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Compensation of Low Current by Photoelectric Methods

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Abstract

The cost of extracting conventional energy is increasing and conventional energy itself is becoming very scarce and research indicates an increase in pollution, and it also shows that the depletion of conventional energy sources is inevitable. All that means there is a dire need for an alternative type of energy, that is clean, easy to install and cost effective and that is Photovoltaic (PV) energy, which is available in abundance in the study area of research, in which unreliable conventional energy is used, is usually out of power for more than 12 hours a day and this shortage in power affects many sectors in the city, such as hospitals, schools, farms and basic facilities and even the refrigerators of the dead, whose bodies have been decomposed due to power shortage.

This paper studies the power situation in the town area, on latitude (31.53) and longitude (23.54), and finds an alternative renewable energy source, namely PV, and designs a reliable PV system that would compensate for the usual conventional power shortage suffered by Tobruk City. Two load scenarios are considered, one is the required load in which only the essential electric devices are involved and the

other is optional in which some extra electric households are added. It is believed that this power solution would not only guarantee the availability of power for the town area, but it also saves money in the long run and saves the environment since it is a clean that is easy to install and maintain.

Keywords: PhotoVoltaic, PV, Renewable Energy.

1. Introduction

The cost of extracting conventional energy is increasing and energy is becoming very scarce and could be affected by politics and war, as shown in Fig. 1, which shows the effect of 2011 revolution on oil production (Chivvis and Martini, 2014)

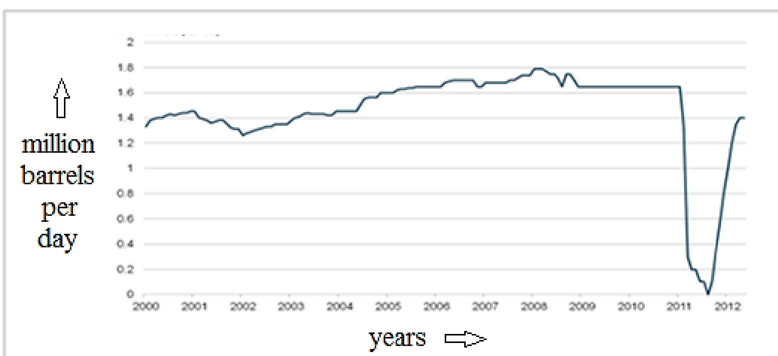

Fig. 1. The Effect of politics and war on oil production (Chivvis and Martini, 2014).

Research also indicates an increase in pollution (Fig. 2) and predicts the depletion of conventional energy resources during the last quarter of the 21st century. All that means that there is a dire need for an alternative type of energy, which is clean, reliable, easy to install and cost effective, and that is Photovoltaic (PV) energy, which is available in abundance in Libya. Fig. 3 shows solar radiation falling in this study area in a year (in kWh/m2/day) (Ahwide and Aldali, 2013).

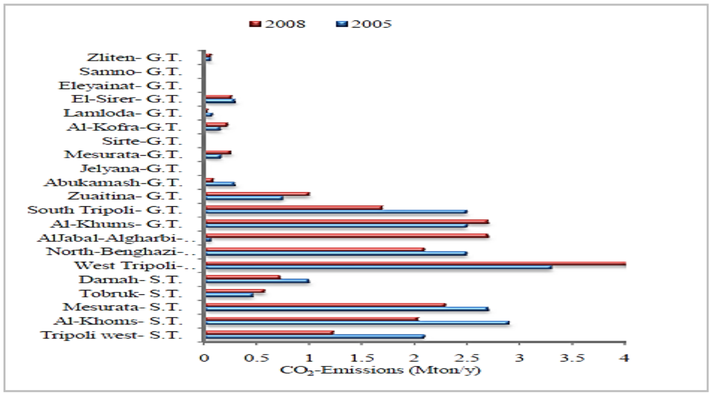

Fig. 2. CO_2 Emissions in 2005 and 2008 by Libyan electric companies (Ahwide and Aldali, 2013).

