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Comparison between two calculation methods for designing a stand-alone PV system according to Mosul city basemap

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Abstract: Global heating, depletions, and high cost of fossil fuels ensued the exploitation of AC sources of energy such as solar stamina. The peculiarities of photovoltaic PV module are a condition for dimensioning and designing a PV system. The causation for developing PV modules beneficial for electrical applications, this manner permits the development of new hefty-performances stand-alone PV system. PV ingredients are permitting the computation of the demeanor of the total system in medley scenarios. In this work, a comparison between calculation solar program and manual mathematical method are made according to Mosul-Iraq site.

Keywords: calculation solar program, mathematical solar PV, Mosul city basemap, solar modeling, stand-alone PV system

1 Introduction

PV is a manner of procreating electrical power by changing solar radiation to DC electricity using semiconductors that induct in PV technology. PV generation uses solar panel compounded of many solar cells. Because of the growing demand of clean energy sources, the fabrication of PV modules has developed considerably in recent years [1]. PV is one of the essential universal trends connected to gaining energy from renewable energy sources

(RES) [2]. PV inability has important effect on the safety, accuracy, and energy balance of PV devices [3]. PV systems are growing rapidly, starting from low capacity to high capacity around 40,000 MW at the end of 2010. More than 100 countries use PV system [4]. PV is a technology that credibly converts sun light to DC electricity. Variable kinds of PV modules accredit on the rating scale of the power. Solar cell is a fabric cited by famous semiconductors like silicon [5]. Changeability in the temperature will affect the solar module efficiency, and because of these mutations this technology is facing big defiance in its power finesse rendition. Reintegrated of clean energy is considered a screed route [6]. Efficiency is a very significant signal for PV systems [7]. The requirement to decrease the environmental effect of conventional fossil fuels, as well as the depletion of these resources and the intense increase in fossil fuel prices, is the cause for the rising use of RES [8]. PV technology is very well suited to supply the stand-alone locations. It has good reliability [9].

Are obtained from calculation solar program by software package according to the longitudinal and latitude site in formation for a certain loads are given various premiums about the PV generation [10].

2 Literature review

Angga Romana, Eko Adhi Setiawan, and Kumianto Joyonegoro (2018) studied the design of solar PV system according to two methods: Australia/New Zealand Standard and manual methods. The two methods take constant values for DC voltage bus (48 V) and oversupply coefficient (2). They concluded that Australian design method is better than the manual method [11].

Preeti Bhatt and Arunima Verma (2014) studied the design of solar PV system. They made a comparison between congenital and nano PV system they take (200 V) for bus voltage but did not include the dirt factor

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tilt angle, inverter efficiency, and oversupply coefficient in the calculations of solar PV system design for conventional and nano types. They concluded that nano PV system cannot be used for high power load on computation of its low conversion efficiency and the design for three phase load requirement of the whole building [12].

Ayaz A. Khamisani (2019) studied the design of off-grid solar PV system. He included the system losses in the calculations and he depended on the PWM charge controller instead of MPPT charge controller in the design of the charger. Solar PV system (off-grid) type systems more agreeable to areas where the consumer opts not to be supply back the energy that generated at this end and the electrification is yet to be accomplished [13].

3 The uniqueness of this work

PV models have nonlinear characteristics of voltage–current relationship, and therefore, there is only unique point for stand-alone solar PV system as compared with the other previous design; in this work all practical environmental conditions are included in the design according to calculation solar program, and all main practical environmental conditions are taken from this program and compensated in the mathematical method. These practical conditions gave true sizing of PV modules, batteries, charge controller, and inverter as compared with previous works.

4 Stand-alone/off grid solar PV system

PV systems are considered a simple application for the customers to connect their loads to the grid [14]. Battery storage system is used in off-grid PV systems for providing the electricity during cloudy days and at night. The weather changes and the year round conditions must be considered at designing these systems [15]. When sun does not appear for many continuous days, back-up generators are required such as diesel, gasoline, and petroleum. The advantages of stand-alone PV systems are to give adequate energy to a house hold and powering the place which are distant from the grid [16]. Off-grid systems have further ingredients and these systems are considered expensive and comparatively costlier

than grid direct system [17]. Table 1 illustrates the PV system components.

