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Research Article

Using Floating Photovoltaics, Electrolyser and Fuel Cell to Decrease the Peak Load and Reduce Water Surface Evaporation

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Abstract
Fossil fuel consumption problems and water crisis are serious dangers. Using renewable energy is a solution to reduce fossil fuel consumption. Photovoltaic is a renewable energy generation method which is abundantly used all over the world. By installation of solar panels on the surface of water, the efficiency of panels increases and in addition, the surface evaporation of water will be reduced. Dams are one of the main sources of water. In the present study, installation of solar panel on surface of the Tanguie dam is studied from technical point of view. The generation PV power is used to produce hydrogen by electrolysis process and consume it in PEM Fuel cell to decreases the peak load. Results show 2.6% increase in panel efficiency when they are installed on water. And this increase in efficiency causes that 360780 installed panels generate 4 million kWh additional electricity power in the year. As well as, covering 678628 m^2 of dam with these panels prevent from 1.97 million m^3 water evaporation in the year. Also, the generated PV power could supply about 99% of load which is above 90MW.

Keyword: Floating photovoltaic, Fuel cell, Technical study, Environment, Surface evaporation

Introduction

Environmental crisis is one of the main human problems nowadays. Increase in fossil fuel greenhouse gases cause global warming which itself has other destructive effects. On the other hand, fossil fuel resources are limited. These have led scientists to seek alternative energy resources. An alternative energy resource is solar energy which is a renewable energy source. The sun is an endless source of energy which can be used in different ways. Photovoltaic panels convert solar energy to electrical energy, directly. Using photovoltaic panels is very common nowadays. There are many researches about using photovoltaic panel to supply the needed electrical energy. A photovoltaic park was designed in Romania to supply a rural community electricity (Dumitru and Gligor, 2018). They performed an analysis in order to design the 1 MW photovoltaic park installations and consumer sizes by taking into account the local condition and

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the history of solar energy of the considered place. Ferreira et al. (2018) demonstrated the key aspects of the evolution of regulatory incentives to use photovoltaic solar energy in Brazil and presented the technologies and characteristics of photovoltaic power generation. Li et al. (2012) studied a grid-connected PV system installed in an institutional building. Their results showed that the monetary payback period for the PV system was 72.4 years when the electricity buying price is equal to the electricity selling price and if carbon trading was considered, the payback was shortened to 61.4 years. Liu et al. (2012) investigated the economic, technical and environmental performance of residential PV system running under the Queensland climatic conditions, and optimized the size and slope of PV array in the system. They carried out their study for the 4 typical climate zones, including tropical, sub-tropical, hot arid, and warm temperature zone and showed that the systems with 20-25 degrees of slope have the best performance. Due to the unreliability of solar energy, PV panels are usually used in combination with electrical energy storage system and auxiliary power generation system. Devrim and Bilir (2016) investigated the combination of photovoltaic solar panels, a small scale wind turbine, an electrolyzer and a proton exchange membrane fuel cell hybrid system for electrical power generation for an average house of 150 m^2 located at Turkey. Their proposed system can provide all electrical need of the house all year round, except November. Noguera et al. (2018) presented an optimal design for a hybrid system, consisting of photovoltaic panels, a diesel generator, batteries and an organic Rankine Cycle by using Particle Swarm Optimization technique. Their simulation results showed that the hybrid system is profitable to supply electric power demand of a selected city.

Application of photovoltaic (PV) panels, wind turbines and diesel generators in a standalone hybrid power generation system for rural electrification in three off-grid villages in Colombia with different climatic characteristics were studied by Mamaghani et al. (2016). They used HOMER software to perform a techno-economic feasibility of the proposed hybrid systems. Sadeghi (2018) considered the effect of the number of solar panels, the power of SOFC and the current density of SOFC on the economic, environmental and reliability operation of a hybrid system consisting of solar panels, solid oxide fuel cell, and flow batteries. And suitable values for these parameters were recommended. One of the most important problems of human societies is lack of drinkable water. Nearly 70% of Iran's area is covered by arid and semi-arid regions (Gorjian and Ghobadian, 2015) and it is experiencing a serious water crisis nowadays. Karbalaee (2010) tried to review some data and mirror Iran's Water crisis situation. And it can ring the bell for whom it may concern actions or policy making in this field, before it is too late.

Covering surface of water with solar panels is a way to prevent from surface water evaporation and also is an efficient way to generate renewable power. Liu et al. (2017) studied the power generation efficiency of floating PV systems and analyzed the advantages and potential of floating PV systems in China. A new photovoltaic floating cover system for water reservoirs developed jointly by the company CELEMIN ENERGY and the Universidad Politécnica de Valencia. Ferrer-Gisbert et al. (2013) described this system and showed it minimized evaporation losses from water reservoirs. Lee et al. (2014) discussed the design and fabrication of the floating type photovoltaic energy generation system. They presented the mechanical characteristics of pultruded fiber reinforced polymeric plastic (PFRP) members used in the fabrication of the floating type photovoltaic energy generation system and the energy generation of the system is measured and analyzed. An overview of the potential negative and positive environmental impacts caused by photovoltaic systems with particular interest on large-scale conventional and floating photovoltaic was presented by Da Silva and Branco (2018). Their results highlighted advantages of floating PV over conventional PV during the operational and decommissioning phases as well. Khosravi et al. (2018) studied to define and assess an off-grid hybrid renewable energy with hydrogen storage system. Their system focused on a large scale usage with constant electrical load, and it especially was suitable for remote area applications. Singh et al (2017) proposed a hydrogen fuel cell and solar photovoltaic hybrid renewable energy system (HRES) for stand-alone applications. They studied the economic viability of using HRES power to supply the electrical load demand of an academic research building. Ghenai et al (2018) investigated a techno-economic analysis based on integrated modeling, simulation, and optimization approach to design an off grid hybrid solar PV/Fuel Cell power system. The main objective of their study was to optimize the design and develop dispatch control strategies of the standalone hybrid renewable power system to meet the desired electric load of a residential community located in a desert region.

