Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2011
(ICMERE2011) 22- 24 December 2011, Chittagong, Bangladesh

ICMERE2011-PI-052

PERFORMANCE ANALYSIS, ECONOMICAL FEASIBILITY AND ENVIRONMENTAL IMPACT OF 17.5 KWP SOLAR ELECTRICITY GENERATION PLANT AT HEAD OFFICE BUILDING OF ATOMIC ENERGY COMMISSION

Md. Shafiqul Islam[1], Md. Rakibul Hasan[2] and Md. Shahidul Islam Bhuiyan[3]
Central Engineering facilities
Atomic Energy Research Establishment
Ganakbari, DEPZ, Savar, Dhaka
Email: shafiq12@dhaka.net[1], rakibmist@gmail.com[2], sohel95@gmail.com[3]

Abstract -*In order to face the energy crisis, the government has given directives to the public and private sectors to take various projects on utilization of solar energy and development of its related technology in the country. In response to this, a solar power plant of 17 kW_p, solar irradiation of 7.5 hr/day duty and battery backup of 5 hours is designed and then commissioned to run the total AC load of 7.5 kW excluding air conditioning (A/C) equipment of the 2nd floor of the Bangladesh Atomic Energy Commission (BAEC) Head Office building. The system has been designed with Maximum Power Point Tracking (MPPT) charge controller and with 1(one) day Autonomy. This solar electricity generation plant provides 2015 kW_p of electricity throughout the year with an expected lifetime of 25 years. The plant will save 8.4 ton CO_2 emission potential from our atmosphere. In 25 years, it will save 210 ton CO_2 .which is a significant step in sustainable development. This plant is used for direct application of solar energy and other related R&D activities. In this paper, it has analyzed the performance of the solar electricity generation plant and load shared by the plant. A brief study on environmental impact of solar electricity plant is included in this paper. Also there is a comparison between a system supplied by diesel generator and a system supplied by PV-Generator combination which will show the economical feasibility of using solar electricity generation plant.*

Key words: Utilization of Solar energy, Solar power plant, MPPT**,** Autonomy**,** Save CO_2 emission,

1. Introduction

Our Energy Sector has been going through a very torrid time in the recent years. Power Crisis has become the most significant concern for Bangladesh. The total generation of electricity in the country is about 3,000 to 4,000 MW against the peak demand of 4,500 to 5,000 MW at the present consumption rate. The electricity is mainly generated from the thermal power plants where the primary fuels are based on indigenous natural gas (≈ 85%). The shortage is about 1,000 to 1,500 MW at present and the gap between the supply and demand of energy is increasing day by day. As the conventional sources of energy are getting fast exhausted, this situation is not going to improve any soon. So the Government of Bangladesh has rightly focused on the development of renewable sources of energy mainly solar power. In these days of global warming and climate change, a huge movement towards the renewable energy has been evident throughout the world. Bangladesh being this most vulnerable country to global warming should also focus on adapting renewable energy technologies. In accordance with the Government directive to encourage the use of solar electricity in government offices, Bangladesh Atomic Energy Commission has been installed a solar electricity generation plant in its Agargaon premises. This major task has been completed under the project named "solar energy utilization and development of related technology". Solar energy will be used as primary source to illuminate the major loads in the third floor of the building. Grid power will also be used as secondary source to back-up the system. The paper describes the author's experiences about the operation and performance analysis of a 17.5 kWp solar electricity generation plant at Head office building of Bangladesh Atomic Energy Commission. The objective for installations of this solar power plant is to strengthen the utilization of solar energies and development its related technology through R&D activities. The installations will play an important role to promote the use of environmental friendly technologies, to create awareness among policy makers, academics and professions. Apart from these will justify the reliability of technologies, prolong the operation, and optimize the usage of renewable resources.

