installed with a capacity of 100 MW each in settlements in Mary (Serhetabat) and Lebap (Kerki) districts. They can serve as an energy source for generation of «green» hydrogen. If electrolyzers used jointly with photovoltaic solar station for current goal, then there is no need for use of special equipment both for produced energy conversion (generators, inverter), and for synchronization with total energy system. Water, besides electric energy, serves as a raw material for generation of hydrogen with the means of eletrolyzer installation (device). Electrolyzer's work efficiency and reliability rate directly depends on decontamination (purifying) degree. There is an opportunity to use non-fresh water in the technical way of generation of hydrogen, for this, a water-desalinating plant is needed. This can lead to the appreciation of the generation of hydrogen. Realization of the activities mentioned above (water preparation to the hydrogen production) costs 1 US dollar per m^3 or approximately 0.01 US dollar per kg of hydrogen on average. The process of electrolyzer, at perfect conditions, demands 9 kg of water to produce 1 kg hydrogen. These data were used in the analysis part (Джумаев, 2020; Jumayev, 2022; Jumayev, Atayev, 2022; Джумаев, 2022).

In the pilot project, the issue of connecting the PV station to the general power supply network is emphasized. This paper (Osama, 2022) introduced two PI-PSO controllers to stimulate a DVR for enhancing the on-grid hybrid system under misfire and fire-through faults. The PI-PSO controllers' goal is to force the system voltage at the POT to control the voltage between the DVR and the load and consequently enhance the performance of the system during misfire and fire-through faults. The proposed PI-PSO controller showed a better performance concerning the system voltage, RESs' powers, and the WECS speed, electromechanical torque, and power. The proposed controller for the DVR also succeeded at keeping the continuous connection of the PV/wind/fuel cell to the system without disconnection for longer fault clearing times. The implementation of the hybrid system with the DVR creates an advantage that can ameliorate the efficacy of the on-grid HPS. In the future, this work may be implemented in a real hybrid power system.

Materials and methods:

– According to data, derived from open sources, method of analysis of the electric energy source's amount; also the method of pilot project's realization cost and its recoupment were employed to achieve the set goals (Бекиров, 2021; Филимонова, 2022; Nazarow, Jumaýew. 2019; Мхитарян 2013);
– This work carries out project simulation, which consists of electric power source – photovoltaic solar station (PVS) with a capacity of 100 MW, system of generation of hydrogen (electrolyzer with a capacity 50 MW,) and the system of freshening – installation of the reverse ocmosis with an output of 80 tons water a day;
– Analysis of various types of electrolyzers was undertaken.

Results and discussion: To assess the prospects of an interaction of the solar energy source and electrolyzer in the generation of hydrogen at the territory of Turkmenistan, photovoltaic solar stations installed with a capacity of 100MW each in settlements in Mary (Serhetabat) and Lebap (Kerki) districts were chosen as the main source of electric power. It is observed that only electrolyzer and water-desalination plant are involved in photoelectric solar plants. Technical data of electrolyzer with a capacity of 1 MW were used in an analysis (table1).

The calculations of electric power's quantity generated in photoelectric solar plants per year carried out as following:

$$E = E_{udel,\beta} \cdot S = \sum_{i=1}^{12} E_{i,z} \cdot \eta_p \cdot \eta_{inv} \cdot \eta_m \cdot S\,, \qquad (1)$$

where E – annual energy production of PVS; $E_{udel,\beta}$ – specific production PVS with a slope β per year; S – PVS's area; $E_{i,\beta}$ – solar energy receipt to optimal oriented area with an angle $\beta = 36^{o}$ at an array latitude of PVS in i-th month. Losses of η_p in PSP is up to 25%, and efficiency η_{inv} direct current to alternating current is 98,8%, accepted efficiency η_m 19,2 % solar component cell.

Table 1

Technical characteristics (features) of electrolysis installation with power of 1 MW.

