ELSEVIER

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Energy Procedia 32 (2013) 90 – 98

Energy Procedia

International Conference on Sustainable Energy Engineering and Application

[ICSEEA 2012]

Design optimization of solar powered aeration system for fish pond in Sleman Regency, Yogyakarta by HOMER software

Igib Prasetyaningsari, Agus Setiawan and Ahmad Agus Setiawan*

Department of Engineering Physics, Gadjah Mada University, Jl. Grafika 2 Yogyakarta 55281 Yogyakarta , Indonesia

Abstract

Aquaculture centers in Yogyakarta located in Sleman District. The main contributors to fish farming in Sleman came from Sendangsari village, Minggir sub district. Fish farming carried out by individuals or groups. By 2010, this area accounts for 77,2 % of total fish production in Sleman, Yogyakarta. One of the problems of fish growing in ponds is the dissolved oxygen (DO) concentration in the water. In the fish farming business, the ability to maintain water quality is the key of improving fishery production capacity. The solution to maintaining water quality is the implementation of the aeration with renewable energy source.
Based on the geographical region, fish pond located away from power lines. So, it is necessary to use local potentials of renewable energy such as solar energy. The annual average solar radiation in Indonesia is 4.5 kWh/m2/day with 9% monthly variation. The main objective of the present study is to design the optimum sizing of electric power design to support the electricity demand of fish pond aeration system. Applied methodology provides a simple approach for sizing electricity system using HOMER software (Hybrid Optimization Model for Electric Renewables) to fulfill the requirement of 450 Wh/day primary load with 1.692 Wh/day peak load. The result of the analysis is a list of feasible configuration power system sorted according to the cost of energy (COE). The result show the optimal sizing of photovoltaic 1 kW, 8 battery of 200 Ah and inverter 0,2 kW. This is the most economically feasible and least cost of energy (COE) is about 0,769 $/kWh.

Keywords: Aeration; HOMER; optimum design.

* Corresponding author. Tel.: +62-856-288-6212
E-mail address: a.setiawan@ugm.ac.id.

doi:10.1016/j.egypro.2013.05.012

1. Introduction

Aquaculture centers in Yogyakarta located in Sleman District. The main contributors to fish farming in Sleman came from Sendangsari village, Minggir subdistrict. Fish farming carried out by individuals or groups. By 2010, this area accounts for 77,2 % of total fish production in Sleman, Yogyakarta [1]. One of the problems of fish growing in ponds is the dissolved oxygen (DO) concentration in the water. The level of DO under 2 ppm is dangerous to the life of the fish because at this level of DO the probability of mortality among the fish is high [2]. In the fish farming business, the ability to maintain water quality is the key of improving fishery production capacity. The common used in maintaining water quality is the implementation of the aeration.

Aeration is the process of bringing water and air into close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air and letting them rise through the water. Aeration can remove certain dissolved gasses and minerals through oxidation. We can use either the typical design of aerator which is introducing air into water or water into air. All aerator are designed to create a greater amount of contact between the air and water to enhance the transfer of gasses [3]. Aerator can driven by mechanical energy or electrical energy. It is depend on the type we use. Various types of aeration can be found in the field, ranging from splasher system, bubbler and pump [4].

Based on the geographical region, fish pond located away from power lines. So, it is necessary to use local potentials of renewable energy such as solar energy. The annual average solar radiation in Indonesia is 4.5 $kWh/m^2/d$ with 9% monthly variation [5]. The sun is a clean and renewable energy source, which produces neither green house effect gases nor hazardous wastes through its utilization. Renewable energy sources are being widely use due to the global environment issue.

Many literatures reported the application of renewable energy in remote area which located away from power lines or where the grid is not feasible. Mozes et al [2] demonstrate an aeration system, using a paddle wheel, powered by a photovoltaic power supply. The study was carried out on the coastal area in the center of Israel. Ghoniem [6] describes a computer simulation to determine the solar water pumping system performance in the Kuwait climate. Meah et al [7] show the design, instalation, site selection and performance monitoring of solar system for small-scale remote water pumping application. Noroozi et al [8] show the hybrid power system to supply electrical and thermal energy in Shahdad village in Chahabar, south east of Iran using HOMER (Hybrid Optimization Model for Electric Renewables) as a software tools for electric power system design.

