Automatic control system of greenhouse soil moisture using solar photoelectric systems research

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Abstract. This research work is devoted to the study of automatic control of soil moisture in the greenhouse using photoelectric systems. In this regard, work continues to modernise existing and develop new designs of heliothermal greenhouses, in particular, energy-efficient greenhouses with transformable enclosure, in which the volume can be changed by transforming the enclosure. The main objective of the research work is to create an efficient way to save energy and water consumption in greenhouses. The use of solar water pump sprinklers in the soil irrigation system inside the greenhouse can reduce water consumption and electricity consumption. A special sprinkler device is used to spray water on the irrigated area to reduce water consumption. The combined sprinkler is an environmentally friendly and economical device used to minimise electricity and water consumption. Improved systems for saving and rational use of electricity and water resources were used in our research work.

1 Introduction

Ensuring the rational use of water, its quality and the safety of water management facilities in our country, as well as reducing water consumption, involve collective (complex) measures to introduce modern innovative accounting systems, along with consistent reforms in the field of groundwater extraction. New structures of water resource management are being created to effectively regulate water use [1].

Water pumps have a significant role in water production and storage. Nowadays, water pumps are widely utilized for water extraction and storage. They find extensive use in pumping water from wells, filtering water bodies and transporting water over long distances. The working principle of the water pump primarily relies on the principle of positive water displacement and kinetic energy [2].

In this regard, work is continuing on modernising existing and developing new heliothermal greenhouse designs, particularly in energy-efficient greenhouses with a transformable enclosure, in which the volume can be changed by transforming the enclosure. The use of solar water pump sprinklers in the soil irrigation system helps minimize water consumption and reduce electricity usage. Sprinklers are utilized to spray water on the irrigation field, thus reducing water consumption. Combined sprinklers are environmentally friendly and economical devices aimed at minimizing electricity and water consumption [3]. The effect of the soil heat field on changes in the air inside the greenhouse was explored in scientific works [4, 5]. Alterations in the air inside the greenhouse directly affect the soil temperature. Soil temperature changes were studied in the upper layers at 5, 10, 15, and 20 cm depths [6]. In scientific research, the impact of soil temperature on the water heating device placed on the soil was also considered. Studies of radiation and thermal engineering calculations of solar greenhouses are considered in [5].

In [6], a thermal model of ground-mounted solar water-heating collectors is developed. To determine them, a non-stationary unit thermal model of solar water heater is proposed, which allows to study the dynamics of heating temperatures of the main elements of SVC (transparent enclosure, receiver, heat-insulating ground bottom).

In the work [7] presented research, the choice of heating system on the basis of calculations of economic efficiency and payback period of alternative systems, solar greenhouse with a transformable enclosure. Depending on the shape of the greenhouse, the total costs, economic efficiency and payback period are determined. The conducted research work shows that the developed greenhouse with transformable (adjustable) body is quite acceptable for its successful use among farmers and private farms in the Republic of Uzbekistan in terms of construction cost and material consumption. Calculation of economic efficiency and payback period of greenhouses with transformable enclosure

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allows to choose the most acceptable heating system and technical characteristics of alternative systems acceptable for climatic conditions.

Scientists from the National Research Institute of Renewable Energy are conducting numerous scientific studies on the development and implementation of energy-efficient water management systems. Our institute's researchers have designed a 6 kW photoelectric module system for replenishing water supply reservoirs for consumers. By implementing this system, the electricity consumption of water supply facilities can be reduced by up to 70%, resulting in high efficiency [8].

The purpose of this research work is to develop an automated system for irrigating crops in a greenhouse, utilizing power from an autonomous photoelectric station, and effectively controlling the water quantity for watering plants while saving electricity.

2 Methods and materials

Electricity is supplied to the automated system through a photovoltaic station (FES). The electricity generated by the photovoltaic plant is used to charge batteries, ensuring the system's operation during the day and providing continuous power supply at night. Moisture sensors are employed to measure soil moisture levels and transmit signals to the control unit. To achieve effective crop irrigation, the soil composition is monitored using a moisture sensor until it reaches the desired moisture level.

