Design and Verification the Results of Electrification Small Communities in Palestine by Using Decentralized Off-Grid PV Systems

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***Abstract*: The objective of this paper is to study the optimum design and results verification of de-centralized solar photovoltaic system in electrification of small villages in Palestine, two of rural areas through a software simulation considering the weather and the environment issue, and compare the result with the analyzed real data from the site. The result of this study will predict the long-term success of small sustainable energy project in developing the countries; this can help to improve the project designs and certainty for future investment decision [1] in country as Palestine, which need to find energy sustainable resources due to the political and economic status.**

***Keywords*: Data comparative, domestic photovoltaic solar system, PV*SOL software, PV system design, rural area, simulation.**

I. INTRODUCTION

In recent years, using renewable resources in project have become the key component for Palestine and rural area, whereas Palestine import most of its needs of electrical energy from Israeli Electric Corporation (IEC), as result of absence of fossil fuel resources, in other hand there is a large number of rural area which lack the basic life services specially electricity because it is located in place far from high voltage grid which cause any connection with grid is very poor, and also this remote small villages are located in area C; under Israeli governmental control, which try to force the people of those areas to leave their lands, in order to take over their right to live a good life. Palestine has a high solar energy potential, where the daily average of solar radiation intensity on the horizontal surface is 5.4 kWh/m2, while the total annual sunshine hours amounts about 3000 [2]. Yarza and Ibziq are small villages of 23 families in Tubas district, the resident of those villages have a low daily average energy demand about 1.1 kWh/day/household and they live in far apart houses from each other, so the idea of project is to install 23 micro-power system and electrical energy storage for individual domestic use in remote area. Where there is no grid access through conventional distribution network.

The PV electrification has turned out to be the ideal for Yarza and Ibziq villages. It was also carried out using a few integration standards towards the environment, minimal visual impact regarding supporting for the PV modules and low environmental impact regarding the use of construction material and energy generation and consumption systems.

In the light of this, the study is guided by some indicator of solar PV electrification which affects the rural life.

II. PV SOLAR SYSTEM DESIGN

If The idea of project was installing small PV solar system that covers the basic needs of each family separately due to the harsh nature of two areas " Yarza & Ibziq ", and also because of the houses in two villages are is distant from each other's, so we consider designing a PV system with self-reliability of energy supply, Energy production can be done in the same place where it is needed, without any losses in transport, not consume any fuel, and his energy source is inexhaustible, It represents an economic saving in this type of applications. The completion of project is done in three stage:

- In first stage; we put an estimation of load demand for the families in villages through several visit and by using questionnaire in order to collect the information related to the beneficiaries, energy resource in village, their livelihoods, and survey the number of beneficiaries from project. As well as introduce an initial explanation of solar PV system and it's important for community.
- In second stage; considering the information in first stage, we design a suitable and high efficient system to cover the needs of beneficiaries and then we simulate the system using PV*SOL or similar software to get estimation for energy output.
- In third stage; we installed the designed system and train the beneficiaries regarding the system parts, the function of each one, and how to identify if there is a problem in system, and give tips and guidance of how to conserve the available data, then we start to download the data in order to perform analysis after 1 year of implementation.

A. Electrical load

An estimation of family user daily consumption has been realized based on the information in questionnaire and the beneficiaries needs regarding the electricity. The estimated daily demand and all the appliances which will/may be used in communities as shown in the table 1.

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Table 1. Estimated Total daily consumption

Applications	# Quantity	Power (Watt)	h/day	Wh/day
PL lamp	2	11	4	88
TV	1	120	3	360
Radio	1	20	3	60
Mobile charger	1	10	1	10
Small refrigerator	1	50	4	200
High efficient washing machine	1	180	2	360
			Total =	1078

Using high efficient appliances in this kind of project and load management steps are prior in order to achieve successful project.

B. Sizing PV Generator

In selecting a suitable PV module when designing PV solar system to cover average load energy demand of (1100 Wh/day) , we consider the performance warranty in case of any problems; to replace any module easily, and the manual to see the quality and characteristics of module [3].

