Feasibility Study and Design of a Stand-alone Floating Photovoltaic Structure for Toshka Lake

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Abstract: - A novel energy production system known as floating photovoltaic technology has captured the interest of many people due to its many advantages. The floating photovoltaic system contributes to a reduction in water evaporation and an increase in energy output. The development of floating photovoltaic power plants necessitates the study of these systems from both an electrical and mechanical structure perspective for research objectives. Numerous studies have been conducted on floating photovoltaic systems from various angles that have examined these systems. The goal of this paper is to provide a standard design procedure and performance for the construction of a floating photovoltaic energy system at the surface of Toshka lake for the generation of electricity to a household using PV Syst. software. Also it provides a logical analysis and up-to date assessment of the many characteristics and elements of floating photovoltaic systems as an energy production system. The performance ratio analysis reveals that the lowest value was obtained in the month of March is 64% and the maximum value was obtained in the month of December is 82%whereas the average value for year is 71.3%. Analysis of losses has also been done.

Keywords: - PV Syst. Software, Toshka Lake**,** Floating PV, Performance Ratio.

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1 Introduction

Solar energy is the most suitable energy source.is now being used in many ways and have the potential to serve as an alternative source of energy-to-energy sources that are conformist [1]._The most well-known application for converting light energy into electrical power is a solar photovoltaic (PV) energy system [2].__A novel design approach for photovoltaic (PV) power plants is floating photovoltaic systems (FPVSs)._FPVSs are often built on water bodies like natural lakes or dam reservoirs. Since 2007, this technology has gained more global interest, and medium- and large-scale FPVSs have already been installed in various countries [3]. The first 20 kW FPV system installation was documented in Aichi, Japan and was built for research purposes [4]. Trapani and Santafé examine the floating PV developments installed between 2007 and 2013, including significant high-capacity setups with installed sizes of 175 kW carried out in California in 2008 and a 24 kW floating PV model installed in Spain in 2015 with the aim of reducing water loss as evaporation [5]. Ueda et al. construct the research for investigating the cooling effect and power output of FPV modules [6]. A 40 MW floating photovoltaic (FPV) system was recently installed in China, and it appears that in the near future, the capacity of floating PV installations will expand quickly [7]. Along with the mooring system, separate floats, PV panels, electrical cables, connections and power solar inverters utilized in the water, these components are crucial to the FPV power systems [8]._Additionally, Sacramento et al. examined the cooling effect of FPV panels on various water storage structures in Brazil in an area with moderate rainfall throughout the year and compared the productivity of floating PV power systems to solar PV systems mounted on the land [9]._In 2016, Sahu et al. examined the advantages and disadvantages of these systems [10]. This paper offers a logical analysis and contemporary evaluation of the many characteristics and components of FPVT systems as an energy production system. This work placed a lot of emphasis on modelling a 2.2 KWp **Stand-**alone floating photovoltaic and described the design procedure to address problems with PV module selection, inverter power sizing, site selection, string arrangement, and other relevant difficulties.

2 Location

Toshka Lakes in New Valley Governorate as shown in Fig. 1 has been chosen as an under consideration site The specific geographical location of Toshka Lakes is at a location of 23.1°N latitude, 30.9°E longitude, with an average daily solar energy of about 6.72 kWh/m2 global Horizontal Irradiance (GHI), while average Direct Normal Irradiance (DNI) reaches 7.92 kWh/day [11]. Toshka Lakes are natural depressions in the Sahara Desert that receive runoff from Lake Nasser, a 340-mile Nile River reservoir. The rise and decline of the lakes is influenced by changes in the flow of the Nile. In 2017 and 2018, for example, the lakes had shrunk to the size of tiny water remnants. This tendency began to reverse in 2019, when abundant summer rainfall in Sudan raised the water level in Lake Nasser, which began to fill the Tosha Lakes as well. This pattern continued in 2020, when record-breaking floods caused the highest water level ever measured in Lake Nasser. In 2021, Sudanese floodwaters reached new highs [12].

