Designing an irrigation system using photovoltaic energy by considering crop type in Fergana Valley

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Abstract. Today, the importance of energy cost and efficiency is gradually increase. The decrease in drinking water and agricultural water resources, increases the interest in drip irrigation systems in agricultural irrigation. Environmentally friendly photovoltaic drip irrigation systems (PVDIS) are the appropriate solution in regions where there is no electricity distribution network, where it is far away, or where power cuts are frequently. This study is carried out in the Fergana Valley of Uzbekistan. Regional climate data obtained from Climwat 2.0 software are processed in Cropwat 8.0 software. Crops that are both the source of livelihood of the people of the region and that can be used in this study have been determined. Annual and daily water needs are analyzed so that these crops are irrigated every seven days. A system is designed by taking the data of the crop with the highest water requirement as a reference. The drip irrigation system is set up in a PVsyst 7.1.7 simulation environment to pump 114.24 m^3 of water daily from a 5-meter-deep river with a 1.8 kW photovoltaic system. The efficiency of the system is 58.7% and the efficiency of the pump is 34.5%. Crop water need is met at the rate of 98.87%. It is predicted that the designed and analyzed PVDIS will provide efficiency in energy and water resources.

1 Introduction

Water is the basic food source for all living things on earth. Two-thirds of our world and our bodies are made up of water. This highlights the importance of water for life. Irrigation is the delivery of the water to the plant roots at the right time and amount. Thus, the water that plants need to go on growing, and which cannot be met naturally is provided [1-3].
From past to present, many methods have been developed to pump water with minimum power consumption. Quite different power sources such as human and animal power, wind energy, solar energy, and fossil fuels have been utilized [4-6].
Some regions of Uzbekistan are in the arid and semi-arid climate zone. Plants grown in these regions do not receive sufficient precipitation. It should be irrigated with the most appropriate method to maximize yield and quality. Also, the population has been increasing rapidly in recent years. In response to the increasing population, enough energy cannot be obtained from existing energy sources. All countries of the world are turning to new strategies to meet their energy needs. This makes it necessary to investigate the use of renewable energy sources [7-9].

Solar energy is one of the most important renewable energy sources. The use of solar energy in agricultural irrigation reduces the total production costs. Irrigation cost has the largest share in production costs. Solar irrigation systems require no daily maintenance and can be easily installed anywhere rich in sunlight. Besides, solar irrigation systems have less negative impact on the environment compared to non-renewable energy sources. Therefore, they are more preferred than non-renewable energy sources [10].

Considering some values related to solar radiation intensity, the variation of the amount of power obtained from the PV water pumping system is investigated [11]. The size, life cycle, and cost of a system that can pump an average of 60 m^3 of water per day in Algeria have been analyzed. It has been evaluated economically [12]. PV installation was used to pump water to the orchards. The design criteria of the system using the drip irrigation technique were determined [13]. The efficiency of the water pumping system directly connected to the DC power generating PV unit is evaluated. An experimental study has been done [14]. In Tunisia, 3000 hours of sunshine duration per year and 6 kWh/m^2 day of solar energy are used for pumping water [15]. An optimization study has been carried out for sizing an AC motor PV irrigation system [16]. Electricity is produced from solar energy based on the PV principle. A centrifugal pump is operated with the generated electricity. With this pump, a solar irrigation system has been developed [17].

In this study, a PVDIS is designed from the river or the lake to the tank. PVDIS design and analysis is made for the Fergana city, located in the Fergana Valley of Uzbekistan. The region, where many crops are grown, has very fertile soils. Agricultural products such as cotton, wheat, and corn, which contribute to the economy of Uzbekistan, are grown in this region. In addition, the local people in this region earn their living from agriculture. For this reason, Fergana Valley is chosen as the pilot region in this study. In the study, a solar energy system with a power of 1.80 kWh is installed. The system has a daily pumping capacity of 114.24 m^3 from the water source, whose depth is estimated to be 5 meters. The design of this system has been done in a simulation environment.

