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DESIGN, PERFORMANCE AND ECONOMIC ANALYSIS OF A SOLAR HOME SYSTEM IN REMOTE AREA OF BANGLADESH

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Abstract*- This paper presents a study on necessary design and economic analysis of solar home system for single residential household remote area of Bangladesh. About 70% of the total population of Bangladesh does not have access to electricity. A major portion of the population located in off-grid areas will not be able to get electricity in the foreseeable future due to several constraints, including low consumer density and inaccessibility. They have to rely on highly polluting Kerosene oil and diesel generators for lighting and depend on bio-mass, wood, cow dung and crop residue for cooking, which not only create indoor pollution but through misuse of resources, lead to deforestation, soil erosion and floods. It is expected that Renewable Energy Technologies (RET's) can play a significant role in the far-flung remote locations of Bangladesh. The proposed solar home system involves a photovoltaic panel that converts sunlight into electricity, a battery that stores the electricity, a charge controller that regulates charging and discharging of battery, a fluorescent tube light with special electronic ballast, installation kits and connecting devices. Everybody wants maximum output with low cost and minimum input. Depending on demand of consumer, cost and some other factor, solar home systems need proper design. These papers represent the solar home system design for remote area with minimum cost to get optimum output.*

Keywords: *Solar panel, charging and discharging battery, load, charge controller, Matlab software, hou*se.

1. INTRODUCTION

Bangladesh is one of the most densely populated countries with 79% of the population living in rural areas. The electrification rate of the country is now 49%, but the rural areas are not as developed as the urban areas seeing that their electrification rate is only 23 % (against 79% or urban areas). Energy is the basic need of human life and with the rapid growth of population; its demand is increasing day by day in urban as well as in rural sectors of the country. Per capita electricity generation of our country only 236 KWh which is very poor of the other country of the world. With the present power generation capacity of 6727 MW but Maximum generation in history 4876.00 MW as on 13/06/2011[10],it is very difficult to manage the growing demand of electricity resulting persistent load shedding. This shortage and unreliable power supply have negative impact on social and economic development. Government of Bangladesh has declared its vision to provide electricity for all by the year 2020[1]. There is no possibility of connecting all the homes of remote villages and isolated areas, business centers and other establishments, to grid system in the near future. Power system in Bangladesh almost entirely depends upon fossil fuels, which are depleting fast. At this stage electrification by solar photovoltaic's has emerged as a viable technical option for meeting lighting and other small energy needs of the millions of people living in isolated background areas of Bangladesh. To fulfill the (Government of Bangladesh's) GOB's objectives of electrification, utilization of renewable energy technologies may play a vital role for off-grid electrification. So these state solar photovoltaic systems call solar home system (SHS)are most suitable for electrification of isolated remote areas in developing countries like Bangladesh. This paper represents design and economic analysis of solar photovoltaic-based home systems (SHS) for application in the remote area of Bangladesh

2. SYSTEM CONFIGURATION AND OPERATION (SOLAR HOME SYSTEM)

A solar home system consists of a photovoltaic (PV) solar panel, a storage battery, a battery charging controller, and various end-use equipment like florescent lamps. During the day, electricity from the PV module charges the storage battery. In the evening, the battery is discharged to power lights and other appliances.[2] The charge controller protects the batteries from overcharging and over-discharging by controlling the flow of electricity between the PV module, battery and the loads. Solar home systems can eliminate or reduce the need for candles, kerosene, LPG, and/or battery charging, and provide increased convenience and safety, improved indoor air quality, a higher quality of light than kerosene lamps for reading, and reduced CO2 emissions. Solar home systems are also an alternative to grid-based rural electrification. Fig. 1 shows the different components used in solar home system