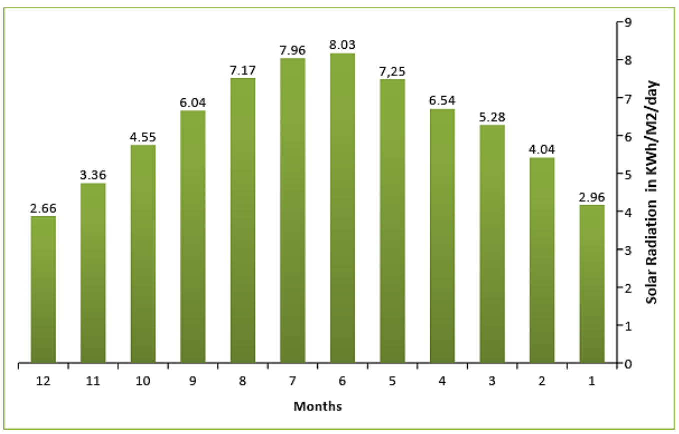

Fig. 3. Solar radiation in the area's of study throughout the year (kwh/m^2/day)(Ahwide and Aldali, 2013).

Unlike conventional generation systems, solar PV energy is available at no cost and it generates electricity pollution-free and can easily be installed on the roofs of residential homes as well as on the walls of commercial buildings. Another thing, is that demand and need for electricity is increasing rapidly, as shown in Fig. 4. in the near future the need for power consumption goes to about 9000 MW in 2020 (Ahwide and Aldali, 2013).

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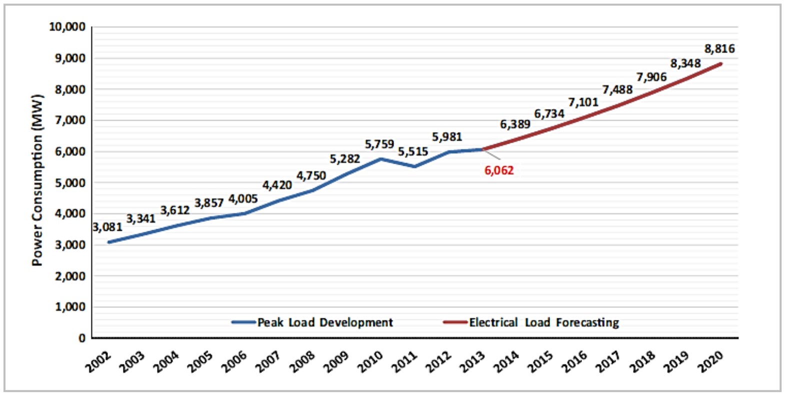

Fig 4. Increase in energy demand in Libya, now and in the near future (Ahwide and Aldali, 2013).

2. Photovoltaic (PV) Systems

Photovoltaic (PV) gets its name from the process of converting light (photons) to electricity (Fig. 5). Traditional solar cells are made from silicon, and they are generally very efficient (Knier, 2002). Thin film cells use semiconductor materials only a few micrometers thick. Because of their flexibility, thin film cells can double as rooftop shingles and tiles and building facades (NREL, 2019).

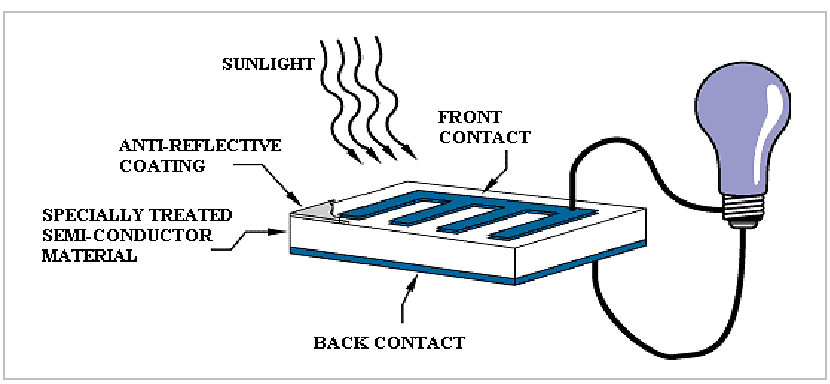

Fig. 5. The process of converting light (photons) to electricity (Knier, 2002).

