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Investigating the Installation of Solar Panels in Reducing the Evaporation of Canal Water

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Abstract

The simultaneous use of the solar panel system on water tanks and canals is a novel and efficient process in today's hydrology due to its many benefits. The positive and effective effects of this method, especially in hot and dry areas around the world, have increased. Minab region in Hormozgan province has become the southern agricultural pole of Iran, due to the presence of the Esteghlal Dam basin, and with off-season crops in this region, it has met many of the country's needs in agricultural products. In the past few years, due to the decrease in rainfall and successive droughts, the supply of sustainable water for the gardens of this city has become one of the most important challenges. Based on this, to reduce the effect of solar radiation on the water passing through the irrigation canal of Minab city, the simulation of the installation of solar panels on this 8 km long canal has been done by PVSol 2021 software, and the simulation results conducted by the research team show with a coverage factor of about 60% of the length of the canal by these panels, about 5 MW of electricity can be obtained from this renewable source. The great point in this simulation is the 0.78 performance ratio of this power plant, which shows suitable output compared to similar cases. In addition, based on the calculations, the installation of panels with the effect of shading prevents the wastage and evaporation of more than 6000 cubic meters of water in the canal.

Keywords: Evaporation, PVSol, Renewable Power Plant, Solar Energy, Sustainable Electricity.

1. Introduction

Water, energy, and food are the basic needs and challenges of people's advancement in other places. Population growth and unbalanced development have increased these needs along with the development of countries and the need for a sustainable energy supply, the use of non-renewable energy sources has led to an increase in greenhouse gas emissions. Solar canals are photovoltaic[1] solar energy generating systems based on covering the top of water bodies, namely water canals with PV panels. Unlike land-based PV systems, this PV system does not occupy large land areas, which will save on land for the high demands of the increase in population. The simultaneous use of solar panels with other technologies has a very wide scope.

Clot et al., investigated the possibility to use PV modules submerged in water or simply covered by a water veil suggesting the possibility to use this renewable energy source[2] integrated with swimming pools or with decorative pools and fountains. Submerged PV plants are suggested as a solution with minimal environmental impact, as they avoid or reduce the cleaning problem and increase efficiency owing to the elimination of the thermal drift effect. Solar heating

[1] Photovoltaic (PV)

[2] Renewable Energy Source (RES)

together with electrical energy production coming from PV effects can be naturally coupled to water basins such as swimming pools, fountains, etc. The possibility to capture solar radiation efficiently to produce both electric power and heat are proved in several tests already done and documented in the research (Clot et al., 2017).

Kobougias et al., considerations are held about the specifications which the PV plants have to fulfill so that they can be installed on ships. The resulting restrictions are the parameters that define not only the type of solar cells but also the applied PV system technology which refers to the interconnections Types between panels and converters (Kobougias et al., 2013).

The use of solar panels on the roof of agricultural greenhouses and the use of their energy production has increased significantly in developing countries. In some research, the covering shading factor of these panels and the water piping system passing by them in the roof of the greenhouse to irrigate and cool the temperature of the solar panel have had an important effect on increasing the efficiency of energy production and harvesting agricultural products (Amaducci et al., 2018; Beck et al., 2012).

One of the challenges is associated with the sustainable use of land resources. Floating PV[1] plants on water bodies such as a dam, reservoirs, canals, etc. are being increasingly developed worldwide as a choice. FPV is a rapidly emerging technology that provides an alternative to ground-mounted PV[2], particularly where land is scarce or expensive. Despite impressive technological development and growth in installed capacity in recent years. Kjeldstad et al., provide insight concerning the operation, validation, and operational characteristics of a new FPV technology to identify innovation opportunities, decrease risks, develop improved solutions, and improve the bankability of FPV. They found that the technology gives an annual sustained total performance and that the period of amphibious operation did not impact the continued efficiency of the system. Calculations give a median U-value of 33 W/m^2K, slightly higher than the default PVsyst value of 29 W/m^2K for freestanding GPV systems (Kjeldstad et al., 2022).

Electricity production through the PV result is considered a desire in South Sumatra as a response to the government policy to increase the utilization of renewable energy to support the depletion of conventional energy. Sasmanto et al examined the eligibility analysis for the installation of PV panels on brackish water. This experiment showed that electricity produced by floating PV panels is an average of 11.89 W higher, and the efficiency is 4% higher than that of ground installation. This experiment also shows that PV panels can be installed over brackish water in the fishing village of Sungsang Estuary (Sasmanto and Dewi, 2020).

Lee et al., present the result of investigations into the expansion of a floating-type photovoltaic energy production system. Moreover, the energy production of a floating PV energy generation system is measured and compared with that of a land-type plant. Energy productions of the floating type from June to August are significantly higher, but the energy productions from September to October are lower (Lee et al., 2014). A novel energy production system that has fascinated wide consideration because of its several benefits that are called floating photovoltaic technology[3] (Yousuf et al., 2020).

