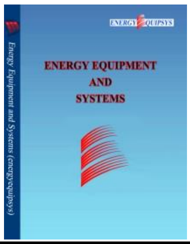
Energy Equip. Sys./ Vol. 10/No. 4/Dec. 2022/ 375-388

ENERGY EQUIPSYS



Energy Equipment and Systems

http://energyequipsys.ut.ac.ir
www.energyequipsys.com

Green cottage power supply and floating solar power plant: A Techno-Economic analysis

Authors

Mostafa Esmaeili Shayan [a]
Gholamhassan Najafi [a *]
Barat Ghobadian [a]
Shiva Gorjian [a]

[a] Department of Biosystem Engineering, Tarbiat Modares University, Tehran, Iran

Article history:

Received : 30 September 2021
Accepted : 9 December 2021

ABSTRACT

Iran's energy sector, which includes power generation, transportation, industry, buildings, and homes, is a significant source of greenhouse gas emissions. Plans for efficient design and development of maximum power control systems aim to increase the share of renewable energy in electricity usage. Floating photovoltaic systems combine existing photovoltaic systems with a floating structure to generate clean energy and integrate existing dams to enhance power sources. The results indicate that installing a hybrid floating solar power plant at a level of more than 1 km² over the dam reservoir's surface provides 194 GWh to 257 GWh of electricity per year. Installation floating photovoltaic plant would supply electricity for 2260 green cottages while also improving the environment and reducing water evaporation. Adding a floating solar power plant with 10% of the lake reservoir cover of six dams saves 70.7 million cubic meters of water per year which is enough to meet the annual needs of one million people. This study fills a research gap in the energy sector by studying the economics of hybrid renewable energy systems in Net-zero energy buildings.

Keywords: Renewable Energy; Electricity; Floating Photovoltaic; Green Cottages; Net-Zero Energy Buildings.

1. Introduction

Renewable energy sources can vary widely geographically. Photovoltaic systems do not work at night, and wind energy systems do not always work. As a result, optimal storage and backup systems and the design and integration of multiple renewable energy sources can improve the desire to utilize renewable systems and manage the energy cycle. This technique supports local or household renewable energy consumption while also establishing the groundwork for large-scale electricity generation. However, According to the Ministry of Energy's 2019 report, more than 96 percent of the electricity produced in Iran came from fossil power plants, with less than 4 percent coming from renewable sources [1]. Almost all renewable electricity is generated by significant hydropower facilities, with wind energy, solar energy, small hydropower, and playing a minor role. As a result, only 200 megawatts of electricity generated in Iran is generated from renewable sources – other than large hydropower. However, fossil fuels are finite resources, so researchers are looking for alternative sources of energy supply when planning the country's energy portfolio [2]. Solar irradiation conditions revealed that the majority of IRAN's geographical area is in hot

* corresponding author: Gholamhassan Najafi
Department of Biosystem Engineering, Tarbiat Modares University, Tehran, Iran
Email: g.najafi@modares.ac.ir

and dry regions with a strong potential for photovoltaic and solar heating system operation [3]. At the same time, it promotes stationary water evaporation [4]. The worldwide average annual evaporation potential is 700 mm, whereas IRAN has three times the global average yearly evaporation [5]. High-potential photovoltaic technology has the potential to contribute to 5% of Europe's power needs by 2030 and 11% by 2050[6]. However, just 1% of the total electrical power required by humans, or 18,400 terawatts, is supplied by various solar-to-electricity conversion systems [7]. In addition to the benefits listed above, floating solar power plants have a strategic advantage in terms of IRAN's location. Karun 4 Dam is the largest arch dam in the country and the world's fifth-largest dam and power plant [8]. With its prior features and the utilization of new resources, this dam can be a pioneer in establishing the balance of energy management and a viable model for transitioning to renewable energy in the economic and executive management systems, as well as in energy policy [9]. The usage of floating solar power plants on dams and lakes has the advantage of reducing evaporation, requiring no land space, and utilizing the water cooling effect, which can improve the performance of the solar panel.

This research aims to maximize the use of local renewable energy sources, develop a sustainable energy network, and promote sustainable development. As a result of this study, a research gap in the energy sector has been filled. A floating photovoltaic power plant has been designed to supply electricity to green cottages, minimize freshwater evaporation, and keep the electricity grid reliable.

Nomenclature

Symbols

g_h	amount of water evaporated (kg/h)
A	water surface (m^2)
g	amount of evaporated water (kg/s)
h	the heat of evaporation of water (kj/kg)
i	discount rate (%)
q	Heat (kJ/s)
V	Wind Speed (m/s)
x	Wet air humidity (kg/kg)
X_s	Dry air humidity (kg/kg)

Greek Symbols

η	Efficiency (%)
γ	Azimuth Angle (Degree)
θ	Evaporation Rate (Kg/M^2)

Subscript

s	Per Second
we	Evaporation Of Water

Acronyms

COE	Cost of Electricity
FPVS	Floating Photovoltaic Systems
GHG	Greenhouse Gas
HERS	Hybrid Renewable Energy System
IRR	Internal Rate of Return
MCM	Million Cubic Meters
NCF	Net Cash Flow
NPV	Net Present Value
NZEB	Net-Zero Energy Buildings
RE	Renewable Energy

2. Literature review

Energy-related CO_2 emissions account for two-thirds of total greenhouse gas emissions (GHG). Innovative technologies, particularly in solar energy, will facilitate this energy revolution [10]. Long-term initiatives for sustainable development are required to solve the environmental problems we are now dealing with one of the most efficient and successful options in this regard appears to be the use of renewable energy sources. Because of this, renewable energy and sustainable development are inextricably linked [11]. The world's energy consumption is outpacing the world's installed generation capacity. Energy demand should be met and developed in a safe, efficient manner to meet future energy needs [12].