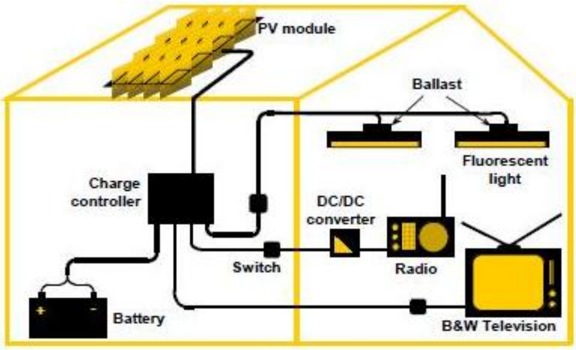

Fig 1. Solar home system component

3. DESIGN OF SOLAR HOME SYSTEM COMPONENT

For proper service of Solar Home System(SHS),which is technology dependent it is necessary to design it properly for optimum and economic use. Various component of solar home system such as photovoltaic (PV) solar panel, a storage battery, a battery charging controller, and various end-use equipment like florescent lamp etc[3] which are produced by different manufacturer. If solar home system establishing organization can install the solar home system according to the demand of consumer which fulfills the correct design and least cost then it can acquire the satisfaction of the consumer. For that reason everybody involve with installing and maintaining the system must know how to design the system. There is no unique way which is used to design the system. The following subsections describe the working and designing procedures components of SHS.

3.1. SOLAR ENERGY, PHOTOVOLTAICS

Photovoltaic's (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of cells containing a photovoltaic material. Materials presently used for photovoltaic's include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide[4]. Fig. 2 shows the solar cell construction, the sandwich of semiconductor materials that produce electricity directly from the sunlight without any moving parts[5]. In principal, a solar cell is a large-area silicon diode

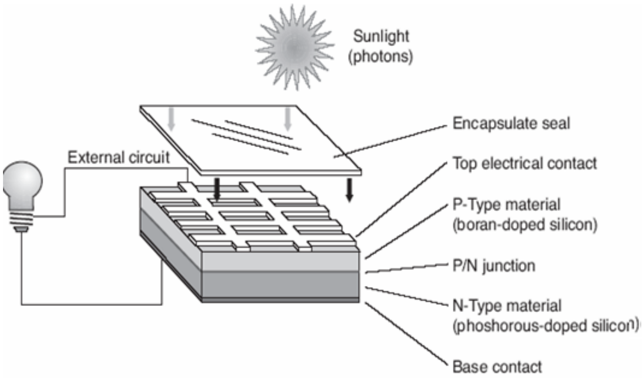

Fig 2 .photovoltaic cell

The mathematical function of an ideal illuminated solar cell is illustrated in the following equation:[5]

$$I_{pv}=I_{ph}-I_d=I_{ph}-I_o.\left(e^{\frac{qV}{KT}}-1\right) \quad \ldots\ldots\ldots(1)$$

Where:
IPV : Load current [A]
Iph : photocurrent [A]
IO : dark current [A] or saturation current
q : Elementary charge [e =1.6*10-19 As]
V : voltage [V]
K : Boltzmann constant [8.65*10-5eV/K]
T : diode temperature [K]

The rated power of a solar cell or a module is basically reported in "peak watts" [Wp] and measured under internationally specified test conditions, namely Standard Test Conditions (STC), which refers to global radiation 1000 W/m2 incident perpendicularly on the cell or the module, cell temperature 25 °C and AM 1.5 (AM: air mass) etc.

3.2. EFFECT OF TEMPERATURE ON PV PERFORMANCE

Solar cells vary under temperature changes; the change in temperature will affect the power output from the cells. The voltage is highly dependent on the temperature and an increase in temperature will decrease the voltage. Each solar module will have manufacturing standards; the normal operating cell temperature (NOCT) should be among these standards. The NOCT is the temperature the cells will reach when operated at open circuit in an ambient temperature of 20^{0}C at AM 1.5 irradiance conditions, G = 0.8 kW/m2 and a wind speed less than 1 m/s. For variations in ambient temperature and irradiance the cell temperature (in oC) can be estimated quite accurately with the linear approximation by the following equation[5]

$$T_c = T\ A + \left(\frac{NOCT\ 20}{0.8}\right) \times G \qquad \ldots\ldots\ldots\ldots(2)$$

Fig. 3.shows the effect of temperature variation at PV module consisting of 36 cells of mono crystalline silicon [Siemens, SR50] at constant radiation