Base on the above named papers we continue the research work on renewable energy for small-scale application. We focus on how to design the optimum sizing of electric power design to support the electricity demand of fish pond aeration in Minggir, Sleman, Yogyakarta, Indonesia.

2. Analysis

The area size will be used for carp's seeding is 1000 m2. The area divided into 7 parts; 3 parts for master pond, 2 parts for enlargement pond, 1 for pond nursery and also 1 for control room area of the solar power generation.The location of fishpond is far from power lines, so that the solar power generation system that is used is off-grid system. All of the loads will be supplied by the solar power generation. The need of pond aeration will be consentrated to the nursery pond, the the area size is 50 m2. This pond area will be divided into 10 ponds, the size is 2 x 1 x 0.5 m and this pond area also will be used for carp seeds, the age of the seeds are 2 weeks until 2 months.

The aeration will be needed in the evening, it is the lowest point of oxygen in the air. The blower can be used effectively and efficiently at 10:00 pm until 7:00 am or during 9 hours aeration in the evening.

The blower with big capacity is more efficient if it is supported by good distribution network system. The blower with big capacity will make easier for managing the aeration.

The larva of carp only need the small aeration. In the afternoon while the fitoplankton produce oxygen, aeration can be managed in a small scale. The faucet regulator in a distribution hose use to manage the aeration flow.

The blower that can be draining the water with a speed 60 liter/minutes. The volume flow will be distributed to 10 ponds so that every pond will get volume flow approximately 6 liter/minutes. The maximum volume flow is 6 liter/minutes, it can be varied with the regulator hose in a network distribution to every pond. The aeration speed can be controlled based on every pond's need. The blower with flow rate 60 liter/minutes needs 50-60 watt.

The lighting used to help the pond security at night. The lamps should provide enough illumination for people to keep watch the condition around the pond. The illumination of the lamp is about 1 foot-candle. The area is 15 ft (4.572 meter) x 40 ft (12.192 meter) [2]. The carp seeds pond that will be given the lighting is divided as five major spot; two spot in the solar cell house control, two spot in a nursery pond and one spot in a way to village. Every point using 23 watts of compact flourescent lamp (CFL). CFL lamps save money, use less energy, reduce light bulb changes, and lower greenhouse gas emissions [9].

2.1. Solar resources

The solar powered aeration is located in Sendangsari village, Minggir subdistrict. There are no solar radiation data measurement in Sendangsari village annualy. The annual average solar radiation based on NASA. The NASA satellite data will provide the annual average of solar radiation in a certain place. Sendangsari village, Minggir sub district located in latitude 7,590 South and longitude 110,260 East. Fig.1 shows the annual solar radiation based on NASA satellite.

2.2. Load calculation

The load determined by the energy demand. Table 1 shows the energy demand of fish pond in Sendangsari village.

Table 1 Calculation of fish pond load

No	Utilization	Power	Value	Working time	Energy demand
1	Aeration (blower)	50 W	1 unit	9 hours (22:00-07:00)	450 Wh/day
2	Indoor lighting	23 W	1 unit	6 hours (18:00-24:00)	138 Wh/day
3	Outdoor lighting	23 W	4 unit	12 hours (18:00-06:00)	1104 Wh/day
	Total				1.692 Wh/day

Calculating the overall system losses, assumed that the battery efficiency at 90%, inverter efficiency at 85% and wiring efficiency at 93%, the total load calculated to be 2.378 Wh based from equation below :

$$Total\,load = \frac{\sum E_{demand}}{\eta_{bat}\; x\, \eta_{inv}\; x\, \eta_{wire}} \qquad (1)$$

3. System components

3.1. Solar PV

The value of adaptation factor for the typical solar power generation's installation is 1,1 [10]. The proposed solar power modules capacity "PS" is calculated to be:

$$P_S = \frac{\sum E_{demand}}{E_{sun}}\, x\, 1{,}1 \qquad (2)$$

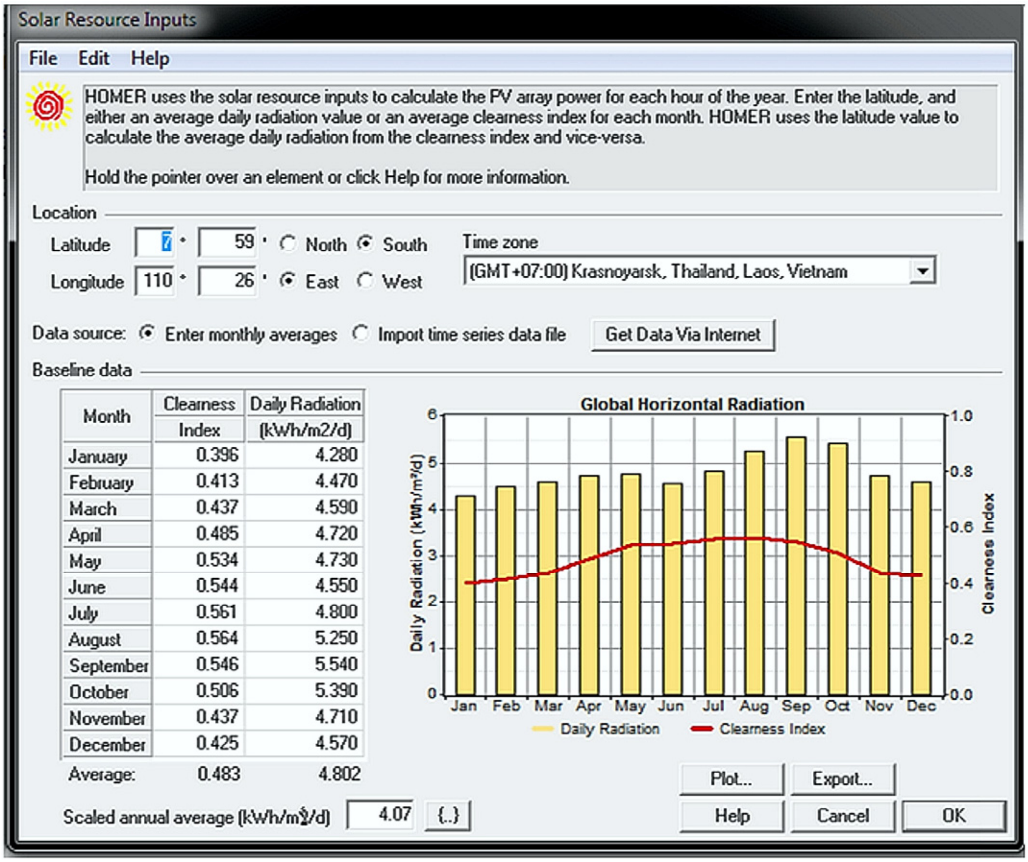


Fig.1. HOMER solar resources inputs

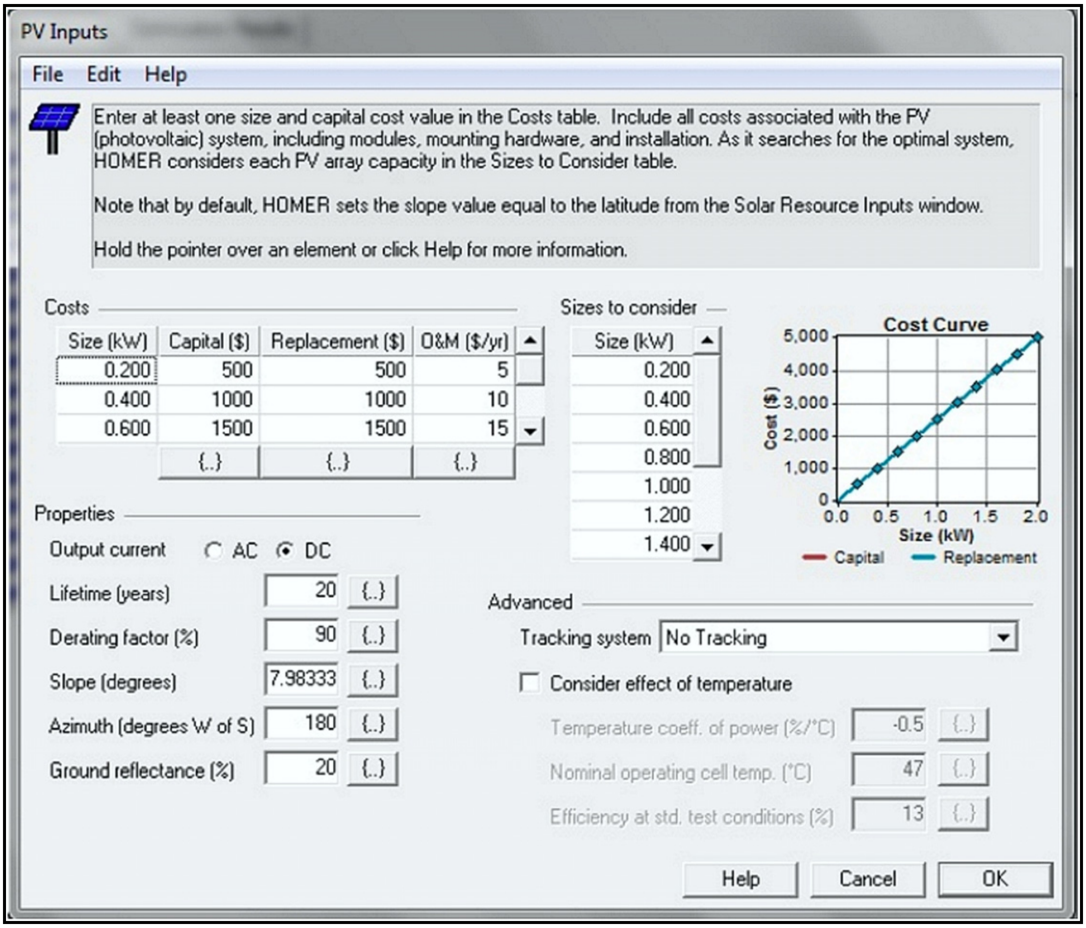


Fig. 2. PV inputs in the HOMER

where Edemand is the total load of the system and Esun is the solar insolation (kWh/m2/d). Fig. 2 shows the photovoltaic (PV) cost is $ 2,5/watt. According to the availability of the component in the local market, the PV cost for 0,2 kW is $ 500. In the proposed system, the size of PV varying from 0.2 kW; 0.4 kW; 0.6 kW; 0.8 kW and 1 kW. We assume PV array lifetime corresponding to 20 years and the maintenance cost set at 1 % of capital cost.

3.2. Battery

The function of battery is an electric storage container. The battery consists of reversible electrochemical cell and has a high efficiency. The accumulator battery capacity is more than 50%. The system carried out for 2 days of autonomy. The accumulator should be adjusted with the power needed. The storage capacity calculated to be 9.512 Wh. The 48 V DC used, consequently the battery capacity calculated to be approximately 198 Ah.

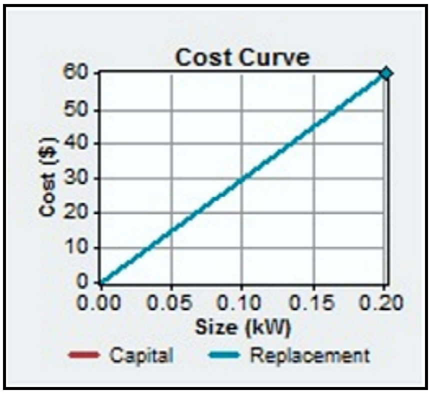


Fig.3. Inverter cost curve