Table 1: PV system components

Particular	Company
PV modules	ATERSA
Batteries	STECA TAROM
MPPT controller	KHUN
Inverter	VICIORO

Figure 1 represents the stand-alone PV system.

Figure 1: Stand-alone PV system.

5 Materials and methods

Many materials and two calculation methods are suggested in this work.

5.1 Materials

Materials used in this work are given in Table 2.

5.2 Methods

Calculation solar program is an implementation that determines the energy during 24 h, requested of a house hold and depending on the numerate that represented by batteries required and number of PV modules [18]. The implementations included the presumptive wattage of each appliance. Calculation solar program the appliances are collected to gather into four categories called

Table 2: Materials of suggested PV system

Name/type	Shapes	Rating
Solar panel: ATERSA A-100M MONOCRISTALINO		Product warranty 10 years, $P_{\max}$ (100 Wp), $V_{\max}$ (18.95 V), $I_{\max}$ (5.28 A), V_{oc} (22.21 V), I_{sc} (5.79 A), panel efficiency (15.07%)
Regulator: STECA TAROM 245 PWM.		System voltage 12 V/24 V, input I_{sc} (45 A), maximum output current at load (45 A), maximum self-consumption (14 mA), charge voltage of the boost (14.4 V) and (28.8 V), floating case end of charge voltage (13.7 V) and (27.4 V), equalization charge (14.7 V) (29.4 V). Deep discharge protection (SOC/LVD) < 30% SOC/11.1 V (22.2 V/44.4 V)
Battery: KHUN 100 AH TUBULAR-PLATE.		Model type LPTT 12100H, warranty 5 years, rated capacity 100 A h, inverter support 10KYA-900 VA, nominal voltage 12 V, tall tubular technology, depth of discharge 80%
Inverters: VICTRON MULTIPLUS C 24/2000/50-30.		1,600 W constant output and 4,000 W peak current for 24 V battery voltage. Combination of inverter with transfer switch and 50 A battery charger. Provides pure sine wave at 50 Hz. VE.Bus communication port allows extensive possibilities in terms of connection, configuration, and controlling of victron multiplus devices. Supports three-phase operation (three units of the same model needed). Supports parallel operation – up to six units can be connected parallel to increase system power if needed. Inverter efficiency 94%
Appliances: Television, refrigerator, microwave oven, computer, and lighting		

entertainment, cleaning, air-conditioning, and lighting energy requested for each category is determined separately then displayed [19]. The forerunner version ditto numerates the rating of the inverter and the charge controller that required by the solar system [20]. These are necessary components for a solar system. In addition, the full clone takes within the account the system efficiency, depth of discharge, and offline verses online usage [21]. Solar are rate of the peak sunshine hours, there are three various estimation manners. The estimation manners annexing use of air mass formula, half-sine model and NASA solar insolation data [22]. The mechanism for calculating the area and panel tilt angle was included.

The proposed model is said to perform better at energy prediction than software tools such as PV watts, PV system, or ret screen. The approach was validated on two 5 MW PV plants in the same district of Mosul-Iraq [23]. Method to curriculum the demeanor of a PV apparatus as a prosthesis to the equivalent circuit model. In some implementation a very prompt and cushy approach

to a solar panel demeanor is required [24]. Daytime temperature and global horizontal insolation (GHI) are the two core parameters affecting the PV plant output. According to these parameters, Mosul can be classified into 15 climatic zones [25]. From National Renewable Energy Laboratory (NREL) Mosul is classified into various climatic zones. Finally, the results show a decisive study to select the best PV technology for various climatic zones of Mosul [26].

