Design and Evaluation of Solar Power Systems Using Different Techniques

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Abstract-In this study, photovoltaic system design intuitive, numerical and analytical techniques are revised and discussed. The intuitive and numerical methods are used to design and evaluate PV system for supplying lighting for renewable energy lab in Higher Institute for Mechanical and Electrical Engineering, Zwara, Libya. In the numerical techniques, two softwares are used. The average daily load demand of the test system is 1.198 kWh/day by using real weather data for Libya. HOMER software is used to design and evaluate the PV system. The results indicate that the solar energy utilization is an attractive option with net present cost of the system, and cost of energy are, 443.7 USD and 0.151 USD/kWh, respectively, in comparison with diesel generator operating cost which is 0.558 USD/kWh. It is recommended to use the PV system instead of diesel generators in rural areas in Libya, which is justified on economic grounds.

Keywords*-HOMER, numerical and analytical techniques, solar PV, energy cost.*

I. INTRODUCTION

Energy is the total of force or power when applied can move one object from one position to another or Energy defines the capacity of a system to do work. Energy can be found in a number of different forms. Energy exists in everybody whether they are human beings or animals or nonliving things. Input or output of work changes the energy content of a body. Energy can have many forms such as: electrical energy, radiation energy, mechanical energy, potential energy, kinetic energy, chemical energy, thermal energy, magnetic energy and nuclear energy. As example sunlight can be converted to heat thus light is another form of energy [1, 2].

Mainly the energy resources are two types which are nonrenewable and renewable energy, nonrenewable energy resources is a natural resource which can't be produces or used more than first use, these resources are consumed much faster than natural can create them, for example oil, coal, natural gas and uranium also this type it can't be last forever [3, 4]. Non-renewable sources are not environmental friendly and can have serious effect on our health [5, 6]. They are called non-renewable for the reason that they cannot be re-generated within a short span of time [7]. The world is looking forward to find and make available alternative resources of energy, this is because it is expected that supplies of oil and gas will face shortage in the near future [8]. Renewable energy is energy which comes from natural resource which can be produced and grow or used like more than one time its unlimited resources such as a sunlight, wind, rain tides and geothermal heat [9]. They are available in plenty and by far most the cleanest sources of energy available on this planet [10]. For example energy that we receive from the sun can be used to generate electricity [11].

Similarly, energy from wind [12], geothermal [13], biomass from plants [14], tides can be used to fulfill our daily energy demands [15]. Solar energy is a promising resource and can be obtained easily [16]. However to let the solar energy compete with oil and gas better and high efficiency equipment are required to be developed [17]. Solar cells or photovoltaic have recently become available at acceptable price [18]. However, to enable better performance a tracking system can be developed to follow sun light [19]. Tracking system needs to be designed in a way to use minimum energy. The tracking system is can be design in one axis or more. Nevertheless, if more than one axis used more energy are required to run the system [20, 21].

The rate at which the energy is being produced and consumed can damage our world in many ways. In other words, it helps us to save the environment [22]. We can reduce those impacts by consuming less energy [23]. The cost of energy is rising every year. It is important for us to realize how energy is useful to us and how can we avoid it getting wasted [24].

Electricity is currently generated in Libya using domestically produced gas and oil [25]. The gas turbines aresomehow environment friend generators. They are very efficient, can be turned on or off relatively quickly [26, 27]. There are ranges of ways to convert sunlight into useful energy [28]. One method used for many centuries is to convert sunlight into heat, which can then be used for building heating or water heating [29, 30]. Two common examples of solar energy into heat are solar pool heating and solar water heaters [31, 32]. There are also two ways to convert sunlight into electricity [33, 34]. One is solar thermal electricity generation [35, 36], which uses much of the technology from conventional utility electricity generation [37]. In most utility electricity generation, heat is generated by burning a fuel such as coal or by a nuclear reaction, and this heat is turned into electricity [38]. Photovoltaic is another mechanisms for converting sunlight into electricity [39]. Photovoltaic are basically different in that they convert sunlight directly into electricity without transitional steps [40].

PV system size and performance strongly depend on metrological variables such as solar energy and ambient temperature and therefore, to optimize a PV system, extensive studies related to the metrological variables have to be done [41-45]. The importance of the meteorological data in sizing PV systems lies in the fact that the PV modules output energy strongly depends on the available solar energy, and ambient temperature [46-50]. The performance of a PV module strongly depends on the sun light conditions [51]. Furthermore, cell temperature is an important factor in determining the performance of PV cells [52]. The increase in cell temperature decreases PV module’s voltage linearly, while increasing cell temperature increases PV module’s current [53]. The effect of cell temperature on PV modules performance depends on PV cells manufacturing [54]. Thus, a different output power is expected when PV modules are working under different climate conditions [55]. In general, the most common optimization methodology that is followed by the researcher's starts by defining a specific area, and then a time series data for solar energy, and ambient temperature is obtained [56-58].