The Vision 6FM 200 D battery used in this simulation. This battery specification is the most appropriate specification of the system demand. Assumed that the battery cost is $ 1.200/4 pieces of battery. We assume in the next 10 years the battery cost decrease until 50% from present capital cost. The battery storage will need to replaced along the system lifetime. The replacement cost is $ 600/4 pieces and the annual operation and maintenance cost set at 1% of capital cost. The batteries varying from 4 pieces, 8 pieces, and 12 pieces.

3.3. Inverter

Inverter is an electricity tools used for convert the direct electrical current (DC) to alternating electrical current (AC). The inverter convert the DC current from the battery. As electrical devices, there are lacks efficiency because of electrical losses. The typical inverter efficiency is 85%. Consequently, the inverter input calculated to be:

$$C_{inverter} = P_{Peak} \text{ x } (100 \div 85)$$

$$C_{inverter} = 165 \text{ W x } 1.18$$

$$C_{inverter} \approx 194 \text{ W}$$

Assumed that the inverter and replacement cost is $ 60/0,2 kW. The annual operation and maintenance cost set at 1% of capital cost. Fig.3 shows the cost curve of the inverter capacity. Inverter capacity calculated based on the peak power of the system demand. Since the peak power at 165 W and the avalailability component in the market, the inverter capacity considered to be 200 W. Fig. 4 shows the schematic diagram of the component used in HOMER software. The stand alone off-grid system only use the solar energy resources to satisfy the demand.

