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Research Article/Araştırma Makalesi

A Study of the Importance of Using Solar Pumps for Pumping Water from Deep Wells and Ways to Increase the Efficiency of their Production

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Keywords
Solar energy, photovoltaic system, water pumping systems, solar radiation, agricultural,increase power ,increase efficiency.

Abstract
Due to the deterioration of world oil prices, it has become necessary to look for alternative sources to provide energy, and among these alternatives is solar energy, as it is one of the most important alternative energy sources that can be used in various fields such as agriculture and other - due to its many advantages, and the geographical position of Iraq has contributed to the development of the use of energy solar panels in the country due to the intensity and duration of solar radiation, and thanks to this feature, our country can cover its needs with energy to fill the gap in most vital areas, and also for use in agriculture, industry where Stand - alone solar pumping systems typically use a Variable Speed Drive to control the electric motor to run at various speeds depending on the available sunshine power.And also The inverter that converts the dc power from the sun to ac power uses the space vector pulse width to feed the motor. Under a constant v/f ratio,where a modulation method is used It controls the motor's power consumption (rather than its speed) in order to adapt it to the available power on the photovoltaic system. The variable speed operation of the motor as a result of solar power's flux increased has an impact on Pump hydraulic efficiency and performance (The electric pump cures) a result, on the yield of water. Because the operating flow is not continuous, this speed control operation has an impact on the well characteristics.

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The aims and objectives

The aim of the project is to analyze conduct design a water pumping system that works with photovoltaic system and meets the needs of agricultural regions, and find ways to use most of the incident solar radiation to drive a solar pump and benefit from it in the field of irrigation or watering water, where PVsyst 7.3 programs will be used.

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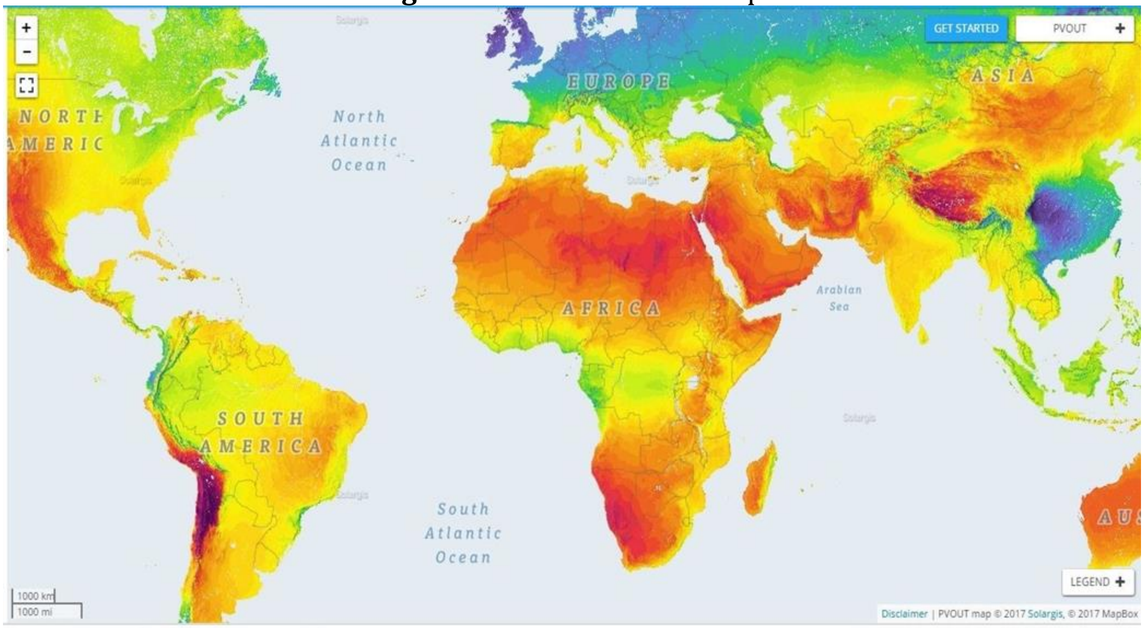
1. Introduction

Parallel to the rapid increase in the world population, the need for food and energy is also increasing rapidly. According to 2018 data of the United Nations Food and Agriculture Organization, 45% of the world's population lives in rural areas, more than 2 billion people (26.7%) live their lives based on agriculture, of more than 570 million agricultural lands in the world. Much of it is cultivated by individuals or families, and more than 80% of agricultural production worldwide is carried out by these families [1]. Irrigation is the supply of water to plant roots in a controlled manner, when necessary, in order to help agricultural plants grow. A large amount of water is required for production. Three sources that can be used as irrigation water; Surface water, groundwater and treated wastewater obtained from unconventional sources (treated wastewater and desalinated water) Summer periods are the only irrigation periods in some regions, while irrigation may be required throughout the year in some regions. This situation varies according to the amount of sunshine in the irrigation area, the amount of groundwater, rain, soil structure and product [2]. Electric pumps and therefore electricity are needed to carry this water, which is needed for irrigation purposes, from one place to another. Today, Solar Water Pumping Systems are widely accepted around the world, the fact that fossil fuel reserves will decrease in the future and electricity transmission infrastructure investments cause high costs, especially in developing countries, make Solar Water Pumping systems more important. Solar Water Pumping systems provide reliable and acceptable performance while providing utility and irrigation water supply, especially in remote rural areas. And in regions where transmission line infrastructure is not available, Solar Water Pumping systems are becoming increasingly common [3]. Solar Water Pumping System is very advantageous compared to conventional systems, especially in regions with high radiation amount such as Africa, and South America, South Asia. As shown in Fig (1), the applications of Solar Water Pumping System in all regions where the amount of radiation is high in the world radiation map have become very attractive today [4]. The highest solar radiation values in the world are in the regions close to the equator. In these regions, the amount of radiation in winter and summer months is very close to each other. In regions far from the equator, the highest amount of radiation is observed in summer. Generally planting and growing periods of plants are spring and summer respectively. Therefore, the irradiance values in these periods are of critical importance for the analysis of Solar Water Pumping System applications. In the literature, studies comparing the Solar Water Pumping System and conventional water pumping systems (Diesel generator, grid-connected systems) across the world and revealing the advantages and disadvantages of Solar Water Pumping System applications.

Figure 1. World radiation map



2. Material and Method

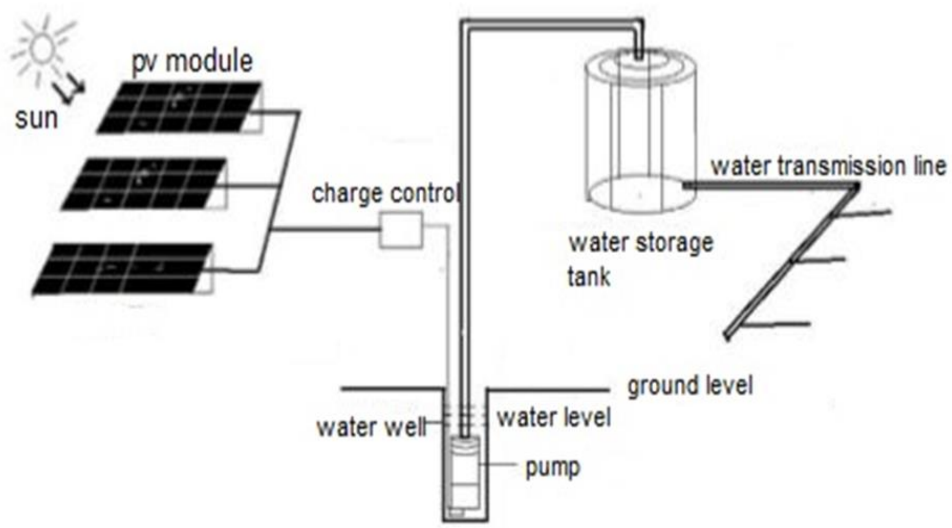
2.1. Components of a solar water pumping station [5].