2. Description of the 17.5 kW_p Solar Electricity Generation plant

This solar electricity generation plant in Bangladesh Atomic Energy Commission head office building is an independent solution which will generate

electricity from sunlight by solar panels and supply AC current through Battery and inverters. A total no of 64 solar panels of 270 watt capacity have been installed on the roof top. There are a total of 48 batteries (two parallel branches, each having 24 NOs) which will act as the source of storage power for 1430AH.

Table 2.1 Major Components of 17.5 kWp Solar Electricity Generation Plant at HO of BAEC

Name Of Device	Capacity	Type of Devices	Efficiency
Solar PV Module	270Wp@ 24V each, Multi crystalline		14 to 15%
Solar Charge Controller(SCR)	Nominal 80A	Maximum power point tracing	97.5 %
Solar Battery	2,860AH, 24V	transparent Styrene Acrylo-nitrite	96%
Hybrid Inverter	3000VA	True Sine wave	93%

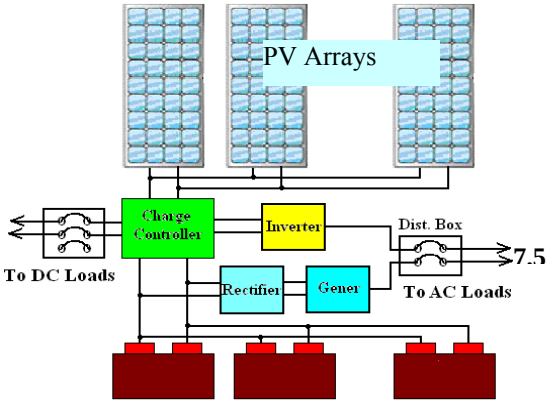

Fig. 2.1 solar hybrid system

2.1 Battery Bank selection procedure:

Required battery capacity@10Hrs for this system= 1340.608 Amp-Hr/1 = 2681 Amp-Hr@10Hrs/Day

Selecting each battery as 2V 1430 AH@10Hr,

Battery unit required: 2681Amp-Hr/1430 Amp-Hr

= 1.87 Nos. of parallel battery bank

= 2 units of parallel battery bank

Number of batteries in series in each parallel bank = 24 Units

Hence, the system requires 48 units of 1430 AH@10Hr batteries

2.2 Working Principle:

Solar photovoltaic (PV) systems are like any other electrical power generating systems. In solar PV system, just the equipment used is different than that used for conventional electromechanical power generating systems. However, the principles of operation and interfacing with other electrical systems remain the same. Although a solar 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. The solar radiation falling on the solar photovoltaic modules is converted into electricity by photovoltaic principle. The generated current from different panels is accumulated by Main Junction Board (MJB) and goes to charge controller. The energy generated shall be max when the solar insolation is max and vice versa. The energy production by Solar Array is site dependent and varies from place to place. The energy generation considered for designing the system is valid only if solar radiation, ambient temperature is as considered. The required voltage for charging the battery is obtained by connecting modules in series called as 'Solar String' and such strings are connected in parallel through Array Junction Boxes and Main Junction Boxes called as 'Solar Array'. To meet the AC load, solar electricity is driven to the inverters. Inverters invert DC to AC and then it goes through the AC distribution board to load. Hybrid inverters are also connected with AC supply in order to convert AC to DC and make battery charged when the system is on grid. Solar modules are mounted on module mounting structure at 23 ± 2^{o} tilt angle for maximum array energy utilization. The south facing shadow free area is made available for mounting modules. The energy generated by the solar modules is stored in the battery bank by charging the battery bank. This is accomplished by the Solar Charge Regulator (SCR). The Battery bank shall be discharged up to 80% of DOD (Depth of Discharge), provided load is connected to load terminals of SCR. For the purpose of design, an average peak sun shine hours has been considered.