4. Result and discussion

The HOMER Software applied to optimize the sizing configuration of the component. The design optimization begins by obtaining horizontal radiation data from NASA satellite in the proposed location. The component configuration of power generation system consist of photovoltaic (PV), battery, inverter and the primary load. The simulation include the cost of each component, the number of unit used in simulation, the economical and control parameter. The HOMER calculates the sizing configuration of each component to satisfy the demand with the minimum cost of energy (COE).

Fig. 5 shows the optimization result. The analysis shows the configuration of photovoltaic 1 kW, 8 batteries of 200 Ah, and inverter 0.2 kW. This is the most economically feasible and least cost of energy (COE) is about 0,769 $/kWh.

COE showed high value due to high component cost compared to the conventional power generation. High cost energy due to the lack of penetration of the components to the market in the proposed location. In the future, the energy prices will decrease during the rapid production of renewable energy components. The availability of the component in the market is essential. The selection of component is very sensitive to energy prices.

5. Conclusion

In this paper, a design optimization of solar powered aeration system by HOMER software is presented. Small-scale of fish pond with solar powered aeration system meets the feasibility demand of 1.692 Wh/day peak load by Photovoltaic 1 kW, 8 battery of 200 Ah, Inverter 0,2 kW when COE is about 0,769 $/kWh.

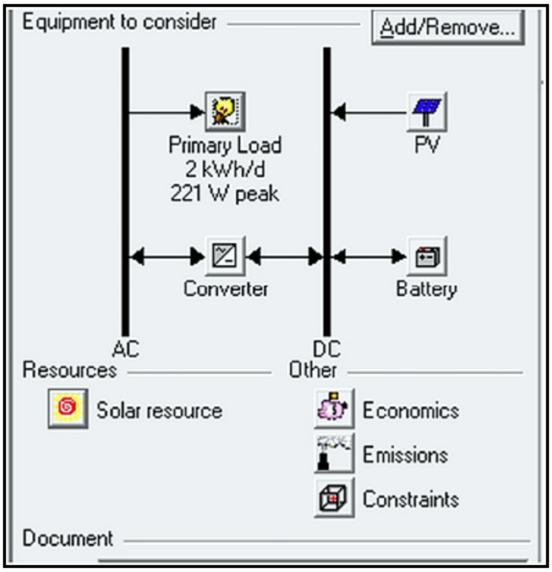
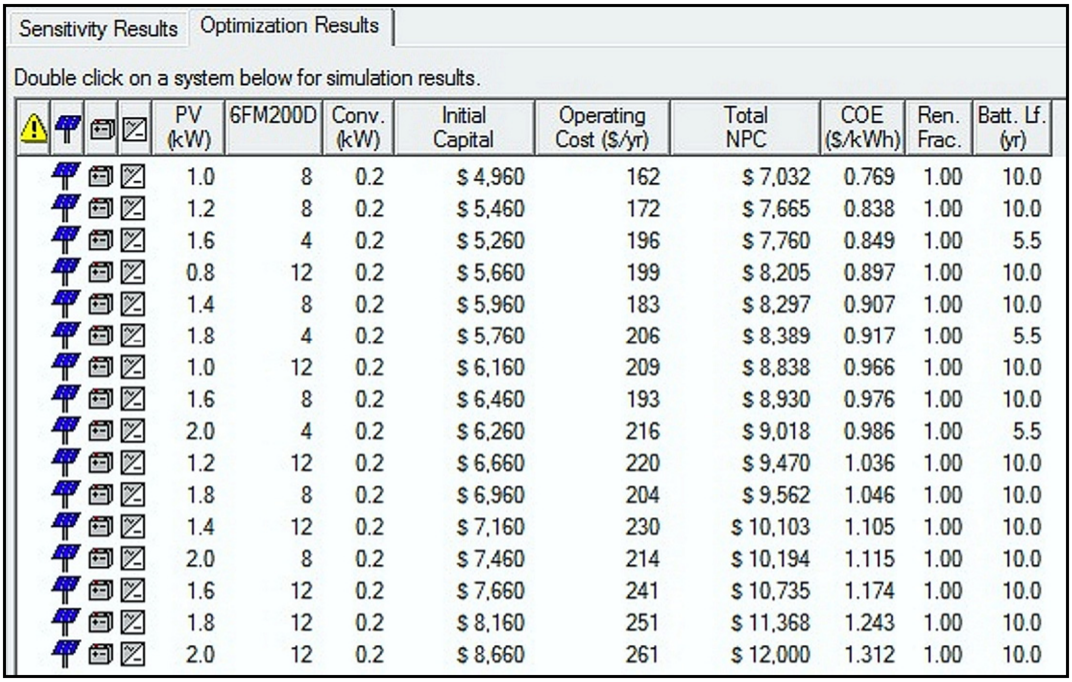


