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Innovative methods of developing solar power systems for remote and agricultural facilities in Uzbekistan

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Abstract. This paper presents innovative methods and techniques for the development of small solar power systems in Uzbekistan, based on the properties of patterning and prosumerism, adoption of which would increase the efficiency of power supply. It also provides examples and results of their application in solar systems for remote and agricultural power supply developed by MIR SOLAR LLC, as well as the experience of teaching these innovations to students of Uzbek universities (Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent State Technical University, and others).

1. Introduction

In the modern world, renewable energy sources are growing rapidly due to a number of reasons: scarcity of traditional fuel resources, environmental imperatives, consumer demand and others [1-5]. The factors determining the development of renewable energy technologies are: forecasting of electric power consumption, deteriorating climatic conditions, environmental pollution, success of relevant scientific and applied research and low-carbon energy, availability of qualified specialists and others. All countries around the world including Uzbekistan are, to varying degrees, expanding the use of renewable energy sources (RES).

Trends in the development of small-scale energy in the Republic of Uzbekistan and facts indicate the beginning of transition to a combined system of centralized and decentralized energy supply in our Republic, in which solar energy will occupy the most important place [2, 3, 5-7]. The analysis shows that its development and functioning require the corresponding components of support: legislative, technical and technological, financial and investment, organizational, scientific, as well as the training of appropriate qualified specialists; at the same time, strong government support is needed in all areas of RES implementation.

In accordance with the government's "Strategy for Innovative Development of the Republic of Uzbekistan" program, the share of RES in total energy balance of the country should constitute 20% by 2025 [6]. The successful implementation of this task requires extensive use of modern solar technologies based on innovative methods and training of qualified engineers.



2. Methods

In addition to the already mentioned components, new innovative approaches, including such concepts as patterning and prosumerization (prosumerism) [8-10], are needed for the widespread introduction and application of new technologies and innovative methods in the solar energy sector of Uzbekistan.

The concept of patterning is derived from the English word "pattern", which could be translated as "template", "example", "form", "structure". The term "pattern" is used in many fields of activity, science, and modern technology.

A pattern is a scheme by means of which it is possible to identify various regularities, for example, in nature and in engineering. The term pattern refers to a repeating arrangement that is predictably reproduced. When we talk about patterns, we mean their presence or absence in the relevant field of activity. They often look the same, but normally they do not copy each other and may take various forms.

Currently, there are many varieties of patterns, which in our case can be divided into two groups: the formation of the continuation and reversal of the trend. For solar energy, these groups represent a further development of the trend and are generally interpreted as the opening of new positions (patterns) in accordance with the current trends in technological, regulatory, organizational and other areas.

The innovative role of using the patterning technique in small energy is that it allows you to highlight its best properties: reliability, efficiency, low prices, simplicity of installation and maintenance, while providing durability and adequate rate of return. That said, we are talking about using equipment produced on a large scale with low market prices and easy maintenance.

It is essential to draw on the experience of other countries, where patterning has a wide application in energy. For instance, Pattern Energy Group (PEGI) is an independent international company in the field of renewable energy, successfully engaged in solar and wind energy production in a number of countries, in particular, in the USA, Canada, Chile and Japan [9-11]. The company operates 25 wind and solar power stations with a total capacity of about 3,000 MW.

Prosumers comes from the word prosumer - an individual who takes an active part in the production of electric power consumed by himself. In the "prosumer" technology, the boundaries between the owners of the electric power generation facilities and its consumers are blurred. The term "prosumer" is often translated as "manufacturer for himself". It is related to the fact that the distributed and decentralized individual power generation is more cost-effective and efficient relative to traditional. This is especially true in low-capacity renewable energy sources and in remote areas.

Here, the global goal is achieved – the most efficient satisfaction of individual consumer needs, given that manufacturer and consumer are combined into a unified technological complex with a low dependence on external power supply.

3. Results and Discussion

Estimates show that the technical potential for using solar energy in Uzbekistan is 176.8 million tons of oil.

The number of Sunny days in a year is 300 or more (Table.1). The number of Sunny hours in winter is 3-5 hours; in summer it is 10-13 hours. The intensity of solar radiation on the territory of the Republic varies from 1600 kWh/m²·year for the Ferghana valley to 2100 kWh/m²·year for the North of the Republic (Figure 1). For comparison, the energy illumination of the territory of Central Europe is 1000 kWh/m²·year; the Mediterranean is approximately 1700 kWh/m²·year.