After that, the calculation of optimum tilt angle is conducted by modeling the solar energy on a tilt surface. Then based on the nature of the PV system (Standalone, grid or Hybrid) the calculation of system energy sources (PV array battery, wind turbine, diesel generator) optimum capacity is done [59-61]. Finally, the size of the inverter in the PV system is calculated optimally [62].

Standalone PV systems are widely used in the remote areas where there is no access to the electricity grid [63]. These systems prove its feasibility as compared to conversional standalone power systems such as diesel generators especially for remote applications because of the difficulty in accessing the remote areas and the cost of the transportation [64]. However, a PV system must be designed to meet the desired load demand at a defined level of security [65]. Many sizing work for PV system can be found in the literature. Based on the reviewed work it is found that there are three major PV system sizing procedures namely intuitive, numerical (simulation based) and analytical methods in addition to some individual methods.

Photovoltaics are the direct change of sunlight into electricity using the physical device called the photovoltaic effect. These devices affected highly by the reduction of solar radiation because of dust and clouds [66-70]. Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid [71]. The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU) [72]. The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized [73]. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance [74]. This allows the AC power produced by the PV system to either supply on-site electrical loads or to back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility [75]. This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for service or repair [76].

Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads [77]. These types of systems may be powered by a PV array only, or may use wind, an engine-generator or utility power as an auxiliary power source in what is called a PV-hybrid system [78].

The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load [79]. Since there is no electrical energy storage (batteries) in direct-coupled systems, the load only operates during sunlight hours, making these designs suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems [80, 81].

Matching the impedance of the electrical load to the maximum power output of the PV array is a critical part of designing well-performing direct-coupled system. For certain loads such as positive-displacement water pumps, a type of electronic DC-DC converter, called a maximum power point tracker (MPPT), and is used between the array and load to help better utilize the available array maximum power output. In many stand-alone PV systems, batteries are used for energy storage [82-85].

In this study, the design and analysis techniques of standalone PV systems are evaluated. The energy that is generated by this system is to be estimate using real weather data for Zwara-Libya to supply lighting load for Renewable Energy Lab. Basic principles of designing a quality PV system used to design the system have been described. Numerical software has used for design, analyze and estimate different components of the system. A sensitivity analysis has been carried out on some factors: initial cost, discount rate and conversion efficiency. Some experimental results are going to be carried to verify the simulation results.

II. CHARACTERISTIC EQUATION OF PV

In an ideal cell, the total current, I, is equal to the current I_L generated by the PV effect minus the diode current I_D, according to the equation (1):

$$I = I_L - I_D = I_L - I_o(\exp^{qV/kT} - 1) \qquad (1)$$

where I_o is the saturation current of the diode, q is the elementary charge 1.6×10^{-19} Coulombs, k is a constant of value 1.38×10^{-23}J/K, T is the cell temperature in Kelvin, and V is the measured cell voltage that is either produced (power quadrant) or applied (voltage bias). A more accurate model will include two diode terms. Expanding the equation gives the simplified circuit model, and the following associated equation, where n is the diode ideality factor (typically between 1 and 2), and R_S and R_{SH}represents the series and shunt resistances:

$$I = I_L - I_D - I_{SH} \qquad (2)$$

$$I_D = I_o(\exp^{qV_D/nkT} - 1) \qquad (3)$$

$$V_D = V + I.R_S \qquad (4)$$

$$I = I_L - I_o(\exp^{q(V+I.R_S)/nkT} - 1) - \frac{V + I.R_S}{R_{SH}} \qquad (5)$$

$$I_{SH} = \frac{V_D}{R_{SH}} \qquad (6)$$

A. Photovoltaic System Design Techniques

Solar power systems are widely used in the remote areas where there is no access to the electricity grid. These systems show its feasibility; however a PV system must be design to meet the desired load demand at specific level of security. Many sizing work for PV system can be found in the literature. Based on the review work we found that there are three major PV system sizing procedures namely intuitive, numerical (simulation based) and analytical methods in addition to sum individual methods.

III. INTUITIVE METHODS

The intuitive method is defined as a simplified calculation of the size of the system carried out without establishing any relationship between the different subsystems or taking into account the random nature of solar radiation. These methods can be based on the lowest monthly average of solar energy (worst month method) or the average annual or monthly solar energy.

However, the major disadvantage of this method that it may cause an over/under sizing of the designed system which results a low reliability of the system or high cost of energy produced. Some related work to this method can be found in literature [82]. In the definition of optimizing a PV system is whereas it has been defined as the process of determining the cheapest combination of PV array and battery that will meet the load requirement with an acceptable level of security over the expected life time [74].