This study considers the advantages of installation of solar panels on the dam's water surface from technical and environmental point of view. The desired dam is the Tanguie dam which is located near the Sirjan. The amount of increase in power generation and panel efficiency in relative to conventional PV; and also the amount of reduction in water surface evaporation are determined. The ability of storing hydrogen which produces by an electrolyaer and generate power with a proton exchange membrane (PEMFC) to decrease the peak load of Sirjan is investigated.

Temperature distribution in panel

The panel power generation depends to the operation temperature of panel. To determine the temperature distribution in solar panels, some assumptions are considered. Thickness of panel is very small in relative to other panel's dimensions. Therefore, heat transfer in panel can be considered one dimensional with acceptable accuracy. The rear temperature of panel is assumed to be equal to temperature above the water surface.

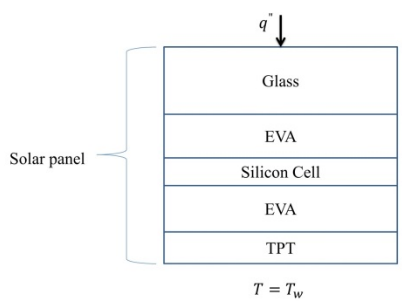

Figure 1. boundary conditions and different layers of solar panel

Table 1. properties of different layers of photovoltaic panel (Liu et al., 2017)

Material	Thermal conductivity (W/m.K)	Specific heat (J/kg.K)	Density (kg/m^3)	Thickness (mm)	Absorptivity
Glass	0.7	790	2450	3.2	0.04
EVA	0.311	2090	960	0.5	0.08
Silicon	130	677	2330	0.2	0.9
TPT	0.15	1250	1200	0.3	0.13

It is assumed that solar radiation, ambient temperature, water temperature, and wind velocity are constant in hourly intervals. Therefore, steady state equations are considered in hourly intervals to obtain temperature distribution. The effect of edge of panel is neglected. PV module consists of five layers: glass, EVA, polysilicon solar cells, EVA and TPT backsheet layer (Figure 1). The properties of each layer are given in Table 1. The average thermal conductivity which is obtained from equation (1), is considered in calculations.

$$k_{ave} = \frac{L}{\sum_{i=1}^{n} \frac{L_i}{k_i}} \tag{1}$$

where L is the total thickness of panel, n is the number of layers, L_i and k_i is i^{th} layer thickness and thermal conductivity, respectively.

Figure 1 shows boundary conditions of the panel and governing heat transfer equation is:

$$\frac{d}{dy}\left(\frac{dT}{dy}\right) = 0 \tag{2}$$

The temperature distribution is obtained as the following equation:

$$T = \frac{q^{"}}{k_{ave}} y + T_w \tag{3}$$

where T_w is the rear temperature of panel. $q^{"}$ is the combination of solar radiation and wind convection heat fluxes on the above of panel and generated electrical power of panel. According to the statement of the dam authorities, water temperature varies from 5ºC to 20ºC during the year. Therefore, it is assumed that the water temperature varies linearly during the year between these two temperatures. The variation of wind speed, ambient temperature and solar radiation during the year from Kerman meteorological organization are shown in figures 2 and 3. The wind convection heat transfer coefficient is (Liu et al., 2017):

$$h_w = 8.55 + 2.56v \tag{4}$$

where v is the wind speed.

Power generation of panel

There is a model which use of five parameters to obtain the current and voltage of photovoltaic panel in maximum power point (Wang et al., 2017). The equation of current-voltage for the PV modules is:

$$\mathrm{I} = \mathrm{I_{pv}} - \mathrm{I_D} - \mathrm{I_{R_p}} = \mathrm{I_{pv}} - \mathrm{I_o}\left[\exp\left(\frac{\mathrm{V} + \mathrm{IR_s}}{\frac{\mathrm{a.N.k.T}}{\mathrm{q}}}\right) - 1\right] - \frac{\mathrm{V} + \mathrm{IR_s}}{\mathrm{R_p}} \tag{5}$$

where, $\mathrm{I_{pv}}$ and $\mathrm{I_D}$ are the light-generated and the Shockley diode currents, respectively:

$$\mathrm{I_{pv}} = \left[\mathrm{I_{pv,n}} + \mathrm{K_i}(\mathrm{T} - \mathrm{T_n})\right]\frac{\mathrm{G}}{\mathrm{G_n}} \tag{6}$$

