Comprehensive automated drip irrigation system

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Abstract. Providing the population with clean drinking water and agricultural water, which provides humanity with food, has become one of the main problems around the world. In the Republic of Uzbekistan, as well as in other countries of the world, the shortage of water is growing every year. The article states that one of the main factors for mitigating water shortages in agriculture is the introduction of water-saving technologies. Among water-saving technologies, the most effective system is drip irrigation. Therefore, introducing an integrated drip irrigation system in the mountainous and foothill regions of the republic, where there is a shortage of water and energy resources, will be very effective. To provide an integrated drip irrigation system with energy, it is proposed to use renewable energy sources (solar) and automation of the entire irrigation process for reliable operation.

1 Introduction

Currently, providing a rapidly growing population with environmentally friendly food is becoming one of the main problems on Earth. Therefore, in all countries in the world, and in the United Nations, there are food security programs [1]. By decree of the President of the Republic of Uzbekistan, in 2018, the program “On measures to further ensure the food security of the country” was adopted [2]. Agriculture is the main source of food security and the main consumer of water resources. Today, 90-91% of the water limit allocated to our country (51-53 billion m3) is consumed by agriculture [3]. In our republic, providing water for the drinking and household needs of the population is considered a paramount task. Article 25 of the Law of the Republic of Uzbekistan, "On Water and Water Use", states that "Water facilities are used primarily to meet the needs of the population in drinking water and household needs" [4]. Water insufficient for the population's needs is subtracted from the water diverted for the needs of agriculture. At the same time, due to

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global climate change, the growth of population and economic sectors, and their need for water, the water resources shortage increases yearly [5]. In such a situation, life itself proves that the most optimal solution to the problem of water scarcity is water saving and its reasonable use [6]. Currently, the following methods are used for irrigation of agricultural crops in the countries of the world: surface irrigation by flooding; superficial along the furrows; surface drop; sprinkling; aerosol humidification (fine sprinkling); intrasoil; intrasoil drip; subirrigation (raising the groundwater level) [7]. Methods that differ from surface irrigation and furrow irrigation are non-traditional and allow efficient and economical use of water resources. The use of non-traditional irrigation methods provides an increase in productivity by 30-45% and labor productivity by 25-30%, 45-60% less water consumption [8], less demand for internal irrigation networks, an increase in land utilization factor and environmental safety in irrigation systems. To date, the following methods of water-saving technologies are used in our republic: irrigation with short furrows; sprinkling; the use of hydrogel granules; land leveling with laser devices; irrigation from under the soil; irrigation with portable, flexible plastic pipes and polyethylene trays; furrow irrigation with perforated film coating; drip irrigation [9].

2 Materials and methods

Drip irrigation is the most effective method among water-saving technologies [8, 10, 11, 12]. With drip irrigation, water and mineral fertilizers are not supplied to the entire cultivation area, but only to the zone of each plant's root system. The drip irrigation method can be used in the following cases:
- in areas with small water resources and hard-to-reach supply;
- on lands with large slopes (mountain and foothill areas);
- on soils with high water permeability;
- in clean water sources;
- in crops with a large distance between rows (orchards and vineyards).

Currently, there are about 750 thousand hectares of abandoned fertile rainfed lands in Uzbekistan, located in mountainous and foothill areas, where it is possible to develop agricultural crops such as vegetables and melons, horticulture, and viticulture, thereby increasing the supply of quality products not only to the domestic market but also for export.

The main problem for effectively developing these crops on these lands is the lack of water and energy resources. One of the solutions to this problem from an economic point of view is introducing a drip irrigation system using renewable energy sources [13]. It is also known that the yield is affected by the timeliness of irrigation of crops to meet their biological needs, where the human factor plays a significant role in traditional irrigation. To solve this problem, it is proposed to introduce an automated drip irrigation system.

An integrated drip irrigation system is proposed to achieve this goal, consisting of the following three systems (Fig. 1).