Important steps required for design solar power systems using intuitive method. It includes load estimation, calculation of the solar potential, batteries, PV array and economic evaluation.

IV. LOAD ESTIMATION

An estimation of the energy demand of the load should be done firstly in designing the PV power system. This estimation is done by multiplying the power of each appliance by the average number of hours of use. Then a 20 % might be add to allow for losses caused by wiring dropped to ac conversion, dirty modules, ect. Load whatever AC or DC loads should be described in a work sheet by load quantity, load voltage, load run watts, hors/day, days/weeks, load surge watts, load average W h/day and percent of total (contribution). Table 1 shows the load work sheet of this project to estimate the load demand for the design.

Electrical load	Qty	Volts	Run watts	Hours / day	Days/ weeks	Surge watts	Ave. WH / Day	Per cent of total
LEDLights Day – Load A	10	220	12	9	5	13	771.4	64.34%
LEDLights Night – Load B	19	220	1.5	24	7	2	427.5	35.66%

The designer should consider energy conserving substitutes for items that are used often. Identify large and/or variable loads and determine if they can be eliminated or changed to operate from another power source. Glowing lamps should be used in place of incandescent lamp. They provide the same light levels with much lower power demand. Consider using DC appliances to avoid the loss in the dc/ac power conversion process. DC lights and appliances usually cost more, but are more efficient and last longer. The numbers of AC application are usually lower because these appliances were designed for use on an infinite utility power supply [63].

V. CALCULATION OF THE SOLAR POTENTIAL

Solar irradiance is the amount of solar power striking a given area. It is a measure of the intensity of the sunshine and is given in units of watts (or kilowatts) per square meter (wm^{-2}) . Insulation is the amount of solar energy received on a given area measured in kilowatt-hours per square meter ($kWhm^{-2}$) --this value is equivalent to peak sun hours.

Solar radiation data are often presented as an average daily for each month of course, on any given day the solar radiation varies continuously from sunup to sundown. The maximum irradiance is available at solar noon which is defined as the midpoint, in time, between sunrise and sunset. The term peak sun hours is defined as the equivalent number of hours per day, with solar irradiance equaling 1,000 Wm^{-2} that would give the same amount of energy. Therefore, peak sun hours correspond directly to average daily insulation in $kWhm^{-2}$. Insulation varies seasonally because of the changing relation of the earth to the sun. This is change, both daily and annually, is reason some systems use tracking array to keep the array pointed at the sun [66]. In this study, the solar potential in Zwara about 30° all the data of each month over a year of correctload (AH/day), peak sun (Hrs/day) and design current (A) from the load profile correct load (AH/day) we concede that correct load is constant through all the year then peak sun data from 0 to 30°. Finally design current (A) we get it from division correctload (A h/day) with peak sun (hrs./day) as shown in table 1 below of 30° solar potential data though a year.

Table 1: Solar potential at 30°

Tilt at latitude 30°					
Month	Correct load (A h/day)		Peak sun (hrs/day)		Current Design (A)
Jan.	5.44	÷	4.14	=	1.3
Feb.	5.44	÷	4.69	=	1.2
March	5.44	÷	5.39	=	1.0
April	5.44	÷	6.04	=	0.9
May	5.44	÷	6.42	=	0.8
June	5.44	÷	6.08	=	0.9
July	5.44	÷	5.35	=	1.0
August	5.44	÷	5.41	=	1.0
Sep.	5.44	÷	5.44	=	1.0
Oct.	5.44	÷	5.15	=	1.1
Nov.	5.44	÷	4.45	=	1.2
Dec.	5.44	÷	3.93	=	1.4

As mentions before that the definition of optimizing a PV system is has been defined as the process of determining the cheapest combination of PV array and battery that will meet the load requirement with an acceptable level of security over the expected life time that's mean we are looking also in solar potential part for define the worst energy by choosing worst peak angle that used to install system to avoid any weak possible of energy in the operation. Finally, the peak sun hourly per day will be 6, the design current 1.4 and the tilt angle is 30^{o}.

