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RESOLUTION OF ELECTRICAL POWER CRISIS THROUGH OPTIMAL DESIGN AND SIMULATION OF A GRID CONNECTED SOLAR POWERED HOME SYSTEM IN LIBYA

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ABSTRACT

This paper deals with the dilemma of shortfall in the supply of electrical energy that is currently being faced by Libya residents. After describing the causes of this shortage in the supply of energy, design of a grid connected photovoltaic (PV) system for Libyan typical house is proposed in terms of sizing of P-V units, inverter and battery storage. The sizing of the system is determined based on the expected loads, characteristics of the used PV module and the meteorological data of the site of installation. Matlab/Simulink and HOMER software's are used as sizing and optimization tool to determine the optimum size and specifications of renewable system components. Estimation of system cost and corresponding produced electrical energy are taken. The results show that using PV system is very beneficial besides being economical, especially considering the decreasing prices of PV systems and their increasing efficiencies and reliability. This type of study encourages the entrepreneurship in the field of rooftop solar home system in Libya; inherent advantage of maintaining a clean environment.

Keywords: Photovoltaic (PV), PV-grid connected, solar energy, solar irradiation, solar energy.

I. INTRODUCTION

Solar energy is virtually inexhaustible source. The total energy we receive from the sun far exceeds our energy demands. It is the most reliable form of energy available for everyone and everywhere, unlike other sources of energy. Implementation of renewable energy resources, such as solar energy, leads to economical, social and environmental benefits. It offers a great potential for reducing the green house gases (GHG) emission for minimizing, environmental impacts of electricity production [1].

Electrical energy is vital for sustaining life on earth. It is needed to improve the quality of life by exploiting the natural resources. In Libya like the rest of the world countries, the demand for power is increasing day by day. At present, Libyan electrical power shortage has become an acute problem. There are several reasons behind this problem such as political and military conflict which expose the Libyan national electrical power system (power plants, substations, transmission Lines) to distraction in addition to high demand, derated capacity of power station machineries. Libya is suffering from a scarcity of services, processing power since early 2011 also by spread the phenomenon of interruptions in electric power, which result in curbing the wheel of everyday life and cast a shadow on the different levels of health, economic, social, with increased suffering of Libyan citizens increased hours of electric power cutting. This situation gives a reason for pushing the Libyan citizen to look for a n alternative such as diesel generators to supply their electrical loads. The form of the additional consumption of money, fuel and energy drains on the environment of Libya resulting in an increasing pollution of gases that cause global warming, leading climate change and the subsequent deterioration of other natural resources. Political instability has also hindered any possibility of Progression in the energy sector, with the sacking of numerous high profile figures that have the interest of the Libyan masses at heart. This selfish act is seen by Libyan masses as a way for the political leaders in this country to manipulate the citizens by pressing on their own self-interested agenda, while the society infrastructure remained in bad conditions. It has become hard to solve the power crisis under this situation where there is unified power system under the two authorities each claiming has the right rolling the country. The extent of this is underlined by the fact that Libya business stared purchasing a large quantities of standby electricity generating. To solve this energy crisis we can use different form of renewable energy to generate power. Renewable energy is the energy that comes from different types of natural resources mainly from sunlight, wind, rain, tides, and geo thermal heat, biodiesel, etc [2].

This paper discusses the prospects of solar energy to eradicate the power crisis of Libya, it also explain their present scenario and future potential. The present paper uses the softwares Matlab/Simulink, and Hybrid Optimization Model for Electric Renewable (HOMER) to design and analyze a non-autonomous power system which includes a grid connected solar photovoltaic (PV) based power system with battery storage to supply a residential load located in Tripoli-Libya, (with latitude and longitude of 32^0 54'N and 13^0 11'E respectively) [3]-[4]. For optimal system design the analyses have been carried out in two modes – grid connected as well as stand-alone. The simulation results of these two modes have been studied on the basis of cost of energy, pay-back period, environmental emissions etc. and compared with the grid-only (base) mode. Performance of each component (i.e. battery, inverter, rectifier etc.) of the model is evaluated and finally sensitivity analysis is performed to optimize the system out of different conditions.

II. ELECTRICAL ENERGY SITUATION IN LIBYA

Electricity generation in Libya currently is provided by gas-turbine, steam-turbine and combined cycle power plants which use heavy oil, light oil and natural gas respectively. Gas- turbine and combined cycle power plants have a share of 30% and 20% respectively in total installed power capacity; the share of steam power plants is 50% in total. Furthermore, some small diesel power plants are also used to contribute to the energy supply, especially in remote areas. Currently power generation capacity in Libya is estimated to be around 6,000 megawatts, with average working capacity of 4,000 megawatts, to provide electricity for about 6 million people compared to Finland where the current generated megawatts are estimated to be around 36,000 megawatts, providing electricity for 5.5 million people.