PV array size can be determined, using equation (1) [4].

$$P_{PV\text{-}array} = \frac{E_L}{\eta_v \times \eta_R \times PSH} \times S_f \quad (1)$$

E_L : Estimated average daily load energy consumption in Wh/day (1100 Wh/day)

PSH : Peak Sun Hours (5.4 h) [5]

η_v : Efficiency of inverter (95%)

η_R : Efficiency of wire losses (97%)

S_f : Safety factor (1.15)

$P_{PV\text{-}array}$ = 254.22 watt

The PV module of type 135 Wp Canadian solar is installed in this project, so number of modules in system (Nm) is determine in equation (2).

$$Nm = \frac{P_{PV\text{-}array}}{P_{selected\ module}} \quad (2)$$

Nm = 1.88 ≈ 2 module

Table 2. Characteristics of installed PV Array

Rated PV-Power (STC)	270Wp
PV Module Type	135Wp CANADIAN SOLAR CS6C-135
No. of Module	2
Inclination/orientation	55˚ / 10˚ S
Approximate area	2m2
Vo.c.	22 V
Is.c	8.19 A
Vmp	17.6 V
Imp	7.65 A

C. System Voltage Selection

Selecting the operating DC voltage of standalone PV system is based on system requirements, the available inverter and characteristics of the available inverter. In general, if the total AC load is greater than 5Kw, so the selected system voltage is 48 Vdc [6], so since the total AC-load is less than 5Kw, the voltage of installed system is 24Vdc.

According to system voltage, the number of modules in series (Nms) is calculated according to equation (3).

$$N_{ms} = \frac{V_{system}}{V_{module}} \quad (3)$$

= 24 / 17.6 = 1.36 ≈ 2 module in series

So, the modules of system were installed in series, and as a result;

$V_{o.c.array}$ = 22 × 2 = 44 V

$I_{S.C.\ array}$ = 8.19 × 1 = 8.19 A

D. Sizing of Battery Bank

Battery is the most important part in stand-alone PV system, so we consider that the battery will cover the needs of beneficiaries at night and cloudy day which required high efficient battery. The capacity of battery ($C_{A\text{-}H}$) is measured in Ampere-hours, as in equation (4).

$$C_{A\text{-}H} = \frac{N_c \times E_L}{V_B \times DOD \times \eta_v \times \eta_R} \quad (4)$$

N_c : numbers of days of autonomy (1.5 - 3 days)

V_B : operating voltage for system (24 V)

DOD: maximum depth of discharge (0.6-0.75)

$C_{A\text{-}H}$ = 134.02 A.H

Table 3. Characteristics of installed PV Array

PV Module Type	AGM LEAD ACID RITAR 12 V
No. of Battery Bank	2
Capacity (100)	145Ah
days of autonomy	1.5

$$C_{WH} = C_{A\text{-}H} \times V_B \quad (5)$$

C_{WH} = 145 Ah × 24 V = 3480 Wh

E. Sizing of Charge controller

The basic function of charge controller is to extract as energy as possible from PV array in order to maintain a high state of charge of the battery and avoid its complete discharge, so it controls the cycle of charge and discharge avoiding over charge and deep discharge. When we selected the charge controller, we consider that the unit has the following characteristics:

- High efficient charge controller with low self-consumption
- Maximum power point tracker (MPPT) to get the maximum power of PV array
- Possibility to maintain the batteries at floating voltage to compensate the losses in case of full charge
- Advanced algorithm of charge and discharge control

The size of the charge controller will be selected according to following equation:-

$$P = V_B \times I \quad (6)$$

270 = 24 × I × 1.15

I = 11.25 A × S_{f2}

I = 14.0625 A

S_{f2} : Safety factor (1.25) ; in special conditions, the panel produce more power from its normal rated (about 25% - 30%). For example, sun light reflects from snow, water.

So, we used Sun-power (SS-MPPT-15 L Morning Star) with maximum battery current equal 15A and peak efficiency of 97.5%.