2.3 BAEC 17.5 KW Solar Electricity Generation Plant's Wiring Diagram

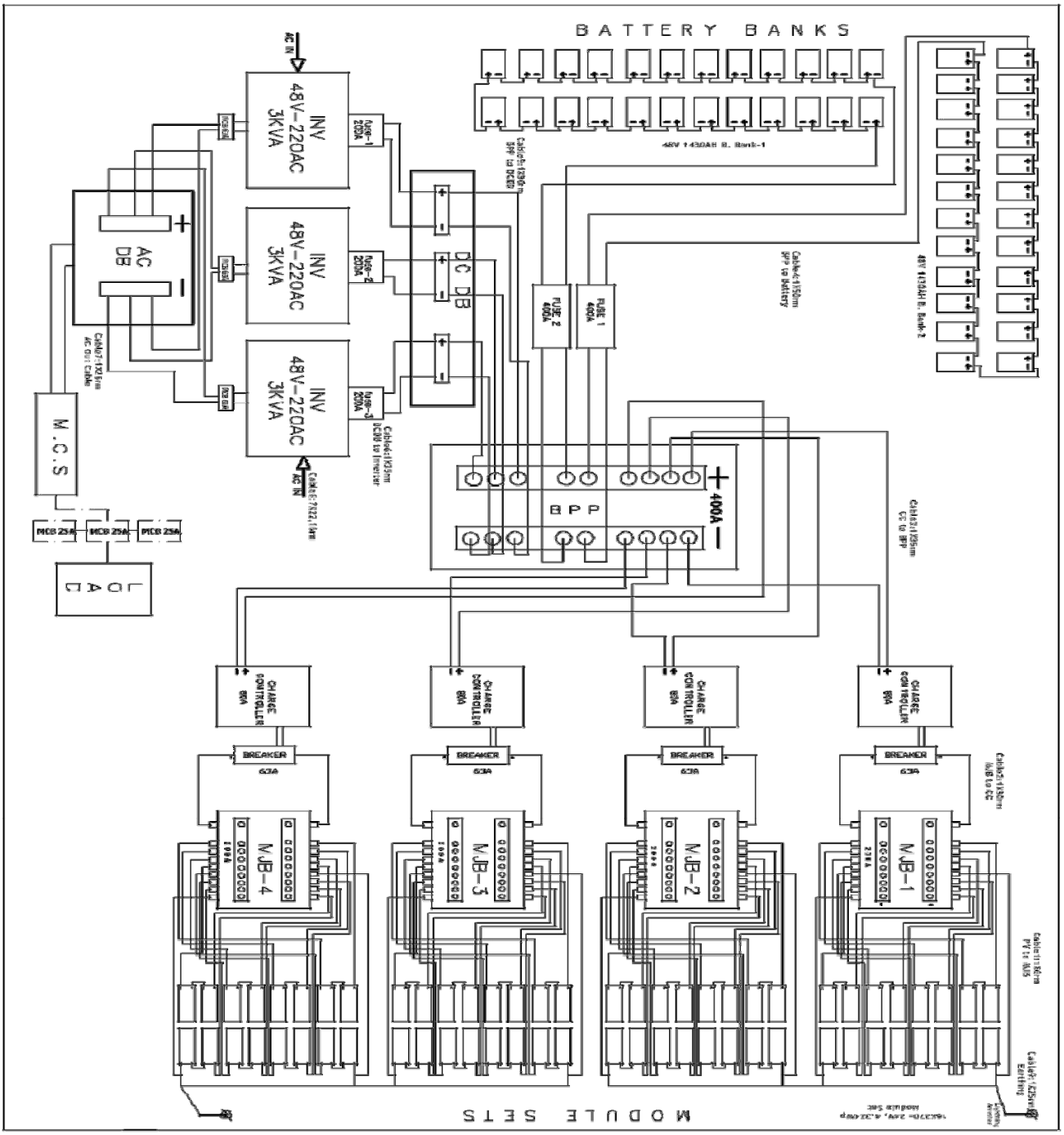

Fig: 2.2.1 Wiring Diagram of BAEC 17.5 kW Solar Electricity Generation Plant

3. Performance Analysis:

Figure 3.1 shows the daily generation in kWp. On Friday it was 6.79 kWp. This was the highest generation in that particular week (23 Jan to 29 Jan 2011). This is because of high availability of sun light on that particular day. On the other hand figure 3.2 shows the daily consumption in kWh for the week of 23 Jan to 29 Jan 2011. The consumption was highest on Tuesday on that particular week (23 Jan to 29 Jan 2011) and it was 17.1kWh.