Libyan national electric grid consists of an ultra-high voltage level of 400kV with a total circuit length of 442km, and a high voltage transmission level of 220kV with a total circuit length 13,677km. The sub transmission voltage level is 66kV, with a total circuit length of 13,973km. The distribution network's voltage level is 30kV with a total circuit length of 6,583km [5]. In Libya all of the electrical energy demand comes from fossil-fuelled power plants. Libya's power demand is growing rapidly (around 6%-8% annually.

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For Libya to meet up with its energy needs, it must look for alternative energy sources. Therefore, to solve this energy crisis requires use a different form of renewable energy to generate power. In this paper we have discussed the prospects of solar energy to eradicate the power crisis of Libya. Solar energy technology is seen as having a significant unexploited potential to enable countries to meet their growing energy requirements. If solar energy is properly harnessed, it could meet a significant proportion of energy demand with less deteriorating effects on the environment.

III. POTENTIAL OF SOLAR ENERGY IN LIBYA

Libya is located extensively between 18°45' and 32° 57' north. The Libyan desert covers the entire range of Libyan longitude $11^{o\ 44'}$ to $23^{o\ 58'}$E and a latitude range of 24^{o} 17' through to 30^{o} 3'N. Libya is exposed to the sun's rays throughout the year with long hours during the day. The sunshine and daylight hours in Tripoli-Libya is summarized as follows: [6]

- Average hours of sunlight in Tripoli range from 6:23 for each day in December to 12:07 daily in July
- The longest day of the year is 14:09 hours and the shortest day is 9:50 hours.
- The longest day is 4:18 longer than the shortest day.
- There is an average of 3187 hours of sunlight per year (of a possible 4383) with an average of 8 hours:43 mints of sunlight per day.
- It is sunny for 72.7% of daylight hours. The remaining 27.3% of daylight hours are likely cloudy or with shade, haze or low sun intensity.
- At midday the sun is on average 57.7° above the horizon at Tripoli.

Libya has an average daily solar radiation rate of about 7.1 kilowatt hours per square meter per day (kWh/m²/day) on a flat plane on the coast and 8.1kWh/m²/day in the south region.

Hence Libya is located within the high solar belt, which requires not to miss this opportunity, and to take advantage of this feature lacking in most the European countries by takeing the advantage of the sun's energy to maximum levels. Solar energy in Libya is the most easily available renewable source of energy which can be implemented at comparatively low cost in the huge amount. The long term average sunshine data indicates good prospects for solar thermal and photovoltaic application in the country.

IV. CASE STUDY SOLAR ENERGY POTENTIAL ON THE HOUSES ROOFTOPS IN TRIPOLI CITY

The total solar energy output potential for the housing rooftops are calculated by using the value for average annual solar insulation, on city of Tripoli. The available roof area for the possible plant capacity is estimated based on commercially manufacturer's data available by considering the PV module efficiency as 15.2%. Assuming that the solar energy is available for about 6 hours during the normal day, the average solar insulation in Tripoli can be calculated using equation (1); [1].

$$\text{the average solar insulation in Tripoli} = 5.48\text{kWh/m2/day} = \frac{913W}{m2}/day \quad \ldots\ldots\ldots (1)$$

After estimating the potential, the design of grid as connected to solar PV power plant is made. The energy generated from photovoltaic solar system installed in the roof of the building is estimated as shown in Table 1.

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TABLE .1 energy generated from available roof-top area on the typical Tripoli houses

Available area (m^2)	Effective area (m^2)	Average peak output	Possible plant capacity (kW)	Energy generated	Energy generated /month (kWh)
144	$144 \times 0{,}70 = 100$	913	13.9	83.4	2502
250	$250 \times 0{,}70 = 175$	913	24.3	145.8	4374
380	$380 \times 0{,}70 = 260$	913	36.1	216.6	6498

V. ROOFTOP PLANT CAPACITY AND MAXIMUM POSSIBLE NUMBER OF PV BASED ON AVAILABLE AREA

Results obtained show that a 13.9 kWp, 24.3 kWp and 36.1 kWp solar photovoltaic power plants can be developed on 100 m^2 area, 175 m^2 area and 260 m^2 area respectively.