Table 3: Consume appliances per day

Appliances	Consumer appliances (day)		
	Hours (h)	Power (W)	Energy (W h/day)
Computer	5	300	1,500
Television	3	70	210
Microwave oven	0.8	800	640
Refrigerator	8	195	1,560
Total			3,910

Table 4: Lighting consumption

Consumption by lighting (day)				
Type	N°	Hours (h)	Power (W)	Energy (W h/day)
Fluorescent lamp	2	5	11	110
Fluorescent tube	2	5	30	300
Bulb	2	5	60	600
Total				1,010

Table 5: Performance ratios

Battery depth of discharge	80%
Battery losses coefficient	5%
Wiring loss coefficient	5%
Loss coefficient of DC/AC conversion	6%
Self-discharge coefficient of battery	0.5%
Autonomy system	3 days
Performance ratio	81.9%

6 Location and orientation

From basemap the installation is situated: unnamed road, Mosul, Iraq; the coordinates: 36.541461, 43.19386. PV array is bought according to the following peculiarity: inclination: 73°.

Disorientation belonging the south: 6°. AC with a voltage of 230 is used in this system [27].

6.1 Consumption

The energy consumption is determined from appliances and lighting per day. Tables 3 and 4 show the appliances and lighting consumption per day.

Table 7: Regulator specifications

STECA TAROM 245 PWM			
Voltage (V)	48	Tension (V)	12–24
Consumption (mA)	14	Rated power (W)	0.3
Utilization ray	0.7	Capacity (A)	45
The degree of optimization election equipment/real n		No. of regulator	1

6.2 Theoretical total daily energy 4,920 W h/day

Theoretical energy per day is 4,920 W h/day; the parameters given in Table 5 are used by the calculation of yield (performance ratio) [28–33].

Table 6 represents the calculation of PV modules number.

7 Regulator specifications

The specifications of the regulator are given in Table 7.

8 Batteries calculations

Energy, depth of discharge, bus voltage, and days of autonomy are entered in the batteries calculations.

- Nominal voltage of battery: 24 V.
- Depth of discharge: 80%.
- Days of autonomy: 3 days.
- Daily real energy: 6,007 W h/day.
- Battery capacity calculated helpful: 751 A h.
- Actual capacity batteries calculated: 1,252 A h.

Battery specifications are given in Table 8.

Table 6: PV calculation

ATERSA A-100M Monocrystalino			
Open circuit voltage (V_{oc})	22.21 V	Voltage at max. power	18.95 V
Short circuit current (I_{sc})	5.79 A	Current at max. power	5.28 A
Max. power	100 W	Temperature coefficient of power (C)	0.44%
Real power	98.2928 W	No. of serial model	2
Total Pico Power module	800 Wp	No. of parallel modules	4
Optimization installation/needs most	0.7	Total modules	8
The degree of optimization election equipment/real n			70%

Table 8: Battery specifications

KHUN 100 AH TUBULAR-PLATE				
C10: 200 A h	C20: 200 A h	C40: 200 A h	C100: 200 A h	C120: 200 A h
Tension		12 V	No. of series pcs element	2
Nominal capacity accumulate		200 A h	No. of parallel pcs element	1
Nominal voltage of the battery		24 V	Total element	2
The degree of optimization election equipment/real n				16%

9 Inverter charger

The choice of inverter charger is given in Table 9.

The elements that obtained from the calculation solar program are summarized in Table 10.

Table 9: Inverter specifications

VICTRON MULTIPLUS C 24/2000/50/30			
Tension	24 V	Rated power	2,000 W
Nominal capacity accumulate	1,600 W	Instant power	4,000 W
Battery nominal voltage	11 W	Efficiency	94%
Utilization ray	86%	No. of inverter	1
The degree of optimization election equipment/real n			117%

10 Mathematical calculations

The mathematical calculations are obtained according to the theoretical total daily energy:

$$\text{Real performance} = \frac{\text{Battery capacity on cx}}{(\text{Performance ratio}) 16\%} = \frac{200 \text{ A h}}{0.16} = 1,250 \text{ A h.}$$

No. of series batteries is

$$(N_s) = \frac{\text{Bus voltage}}{\text{Battery voltage}} = \frac{24}{12} = 2$$