Table 3.1: Kilo-Watt Peak (KWp) generation from Solar Electricity Generator

Date	Day	Total Generation(kW_p)
29-Jan-11	Saturday	6.48
28-Jan-11	Friday	6.79
27-Jan-11	Thursday	5.23
26-Jan-11	Wednesday	5.35
25-Jan-11	Tuesday	5.36
24-Jan-11	Monday	5.94
23-Jan-11	Sunday	5

Table 3.2: Kilo-Watt hour (kWh) Consumption from Solar Electricity Generator

Date	Day	Total Consumption
29-Jan-11	Saturday	3.3
28-Jan-11	Friday	3.5
27-Jan-11	Thursday	7
26-Jan-11	Wednesday	7.4
25-Jan-11	Tuesday	17.1
24-Jan-11	Monday	10.8
23-Jan-11	Sunday	7.6

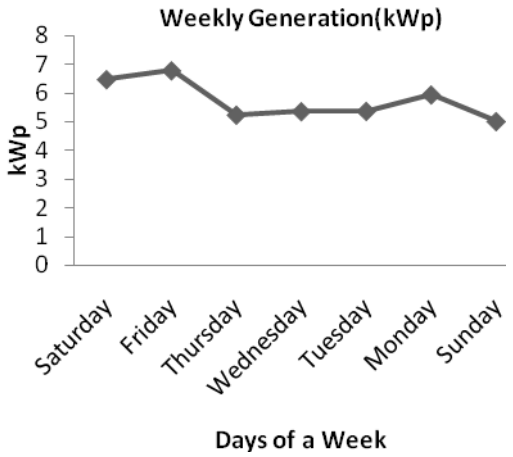

Fig:3.1 Weekly Generation Curve(23 Jan to 29 Jan)

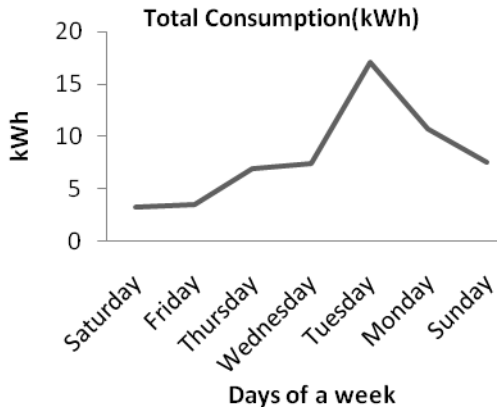

Fig:3.2 Weekly Consumption curve (23 Jan to 29 Jan

Almost five hours in a day connected loads with the solar power plant has been driven directly by the electricity produced from the PV cell. So the load consumption calculation is given below.

7.5 kW AC load for 2nd floor of BAEC, head office building daily 5 hours time operation

Total Watt-hour consumption per day = Load capacity * operating hour/Load power factor

= (7.5 kW x 5 Hours)/0.85

= 37.5/0.85 KW-Hr @5 Hours

=44.1176 KW-Hr/Day @5 Hours

From the generation data the avg. generation per month is 180.5 kWp. So the annual production will be 2025 kWp.

4. Economical Feasibility Study:

We make a feasibility study of this power plant by using Homer.