The required numbers of PV modules are obtained using equation (2) ;

$$\text{numbers of PV modules} = \frac{P_{PV}}{P_{mpp}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where:

$$P_{PV} = possible\ plant\ capacity\ kW$$

$$P_{mpp} = Module\ \text{Max Peak Power}$$

The calculation results tabulated on table 2

Table .2 Energy Generated From Available Roof-Top Area On The Typical Houses.

House type area (m^2)	Possible plant capacity (KW)	NO.PV Modules	Energy generated /d (kWh)	Energy generated/month (kWh)
144	13.9	70	83.4	2502
250	24.3	122	145.8	4374
380	36.1	171	216.6	6498

Using the effective area and the module area the number of PV modules can be obtained as in equation (3).

$$No._{pv}\ modules = \frac{effective\ area}{module\ area} \qquad \ldots\ldots\ldots\ldots \text{(3)}$$

The results are shown in table. 3

Table. 3 Plant Capacity And No Of Pv Modules.

Possible plant capacity (kW)	NO.PV modules
13.9	70
24.3	122
36.1	181

VI. OPTIMAL DESIGN OF PV SYSTEM COMPONENTS

The solar power system design presented, in this paper by reviewing the various electrical design methodologies, provides detailed insight into photovoltaic modules, inverters, and battery sizing. Hence the first step is to determine the load, available sunlight, PV array size, and battery bank size.

6.1 Expexted Load Estimation

The preferred method for determining PV system loads is a "bottom-up" approach in which daily load is anticipated and summed to yield an average daily total. In this paper a typical house in Tripoli–Libya is chosen as a case study. For PV systems designed to power loads, such as a whole house, we need to estimate typical home appliances with its power ratings and estimated operating time per day are as listed in Table 4.

Table 4: Typical Libyan Home Appliances Power Ratings And Estimated Operating Time Per Day.

Load Type	No. Of Units		Rated Power(W)		Av.Hrs Used/Day		KWh/Day
Lights	5	×	60	×	5	=	1.5
Refrigerator	1	×	600	×	8	=	4.8
Television	1	×	100	×	6	=	0.6
Computer	1	×	100	×	5	=	0.5
Washing Machine	1	×	1000	×	0.5	=	0.5
Air-Condition	2	×	1200	×	5	=	12
WATER PUMP	1	×	500	×	1	=	0.5
Vacuum Cleaner	1	×	1200	×	0.1	=	0.12
Total KWh / Day							20.52

6.2 Sizing Pv Panel

Photovoltaic (PV) modules are sized using wattage determined under Standard Test Conditions (STC). This is the manufacturer's specified nameplate wattage and represents module output as measured under very controlled factory conditions. Specifically, STC are 1,000 W/m2 solar irradiance and 25^{o}C module temperature. STC wattage provides a good relative comparison between module and system sizes, but not a good real world output measure. The design criteria for this PV module are based on the manufacturer's data [7]. In order to add reality and plausibility to the system, the design is based on commercially available equipments only. The parameters of the chosen PV module are given in Table5.

Table.5 Specifications For Solar Panels [7].

Electrical Specifications (Standard Test Conditions = 25 °C, 1000W/m2 irradiance and AM=1.5)	
Model	**TSP200W**
Max System Voltage	1000 V
Max Peak Power Pmax	200 W (±3%)
Maximum Power Point Voltage Vmpp	23.9 V
Maximum Power Point Current Impp	8.37 A
Open Circuit Voltage Voc	30.1 V
Short Circuit Current Isc	8.84 A
Module Efficiency (%)	15.20%
Temperature Coefficient of Voc	-0.352%°C
Temperature Coefficient of Isc	0.088% / °C
Temperature Coefficient of Pmax	-0.442% /C

Mechanical Specifications	
Model	**TSP200W**
Cell Size	156 mm x 156 mm
Module Dimension (L x W x T)	1324 mm x 992 mm x 45 mm
No. of Cells	6 x 8 = 48
Weight	19.5 kg (43 lbs)
Cable Length	900 mm

6.3 Pv Sizing Based On Required Power

To design a PV system, the average yearly insolation S [kWh/m^2/day] is taken into consideration where S is 5.48 kW·h/m^2/day using PV system sizing equation as shown in equation (4).

$$365 \times S \times P_{DC\ peak}\,\eta = E_{ac} \quad \text{.. (4)}$$

Where:

S = average yearly insolation [kWh/m^2/day] based on Location Fixed, 1-axis tracking, or 2-axis tracking installation and Tilt angle and Azimuth (ideally South facing). Since *S* is numerically equal to the average number of hours of full sun per day, e.g. *S* = 5.48 hours of full sun in this per day, e.g. *S* = 5.48 hours of full sun in Tripoli city site.