Kumar and Kumar, investigated That canal-top PV systems have different environmental conditions than the land-based system which may affect their performance and degradation rate. The objective of this study is to assess the suitability of PV systems on the canals for their large-scale installations and reliable operation. To understand the long-term performance behavior of the PV systems on the canals, the performance and degradation analysis of the world's first commercial multi-crystalline silicon (Multi-Si) based 10 MWp canal-top PV system installed in the Indian state of Gujarat has been carried out for their initial 2 years 8 months operation. Experimental comparison of water tank-based PV modules and land-based PV module shows that the average performance ratio of Multi-Si module on the water surface is about 1.5% lower compared to land-based Multi-Si module which is contrary to the general perception of higher power production by the Multi-Si PV systems on the canals (Kumar and Kumar, 2019).

In this situation, the best way to prevent the challenging situation in this plan continues to use the available water resources optimally, in such a way that this process does not cause social dissatisfaction with sudden changes. The high evaporation of the water in this canal, as well as incidents such as children drowning in these canals, is the main challenge of this water supply system. There is a canal with a length of about 8 kilometers from the entrance of Minab city to the gardens on Tiab road, which is about 8 meters wide and 2 meters deep, and a very large volume of water is flowing (Fig. 1). The main challenge regarding this irrigation canal is the amount of water evaporation from the surface of the canals. Also, due to the lack of proper coverage on the canal and safety protection around it, humans and animals have fallen in some cases in this canal. The first challenge regarding the installation of these panels is their productivity and performance in the climatic conditions of Hormozgan province, research have shown that the efficiency of solar panels and the electricity produced from them have performed well and performance in this in addition to the technical approach, the regions also have an economic approach (Zarezadeh, 2023; Zahedi et al., 2023).

The researchers of this research aim to investigate the amount of water evaporation in the canal by placing solar panels on the canal. Today, the dual use of solar panels increases the productivity of processes and is considered a new and up-to-date method in advanced countries. This research had limitations. The first limitation is the lack of

[1] Floating Photovoltaic (FPV)

[2] Ground-Mounted Photovoltaic (GPV)

[3] Floating Photovoltaic Technology (FPVT)

Fig. 1. The area of the irrigation canal from the beginning of Esteghlal Dam to the gardens around Tiab Road (green line: Rural Route, Blue Line: Urban Route)

information about the DEM of the study area, which is important to investigate the shading effect. Another limitation is the wide range of the studied area, which is used for simulation in the software and because of its high graphics, the software mostly crashes. Also, there is no similar field research in Iran to investigate the cases and compare the simulation data with the field data.

2. Methodology

In this research, after studying similar articles and experiences and collecting the required data from references, field data such as water flow rate, digital elevation model of the studied area, and a survey of the canal and its route have been obtained. The studied area is the outlet irrigation canal of Esteghlal Minab Dam, which enters the gardens and groves after passing through the city. Based on the field data collected and digitized in ArcGIS software, a UTM[1] map has been prepared. Having information about the region's climate and weather conditions are the main issue for the feasibility of solar panel installation. This issue is the first condition in the upcoming research. These data are obtained from the appropriate database.

Choosing the right software for simulation is the next step. At first, based in the limitations in the simulation process, such as environmental conditions, the dimensions of the panels that can be installed on the irrigation canal, the compatibility of the panel and the inverter with the simulation conditions, etc., the process implementation framework is determined. According to the conditions and technical requirements as well as the required graphics, the appropriate software is selected.

Finally, the effects of installing solar panels on the amount of energy produced as well as the effect on reducing the evaporation of water from the canal are obtained by using calculation relationships. Based on different research and hydrological sources of open irrigation canals, the obtained evaporation rate is estimated and may differ from the actual values. Fig. 2 shows the procedure for conducting advanced research.

2.1. Monitoring the field conditions of the canal, hydrology, and climate of the location

The length of this canal is about 8 kilometers, and 6 kilometers of it are in the urban and administrative areas by passing by the side of the street, they enter the groves and gardens. Based in the field data obtained and digitized in ArcGIS software, the total length of the irrigation canal is 2160 meters with a south-north direction, and the rest of the sections are east-west. The width of this irrigation canal in most of the way is about 8 meters, and the water depth is 2 meters with the maximum flow rate of the northern water supply irrigation canal: 9.6 cubic meters per second.