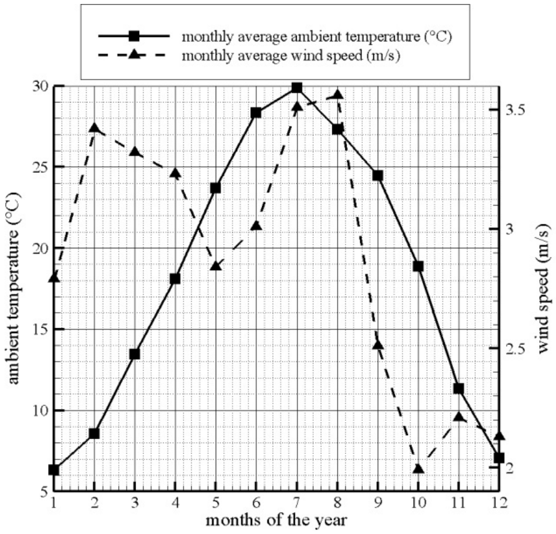

Figure 2. monthly average of ambient temperature and wind speed

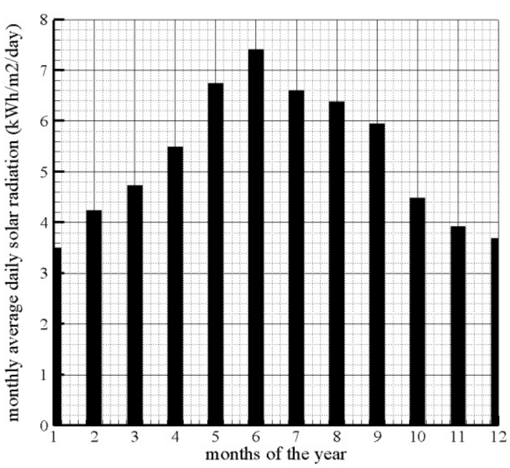

Figure 3. monthly average daily solar radiation

$$I_{pv,n} = I_{sc,n} \frac{R_{p,n} + R_{s,n}}{R_{p,n}} \tag{7}$$

n shows the Standard Test Condition (STC), K_i represents the temperature coefficient of short circuit current, T and G are the cell temperature and the irradiance, respectively. G_n is the irradiance at STC which equals to 1000 W/m^2. In equation (7), R_s and R_p are the equivalent series and the parallel resistance, respectively. An iterative method is used to obtain R_s and R_p at STC. R_s and R_p are determined for other condition as follows:

$$R_s = R_{s,n} \tag{8}$$

$$R_p = \frac{G_n}{G} R_{p,n} \tag{9}$$

Number of cells in series represents with N for a module and a, k and q are the diode ideality factor, the Boltzmann constant and the electron charge, respectively. I_o and V_t are the reverse saturation current of the diode and the thermal voltage of the diode $(k.N.T/q)$, respectively.

$$I_o = \frac{I_{sc,n} + K_i(T - T_n)}{\exp\left(\left(V_{oc,n} + K_v(T - T_n)\right)/aV_{t,n}\right) - 1} \quad (10)$$

Table 2. Electrical Performance of photovoltaic cell under Standard Test Conditions (KC200GT catalogue, 2018)

Power at Maximum Power Point (Pmax)	200W
Voltage at Maximum Power point (Vmpp)	26.3V
Current at Maximum Power point (Impp)	7.61A
Open Circuit Voltage (Voc)	32.9V
Short Circuit Current (Isc)	8.21A
Maximum System Voltage	600V
Temperature Coefficient of Voc	-1.23×10^{-1}V/ºC
Temperature Coefficient of Isc	3.18×10^{-3}A/ºC

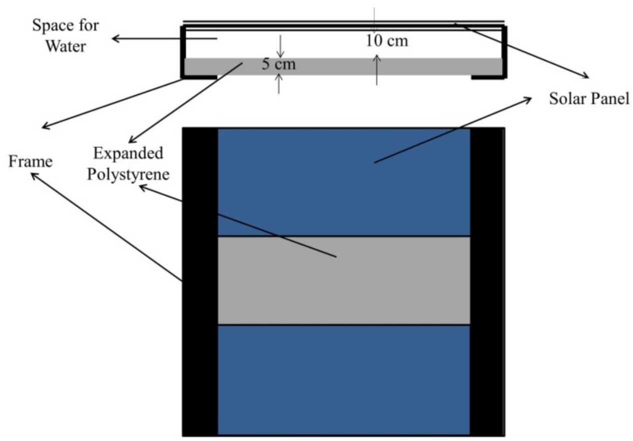

Figure 4. schematic of floating photovoltaic system

The voltage ($V_{m,n}$), current ($I_{m,n}$) and power ($P_{m,n}$) at the maximum power point, the open circuit voltage temperature coefficient (K_v), short circuit current ($I_{sc,n}$) and open circuit voltage ($V_{oc,n}$) are general data which are measured under STC and provided by the Manufactures (Table 2).
The voltage to current curve is obtained with equation (5) and then the maximum power point can be determined. The average temperature of the cell is used as the cell temperature and irradiance is calculated with the TRNSYS software data.