Overall system efficiency η, from PV to ac grid can be calculated using equation (5).

$$\eta = \frac{E_{ac}}{E_{PV\ peak}} \quad \text{.. (5)}$$

Also called "DC to AC derate factor", which including:

- Derating of PV nominal peak power (e.g. due to tolerances, temperature, or aging)
- Module mismatches

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- Losses due to wiring blocking diodes connectors• Losses due to wiring, blocking diodes, connectors
- Efficiency and MPP tracking performance of the power electronics ("inverter").

Typically η = 75% therefore for our case

$P_{DC\ peak} = 1W_p(DC)\,installed\ produces\ E_{AC} = 1.5kWh/year$

Total load consumption of typical Libyan house in Tripoli city is calculated =20.52kWh/day. Hence equal to 7489.8kWh/year.

Therefore the required PV system rating to be installed in rooftop of the house in Tripoli City is calculated as in equation (6).

$P_{DC\ peak} = \frac{7489.8}{1.5} = 4993.2kW_p$ ……………………………….(6)

In order to add reality and plausibility to the system, the design is based on commercially available equipments only. The parameters of the chosen PV module are given in Table 2.

Where module maximum $P_{DC\ peak}$ =200W_P, and its area is A_{PV} = 1.314m^2.

Number of solar panels required to satisfy given estimated load =4993.2/200 = 24.996 = 25 (round figure) modules and in order for the array to be even will be 26 modules. All PV Panels have a voltage (measured in volts) and current (measured in amperes or amps) rating. The selection of other components such as batteries, chargers and inverters depends on the output in volts and amps. In a solar system consisting of several solar panels, these panels can be connected in two ways and the overall voltage and current provided by the system depends on this. In a series connection between two panels, the voltage doubles and the current stays. In a parallel connection between two panels, the voltage remains the same and the current doubles. PV array consist of 26 modules, to determine how many modules would be connected in series requires selecting the voltage of the DC bus. DC voltage is selected as 48 V to reduce the system losses. Since the maximum power point voltage of the PV module is 23.9V,we can connect two in series to get a total voltage of 47.8V and use the DC- DC converter to adjust the output voltage to 48 V. Finally the array would be 2×13 modules.

In this case, the power capacity of the installation would be 26 (number of panels) x 200 W (capacity of each panel) = 5.2 kW (slightly higher than the 4.993 kW power capacity required to supply the house load, the fact that the number of required panels is rounded up to (a whole even number).

- Calculation of Required Area

As solar modules are not energy-dense they require a substantial amount of space in order to work. The 200W solar module selected above as shown in table.2 has a length of 1324mm (1.324 m) and a width of 992 mm (0.992m). This means each panel has an area of 1.605 x 0.909 = 1.314 m^2.

If 26 such panels are used then their area would be 1.314m^2 x 26 = 34.164m^2. Although the panels have a total area of 34.164 square meters, the space between the panels must be accounted for (as these panels require stands) and the total space required can be estimated by dividing the total area by 0.7 which yields to : 34.164m^2/ 0.7 = 48.806m^2 Therefore, as long about 49m^2 actual area required of flat space is available on the roof of the house, the PV panels can be installed. This is a relatively small space (only the equivalent of a 7 x 7 m square) and nearly all houses in Tripoli city would have that much space available, as they are usually flat-roofed and ideal for solar installations.

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6.4 Matlab/Simulink Output of Designed Pv Panel

A general block diagram of the PV model using Simulink is given in Fig. 1. The block in Fig. 1 contains the sub models connected to build the final model. Variable temperature (T), and variable solar irradiation level (G) are the inputs to the PV model. Table. 7 shows the electrical specification of the PV module selected for a Simulink simulation model. The PV module is derived from the equivalent electric circuit of a solar cell [8]. The equation that describes the I-V relationship of the PV cell is written below. The equation of the PV output current I is expressed as a function of the array voltage V as given by equation (7).

$$I = I_{ph} - I_D = I_{ph} - I_{sat}\left[e^{\frac{q(V+IR_s)}{nkT}} - 1\right] \quad \text{...} (7)$$

Where:

I_{ph} the light current [A], I_{sat} the diode reverse saturation current [A], R_s, the series resistance [Ω], V the operation voltage [V], and I the operation current [A].

q = charge of one electron$(1.602 \times 10^{-19} C)$,

n = Diode idealising factor, and k = Boltzman's constant $(1.38 \times 10^{-23}\, J/K)$. T=Junction temperature in Kelvin.