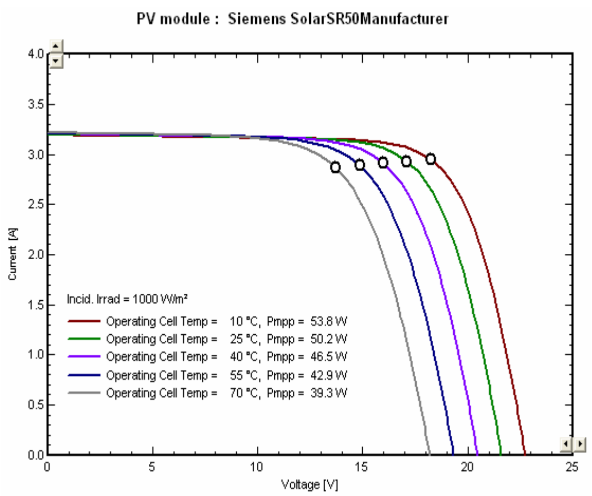

Fig.3.effect of temperature on PV module.

3.3. IMPORTANT OF BATTERIES

The energy produced during the day, which wasn't consumed by loads, is stored in batteries. The Stored energy can be used at night or during the days with bad weather conditions. There are many solar battery types available in the market. Most often used classic Pb acid batteries are produced especially for PV systems, where deep discharge is required. Other, such as NiCd or NiMH are rarely used, unless in portable devices. Hermetical batteries often consist of electrolyte in gel form. Such batteries do not require maintenance. Typical solar system batteries lifetime spans from 3 to 5 years, depending heavily on charging/discharging cycles, temperature and other parameters.

FEATURES: Lifetime depends on charge/discharge cycle rates numbers. The deeper the battery is discharged the shorter the lifetime. The most important parameter is battery capacity, which is measured inAh[2]. That depends on: discharging current; the higher the discharging current the lower the capacity, and vice versa. Batteries can be charged in many different ways, for example with constant current, with constant voltage etc., which depends on the battery type used. The charging characteristics are recommended and prescribed by different standards. The solar batteries prices are higher than the prices of classic car batteries, yet their advantages are longer lifetime and lower discharging rates. Consequently, the maintenance costs of the photovoltaic system are lower.

3.4. CHARGE CONTROLLER :

In nearly all systems with battery storage, a charge controller is an essential component to protect the battery against deep discharge and excessive overcharge. The charge controller must shut down the load when the battery reaches a prescribed state of discharge and must shut down the PV array when the battery is fully charged. The controller should be adjustable to ensure optimal battery system performance under various charging, discharging and temperature conditions. Battery terminal voltage under various conditions of charge, discharge and temperature has been presented in Figure 4.

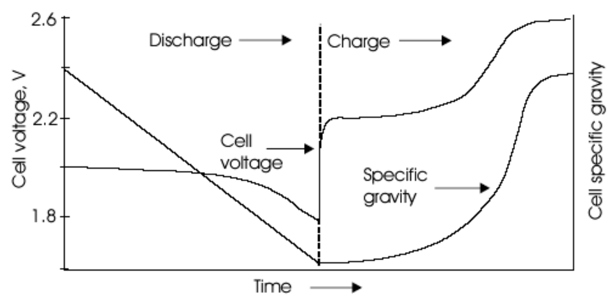

Fig.4.Variation of cell electrolyte specific gravity and cell voltage during charge and discharge at constant rate

3.5. DESIGN AND SIZING OF SYSTEM COMPONENTS

It is important to determine the correct size of system components, If the system is oversized, it will be more expensive without increasing the performance level. However if the system is too small, the system will not be able to reach load demand.

3.6. SHOLAR HOME SYSTEM LOAD

Load profile estimation is an important criterion for sizing and design the power supply system. It varies with respect to the performance of the villagers or consumers. For example in Bangladesh villages the large loads are at around midday (washing, fans...), and the largest occurring at evening. Villagers stay in their homes (lights, TV, appliances).After 10 PM the load is very low because most of the appliances are off except refrigerators

3.7. SIZING OF PV PANEL

The peak power of the PV generator to cover the total load demand is obtained as in equation [5]

$$P_{pv} = \frac{E_L}{\eta_V \times \eta_R \times PSH} \times SF \qquad \text{....................(3)}$$

Where EL is the daily energy consumption in kWh, PSH is the peak sun hours (PSH= 5.4); ηR, ηV are the efficiencies of charge regulator and inverter respectively (ηR 0.92, ηV 0.9) and Sf is the safety factor for compensation of resistive losses and PV-cell temperature losses Sf=1.15.