VI. BATTERY SELECTION

Generally battery work as a source, then to select battery for solar power system Firstly, you must decide the amount of back-up energy you want to store for your application. This is usually expressed as a number of no sun days, in other word, for how many cloudy days must your system operate using energy stored in batteries. There is no right answer to this question. It depends on the application, the type of battery and the system availability desired. When specifying the amount of storage you must be attentive of the difference between rated battery capacity and usable capacity [84]. Battery manufacturers publish a rated battery capacity, the amount of energy that their battery will provide if discharged once under favorable condition of temperature and discharge rate. This is much higher than the amount of energy you can take out of the battery repeatedly in a PV application.The best recommendation for number of days of storage is to put in as much battery capacity as you can pay for. Obviously, if you live in an area with extended periods of cloudiness you will need more storage capacity to keep the load going during these periods of inclement weather .also, if it critical that your load have power at all times, you will want to have a large battery capacity. A smaller battery size can be specified if you can live with some power outage [87]. Choose of batteries possibly the biggest decision to be made if planning a solar power system of any size. You are looking at a very small system; possibly using a truck battery, upgrading your battery capacity is possible to be not easy and expensive. For example, if you are using a 24 volt battery and make your mind up you need extra storage, you will either need to replace the battery for a larger one or connect a second battery of the same size in parallel with the first. When connecting batteries in parallel however, it is important that the batteries are similar. For this reason it may not be suitable to add to the battery after you have been using the system for a while, by which time there would have been some reduction in battery performance [88].

VII. PHOTOVOLTAIC ARRAY

This sizing technique is designed to generate enough energy during the design month to meet the load and cover all losses in the system. This means that in an average year the load will be met and the battery state of charge will be the same on the last day of the design month as on the first day. The design method uses current (amperes) instead of power (watts) to describe the load requirement because it is easier to make a meaningful comparison of PV module performance [89].

The most important thing that we should know when design PV system in PV selection part know the current that will be generate and the effective conditions such as dust on this current that will be produce, the module parameters at standard test conditions and at the highest expected temperatures should be recorded in the space provided on the worksheet as shown in Table 2. The number of parallel connected modules required to produce the design current is rarely a whole number and the number of series connected modules required to produce the design voltage.

There are four factors that determine any photovoltaic module's output-load resistance, solar irradiance, cell temperature and efficiency of the photovoltaic cells. The output of a given module can be estimated by studying a family of current and voltage (I-V) curves. Three signification points of interest on the I-V curve are the maximum power point, the open-circuit voltage and the maximum power point, the open-circuit voltage and the short circuit current. For a given solar cell area, the current is directly proportional to solar irradiance and is almost independent of temperature. Voltage and power reduce as temperature increases. PV modules connected in series must carry the same current. If some of the PV cells are shaded, they cannot produce current and will become reverse biased. This mean the shaded cell will dissipate power as heat and over a period of time failure will occur.

VIII. ECONOMIC EVALUATION

Description: doing a life –cycle cost analysis (LCC) gives you the total cost of your PV system including all expenses incurred over the life of the system. There are two reasons to do an LCC analysis; to compare different power options and to determine the most cost-effective system designs. Some important terms related to renewable energy system economics are presented herein. Example will be taken on PV system but the concept is the same for other renewable energy system. The most important PV economic parameters are the total costs of installing a PV system, electricity price, Feed-In tariffs and the energy payback time- EPBT. Investments into renewable energies, particular into PV and wind technologies are another economics related area. The cost of a PV system is measured in price-per-peak-watt (€/Wp or USD/Wp for example). Peak watt is defined as the power at standard test conditions (solar irradiance 1000 W/m^2, AM of 1.5 and temperature 25$°C$). Photovoltaic system costs encompass both module and BOS cost of installing a photovoltaic system having a power of 1 kW ranges from 4800 USD to 6800 USD/kWp (2009) whilst in 2010 average investment decreased to little more than 4,000 USD. Approximately about half of this investment would be for the PV modules, and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest. Noted BOS and installation costs can vary significantly. For example: when cost for site preparation, laying a foundation, system design and engineering, permitting, as well as assembly and installation labor are higher, total installation costs are higher too. The life cycle cost (LCC) of a PV system may also contain cost for site preparation, system design and engineering, installation labor, operation and maintenance cost. Photovoltaic systems have predictable for 25-year lifetime.

The several unlike equipment taken into account for calculating LCC such as:

- Capital cost
- Replacement cost
- Maintenance cost
- Salvage value

The capital cost is the initial cost that is spent for purchase of PV modules, batteries, charge controller, inverter, and mechanical structures to support PV modules, circuit breakers, and special cables, and installation charges. Replacement cost is the cost incurred for replacing batteries, charge controller, inverter, and the cables at the end of their life time. Batteries have to be replaced once every 6 years and the charge controller, inverter and the cable, once in 12 years. Maintenance cost is the cost incurred every year as annual maintenance cost. Salvage value is the money that is obtained while disposing the solar modules at the end of life cycle period. For calculating LCC, each of the costs is converted to its present worth. Even the salvage amount is converted to its present worth for calculating LCC [1].
Interest rate in Libya, i = 7%
Inflation rate in Libya, f = 4%
Peak Sun Hours for Libya= 5 hours

Table 2: Economic Assumption of PV System

component	Capital (USD)	Lifetime (Years)	Replacement (USD)	O&M (USD)	Fuel (USD)
PV	1,064	25	0	0	0
Inverter	150	15	100	0	0
Battery	200	6	150	60	0

Energy generated/day/module = 140 W x 5 h = 700 Wh

Libya gets 5 to 5.9 hours of peak sun hours in a day on an average over a year.
Total energy generated/day, E = 700 Wh x 2 = 1.4 kWh
The next step is to draw a Cash Flow Diagram for the given data. It is shown in figure3.3.