Fig. 1: Toshka Lakes

3 Stand-alone Photovoltaic System

Stand-alone PV systems are systems that are disconnected from the public electricity grid. Because the energy generated is typically not needed at the same time as it is created, these systems need an energy storage system. They are typically utilized in places where it is either not feasible or not acceptable to install an electrical supply from the main utility grid. Therefore, developing nations where sizable parts are typically still not supplied by an electrical system are preferred to them. The following are the primary parts of a typical stand-alone PV system [13]:

- Solar PV Modules: convert sunlight directly to electricity.
- Charge Controllers: manage the charging and discharging of the batteries in order to maximize their lifetimes and minimize operational problems.
- Battery or Battery Bank: Stores the energy generated by the PV modules.
- Inverter: converts the DC current generated by the solar PV modules to AC current for AC consumer load.

4 Elements of a FPV System

FPV system as shown in Fig. 2 consists of PV modules to collect solar energy, floats to provide buoyancy, a structure to support the PV panels, a mooring system to prevent the plant from moving around freely, electrical components, and optional efficiency systems make up a generic FPV system [14].

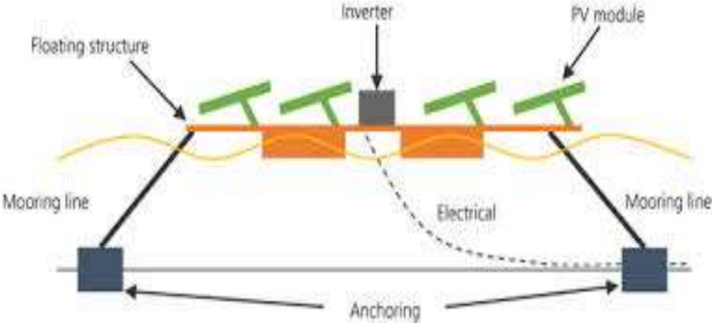


Fig. 2: Components of a generic FPV system.

4.1 Floats

The floats give the structure buoyancy to keep it afloat. They are typically constructed of high-density polyethylene (HDPE), a UV light-resistant, non-hazardous, maintenance-free plastic material with high tensile strength [15]. However, some denser elements, like steel or concrete have been taken into consideration [16]. The material's resilience to rot, fire, and penetration is another important quality. In order to prevent loss of buoyancy due to perforation of the floats, this final feature can be improved using expanding filling foams [17]. The floats are anticipated to resist heavier loads and the effects of saltwater corrosion and biofouling in marine applications [18]. HDPE is resistant to corrosion, but antifouling coatings may still be necessary for floats to maintain their mechanical characteristics [19]. In addition, HDPE has been noted as a possible source of microplastics. Plastic debris is a significant environmental issue. Sustainable plastics should be taken into consideration to lessen the environmental effects of plastic waste [20].

4.2 Supporting Structure

The PV modules and stresses between components are supported by transmitting through a metallic **structure** in the majority of FPV designs. However, some designs do not include this component and instead allow for a single PV module per float [21]. The supporting structure may also significantly contribute to maintaining the panels in marine applications at a safe height above sea level [22].

The structural components are typically made of materials like galvanized steel, high durability steel, or aluminum [23]. Corrosion is the main problem with steel or aluminum in marine industry. due to their exceptional seawater corrosion resistance [24] and lower density [25], composite materials, and particularly fibre-reinforced polymers (FRP), are being used in the maritime sector. On a number of FPV designs, FRP was chosen over steel or aluminum [26].

4.3 The Mooring Mechanism

The FPV plant is secured by the mooring system, which restricts its freedom of movement to reduce risk of harm to it or other floating entities. In freshwater endeavors, synthetic fiber rope, elastic rubber hawsers, or combinations of both, are used [27]. However, mooring lines are typically formed of steel chains or wire ropes in maritime floating structures [28].