Japan presently produces more than half of the world's solar energy [13], followed by Europe (25%) and the United States (19%). Although crystal silicon solar cells are very poor absorbers and require a considerable thickness of a few microns for appropriate performance, they have been absorbed in most systems from the past to the present. They are employed in sunlight and are widely used in microelectronics technology, with 11% to 24%

efficiency [14]. While solar energy has a small role in IRAN's electricity production, it has a global share of over 30% [15]. Rural electricity supply began in 2006 in Qazvin, then Gilan, Zanjan, Bushehr, Yazd, and Kurdistan. In 2008, a project to offer power to 634 rural families was defined, with a capacity of over 386 kW [16]. Around the world, large-scale photovoltaic power facilities (solar farms) have been designed and simulated. Canada created a 5 kW floating PV plant [17]. In 2017, Zhong et al. examined the issue of small consumers using solar electricity [18]. The parametric design of solar farms and small-scale power plants to address urban electricity needs was researched in 2017 and 2020 [19]. To account for the shadow effect in surface-based solar power plant design, Jin et al. proposed a model in 2017 [20]. In 2018, Pratumnopharat et al. used MATLAB to simulate the best solar power plant [21]. Esmaeili Shayan et al. On a floating surface, the ideal angle of solar panels may be calculated [22]. The energy, exergy, economic, and environmental assessments are performed on a MATLAB model. To determine the system's optimum operating condition, five single- and multi-criteria optimizations are performed. The model promotes the best point on the 3D Pareto Frontier of the tri-objective optimization obtained 45.86 % exergy efficiency, 1.161$/s total cost rate, and 17.05 kg CO2 emission [23]. Japan created the world's first floating solar PV plant in 2007. Some other countries have since attempted small-scale solar floating photovoltaic power plants for scientific purposes. First commercial installation of a 175 kW floating photovoltaic power plant in a food processing factory [24]. Immediately, South Korea and the USA built 80 and 12 MW floating solar power plants [25]. Now, 20 countries have developed 40 megawatts of floating solar power [26]. In June 2017, Huainan launched a 40-megawatt floating solar power facility. This floating solar power station can give electricity to a small town and around 15,000 people in an abandoned coal mine [27].

In 2019, a floating solar power plant was installed in one of London's most important water reservoirs. 23000 solar panels formed a 6MW power plant. Temperatures, especially in the summer, lower the effectiveness of all floating solar power plants. However, water and its cooling action prevent this [28]. China will connect the world's largest 50 MW floating solar power facility to the grid in 2020. The first phase of this 150 MW project has entered the network [29]. By 2019, around 300 floating PV solar power plants will be operating globally. The Mackenzie Institute expects a 22% annual rise in demand for floating solar power facilities from 2019 to 2024 [30]. According to a recent report, the market for floating solar power plants will rise by over 31% annually from 2018 to 2022. The Americas will have a 52% rise in capacity, while the global capacity will expand by 1.5 GW annually [31]. We are currently in the early stages of developing grid-connected hybrid systems that mix energy and floating solar PV. There are more than 400,000 square kilometers of extant reservoirs, and artificial ponds worldwide. The effect of water cooling on enhancing the efficiency of floating solar power plants by about 20% has been documented in Iran [19]. Many countries are trying to address sustainable energy supply issues by implementing environmental laws and regulations, as well as financial and technical incentives.

Assessing the economic magnitude of combined renewable energy systems, focusing on the energy controller, is now complex. In 2020, Yang et al. developed a hybrid renewable energy forecasting system. With this technique, renewable energy was controlled alternately and randomly. A study in 2018 proposed the fuzzy logic control system of an independent photovoltaic system with battery storage in terms of intelligent control [32]. In 2021, another study proposes an intelligent control method for a photovoltaic solar power plant with direct connection and tracking [33]. Recent research has focused on network-connected hybrid systems and real-time algorithms [34]. The superconducting magnetic energy storage device was created to increase dynamic responses to diverse operating conditions. The results demonstrated that only axis currents must be measured, and perturbation estimation is easily applicable with control costs [35].

The study's main objective is to increase local renewable energy while minimizing environmental impact. Study of 6 major Iranian dams The amount of evaporation was determined using satellite image techniques. Integrated floating hydropower and the solar generating facility are proposed using a projected weather model with GIS. The Karun 4 mega solar power project analysis. From 2000 to 2020, real-time weather data were used to develop the floating solar power plant. This is the first integrated hydro-solar project in Iran. The technical, economic, and environmental sustainability of a floating solar power plant on a dam reservoir is examined.

3. Materials and Methods

Karun 4 Dam site is 185 kilometers from Shahrekord and 35 km from Lordegan, in the Chaharmahal, Bakhtiari, and Khuzestan provinces (west-southwest of Lordegan). The Armand, Sarkhoon, and Bazaft rivers are tributaries of the Karun River, 670 kilometers from the Persian Gulf. The dam's reservoir volume is 2279 million cubic meters (MCM) and the lake is 41 kilometers long. This dam is Iran's largest double-arch dam. The research uses real and virtual data from meteorological stations at Karun 4 dam for two 20-year periods from 2000 to 2020 and 2020 to 2040. PVsyst and AutoCAD were used to speed up the design. The floating solar power plant's economic performance was based on engineering economics. Economists' Criteria The design and economic performance tests were done with COMFAR 3. Minitab has also been used to analyze data. Temperature and precipitation are essential variables in hydrology. A floating photovoltaic power plant could be affected by these variables and shading.

In this study, the output of six atmospheric circulation models was subscale with LARS-WG statistical model to investigate and analyze the effect of climate change on temperature and precipitation in the Karun 4 dam. The best model and scenario for temperature and precipitation data production for the period 2020 to 2040 were selected. As a result, the A1B scenario uses the HADCM3 model for precipitation and the A2 scenario uses the MPEH5 model for temperature. This project is the first to provide an integrated model for hydropower and solar energy in Iran. Table (1) shows the Karun 4 power plant's technical data. The Karun 4 hydroelectric power plant has for 250 MW reactor.

The lack of land space and the utilization of the cooling water effect, which can improve the solar panel's performance by 5% to 10%, are significant advantages of floating solar power plants on dams and lakes. Other potential advantages include less shading, fewer building activities, less water evaporation, better water quality, and fewer algae growth. A schematic of the System hardware and the block diagram of the system of voltage control and FPV power plant's components is depicted in Figure (1). The Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Capital are some of the economic indicators of a floating solar power plant (PP).