The typical photovoltaic solar water pumping station consists of:

- Photovoltaic solar panels
- The transformer/control unit
- The pump
- Lightning arrester on the direct current side
- Mobile interrupter (on/off)
- The insulator for the continuous electrical current
- AC circuit breaker (for the pump)
- The fuse for alternating current
- The fuse for continuous electric current
- 10-Control box
- The wires
- Tank

When sunlight hits a cell, that light passes through the surface of the cell and some of it is absorbed by the cell's first layer, which is the layer containing phosphorus[6]. As for the greater part of the light incident on this cell, it is absorbed by a special part, i.e. layer containing a mixture of silicon, and in this case free electrons are formed. Movement can flow through the electrical connector at the ends of the cell, since this movement increases with the intensity of the light falling on the cell, and thus a DC electrical current is formed, and this current is produced from solar energy and the panel is converted by a transformer that directs it to the pump and where into an alternating current suitable for its operation, whether it be single-phase 220 volts or three-phase 380 volts, and as know, this transformer can control the frequency of the pump's power depending on the amount of radiation incident by controlling the frequency power supply to the pump, and thus the pumped water flows, so we control the energy absorbed by the pump, and as you know, in the morning, and as soon as there is enough sunlight falling on the photovoltaic panels, the transformer starts to work, and thus Thus, the latter starts to feed the pump at a low frequency, which increases with the intensity of solar radiation, and this works with a transformer equipped with the latest MPPT technology, as it increases the frequency of power supply to the pump by supplying the maximum that the photovoltaic generator can provide directly to the transformer[7] .

Figure 2. Typical photovoltaic solar water pumping station



The number of solar panels is calculated by knowing the peak hours of the sun, as follows:

Panel energy = daily consumption / number of hours of sunshine

Daily consumption = power of any device * duration of use of the device

Number of panels required = total energy / energy per panel

The inverter is also chosen according to the following rules:

Power of inverter > Current solar panels

Power of inverter > Power of the pump

Output of the inverter > The nominal current of the pump

- **Pump efficiency is calculated [8].**

$$\eta = \frac{\rho * Q * g * h}{Pa} * 100\%$$

Pa: active energy

h: required pumping height

And to calculate the flow rate

$$Q = \frac{L}{\sum h} \times \frac{1h}{60min}$$

L: the number of liters of water required per day

h: the number of peak hours per day

- **The pump law is**

Ph = Htot * Qs * ρ * g

Ph: hydraulic power generated by the pump

Htot: water column.

Qs : water flow [m^3/sec].

ρ: 1000 water equals the specific mass [kg/m^3].

The gravitational constant is 9.81 g.

- **To calculate the size of the pump, you must first know the amount of water required per day[9].**

Hd=Hw+Hs+Hf

Hd: dynamic pumping height

Hw: high water pumping

Hs: pumping height of the tank

Hf: Friction losses in pipes

- **The losses are divided into two types [10]**

1- Principal losses, which result from friction losses, and can be calculated from Darcy Weissberg law

$$h_v = λ \frac{ʆ.v2}{2gd}$$

hv: friction loss in the pipe, expressed in metres

λ: friction factor

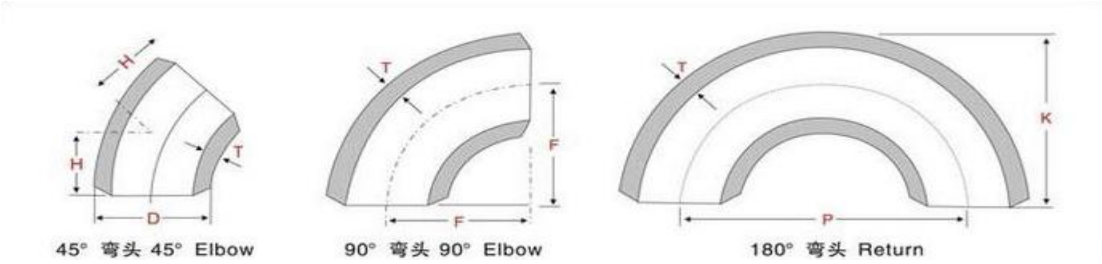
ʆ: The length of the straight pipe is measured in meters

v : average velocity in meters per second

g: gravitational pull

d: the diameter of the pipe is measured in metres

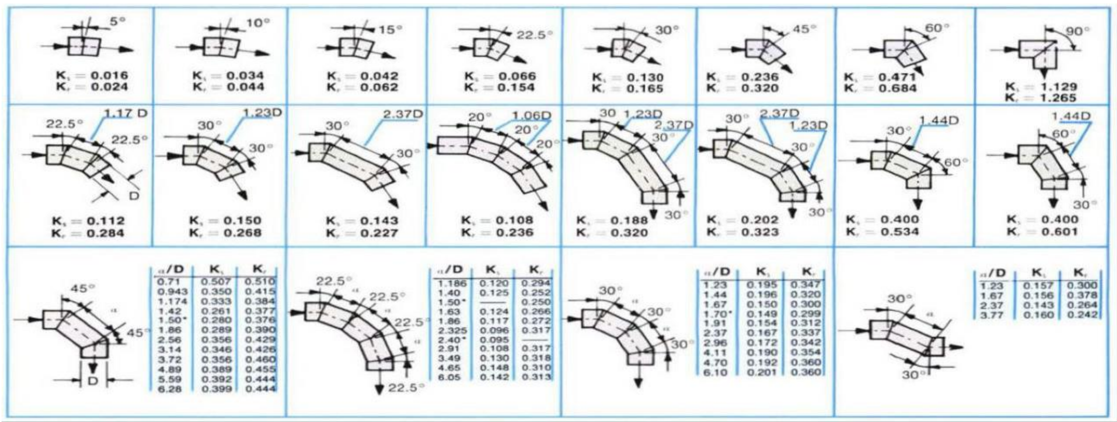
2- Secondary losses, which result from the use of fittings, valves, or pipe bending



Where the value of secondary losses can be calculated through

Minor losses = $kv^2/2g$

Where K = a value extracted from the tables, its value is given for different types of accessories and valves



3. Solar pumping system design

Before designing any solar pumping system, we must know to determine the volume of water to be pumped every day, in addition to determining the location of the system correctly, as well as determining the specifications of the well, where the specifications of the well can be obtained from the Water Resources Department in each country, as in the model to be worked on with the following example and using the program Pvsyst for the purpose of studying the characteristics of a solar pumping system, using the information mentioned above, as this model was obtained from (Green Power Company), the green energy company for solar energy, and through an educational course in knowing the basics of renewable energy .