4.4 Photovoltaic Panels

PV modules are constructed from solar cells, which require light-absorbing materials to absorb photons and produce free electrons via the photovoltaic effect [29]. PV panels are typically made of silicon, cadmium telluride, cadmium sulphide, organic and polymer cells, hybrid photovoltaic cells, and thin-film technology [30]. To date, large-scale FPV deployments have almost entirely used crystalline silicon wafer-based modules [31]. Flexible membranes built on thin-film technology, on the other hand, have been proposed. This adaptability could help maritime FPV systems withstand wave loads. In offshore environments, PV modules' resistance can be increased by raising panel stiffness or mounting strings and cells on the neutral axis. Crack formation can be reduced to some extent by using encapsulates with decreased elasticity. Using half-cut cells can also help to decrease fatigue. The offshore environment may also hasten PV module degradation, reducing plant dependability [32]. The spectral absorption of the solar panel cover glass will be reduced [33]. Salt particles that have accumulated may also impede output [34].

4.5 Electrical elements

To transform and transport electricity from FPV plants to land, a network of cables and electrical components is needed. Wiring can be done either above or below water. To reduce dangers, most electrical components are kept above water, but this does not negate the need to make them waterproof. Most cables that link the system are_subjected to high levels of UV radiation and significant temperature fluctuations, which must be taken into account when designing the cabling system [34]. The output voltage of PV modules does not match the AC grid voltage due to the intermittent nature of solar power plants and variations in load demand [35]. To achieve the required voltage, DC/DC converters are suggested [36]. When the necessary voltage is reached, an inverter connects the plant to the alternating current (AC) grid. These components are best maintained on the ground, but they can be installed on floating islands for large-scale projects and offshore uses [37].

The interconnection of the modules effects the plant's productivity due to partial shading. Partial shading losses can result in a yearly energy loss of 5-10% [38].

4.6 Efficiency systems

To maximize output, FPV plants can handle a range of optional systems. These include tracking, cooling, cleaning, and storage systems.

4.6.1 Tracking system

There is an optimal alignment of solar panels for each place and time that ensures peak performance. As a result, the tracking system's goal is to maximize energy gains over the lifespan of the PV system._Active, passive, semi-passive, manual, and chronological solar tracker drive methods are available [39].

Because the panels are floating, some alignment disturbances are to be anticipated, and the effect on electricity generation must be studied [40] Trackers can rotate around a single (horizontal or vertical) or dual (tip-tilt or azimuth-altitude) plane.

Tracking around the horizontal axis is possible in systems that enable tilting, most notably pontoon-based systems. There are several methods for tracking around the vertical plane in FPV. For this reason, some ideas, patents, and commercial designs include rotating platforms. Concentrating, which uses reflectors to enhance energy harvesting, can be combined with tracking [41]. The actuation method for the tracking system is typically a motor, but a design that uses wave energy to adjust the angle of the PV module for solar tracking has also been suggested [42].

4.6.2 System of cooling and cleansing

The photoelectric effect harvests energy from only a small portion of the sun spectrum. The remainder of the spectrum is unwanted irradiation, which raises the working temperature of the panels and reduces their efficiency. Water cooling can be maximized by positioning the panels on the water's surface, as seen in semi-submerged and thin-film arrangements [43]. Cooling systems are a different method to ensuring a low operating temperature. Cooling techniques suggested including forced air, Water Veil Cooling (WVC), and water spraying [44].

Aside from a reduced operating temperature, techniques based on applying water to PV cells have additional advantages such as solar spectrum modification [45], a change in reflected light, and panel cleaning benefits. These techniques necessitate an energy input that is consistent with the benefits of working at lower temperatures and mitigating negative dust effects. A WVC system requires less than 1% of the energy produced, while the energy gain is anticipated to be around 10% [46, 47].