Table 1. Technical information of Karun 4 hydroelectric power plant

Property	Specifications	Property	Specifications
Average Annual Energy	2107 (GWh)	Nominal Voltage of Generator	75.15 (kV)
Power Plant Capacity	1000 (MW)	Rated Output Power	263 (MVA)
Number of Units	4 per 250 (MW)	Maximum Output Power	300 (MVA)
The Total Volume of The Tank	2190 (M^3)	Number of Transformers	13
Tank Area	29 (Km^2)	Nominal Power of Transformer	100 (MVA)
Height	230 (m)	Secondary Nominal Voltage of Transformer	$(410/\sqrt{3}) \pm 5\%$ (kV)
Turbine Rotation Speed	187.5 (rpm)	Production Capacity in Normal Head	255 (MW)
Normal Operation Head	191 (m)	Flow Design per Unit	171 (M^3/sec)

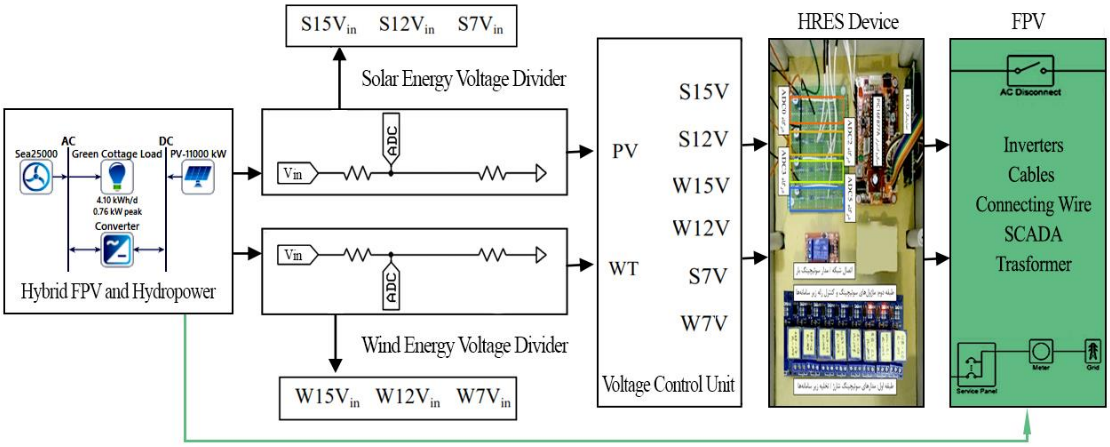


Fig. 1. A floating solar power plant's components

Evaporation from lakes behind dams and freshwater lakes is one of the causes of water waste. The evaporation of water from the surface of the water, such as an open tank, swimming pool, or reservoir behind a dam, is affected by the water temperature, air temperature, humidity, and air velocity above the water surface. Equation (1) is used to compute the amount of water evaporated[4].

$$g_h = \theta A\left(X_s - x\right) \quad (1)$$

where g_h is equal to the amount of water evaporated per hour in kilograms per hour and θ is equal to the evaporation rate in kilograms per square meter and is equal to Eq. (2). A is equal to the water surface per square meter, X_s is the maximum ratio of saturated air humidity at the same temperature as the water level in kilograms per kilogram or kg H_2O per kilogram of dry air and x is the ratio of air humidity. H_2O per kg of dry air. Since this equation is experimental and laboratory, the dimensions of the variable θ do not match. In Eq. (2) V is the wind speed of the air above the water surface in meters per second [30].

$$\theta = \left(25 + 19V\right) \quad (2)$$

The heat required for water to reach the evaporation phase is taken from the water itself and the energy of the solar irradiation, which can be calculated by Eq. (3) [36].

$$q = h_{we} g_s \quad (3)$$

q is the heat supplied in units (kJ/s) and h_{we} is the heat of water evaporation in units (kJ/kg). The Molar diagram is used to calculate the air humidity and the law of ideal gases is used for the humidity ratio of the partial pressure of the vapor and it is 1 kW = 3412 Btu / h.

3.1. Net present value

The timeline adjustment of money intends to attain a balance between investment payments and investment returns. This balance is compared to interest rates as a predetermined criterion for project management. This interest is called the "minimum absorbed interest" or "cost of capital". Equation (1) calculates the net present value of the cash flows:

$$NPV = \mathrm{NCF}_0 + \frac{NCF_1}{\left(1+i\right)^1} + \frac{NCF_2}{\left(1+i\right)^2} + \frac{NCF_t}{\left(1+i\right)^t} \quad (4)$$

In the above relation, the net present value (NPV), the net cash NCF, i is equal to the discount rate and t is equal to the financial period. The NPV may be negative (no project selection) or positive (project selection). If the net present value equals zero, the designer will be indifferent in choosing or not choosing to carry out the project.

3.2. Internal rate of return

IRR is a well-known criterion in the economic evaluation of projects. This criterion considers that the condition for accepting the project is that the IRR is greater than the cost of capital. IRR is the discount rate at which the net present value of the project (NPV) is zero. If the NPV of a project is positive, the IRR of that project is higher than the rate of return used for the investment. In calculating the

NPV, it is assumed that the discount rate is known, and the project NPV is determined.

3.3. Return on investment

The product of the Karun 4 Dam floating photovoltaic power plant is electricity and reduction of surface evaporation loss, which the solar system generates electricity at nominal capacity. The service life or useful life of the systems is equal to 25 years. The inflation rate based on the average inflation rate in the last five years between 2015 to 2020 related to the category of water, electricity, and fuel goods is considered an average of 10 percent. The deposit interest rate in Iran has freshly reduced to 15%, but in the last 10 years, it has equated to 16.7%, which is regarded as the benchmark discount rate [37]. According to the Iranian parliament's legislation, each kilowatt of renewable electricity is purchased from the consumer at ~0.05 $/kWh, which this price is supposed to be 20 years of the solar system's useful lifetime [38]. In [39] the different Feed-In Tariff (FiT) rate is considered to be 0.05 $/kWh.

IRR is calculated by COMFAR through trial and error because you are trying to arrive at whatever rate makes the NPV equal to zero. The price increase rate of energy carriers is equal to 10% per annum. Iran's discount rate is 16%. To get the discount rate in dollar calculations, plus 24% after deducting domestic inflation (according to the Central Bank, the average inflation rate in Iran over the past 5 years has been 20%) and add the US inflation rate (to 2% in 5 years Past) is reduced from 8% risk-free interest rate [40]. Table (2) shows the green cottage's electric consumers.