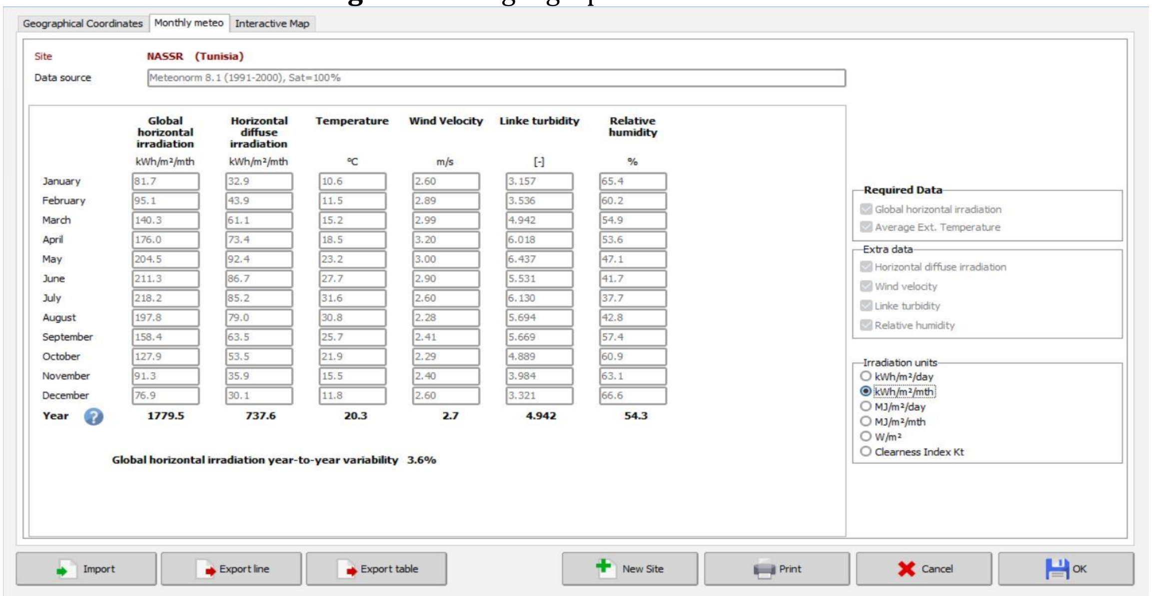
EXAMPLE:-

Designing an irrigation station powered by solar energy for a farm that contains a well. The depth of the well is 176 meters and the height of the tank is 6 meters. Note that the amount of water required is 30 cubic meters / day in the Al-Ramadi district in Iraq. What is the size of the required pump and is there an economic feasibility?

The geographical coordinates of this area

N	33	25	46
E	42	30	20

Figure 3. The geographical coordinates



	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	81.7	32.9	10.6	2.60	3.157	65.4
February	95.1	43.9	11.5	2.89	3.536	60.2
March	140.3	61.1	15.2	2.99	4.942	54.9
April	176.0	73.4	18.5	3.20	6.018	53.6
May	204.5	92.4	23.2	3.00	6.437	47.1
June	211.3	86.7	27.7	2.90	5.531	41.7
July	218.2	85.2	31.6	2.60	6.130	37.7
August	197.8	79.0	30.8	2.28	5.694	42.8
September	158.4	63.5	25.7	2.41	5.669	57.4
October	127.9	53.5	21.9	2.29	4.889	60.9
November	91.3	35.9	15.5	2.40	3.984	63.1
December	76.9	30.1	11.8	2.60	3.321	66.6
Year	1779.5	737.6	20.3	2.7	4.942	54.3

- **Orientation of PV modules**:

For our simulation, we have chosen a fixed inclined plane with an inclination of 33° (for horizontal) as shown in figure (4), this is the optimal inclination given by the PVSYST software, outside the latter the efficiency decreases.

Figure 4. Angle direction

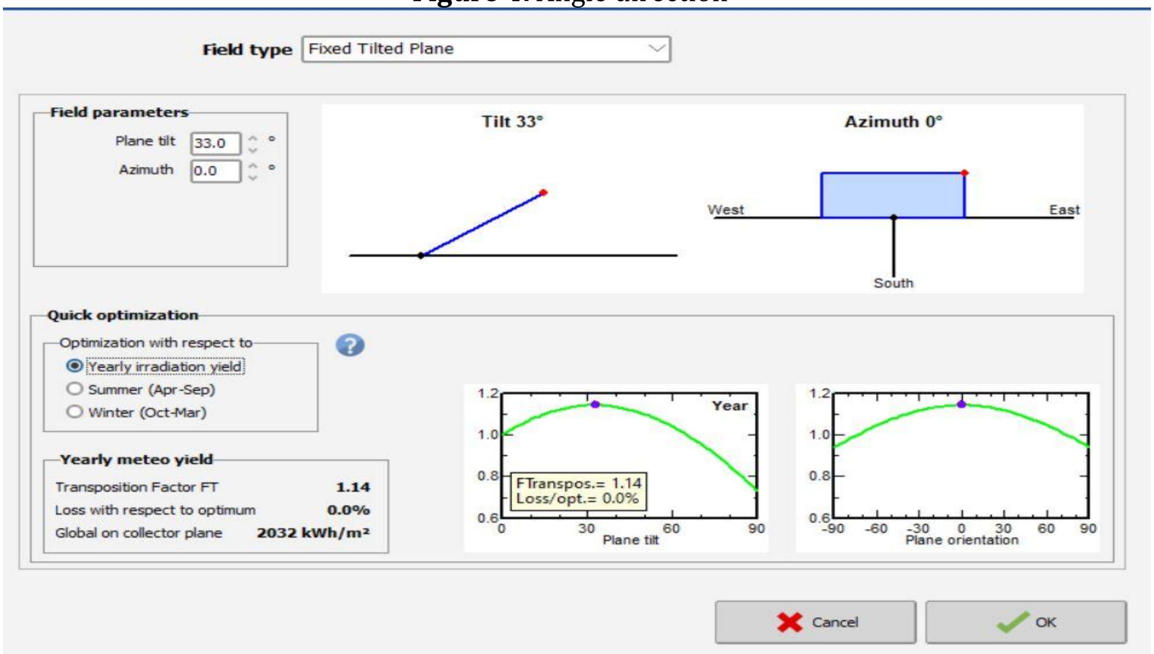


Figure 5. Pumping circuit.