The WVC also benefits from the decrease of reflected radiation. Irradiance reflection usually reduces the electrical yield of PV modules by 8-15% [48]. At high latitudes, where energy gains can rise by 4%, reducing reflection is advantageous. Some studies show that spraying water over the modules is advantageous, because the energy required to pump the water is offset by the efficiency gains. The primary causes of PV module degradation are temperature, humidity, and UV radiation [49]. Overheating of PV modules causes a number of ageing processes, including delamination, cell cracking, and solder bond degradation [50]. As a result, cooling methods may help to extend the life of FPV technology.

4.6.3 Storage system

Because of the variations in demand and generation, as well as the high expense of transmission cables for peak power levels, integrating renewable energy sources into the electric system is difficult. Storage systems may be used to resolve these issues [51]. Batteries, compressed-air energy storage (CAES), pumped water storage, and hydrogen production are examples of renewable energy storage options. The primary PV energy storage method has been limited to batteries [52]. Batteries, on the other hand, are expensive and have a limited life span, which results in the generation of hazardous waste [53]. Compressed-air energy storage (CAES) is a well-known method used in other renewable energy sources such as offshore wind [54].

5 PVSYST Software

The PVSYST is a more effective modelling tool that allows for a variety of possibilities, including creating a grid-connected PV system, a standalone PV system, small-scale energy production for pumping purposes, and just DC power production. The user can pick a certain design area and mitigate for a solution according on the requirement. The software also gives users the chance to create a rough design for marketing and consumer promotion of PV system installations. The detailed design is for solar installers, and it can produce results so that one can start the process of building up a solar PV plant based on the outcomes of the simulation [55]. This software aids in the design of the system's configuration and also allows for the calculation of the quantity of energy generated. The output is based on the simulation of the system, which is further influenced by the geographical location of the PV system. Several simulation factors may be included in the results, which can be displayed on a monthly, daily, or hourly basis values. The "Loss Diagram" forecasts system design flaws [56]. PVSyst simulation is carried out in the following steps.

6 Stand-alone PV system design

Floating stand-alone systems can range in power from a few milliwatts to several kilowatts and are not tied to any electricity grid. Solar modules, a controller, and an inverter are the basic components of floating standalone systems, which run on batteries [57]. DC power is generated by solar modules. The battery is charged by the charge controller, which channels this energy. The controller has two tasks to complete: charge the battery and guard against overcharging batteries. They do away with any reverse current. Anytime, day or night, the energy that is stored in the battery throughout the day can be utilized. The design of the Stand-alone PV system can be done using the following steps.

6.1 Calculating the load

Table 1 below provides information on the household's daily minimum load consumption requirements.

6.2 Battery specifications

Table 2 below provides a detailed list of all battery set specifications used in the design of the PV system.

6.3 PV array specifications

The details of the PV module used for the PV system design are presented in Table 3 below.

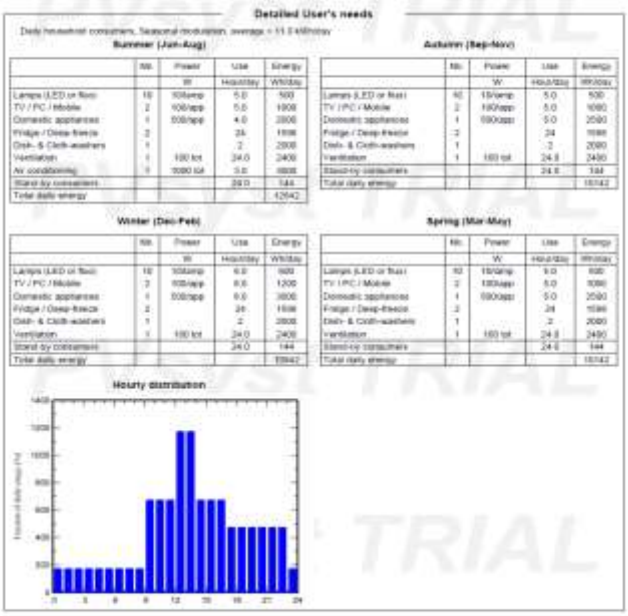
6.4 Charge Controller

The universal controller MPPT Converter as shown in fig.4 of 1000Wand 24 V is used to design the stand-alone PV system having maximum charging and discharging current i.e. 32 A to 20 A.