Usually, PV cells are connected as shown in Fig. 6, where they are connected to inverters to supply AC voltage and tied optionally to the public grid.

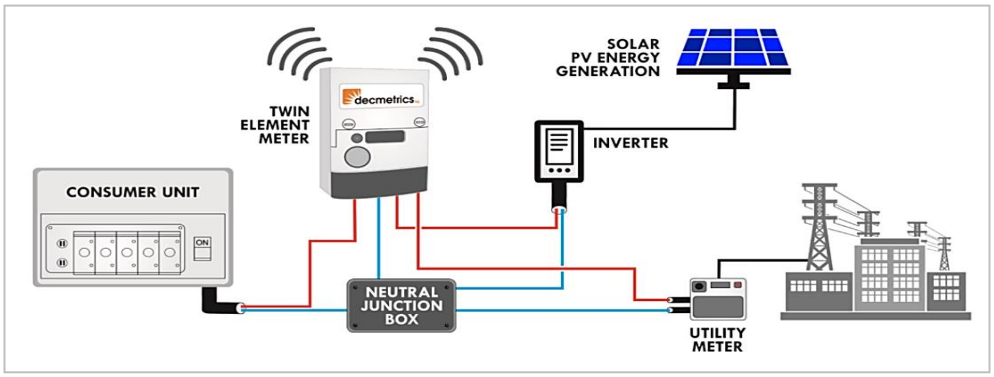

Fig. 6. PV systems connections tied optionally to the public grid (West Magazine, 2012).

3. Power Shortage in Case Study Area

Some areas in Libya are usually out of power for more than 12 hours a day and there are many reasons for that, including increase in population and buildings and the difficulty in maintaining conventional power sources and most of all the chaos and war in the country that destroyed many power equipment, wiring and transmission lines. It is severe electricity crisis involving hospitals, schools, farms and basic facilities and even the refrigerators of the dead, whose bodies have been decomposed due to power shortage. This is due to the war that has been going on for years. Fire has hit the power plants and some of them have been stolen by criminal gangs and copper transport lines have been stolen in more than one area.

4. Problem Statement

The depletion of PowerStation and its equipment led to the suspension of some units and the reduction of generation available to the public network. The workers at the station are trying, to the extent possible and with limited availability, to cover the

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deficit through nutrition from the North Benghazi station, as well as from the districts of the Egyptian Salloum area to prevent increasing the hours of daily loading of the citizens but current consumption makes it more difficult to provide electricity to dozens of residents of the city and neighboring areas because of the low temperatures that sometimes reach below 10 degrees Celsius, which requires the use of heating devices continuously. The case study area is a small town, suffering from a power shortage, and there is a dire need to find an alternative renewable source of energy.

5. Literature Review

Renewable energy (RE) alternatives to conventional energy as an option to solve the power shortage in certain areas of the world have been subject to various research and studies around the globe.

In (Ramelli et al. 2016), a plan is proposed that calls for a wide spectrum of renewable energy applications and renewable energy applications, and the gained RE experience in Libya was highlighted.

Some researchers in Libya (Khalil et al. 2016) studied the effect of conventional on the environment and found out that there has been an enormous increase in CO2 emission and proposed to use RE sources, specifically a photovoltaic system model used it to estimate the energy output of a PV system installed in Libya.

The demand for energy, as (Khalil et al. 2016) suggested, will substantially increase in the near future as a result of the economic development in order to build new infrastructure in Libya after the massive destruction that happened during the last seven years, therefore, Libya should use its alternative energy supplies to cover some of its load requirements, and the country has very high potential for solar and wind energy beside other available renewable sources in the country like geothermal, biomass and tidal waves.