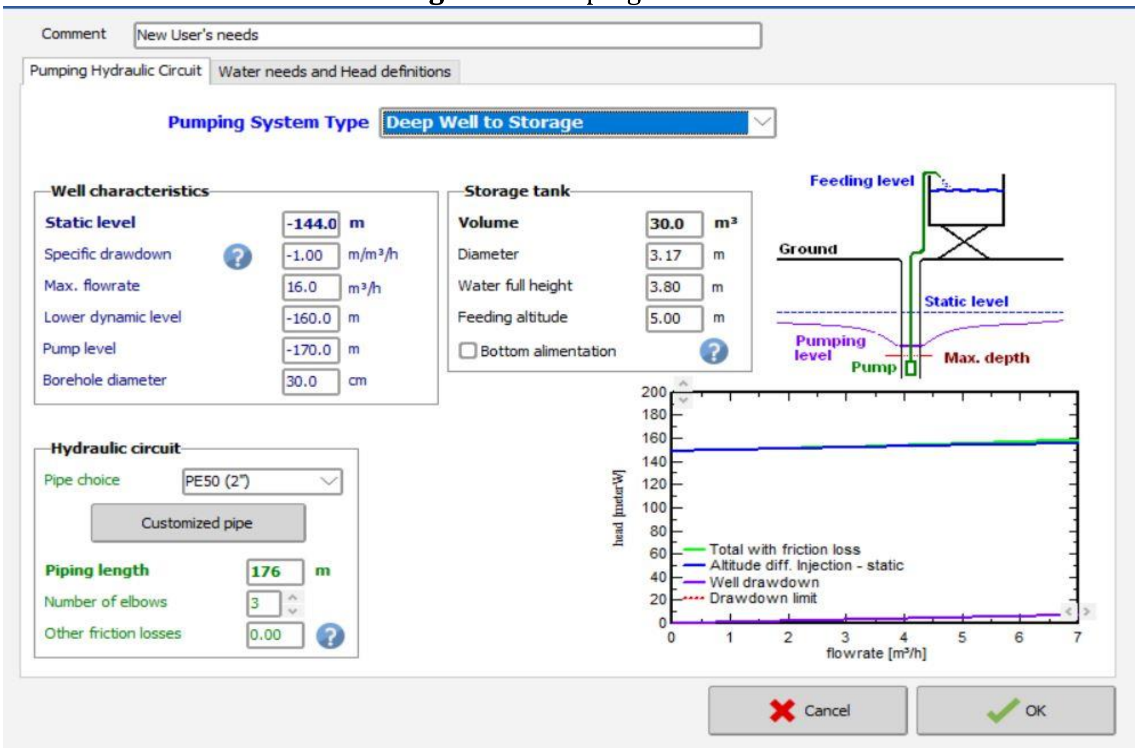
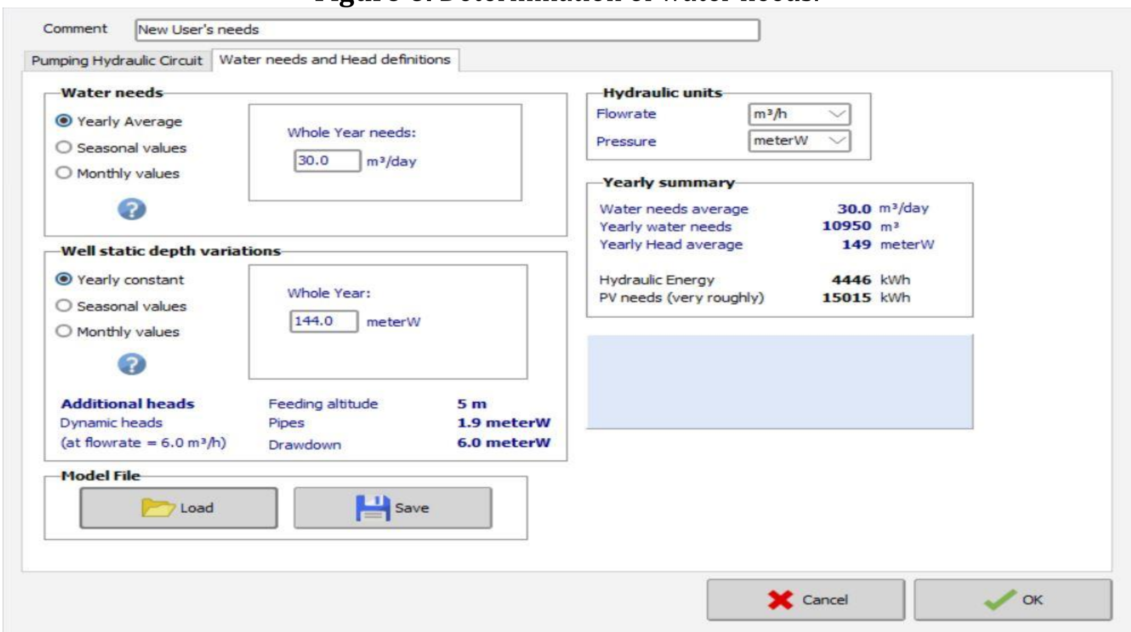


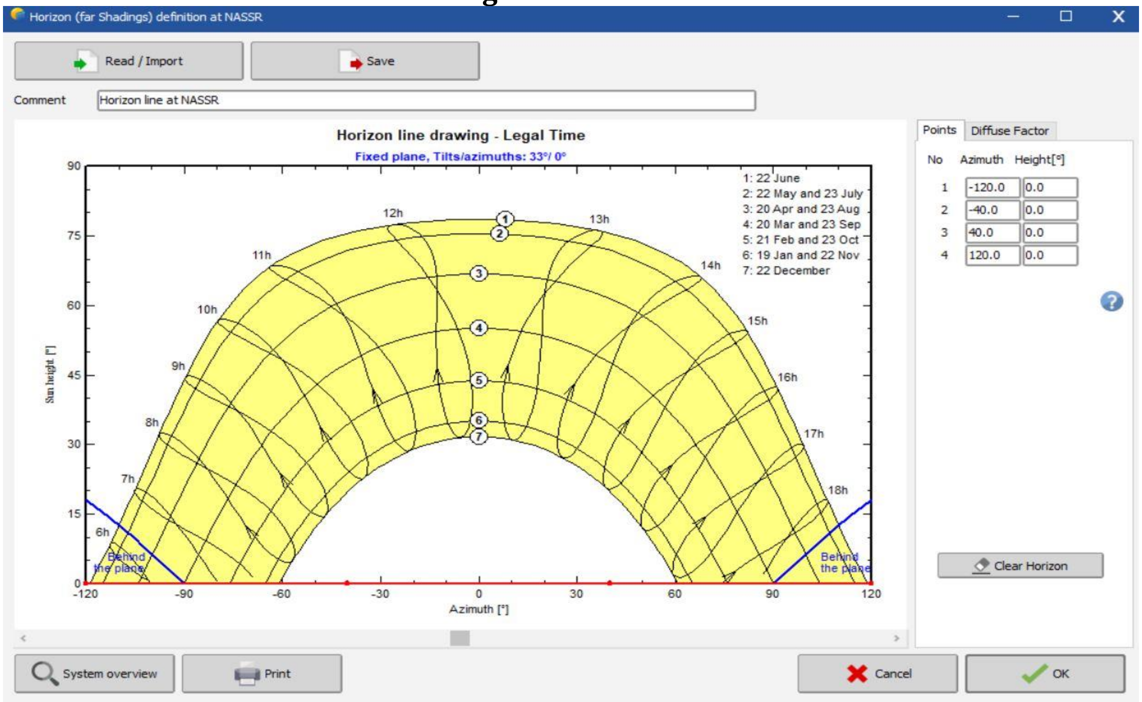
Figure 6. Determination of water needs.