7 Solar horizon and geographic location

The monthly data of global irradiation, diffused irradiation, temperature, wind speed, etc. have been described in Table 5 using the PVsyst software. The section of the horizon in Fig. 3 illustrates how much of the sun is actually accessible. The blue line correlates to the photovoltaic modules' auto-shade, while the red line depicts shading around the sun-powered field that is essentially surrounded by far-off trees.

Table 1. the required load.


Detailed User's needs

Summer (Jun-Aug)

Autumn (Sep-Nov)

Winter (Dec-Feb)

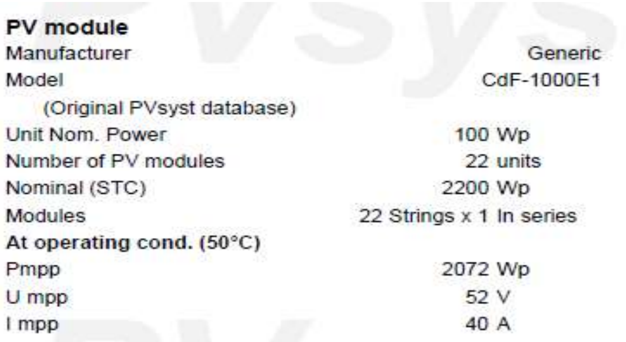
Spring (Mar-May)

Hourly distribution

Table 2. battery specifications

Battery	
Manufacturer	Generic
Model	Adjustable Lead-acid
Technology	Lead-acid, sealed, plates
Nb. of units	12 in parallel x 4 in series
Discharging min. SOC	20.0 %
Stored energy	7.7 kWh
Battery Pack Characteristics	
Voltage	48 V
Nominal Capacity	1200 Ah (C10)
Temperature	Fixed 20 °C

Table 3. PV array data.

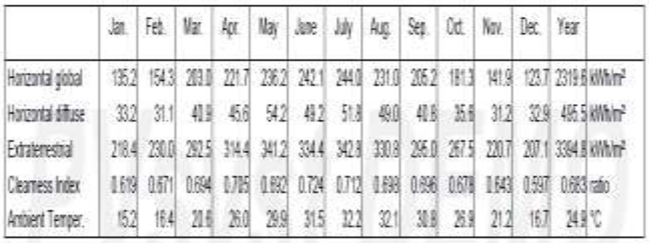


PV module	
Manufacturer	Generic
Model	CdF-1000E1
(Original PVsyst database)	
Unit Nom. Power	100 Wp
Number of PV modules	22 units
Nominal (STC)	2200 Wp
Modules	22 Strings x 1 In series
At operating cond. (50°C)	
Pmpp	2072 Wp
U mpp	52 V
I mpp	40 A

Table 4. Charge Controller specifications.

Controller	
Universal controller	
Technology	MPPT converter
Temp coeff.	-5.0 mV/°C/E
Converter	
Maxi and EURO efficiencies	97.0 / 95.0 %
Total PV power	
Nominal (STC)	2.20 kWp
Total	22 modules
Module area	17.7 m²

Table 5. The incident energy data by Mateo database.



	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Horizontal global	135.2	154.3	203.0	221.7	236.2	242.1	244.0	231.0	205.2	181.3	141.9	123.7	2319.6	kWh/m²
Horizontal diffuse	33.2	31.1	40.9	45.6	54.2	49.2	51.8	49.0	40.8	35.6	31.2	32.9	495.5	kWh/m²
Extraterrestrial	218.4	230.0	292.5	314.4	341.2	334.4	342.8	330.8	295.0	267.5	220.7	207.1	3394.8	kWh/m²
Clearness Index	0.619	0.671	0.694	0.705	0.692	0.724	0.712	0.698	0.696	0.678	0.643	0.597	0.683	ratio
Ambient Temper.	15.2	16.4	20.6	26.0	29.9	31.5	32.2	32.1	30.8	26.9	21.2	16.7	24.9	°C