Figure (2) shows the electricity consumption profile of the green cottages during a year. The load factor of the green cottage is 22% and the average consumption of the cottage is 4.10 kWh per day.

4. Results

An 11MW hybrid renewable energy system was designed and tested to monitor, regulate and optimize existing energy sources to supply green cottages. The dynamic control algorithm optimized the input and output ports of the hybrid renewable energy conversion system. The Karun 4 Dam will add 1 GW per year to Iran's hydroelectric network. The water level in the dam reservoir is measured daily. It is an independent variable that can affect the hydropower plant's efficiency. Figure (3) illustrates the time record of the reservoir water level from March 2010 to March 2017.

Table 2. Green cottage electric consumers [41]

Section	Consumption (W)	Current (A)	ON-Time (Hours)	Ampere Hourly (Ah)
Cooking	40-800	8.33	1	8.33
Entertainment	17-100	2.5	2	5
Lighting	5-10	2.28	5	11.45
Computer	50	4.16	8	33.28
Maintenance	20-100	3.33	24	79.9
Total	132-1060	20.6	-	137.96

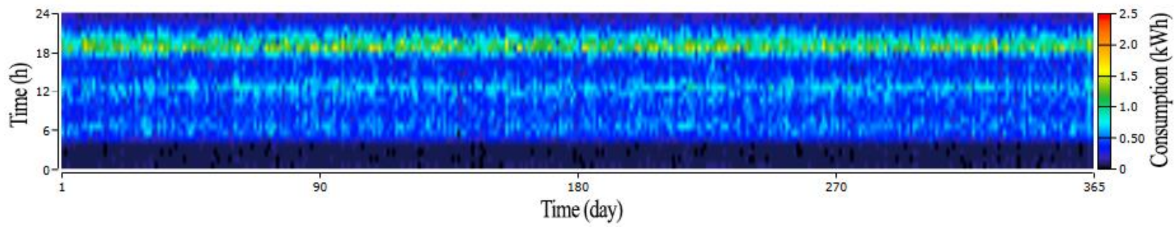


Fig. 2. Green cottages electricity consumption profile.

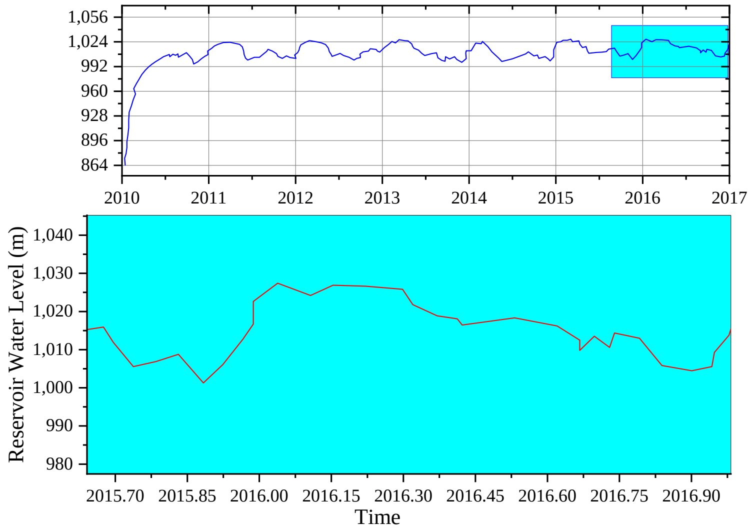


Fig. 3. Reservoir water level

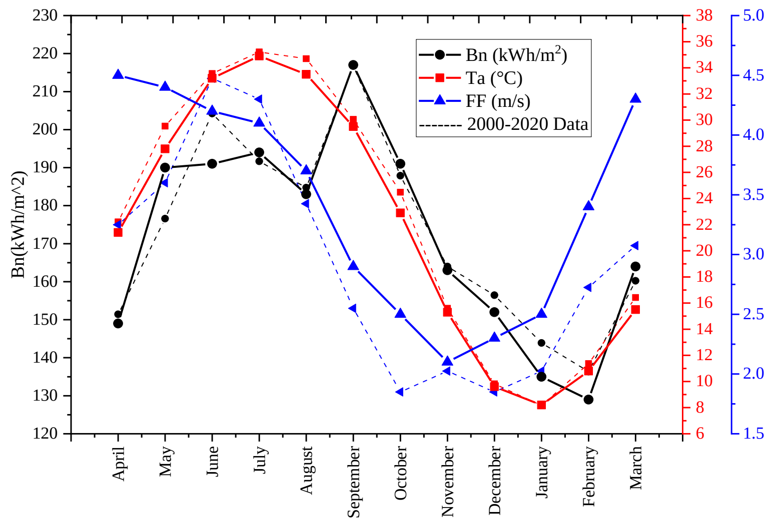


Fig. 4. Real and predicted data from 2000 to 2040.

Figure (4) shows a comparison between the implementation of a model for predicting the future operation of a solar floating photovoltaic power plant and actual meteorological data. B_n is the average of direct irradiation on a surface with zero slopes and T_a is the mean of ambient temperature and FF is the mean of wind speed for a period of 20 years from 2020 to 2040. Dashed lines are actual data for a period of 20 years, from 2000 to 2020.

The majority of the irradiation is attributed from May to October. The intensity of radiant irradiation reaches more than 200 kWh per square meter in August and September. Since April, the temperature has been increasing, reaching more than 34 degrees Celsius in July. Temperatures will continue to fall from September to January, then rise again after February. The intensity of solar irradiation has a direct relationship with the surface evaporation of dam reservoir water. From April until mid-August, the average wind speed will be 3 meters per second or higher. From September through January, wind speeds were at their lowest. Wind energy can evolve the combined energy source from mid-January through March. Figure (5) displays a comparison of rainfall levels and rainy days from 2000 to 2020, as well as the predicted scenario up to 2040.