The modeling of the PV array for Matlab/Simulink environment is discussed in [8] - [9].

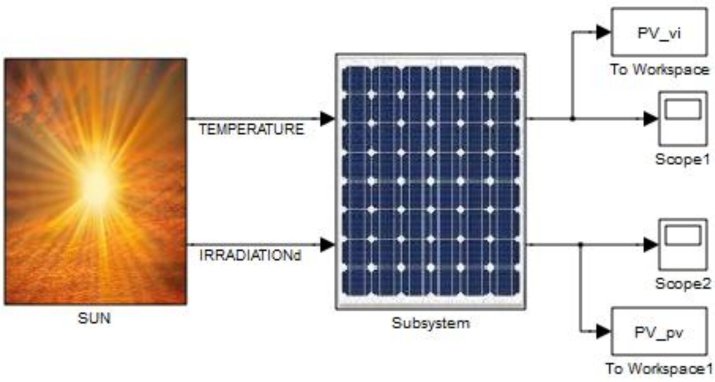

Figure. 1 Simulink model of PV module

The final model consists of 2 modules connected in series and 13 modules connected in parallel with manufacturer's specified nameplate as shown in Table 2. It takes irradiation, operating temperature in Celsius and module voltage as input and gives the output current Ipv and output voltage Vpv. With the developed Matalab/Simulink model, the obtained PV module characteristic is displayed as follows: The I-V output characteristics of PV module with varying irradiation at constant temperature are shown in Fig. 2. The P-V output characteristics of PV module with varying irradiation at constant temperature are given in Figure. 3. When the irradiation increases, the current output increases and also the voltage output increases slightly. This results in increase in output power. The I-V output characteristics of PV module with varying temperature at constant irradiation of 1000W/m^2 are shown in Fig. 4. The P-V output characteristics of PV module with varying temperature at constant irradiation are shown in Fig. 5. When the operating temperature increases, the current output increases marginally but the voltage output decreases drastically results in net reduction in power output with rise in temperature. The results are verified and found matching with the manufacturer's data sheet output curves.

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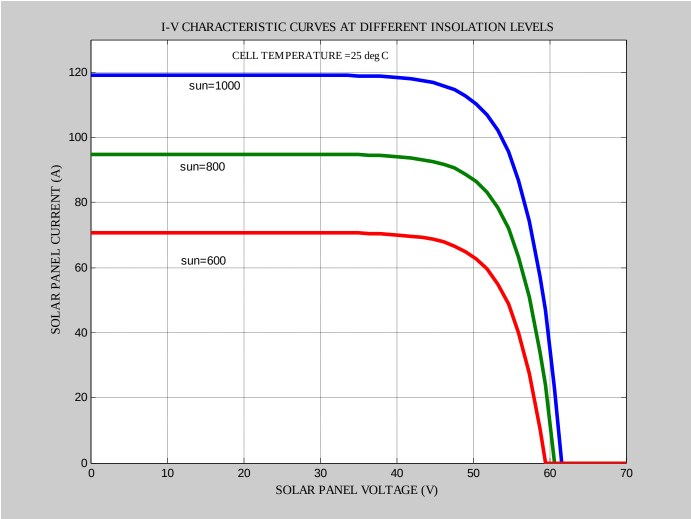

Figure. 2 Simulink model of Solar panel (26 strings) I-V Characteristic curves at different insolation levels (sun= 600, sun, 800, sun=1000)

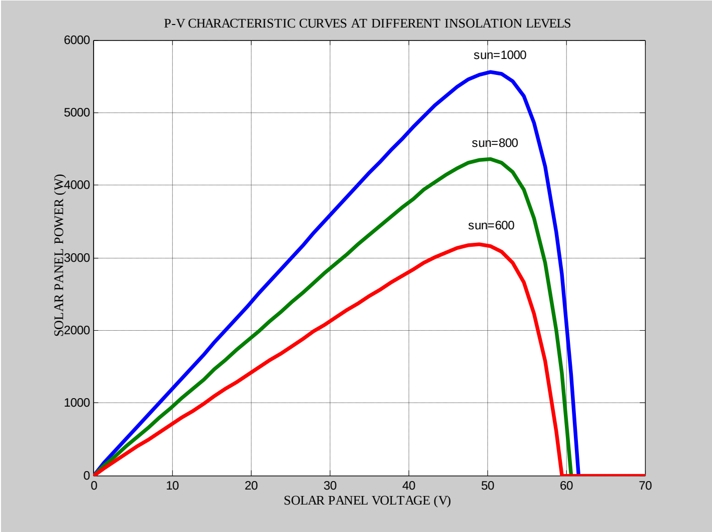

Figure. 3 Simulink model of Solar panel (26 strings) P-V Characteristic curves at different Insolation levels (sun=600,Sun=800,sun=1000)