Floating solar panels

The density of solar panel is greater than water density; therefore, to float solar panels on the water surface, a low-density matter such as expanded polystyrene (EPS) must be used in the solar panel set. The volume of used EPS must have been chosen carefully to make full contact between water and solar panels for effective cooling. For this purpose, the density of solar panel, EPS and water between them should be equal to the water density. The panel dimensions and properties are given in table 1. The EPS thickness is assumed to be constant (5cm). By putting the density of the panel set equal to the density of water, the area of EPS is obtained. Figure 4 shows the floating solar panel set.

Fuel cell and electrolyzer

The electrochemical reactions which occur at the anode and cathode of the PEMFC are

$$anode: H_2 \rightarrow 2H^+ + 2e^- \quad (11)$$

$$cathode: \frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O \quad (12)$$

The fuel cell output voltage is the reversible voltage when over-potentials are subtracted from it. Over-potentials are the activation, ohmic and concentration. The value of over-potentials are different for different types of fuel cells. According to the semi-empirical model presented by Wu et al. (2019), the voltage output V_{cell} is given by,

$$V_{cell} = E - (V_a + V_c + V_{ohmic}) = E - \Delta V_{Loss} \quad (13)$$

where E is reversible potential, V_a is the anodic over-potential, V_c is the cathodic over-potential, and V_{ohmic} is the ohmic overpotential that they obtain according to equations 14-17, respectively.

$$E = 1.229 - 0.85 \times 10^{-3}(T_{FC} - 298.15) + \frac{RT_{FC}}{4F} ln\left(p_{H_2}^2 p_{O_2}\right) \quad (14)$$

$$V_a = 0.948 - \left(0.00286 + 0.0002lnA + 4.3 \times 10^{-5} ln \frac{p_{H_2}}{1.09 \times 10^6 e^{\frac{77}{T_{FC}}}}\right) T_{FC}$$
$$-7.6 \times 10^{-5} T_{FC} ln \frac{p_{O_2}}{5.08 \times 10^6 e^{\frac{-498}{T_{FC}}}} + 1.93 \times 10^{-4} T_{FC} lnI \quad (15)$$

$$V_c = -Bln\left(1 - \frac{i}{i_{max}}\right) \quad (16)$$

$$V_{ohmic} = I \left\{ \frac{181.6\left[1 + 0.03i + 0.062\left(\frac{T_{FC}}{303}\right)^2 i^{2.5}\right]}{\left(\psi - 0.634 - 3ie^{4.18\frac{T_{FC}-303}{T_{FC}}}\right)} \frac{l_e}{A} + 0.0003 \right\} \quad (17)$$

where E is reversible potential, R is gas constant, P_j is the partial pressure of constituent, T_{FC} is fuel cell temperature, F is faraday constant, A cell active area, I electrical current, i is current density, i_{max} is maximum current density, l_e is electrolyte thickness, and ψ and B are constant coefficients.

The inlet reactants temperature and the fuel cell operating temperature are set to a constant value by capture the FC process heat. Cooling fluid passes through the stack, absorbs heat and transfers it.

Water electrolysis produces high pure hydrogen. In practical conditions the water electrolyser consumes about 50-55 kWh/kg (Tebibel and Medjebour, 2017) which is due to the high operating cell voltage. The theoretical voltage for water electrolysis is about 1.23V.

Results and discussion

Installation of solar panel on the dam surface

Water scarcity is a serious danger to human society. Geographically speaking, Iran has major water crisis. Therefore, maintain fresh water resources are vital. One of the water resources is dam. A significant part of the dams' water has been lost by surface evaporation. On the other hand, Using renewable energy sources are a certain solution for environmental problem of the world. Installing photovoltaic panels on the surface of dam can reduce water evaporation and also generate renewable electric power. The present work studies installing solar panels on dam's water from technical, economic and environmental points of view. Study will be done for the Tanguie dam. This dam is located 35 km northeast of Sirjan.

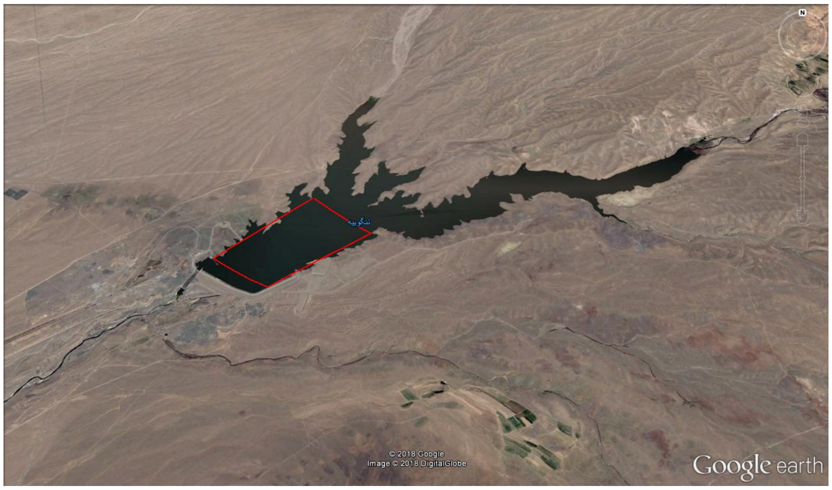

Figure 5. the image of Tanguie dam from google earth

Dam's total surface area is about 2 km^2 and its total volume is about 38.5 million m^3. Figure 5 shows the image of Tanguie dam from google earth. In order to prevent input and output water turbulence, a part of dam is selected to install solar panels. The area of this part is 678628 m^2. For each two rows of panels, one row with about 1m wide is considered for maintenance as shown in figure 6, accordingly, 75% of this area can use for solar panels installation. The maintenance space can be covered by fence and expanded polystyrene. In this research, the KC200GT solar panel with characteristics in table 1 is considered for installation.

