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Study of Cost Analysis of Emergency Electricity Backup for 4th Floor of the Permanent Campus of Southeast University by Using Solar PV System

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Abstract

This paper describes a theoretical design and detailed cost analysis of a stand-alone solar PV system for 4th floor of permanent campus of Southeast University (SEU). Harvesting energy from the sun is one of the most demanding energy production fields nowadays. And in comparison to other energy production systems, PV systems offer some extra benefits like durability, low maintenance etc. In this research paper, basic PV systems along with its various constituent parts are discussed initially. Then various design considerations are highlighted including the factors and parameters as well resources available for Bangladesh. Finally, the theoretical cost analysis has been done by estimating some electricity loads of the 4th floor of the permanent campus, Southeast University. The analysis reveals that the proposed design is economical and cost effective solution in case of emergency electricity back-up for the SEU permanent campus.

Keywords: Solar, Photovoltaic effect, System design, Battery, Inverter, Cost analysis.

I. Introduction

'Energy' is an engineering concept that in simple words can be described as "an ability of a body to do work". One cannot think of living a single day without the use of energy in one form or other. We use energy in cooking our food, cooling our spaces, travelling from one point to other, transportation of goods, watching TV, using our mobile phones, running machines in an industry, water pumping and so on. Common energy forms include the kinetic energy of a moving object, the potential energy stored by an object's position in a force field (gravitational, electric or magnetic), the elastic energy stored by stretching solid objects, the chemical energy released when a fuel burns, the radiant energy carried by light, and the thermal energy due to an object's temperature. All of the forms of energy are convertible to other kinds of energy. In Newtonian physics, there is a universal law of conservation of energy which says that energy can be neither created nor be destroyed; however, it can change from one form to another.

The energy we use must come from somewhere. Normally, the energy we use is supplied to us in the form of diesel, petrol, coal, LPG, CNG and electricity (mostly derived from other fuels like coal and petroleum). These sources of energy are finite in nature and cause environmental pollution. In Bangladesh, every citizen does not get sufficient amount of energy that he/she requires. There is a huge shortage of energy supply. There is either lack of sufficient infrastructure to supply energy to all or sufficient fuel is not available at reasonable cost. Therefore, there are efforts to use infinite or renewable energy sources such as solar radiation, wind and biomass energy. This energy sources are also available in distributed manner which means that the required energy can be generated where there is a need. (C. S. Solanki, 2013)

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II. Overview of a PV System

A photovoltaic system, also PV system or solar power system is a power system designed to supply usable solar power by means of photovoltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. Figure 1 shows basic PV system and its constituent parts.

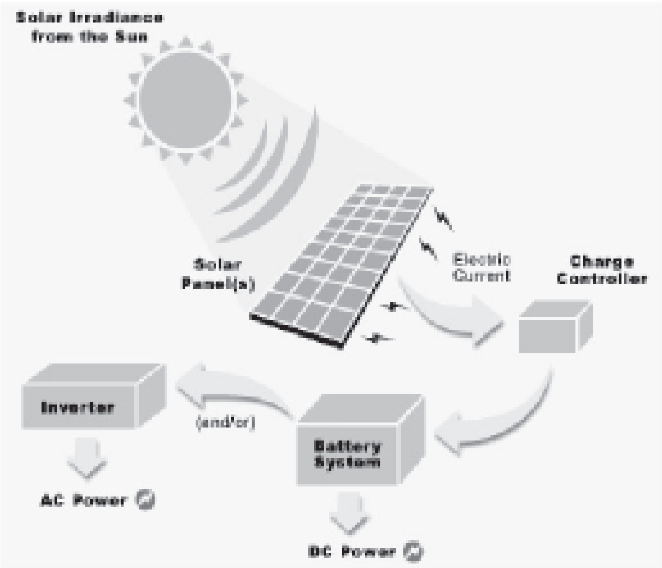

Figure 1: Basic PV systems and its constituent parts (Solar-panel-power. [Online] July 27, 2017)

A How PV system works

PV systems are like any other electrical power generating systems; just the equipment used is different than that used for conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same, and are guided by a well-established body of electrical codes and standards.

Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute, and store the energy produced by the array. Depending on the functional and operational requirements of the system, the specific components required may include major components such as a DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical load (appliances). Figure 2 shows a basic diagram of a photovoltaic system and the relationship of individual components. (How a PV Systems Works [Online] May 26, 2017)

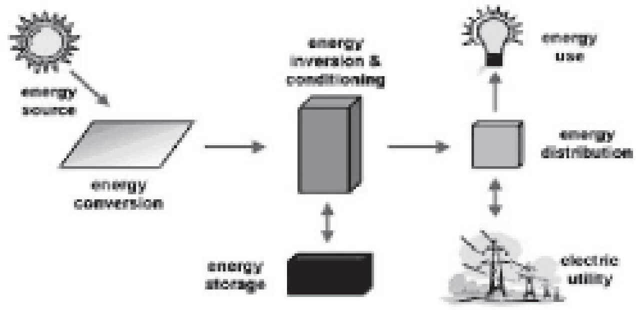

Figure 2: Major photovoltaic system components. (Ref: F1_PVSystems. [Online] July 27, 2017.)

B Components of PV System

Solar panel: Main component of solar photovoltaic system is solar panel. A solar photovoltaic (PV) panel or module can be considered as a big solar cell consists of numbers of smaller photovoltaic (PV) solar cells interconnecting in series and parallel with larger output voltage and current than a single solar cell.

Charge Controller: Charge controller is an electronics device which is used to prevent over-charging or deep discharging of batteries to preserve their life and to ensure good performance.

Batteries: Battery is an electrochemical device that converts the chemical energy contaminated in its active material directly into electrical energy and vice versa by means of oxidation-reduction (redox) reaction. Batteries are used for storing energy.

DC to AC Converter (Inverter): Solar PV generates DC electricity. But to run loads which works with AC, inverter must be used. An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

C Types of PV Systems

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads.

A stand-alone system is the one which is not connected to the power grid. Figure 3 shows the basic diagram of a stand-alone PV system with battery storage powering DC and AC loads.

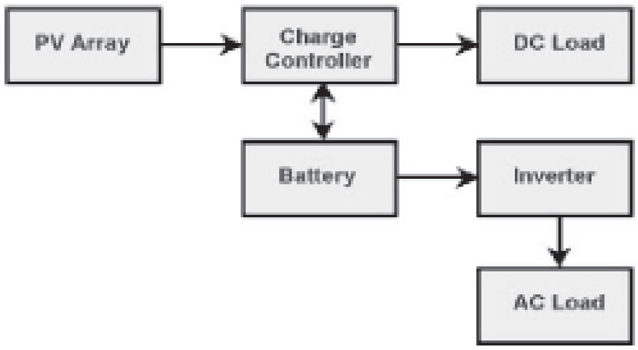

Figure 3: Diagram of standalone PV system (Ref: F3_StandAlonePVWithBattery. [Online] July 27, 2017)

In contrast, the PV systems connected to the grid called grid-connected PV systems. Figure 4 shows the basic diagram of grid connected photovoltaic system.

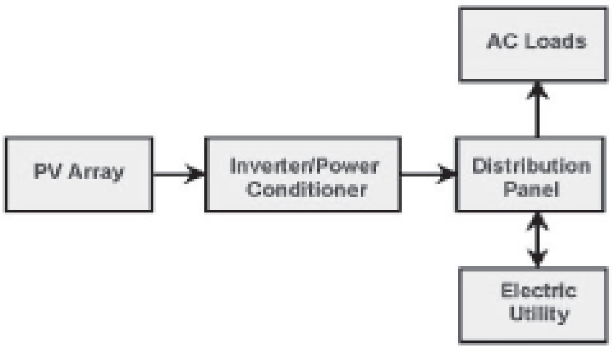

Figure 4: Diagram of grid connected photovoltaic system.
(Ref: F1 GridConnected PV [Online] July 27, 2017)

Hybrid PV systems could be stand alone or grid-connected type, but have at least one more source other than the PV as shown in figure 5

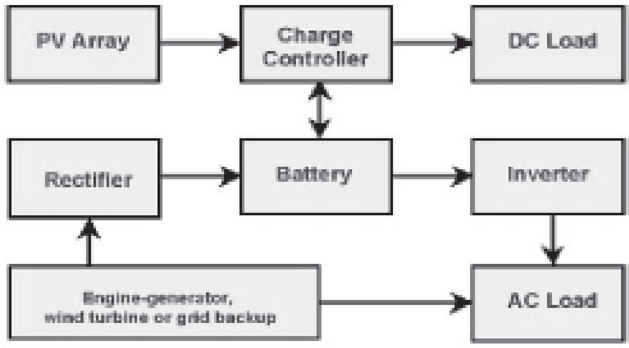

Figure 5: Diagram of photovoltaic hybrid system. (Ref: F4_PVHybridSystem. [Online] July 27, 2017)