In (Frefer et al. 2017) researchers assessed the current situation of the General Electric Company of Libya (GECOL) by measuring the total and partial service productivity from 2006 to 2014 and two phases were used in the study to measure the company's productivity. In phase one, productivity was measured using the outputs data based on the electricity delivered and in phase two; an attempt was made to find the actual output and the results showed that there was a decline in the productivity of the company in all years of the study period and that the company's overall performance during the study period was generally poor.

An investigation of the financial and technological challenges and opportunities facing the utilization of renewable energy resources in Libya was done in (Mohamed et al. 2013), where researchers investigated the availability of different RE resources in Libya and the practicality of implementing some of these options and their study showed that despite the recent political changes, renewable energy is still strategically of high importance with solar and wind energy as the main sources of energy.

A report regarding energy production and consumption in Libya (UNEP, 2015) listed Waddan, Libya, as a prospect for the utilization of the existing geothermal source for power and underground thermal energy storage, in which surplus heat is stored in pipes in the ground during the warmer months to be extracted during the cooler winter seasons is being looked at as an option. The report also stressed that Libya has expansive areas of unencumbered desert land where solar radiation has been measured at 7.5 kWh/m2 and could lend itself to the development of solar energy.

The need for alternative energy pushed authorities in Libya toward a rapid but not well planned investment in RE; Renewable Energy Authority of Libya (REAOL) expects RE share to reach 10% of energy demand in 2025 (Rajab et al. 2017).

6. Proposed Solution and Proposed Model

The expected increase in the load demands can be compensated by utilizing solar PV systems. Based on 100$ price for the crude oil price per barrel the cost of one kWh produced by oil is about 0.176$, while the average cost of one kWh produced by PV is around 0.123$ (Eddine and Salah, 2012), and since this town area has plenty of solar radiation (Fig. 3) that makes PV systems a much better solution than other options. A solar PV system will be constructed to cover part of the deficit from the general electricity network. Looking at the data collected from the Electric Company for the year 2017 (Fig. 7) and the first quarter of 2018 (Fig. 8), indicates that PV systems can do the job efficiently and reliably over other RE options (TEC, 2014).

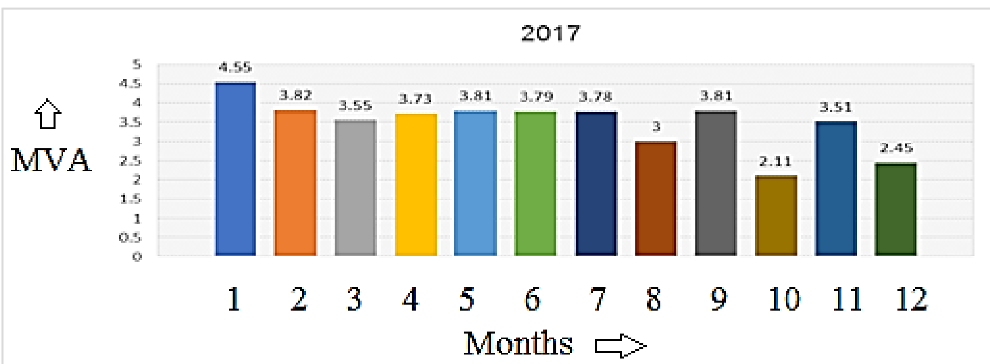

Fig. 7. Power loads in 2017.