The area of this panel is 1.425×0.99 m^2 and thus 360780 solar panels can be installed on the installation area. To float panels on the water, density of the panels system must be equal to the density of water. For this reason, a piece of EPS is embedded under the panels. Thickness of EPS is 5 cm; therefore, a 1×0.26 m^2 part of EPS is needed for each panel. Figure 4 shows a schematic for ESP placement. There is a 10 cm gap between EPS and panel. Water can move to this gap and generate the necessary condition for constant temperature boundary condition under the panel. Due to measurement of evaporation with evaporation pan which is located in dam position, the annual mean surface evaporation is 2903 mm. consequently; it is possible to prevent 1.97 million m^3 of water evaporation in the year by covering 678628 m^2 of dam.

If the average water consumption of an Iranian person is considered about 150 lit/day, this amount of water can provide the yearly needed water for 35981 persons. The Sirjan population is about 199704; accordingly, the saved water can provide the needed water for 18% of the Sirjan population during the year. On the other hand, this number of panels will generate about 135000MWh electrical energy during the year that is the electrical consumption of about 24.6% of Sirjan population. If this amount of power generate with a thermal power plant (the mean efficiency of thermal power plant in Iran is about 34%), about 30 million kilogram natural gas should be burned which generate about 82.5 million kilogram CO_2 emission. And if a combined cycle power plant (the mean efficiency of thermal power plant in Iran is about 45%) was used to generate this electrical energy, about 23 million kilogram natural gas should be burned which generate about 63.25 million kilogram CO_2 emission. Therefore, using solar panels can prevent from emission of large amounts of CO_2 in the environment.

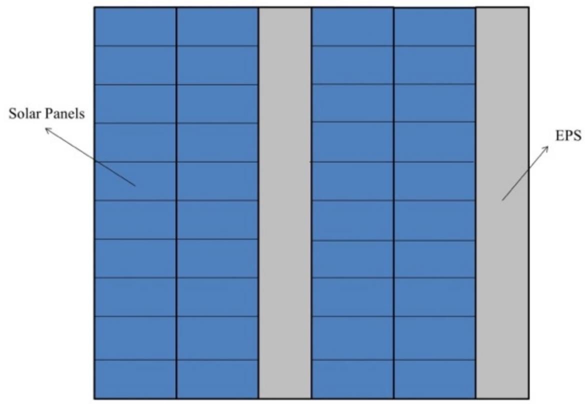

Figure 6. layout of solar panels and EPS on the water surface of the dam

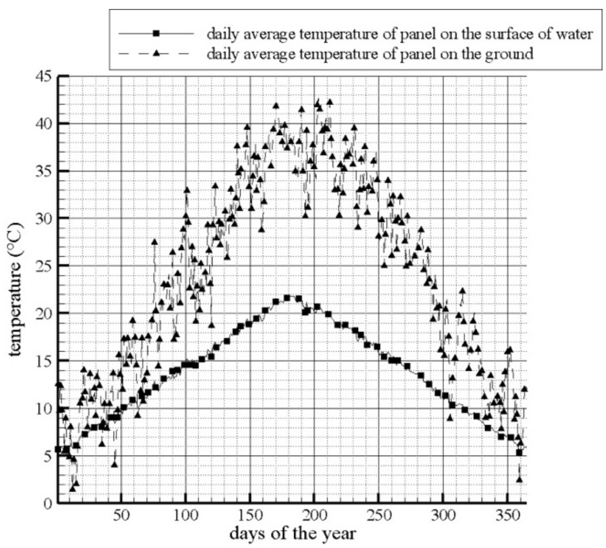

Figure 7. daily average temperature of panel on the water surface and on the ground

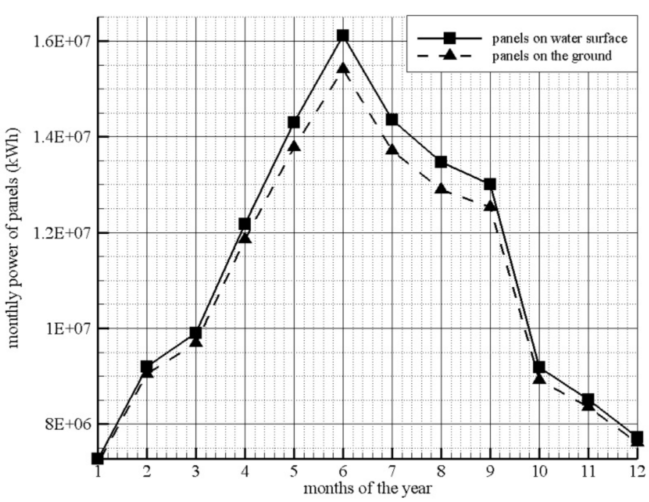

Figure 8. Monthly power generation of total panels on the water surface and on the ground