III. Design Methodology of PV Systems

PV systems are designed and sized to meet a given load requirement. PV system sizing exercise involves the determination of the size and capacity of various components, like PV panels, batteries, etc. PV system design also involves a decision on which configuration is to be adopted to meet the load requirement. Subsequently, one needs to decide on the quality of each component from the consideration of initial cost, its performance and life of the component. A low quality component (charge controller, for instance) may be cheaper initially but higher quality component is more likely to perform better (saving energy and thus cost) and may be able to recover its cost in the long run.

The decision whether to choose a high quality expensive component or a low quality cheap component lies with the design engineer. In fact, the engineer has to first decide whether to use a particular component at all, particularly the performance enhancing components like the charge controllers and MPPT circuits. As these circuits themselves consume energy, one must determine whether their use would really result in energy saving or not. Needless to say that, the use of any additional circuitry adds to the system cost. Thus, an engineer has to judiciously optimize the system performance and cost. Issues such as system reliability, complexity, component availability in a given area, etc.

should also be considered. In general, there is no unique design to meet a given set of specifications. The design engineer should think of all possible alternatives to provide the user with the 'best possible performance at lowest possible cost.

In this paper a design is proposed for the Southeast University (SEU) permanent campus.

Commercially available solar PV panels are considered for the design and cost analysis.

A. Location of SEU Permanent Campus

Bangladesh is situated between 20.30^0 - 26.38^0 north latitude and 88.04^0 - 92.44^0east which is an ideal location for solar energy utilization. Dhaka is situated at 23.76 latitude and 90.40 longitudes. The SEU campus is situated at Tejgaon Industrial Area at the city of Dhaka. The geographical co-ordinates of the campus are 23°45' north, 90°24' east.

B. Local Weather Analysis

Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Monthly global solar insolation and daily average bright sunshine hour in Dhaka city are presented in Tables I and II respectively.

Table 1: Monthly global solar insolation at Dhaka

Month	Solar insolation kWh/m^2	Month	Solar insolation kWh/m^2
January	4.03	July	4.41
February	4.78	August	4.82
March	5.33	September	4.41
April	5.71	October	4.61
May	5.71	November	4.27
June	4.80	December	3.92
Average insolation			**4.73**

Table 2: Daily average bright sunshine hours at Dhaka city

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	**7.55**	**9.13**	**6.03**

C. LOAD CALCULATION

In this research work, the existing electricity load of 4th floor of Tejgaon Campus (Permanent Campus) is calculated which is shown in the following tables. Table-3 and Table -4 shows the existing load according to the number of power consuming quantities and their power consumptions respectively.

Table 3: Existing Load quantities

Room	Fan	CFL	Energy Saving Light
401	1	0	1
402(+Wash room)	1	4	2
403	1	0	4
404	6	16	0
405	4	8	0
406	2	3	0
407	5	12	0
408	5	12	0
409	2	6	0
410	5	8	0
413	5	8	0
415	5	12	0
417	5	8	0
418	4	6	0
Program Office	2	0	4
Faculty Washroom	0	0	7
Gents Toilet	0	0	5
Corridor	2	0	50
Total	**55**	**103**	**73**

Table 4: Existing Load Energy
Power rating of Fan=75W, CFL (4*14) =56W, Energy Saving Light=23W

Room	Fan	CFL	Energy Saving Light
401	75	0	23
402(+Wash room)	75	224	46
403	75	0	92
404	450	896	0
405	300	448	0
406	150	168	0
407	375	672	0
408	375	672	0
409	150	336	0
410	375	448	0
413	375	448	0
415	375	672	0
417	375	448	0
418	300	336	0
Program Office	150	0	92
Faculty Washroom	0	0	161
Gents Toilet	0	0	115
Corridor	150	0	1150
Total	4125	5768	1679
Total Existing Load (W)	**11572**		