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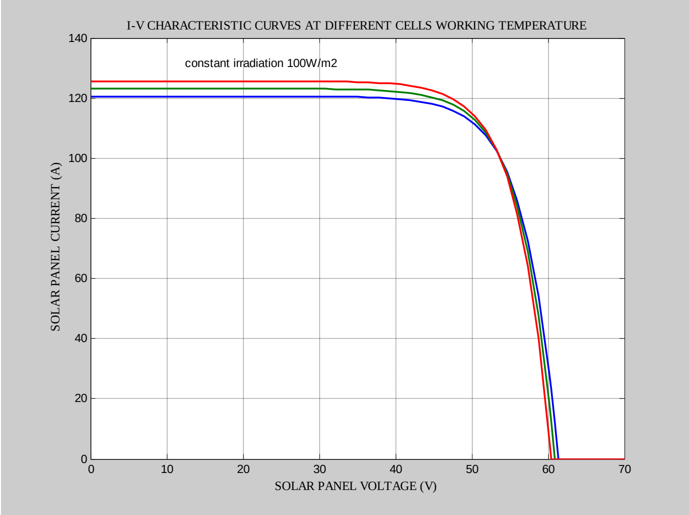

Figure. 4 Simulink model of solar panel (26 strings) I-V Characteristic curves at different cells working temperature($T=25^oC, T=50^oC$ $T=75^oC$)

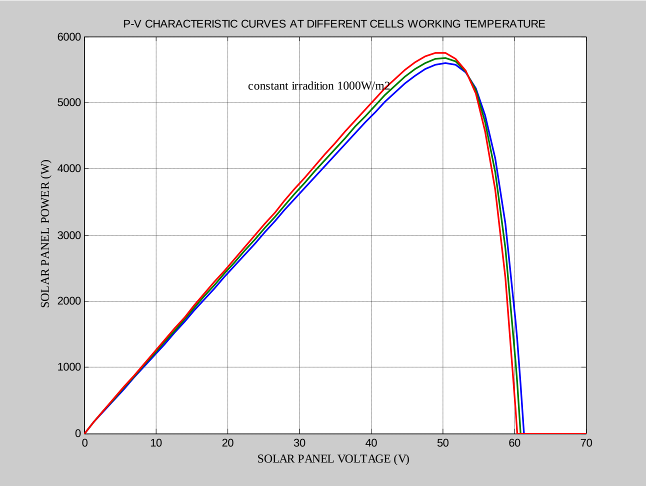

Figure. 5 Simulink model of solar panel (26 strings) P-V Characteristic curves at different cells working temperature ($T = 25^oC$, $T=50^oC$, $T=75^oC$.

6.5 Sizing of the Inverter

An inverter is used in the system to meet the need for AC power output. For correct solar system sizing the solar panels, inverter and battery bank all need to use the same voltage. The input voltage of the inverter depends on the inverter's power or watt ratting. For grid connected systems, the inverter must be large enough to handle the total amount of Watts needed at one time. Table.1 shows the peak possible power is 4760W; the inverter need to be able to deliver this power plus the highest starting load, in THIS case it is 1200 watts. So the peak at worst case at any time would be 4760+1200= 5960W. But In order to facilitate the efficient design of PV systems the inverter nominal .AC power output cannot be less than 75% of the array peak power and it shall not be outside the inverter. Therefore, the optimal selection of the inverter size is 6.0kW. The inverter is also chosen based on the selected PV modules. The selected inverter is shown in Table 6.

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TABLE 6 inverter specifications

Rated power	HYD-6000W+LED/LCD
Output continuous power	6000W
Output peak power	12000W
Input Input	DC input voltage
	DC working voltage
	DC input Low voltage protection
	DC input lack voltage alarm
	DC input Over voltage protection
	DC input fuse
	DC input voltage
	DC working voltage
	DC input Low voltage protection
	DC input lack voltage alarm
Output Output	Output wave form
	AC Output voltage
	Output frequency
	Output wave form
	AC Output voltage
	Output frequency
Static current	≤ 2A
Reversing efficiency	≥85%
Overload protection	6000W-6500W
Short circuit protection	Yes
Working temperature	-10℃ + 50℃
Temperature protection	+60℃ +70℃

6.6 Battery Sizing

As the system considered working 24 hours, battery is also taken as a main part of the system. Battery sizing is the capability of a battery system to meet the load demand with no contribution from the photovoltaic system or grid. Battery bank sizing is achieved by determining how many days needed to power the backed-up loads without a charging source (days of autonomy). Since the grid is the primary energy source, the only needs to consider the amount of time that the grid won't be available.