2 Material and Method

2.1 Land Parameters

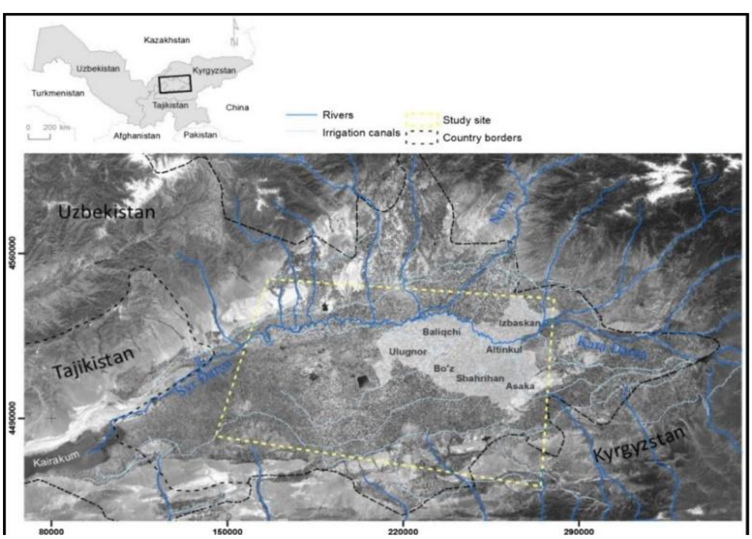


Fig. 1. Location map of the research area

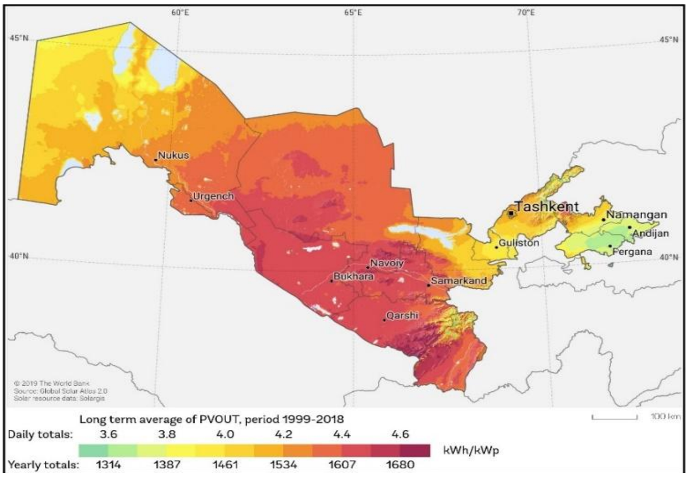
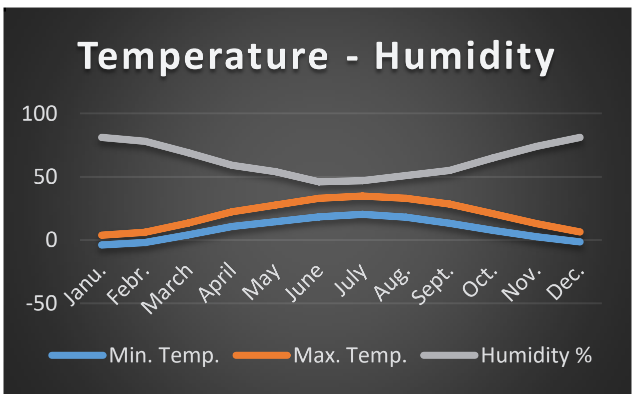
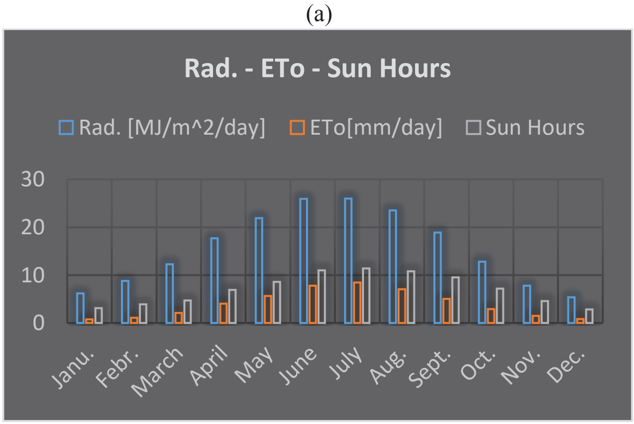