3.8. SIZING THE BATTERY BLOCK

The storage capacity of a battery block for such PV power systems is considerably large. Therefore, special lead–acid battery cells (block type) of long life time (>10 years), high cycling stability-rate (>1000 times) and capability of standing very deep discharge should be selected. Such battery types are available but at much higher price than regulars batteries. The Ampere hour capacity (CAh) and Watt hour capacity (Cwh) of the battery block, necessary to cover the load demands for a period (day) without sun, is obtained as in equation [5]

$$\text{Cwh} = \frac{E_L \times \text{AD}}{\eta_V \times \eta_B \times \text{DOD}} \qquad \text{.......................(4)}$$

AD is the autonomy days: period of time (day) necessary to cover the load demands by the battery without sun.

3.9.SIZING OF CHARGE REGULATOR

The charge regulator (CR) is necessary to protect the battery block against deep discharge and over charge. Input/output ratings of CR are fixed by the output of the PV array and the battery voltage

3.10. SIZING OF INVERTER

The input of inverter has to be matched with the battery block voltage while its output should fulfill the specifications of the electric grid supplying the load

4. ECONOMICAL ANALYSIS

In our countries, rural electrification is considered to be an important component of the national development initiatives especially as a means to promote development in rural areas. There are quite a number of social and economic benefits assigned to electrification. Overview of benefits associated with rural electrification Including solar home system,

1.No fuels cost
2. Improved quality of life and living standards;
3. Improved education through the availability of light;
4. Improved health conditions in households;
5. Improved communications
6. Reduced crime
7. Improved rural/urban balances

Three different types of costs are analyzed for solar home system(SHS) and these are followings

1. Initial capital cost of purchasing equipment and installation.
2. Recurring costs that occur every year of operation such as fuel and Maintenance costs.
3. Non-recurring costs that may occur on an irregular basis, such as equipment replacement or repairs.

A Solar Home System can provide un- interrupted fuel free supply for 25 years with negligible maintenance cost (battery replacement cost after 5 years). Though the initial installation cost is high, but the tradeoff is the large savings afforded to the economy's power grid since each household with a PV Solar Home System is actually the owner of an individual PV power plant.[6].
We have developed an innovative installment based financial model to reduce the cost of Solar Home System to monthly kerosene cost. I took the pioneer role to develop , fine-tune and implement a financial model where monthly payment of a Solar Home System matches the monthly energy expense (the cost of kerosene) of a rural household Bangladesh has gained the capacity of producing all components of Solar Home Systems except for the Solar Panel. Not only that, we have taken the assembly, repair and maintenance of one of most updated technologies to the rural level. Our rural technician's especially rural women know how to assemble, repair solar accessories such as invertors, mobile chargers, charge controllers etc

4.2.LIFE CYCLE COST(LLC)

The life cycle cost (LCC) is defined as the sum of the PWs of all the components. The life cycle cost may contain elements pertaining to original purchase price, replacement prices of components, maintenance costs, fuel and/or operation costs, and salvage costs or salvage revenues. Calculating the LCC of an item provides important information for use in the process of deciding which choice is the most economical

LCC = Initial cost + (Pa x Ann. Cost) + (Pr x repl.Cost)-(Pr x salvage) …………..(5)

The negative sign because salvage value is the revenues at the end of the project.