Technical features	Value and measurement unit
Nominal power	1 MW
Generation of hydrogen	300 Nm^3/h, 27kg/h
Control of hydrogen output	15-100%
Specific consumption of electric power	4,4 kW·h/Nm^3, 48,88 kW·h/kg
Hydrogen's outlet pressure	30-200 kgs/sm^2
Hydrogen's specific outlet	0,08988 kg/Nm^3
Lower heating power	119,96 MJ/kg (33,32 kW·h/kg or 3,00 kW·h/Nm^3)

During calculations, following presumptions were accepted:

Working hours of electrolyzer with maximum mounted output in a day: December, January, February – 3 hours, March, April, May, September, October, November – 5 hours, June, July, August – 6 hours;

– Total amount of solar energy coming to the photovoltaic solar stations surface located in the settlement with an angularly slope $\beta = 36°$ of south orientation: Atamyrat (Kerki), Lebap province: 1919,328 kW·h/m^2 per year; Serhetabat (Kushki), Mary province: 1892,972 kW·h/m^2 per year.

– Power of electrolyzer designed with a condition that PVS would cover demands in electric power. Therefore, generation of hydrogen would depend on output and mode of operation of PVS. Hence, it was decided to use electrolyzer with a powe or 50 MW.

Hydrogen's mass was calculated using the data, given in the table 1 (figure 2), derived or taken from electrolyzer with corresponding power of:

$$m = \sum_{i=1}^{12} m_i = \sum_{i=1}^{12} \eta_{el} \cdot t_i \cdot N_i \qquad (2)$$

where m – mass of hydrogen produced in a year; m_i – mass of hydorgen, generated by electrolyzer in i-th month; η_{el} – work efficiency of electrolyzer; t_i – working hours of electrolyzer with maximum mounted output in a day; N_i – number of days in month.

Balance of generated and consumed energy of system components used in generation of hydrogen defined in (figure 1).

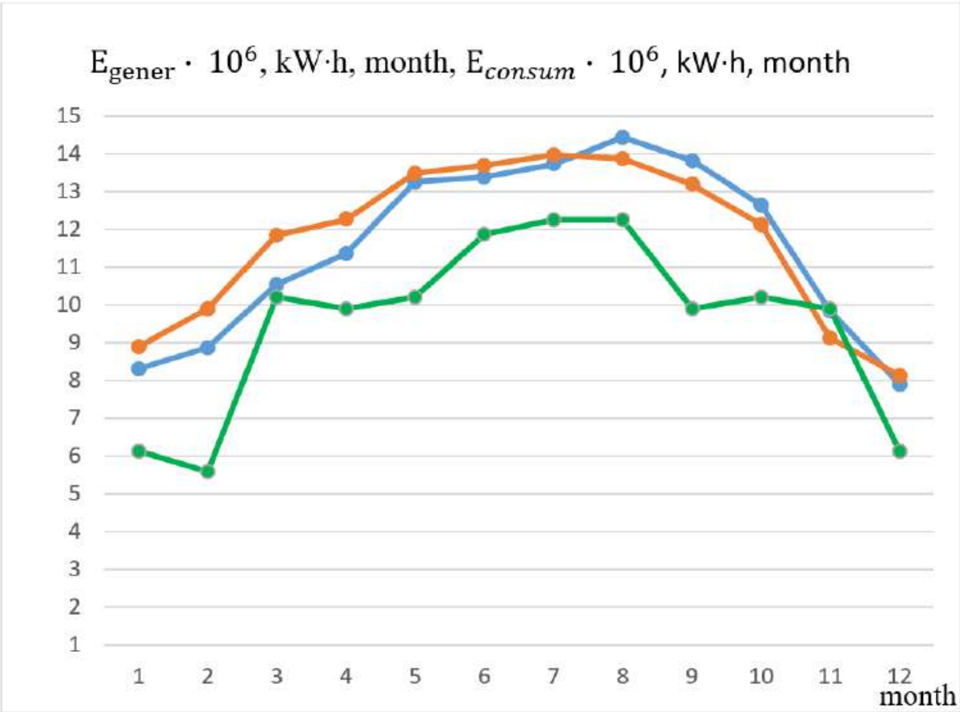

Figure 1. Generated electricity of PVS and consumed energy of electrolyzer
(red and blue is PVS's generated energy; green – electrolyzer's consumed energy)