Sustainable operation of more than 1500 PV power plants installed by "MIR SOLAR" LLC is confirmed by their long-term operating stability (5 to 15 years or more). Wherein the cost recovery period—meeting the costs of purchased equipment and maintenance of PV power plants – is between 4 and 14 years [7, 8, 12].

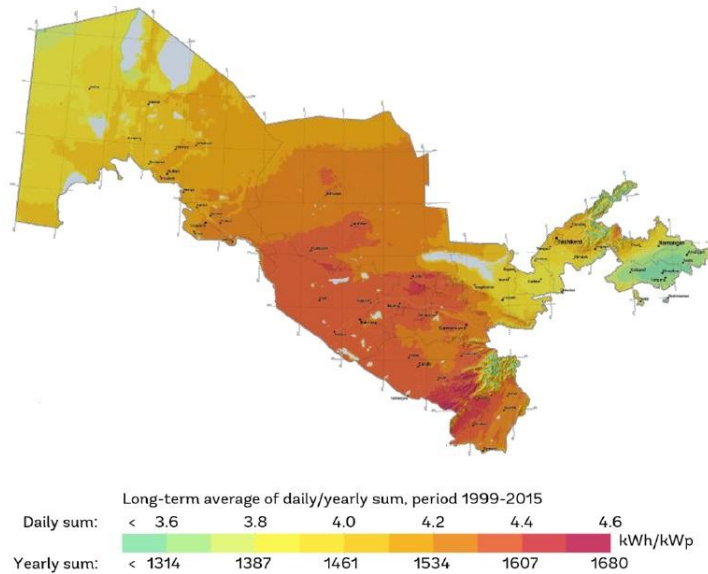


Figure 1. Photoelectric potential of the Republic of Uzbekistan: the map shows the average daily and average annual generation of electric energy from a photovoltaic station with a nominal capacity of 1 kW

Table 1. The Number of clear and unclear days per year according to 6 weather stations in the regions of the Republic of Uzbekistan

Name of weather stations	Number of clear Sunny days	The number of unknown days
Guzar (Kashkadarya)	323	43
Karmana (Navoi)	329	37
Pap (Namangan)	316	50
Parkent (Tashkent)	319	47
Sherabad (Surkhandarya)	343	23
Dagbit (Samarkand)	331	35

“MIR SOLAR” LLC has its own "know-how" for all of the technologies applied and kinds of the equipment used. For instance, it includes the quantitative ratios used simultaneously on PMT panels from mono- and polycrystalline silicon, their alignments in relation to the cardinal points and the horizon, correction of the features of standard and specially designed controllers, cooling systems for inverters, choice of the battery, availability of snow cover, the intricacies of the installation, specific features of warranty system and etc. The PV power plants installed by “MIR SOLAR” LLC have different patterns (sets, structures), depending on the purpose, distance from the centralized grids, consumption modes at different times of the year, level of insolation, financial investments, service qualification during operation, and other aspects.

Various options are always considered in order to find the most acceptable and effective one for a specific prosumer: power, voltage, consumption structure, load composition, installation site, etc., depending on which the composition, parameters and properties of a specific solar installation are determined. This determines the most acceptable and effective pattern.

This enables the long-term reliability and efficiency of installed equipment, and expansion of the market for photovoltaic power plants [13].

The specialists from "MIR SOLAR" LLC together with the scientists from International Solar Energy Institute (ISEI), TIAME and TSTU constantly analyze the prospects for implementation of solar energy in Uzbekistan, especially in remote and arid areas where the main way to solve the problem of providing the population and agriculture with fresh water is the use of underground sources from

artesian wells. In this regard, deep artesian wells are drilled in areas including the sub-mountainous and remote districts, where, as a rule, there is no power supply for electric pump drives. Thus, the matter of a guaranteed electric power supply for the drives of such pumps is highly relevant for the arid regions of the Republic of Uzbekistan. Solar technology using the consumerism and patterning techniques is successfully implemented in these areas, ensuring the secure water supply for customers who live in such remote areas [8, 9, 12].

At the present time, hundreds of water-lift systems using PV panels (PVPs) with different capacity are effectively operating in Uzbekistan and the demand for them has been rising day by day.