5.LIST OF PACKAGE PRICE OF SHS

The remote areas of Bangladesh there are many NGO, IDCOL pio, company working for installation of solar home system. This solar home system sells in cash paid or credit sell. Following the table given below the solar home system package price which is available and today install in remote areas the various companies. Here given a company package price [9]

Table 1. solar home system package price used in remote areas

SHS (wp)	**Load (Lamp)**	**Package price(Tk)**	**Down payment (Tk)**	**Rest Amount (Tk)**	**Service Charge(Tk) 8%(total taka)**	**Total Amount (Tk)(F+G**
20	2 CFL(5w)	13,100	1,310	11,790	2,830	14,620
40	2 lamp & Tv(bw)	22,800	3,420	19,380	4,651	24,031
45	3 lamp & Tv(bw)	24,300	3,645	20,655	4,957	25,612
50	4 lamp & Tv(bw)	29,500	4,425	25,075	6,018	31,093
65	5 lamp & Tv(bw)	36,000	5,400	30,600	7,344	37,944
75	6 lamp & Tv(bw)	40,500	6,075	34,425	8,262	42,687
85	8 lamp & Tv(bw)	44,800	6,720	38,080	9,139	47,219

5.1. COST EVALUTION

The cost of fuel consumption was evaluated for a period of 1 year (Table 2) and compared with cost of PV system. It is apparent from the table that the payback period the PV system introduced in the scheme is less than two years only as against the fuel consumption and maintenance of DG sets.

Table 2.. Cost evaluation of PV system and comparison with cost of fuel consumption and operational maintenance of DG set

DG Fuel consumption and maintenance cost		Cost of PV system	
Fuel cost Month Tk 2500×8=20000Tk Tk 3000×4=12000Tk	Tk 28000	PV 4 X 75Wp	60000
		Inverter 300VA	Tk5000
		Battery 2 X 100Ah Rs	Tk16000
Operational Maintenance Tk 1000 X 12 = Tk 12000	Tk12000	Maintenance	Tk500
		Misc. Expenses	Tk 4000
Total	**Tk 44000**	Total	Tk 85500

6. SHS INSTALLATION STATUS UP TO JUNE 2011 BANGLADESH

The currently installed 925000 systems bring electric light to around 4 million people in Bangladesh (IDCOL, 2011a). But from a social perspective it is not enough to provide. energy, it must also be affordable for the rural population. Fig shows the installed solar home system in Bangladesh from 1997 to June 2011.

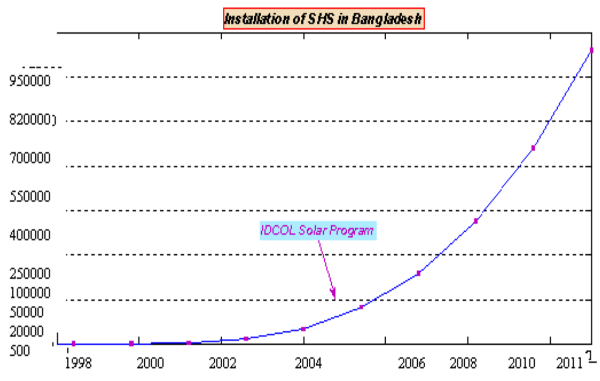

Fig.5. install the solar home system in Bangladesh

7. CONCLUSION

Electrification of remote and isolated sites are very important for our country . The photovoltaic systems are considered as the most promising energy sources for these sites, due to their high reliability and safety. They represent, at the same time, a vital and economic alternative to the conventional energy generators. An electrification study for a single residential household in a remote isolated site of vola,Sandip is carried out using a stand-alone PV system. This study presents the complete design and the life cycle cost analysis of the PV system. The results of the study indicate that electrifying a remote isolated household using PV systems is beneficial and suitable for long-term investments, especially if the initial prices of the PV systems are decreased and their efficiencies are increased .Unlike others, there are, of course, limitations in expanding these solar programmers' in Bangladesh. Research & development is not very significant. Initial investment in solar systems is quite high.[8] Moreover there is no complete manufacturing plant yet of solar systems in Bangladesh. These are expensive and susceptible to frequent change of technology. The private sector in Bangladesh may not be attracted enough to establish solar manufacturing plants. Public Private Partnership might provide a solution.. Despite the limitations, the objective conditions are favorable and ready for expansion of solar energy in Bangladesh. All we need are appropriate policy, planning and initiatives, together with Public Private Leadership.

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