Considering the need for 1 meter from each side of the canal bank, the entire route was examined for the

[1] Universal Transverse Mercator (UTM)

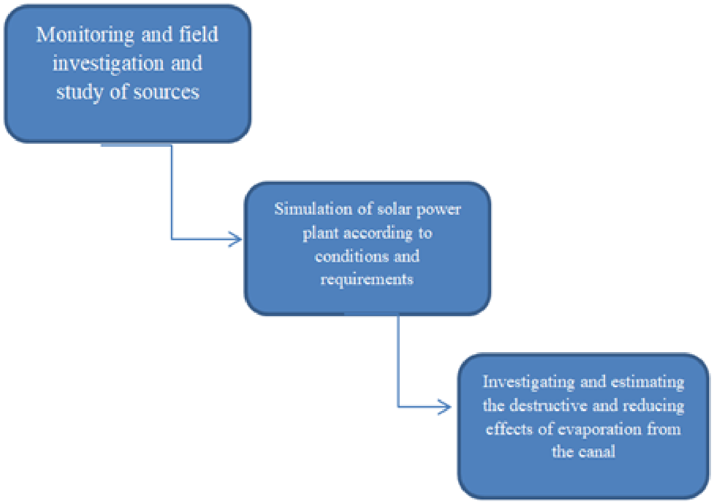

Fig. 2. The procedure for conducting advanced research

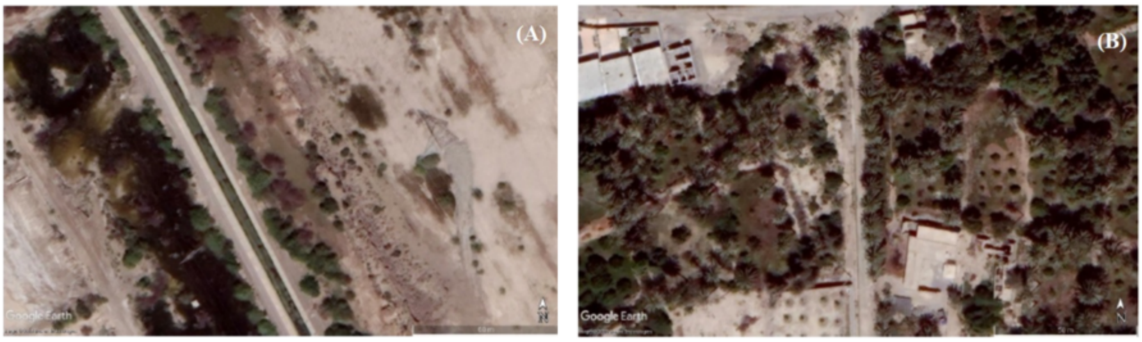

Fig. 3. View of the canal route in A) the urban part and B) the rural part

Table 1. Environmental conditions of the area under investigation

	GolbHor (KWh/m^2)	DiffHor (KWh/m^2)	T_amb (^oC)	Globinc (KWh/m^2)	GlobEff (KWh/m^2)
January	128.6	32.2	17.5	183.7	172.4
February	123.9	54.6	19.5	154.3	142.1
March	160.3	79.4	23.2	178.0	160.4
April	185.2	82.3	27.4	188.8	170.3
May	216.2	91.1	32.0	202.7	184.2
June	215.6	95.4	33.9	195.5	177.5
July	207.2	103.5	35.0	191.7	174.2
August	192.6	97.3	34.4	190.0	172.3
September	175.8	73.6	32.1	191.2	171.8
October	164.8	50.2	29.7	203.5	183.0
November	131.4	35.1	23.7	182.4	169.1
December	120.4	30.1	19.2	178.1	162.6
Year	2022.2	824.9	27.4	2202.2	2039.8

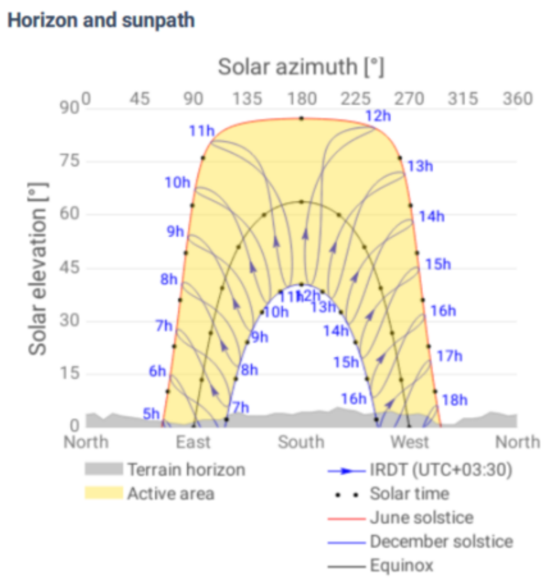

Fig. 4. The annual sun path in the study position To install photovoltaic power plant equipment

installation of the infrastructure structure for placing solar panels on it. It is possible to install in the entire route. Of course, the part of the canal route that is in the rural part becomes complicated and winding, and in that part, the installation of little infrastructure is possible (Fig. 3).

To study the climatic conditions of the region and the amount of radiation in the studied location, these data were obtained from international databases (Table 1).