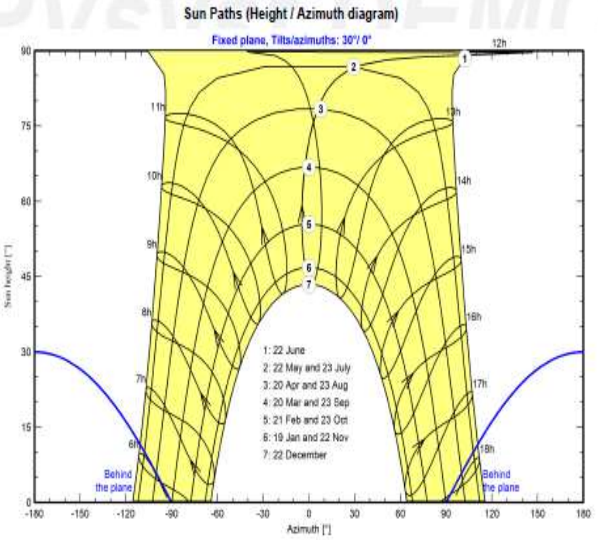


Fig. 3: Solar horizon.

8 Solar module tilting

According to Fig. 4, the filed structure is a fixed plane with a tilt of 20 and an azimuth of 0. The optimization is carried out for yearly irradiation yield with regard to the energy collector on the plane, which is 2481 kWh/m2,

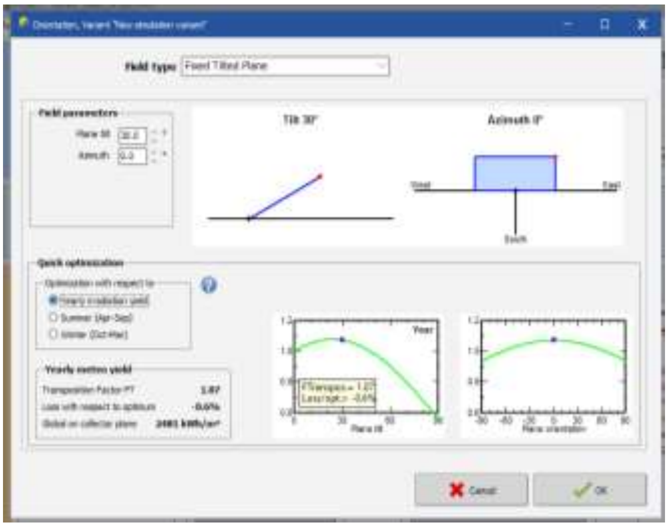


Fig. 4: Module orientation and tilt angle

9 Stand-Alone System Layout

The inverter module within the standalone PV architecture needs to be selected from the inverter database. A stand-alone SYSTEM schematic diagram is depicted in the figure below. The diode displayed here is the bypass diode used for protection, as shown in Fig.5. Due to the solar PV system's lower energy abdication, the power generated by it is utilized with as few losses. Therefore, it is necessary to reduce these losses by removing the parts that have an impact on the losses generated within the PV system. A few of the natural factors that affect PV system losses include dust, rain, and temperature, in addition to losses brought on by system components like cables and inverters.

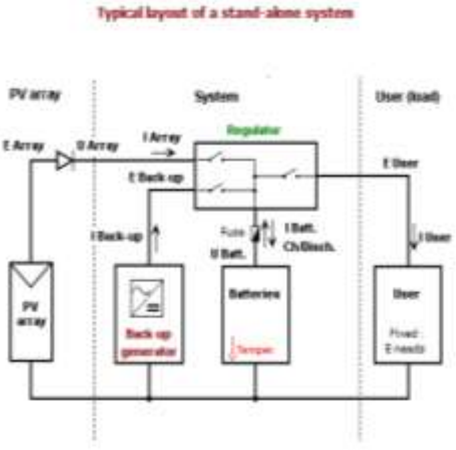


Fig. 5: Layout of stand-alone system.