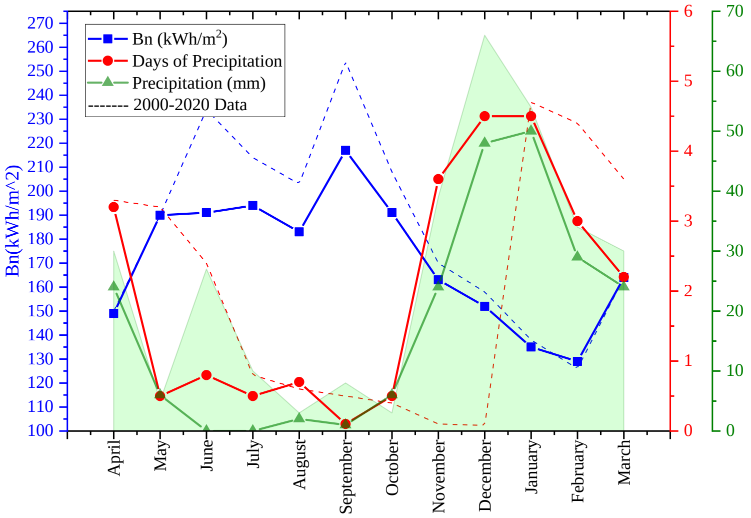


Fig. 5. Real data and prediction of rain and solar energy from 2000 to 2040.

The volume of rainfall is hard to estimate based on statistics from 2000 to 2020. Suppose the amount of rainfall from October to April exceeds that from July to October. The rainiest days fall between November and February, whereas the brightest days fall between May and October. Suppose throughout the 20-year prediction scenario until 2040, the intensity of solar irradiation energy has fallen somewhat compared to 2000-2020. In that case, the radiant energy will be more than 150 kWh per square meter from April to November. The results of water evaporation from 2000 to 2020 show that the reservoir of Karun 4 dam with a reservoir area of 29 square kilometers and a maximum ratio of saturated air humidity at the same temperature as the water level in winter with an average temperature of 10 °C equal to 0.007612 kg/kg in summer with an average temperature of 30 °C equal to 0.027125 kg/kg and a maximum ratio of saturated air humidity at the same temperature as the water level In winter, with an average wind speed of 2.5 m/s, it is equal to 37845 kg / h (10.5 kg / s and input heat of 25767 kW) and in summer, with an average wind speed of 4 meters per second, it is equal to 248965 kg / h (69.2 kg / s and the input heat is 169817 kW). Winter evaporation is 557% more than summer evaporation in an hour. Calculations of evaporation from 2020 to 2040 reveal that the highest ratio of saturated air humidity in summer with an average temperature of 32 °C is 0.031125 kg/kg, while the ratio of humidity in winter is 0.00763 kg/kg and in summer is equivalent to 0.03253 kg/kg and in winter is equal to 2454 kJ / kg with an average wind speed of 1.5 m/s equal to 27927 kg/h (7.76 kg/s and input heat of 19043 kW). In the summer, with an average wind speed of 3 m/s, it is 3341090 kg/h (928 kg/s, and the input heat is 2277312 kW). In one hour, the difference in water evaporation between winter and summer will be more than 11863%. This will suggest a shift in the climate toward warmer summers. Summer evaporation capacity is 1241 percent higher than winter evaporation capacity.

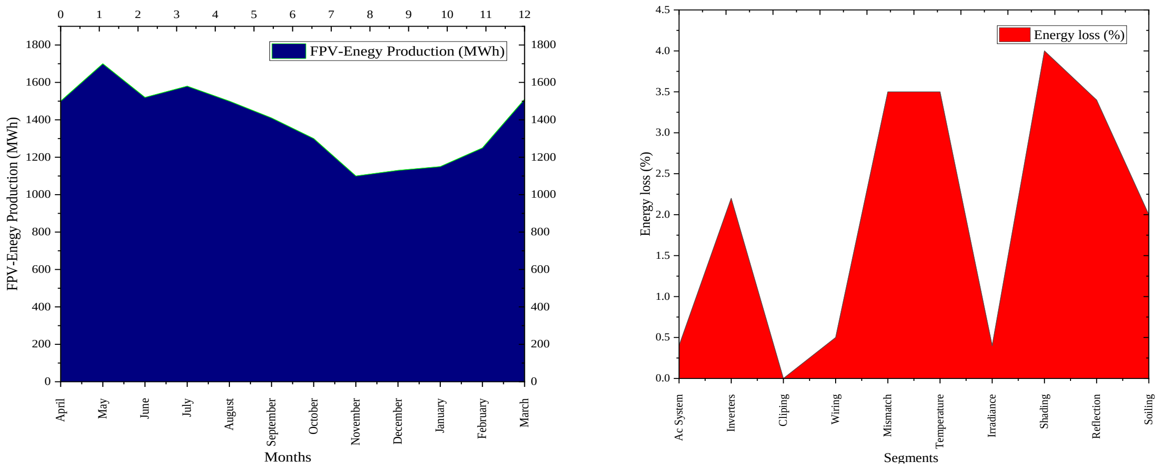
The Karun 4 floating solar power plant is designed to be 200 m by 500 m, or 100,000 m^2. This power plant is a single frame with a totally south direction, a 20-degree slope, and a 70 cm row spacing and uses Yingli 365-watt solar panel YL365D-36b. The solar power station has 30203 panels with a capacity of 11 MW. This facility also utilized 177 STP 50-40 inverters from SMA with a capacity of 8.85 MW, 1657262578 m of copper wire and 177136298 m of aluminum wire. It uses actual data from 2000 to 2020 and model data from 2020 to 2040. In the first scenario, the 11 MW power plant with a load factor of 1.25 will produce 8.85 MW. This power plant's annual production capacity is 16760 MWh and its nominal performance is 81.7 percent. In the second scenario, the yearly production capacity of the power plant is 18880 MWh, and the nominal performance is 81.2 percent. This power plant's hourly production capacity is 1712.2 kWh. Figure (6) indicates the output capacity of the

Karun 4 Dam floating solar power plant and energy loss in substantial segments of the operation per month. The total percentage of losses is 19.9% and the highest is related to the shading effect. As is usually the case in solar power plants, the loss is due to temperature. However, here the effect of temperature has reduced the performance by 3.5%.