1. Drip irrigation system
2. Solar power plant system with pumping units
3. Irrigation automation system

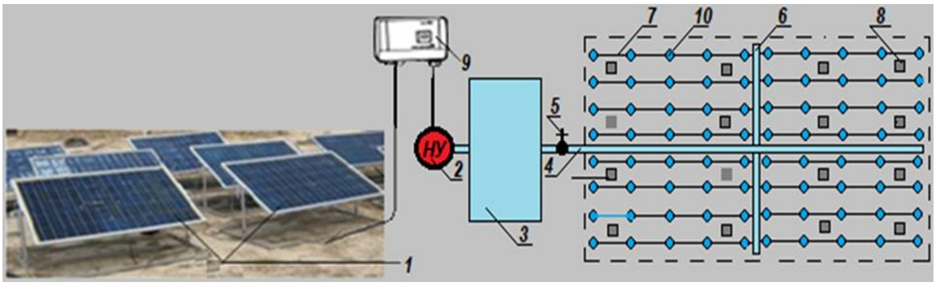

Fig. 1. General scheme of integrated drip irrigation system:
1 is solar panels; 2 is pump unit; 3 is water tank; 4 is pipeline for water supply; 5 is faucet for regulating water flow; 6 is distribution pipes; 7 is irrigation pipeline with droppers; 8 is automation devices; 9 is control unit; 10 is fruit trees.

3 Results and Discussion

3.1 Drip irrigation system

As a result of 3-year field research on drip irrigation conducted in the Surkhandarya region, water resources were saved by 39.4-41.7% when irrigating soybeans and sunflowers, as well as by 58.3-62.0% in orchards and vineyards [8]. Thus, the drip irrigation method is one of the most efficient irrigation methods.

The traditional drip irrigation system is essentially a pressurized system. It is known that all water sources in our country are muddy. In addition, the water contains the smallest colloidal particles that can pass even through a thin filter and many microorganisms that appear quickly and die quickly [14]. As a result of mixing colloidal particles and dead microorganisms, a mucous substance is formed. As the mucus settles in the droppers, it forms a very hard mixture that clogs the droppers. If droppers are not cleaned in time, they become unusable. In water with high salinity (up to 3 g/l), which is used for irrigation during periods of low water, this process accelerates, and as a result, the drip system fails very quickly.

Since the holes in the droppers are very small, they get clogged up very quickly with a small amount of turbidity and slimy substance. Therefore, the liquid entering the droppers must be cleaned. Water is pumped from the source to the settling tanks and from the settling tank to the filters by a pump that creates a pressure of 35-40 m (Fig. 2).

Depending on the terrain and water intake (surface or underground), the general scheme may differ; that is, design schemes for different regions may differ. Based on these individual designs, all components of the drip irrigation system will be manufactured.

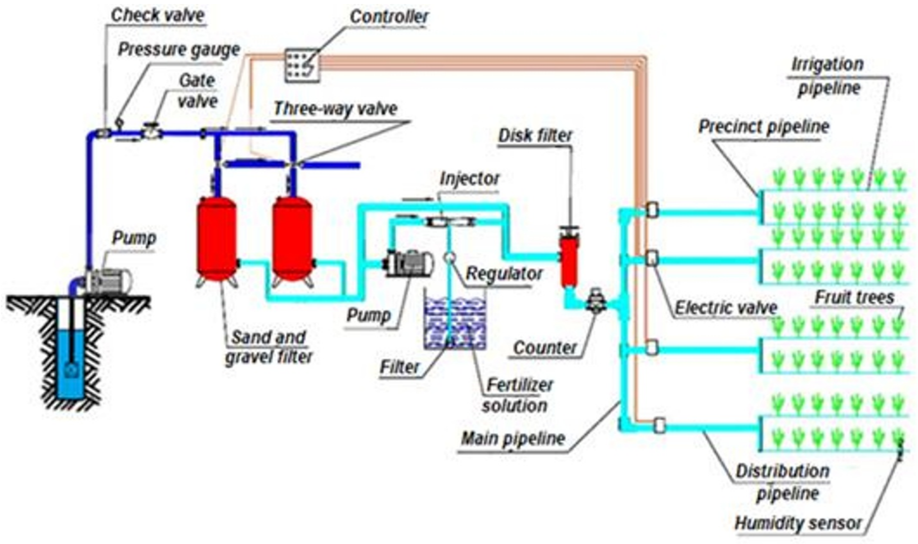

Fig. 2. (This picture is taken from the site 1povinogradu.ru) General scheme of drip irrigation system for fruit crops.