- **Horizon profile:-**

A horizon profile is a dashed line superimposed on a path diagram the sun, which can contain any number of elevation points and the direction of the PV modules For our simulation, we chose a fixed inclined plane with an inclination of 33 degrees (for Horizontal) As shown in Figure (7), this is the optimum slope given By PVsyst software, outside of the latter the efficiency decreases

Figure 7. Horizon

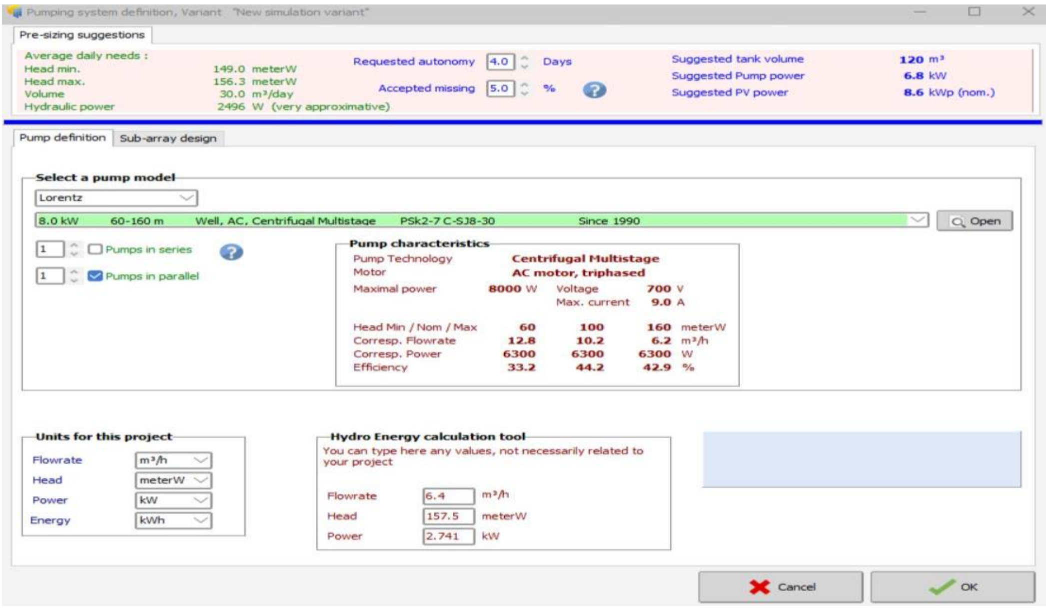


- **Determination of hydraulic power:-**

The hydraulic power is expressed by the relation

Ph=Ep*Qv

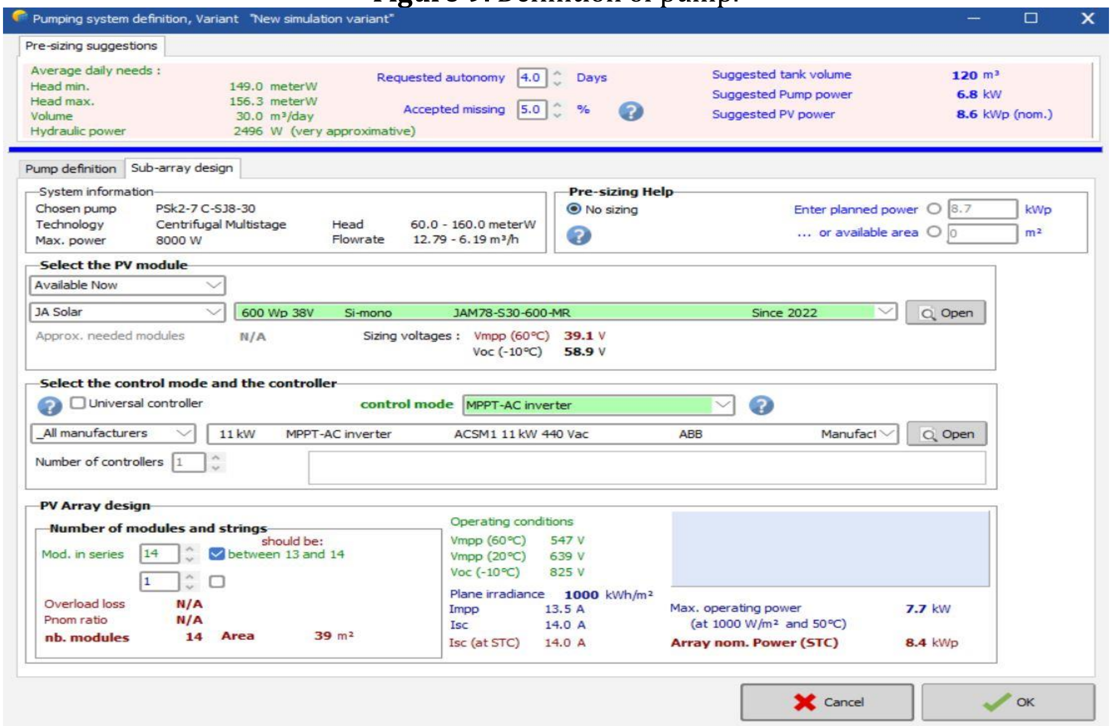
Figure 8. Hydraulic power



- **Choice of pump:-**

We will choose the pump that best meets the conditions that we have defined in sizing

Figure 9. Definition of pump.



- **Characteristics of the pump:-**

  1- Model: PSK2-7C-SJ8-30 Lorentz.

  2- Pump technology: multi-stage centrifugal.

  3- Type of pump: submerged.

  4- Maximum power: 8000W.

  5- Flow rate: 12.79-6.19 m3/h.

  6- MPP voltage:500 - 850V.

  7- Maximum height: 60-160m.

  8-Efficiency :42.9%

- **Inverter Characteristic:-**

  1- Minimum MPP voltage: 500 V.