According to KMK 2.09.08.07 "Greenhouses and Polytunnels" Table 5, recommended conditions for growing vegetable crops in greenhouses are as follows: cucumbers (autumn turnover) - overcast day, daytime temperature 22-23 °C, nighttime temperature 17-18 °C; tomatoes (winter-spring turnover) - overcast day, daytime temperature 19-20 °C, nighttime temperature 16-17 °C [8,9,10,11].

Such thermal regimes can be widely used on farms engaged in the cultivation of plants or vegetables with the assistance of greenhouses equipped with heating systems.

This system was developed for use in the cultivation of medicinal and valuable plants. One such plant is BLUEBERRY, which has a rich vitamin C content, along with numerous other beneficial vitamins and trace elements [12]. The average price of blueberries, a fruit-bearing bush that grows in northern swamps, is 49,000 soums for a 150-gram package, which translates to approximately 327,000 soums per kilogram. In other words, at the current exchange rate, 1 kilogram is nearly equivalent to 37.6 US dollars. However, its retail price in Ukraine is much cheaper, ranging from 9 to 12 per kilogram [5]. Therefore, there is potential to expand the cultivation of this fruit on a local scale. To achieve this, seeds should be germinated with watering at a soil temperature of 23-25°C and soil moisture levels up to 40%. Maintaining a moderate air temperature and soil moisture is of great importance when caring for seedlings. We propose the following innovative solutions for the reliable utilization of this system.

Variation of soil temperature fluctuation amplitude depending on depth, namely the reduction of soil temperature fluctuation amplitude [13,14,15,16,17], has been studied in scientific works. As a result, it was determined that the influence of the variation of the fluctuation amplitude of the temperature of the soil on the devices located on the upper part of the soil is very small.

Controlling soil moisture in a greenhouse and having an effective irrigation system are of great importance in influencing the crops grown in the greenhouse.

Below is a block diagram of an automated irrigation system based on a photoelectric system in Figure 1.

![Figure 1. Automatic irrigation based on photoelectric modules block diagram of the system.](image-url)
Table 1

<table>
<thead>
<tr>
<th>№</th>
<th>Name of devices</th>
<th>number, piece</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Photoelectric modules</td>
<td>6, 410 W</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1-phase machine</td>
<td>3, 220V/32A</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Inverter (hybrid)</td>
<td>1, 2 kW</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Humidity measuring sensor (XN-M214)</td>
<td>2, 4...20mA, DC 12V, RH 20-90%, RH ±1.3%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Microcontroller</td>
<td>1, Atmega 328</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Limiter (relay)</td>
<td>1, 220V</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Water pump</td>
<td>1, 220V, 50 Nz, 1.5 kW</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Water storage capacity</td>
<td>1, 500 liters</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 below shows the principle diagram of the electronic devices placed in the control panel of the Photoelectric system.

![Figure 2](image)

Figure 2 shows that the FES, the control circuit, and the water pump are connected in series. The elements listed in the control scheme: voltage and current control, data output screen, comparator (microcircuit), inverter, relay block - serve to ensure the continuity of water supply to the irrigated area.

The difference between the control scheme of this automated irrigation system and other similar irrigation systems is that it uses an autonomous photoelectric system, which provides continuous energy and water supply, as well as drip irrigation to achieve energy and water savings of up to 70%. As a result, irrigating crops in the greenhouse with the help of an autonomous photoelectric system that automatically controls soil moisture reduces water wastage and saves electricity, ensuring uninterrupted electricity and water supply.

3 Conclusion

The following conclusions can be drawn based on the conducted scientific research:
1. The use of solar water pump sprinklers in the greenhouse soil irrigation system is employed to minimize water consumption and reduce electricity usage.
2. Integrated (combined) systems, such as sprinklers, are environmentally friendly and cost-effective, serving to minimize both electricity and water consumption.
3. The automated control system, based on a photoelectric plant, effectively ensures the continuity of water supply to the irrigated area.

In summary, this research work has led to the development of an automated system powered by a photoelectric station, taking soil moisture into account for greenhouse crop irrigation. This system allows for the prevention of water wastage, efficient water management during plant irrigation, and electricity savings.

References
1. [https://lex.uz/docs/-4611198](https://lex.uz/docs/-4611198).
12. KMK 2.09.08-97 "Teplitsy i parniki" / Ministry of Construction of the Republic of Uzbekistan - Tashkent, 1997y.