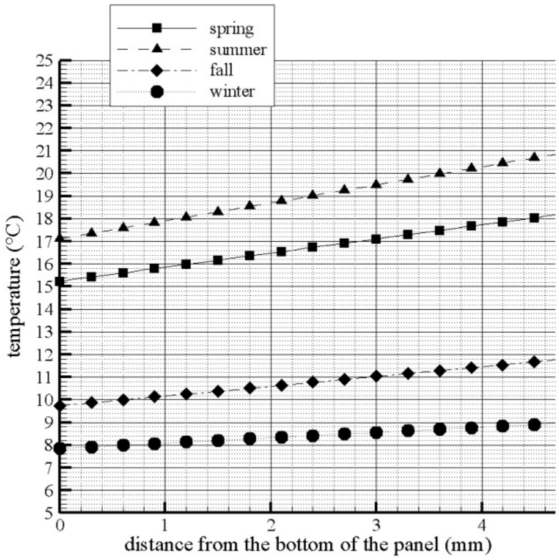

Figure 9. Temperature distribution in panel for different months on average

Installation of panels on dam surface causes to reduce panel operation temperature (figure 7); and so increase the panel efficiency and the power generation. The panel annual average efficiency is 19.7% when it installs on water and its annual average efficiency is 19.2% when it installs on the ground. This results show an increase of 2.6% in panel efficiency. This increase in efficiency causes to generate 4 million kWh additional electricity power in the year by these number of panels. Figure 8 compares amount of power generation for two situations: when panels are install on water and when panels are install on ground.

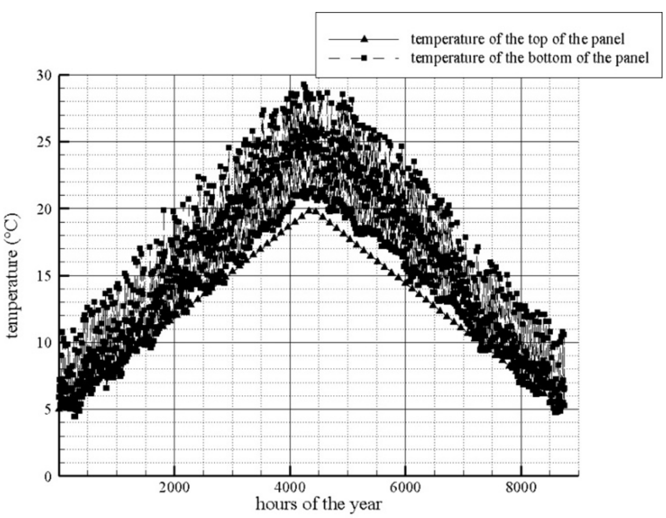

Figure 10. temperature of the top and the bottom of panel during the year

According to the statement of the dam authorities, water temperature varies from 5ºC in the coldest day of the year to 20ºC in the hottest day of the year. In this research, it is assumed that the water temperature varies linearly during the year. Temperature distribution in solar cell is obtained by assuming: one dimensional heat transfer in cell, constant temperature boundary condition under the cell, and constant heat flux boundary condition above the cell. The steady state energy equation is solved in one-hour intervals which boundary conditions can considerer

constant. Figure 9 shows the variation of the panel's temperature on average for different seasons. The maximum temperature variation in the panel (about 5ºC) occurs in summer. The average temperature in panel is used for the panel power generation calculation.
The temperature distribution of the upper and lower surfaces of the panel during the year is shown in figure 10.

Supplying peak load

If PV generation power is used to produce hydrogen by water electrolysis, the peak load could supplied by consuming hydrogen in a PEM fuel cell. It means that the PV generation power transfers to electrolyzer until the load is bellow a determined value (DV). When the load increases above this determined value, PV generation and stored hydrogen use to supply amount of load which is above the determined value. The fuel cell output contains some unreacted hydrogen which burn to increase the output gas temperature. This high-temperature gas is used to preheat the input reactants of fuel cell in two heat exchanger. Figure 11 shows the schematic of the system. Figure 12 shows yearly average load of Sirjan for hours of the day which obtains from Sirjan Electric Power Distribution Company. The peak load is about 163MW which happen at about 7 o'clock in the evening. At this time, the PV generation power is approximately zero. Therefore, the stored hydrogen and PEMFC can generate the excess power (which is the load above the determined value).