The photovoltaic system must maintain a continuous energy supply at night and on cloudy days when there is little or no solar energy or no grid available. The amount of battery storage needed depends on the load energy demand and on the weather patterns at the site. Having too much energy and storage capacity increases cost, therefore there must be a trade-off between keeping the cost low and meeting the energy demand during low-

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solar-energy periods. Here the battery must be chosen to be capable of giving required back up during load-shedding. The battery stores the energy to a maximum value as per average load energy requirement. Since the backup load daily requirement is 20520 W h/day. The battery storage capacity can be obtained using equation (8).

$$Battery\ storage\ capacity = \frac{energy\ demand \times autonomus\ days}{orrect\ ion\ of\ inverter\ losses \times Depth\ of\ dicharge \times system\ voltage} \quad .... (8)$$

$$Battery\ storage\ capacity = \frac{20520\ Wh}{0.85 \times 0.8 \times 48V} = 628.675Ah/d$$

Two 250Ah, 12V batteries in series yields 48 V at 250 Ah. Divide the 628.675 Ah total capacities by 250 Ah series battery capacity, which equals 2.515. Round up to 3 since batteries cannot be divided—the total bank (consisting of 6 batteries) would provide a capacity of 1500 Ah.

VII. SYSTEM DESIGN ANALYSIS AND OPTIMIZATION USING HOMER SOFTWARE

It is important to fully test the designed system against practical application before being fully implemented. HOMER software focused on, in addition to the technical aspects of the design, the cost, lifetime, and depreciation of the project as a whole. HOMER is a simulation and optimization software tool. It is comprised of renewable energy technology models that evaluate renewable technologies based on cost and availability resources. It is a tool which simplifies the task of evaluating design options for both on-the-grid and off-grid-connected systems. It consists of three different modules: simulation module, optimization module, and sensitivity analysis module. In this paper HOMER software is used to analyze the hypothetical effects of implementing a grid-tie PV (GPV) system model for home supply in Tripoli city, the capital of Libya. Figure. 6 show Site Characteristics of the proposed scheme as implemented in the Homer simulation tool.

7.1 System model

The proposed model consists of solar photovoltaic modules of 5 kW PV system, a grid connected power inverter r of 6 kW capacity to maintain the flow of energy between the AC and DC sides and the grid-utility with an H-1000 battery storage. The system is designed to have a life time of 25 with no replacement. During daylight time, PV array should do two functions; supply the required power to loads and recharge the batteries. During night and cloudy day's time, the batteries should have the capability of supplying the loads continuously. The proposed system is shown in Figure. 6.

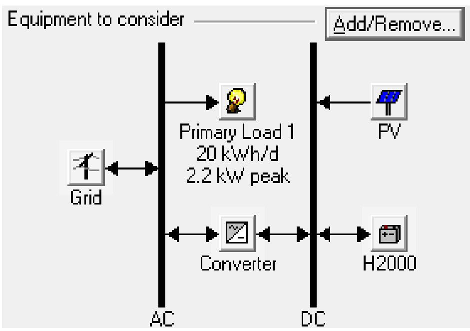

Figure. 6: System Configuration using HOMER

7.2 Daily Load Profile

A typical house in Tripoli city is chosen for case study. The daily electrical load profile in the proposed area is based on basic demands of utilities such as appliances and equipment which the family owned. The average daily load profile data is shown in Figure. 2. Also the seasonal profile for the load is given in Figure. 3. Both these figures are prepared by the HOMER software based on the input data of the daily load profile. The average daily load profile data is shown in Fig. 7. this is prepared by the HOMER software based on the input data of the daily load profile.