The weather conditions and climate of the region are hot and dry with little rainfall. Based on the data obtained from climatological sources and databases, the amount of radiation in the area is suitable for installing solar panels. The relative position of the sun is an important factor in the thermal efficiency of buildings and the performance of solar energy systems. Knowledge of the exact local location of the sun's path and climatic conditions are necessary for economic decisions about the area of solar collectors, orientation, landscaping, and shading in the summer, and the economical use of solar collectors. A thorough knowledge of the Sun's path is essential for modeling and computationally predicting the efficiency of the annual solar system. The graph of the sun's path in the studied location also shows the appropriate output data (Fig. 4). The amount of radiation per year in the study area is acceptable. The average annual temperature is 27 degrees Celsius, which is a suitable value for the optimal operation of the panels.

2.2. Simulation of installation a solar panel on canal water

There is different software for simulating the installation of panels on the irrigation canal, but due to the high three-dimensional capability of PVSOL software as well as the suitable graphics of this software, this software has been used to continue the simulation process and obtain the output. To simulate the areas that the canal passes through, it is divided into three separate areas. Part 1 includes the south-north region of the water irrigation canal exit from the great source, part 2 of the east-west region of the canal that passes water through urban areas, and part 3 of a regions with a mixed south-north and east-west location, and a spiral path, which transports canal water to gardens and groves (Table 2). The monitoring of the reference ground images and the UTM map of the investigated location have shown that most of the canal's routes are east-west. Determining the direction of the canal in the orientation of the installed panels is very important to the latitude of the position and the azimuth angle.

PVSol Perimum 2021 software was used for the simulation. Due to the large dimensions of the simulation area, to better implement the software and also graphical validation of the process, the simulation has been performed in three separate sections according to the geographical location stated in the previous section. The total area of the installation of equipment and simulation is 500,000 square meters, and therefore its full implementation is time-consuming and with continuous interruptions, and its high graphics in the 3D simulation will cause problems.

Section 1, due to its orientation, in the simulation, the panels were placed in two rows and at an angle of 24 degrees to the south. In section 2, the canal's direction is towards the west, and therefore, the type of installation is considered to be delta-shaped and with an angle of 10 degrees. In section 3, due to the roughness of the canal route and its complexity, the simulation was done in several sections. It is worth mentioning that there is no shading problem in sections 1 and 2 due to the distance of the canal, but in section 3 due to passing through the groves and gardens, as well as the wall next to this garden, the shading problem has been concretely observed and included in the calculations. Table 3 shows the number of panels and inverters installed in the simulation, along the water irrigation canal, and in three sections separately. As expected, Section 2 has the highest number of solar panels installed in that route due to the high length of the route and the orientation of the delta wing.

The technical specifications are determined according to the relevant requirements and standards and the type of distribution of panels on the irrigation canal (Tables 4 and 5). Based on the simulation and according to the location of the track and the irrigation canal, the coverage factor of the irrigation canal by the panels is 60%, which is placed at an angle of 24 degrees to the south (Fig. 5).

The high temperature of the region, especially in summer, can have a bad effect on the performance of solar panel systems. One of the recommended methods to reduce the bad effect of temperature is to use cooling systems (Oliveira-Pinto and Stokkermans, 2020; Dahlen, 2018). The water flowing in the irrigation canal under

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Table 2. The location and dimensions of the water canals

	Latitude of initial point	Latitude of final point	Longitude of initial point	Longitude of final point	The length of the route(m)	Direction
Part1	27.164N	27.180N	57.091E	57.078E	2160	North-South
Part2	27.180N	27.173N	57.078E	57.042E	3900	East-West
Part3	27.173N	27.170N	57.042E	57.026E	2050	Combinatorial

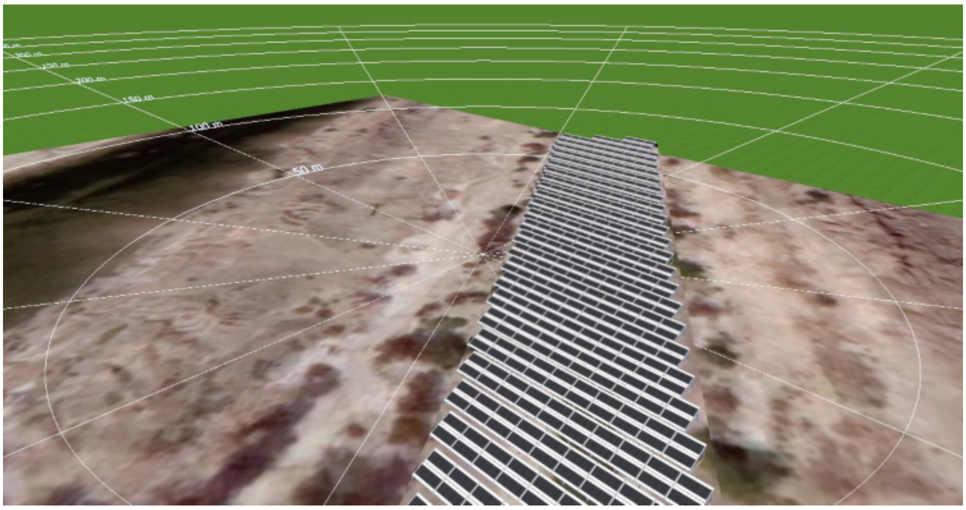

Fig. 5. A view of the simulation done and the orientation of the panels on the irrigation canal