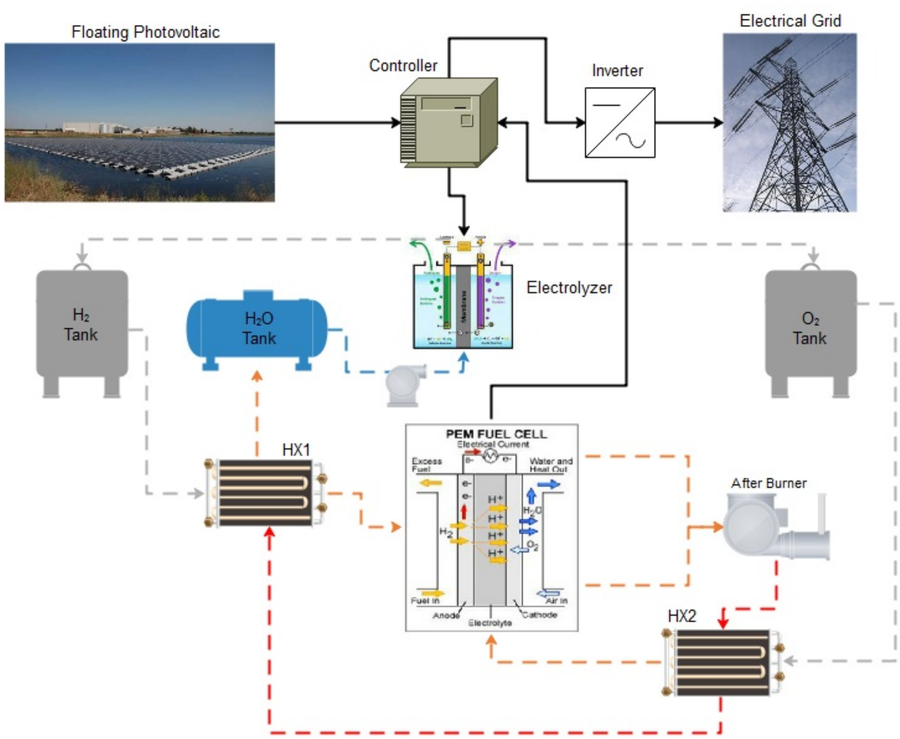

Figure 11. Schematic of the system.

By setting DV in different values, different the loss of power supply probability (LPSP)s are obtained. If DV sets at 80MW, the PV generation power is used to produce hydrogen until the load is bellow 80MW. The PV power and hydrogen stored use to supply the excess load when load increases above 80 MW. If they could not supply the excess load, system counts this hour as an hour that the system cannot supply peak load. Sum of the hours that the system cannot supply the peak load are used to calculate LPSP. Figure 13 shows LPSP for different DVs. For the case DV=80MW, LPSP is 8.49%. It means in about 743 hours of the year, the peak load cannot supply with the present system. If DV=90MW is chosen, the LPSP decreases to about 1% which means only for about 87 hours of year, the peak load cannot supply by the present system. Actually the DV=90MW means that the system uses storage hydrogen when the load be above 90MW and therefore the consumed amount of hydrogen is lower than the DV=80MW situation and the LPSP also becomes lower than the DV=80MW situation.

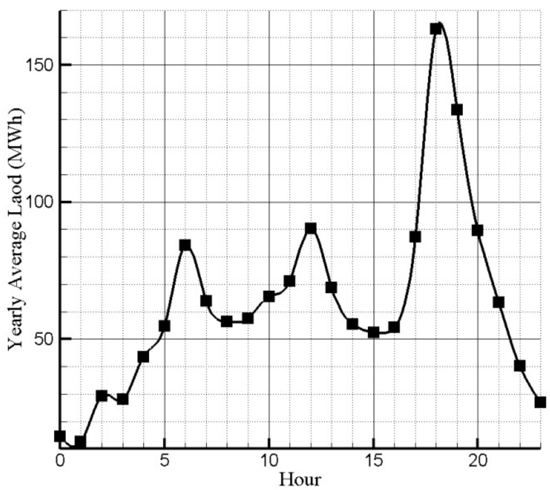

Figure 12. Yearly average electrical load of Sirjan

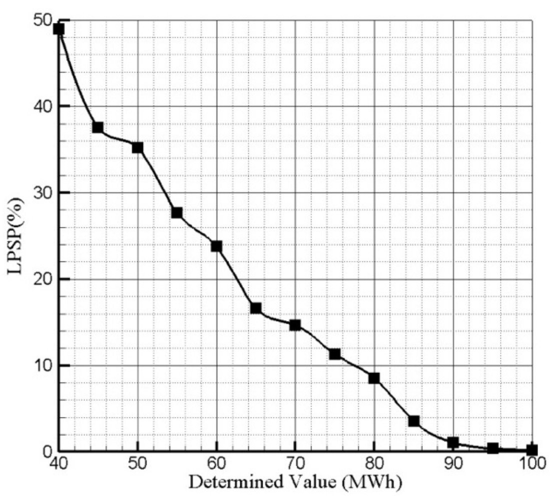

Figure 13. Change of LPSP with change in the Determined Value

Conclosion

In this study, an approach recommended to reduce the surface evaporation of the Tanguie dam. Installation of solar panels on the surface of dam water can reduce surface evaporation and also generate significant electrical power. By this approach, the photovoltaic panel efficiency increases and it causes to generate about 4 million kWh additional electricity power in the year relative to when the panels install on the ground. 360780 solar panels which can install on the dam water surface generate the power consumption of about 24.6% of Sirjan population. As well as, this approach prevent from evaporation of about 1.97 million m^3 water which is the yearly water consumption of about 18% of Sirjan population. If the PV generation power is used to produce hydrogen, the system could supply a large portion of the peak load during the year. For example, if DV=90MW is chosen, the LPSP decreases to about 1% which means for about 8673 hours of year, the peak load can supply by the present system.