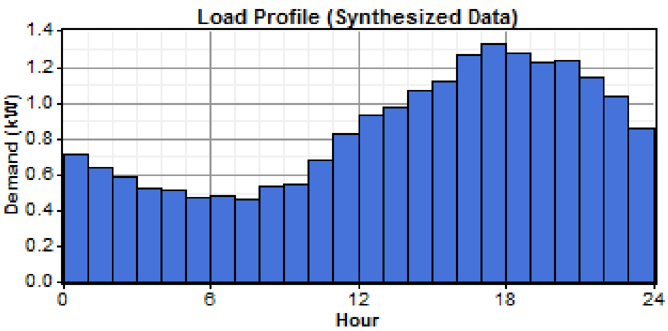

Figure. 7 The daily load profile of typical Libyan house

7.3 Solar Irradiation

The solar irradiance data of the site is obtained automatically by Homer software from the NASA Surface Meteorology and Solar Energy web site for Tripoli city 32^0.9022' North latitude and 13^0. 1858' East [6]. The annual average solar radiation for this area is 5.48kWh/m2/d. Figure 8 shows the solar resource profile over a one-year period. It can be seen that the average solar radiation in Tripoli is very high (5.48) kWh/m^2/d), i.e is suitable for Photovoltaic generation, and the clearness index shows that Tripoli is a sunny area, which predicts a promising energy production. It is shown in the Figure. 8 that the maximum solar radiation occurs in June and the lowest average radiation is in the month of December. It's clear from the site analysis and solar radiation data that Tripoli location has a great potential for a PV energy generation.

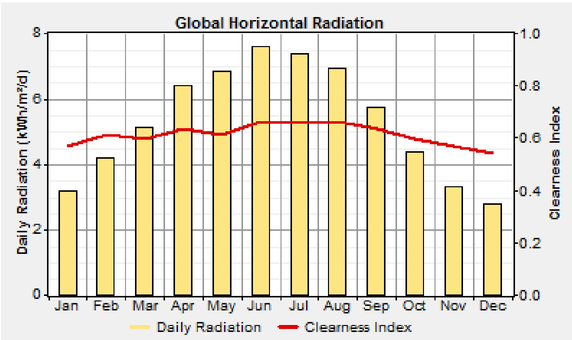

Figure 8. Monthly average solar radiation in Tripoli-Libya

VIII. RESULTS AND DISCUSSION

From the optimization results the best optimal system is designed in which components are 5 kW PV-Array and 6 kW inverter and 6 battery bank. The analysis also reveals that in case of load shedding or even grid failure the selected number of battery bank can give the necessary back up for 24 hours to run daily load house. After running the data through HOMER the optimal results data for the system in Tripoli city as shown in Table.7 indicates that the costs is the highest part of the system due to the PV panels. It has no or low

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maintenance and operation costs. On the other hand the converters and grid connection has a relatively low capital cost but it contributes to the total cost by the maintenance and operation cost.

TABLE 7. The optimization result of homer

	PV (kW)	H2000	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	5	6	6	5	$ 9,100	92	$ 10,275	0.108	0.69

Figure 10 shows the monthly electric production by the PV increases in summer months namely (March, April, May), and least in the winter months. Table 1.4 shows the costs associated with the system. The highest part of the system is due to the PV panels but has no or low maintenance and operation costs. On the other hand the converters and grid connection has a relatively low capital cost but it contributes to the total cost by the maintenance and operation cost.

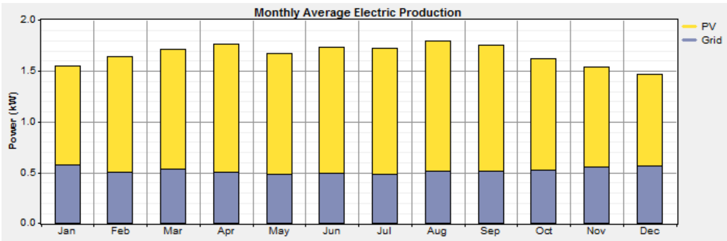

Figure 10. Monthly average electric production for grid connected PV system

IX. CONCLUSION

Libya is very rich in the solar resources and has a great potential for PV powered projects. In this paper, the design and energy management of a grid-connected PV system for home applications were presented. Comprehensive and simple procedure for designing the PV system was provided. The design was based on commercially available equipments. The total consumption of a typical house in Tripoli city was estimated. The number of required PV modules was calculated based on load estimation, available area and site location. A battery bank was used to supply the load during utility frailer, at night and on cloudy days. The numbers of batteries connected in series and in parallel were determined. The system is sized and simulated using Matlab/Simulink and HOMER software, and the resulted system is composed of 5.0kW of PV and 6.0 kW inverter and 6 battery bank. The design was carried out with taking into consideration the minimization of the total cost. The important advantage of this approach is that in case of load-shedding & grid power failure battery can give the required back up for the whole house load. Due to incorporation of solar PV to the grid, it reduces the carbon dioxide and other harmful gases emission to a large extent in environment.

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