  2- Maximum MPP voltage: 850V

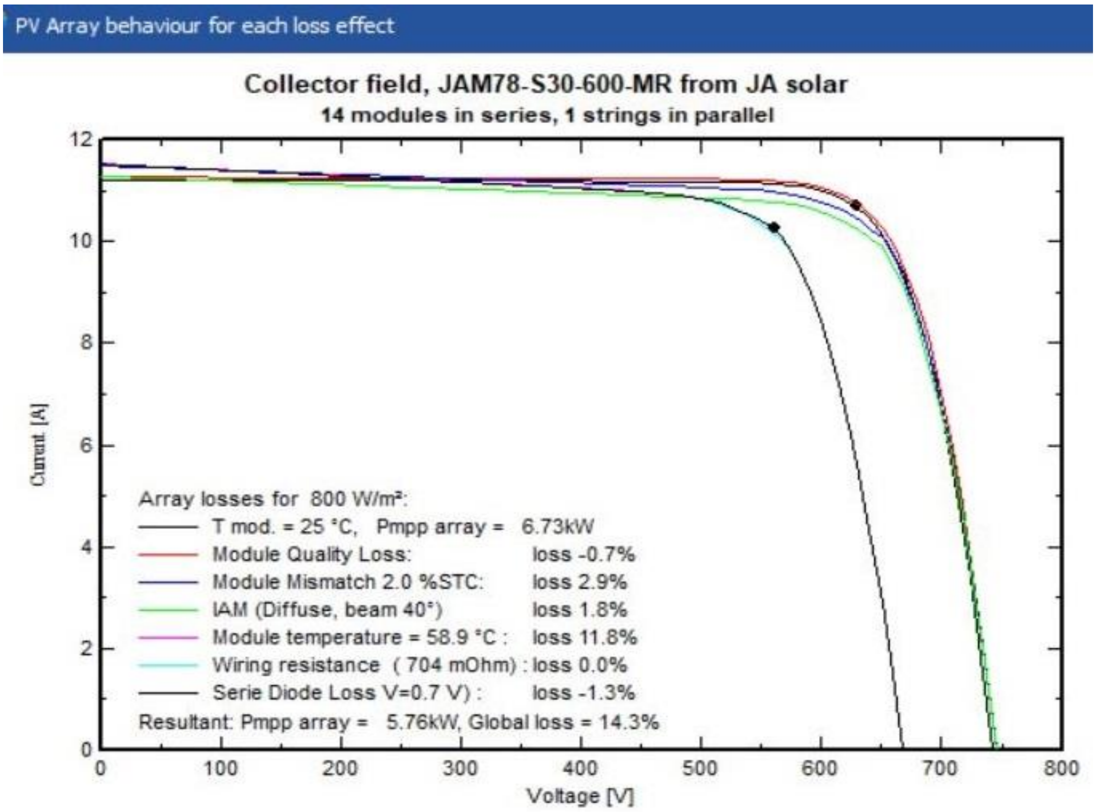
  3- Maximum input current: 13 A.

  4- Power: 8000 W.

  5-Yield: 98%.

- **PV generator size:**

Depending on the power required by the pump and the incident daily irradiation on the plane the generator which converts solar energy into electrical energy in the form of voltage and direct current, in our case we will choose an inclination of (33°) with respect to latitude of place alramadi in iraq, the face of the panels must be oriented towards the south, to take advantage of sun all day, and choice of PV solar panels it is mandatory to know the operating voltage of the pump (Vch500-850V) before defining the type and number of solar panels as well than their coupling. A-14-1 The type of PV module for the similar application For our simulation, the model (JAM78-S30600-MR JA solar) which best responds to this condition has as above.



- **Influence of illumination on the external characteristics of the module:**

To carry out a study on the influence of illumination on the external characteristics of the panel, the temperature is fixed at 45°C and only the illumination is varied. The figure presents curves for different levels of illumination.

- **Where the results of the analysis appear in the program pvsyst 7.3 as follows**

Project: NASSR

Variant: New simulation variant

PVsyst V7.3.1
VC0, Simulation date:
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with v7.3.1

General parameters

Pumping PV System — **Deep Well to Storage**

System Requirements

Basic Head	149 meterW

Water needs

Yearly constant	30.00 m³/day

Well characteristics

Static level depth	-144 m
Specific drawdown	-1.00 m/m³/h
Diameter	30 cm
Pump level	-170 m
Lower dynamic level	-160 m

Storage tank

Volume	30.0 m³
Diameter	3.2 m
Feeding by top	
Feeding altitude	5.0 m
Height (full level)	3.8 m

Hydraulic circuit

Piping length	176 m
Pipes	PE50
Dint	54 mm

PV Field Orientation

Fixed plane	
Tilt/Azimuth	33 / 0 °

PV Array and Pump

PV module

Manufacturer	Generic
Model	JAM78-S30-600-MR
(Original PVsyst database)	
Unit Nom. Power	600 Wp
Number of PV modules	14 units
Nominal (STC)	8.40 kWp
Modules	1 String x 14 In series
At operating cond. (50°C)	
Pmpp	7.67 kWp
U mpp	570 V
I mpp	13 A
Total PV power	
Nominal (STC)	8 kWp
Total	14 modules

Pump

Manufacturer	Generic
Model	PSk2-7 C-SJ8-30
Pump Technology	Centrifugal Multistage
	Deep well pump
Motor	AC motor, triphased
Associated or Integrated converter	
Type	MPPT
Voltage range	500 - 850 V

Operating conditions

	Head min.	Head Nom	Head max.	
	60.0	100.0	160.0	m
Corresp. Flowrate	12.79	10.21	6.19	m³/h
Req. power	6300	6300	6300	W

Control device

Manufacturer	Generic
Model	ACSM1 11 kW 440 Vac
System Configuration	MPPT-AC inverter

Pumping system controller

System Operating Control

Power Conditioning Unit

Type	MPPT-AC inverter
Operating conditions	
Nominal power	8000 W
Power Threshold	80 W
Max. efficiency	98.0 %
EURO efficiency	96.0 %
Minimum MPP Voltage	500 V
Maximum MPP Voltage	850 V
Maximum Array Voltage	850 V
Maximum Input Current	13.0 A

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System losses

Array Soiling Losses

Loss Fraction	3.0 %

Thermal Loss factor

Module temperature according to irradiance

Uc (const)	15.0 W/m²K
Uv (wind)	0.0 W/m²K/m/s

DC wiring losses

Global array res.	704 mΩ
Loss Fraction	1.5 % at STC

Serie Diode Loss

Voltage drop	0.7 V
Loss Fraction	0.1 % at STC

LID - Light Induced Degradation

Loss Fraction	2.0 %

Module Quality Loss

Loss Fraction	-0.8 %

Module mismatch losses

Loss Fraction	2.0 % at MPP

Strings Mismatch loss

Loss Fraction	0.1 %

Module average degradation

Year no	25
Loss factor	0.4 %/year
Mismatch due to degradation	
Imp RMS dispersion	0.4 %/year
Vmp RMS dispersion	0.4 %/year

IAM loss factor

Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

Project: NASSR

Variant: New simulation variant

PVsyst V7.3.1
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Main results

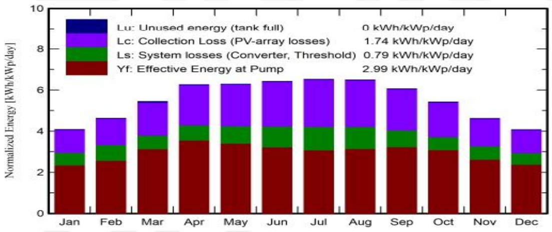
System Production

Water		**Energy**		**Efficiencies**	
Water Pumped	6577 m³	Energy At Pump	9177 kWh	System efficiency	79.1 %
Specific	52 m³/kWp/bar	Specific	1.40 kWh/m³	Pump efficiency	29.9 %
Water needs	10950 m³	**Unused (tank full)**			
Missing Water	39.9 %	Unused PV energy	7 kWh		
		Unused Fraction	0.1 %		