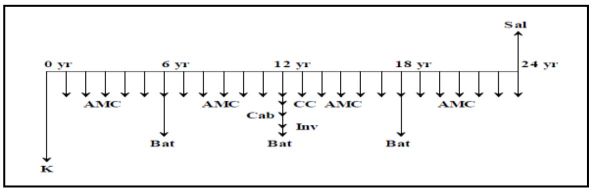

Figure 1: Cash Flow Diagram

In the cash flow diagram, **K** stands for capital cost incurred at year 0, **AMC** stands for annual maintenance cost accounted at the end of each year, **Bat** stands for replacement cost of batteries at the end of 6 years, 12 years, and 18 years, **CC** stands for replacement cost of charge controller at the end of 12 years, **Cab** stands for replacement cost of cables at the end of 12 years, **Inv**stands for replacement cost of inverter at the end of 12 years, and **Sal** stands for salvage value that is obtained at the end of 24 years.
The next step is to calculate the present worth of each expenditure occurred at year 0.
The present worth of capital cost, K is *PW1* = USD 3733
The present worth of replacement cost of batteries after 6 years,

$$PW2a = Bat \times \left(\frac{1+f}{1+i}\right)^{6} = 337USD$$

The present worth of replacement cost of batteries after 12 years,

$$PW2b = Bat \times \left(\frac{1+f}{1+i}\right)^{12} = 284USD$$

The present worth of replacement cost of batteries after 18 years,

$$PW2c = Bat \times \left(\frac{1+f}{1+i}\right)^{18} = 240USD$$

The present worth of replacement cost of charge controller, inverter, and cables after 12 years, 98, 100, and 228 respectively.

$$PW3 = C \times \left(\frac{1+f}{1+i}\right)^{12}$$

Where *C = CC + Cab + Inv.*
The present worth of the annual maintenance cost considered over the period of 24 years,

$$PW4 = AMC \times \left(\frac{1+f}{i-f}\right)^{12} \times \left[1-\left(\frac{1+f}{1+i}\right)^{24}\right] = 529USD$$

The present worth of the salvage value obtained by disposing solar modules and mechanical frames at the end of 24 years,

$$PW5 = Sal \times \left(\frac{1+f}{1+i}\right)^{24}$$

Therefore the *Life Cycle Cost = LCC = PW1 + PW2a + PW2b + PW2c + PW3 + PW4 – PW5*
LCC = 5002 USD
Now, the annual life cycle costing is calculated from the following expression:

$$ALCC = \frac{1}{\left(\frac{1+f}{i-f}\right) \times \left[1-\left(\frac{1+f}{1+i}\right)^{24}\right]} = 284USD$$

Hence, the cost per unit of energy is calculated to be:

Cost/unit

$$= \frac{284}{365days \times 1.4kWh} = 0.555USD/kWh = 0.21OMR/\text{kWh}$$

IX. NUMERICAL METHODS

A system simulation is used in this case. For each time period considered, usually a day or an hour, the energy balance of the system and the battery load state is calculated. These methods offer the advantage of being more accurate, and the concept of energy reliability can be applied in a quantitative manner. System reliability is defined as the load percentage satisfied by the photovoltaic system for long periods of time; these methods allow optimizing the energy and economic cost of the system. However, these methods can be divided into two types namely stochastic and deterministic. In stochastic methods, the author considers the uncertainty in solar radiation and load demand variation by simulating an hourly solar radiation data and load demand. Meanwhile the deterministic method is represented by using daily averaged of solar energy and load demand due to the difficulties in finding hourly solar energy available data set.

In the total life –cycle cost of standalone photovoltaic (SAPV) power system is mathematically formulated. Meanwhile, an optimal sizing algorithm for the PV array and battery capacity is presented.

X. HOMER

HOMER, the micro power optimization software developed by Mistaya Engineering, Canada for the National Renewable Energy Laboratory (NREL) USA, used in this analysis simplifies the task of evaluating designs of both off-gird and grid-connected power system for a variety of applications. In designing a power system, many decisions about the configuration of the system are to be made: components to include in the system design, size of each component to use etc. the large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult. HOMER'S optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations.