3.2 System of solar power plant with pumping units

Photovoltaic systems will provide electricity to pumping units and control equipment for efficient operation of an intelligent drip irrigation system in places with a shortage of water and energy resources.

On the proposed equipment set, modernized photovoltaic batteries are new (Fig. 3). Everyone knows that photovoltaic batteries have the lowest efficiency. The use of photovoltaic batteries (PVB) without considering the regions' climatic conditions greatly affects their efficiency. Especially under high atmospheric temperature conditions, the PVB's efficiency decreases, which is associated with a decrease in the generated power of the PVB. This process hurts the energy and economic performance of the PVB-based system. The use of photothermal batteries (PTB) on autonomous mobile photothermal water-lifting units (AMPWLU) increases the efficiency of use, including in dry climate conditions [15, 16, 17]. Typically, the following options for photovoltaic systems are used to lift water from wells:

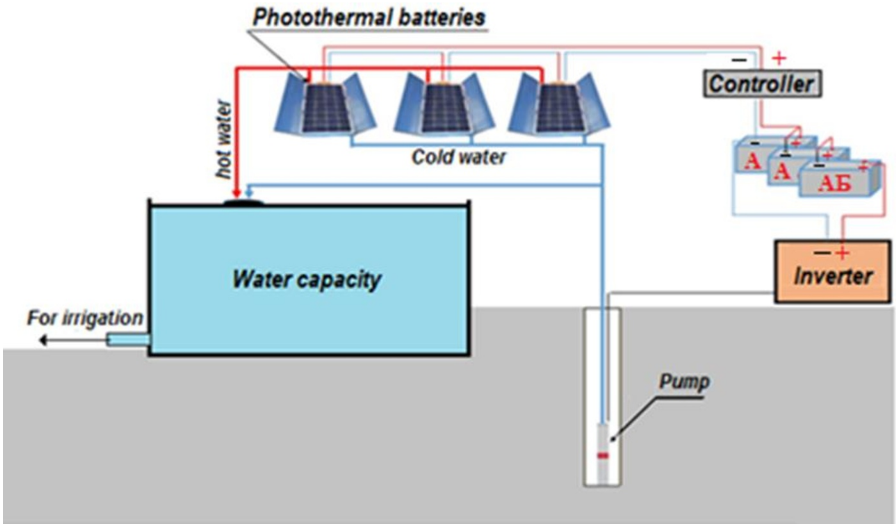

Fig. 3. Schematic diagram of lifting, redundant, and flowing water using autonomous photovoltaic installation.

- Direct water lifting system. It is easy to maintain and relatively inexpensive. For the system to work effectively, the intensity of solar radiation must be sufficient to generate the electricity needed to operate the lifting pump. Due to the lack of accumulation of electrical energy in this system, it does not work on cloudy days and at night, and it is also not advisable to connect the system to other external electricity consumers.
- AMPWLU of various capacities, capable of ensuring the operation of a water-lifting pump at any time of the day (accumulator systems). The AMPWLU storage system is more expensive than the direct water lifting photovoltaic system. However, the power generation efficiency of the system is substantially higher.

The solar photovoltaic water lifting system is becoming an important factor that significantly reduces the use of electricity produced from fuel. The efficiency of the water-lifting pumps is determined by the power generated by the PVB. The power produced by the PVB can be expressed by the following equation (1).

$$P_{ch} = U_M I_M,$$

where U_m and I_m are the maximum current and voltage of the photovoltaic array, respectively.