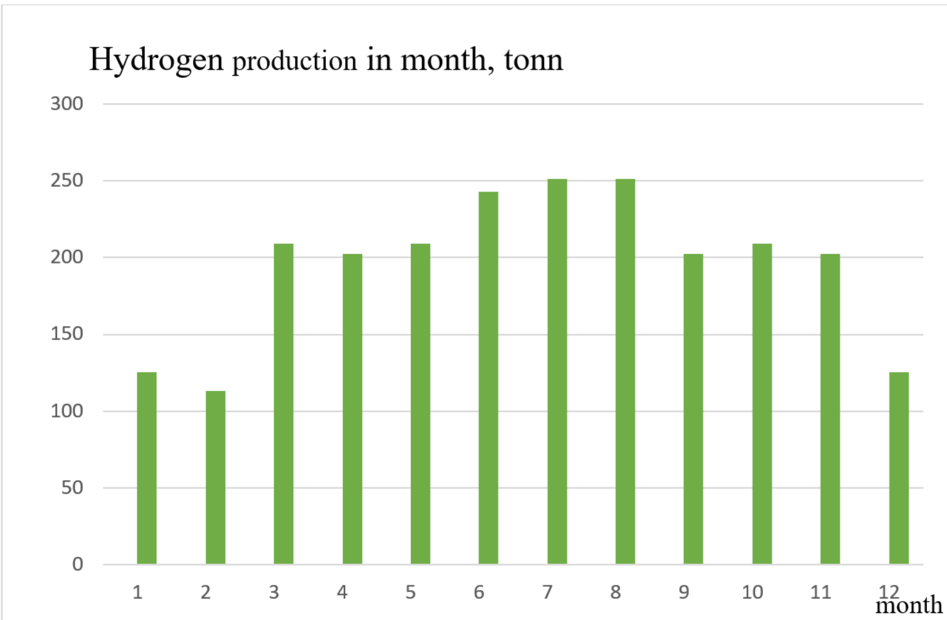

Figure 2. Hydrogen production in month

Table 2

Technical features basic blocks

1	PVS power	2745x2=5490 kW
2	Maximum power (Pmax) photovoltaic (PV) module	380 W

3	Total number of PV modules	7224x2=14448
4	Total number of PV modules per string	28
5	Total number of strings	258x2=516
6	PV modules size	28578 m^2
7	Total number of inverters	2
8	Nominal inverter power	2841 kVA

Table 2 and table 3 show technical features of basic blocks station and PVS with a power of 100 MW. A scheme of basic blocks station shown in figure 3.

Table 3

Technical features of PVS with a power of 100 MW.

1	PVS power	100 MW
2	Total number of basic blocks	18
3	Power of basic block	5490 kW
4	Power of PV module	380 W
5	Total number of PV modules	260064
6	Total number of PV modules per string	28
7	Total number of strings	9288
8	Total number of inverters	36
9	PVS size	514406 m^2
10	Annual energy production	$138{,}538 \cdot 10^6$ kWh/year