Using HOMER software for optimizing to find the best cost benefit of hybrid-solar power generation relative use cost in Nigeria. The cost benefit analysis of a wind/solar hybrid system was done using HOMER software and comparison was also made with utility supply. Central grid power is the least luxurious option but may not be available to most rural households far from the grid. Hence it is necessary to supply these areas from isolated power sources. The proposed system used (0.05 – 0.4 kW) PV panel with (0.4 kW DC) FD series wind turbine, (0.1 – 1.5 kW) converter, and (200 Ah/12 V, bank size: 1-8 batteries, vision 6 FM200D) battery. The authors result obtained from the optimization gave the initial capital cost as 3,455 USD while operating cost is 69 USD/year. Total net present cost (NPC) is 4251 USD and the cost of energy (CoE) is 1.74 USD/kWh. The authors found that, the hybrid system have a pay-back period of about thirty-three years and at current costs.

It recorded data that have been used to assess solar energy potential in Zwara and it is found that the average global horizontal solar resource is about 4.3kWh/m^2/day . Homer allows the modeler to compare many different design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs. Figure 2 shows the schematic diagram considered are PV, converter, battery bank and loading system from HOMER software that have been used.

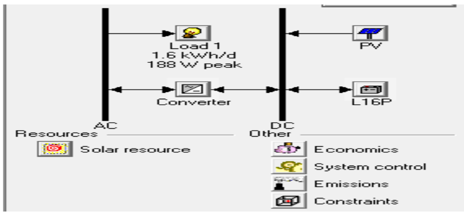

Figure 2: HOMER schematic diagram for the PV system

In these research 280 Wp PV systems is installed at Zwara zone for search work purposes. Table 3.6 below shows the specifications of the modeled PV system.

Table 3: Modeled Standalone (SA) 1680 W PV System Specification

PV module	
PV module rated power	140 Wp (2 module)
Maximum voltage	17.7
Maximum current	7.91
Open circuit voltage	22.1
Short circuit current	8.68
Efficiency	13.9%
Temperature coefficient of *Voc*	-0.36 %/k
Temperature coefficient of *Isc*	0.06 %/k
Inverter	
Rated power	1 kW
AC voltage	220-240
Efficiency	94.1%

Table 3 shows the specification of the modeled PV system that using in this project with 140Wp (2 module) PV module rated power which are 280 W/PV with tow batteries in series for 50 Ah each ,that selected to install in the roof of faculty of Engineering building in Zwara. The system contains PV modules, inverter, batteries, solar charge Regulator and special cables in order to supply efficient power for the specified load.

HOMER software Data input

PV Array Data

For the PV array the capital and replacement costs were specified with 532 USD and 420 USD, respectively. Little maintenance cost was considered for the panels around 20 USD/yr. A derating factor of 90 % and 25 years lifetime was considered as shown in Fig 3.

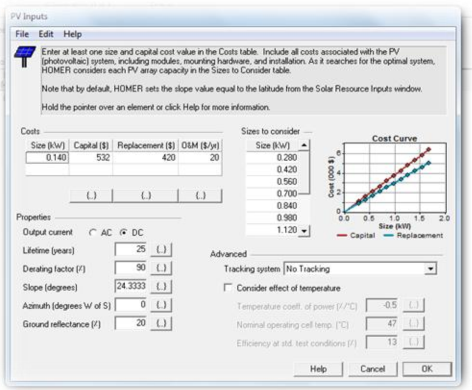

Figure 3: Photovoltaic solar inputs

Battery Data

The battery chosen is the Vision 6FM55D. It has a nominal voltage of 12 Volts and nominal capacity of 55 Ah (0.66kWh). There were four batteries considered by HOMER in the simulation shown in Fig. 4.

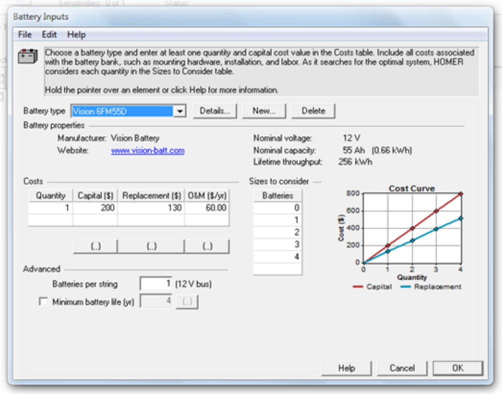

Figure 4: Storage batteries input

Inverter Data

The inverter efficiency was assumed to be 94.1 % for all the size considered. The size considered is 0.300 kW. The converter input is shown in Fig 5.