To calculate the system's electrical efficiency, it is necessary to determine the input power, expressed as follows.

$$P_k = ES$$

Where: E is intensity of solar radiation (W/m^2);
S is PVB surface (m^2)

The system's efficiency is determined by the ratio of the power produced by the PVB to the power of the radiation incident on the surface of the PVB.

$$\eta = \frac{P_{ch}}{P_k} = \frac{P_{ch}}{ES}$$

To lift water from wells, AMPWLU based on PVB with a power of 4000 W will be used, based on which 8 PTB with a power of 500 W each will be manufactured. A 3000 W water lifting pump will be used. To evaluate the effectiveness of the devices, test experiments will be carried out in the objects of implementation. To ensure maximum cooling of the rear surface of the PTB in the dry climate of the regions of the republic, a thermal collector will be made of cellular polycarbonate, the geometric dimensions (width and height) of the parallel channels of which are 1.5 times larger than those commonly used collectors in power plants based on PTB. Conditions will be created to increase the rate and volume of water exit from the thermal collector and, as a result, reduce the temperature of the PVB to PVB passport values for the AM 1 certification condition at a temperature of 25^0C.

Table 1. Physical and technical characteristics of parts PVB with power of 4000 W.

The maximum power of the PVB, P_{max}	500W	8 PVB
Efficiency of the PVB, η	20. 3%	20.3%
Open circuit voltage of the PVB, U_{oc}	22.8V	22.8V
Short circuit current PVB, I_{sc}	8.9 A	8.9 A
Fill factor VACh, *ff*	0.71-0.73	0.71-0.73
Thermal collector capacity (CC) made of cellular polycarbonate, *V*	17 l	17x8=136 l
Thermal conductivity of cellular polycarbonate, *r*	0.2-3.9W/m·°C	0.2-3.9W/m·°C

To manufacture AMPWLU, the platform of a trolley widely used in public utilities for transporting waste in urban areas will be used. In the future, when modernizing the design of the trolley platform, it is possible to increase the power of the photovoltaic part to 6-7 kW. Table 1 shows the physical and technical parameters of the parts of the PTB with a power of 4000 W.

Dependences of changes in solar radiation flux density, air temperature during daylight hours, and the temperature of water pumped out from a depth of 30-40 meters will be taken. The water rising through the pipes is divided into two parts by a special distribution device, 1/3 of it is sent to the water lifting unit, passes through the heat collector located on the rear surface of the PVB, then joins the main water flow, and enters the water pool.

AMPWLU have a high efficiency of lifting water at any time of the day due to the presence of a storage system of electrical energy. In the electric energy storage system, modern helium batteries with an efficiency of up to 80% and a service life of up to 8-10 years are used, and inverters with a "pure sine" signal shape are well compatible with modern water-lifting pumps with a water lifting depth of up to 80-100 m. Mobile (mobile) AMPWLU design allows orientation along the solar disk in two coordinates with high accuracy. In contrast to permanently installed stationary water-lifting photovoltaic installations, AMPWLU significantly reduces the loss of solar radiation incidents on the surface of photovoltaic batteries by up to 80%. In addition, the utilization factor of the power plant's installed capacity increases several times (3-4 times) compared with a stationary power plant. Modern service and control electronics AMPWLU controllers with load point tracking point of current-voltage characteristic, inverter with "pure sine" signal form have high efficiency and low electrical losses.

3.3 Irrigation automation system

Higher yields can be obtained if the plant is not subjected to biological stress during watering. The human factor plays an important role in the irrigation process. To overcome the human factor, the project's drip irrigation system is automated, i.e., automation tools

have been introduced into the system that will control the drip irrigation process based on a special program that considers the need of plants for water [18, 19]. An intelligent drip irrigation system will allow more economical use of water for agriculture irrigation, providing a more efficient and rational use of water resources.
By studying the type of soil on the site and its water-physical properties, such as water permeability, capillarity, maximum field capacity, volume, comparative soil mass, and porosity, depending on the growing season, the calculated soil moisture for these agricultural plants is established. All this is included in the irrigation management program. Intelligent drip irrigation consists of three parts (Fig.4).
Humidity sensor. First, we will install moisture sensors in the irrigated area. The soil moisture measurement process will begin.