Table 3. The number of panels and inverter installed

	Number of panels	Number of inverters	Area of installation area of panels and structure (m^2)	Type of electricity produced
Part1	5042	9	150000	3-phase
Part2	9853	12	260000	3-phase
Part3	2541	5	87000	3-phase

Table 4. Features of the solar panel used in the research at STC

Irradiance in W/m^2	665
MPP Voltage in V	40.2
MPP Current in A	17.5
Open Circuit Voltage in V	46
Short-Circuit Current in A	18.2
Fill Factor in %	83.02
Relative Efficiency in %	97.19
Width in mm	1303
Height in mm	2384
Surface in m^2	2.92
Depth in mm	35
Output coefficient in %K	0.036
Maximum System Voltage in V	1500
Incident Angle Modifier (IAM) in %	98

Table 5. Features of the inverter used in the research at STC

DC nominal output in kW	50
Max DC Power in kW	66
Nom DC Voltage in V	860
Max Input Voltage in V	1100
Max Input Current in A	90
AC Power Rating in kW	50
Max AC Power in kVA	50
Number of Phases	3

the solar panels is one of the best naturals cooling systems.

Important and influential factors in the performance of solar panels include sunlight, temperature, the direction of the panels, and shading. It is worth mentioning that the performance of solar cells in an ideal state increases logarithmically with radiation, but in practice, the presence of series resistance in the panels limits their performance. Conversely, increasing temperature decreases the efficiency of solar panels. The use of trapezoidal panels that are placed on sections of water irrigation canals is usually used to transfer water for irrigation, industrial, and domestic purposes (Dahlen, 2018).

2.3. Investigation the effect of instlling panels on reducing water evaporation

One of the main goals of this investigation was to ascertain the decrease in water evaporation in the canal due to placing solar panels on that. Considering that in the fluid mechanics of open irrigation canals, most calculation methods are based on experimental estimates, this section has been done using the references and results of past research.

Based on the empirical relationship (1), the amount of water evaporated in open irrigation canals is obtained (Augustin et al., 2016)

$$E = 4.57T + 43.3 \quad (1)$$

Where

E is the rate of evaporation in (mm/year), and T is the average annual temperature of the region in ^oC. The presence of water under the canal makes its temperature moderate and prevents its significant increase. Since fish and other similar organisms do not generally live in irrigation canals, the presence of panels and their shading on the surface of the canal does not cause any environmental damage or danger for these types of organisms (Augustin et al., 2016). The most important factors affecting the evaporation of canal surface water are GDI, DHI, air temperature, relative humidity, and wind speed. It is used by using empirical relationships (Augustin et al., 2016)

$$E = 0.403nD^{0.73} (1+0.39V) \quad (2)$$

Where

E is the evaporation from the water level of the canal in mm, n is the number of days in the month, V is the wind speed in m/s, and D is the lack of saturated air, which is obtained from the following equation

$$D = 0.0632 (100- R_h)e^{0.0632(Ta)} \quad (3)$$

Where

Rh is the relative humidity in percent, and Ta is the temperature in Celsius. Evaporation is converted to water lost per unit area. The changes in lost water in the daily time scale are obtained by the following relationship

$$W_L = (E \times A) \times 100\% \quad (4)$$

Where

A is the cross-section of the canal. The total monthly water loss is obtained. Hydrological conditions include volume flow rate, water speed, atmospheric pressure, and wind speed (Augustin et al., 2016). With the increase of the irrigation canal coverage by photovoltaic panels, the quality of the water in the irrigation canal changes. Since part of the radiation that hits the solar panels is caused by the return of direct radiation from the water surface, which depends on the angle of the incident radiation, the value of the albedo coefficient varies from 0.05 to 0.22, but generally, the amount of the coefficient The average albedo in this water irrigation canal is around 0.08 (Dahlen, 2018). All data relating to the region's climate, including wind speed, temperature, relative humidity, etc., were obtained from the Meteorological Organization station of Minab city.

3. Results and discussion

The average monthly direct radiation in the region shows the appropriate amount of this radiation for installing solar panels. Based on this estimate, the maximum amount of radiation is in June, May, and October (Fig. 6).

Based on the results of the research, the climate of the region and the amount of direct radiation are suitable conditions for installing solar panels. The region has suitable radiation and very low cloudiness and based on the results, more than 8 months of the year, about 10 hours of sunlight shines on the earth's surface. The dust in the area is also low, and this issue will increase the efficiency of the system (Fig. 7).