Fig. 2. Photovoltaic power potential Uzbekistan



(a)



(b)

Fig. 3. Fergana valley (a) Temperature and Humidity (b) Radiation, ETo ve Sun hours

Solar energy is an important factor in reducing farmer costs and increasing crop yields. With the designed photovoltaic irrigation system, the cost of crop irrigation is significantly reduced. In this study, the design and analysis of a river-to-tank photovoltaic drip irrigation system for the Fergana Valley of Uzbekistan are carried out. Fergana valley is in the southeast of Uzbekistan. It is located between two mountains, Tien Shan in the north and

Alai in the south [18]. In Fig. 1 [19], the study area and the irrigation resources of the region are shown. The region is rich in terms of rivers and irrigation channels. For this reason, it has an infrastructure compatible with PVDIS.

The climate of the region is continental. The average annual precipitation is between 100- and 200-mm. Potential evapotranspiration occurs up to 1300 mm [20]. Fig. 2 shows the photovoltaic power potential of Uzbekistan. In the figure, the photovoltaic power potential of the regions increases as one move towards the dark red color. Fergana Valley is below the country average in terms of photovoltaic power potential. However, this region is preferred for the study because of the high agricultural crop potential of the region. Majority of the people earn their living from agriculture. The irrigation canals in the region and the river structure are suitable for agricultural irrigation. It is predicted that the efficiency of PVDIS will be higher in regions with the high photovoltaic power potential of Uzbekistan.

Fig. 3 shows the climatic data of the Fergana valley. In June, humidity is the lowest level with an average value of 46%. In January and December, the humidity the highest level with an average value of 81%. The average temperature in the valley is the lowest in January with 3.9°C. It is the highest level with 34.7°C in July. While the sunshine duration is the highest with 11.4 hours in July, it has the lowest value with 2.8 hours in January.

2.2 Irrigation System Components and Simulation Environment

The climate data of the region determined in this study are obtained from the CLIMWAT 2.0 software. Climwatt 2.0 software has climate data stations at certain points around the world. The data obtained from the station of this software located in the Fergana region at the coordinates Latitude: 40.36°N, Longitude: 71.75°E are defined to the CROPWAT 8.0 software. Thus, the water needs of cotton, winter wheat, and corn produced in the region are determined. The most suitable software to determine the irrigation water requirement of any plant in any region is CROPWAT 8.0 [21].

The CROPWAT model is an irrigation management model. It determines the water requirements and irrigation needs of the crop. In this model, the potential evaporation (ETo) parameter is used. Potential evaporation (ETo) is estimated using crop parameters and the Penman-Monteith equation.