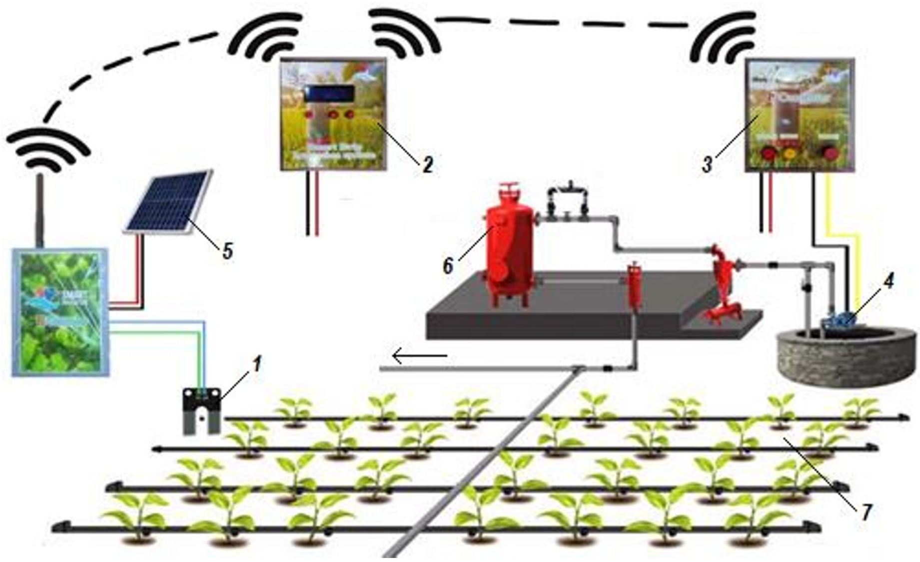

Fig. 4. General scheme of automated drip irrigation system:
1 is humidity sensor; 2 is central part; 3 is pump controller; 4 is pump and water source; 5 is solar panel; 6 is filter drip system; 7 is irrigated field.

The measured data are transmitted online to the central part. At the same time, the humidity sensors are powered by solar panels.

The central part analyzes the data from the moisture sensors and sends online commands to the pump controller when moistening the soil under the crops is necessary.

Pump controller. The pump controller performs the function of turning the pump on and off and controls the water level in the water source. When the water supply drops below a certain level, the pumps automatically shut down and prevent short circuits. The pump controller is subordinate to the central part and executes a command to turn it off or on, depending on the data coming from it.

3.3.1 Development of software and mobile applications for the automation system

The project participants will develop the software and mobile application of the automated system [18]. The software will provide communication and control between soil moisture sensors, turn on and off pumping units, and control elements of the drip irrigation system. The mobile application will allow you to receive information about the operation of the automated drip irrigation system and control the start and stop of the system [20, 21, 22] during the operation of the devices are studied from a scientific and technical point of view.

4 Conclusions

1. The most cost-effective water-saving technology is drip irrigation. Using an intelligent drip irrigation system allows you to:
- saving water resources on an average of up to 40%, additional development of new agricultural lands due to water saving;
- increasing crop yields;
- reducing the cost of irrigation work and the processing of crops;
- organic fuels polluting the environment are not used; clean ecological (solar) energy is used;
- the environment is not polluted, and no waste is generated;
- does not disturb the local population during construction and operation (noise, vibration, smell, dust, the local landscape does not change, etc.).
2. The generated electrical energy of installations using photothermal batteries (PTB) in the summer season will be almost 2 times higher than the energy of photovoltaic batteries (PVB) of a conventional traditional design.
3. The mobility of the photothermal battery system allows it to be used throughout the year.
4. Automation and programming of drip irrigation allows
water crops according to their biological needs, increase yields, save water resources, avoid the negative impact of human factors and save labor.
5. With the use of an integrated drip irrigation system, the income of producers and the population will increase, the living standards of the population will increase, lead to a reduction in poverty of the population, and provide the population with reliable and stable food.

Acknowledgments

This publication has been produced within the framework of the Grant "Automated drip irrigation system for agricultural crops using renewable energy sources", funded under the MUNIS Project, supported by the World Bank and the Government of the Republic of Uzbekistan. The statements do not necessarily reflect the official position of the World Bank and the Government of the Republic of Uzbekistan.

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