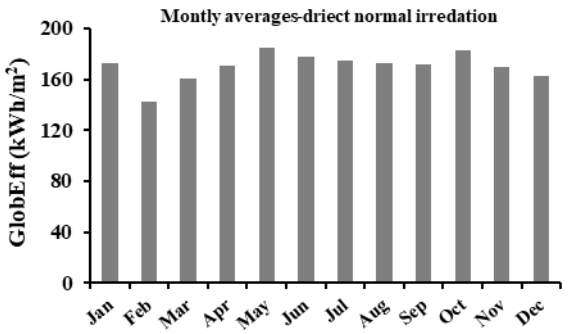

Fig. 6. Monthly average direct normal irradiation in location of canals

The output results of modeling with PVSOL have shown that, since the amount of shading is very low in sections 1 and 2, the performance output is suitable and around 0.7. But in section 3, due to the presence of grove walls, and trees with a height of more than 4 meters, the efficiency of the panels is very low (Table 6).

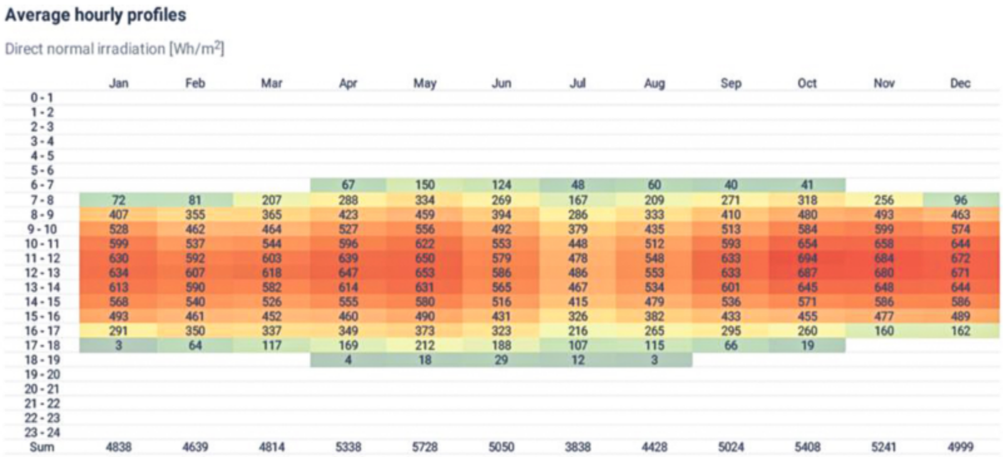

Fig. 7. Average direct radiation in the location of the case study

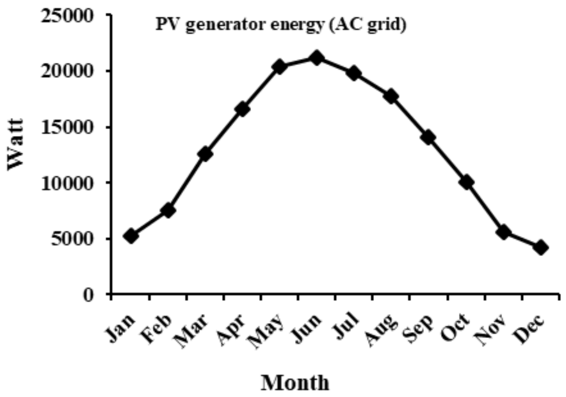

Fig. 8. Monthly energy production

Table 6. Simulation output in different irrigation canals

	PV power (KW_p)	Performance ratio (%)	Reduced productivity due to shading (%/year)
Part1	5050.3	78.9	3.6
Part2	273.2	76.1	7.8
Part3	108.4	42.4	33.2

The monthly estimate of the amount of energy produced from solar panels has shown that the highest amount of solar energy is produced in May, June, and July (Fig. 8).

The performance ratio is an important factor that indicates the efficiency of solar panels. Based on this, the climatic conditions and the arrangement of solar panels in the Minab region have shown that the performance ratio is always more than 78% for all months of the year and 80% in 9 months of the year, which is an acceptable value for the efficiency of solar panels and is considered optimal (Fig. 9).