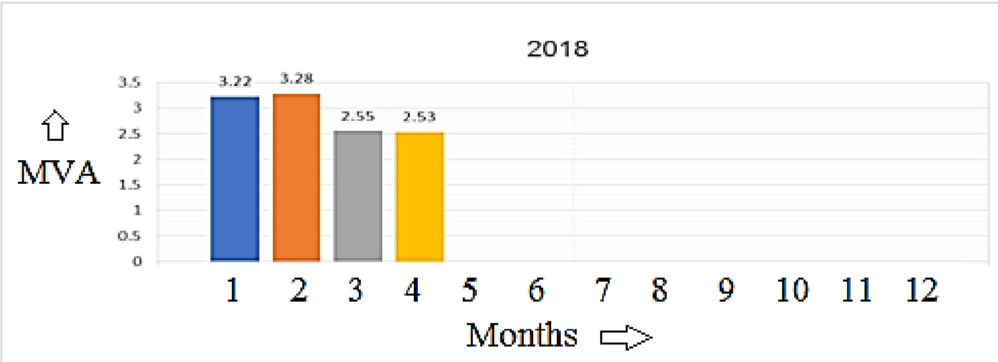

Fig. 8. Power loads in the first quarter of 2018.

Load accounts in the case study town (latitude (31.53) and longitude (23.54)) are all considered in the system design and calculations. The average monthly solar radiation, the angle of solar radiation, the angle of the solar panel's inclination are measured and/or calculated and that decided exactly how much energy needed for each home about 400 homes.

Two load scenarios are considered, one is the essential load in which only the essential electric devices are considered and the other is optional in which extra electric devices are added. Comparing costs of PV systems with the conventional sources of energy would lead to deciding which one is the most effective, reliable and efficient technique.

Designing of PV systems that would be installed in each one of the 400 homes in the case study town had been planned and implemented after a detailed study of the area and the various power supply options. It is a stand-alone system for each home that provides the essential electricity needs for residents in the area (extra power needs are considered as another option).

Although data collected and system design had been carried out for single homes, it could be easily connected to the general electric power grid as shown in Fig. 9. An important factor considered in this study is the cycle cost (LCC) which is conducted to show that although PV systems cost is large compared to conventional power cost, PV systems cost much less on the long run.

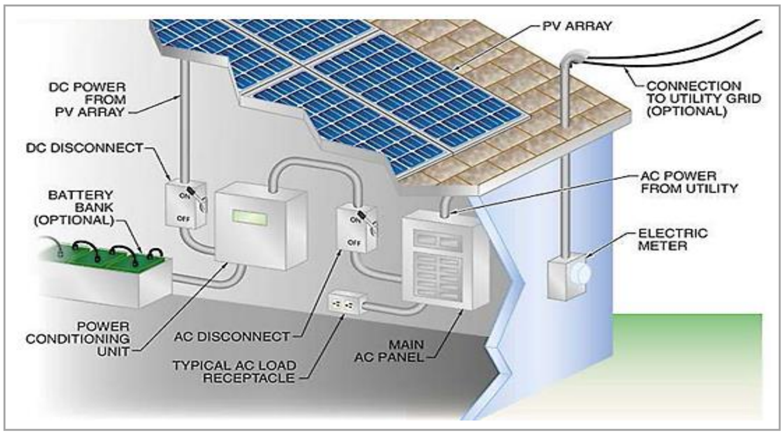

Fig. 9. A typical PV system (Sun Run, 2019).

Based on data collected from the Electric Company (Fig. 7 and Fig. 8), the power demand could be met using PV systems and that is proved by the calculations of load below, considering all factors affecting PV efficiency like latitude, longitude and PV load equations which were calculated using real data and the final results were compared with the value of the load resulting from the general grid electricity cost wise and environment wise. The main components of the PV system for each one of the 400 homes are shown in Fig. 10.

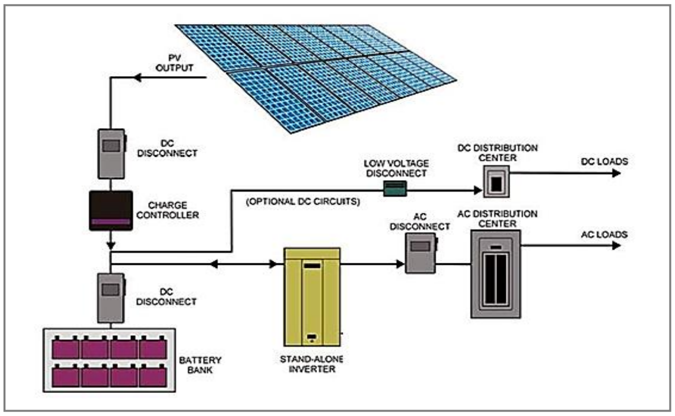

Fig. 10. PV systems components (Sun Run, 2019).

