Major trends characterizing solar energy development in Uzbekistan

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A Mirzabaev[1,2*], A Isakov[1], O Soliev[3], M Makhkamova[4], and D Kodirov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000 Tashkent, Uzbekistan
[2]International Solar Energy Institute ISEI, 100084 Tashkent, Uzbekistan
[3]Tashkent State Technical University, 100097 Tashkent, Uzbekistan
[4]"MIR SOLAR" LLC, 100076 Tashkent, Uzbekistan

[*]Email: mirenergy@yandex.ru

Abstract. This paper examines the main trends in the development of solar energy in Uzbekistan. It also describes various schemes for powering deep-water pumps using PV power plants and analyzes the payback period of small autonomous (off-grid) solar systems.

1. Introduction

The technological innovations, large investments, and a significant reduction in the cost of equipment in the field of solar energy marked the late 20th and early 21st centuries. Inexhaustibility, accessibility, and sustainability are the indisputable advantages of renewable energy sources [1]. The 21st century can be called the century of solar energy, since today renewable energy sources (RES) are already competitive with traditional energy.

Today, photovoltaic power plants (PVP) are actively used on an industrial scale in more than 75 countries around the world. Over the past five years, the total installed capacity of solar energy in the world has increased almost sixfold and by the beginning of 2021 exceeded the figure of 650 GW [1-3].

The climatic and natural conditions of the Republic of Uzbekistan, as well as the availability of highly qualified scientific and engineering personnel, provide ample opportunities for the use of solar energy. The total capacity of solar energy is 50973 million tons per year, and its technical capacity is 177 million tons per year.

The average number of sunny days in the republic is 250-270, the duration of sunshine is 2850-3050 hours per year [4-7].

2. Methodology

Analysis of the current state of solar industry shows three priorities for solar energy application in Uzbekistan: electricity generation (centralized and decentralized), production of thermal energy and "green" hydrogen.

The development of centralized electricity generation is carried out through public-private partnerships (PPP), including the involvement of major investors: “Masdar Energy” (UAE), “Juru Energy” (Great Britain), “Total Eren” (France) and etc. The targets for the subsequent evolution of RES, installation of large-scale wind and solar photovoltaic power plants, thereby increasing the share of RES in the total electric power generation in Uzbekistan to at least 25% by 2030, have been approved under the Presidential Decree of the Republic of Uzbekistan "On accelerated measures to improve the energy efficiency of economic and social sectors, the introduction of energy-saving technologies and the development of renewable energy sources"[8, 9].

Table 1. The list of breakthrough projects on "green" growth in renewable energy sources (RES), which are under construction

Title	Capacity	Location	Commissioning date
Construction of PV power plant	100 MW	Navoiy region	September 2021
Construction of PV power plant	100 MW	Samarkand region	December 2021
Construction of wind power plant	500 MW	Navoiy region	September 2024
Construction of 2 wind power plants	1000 MW	Bukhara region	December 2023
Construction of PV power plant	200 MW	Nurata district of the Navoiy region	2nd quarter of 2023
Construction of PV power plant	457 MW	Surkhandarya region	2nd quarter of 2023
Construction of 2 PV power plants	440 MW	Samarkand and Jizzakh regions	4th quarter of 2022
Total	2797 MW		

Building PV power plants with a capacity of 20 to 500kW on the rooftops, integrated with a local network to meet the needs of industrial enterprises and educational institutions, together with the small stand-alone PV power plants for the population serves the development of decentralized electric power generation. The exception is a stand-alone PV power plant with a capacity of 1.2 MW in the Kandym Gas Processing Complex of the Karakul district of the Bukhara region.

3. Results and Discussion

In our view, the best development scenario for solar industry in Uzbekistan is precisely decentralized and distributed generation. This has the advantage of minimization of the negative impact of the PVP on the mode of the electric power system (EPS), grid failures and etc. The possibility of installing PVP on the roofs of industrial enterprises further strengthens the competitive advantage of these power plants. Figures 1 and 2 show the general view and circuit diagram of the GRID ON PVP with a capacity of 30kW installed on the roof of the Samarkand Cigarette Factory.

Figure 1. PVP with a capacity of 30kW installed at the Samarkand Cigarette Factory "UZBAT A. O." JSC JV