April through August have the largest production capacity, whereas November, December, and January have the lowest production capacity. The average monthly radiation was 1387.5 MWh and the lower 95% CI of the Mean was 1262 MWh and the upper 95% CI of the Mean was 1512 MWh. The lowest power generation month was recorded with 1100 MWh for November and the highest in May with the amount of 1700 MWh. Cable losses of 3.4 percent, soil and air pollution losses of 2%, irradiation losses of 0.4% , adverse effect of temperature on the performance of solar panels, followed by temperature deviation from the standard (25 °C) losses of 5.3%, shading losses of 4%, subsystem level losses of 3.5%, and total transmission wire losses of 3.5 percent Fig. (7) shows the floating solar power plant of Karun 4 Dam, as well as the geometric dimensions, potential shading challenges, and electrical engineering drawing.

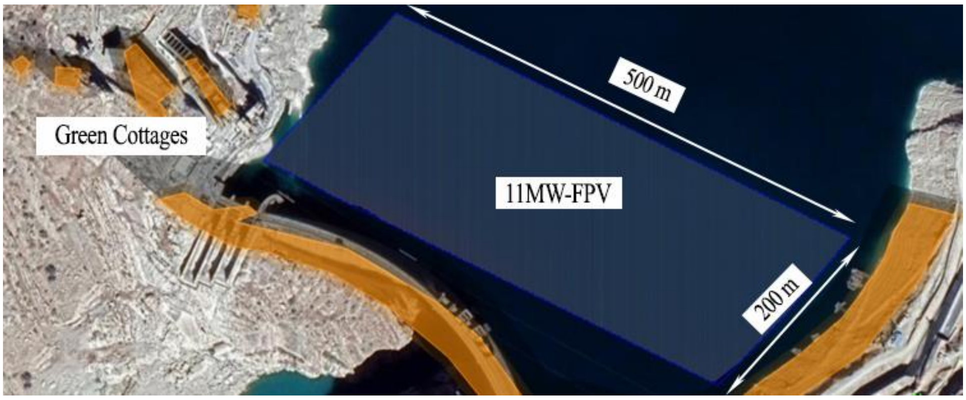
The dimensions of Karun-4 dam's floating solar power plant are 200 meters by 500 meters, with a total area of 100,000 square meters. This power plant has a single frame with a slope angle of 20 degrees and a row spacing of 70 cm. Figure 6 depicts guidance for connecting solar panels to the AC fuse, system maintenance panel, power meter monitoring, and mains circuit. The shading study findings reveal that solar irradiation on the surface is 97.5 %, by adjusting the angle structure, the inclination angle is suitable to reduce the shading effect and achieve the best nominal performance, 27.1 degrees in 175 degrees will be azimuth. The average amount of irradiation in this situation is found to be 2138.2 kWh/m^2. After removing the impacts of shadows and pollution, the total irradiation energy was calculated to be 1691.9 kWh/m2. Thus, in 4297 hours of operation, the hybrid renewable energy management system supplied 16758969 kWh to the grid.

The total emission of greenhouse gases equivalent to the energy produced by the floating solar power plant, which is equivalent to carbon dioxide, was calculated to be 13349 metric tons. Installation and covering of one square kilometer of FPV plant (Scenario 1) would supply electricity for 2260 green cottages while also improving the environment and reducing water evaporation. The standard operating temperature of a power plant is 18.9°C, whereas the average surface temperature of solar cells is 29.7°C. Expansion of analyses shows that if a floating solar power plant covers 10% of the lake reservoir of 5 dams with the requirements of Table (3), a total of 70.7 MCM will be saved each year. In terms of residential usage, this amount of water is enough to cover the annual demands of a city of one million people.

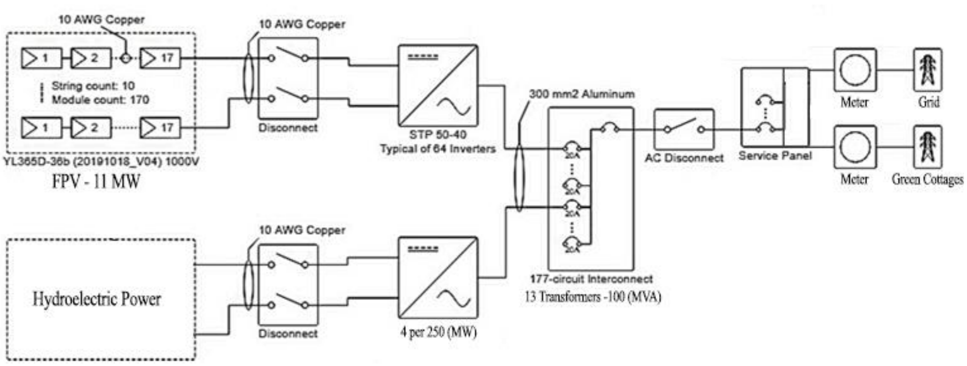


Monthly Production Energy Loss

Fig. 6. Monthly production capacity and energy loss in the power plant



A



B

Fig. 7. Karun-4 Dam's FPV power plant. A) power plant; B) electrical engineering drawing.

Table 3. Expansion of design results of Karun 4 dam floating solar power plant in Iran dams.

Characteristic	Unit	Dosti	Aras	Karkheh	Doroodzan	Kazemi
Dam tank volume (NWL)	ha	4932	15200	2100	5500	4150
NWL Save the entire tank	MCM	1250	1254	5600	960	650
Annual production energy	GW/h	-	86	394	45.5	-
Cover energy 2% of the dam reservoir surface	10^6 kWh	235.71	1178.53	2357.06	589.64	942.24
Cover energy 10% of the dam reservoir surface	10^6 kWh	591.47	2959.29	5918.43	147.10	236.74
Reduction of evaporation by covering 2% of the dam reservoir surface	MCM	524.1	1.469	6.911	3.076	1.161
Reduction of evaporation by covering 10% of the dam reservoir surface	MCM	7.620	7.345	34.554	15.378	5.804

Economic results show that investment costs for energy production return in 8.25 years. Floating solar power plant in the operation phase of 01/2020 to 01/2045 for 25 years and figures with a unit of one USD is assumed. The total cost of fixed investment before production is 3,345,392.00 USD. Net present value of total capital at 16.7% is equal to 2,685,633.66 USD and the Internal rate of return on investment (IRR) is equal to 26.96%. The period of return on movable capital at a discount rate of 16.7% is 8.25 with 0.8 NPV Ratio. At zero discount rate, the net present value is equal to 37,483,490.90 USD and at 10% is equal to 7,454,148.63 USD. At a discount rate of 30% net, the value of the negative capital is calculated to equal to -408,120.93. In this case, the NPV will be negative, and the project will not be economical. The value of a scrap of site number one of the floating solar power plant of Karun 4 dam in 2045 (end of operation period) will be equal to 2,685,633.66 USD. In this study, the benefit-cost ratio was calculated to be equal to 1.61.