No. of parallel batteries is

$$(N_p) = \frac{\text{Required battery capacity}}{\text{Battery capacity on cx}} = \frac{1,078 \text{ A h}}{1,250 \text{ A h}} = 0.862 \approx 1.$$

$$N = N_p \times N_s = 1 \times 2 = 2.$$

10.1 PV sizing

$$\text{Total load (W h)} = 3,910 + 1,010 = 4,920 \text{ W h.}$$

$$\text{Total power} = \frac{\text{Total load}}{\text{Sun Arc Rate}} = \frac{4,920 \text{ W h}}{6.5 \text{ h}} = 756 \text{ W.}$$

$$\text{Power of PV module} = 100 \text{ W.}$$

Then,

$$\begin{aligned} \text{No. of PV modules} &= \frac{\text{Total power}}{\text{Power of PV module}} = \frac{756 \text{ W}}{100 \text{ W}} \\ &= 7.56 \approx 8 \text{ pcs.} \end{aligned}$$

10.2 Battery sizing

$$\begin{aligned} \text{Required battery capacity} &= \frac{\frac{\text{Total energy}}{\text{DC voltage}} \times \text{Day of autonomy}}{\text{Depth of discharge} \times \text{Temperature correction factor}} \\ &= \frac{\frac{4,920}{24} \times 3}{0.6 \times 0.95} = \frac{615}{0.57} = 1,078 \text{ A h.} \end{aligned}$$

Table 10: Stand-alone PV components (calculation solar program)

Units	Elements
8	Module type – ATERSA A-100M MONOCRISTALINO
1	Regulator type – STECA TAROM 245 PWM
2	Battery type – KHUN 100 AH TUBULAR-PLATE
1	Type of inverter – VICTRON MULTIPLUS C 24/2000/50-30

Table 11: Stand-alone PV components (mathematical calculations)

Units	Elements
8	Module type – ATERSA A-100M MONOCRISTALINO
2	Battery type – KHUN 100 AH TUBULAR-PLATE
1	Type of inverter – VICTRON MULTIPLUS C 24/2000/50-30 (MPPT built-in)

10.3 Inverter sizing

$$\begin{aligned} \text{Inverter sizing} &= \text{Total energy} \times f_o \\ &= \frac{\text{Energy (W h)}}{\text{Sun Arc Rate (h)}} \times f_o, \end{aligned}$$

where f_o is the oversupply coefficient.

$$= \frac{4,920}{6} \times 1.7 = 1,394 \text{ W.}$$

The elements obtained from the mathematical calculations are summarized in Table 11.

11 Discrepancy

The discrepancy between calculation solar program and mathematical method are made in this work: The solar PV components (PV sizing, battery sizing, charger sizing, and inverter sizing) are included in this study for two methods. Effective coefficients of the calculation solar program in the equations of the mathematical method in addition to the data of Mosul base map, like performance ratios, days of autonomy, nominal battery voltage, battery efficiency, inverter efficiency, and sun are rate.

The number of PV modules, batteries, chargers, and inverter capacity are appeared approximately equal. As compared with the literature review, all necessary parameters of calculation solar program are included in this work; therefore, the sizing of all solar PV system components obtained from this work is accurate and closed to the truth as compared with the previous works, and also

this work can be applied on all types (conventional and nano) solar PV system.

12 Presumptions

The presumption effects of the practical conditions are:

- Dust particles are litters in the midair and are readily carried by the wind; these dust particles generated from industrial ambient cause 80% softening in the PV electrical output. Also the effect of dust and sighting will decrease the efficiency.
- The poor solar irradiant and inclination angle will lead to the fakir PV systems, also the wrong angles will cause a poor received of radiation.
- Day of autonomy can be expressed by the time that the load can be met with the batteries a lone unrested any solar inputs, embarking from full charged battery state, this may perform to sorely low average state of charge premium over broad periods of the year which is fully damaging for batteries bank.

13 Conclusion

The comparison results of two methods appear that the number of PV modules, batteries, and inverter are equally for same provenance and specifications of solar PV system components depending on the real cautions of calculation solar program and the theoretical mathematical calculations. Stand-alone PV system is more reliable than the on-grid PV system because of using battery storage system that gives more stability for this system. Days of autonomy have a large effect on the number of the batteries, which in turn will effect on the total cost of the system.

14 Future prospects and drawback

Stand-alone PV system is expected to grow very quickly from now to 2030. The drawbacks of these systems are very high initial cost, especially the storage back and the dust in the weather.

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