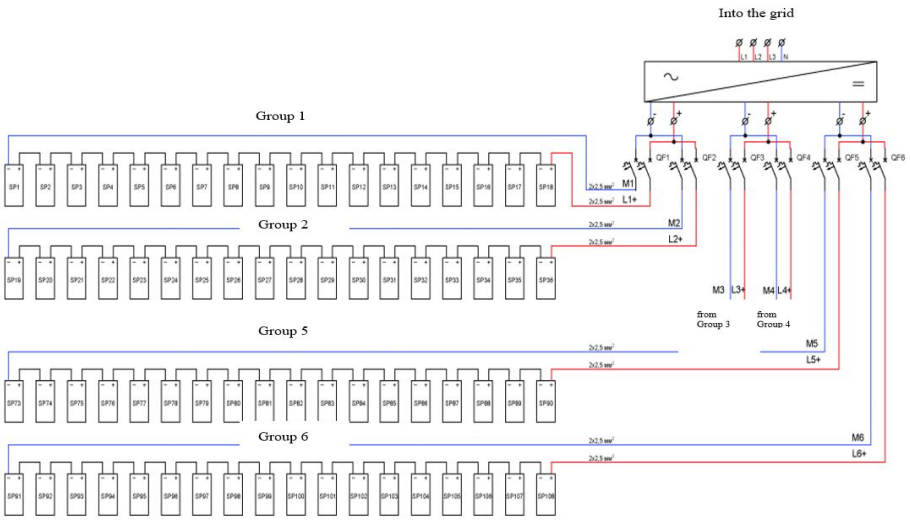

Figure 2. Circuit of PVP with a capacity of 30kW installed at the Samarkand Cigarette Factory "UZBAT A. O." JSC JV

The circuit indicates that the total capacity of the PVP in the amount of 30 kW comes from 108 monocrystalline panels with a unit capacity of 280W. Six parallel working groups of 18 panels are assembled to work at the maximum power point to ensure optimal voltage at the input of MPPT controllers.
To demonstrate the economic efficiency of small-scale PV power plants connected to the network in the example of this station, the table below provides the hourly schedule of electricity generation for July 30, 2021.

Table 2. Schedule of the daily electric power generation of the PVP with a capacity of 30kW installed at the Samarkand Cigarette Factory "UZBAT A. O." JSC JV

Time	7	8	9	10	11	12	13	14	15	16	17	18
P, kW*h	3.42	10.58	16.70	20.99	23.83	24.4	23.2	20.5	18.8	14.88	8.68	2.59

Table 3. The main incentives offered to the producers and consumers of RES in the Republic of Uzbekistan

Incentives offered to the producers and consumers of RES	Legal basis
Exemption from all taxes for the period of 5 years from the date of incorporation.	LRU-539 dated May 21, 2019
Exemption from a property tax for renewable energy installations(rated capacity of 0.1MW or more) and a land tax on areas occupied by the said installations for 10 years since the date of their commencement.	LRU-539 dated May 21, 2019
Exemption from a property tax for the residential premises with a complete disconnection from the existing power grids for a period of 3 years starting from the month of using renewable energy installations.	LRU-539 dated May 21, 2019
Exemption from a land tax for a period of 3 years for the residential premises with renewable energy installations with a complete disconnection from the existing power grids.	LRU-539 dated May 21, 2019
Ensuring a guaranteed connection to the unified electric power system of renewable energy installations.	LRU-539 dated May 21, 2019
Reimbursement to individuals in the amount of 30 percent of the cost of PV power plants.	PD-4422 dated August 22, 2019
Reimbursement to individuals and legal entities for interest costs on commercial bank loans for the purchase of renewable energy installations.	PD-4422 dated August 22, 2019

Since the PV modules are fixed rigidly with an orientation to the south at an angle of 40 degrees, the values of the generated capacities in the morning and evening hours are relatively small. From 10 am to 4 pm, the PVP generates more than 20 kW of power which is a good indicator for latitude 41.

The estimates indicate that the payback period of this PVP, taking into account the benefits provided for by the Presidential Decree of the Republic of Uzbekistan of August 22, 2019 No. PP-4422 "On accelerated measures to improve the energy efficiency of economic and social sectors, the introduction of energy-saving technologies and the development of renewable energy sources", is less than 6 years with a service life of at least 25 years (Table 3) [10, 11].

There has been a broad development of solar water heating systems providing the population and industrial enterprises with hot water almost all year round. These systems mainly use flat and tubular solar collectors, the production of which has been mastered in the republic. Major manufacturers of solar collectors are "Quyosh issiqlik energiyasi" JV, "MIR SOLAR" LLC, JV "Artel group", "All solar" PE.

In Uzbekistan, the first steps have been taken in the field of industrial development of "green hydrogen" technology - the institute of renewable energy sources has been established.

Let us take a closer look at one of the promising areas of decentralized generation – solar water lifting systems.

The application of renewable energy sources in water industry is gaining momentum in all countries of the world, particularly in the Republic of Uzbekistan. Modern practice distinguishes two successfully operating circuits that use PV power plants for lifting water, namely battery-less circuit and storage battery (SB) circuit [11, 12, 14].

1. Battery-less circuit for lifting water using the PV power plant

Figure 3. Diagram of battery-less circuit for lifting water

The main element of this system is a special inverter for driving pumps with asynchronous motors, which ensures a smooth start of the pump as the Sun rises. At the same time, the deep pumps start working at a frequency of 38 hertz, and as the solar radiation increases, the frequency gradually rises to 50 hertz. In the afternoon, as the incident solar radiation decreases, the frequency slowly decreases, and at 38 hertz, the pump turns off.