F. Sizing of Inverter

When we select the inverter which will be used in project, we consider; the system voltage, output voltage 230V/50Hz, low self-consumption with efficiency, max charge current > 15A and as well as, the input of inverter have to be matched with the battery bank voltage as in electric grid as follow [6]:

Rating inverter = PV rating = 135 Wp × 2 = 270 W

The input energy of inverter = PV rating × PSH × η_R

= 270 × 5.4 × 0.97

= 1414.26 Wh

The output energy of inverter = input energy of inverter × η_V

= 1414.26× 0.95

= 1343.547 Wh

But the required energy is 1100 Wh only, so we installed inverter (Studer XTS 1200-24)

III. SIMULATION OF PV DESIGN USING PVSOL SOFTWARE

Evaluating solar energy production can vary in complexity and are based on the range of variable used to predict performance under operating conditions; several important factors to consider include the use of solar resource characterization, site characterization, computer simulation model, system specifications, and power plant losses.

Using PV*SOL software, we consider evaluating carefully to ensure the most accurate simulation of energy production.

A. PV power plant characteristics - PVSOL software

By using PV*SOL 5.5 software, it is possible to have preliminary and as well as post evaluation test data for feasible power generation. The simulation for project proposes analysis of energy efficiency and environmental conditions of PV system shown in fig.1.

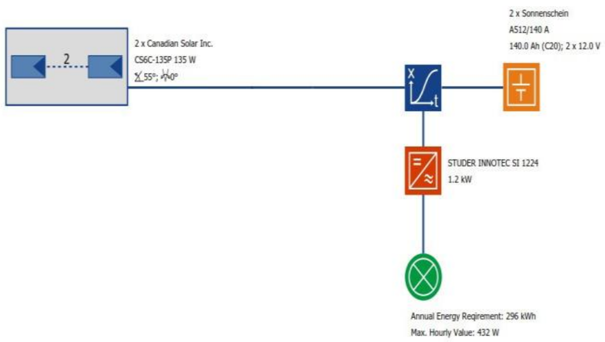

Fig. 1. PV system –PV*SOL

Taking into consider, using a suitable specification for power plant and matching the real installed components specifications. The PV system consists one array which has 1.98m2, inclination angle of 45 degree and total power 0.27 kWp. The system contains 2 PV module connected in series, thus, are in total 2 Canadian solar CS6C-135P PV module which connected to 2lead acid battery through charge controller and then to an inverter Studer XTM-1200-24. The inverter characteristics are: power 1.2 Kw and efficiency 94% and according to the standard test condition, the energy efficiency of array is 13.7% and maximum voltage for FS module is 35V.

B. Theoretical PV power production

Using the PV*SOL software, the yearly produced and used energy have been determined. The corresponding monthly contributions are reported in table 4 and fig 2.

Table 4. PV System power production using PVSOL

Item	Value
PV Array Irradiation	4126.5 kWh
Energy Produced by PV Array	375.86 kWh
Consumption Requirement	296.47 kWh
Consumption Covered by Solar Energy	253.33 kWh
Consumption not Covered by System	43.1 kWh
Solar Fraction	85.4 %
Performance Ratio	44.7 %
Specific Annual Yield	kWh / kWp
Co2 Emissions Avoided	156 kg/a

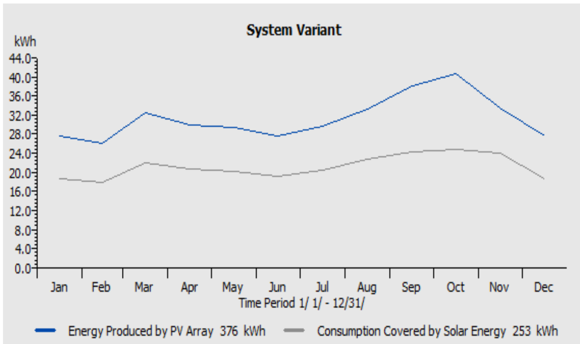

Fig. 2 PV System power production using PV*SOL

The results of simulation are almost similar for both sites and that because of similarity of environmental conditions and using the same system specification. In fig 3 the environmental parameters are shown in graphical form ,Specific Irradiation onto Horizontal", "Specific Irradiation minus Reflection", "External Temperature", "Specific PV Array Irradiation" and "Wind Speed at Height of 10 m" that can influence the energy efficiency of the analyzed PV arrays:

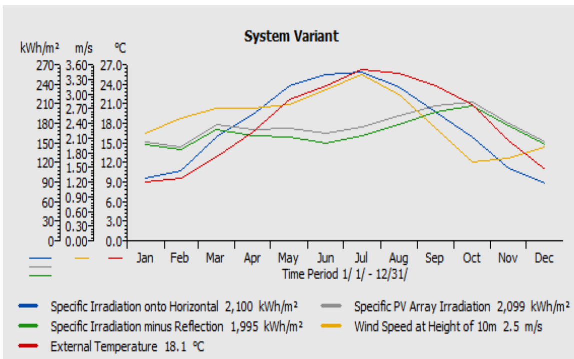

Fig. 3 The Environmental Parameters Using PVSOL

By comparing the simulation results for Yarza and Ibziq sites which obtained for the environmental conditions of the system in time period 1/1

- 31/12, the result as follow for both sites:

*The highest value of parameter „Specific Irradiation onto Horizontal" is 2018 - 2142 kWh/m2 in July.

* The highest value of parameter „Specific Irradiation minus Deflection" is 1898 - 2040 kWh/m2 in October.

* The highest value of parameter „Specific PV Array Irradiation" is 1997 - 2148kWh.

* For parameter „External Temperature" the limits are between 9C, 26C and the average is 17.7 – 19.2 C.

* For parameter „Wind Speed at Height of 10m" ranges between the values 2.4, 3.6m/s for and the average is 2.7 m/s.

IV. EVALUATING METHDOLOGY OF REAL DATA

A. *Applied Data*

Previously, a simple feasibility study using PVSOL is applied to obtain an idea of the amount of energy that will be generated by the system, and access the economics of the whole project and compare the result with the real energy production which obtained from station by the sensor. The irradiation data for both sites is obtained as follow:

For Yarza site:

Table 5. Irradiation data for Yarza site

Inclination=45 deg
Orientation = 0 deg

Month	Monthly radiation (kWh/m2)
January	120
February	122
March	153
April	155
May	164
June	165
July	171
August	182
September	182
October	174
November	144
December	122
year	155
Total	1850

As a result, from this data, the approximate annual energy production:

Annual Energy Production = STC capacity of PV generator * total annual radiation* performance ratio

= .27 kWp*1850kWh/m2 * 60%

= 299.7 kWh

The system will produce about 75% of its real production if we consider the heat and cable losses, so the expected estimated annual energy production = 224.8 kWh

For Ibziq site:

Table 6. Irradiation data for Ibziq site

Inclination=45 deg Orientation = 0 deg

Month	Monthly radiation (KWh/m2)
January	115
February	119
March	152
April	156
May	167
June	168
July	173
August	184
September	183
October	172
November	137
December	115
year	154
Total	1840

As a result, from this data, the approximate annual energy production:

Annual Energy Production = STC capacity of PV generator * total annual radiation* performance ratio

= .27 kWp * 1840 kWh/m2 * 60%

= 298.08 kWh

The system will produce about 75% of its real production, if we consider the heat and cable losses, so the expected estimated annual energy production = 223.56 kWh

V. COMPARATIVE OF EXPECTED AND PREDICTED OUPUT

The table below show, the comparison of data performance result for Yarza and Ibziq Project:

Table 7. Comparison table between real and predicted values -Yarza site

	Yarza site - result comparison				
	Total Irradiation (kWh/m2)	kWh/kWp	PV gen. (kWh)	kWp	PR %
Predicted (PVSOL)	2084	1187.5	346.91	0.27	56.6
Real value	1850	1110	299.7	0.27	56.2

Table 8. Comparison table between real and predicted values -Ibziq site

	Ibziq site - result comparison				
	Total Irradiation (kWh/m2)	kWh/kWp	PV gen. (kWh)	kWp	PR%
Predicted (PVSOL)	1982.6	1128.7	329.65	0.27	56.5
Real value	1840	1104	298.08	0.27	56.25

VI. CONCLUSION

Using Domestic photovoltaic solar system for rural area with residences far away from each other is more convenient to cover the needs of each house individually. The systems cover the needs of the Yarza and Ibziq residents and the installed devices are efficient and this clearly shown through the satisfaction of the people during our inspecting visit for the PV systems of the area. This project considers as a turn point which encourage us and other institutes to install the decentralized PV system in more project and sites which have the same circumstances.

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