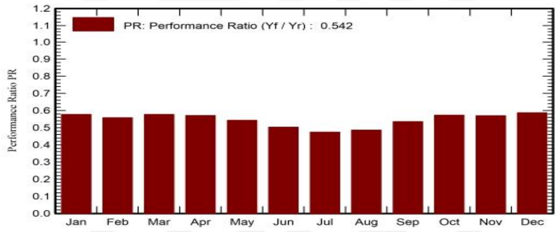
Economic evaluation

Investment		**Yearly cost**		**Specific Cost**	
Global	64,689.06 USD	Annuities	0.00 USD/yr	Water Cost	0.00 USD/m³
Specific	7.70 USD/Wp	Run. costs	0.00 USD/yr	Energy cost	0.00 USD/kWh

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

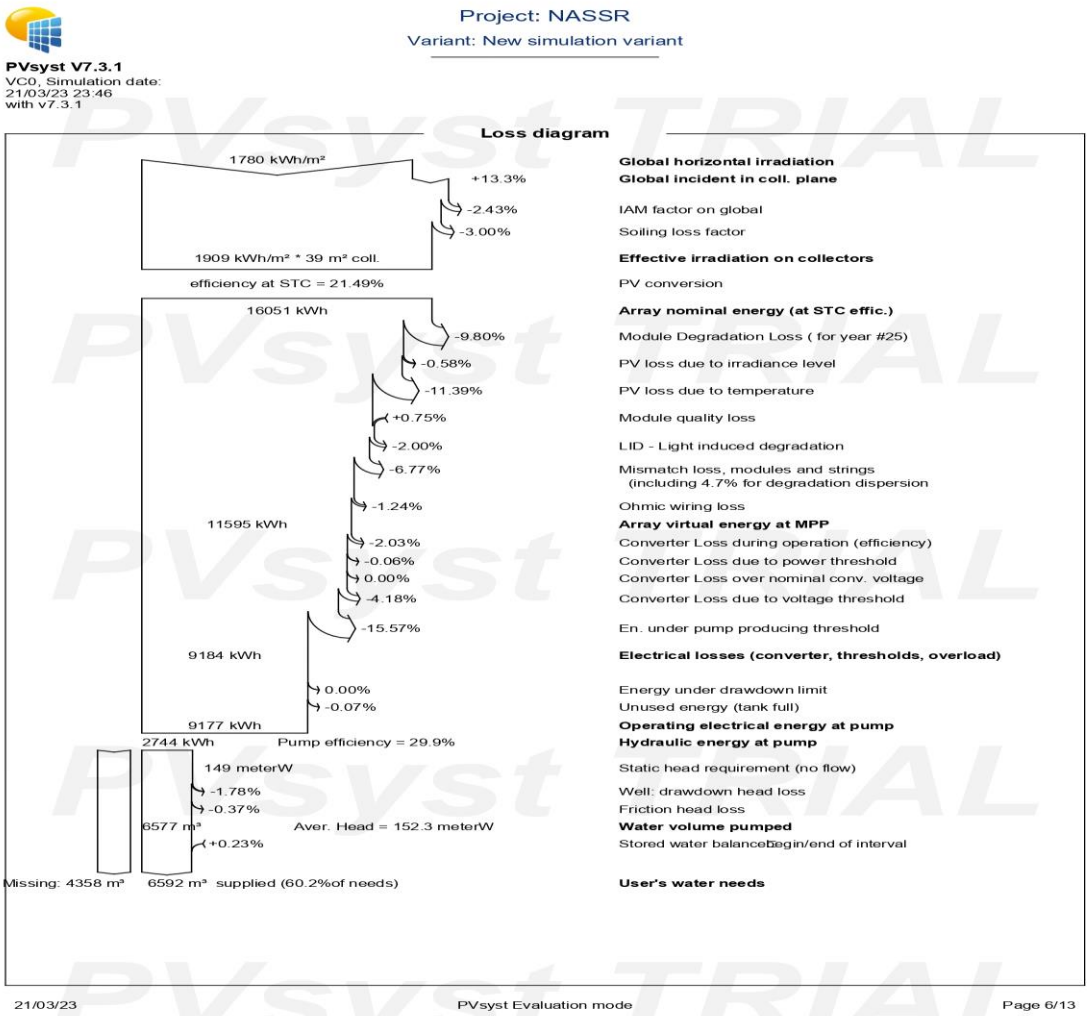
	GlobEff kWh/m²	EArrMPP kWh	E_PmpOp kWh	ETkFull kWh	H_Pump meterW	WPumped m³	W_Used m³	W_Miss m³
January	120.4	772	614.0	0.000	152.5	453.8	464.3	465.7
February	122.9	785	606.1	0.000	152.7	461.5	464.3	375.7
March	159.9	997	817.9	6.701	152.7	618.9	620.6	309.4
April	177.4	1084	899.5	0.000	152.7	679.2	672.7	227.3
May	183.3	1108	889.0	0.000	152.2	635.3	638.8	291.2
June	181.1	1069	814.2	0.000	152.0	563.6	565.4	334.6
July	190.1	1099	804.2	0.000	151.6	513.9	515.1	414.9
August	190.0	1098	820.6	0.000	151.8	546.0	546.0	384.0
September	172.2	1020	818.4	0.000	152.3	592.5	585.0	315.0
October	159.5	970	808.3	0.000	152.2	573.8	581.3	348.7
November	131.7	826	663.1	0.000	152.5	489.6	489.6	410.4
December	119.9	766	621.5	0.000	152.3	449.2	449.2	480.8
Year	1908.5	11595	9176.9	6.701	152.3	6577.4	6592.4	4357.6

Legends

GlobEff	Effective Global, corr. for IAM and shadings	WPumped	Water volume pumped
EArrMPP	Array virtual energy at MPP	W_Used	Water drawn by the user
E_PmpOp	Pump operating energy	W_Miss	Missing water
ETkFull	Unused energy (tank full)		
H_Pump	Average total Head at pump		

Assessment of standardized production:

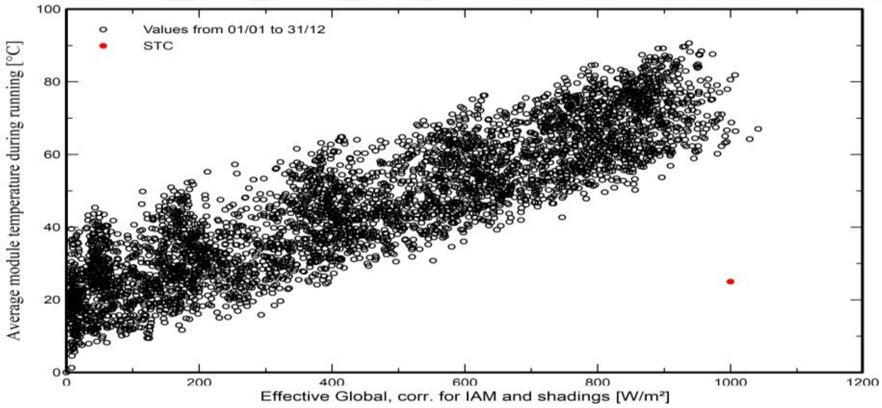
The prediction of the system (at the exit of the storage: Yf) is represented in the figure . The losses Lc, Ls and Lu are the losses corresponding to the PV field, the losses of storage system and unused energy, respectively. Indeed, there are losses during the collection of solar irradiation this loss is worth 1.74 kWh/d, system losses of the order 0.79 kWh/d, and finally the energy produced at the outlet of the pump is 2.99 kWh/d.The amount of unused energy is less in the summer period and it is greater in winter. The collection losses of solar irradiation and the system losses are low of months from November to March, and they are more important the other months of the year.