5. Conclusions

Iran's 11 MWp FSPV design was explained in this study. The results include an FSPV design with the potential of the Karun-4 dam in Iran, producing over 11 MWp. On the 29 square kilometers of the Karun-4 dam reservoir, evaporation increases from shallow to more profound. This shows the inefficiency of extending point measurements to the whole dam reservoir surface. This is one of the benefits of the satellite HRES algorithm. The high surface evaporation of the water reservoir highlights the need to explore water loss prevention techniques. Water loss by evaporation at the surface of freshwater dam reservoirs should be measured more accurately using this result. With 2.09 kW usage, the green cottage was the most energy-efficient. Floating solar power plants generate 194 to 257 GWh of electricity per year when installed over a dam reservoir. The creation and coverage of one square kilometer of floating solar systems will generate electricity for 2260 green cottages while improving the environment and reducing water evaporation. Consumption began at dawn and reached 0.33 kW. The green cottage's load factor was 22%. In Iran, where discount rates are high and low feed-in tariffs, using 100% renewable electricity is not cost-effective. Cost-benefit analysis of a hybrid renewable energy conversion system from $0.05 to $ 0.06. The following suggestions are provided to manage and consume energy in a sustainable development model.

- Reduce or eliminate environmental impact.
- Increasing renewable energy feed-in tariffs (for residential use) is preferred in countries with weak economies.

The shift in precipitation distribution, temperature, and wind speed is significant and will likely impact the hydroelectric power plant and storage tank. Combining surface-floating photovoltaic power plants with conventional hydroelectric grid networks reduces energy costs and usage in the following ways:

- Hybrid Power Management can boost renewable energy usage and reduce environmental impact.
- Dynamically adjust power plant energy and water consumption management models.
- A distribution network's input load is related to its balance or imbalance.

Reference

[1] Norouzi M, Yeganeh M, Yusaf T. Landscape framework for the exploitation of renewable energy resources and potentials in urban scale (case study: Iran). Renew Energy 2021;163:300–19. https://doi.org/10.1016/j.renene.2020.08.051.

[2] Esmaeili Shayan M, Hojati J. Floating Solar Power Plants: A Way to Improve Environmental and Operational Flexibility. Iran J Energy Environ 2021;0.

[3] Mostafaeipour A, Zarezade M, Goudarzi H, Rezaei-Shouroki M, Qolipour M. Investigating the factors on using the solar water heaters for dry arid regions: A case study. Renew Sustain Energy Rev 2017;78:157–66. https://doi.org/10.1016/J.RSER.2017.04.102.

[4] Gonzalez Sanchez R, Kougias I, Moner-Girona M, Fahl F, Jäger-Waldau A. Assessment of floating solar photovoltaics

potential in existing hydropower reservoirs in Africa. Renew Energy 2021;169:687–99. https://doi.org/10.1016/j.renene.2021.01.041.

[5] Haas J, Khalighi J, de la Fuente A, Gerbersdorf SU, Nowak W, Chen PJ. Floating photovoltaic plants: Ecological impacts versus hydropower operation flexibility. Energy Convers Manag 2020;206:112414. https://doi.org/10.1016/j.enconman.2019.112414.

[6] IEA. Global Energy Review 2021 – Analysis - IEA n.d. https://www.iea.org/reports/global-energy-review-2021 (accessed August 27, 2021).

[7] Esmaeili Shayan M. Solar Energy and Its Purpose in Net-Zero Energy Building. In: Pérez-Fargallo A, Oropeza-Perez I, editors. Zero-energy Build. New approaches Technol., IntechOpen; 2020. https://doi.org/10.5772/intechopen.93500.

[8] Akbarifard S, Sharifi MR, Qaderi K. Data on optimization of the Karun-4 hydropower reservoir operation using evolutionary algorithms. Data Br 2020;29:105048. https://doi.org/10.1016/j.dib.2019.105048.

[9] Esameili Shayan M, Najafi G, Esameili shayan S. Design of an Integrated Photovoltaic Site: Case of Isfahan's Jarghouyeh photovoltaic plant. J Energy Plan Policy Res 2021;6:229–50.

[10] Mostafa Nosratabadi S, Hemmati R, Bornapour M, Abdollahpour M. Economic evaluation and energy/exergy analysis of PV/Wind/PEMFC energy resources employment based on capacity, type of source and government incentive policies: Case study in Iran. Sustain Energy Technol Assessments 2021;43:100963. https://doi.org/10.1016/j.seta.2020.100963.

[11] Alijani Z, Hosseinali F, Biswas A. Spatio-temporal evolution of agricultural land use change drivers: A case study from Chalous region, Iran. J Environ Manage 2020;262:110326. https://doi.org/10.1016/j.jenvman.2020.110326.

[12] Arnell NW, Kay AL, Freeman A, Rudd AC, Lowe JA. Changing climate risk in the UK: A multi-sectoral analysis using policy-relevant indicators. Clim Risk Manag 2021;31:100265. https://doi.org/10.1016/J.CRM.2020.100265.

[13] Sadorsky P. Wind energy for sustainable development: Driving factors and future outlook. J Clean Prod 2021;289:125779. https://doi.org/10.1016/j.jclepro.2020.125779.

[14] Sarbu I, Sebarchievici C, Sarbu I, Sebarchievici C. Solar Collectors. Sol Heat Cool Syst 2017:29–97. https://doi.org/10.1016/B978-0-12-811662-3.00003-7.

[15] Noorollahi Y, Janalizadeh H, Yousefi H, Jahangir MH. Biofuel for energy self-sufficiency in agricultural sector of Iran. Sustain Energy Technol Assessments 2021;44:101069. https://doi.org/10.1016/j.seta.2021.101069.

[16] Esmaeili shayan M, Najafi G, Gorjian S. Design Principles and Applications of Solar Power Systems (In Persian). First Edit. Tehran: ACECR Publication- Amirkabir University of Technology Branch; 2020.