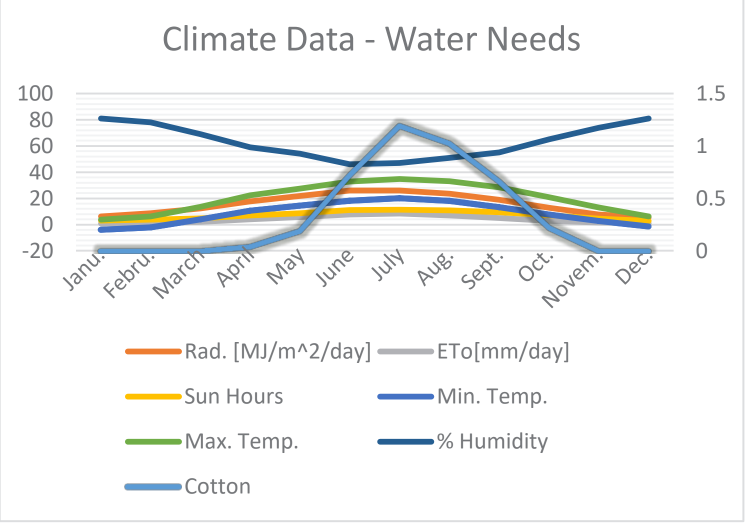


Fig. 4. The relationship between climate data and cotton water need

Table 1. System data

Parameter	Characteristic	Parameter	Characteristic
Design location	Uzbekistan-Fergana Latitude:40.38° Longitude:71.78°	Pipe	DN100
Altitude	585 meter	Water needs	114.24 m^3/day
System type	Lake or river to storage	Pump	Generic PS1200 SJ12-3
Tilt	33°	Power conditioning unit	MPPT-DC Converter
Azimuth	-3°	PV module	Generic Aleo S-59/300
Meteo data	Meteonorm 7.3	PV module in series	2
Pump level	-7 meter	PV nodule in parallel	3
Lake level	-5 meter	Module area	10 m^2
Storage tank	600 m^3	Total modules power	1,80 kWp
Number of elbows	4	Total PV P_{MPP}	1.635 kWp
Other friction losses	5 %	Water pumping (year)	41226 m^3

The solar power system is designed in the Pvsyst 7.1.7 simulation environment. The data of the cotton is used when determining the amount of water to be pumped into the land. Because the crop with the highest water requirement is cotton. The values of the month when cotton needs the most water determined the system capacity. The water requirement of cotton is given in Fig. 4. It is clearly seen that cotton needs the most water in July. In this month, the water requirement of cotton reaches 1.19 liters/second/ha. The parameters used in the Pvsyst 7.1.7 simulation environment are summarized in Table 1.

4 Results and Discussion

System efficiency and pump efficiency were calculated 58.7% and 34.5% respectively. The values found are low in terms of performance. Although these values seem low in terms of performance, in fact, while the tank capacity was calculated as 571.2 m^3, it was ignored due to the force of the actual conditions, such as it designed as 600 m^3.
The design of the irrigation system is done in the PVsyst 7.1.7 simulation environment. There is no pump with optimum values for every system designed in a simulation environment. In this case, the optimum pump possible in the simulation environment is selected. Generic brand PS1200 SJ12-3 water pump with 1.2 kW power is selected.

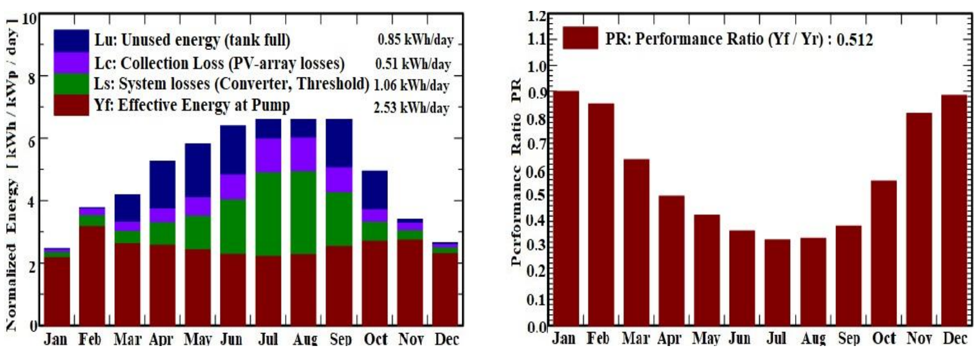


Fig. 5. Energy flow and performance ratio

5 Conclusions

In the design, a maximum PV power of 1.80 kW and a 1.2 kW pumped 41226 m^3 of water annually to the tank. In the months when the amount of sunshine duration and radiation increased, energy production exceeded the desired level. Unused energy is wasted. This has reduced the efficiency and performance ratio. Therefore, in real practice, the photovoltaic system design should be done with the optimum value pump. In the months when the sunshine duration and the amount of radiation decreased, the energy produced approximately met the water need. For this reason, the efficiency and performance ratio of the system has increased. Since the most important purpose here is to meet the water need, the decrease in yield is negligible. The system met the water needs of the crops at a rate of 98.87%. Choosing a large tank prevents energy loss. In addition, if the photovoltaic drip irrigation system is connected to the electricity distribution network, energy can be transferred from the system to the grid. Thus, efficiency can be increased.

6 References

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