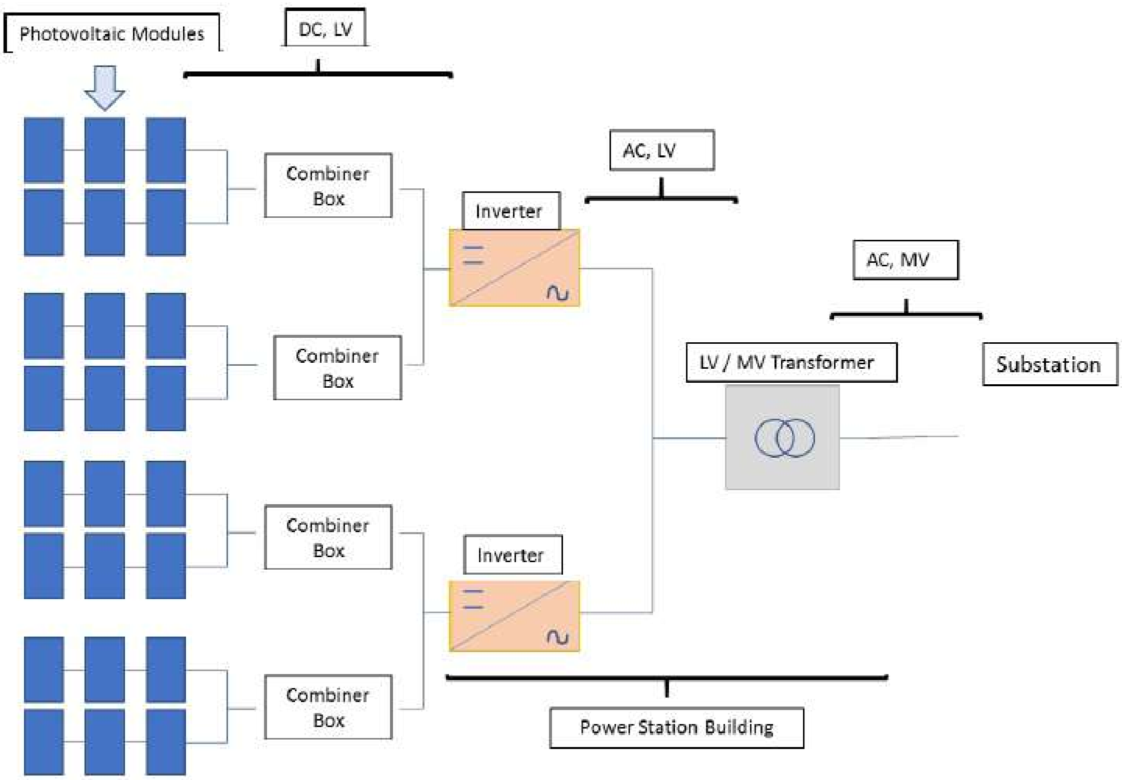

Figure 3. Scheme basic block

Pilot project considers the construction of the two photovoltaic solar stations installed with a capacity of 100MW each in settlements in Mary (Serhetabat) and Lebap (Kerki) districts; and the derived results are shown in table 4. A realization of current pilot project enables to generate 2344,45 t of «gree» hydrogen in a year.

Table 4

Basic results of pilot project

Technical features and data	Value and measurement unit
Settlement, coordinates	Atamyrat (Kerki): northem latitude 37,80; eastern longitude 65,20
	Serhetabat (Kushki): northem latitude 35,20; eastern longitude 62,40
Total amount of solar energy coming to the solar panel's surface located in the settlement with an angularly slope β=360 of south orientation	(Kerki):1919,328 kW·h/m^2 year
	Serhetabat (Kushki):1892,972 kW·h/m^2 year
PVS's electric energy output (generation) per year	(Kerki):140,467·10^6 kW·h
	Serhetabat (Kushki):138,538 ·10^6 kW·h
Hydrogen generation	2344,45 t
Consumed energy in the generation process of hydrogen	114,443·10^6 kW·h
Consumed water in the generation process of hydrogen	21104,550 t

RESULTS

1. Recommend to realize a pilot project on «green» hydrogen generation at the territory of Turkmenistan.
2. This work carries out project simulation, which consists of electric power source – photovoltaic solar station (PVS) with a power of 100 MW, system of hydrogen production (electrolyzer with a capacity 50 MW,) and the system of freshening – installation of the reverse ocmosis with an output of 80 tons water a day.
3. A realization of current pilot project enables to generate 2344,45 t of «green» hydrogen in a year to create an empty row at the bottom of the table to contain them.

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