Table-5 and table-6 shows the estimated load accordingly

Table 5: Estimated load quantity

Room	Fan	CFL	Energy Saving Light
401	1	0	1
402(+Wash room)	1	1	1
403	1	0	2
404	3	6	0
405	2	4	0
406	2	2	0
407	2	6	0
408	2	6	0
409	1	2	0
410	2	4	0
413	2	4	0
415	2	6	0
417	2	4	0
418	4	4	0
Program Office	2	0	2
Faculty Washroom	0	0	3
Gents Toilet	0	0	3
Corridor	1	0	10
Total	**30**	**49**	**22**

Table 6: Estimated Load energy
Power rating of Fan=75W, CFL (4*14) =56W, Energy Saving Light=23W

Room	Fan	CFL	Energy Saving Light
401	75	0	23
402(+Wash room)	75	56	23
403	75	0	46
404	225	336	0
405	150	224	0
406	150	112	0
407	150	336	0
408	150	336	0
409	75	112	0
410	150	224	0
413	150	224	0
415	150	336	0
417	150	224	0
418	300	224	0
Program Office	150	0	46
Faculty Washroom	0	0	69
Gents Toilet	0	0	69
Corridor	75	0	230
Total	2250	2744	506
Total Estimating Load (W)		**5500**	

D. PV System Compoent Sizing

Inverter sizing: Total load connected to the inverter is = 5500 W. So the inverter power handling capacity should be more than 5500W. To remain secure in default condition we are taking 10% extra capacity inverter. The inverter capacity becomes 6050W. So PS6000-248 Model inverter of "Passpower" Brand can be selected.

Table 7: Battery Sizing

Daily energy used by the load	11000 Wh.
Considering Inverter efficiency	95%
Energy supplied to inverter by battery	11578.947 Wh
PV system voltage	48 V
Battery Capacity	130 Ah
DoD of Battery	60%
Required charge capacity	241.228Ah
Required battery	3.09Pieces
Round Off	3 Pieces
Though battery voltage 12V and system voltage 48V Total Required battery	12 pieces
Battery efficiency	90%
Required energy to battery input terminal	12865.5Wh

Charge controller sizing: Rich Solar 200 W solar panel has a short circuit current of 5.16 Amp.

Module Short Circuit Current x Modules in parallel x Safety Factor = Array Short Circuit Current

5.16 Amp x 3 x 1.25 = 19.35 Amp (minimum Controller input current)

This is the input current that comes from the solar array. The number of parallel strings in the array increases the current. To be on the safe side, it is advised to multiply the result by a safety factor of 1.25.

Total DC Connected Watts / DC System Voltage = Max. DC Load Current

5500 W / 48 V = 114.58 Amp (minimum Controller output current)

This is the output current that is drown from the batteries through the controller. It is calculated via dividing the total connected DC power by the DC system voltage. The total connected DC power is the total power that all equipment would run on simultaneously. Here this is equivalent to the AC load.

From previous data FC-S048120 Model Charge controller of SNAT/OEM Brand can be selected.

Table 8 : PV Array Sizing

Average Sunshine hours	7 h
Total W_p of PV panel capacity needed	2042.14
PV Modules W_p	200 W_p
Number of PV panels needed	10.21 Pieces
Extra modules	10 %
Having extra modules we need	12 Pieces
Though PV module voltage 12V and system voltage 48V Total PV module required	12 Pieces
RS-M200 Solar panel can be selected.	

Table 9 : Cost Analysis

Component	Price (Taka)
Price of PS6000-248 Model inverter	94655
Cost per battery	12629
Total cost of battery	151400
Price of charge controller	15000
Price per W_p of PV module	58
Total cost of PV module	139200
Total cost for the PV system	**400255 Tk.**

IV. Conclusion

In this work, detailed design issues have been highlighted to design a stand-alone PV system. The first and foremost part of designing a PV system is to know how much power it needs to harvest from the sun. So in the first step existing and estimated load is calculated concerning the real scenario of load shading. It has been found that to support the electricity back up for two hours around 14.3kWh of energy is needed to produce. Now to generate and store this huge amount of energy around 12 PV module of 200 W_p and 12 batteries of 130 Ah is required. Here in this system an inverter of 6000W rating is used. Most of the people of Bangladesh are using IPS or fuel generator as a backup power system to get rid of the power shortage problem. But these systems are very expensive to buy and run, instead a stand-alone PV system can be used for the same purpose. In a PV system the initial cost may raise a little but for rest of the life generating electricity using this system is merely free of cost, as PV system needs a very little maintenance. Most of the PV modules come with 20-30 years life time and battery with 5 years.

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