PV	Photovoltaic
EVA	Ethylene vinyl acetate
TPT	Tedlar polyester tedlar
STC	Standard Test Condition
EPS	Expanded polystyrene
EG	Total annual electrical energy
$\dot{W}_{PV}$	Power of photovoltaic panel
V_{EPS}	Volume of EPS
PEMFC	Polymer exchange membrane fuel cell
LPSP	Loss of power supply probability
PL	Peak load

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References

Da Silva, G.D.P. and Branco, D.A.C. (2018). Is floating photovoltaic better than conventional photovoltaic? Assessing environmental impacts. Impact Assessment and Project Appraisal 1-11.

Devrim, Y. and Bilir, L. (2016). Performance investigation of a wind turbine–solar photovoltaic panels–fuel cell hybrid system installed at Incek region – Ankara, Turkey. Energy Conversion and Management, 126, 759–766.

Dumitru, C.D. and Gligor, A. (2018). An approach to photovoltaic based power supply designing of a Transylvanian rural community. Procedia Manufacturing, 22, 826–832.

Ferreira, A., Kunh, S.S., Fagnani, K.C., De Souza, T.A., Tonezer, C., Dos Santos, G.R. and Coimbra-Araujo, C.H. (2018). Economic overview of the use and production of photovoltaic solar energy in brazil. Renewable and Sustainable Energy Reviews, 81, 181–191.

Ferrer-Gisbert, C., Ferrán-Gozálvez, J.J., Redón-Santafé, M., Ferrer-Gisbert, P., Sánchez-Romero, F.J. and Torregrosa-Soler, J.B. (2013). A new photovoltaic floating cover system for water reservoirs. Renewable Energy, 60, 63-70.

Ghenai, Ch., Salameh, T. and Merabet, A. (2018). Technico-economic analysis of off grid solar PV/Fuel cell energy system for residential community in desert region. International Journal of Hydrogen Energy. https://doi.org/10.1016/j.ijhydene.2018.05.110.

Gorjian, Sh. and Ghobadian, B. (2015). Solar desalination: A sustainable solution to water crisis in Iran. Renewable and Sustainable Energy Reviews, 48, 571–584.

Karbalaee, F. (2010). Water crisis in Iran. International Conference on Chemistry and Chemical Engineering. 10.1109/ICCCENG.2010.5560403.

KC200GT catalogue. (2018). (https://pdf.wholesalesolar.com/module%20pdf%20folder/KC200GT.pdf?_ga=2.199346158.1121224831.1532687713-2018600073.1532687713)

Khosravi1, A., Koury, R.N.N., Machado, L. and Pabon, J.J.G. (2018). Energy, exergy and economic analysis of a hybrid renewable energy with hydrogen storage system. Energy, 148, 1087-1102.

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

Li, D.H.W., Cheung, K.L., Lam, T.N.T. and Chan, W.W.H. (2012). A study of grid-connected photovoltaic (PV) system in Hong Kong. Applied Energy, 90, 122–127.

Liu, G., Rasul, M.G., Amanullah, M.T.O. and Khan, M.M.K. (2012). Techno-economic simulation and optimization of residential grid-connected PV system for the Queensland climate. Renewable Energy, 45, 146-155.

Liu, L., Wang, Q., Lin, H., Li, H., Sun, Q. and Wennersten, R. (2017). Power Generation Efficiency and Prospects of Floating Photovoltaic Systems. Energy Procedia, 105, 1136 – 1142.

Mamaghani, A.H., Escandon, S.A.A., Najafi, B., Shirazi, A. and Rinaldi, F. (2016). Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia. Renewable Energy, 97, 293-305.

Noguera, A.L.G., Castellanos, L.S.M., Lora, E.E.S. and Cobas, V.R.M. (2018). Optimum design of a hybrid diesel-ORC / photovoltaic system using PSO: Case study for the city of Cujubim, Brazil. Energy, 142, 33-45.

Sadeghi, S. (2018). Study using the flow battery in combination with solar panels and solid oxide fuel cell for power generation. Solar Energy, 170, 732–740.

Singh, A., Baredar, P. and Gupta, B. (2017). Techno-economic feasibility analysis of hydrogen fuel cell and solar photovoltaic hybrid renewable energy system for academic research building. Energy Conversion and Management, 145, 398–414.

Tebibel, H. and Medjebour, R. (2018). Comparative performance analysis of a grid connected PV system for hydrogen production using PEM water, methanol and hybrid sulfur electrolysis. International Journal of Hydrogen Energy, 43, 3482-3498.

Wang, G., Zhao, K., Shi, J., Chen, W., Zhang, H., Yang, X. and Zhao, Y. (2017). An iterative approach for modeling photovoltaic modules without implicit equations. Applied Energy, 202, 189–198.

Wu, Zh., Ni, M., Zhu, P. and Zhang, Z. (2019). Dynamic modeling of a NG-fueled SOFC-PEMFC hybrid system coupled with TSA process for fuel cell vehicle. Energy Procedia, 158, 2215-2224.