[17] Abdi A, Taghipour S. An optimization model for fleet management with economic and environmental considerations, under a cap-and-trade market. J Clean Prod 2018;204:130–43. https://doi.org/10.1016/j.jclepro.2018.08.345.

[18] Esmaeili Shayan M, Esmaeili Shayan S, Nazari A. Possibility of supplying energy to border villages by solar energy sources. Energy Equip Syst 2021;9:279–89. https://doi.org/10.22059/EES.2021.246079.

[19] Sulaeman S, Brown E, Quispe-Abad R, Müller N. Floating PV system as an alternative pathway to the amazon dam underproduction. Renew Sustain Energy Rev 2021;135:110082. https://doi.org/10.1016/j.rser.2020.110082.

[20] Jin X, Sun X, Zhang X, Sun H, Xu R, Zhou X, et al. Sun orientation estimation from a single image using short-cuts in DCNN. Opt Laser Technol 2019;110:191–5. https://doi.org/10.1016/J.OPTLASTEC.2018.08.009.

[21] Pratumnopharat P, Leung PS. Validation of various windmill brake state models used by blade element momentum calculation. Renew Energy 2011;36:3222–7. https://doi.org/10.1016/J.RENENE.2011.03.027.

[22] Esmaeili MS, Najafi G. Energy-Economic Optimization of Thin Layer Photovoltaic on Domes and Cylindrical Towers. Int J Smart Grid - IjSmartGrid 2019;3:84–91.

[23] Fakhari I, Peikani P, Moradi M, Ahmadi P. An investigation of optimal values in single and multi-criteria optimizations of a solar boosted innovative tri-generation energy system. J Clean Prod 2021;316:128317. https://doi.org/10.1016/J.JCLEPRO.2021.128317.

[24] Li Y, Gao W, Ruan Y. Performance investigation of grid-connected residential PV-battery system focusing on enhancing self-consumption and peak shaving in Kyushu, Japan. Renew Energy 2018;127:514–23. https://doi.org/10.1016/j.renene.2018.04.074.

[25] Huang GCL, Chen RY, Park BB. Democratic innovations as a party tool: A comparative analysis of nuclear energy public participation in Taiwan and South Korea. Energy Policy 2021;153:112251. https://doi.org/10.1016/J.ENPOL.2021.112251.

[26] Rauf H, Gull MS, Arshad N. Integrating floating solar PV with hydroelectric power plant: Analysis of Ghazi barotha reservoir in Pakistan. Energy Procedia, vol. 158, Elsevier Ltd; 2019, p. 816–21. https://doi.org/10.1016/j.egypro.2019.01.214.

[27] Pouran HM. From collapsed coal mines to floating solar farms, why China's new power stations matter. Energy Policy 2018;123:414–20. https://doi.org/10.1016/j.enpol.2018.09.010.

[28] Ghasemzadeh F, Esmaeili Shayan M. Nanotechnology in the Service of Solar Energy Systems. Nanotechnol. Environ., London: IntechOpen; 2020. https://doi.org/10.5772/intechopen.93014.

[29] Fereshtehpour M, Sabbaghian RJ, Farrokhi A, Jovein EB, Sarindizaj EE. Evaluation of Factors Governing the Use of Floating Solar System: A Study on Iran's Important Water Infrastructures. Renew Energy 2020;171:1171–87. https://doi.org/10.1016/j.renene.2020.12.005.

[30] Ranjbaran P, Yousefi H, Gharehpetian GB, Astaraei FR. A review on floating photovoltaic (FPV)power generation units. Renew Sustain Energy Rev 2019;110:332–47. https://doi.org/10.1016/j.rser.2019.05.015.

[31] Lee N, Grunwald U, Rosenlieb E, Mirletz H, Aznar A, Spencer R, et al. Hybrid floating solar photovoltaics-hydropower systems: Benefits and global assessment of technical potential. Renew Energy 2020;162:1415–27. https://doi.org/10.1016/j.renene.2020.08.080.

[32] Ghritlahre HK, Prasad RK. Application of ANN technique to predict the performance of solar collector systems - A review. Renew Sustain Energy Rev 2018;84:75–88. https://doi.org/10.1016/j.rser.2018.01.001.

[33] Rauf H, Gull MS, Arshad N. Complementing hydroelectric power with floating solar PV for daytime peak electricity demand. Renew Energy 2020;162:1227–42. https://doi.org/10.1016/j.renene.2020.08.017.

[34] Menke JH, Bornhorst N, Braun M. Distribution system monitoring for smart power grids with distributed generation using artificial neural networks. Int J Electr Power Energy Syst 2019;113:472–80. https://doi.org/10.1016/j.ijepes.2019.05.057.

[35] Armghan H, Yang M, Wang MQ, Ali N, Armghan A. Nonlinear integral backstepping based control of a DC microgrid with renewable generation and energy storage systems. Int J Electr Power Energy Syst 2020;117:105613. https://doi.org/10.1016/j.ijepes.2019.105613.

[36] Kalogirou S. Survey of solar desalination systems and system selection. Energy 1997;22:69–81. https://doi.org/10.1016/S0360-5442(96)00100-4.

[37] Adesanya AA, Pearce JM. Economic viability of captive off-grid solar photovoltaic and diesel hybrid energy systems for the Nigerian private sector. Renew Sustain Energy Rev 2019;114:109348. https://doi.org/10.1016/j.rser.2019.109348.

[38] Zakeri B, Cross S, Dodds PE, Gissey GC. Policy options for enhancing economic profitability of residential solar photovoltaic with battery energy storage. Appl Energy 2021;290:116697.

https://doi.org/10.1016/J.APENERGY.2021.116697.

[39] Dehghan M, Rahgozar S, Pourrajabian A, Aminy M, Halek FS. Techno-economic perspectives of the temperature management of photovoltaic (PV) power plants: A case-study in Iran. Sustain Energy Technol Assessments 2021;45:101133. https://doi.org/10.1016/j.seta.2021.101133.

[40] Esmaeili shayan M, Najafi G, Banakar A. Design Green Branches of Iran's Banks with Renewable Power Plant. J Hum Environ 2019;0.

[41] Leonard MD, Michaelides EE. Grid-independent residential buildings with renewable energy sources. Energy 2018;148:448–60. https://doi.org/10.1016/J.ENERGY.2018.01.168.