10 Simulation Results

In this study, simulation is carried out using PVsyst software. For the proposed site only, all of the figures were produced through the simulation. The yearly equalizations and key outcomes for the standalone PV system are shown in Table 5 below. It is evident that the vitality which client can receive is 3890.6 kWh. Also, table 5 displays the solar fraction's numerical value for each month. The simulation computer program's execution proportion was nearly comparable for each month, as shown in Fig. 6 Figure 6 also displays the performance ratio and solar fraction. The final PV system yield (Yf) to the reference yield (Yr) ratio is known as the performance ratio (PR) The lowest PR was obtained in the month of March due to the high temperature of the PV module, and the maximum PR was obtained in the month of December because of the low module temperature. The PR is 71.3% on average each year. Fig. 7 shows the month-to-month vitality generation with losses Throughout the year, many types of field losses can occur in standalone photovoltaic systems, as shown in Fig. 8.

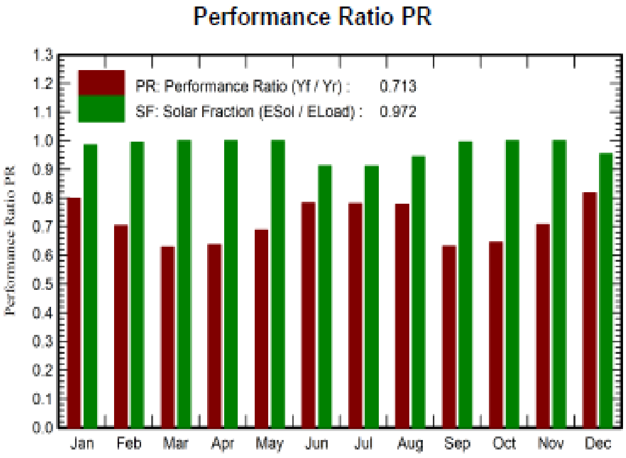


Fig. 6: Performance Ratio and Solar Fraction.