Fig. 4. Schematic diagram of component



Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

PV (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Batt. Lf. (yr)
1.0	8	0.2	$ 4,960	162	$ 7,032	0.769	1.00	10.0
1.2	8	0.2	$ 5,460	172	$ 7,665	0.838	1.00	10.0
1.6	4	0.2	$ 5,260	196	$ 7,760	0.849	1.00	5.5
0.8	12	0.2	$ 5,660	199	$ 8,205	0.897	1.00	10.0
1.4	8	0.2	$ 5,960	183	$ 8,297	0.907	1.00	10.0
1.8	4	0.2	$ 5,760	206	$ 8,389	0.917	1.00	5.5
1.0	12	0.2	$ 6,160	209	$ 8,838	0.966	1.00	10.0
1.6	8	0.2	$ 6,460	193	$ 8,930	0.976	1.00	10.0
2.0	4	0.2	$ 6,260	216	$ 9,018	0.986	1.00	5.5
1.2	12	0.2	$ 6,660	220	$ 9,470	1.036	1.00	10.0
1.8	8	0.2	$ 6,960	204	$ 9,562	1.046	1.00	10.0
1.4	12	0.2	$ 7,160	230	$ 10,103	1.105	1.00	10.0
2.0	8	0.2	$ 7,460	214	$ 10,194	1.115	1.00	10.0
1.6	12	0.2	$ 7,660	241	$ 10,735	1.174	1.00	10.0
1.8	12	0.2	$ 8,160	251	$ 11,368	1.243	1.00	10.0
2.0	12	0.2	$ 8,660	261	$ 12,000	1.312	1.00	10.0

Fig. 5. Optimization result

Acknowledgement

The authors acknowledge the financial support by Ministry of National Education, Indonesia. We also thank Faculty of Engineering, Gadjah Mada University, Indonesia for the support.

References

[1] Trobos. (2011, July 1st). Prawn: Trick to More Profit. Available: www.trobos.com/show_article.php?rid=12&aid=3012

[2] Appelbaum J, Mozes D, Steiner A, Segal I, Bark M, Reuss M, Roth P. Aeration of fish-ponds by photovoltaic power. *Progress in Photovoltaics*. 2001; 9:295-301.

[3] Bhuyar LB, Thakre SB, Ingole NW. Design characteristic of curved blade aerator wrt aeration efficiency and overall oxygen transfer coefficient and comparison with CFD modelling. *International Journal of Engineering, Science and Technology*. 2009; 1:1-15.

[4] Satriadi AB. *Designing windmill as a driver of shrimp pond aerator*. Undergraduate Thesis. Department of Engineering Physics Faculty of Engineering Gadjah Mada University Yogyakarta; 2010.

[5] Bien LE, I. Kasim, W Wibowo. The design of a hybrid system of solar power generation with grid electricity for urban homes. *JETri*. 2008; 8:37-56.

[6] Ghoniem AA. Design optimization of photovoltaic powered water pumping system. *Energy Conversion and Management*. 2006; 47:1449-63.

[7] Meah K, Fletcher S, Ula S. Solar photovoltaic water pumping for remote location. *Renewable and Sustainable Energy Reviews*. 2008; 12:472-87.

[8] Noroozi, Ramin et al. *Techno-economical study of two hybrid power systems for a remote village in Iran by homer software.* Shahid Rajae Teacher Training University. Tehran, Iran; 2011.

[9] U.S. Environmental Protection Agency. Compact Fluorescent Light Bulbs**.** Available: http://www.epa.gov/cfl/

[10] Hankins M. *Small solar electric systems for africa*. Kenya: MotifCreative Arts, Ltd.; 1991.