The diagram summarizes the losses of the production of PV system namely: the losses due to the temperature of the field, losses due, loss for module quality, etc.Solar energy when it arrives at the panel with the photovoltaic conversion and the yield of the panel there are energy losses therefore the production decreases at the exit of the panel we also have the losses due to the ohmic losses of the wiring losses due to the temperature of the field, there are also losses of the inverter so the energy at the input and at the output is not the even because of the losses and these losses negatively influence the production.

Predef. graphs

Array Temperature vs. Effective Irradiance



Daily Input/Output diagram

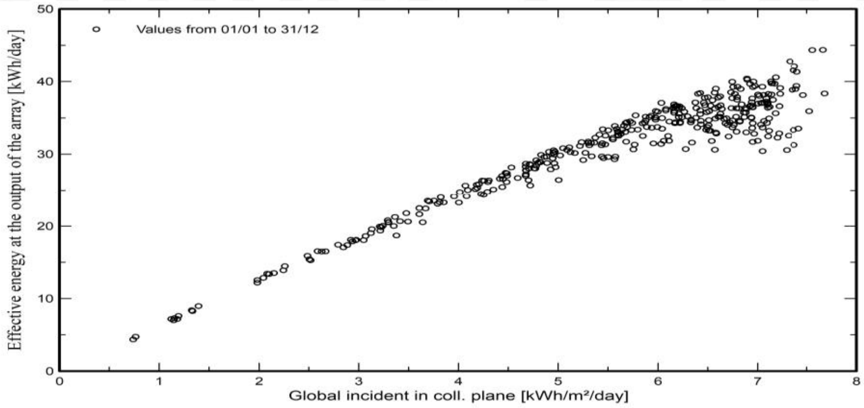
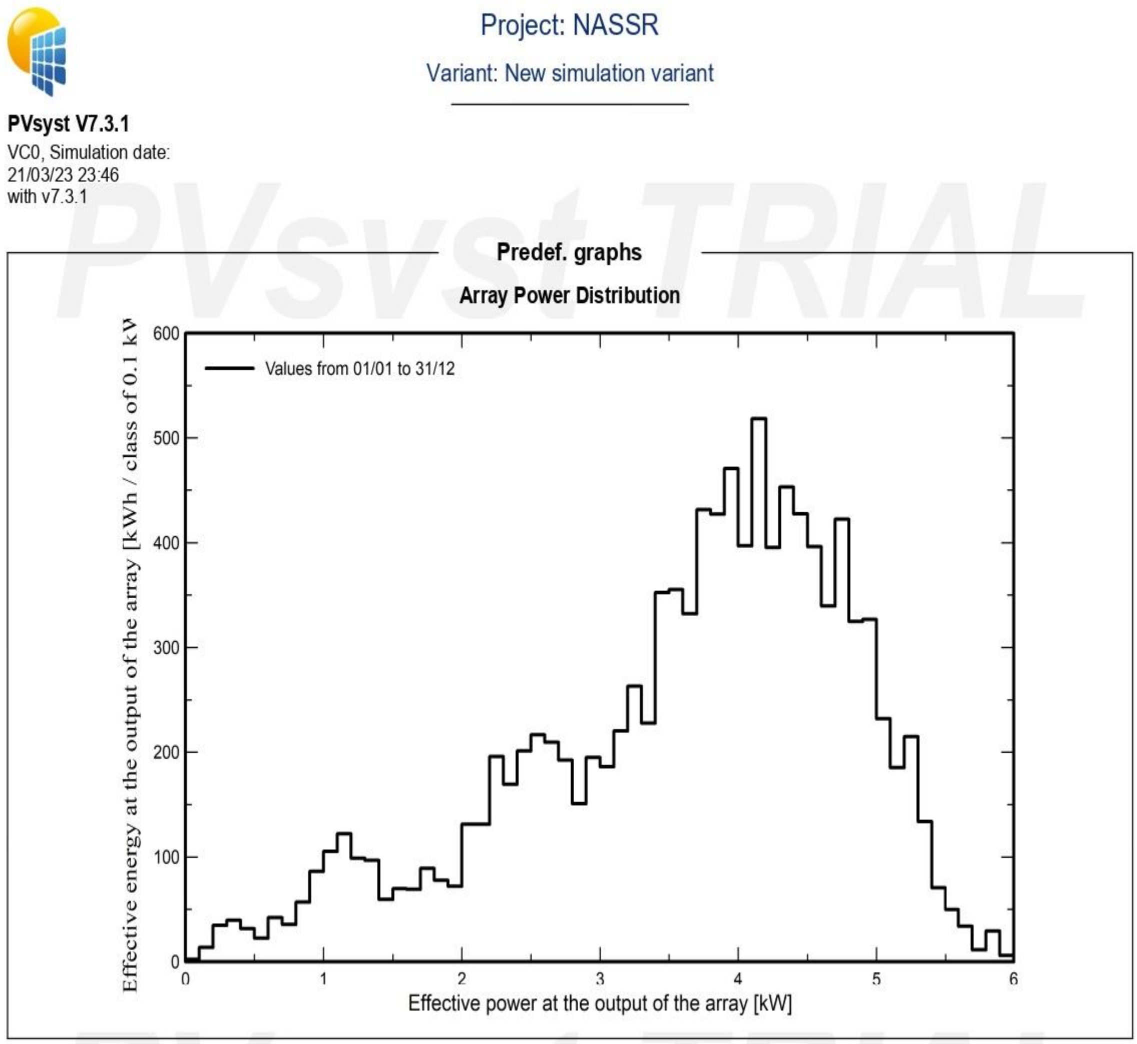


Diagram of temperature as a function of effective irradiation:-

We note that the higher the temperature, the more we have an increase in radiation.

Daily Entry/Exit diagram

The daily Input/Output diagram represents the effective Energy at the output of the modules/Global Incident Daily Irradiation. It is given by the figure as above



- **Effective energy at the output of the modules**

The effective energy at the output of the modules is given in the figure The distribution graph of the power at the output of the modules defines an hourly profile at during the day, it follows exactly the same distribution of the incident radiation, at a obviously different scale.

4. Conclusion

In this search, we have presented the necessary steps to develop a system Autonomous photovoltaic pumping without batteries with their main characteristics, as well as the effect of illumination on the external characteristics of the module. As well as the dimensions of each element of the system. We have calculated the installation of our system according to the needs. energy. The PVsyst 7.3 software allows you to model a photovoltaic pumping system considering all aspects: losses, geographic location, etc. This allowed a better assessment of losses that can affect the overall output. We have tried to minimize the various losses, which allows us to make certain choices. Especially the dimensions, such as the height and length of the pipe. autonomous photovoltaic is an interesting solution for isolated sites.

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