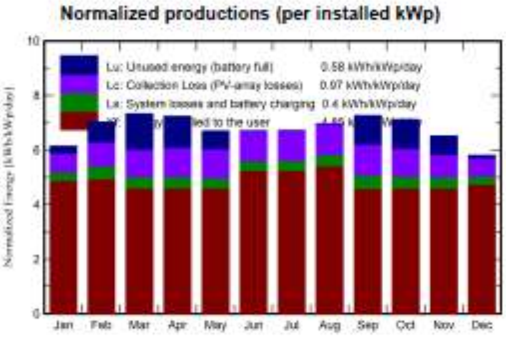


Fig. 7: Monthly Normalized productions with losses

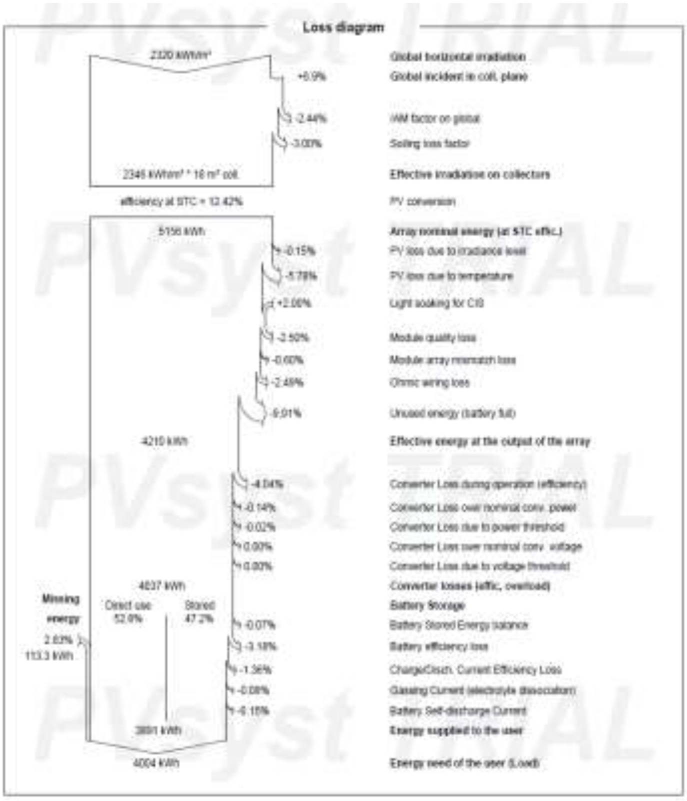
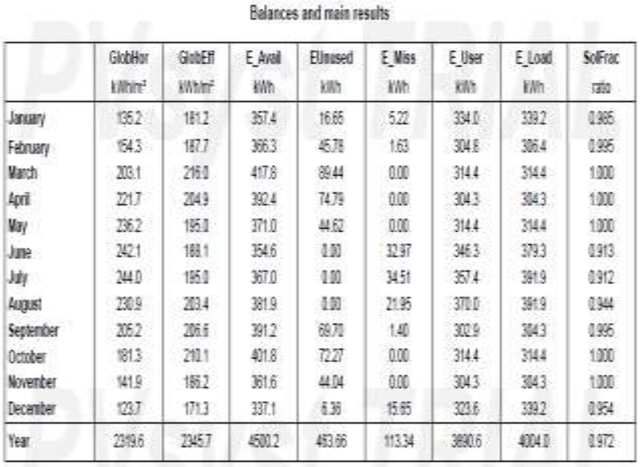


Fig. 8: Loss diagram for the whole year.

Table 6. The yearly equalizations and fundamental results of off-grid PV framework.



Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac ratio
January	135.2	181.2	357.4	16.65	5.22	334.0	339.2	0.985
February	154.3	187.7	366.3	45.78	1.63	304.6	306.4	0.995
March	203.1	216.0	417.8	89.44	0.00	314.4	314.4	1.000
April	221.7	204.9	392.4	74.79	0.00	304.3	304.3	1.000
May	236.2	195.0	371.0	44.62	0.00	314.4	314.4	1.000
June	242.1	188.1	354.6	0.00	32.97	346.3	379.3	0.913
July	244.0	195.0	367.0	0.00	34.51	357.4	391.9	0.912
August	230.9	203.4	381.9	0.00	21.95	370.0	391.9	0.944
September	205.2	206.6	391.2	69.70	1.40	302.9	304.3	0.995
October	181.3	210.1	401.8	72.27	0.00	314.4	314.4	1.000
November	141.9	186.2	361.6	44.04	0.00	304.3	304.3	1.000
December	123.7	171.3	337.1	6.36	15.65	323.6	339.2	0.954
Year	2319.6	2345.7	4500.2	463.66	113.34	3890.6	4004.0	0.972

11 Conclusion

This paper presents the design procedure and performance of a floating photovoltaic energy system for the generation of electricity at the surface of Toshka lake. The performance ratio and losses of this system have also been thoroughly studied using the PVsystsoftwre... The typical annual energy needs for a household is 4004 kWh, 4500.2 kWh are available from solar panels, and 3890.6 kWh are delivered to the consumer. Different types of losses account for the system's decreased power capacity. The performance ratio analysis shows that the lowest PR was obtained in the month of March due to the high temperature of the PV module, and the maximum PR was obtained in the month of December because of the low module temperature. The average PR for the year is 71.3%. In a simulation of a PV system, the module behavior determines the losses. The PVsyst software application examines all kinds of losses. The PVsyst software application examines every kind of loss. PVsyst tries to use the best models for each component of the PV system, including all potential causes of losses. This document acts as a better reference for solar practitioners and novices who are interested in setting up solar stand- alone photovoltaic systems. PVSYST software can be used to precisely evaluate various system losses.

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