7. Calculations of Power Needs in Al-Wuter

Based on the power needs and the average use of household electrical appliances which could be approximated using a survey of the people in the area, the power consumption needs are calculated and the results are summarized in Table. 1 for essential appliances power loads.

Table 1. Essential power loads per home.

Total cost LD	Price Per kW LD	Daily Energy Wh/day	Number of Hours	Energy Wh/day	Number	Appliance
72	0.02	3600	10	60	6	Lights
67.2	0.02	3360	14	120	2	TV
45	0.02	2250	15	150	1	Refregerator
75	0.02	3750	15	250	1	Freezer
8	0.02	400	1	400	1	Water Pump
13	0.02	650	1	650	1	Wash Machine
12	0.02	600	2	300	//	Others
292.2		14610				

- Power Used by Appliances

Total appliances power use = 15000 Wh / day

PV panels energy = 15000 × 1.2 = 18 kWh / day

- Size the PV Panel

Total Wp of PV panel = 18000 / 5

Capacity needed = 3600 Wp

Number of PV panels = 3600 / 250 = 14.4

Number of PV panels Needed = 16 models

16 modules for one home

6400 modules for total of 400 homes.

- Inverter Sizing

Total Watt of all appliance = 15000 W

For safety, the inverter should be considered 25% - 30 % bigger than that.

The inerter size should be about 18750 W

400 inverters are needed for 400 homes.

- Battery Sizing

Total appliance use = 15000 W

Nominal battery voltage = 12V

Battery capacity = 15000/0.85×0.6×12 = 2450 Ah

Total Ampere hours (Ah) required = 2450 Ah

So, the battery should be rated 12V-2450 Ah.

400 Batteries of the same rating above are needed.

- Solar Charge Controller

Current = (16 × 250/12) × 1.2 = 400 A

Charge controller = (16×250/12) × 1.2 = 400 A

The controller must be rated 400A/12V or greater.

Charge controllers needed for 400 homes = 800.

- Assumptions Taken for the Design

Inverters efficiency is about 90%

Battery voltage used for operation = 12 volts

Combined efficiency is calculated as follows:

combined efficiency=inverter efficiency × battery efficiency=0.9 × 0.9 = 0.81 = 81%

Sunlight in a day = 8 hours/day (peak radiation)

Operation of lights and fan = 6 hours/day

PV panel power rating = 40 Wp.

The operating factor which is used to estimate the actual output from a PV module. [The operating factor is between 0.60 and 0.90] in normal operating conditions, depending on shading, temperature, dust on module, etc. (NIT, 2018).

8. Cost Estimation of PV System Components

Cost = No. of PV modules × Cost/Module = 16 × $250 = $4000

Cost of batteries = No. of Batteries × Cost/Battery = 1 x $1000 = $1000

Cost of Inverters = No. of inverters × Cost/Inverter = 1 × $1000 = $1000

Total cost of system components = $4000 + $1000 + $1000 = $6000

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Additional cost of wiring = 10% of Total = (10/100) x $6000 = $600

Total cost of the system = $6000 + $600 = $6600

≈ 10000 LYD (official rate)

≈ 25000 LYD (in reality)

Cost for 400 homes = 4000000 LYD (official) = 10000000 LYD (in reality)

9. Additional loads (optional/extra Household appliances) Analysis and Cost

Not all the people in the area would use only the essential devices, but many of them will be using some additional optional/extra appliances at different times of the year, so that must be considered in the design so the cost will be known prior to the final design. The additional power loads per home are shown in Table 2.

Table 2. Additional power loads per home.