The simulation performed was such that about 60% of the surface of the irrigation canal is covered by solar panels. Based on this and this level of coverage, the amount of evaporation of water passing through the canal has been estimated. According to the climatic data of the region, and based on relations 1 to 4, the estimation of annual evaporation in terms of mm/year is presented in Table 7. These results are related to the last

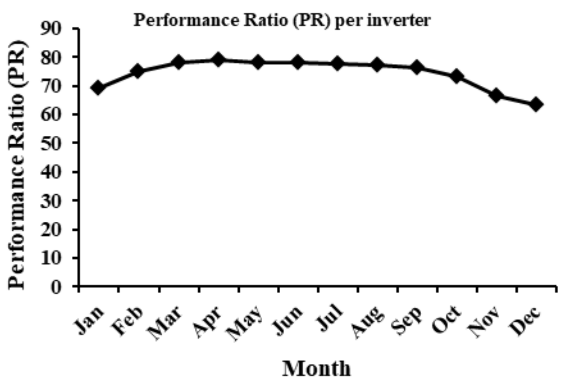

Fig. 9. Monthly performance ratio in Minab

Table 7. Simulation output in different irrigation canals

	Year	Average of temperature (^oC)	Average of evaporation (mm/year)
1	2017	29.19	176.74
2	2018	30.07	180.73
3	2019	28.54	173.74
4	2020	27.97	171.12
5	2021	19.67	133.22

Table 8. Comparison of the simulation output with the field research of other researches

No.	Reseacher group	Location of reseach	Year	Evaporation reduction rate obtained in research with field data (in %)	The difference between field data and simulation data (in %)
1	(Youssef and Khodzinskaya, 2019)	India	2019	40%	0
2	(Shalaby et al., 2021)	Saudi Arabia	2021	43.8%	+3.8%
3	(Abdelal, 2021)	Jordan	2021	50%	+10%
4	(McKuin et al., 2021)	USA	2021	47%	+7%

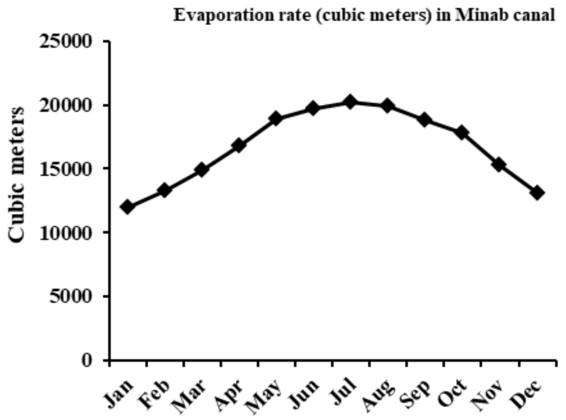

Fig. 10. Monthly evaporation rate in Minab

5 years.

According to the dimensions of the canal and its length, and the average annual evaporation, based on relations 1 and 4, it can be said that about 6000 cubic meters of water in this canal are wasted annually through evaporation alone. The results of similar studies have shown that placing the panels on the irrigation canal has a significant effect in reducing this amount of evaporation. In addition to the fact that the passage of the irrigation canal under the structure of these panels will lead to a decrease in the temperature of the panels and as a result improve the performance and output power of the panels (Govardhanan et al., 2020; Oliveira-Pinto and Stokkermans, 2020). Based on field research and comparison between solar panels installed on canal systems or ponds with systems installed on the ground in the same climatic conditions, it has been shown that the efficiency of solar panels installed on the irrigation canal has improved the performance and increased the performance of those panels by 8-10% due to proper air conditioning (Oliveira-Pinto and Stokkermans, 2020).

The rate of water evaporation from the water channels of the study area varies according to the climatic conditions and ambient temperature in different months of the year (Fig. 10). As a result of placing solar panels on these canals and the effect of shading, the monthly temperature of the fluid under the panel is 3 to 7 degrees lower than the surrounding environment in different months, and this will reduce the effect of evaporation. In addition, the installation of solar panels prevents the wind from passing over the surface of the water, which has a significant effect on the evaporation rate of the canal water. Based on this, as a result of installing solar panels on the channel at a suitable distance, the amount of evaporation will be significantly reduced.

Comparing the simulation results and evaporation calculations with other research shows the appropriate compatibility of the results of this research. The best way to compare the output data of calculations is to compare them with the field data of other researchers. This comparison is presented in Table 8 and it all shows a small difference between the evaporation measurement data and the simulation data. Based on the results of the research and evaporation calculations, the effect of installing solar panels leads to a 40% reduction in the evaporation of canal water. Comparing this number with 4 up-to-date research in different places and other countries shows the appropriate adaptation of this simulation with field data.

4. Conclusion

Since the simulation results in parts 1 and 2, the irrigation canals show proper performance, installing solar panels in this section is economical. However, in section 3, which are the area where the canal passes through the groves, the installation of these panels is not optimal from a technical and economic point of view, due to a significant decrease in output power performance due to the large shading coefficient. The appropriate and optimal output of these panels in parts 1 and 2 of irrigation canals will lead to the creation of sustainable renewable energy and the amount of 5 MW of energy compared to similar power plants is a very appropriate and optimal amount, which in addition to supplying a part of the region's electricity and reducing Pollution will also have a good economic advantage. The installation of these solar panels, in addition to generating energy, will solve several important challenges for these irrigation canals, which include preventing the excessive evaporation of water passing through the canal due to the climatic conditions of the region and also with the covering on the canal, and the surrounding walls are placed, it will reduce the risk of people falling to a great extent. Of course, field investigation and monitoring of the effects of installing solar panels on water quality and the number of materials in it is one of the essential requirements that must be done before any action to ensure that this process does not hurt the environment.