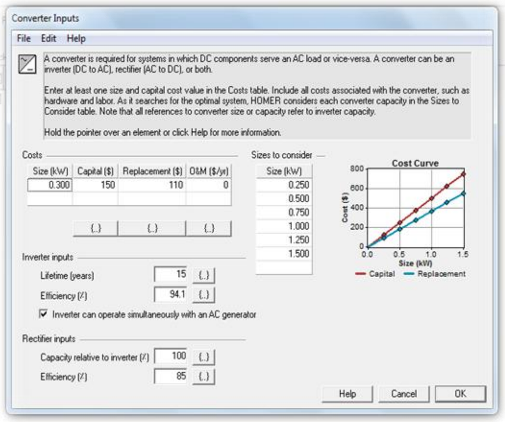

Figure 5: Converter input

Load Data

Figure 6 below shows that a typical lighting load was considered. The consumption includes LED points.

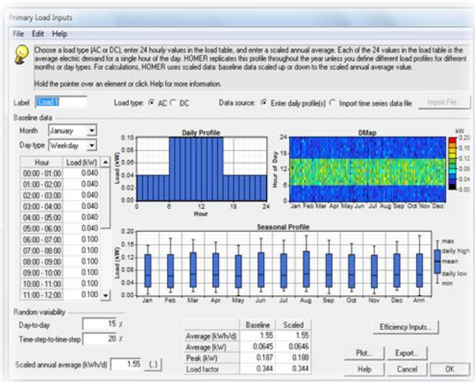

Figure 6: Load input

HOMER software result

Figure 7 shows the power generation shares in the planned system. The PV array rate capacity is 0.420 kW and it is produces 712 kWh/yr. Also, it is meaning output is 1.95kWh/d and capacity factor is 19.4 %. As for battery, it is used in almost 25 % of year time and the annual throughput is 259 kWh/yr. the energy demand of the propose system is 506 kWh/yr. the initial cost, net present cost of the system , and energy cost are 2121USD, 5.724USD and 0.315 USD/kWh, respectively.

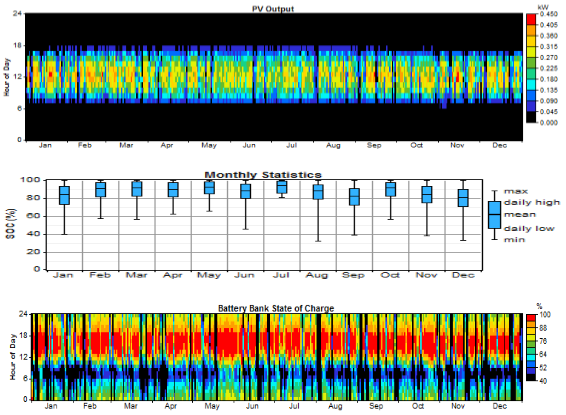

Figure 7: Power generation share of the proposed system

As the expected of lifetime of the component of this system in input into the HOMER software for PV, Battery and Inverter: 25 years, 5years and 15years respectively. The acquisition cost shown in table 4. Also, figures 8 and 9 show the power generation, which relatively high, cash flow and cash flow summary, respectively.

Table 4: Economic optimized of PV System components

component	Capital (USD)	Lifetime (Years)	Replacement (USD)	O&M (USD)	Fuel (USD)
PV	1,596	25	0	767	0
Inverter	125	15	38	0	0
Battery	400	6	1,306	1,534	0

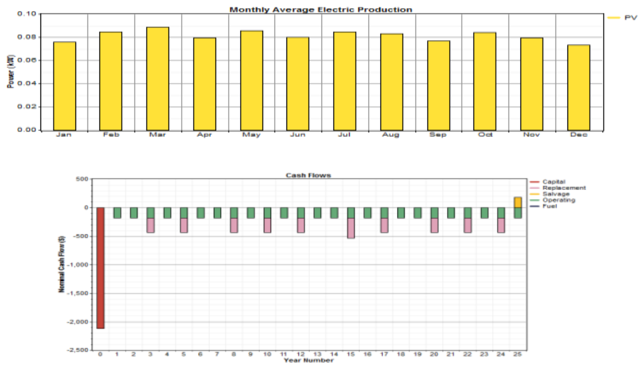

Figure 8 Cash Flow Diagram

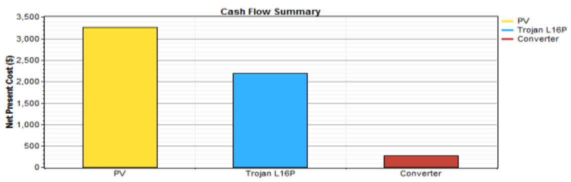

Figure 9: Cash Flow summaries Diagram

Global radiation on a horizontal surface usually used to determine the energy input to PV system. Therefore, PV modules generate DC electricity which converted to AC using inverter to supply the AC load. This electricity can be used at night by employing a storage mechanism such as a battery. Batteries used for this purpose have a large storage capacity. As we know that PV system will produce DC current in order to provide AC current we use inverter.