Academic programs for specialists in the field of renewable energy sources in accordance with the international standards were developed thanks to the close cooperation of the academic faculty of national educational institutions with representatives of leading universities in Europe within the framework of RENES program. Financial support was provided to equip five higher educational institutions of the Republic of Uzbekistan with modern laboratory equipment, in which the production enterprise “MIR SOLAR” LLC also takes an active part.

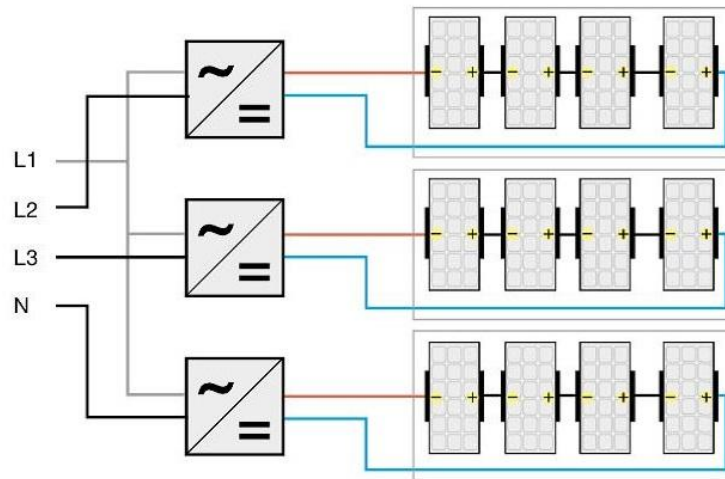


Figure 2. Connection diagram photovoltaic power plant

It should be noted that several groups of students studying at the faculty of energy of the Tashkent State Technical University (TSTU) annually undergo practical training at “MIR SOLAR” LLC as an essential and necessary pattern. Apart from that, “MIR SOLAR” LLC has equipped specialized training laboratories in the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIAME), as well as installing a training ground for water-lift and water supply systems. Training of students with the use of innovative technologies contributes to the development of small-scale solar energy in the country, and allows the company to determine the opportunities of the graduates and provide them with qualified work.

In modern practice, there are two successful circuits that use PVPs for water lifts– battery-less and storage battery (SB). Such circuits were developed by “MIR SOLAR” LLC (see Figures 1-4) and corresponding equipment were selected using patterning and consumerism technique. This enabled the determination of the most appropriate circuits, taking into account the further operation of their equipment under local conditions [8, 11, 13, 14].

3.1. Circuit of water-lift systems without SB using PVP

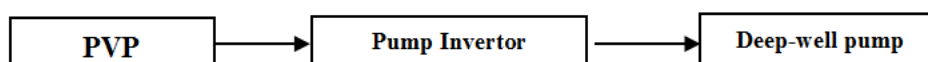


Figure 3. Flow diagram of water-lift systems without SB

The main element of this system (Figure 3) is an inverter for driving pumps with asynchronous motors. The main advantage of such a circuit is its relative simplicity, cost-effectiveness and durability of the plant, and the main drawback is the possibility of its use only for water supply needs, since the continuity of water supply is provided by the accumulation of water [15-17].

In doing so, the equipment used is conventional, including model inverters (see Table 2).

Table 2. Main parameters of widely used pump invertors

Type of the pump inverter	Nominal voltage, V	Nominal power, kW		Recommended voltage from the PVP, V	
		P_{\min}	P_{\max}	U_{\min}	U_{\max}
Single-phase	220	0,5	5	290	500
Three-phase	380	3,0	75	500	900

3.2. Circuit of SB water lift system using PVP

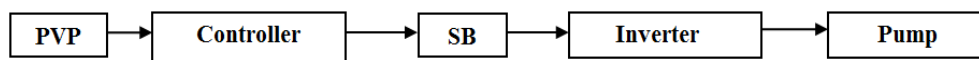


Figure 4. Flow diagram of an SB water-lift system

This consumerist circuit is an example of the use of the classical GRID-OFF circuit (without connection to the common network), the main advantage of which is the ability to operate around the clock and to recharge other consumers, and the main drawback is the relatively high cost due to the cost of installing and the need for regular replacement SBs.

Considering the advantages and disadvantages of the main circuits for water lifts, the scientists from TSTU, TIAME and the specialists from "MIR SOLAR" LLC based on the experience of the development of PV systems, offer a more flexible connection circuit that guarantees the minimal use of SBs. The structure of such a circuit is shown in Figure 4.