Total cost LD	Price Per kW LD	Daily Energy Wh/day	Number of Hours	Energy Wh/day	Number	Appliance
100	0.02	5000	2	2500	1	A/C
120	0.02	6000	3	2000	1	Electric Heater
36	0.02	1800	1	1800	1	Iron
50	0.02	2500	5	500	1	Heater
306		15300				

The cost of the system considering the additional loads (appliances) can be calculated by adding the cost of the extra number of panels needed.

Total appliances power use = 15 K + 15 K = 30 K

Number of panels=32 (twice that in section 8) Cost =Number of PV modules × Cost/Module = 32 x $250 = $8000

Cost of batteries = No. of Batteries × Cost/Module = 1 x $2000 = $2000

Cost of inverters = No. of inverters ×Cost/Inverter = 1× $2000 = $2000.

- Total cost of system components

= $80000 + $2000 + $2000 = $12000

- Additional cost of wiring = 10% of total cost = (10/100) x $12000 = $1200

- Total cost of the system = $12000 + $1200 = $13200 ≈ 20000 LYD (official)

≈ 50000 LYD (in reality)

Cost for 400 homes = 8000000 LYD(official) = 20000000 LYD (in reality).

10. Conventional vs. PV Power Cost

The motivation behind installing PV systems is not only because it is clean and environment friendly, but this study is to find out the difference between conventional power generation, transmission, and distribution and renewable energy generation, where homes have stand-alone PV systems (with no transmission and no distribution costs).

The cost of the same amount of power using PV systems would be considered in the following section, where the cost of panels, inverters, batteries, etc., would be all added to the wiring costs and the Life Cycle Costing LCC of the devices needed between the cells and the loads.

After knowing the price of kilowatt hours in that area of the General Electricity Company and considering the transmission, distribution, labor, and maintenance costs (or $2M per 1MW, or $2000/kW-US standards), total cost of the 400 home power is:

Total cost (essential) = 400 x 15kW x $2000 = $12000000 = 18000000 LYD (official rate) = 50000000 LYD (in reality)

Total cost (essential + options) = 400 x 30kW x $2000 = $24000000 = 36000000 LYD (official) = 100000000 LYD (in reality)

Comparing the cost of conventional systems in use with the proposed PV system, it can be seen that the cost PV systems is much less than that of the conventional one and considering the pollution and maintenance, PV systems has a definite advantage.

11. Life Cycle Costing (LCC)

Life Cycle Costing (LCC) of the PV system includes the sum of all the present worths (PWs) of the costs of the PV modules, storage batteries, battery charger, inverter, the cost of the installation, and the maintenance and operation cost (M&O) of the system. The lifetime N of all the items is considered to be 20 years, except that of the battery which is considered to be 5 years. Thus, an extra 3 groups of batteries (each of 6 batteries) have to be purchased, after 5 years, 10 years, and 15 years, assuming an inflation rate is of 3% and a discount or interest rate of 10%. Therefore, the PWs of all the items can be calculated as follows (for the essential needs) [25]:

- PV array cost CPV = $ 4000
- Initial cost of batteries CB = $ 1000
- The PW of the 1st extra group of batteries (purchased after N = 5 years) CB1PW can be calculated, to be $ 719 from:
- 1000 $((1 + i)/(1+d))^5$, where i = inflation rate = 3% and d = interest rate = 10%
- The PW of the 2nd extra group of batteries (purchased after N = 10 years)
- CB2PW and that of the 3rd extra group (purchased after N = 15 years) CB3PW are calculated to be $ 518 & $ 372, respectively.

- Charger cost CC = $ 1000
- Inverter cost CInv = $ 1000
- Installation cost CInst = 0.1 x 4000 = 400 $

- PW of maintenance cost CMPW is calculated to be $1200 [25], using maintenance cost per year (M/yr) and system's life time (N = 20 years).

Therefore, the LCC of one home system can be calculated, to be $10209, from:

LCC = 4000 + 1000 + 719 + 518 + 372 + 1000 + 1000 + 400 + 1200, and total cost of the 400 homes will be $4083600, which is LYD 18376200, and that is still much less than the cost of conventional energy resources (LYD 40000000), besides it is clean, saves the environment and it is easy to install and maintain.