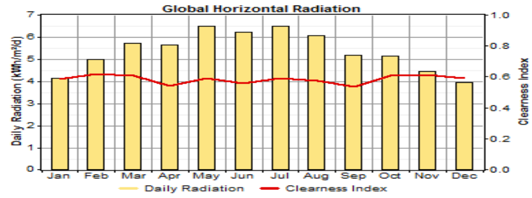

Figure 10: Solar irradiance in Zwara

XI. RESUATS AND DISCUSSION

In the analytical technique, equations describe the size of the PV system as a function. The main advantage of this method is that the calculation of the system size is very simple at the same time as the disadvantage of this method is represented by the difficulty of finding the coefficients of these equation are location dependent factors. All these methods have used for design analyze and estimate different components of the system. A sensitivity analysis has been carried out on some factors: initial cost and conversion efficiency in each method.

Economic Analysis:

life –cycle cost analysis (LCC) gives the total cost of your PV system including all operating cost incurred over the life of the system and this is very important to know before starting to any kind of projects to know the benefit of this system also there are two reasons to do an LCC analysis:

- To compare different power options
- To determine the most cost-effective system designs.

The life cycle cost (LCC) of a PV system may also contain total installation costs and cost for sit training, system design and engineering, installation labor, operation and maintenance cost. Photovoltaic systems have predictable for 25-year lifetime.

The capital cost is the initial cost that is spent for obtain of PV modules, batteries, charge controller, inverter, and mechanical structures to support PV modules, circuit breakers, and special cables, and installation charges. Replacement cost is the cost incurred for replacing batteries, charge controller, inverter, and the cables at the end of their life time. Batteries have to be replaced once every 6 years and the charge controller, inverter and the cable, once in 12 years. Maintenance cost is the cost incurred every year as annual maintenance cost. Salvage value is the money that is obtained while disposing the solar modules at the end of life cycle period. Starting with the first method intuitive method after doing all the calculation, the cost of energy equal 0.21 USD/kWh got it from annual life cycle cost which equal $284USD$ and the capital cost equal 1,064 USD the problem in this method is that the calculation of system carrier out without establishing any relationship between the different subsystems or taking into account the random nature of solar radiation. The result is not that much accurate because it comes from estimation calculation it could be over estimations or under estimation from cost of energy unlike in numerical methods presented the advantage of being more accurate, it is much more accurate than intuitive method it calculate automatically using numerical techniques and the result in HOMER found to be more accurate in calculating the initial cost, net present cost and energy cost of the system. HOMER software has been used for the same system and it is found that the capital cost and energy cost are 2121 USD and 0.555 USD/kWh.

In HOMER it gave more accurate information on the technical design side view but on the economic side view the capital cost and CoE is depend on equipment's cost and size plus solar radiation data. Finally, the variation in cost of energy is in the range of 0.151 to 0.555. Also, it is found that the payback period found to be 7.7 years.

Technical Analysis

By evaluating the system in term of technical parameters of standalone PV system for all the three methods used (Intuitive method and Numerical methods and HOMER, it is found that the technical side for intuitive method as mention before in term of the size of the system (PV array size, Batteries size, load estimation, the solar potential) some steps required with many assumptions for this method.

In case of numerical simulation techniques by using HOMER, result shows that PV modules, inverter, batteries, solar charge, regulator and special cables in order to supply efficient power for the specified load. All performance depends on the range of daily radiation (kWh/m^2/d) and the cleanness index for each month during the year.

CONCLUSIONS

This study investigated different design and evaluation techniques for standalone PV power systems. The evaluation presented in terms of technical and economic criteria. The system used to supply lighting load for Renewable Energy Lab in Zwara. The investigation found that there are three main methods that used for PV system design techniques namely intuitive, numerical (simulation based) and analytical methods in addition to some individual methods. The techniques that selected to be used in this project were intuitive, and numerical (HOMER software). The investigations show that numerical is more accurate in comparison with intuitive technique.

The designed system has assessed based on cost of energy per kWh produced using different sizes of PV, batteries and inverters. It is found that numerical technique gives more accurate results. Using HOMER software, the most economic system used to supply light in Renewable Energy Lab has been determined. The test system has a daily load of 1.198 kWh/day. The results show that the optimum cost of PV system energy (0.151 USD/kWh) is more economical in comparison with the cost of diesel engine energy (0.5581 USD/kWh). The intuitive technique is overestimating the net present cost NPC and electricity cost in comparison with HOMER. Also, using intuitive technique in calculating the cost of energy (0.555 USD/kWh) still shows that the PV system cost of energy is more economical than the diesel generator option. Investigations show that PV system could represent a good option to be used to supply lighting and even houses in rural area of Libya.

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