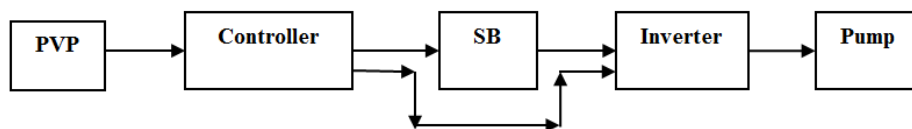


Figure 5. Flow diagram of PV power plant developed by "MIR SOLAR" for remote electric power supply systems

One of the advantages of the proposed circuit is the opportunity to minimize the amount of expensive SBs with high total power and, correspondingly, the connected pump or other equipment. The main highlight of the recommended circuit is a special multi-functional controller developed for this purpose, which allows you to adjust the value of the charging current of the AB to a minimum, while the generated power is directly used to power the pump. The controller can also turn off the function of the charging current stabilization, allowing it to be used as a conventional controller. Thus, if necessary, SB is used as a stabilizing factor: in case of clouds and use for power supply of household equipment in the dark [14].

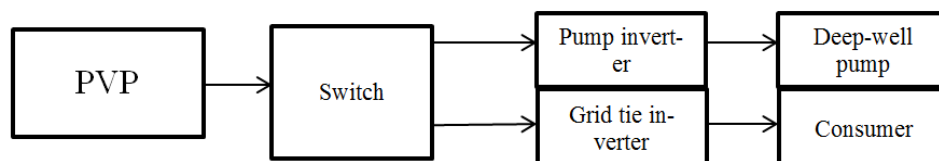


Figure 6. Flow diagram of PV power plant installed at TIAME

It can be noted that such PV power plants can effectively provide energy to water supply systems for livestock in remote and arid areas of our Republic, as well as other power consumers.

The need for irrigation water is seasonal, therefore the PV power plants tend to remain unloaded. Under the existing shortage of electric power in remote rural areas, the use of these power stations at full capacity becomes relevant. To solve this problem, it is proposed to connect network inverters in parallel with pump inverters (Figure 5).

The PV power plant with a capacity of 9.2 kW installed on the training ground of TIAME was assembled according to the scheme on Figure 6, and the types and parameters of equipment are given in Table 3. A pump inverter is used during irrigation in order to ensure guaranteed power supply and smooth start of the pump. The rest of the time, the PV power plant uses a network inverter to provide power to the academic buildings of the Institute (Figure 7).

Table 3. The types and parameters of equipment

Capacity of PV power plant Facility	Depth, (m)	Flow rate not less than (m ³ /h)	Quantity of pumps	Model of deep-water pump	Inverter	Capacity of PVP (W)	Quantity of PVP (pcs.)
9.2 kW Training ground TIAME	40	40	1	6SP46-5	SPRING- 9200-A	265	36

The equipment is also used for educational and practical purposes, whereas the analysis of its exploitation has shown its effectiveness in the educational process, both for bachelor's and master's degree students, allowing within a short time to master innovative technologies, to determine the structure and types of equipment used for PV power plants, optimal capacities and modes of pumps at different depths of artesian wells, different water requirements and etc.



Figure 7. PVPs of the academic PV power plant installed at TIAME

Table 4. Generated electric energy for the first half of 2020

Months of the year 2020	January	February	March	April	May	June
Electric power, kWh	719	1381	2192	2214	2785	3110

It should be noted that the proposed circuit significantly increases the performance ratio (PR) and helps to reduce the payback period of the PV power plant. Only in the first half of 2020, the PV power plant produced "free" electric power in the amount of more than 12,400 kWh (Table 4).

4. Conclusions

Uzbekistan has huge solar energy resources that need to be practically implemented, especially in the energy supply systems of remote areas. This is possible with the implementation of innovative technologies, the inclusion of investment and scientific components in the production technology of electricity and heat, the widespread use of innovation, including those based on patterning and consumerism, effective methods of training and the availability of qualified specialists in this field.

The practical training of students in the workshops of "MIR SOLAR" LLC, training with the use of special laboratories in universities, as well as the training ground of TIAME, combined with the study of innovative methods of consumerism and patterning, will allow the output of specialists of international level in the field of solar energy of the Republic of Uzbekistan.

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