The advantage of such a circuit is the relative simplicity, cheapness, and durability of the installation. The smooth start of the pumps also contributes to the increase in their service life. The main disadvantage is the possibility of using it only in the daytime. In practice, to compensate for this disadvantage, artificial reservoirs are constructed to accumulate water pumped during the daytime for their use in the evening.

Storage pools or sealed tanks are often built at the highest point of the irrigated area so that at night irrigation is carried out by gravity. This system is very convenient for the introduction of modern water-saving technologies, such as drip

irrigation. At the same time, conventional types of equipment are used, including standard pump inverters with long service life.

2. Storage battery (SB) circuit for lifting water using PV power plant (Figure 4).

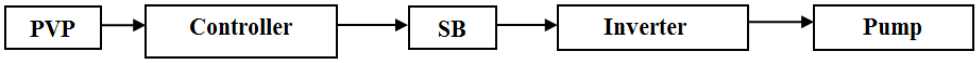

Figure 4. Diagram of an SB circuit for lifting water

This circuit serves as an example of applying a classic GRID-OFF circuit (without integration into the common network). The main advantage of this circuit is the guaranteed provision of electric power to all of the electrical equipment of the farm, not only to pumps at any time of the day. The main disadvantage of this circuit is the relatively high cost and the need for regular replacement of batteries.
Based on these two circuits, it is possible to offer an interim option for powering pump equipment that minimizes their shortcomings. This option requires a minimum number of batteries in the circuit, which will serve as a stabilizing factor when small clouds appear in the daytime. At night, the batteries will serve as an energy source for a small number of lamps and a low-power TV set in the farmer's field camp.

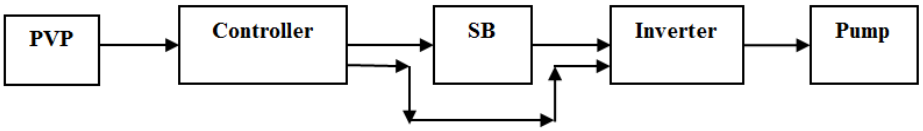

Figure 5. Diagram of interim circuit for lifting water

Over the past few years, there has been a shortage of water for irrigation in all regions of the Republic of Uzbekistan. In this case, the use of groundwater is seen as an alternative. Depending on the regions, the depth of underground sources varies from 40 to 200 meters.
The distribution of groundwater resources across the territory of the Republic of Uzbekistan is uneven, and more than 30% of the population suffers severe shortages of high-quality water. Tashkent (28.5%), Samarkand (13.7%), Surkhandarya (13.1%), Namangan (12.8%), and Andijan (12.3%) regions own the main stock of fresh groundwater reserves (with mineralization of up to 1 g / l). The Bukhara and Navoi regions hardly have fresh groundwater (less than 0.3%), while the Republic of Karakalpakstan and the Khorezm region have a completely depleted reserve of fresh groundwater.
The above-proposed circuits for powering deep-water pumps using solar energy have grand prospects for mass implementation. For example, it was decided to use solar water lifting systems in 198 objects of JSC "Uzsuvtaminot".
As is known, the demand for irrigation water is seasonal. Since November, almost all PV power plants in water lifting systems for irrigation needs have been operating in idle mode. The effective use of these PVPs in the autumn-winter

period is becoming an urgent task. Taking into account the fact that the average capacity of these power plants is 30-50 kW, it is possible to offer their modernization by replacing pump inverters with network inverters during this period and selling the generated energy to the electric grid companies. As another option, we can offer the establishment of charging points. There is a boom in electric cars all over the world on the basis of these PV power plants.
Monitoring of a 9.2 kW PV water lifting system installed on the territory of the irrigation institute shows that only in 2020, during the switch to a network inverter, due to the lack of irrigation, it generated "free" electricity in the amount of more than 26,343 kWh (Table.4) [13, 14].

Table 4. The PV power plant installed at TIIAME

Capacity of PV power plant	Facility	Depth, (m)	Flow rate not less than (m3/h)	Quantity of the pumps (pcs.)	Model of the deep-water pump	Inverter	Capacity of PVP (W))	Quantity of PVP (pcs.)
9.2 kW	Training ground TIIAME	40	40	1	6SP46-5	SPRING- 9200-A	265	36

The trends in the development of solar energy in the Republic of Uzbekistan and the facts indicate that it is necessary to build medium and small solar power plants along with large PVPs, to develop distributed generation.

4. Conclusions

The total potential of solar energy - 50973 million tons of fuel equivalent and its technical potential-177 million tons of fuel equivalent create all the prerequisites for the rapid development of solar energy in the Republic of Uzbekistan. The most promising is the development of distributed generation and photovoltaic water lifting systems.

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