For calculation of the decreasing of harmful greenhouse gases effects, the amount of energy produced by the 5 MW power plant is obtained and compared with the amount of fuel consumed in other non-renewable power plants with 5 MW. The reduction of greenhouse gas effect by replacing the simulated power plants in this research with other types of non-renewable power plants with similar capacity is about 3,900 tons. According to the guaranteed purchase price of renewable electricity, the electricity budget produced by the 5 MW photovoltaic power plants can be calculated by multiplying the electricity produced and the amount of money saved due to the construction and operation of this power plant.

5. Acknowledgment
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References

Abdelal, Q. 2021. Floating PV; an assessment of water quality and evaporation reduction in semi-arid regions. *International Journal of Low-Carbon Technologies*, 16**,** 732-739.

Amaducci, S., Yin, X. & Colauzzi, M. 2018. Agrivoltaic systems to optimise land use for electric energy production. *Applied Energy*, 220**,** 545-561.

Augustin, D., Chacko, R. & Jacob, J. 2016. Canal top solar energy harvesting using reflectors, *GRD*, 1**,** 26-31.

Beck, M., Bopp, G., Goetzberger, A., Obergfell, T., Reise, C. & Schindele, S. 2012. Combining PV and food crops to agrophotovoltaic-optimization of orientation and harvest. *In Proceedings of the 27th European Photovoltaic Solar Energy Conference and Exhibition,* EU PVSEC, Frankfurt, Germany, 24.

Clot, M. R., Rosa-Clot, P. & Tina, G. M. 2017. Submerged PV solar panel for swimming pools: SP3. *Energy Procedia*, 134**,** 567-576.

Dahlen, S. 2018. The Future of Solar Energy in Marine Applications. MSc. Thesis, UiT The Arctic University of Norway.

Govardhanan, M. S., Kumaraguruparan, G., Kameswari, M., Saravanan, R., Vivar, M. & Srithar, K. 2020. Photovoltaic module with uniform water flow on top surface. *International Journal of Photoenergy*, 2020**,** 1-9.

Kjeldstad, T., Nysted, V. S., Kumar, M., Oliveira-Pinto, S., Otnes, G., Lindholm, D., et al. 2022. The performance and amphibious operation potential of a new floating photovoltaic technology. *Solar Energy*, 239**,** 242-251.

Kobougias, I., Tatakis, E. & Prousalidis, J. 2013. PV systems installed in marine vessels: technologies and specifications. *Advances in Power Electronics*, 2013**,** 831560.

Kumar, M. & Kumar, A. 2019. Experimental validation of performance and degradation study of canal-top photovoltaic system. *Applied Energy*, 243**,** 102-118.

Lee, Y. G., Joo, H. J. & Yoon, S. J. 2014. Design and installation of floating type photovoltaic energy generation system using FRP members. *Solar Energy*, 108**,** 13-27.

McKuin, B., Zumkehr, A., Ta, J., Bales, R., Viers, J. H., Pathak, T., et al. 2021. Energy and water co-benefits from covering canals with solar panels. *Nature Sustainability*, 4**,** 609-617.

Oliveira-Pinto, S. & Stokkermans, J. 2020. Marine floating solar plants: an overview of potential, challenges and feasibility. *Proceedings of the Institution of Civil Engineers - Maritime Engineering*, 173**,** 120-135.

Sasmanto, A. A. & Dewi. T. 2020. Eligibility study on floating solar panel installation over brackish water in Sungsang, South Sumatra. *EMITTER International Journal of Engineering Technology*, 8(1), 240-255.

Shalaby, M. M., Nassar, I. N. & Abdallah, A. M. 2021. Effect of continuous and modular floating covers on evaporation losses and microalgal growth. *Journal of King Saud University - Engineering Sciences*. 1-9. (In Press)

Youssef, Y. W. & Khodzinskaya, A. 2019. A review of evaporation reduction methods from water surfaces. *E3S Web of Conferences*, Moscow, Russia. 97, 05044.

Yousuf, H., Khokhar, M. Q., Zahid, M. A., Kim, J., Kim, Y., Cho, E. C., et al. 2020. A review on floating photovoltaic technology (FPVT). *Current Photovoltaic Research*, 8, 67-78.

Zahedi, R., Sadeghitabar, E. & Ahmadi, A. 2023. Solar energy potential assessment for electricity generation on the south-eastern coast of Iran. *Future Energy*, 2(1), 15-22.

Zarezadeh, M. 2023. Feasibility construction of a 4 MW PV power plant to provide sustainable electricity to Bandar Abbas Industrial Estate. *Journal of Solar Energy Research*, 8, 1250-1263.