12. Components of the System

- PV Module Specifications

Fig. 10 shows the specification of PV modules.

- Batteries and Charge Controllers

Fig. 11 shows the battery used and Fig. 12 shows the charge controller, while Fig. 13 shows the charge controller's specifications.

Fig. 10. Specifications of the PV modules.

Fig. 11. 12V, 2450 Ah Battery.

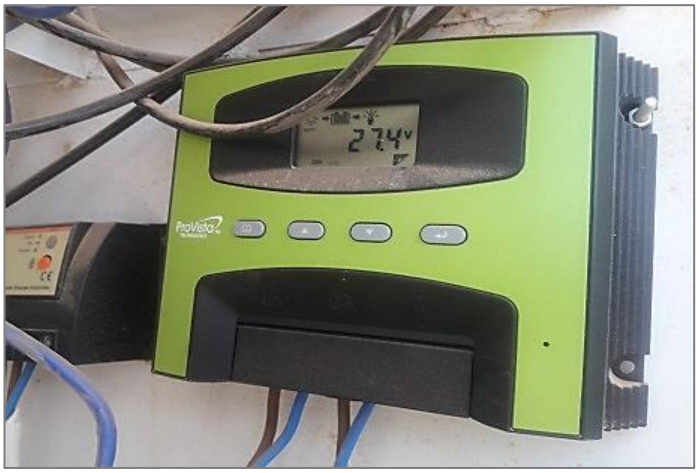

Fig. 12. A charge controller (12/24 DC).

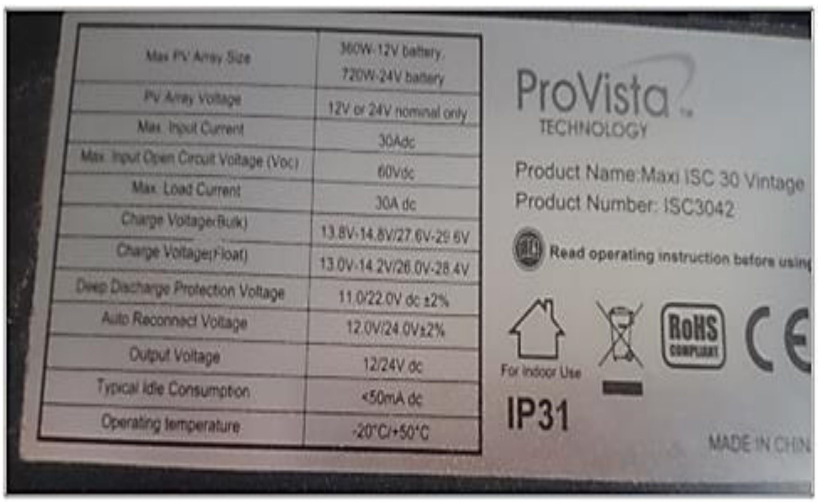

Fig. 13. charge controller specifications.

- DC to AC inverter

Fig. 14 shows the AC/DC inverter.

Fig. 14. AC/DC inverter (1700VA ≈ 1000W).

13. Conclusions

Supplying power energy for areas that suffer from power shortage and regular blackouts is very important, especially in Libya where some places like this town area are suffering power shortage due to war and power equipment damage. An alternative power supply that supply reliable source of energy had to be considered and Photovoltaic (PV) systems are the best choice because it is clean, easy to install and maintain, and cost effective in the long run. PV systems are reliable and excellent economic alternative to conventional energy generators, which are old and suffer from irregular maintenance.

The rural area has been researched and a study is carried out for 400 single residential homes in the area using an independent PV system. Following the detailed research and understanding of the power supply problem in the area, a complete design and cost analysis were done and results showed great power availability and excellent efficiencies. The PV systems alternative does not only guarantee power availability for people, but it also improves the quality of services in the area and decreases deforestation and CO2 emission.

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