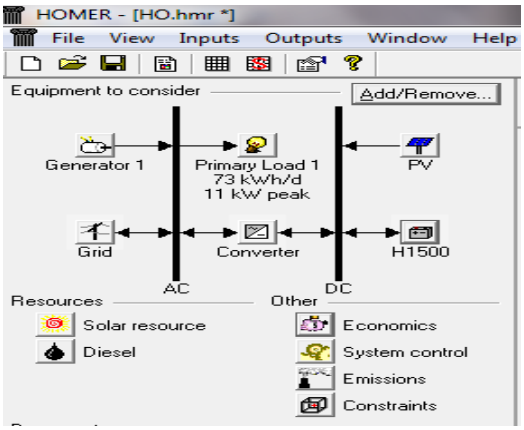

Fig: 4.1 Simulated Diagrams for Economical Feasibility

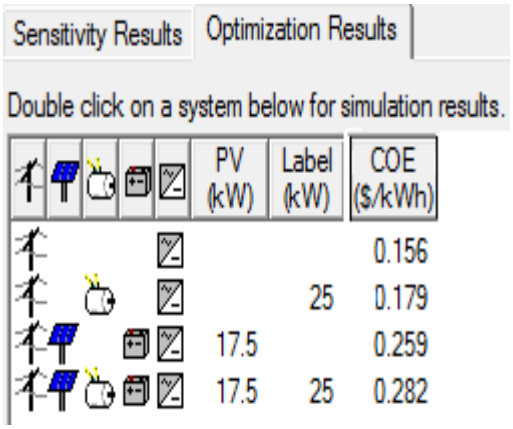

Fig: 4.2 per unit generation cost for different Combination of power sources.

Figure 4.1 shows the simulated diagram used for cost analysis using Homer. We have considered a primary load of 73 KWh/d with a peak of 11 KW in 2nd floor of BAEC HO building. Primarily this load is supplied by 17.5 KWp solar electricity generation plant. A 25 KVA diesel generator and our national grid are also connected with this system to maintain a ring network. Simulation results shows (Fig 4.2) that per unit (KWh) cost is 0.259$ (19.50 BDT) for PV generator while for diesel generator it is .179$(13.50 BDT).

4.1 Discussion on Result

From the simulated result it is found that the per unit production cost is higher than the diesel generator. It is because of high initial cost and low efficiency of solar panels. Attempts on fabricating solar cells from Si-wafers locally and then to assemble PV panels from locally produced solar cells will reduce the initial cost. Regarding R&D activities (i.e. on minority charge carrier, on anti reflective coating etc.) will increase the efficiency of the solar cells.

5. Environmental Impact:

Now a day global warming and climate change is a burning issue throughout the world. And it is carbon which is the main culprit for global warming. Bangladesh being the most vulnerable country to global warming should also focus on saving carbon.

The combustion reaction of diesel and LPG gas is given below

Diesel: $C_{50}H_{93} + 193/4\ O_2 \rightarrow 50CO_2 + 93/2\ H_2O$
1 mol $C_{50}H_{93}$(694.27342 g/mol) --> 50 mol CO_2(44 g/mol) => 694.27g --> 50*44=2200g
=> (3168.8*0.832=2636.44)
1000/694.27*2200=3168.8g
1 kg of Diesel produce 3.17 kg of CO_2.
1 liter of Diesel produces 2.64 kg of CO_2.

LPG GPL: $C_3H_8 + 5O_2 \rightarrow 3CO2 + 4H2O$
1 mol C3H8(44 g/mol) --> 3 mol CO2(44 g/mol)
=> 44g --> 3*44=132g => 1000/44*132=3000g
1 kg of LPG GPL produce 3 kg of CO_2.

It is found that, the amount of CO_2 emission is 573.7 g/KWh. So this plant will save 8.4 ton CO_2 emission potential from our atmosphere in a year. In 25 years, it will save 210 ton CO_2 .

6. Conclusion:

It is expected that if many more solar power plant projects like Prime Minister Office, Bangladesh Bank, BAEC could be taken by other government and private organizations that will strengthen the utilization and development of solar technology and would have been possible to get at least 10% of the total energy supply from the renewable sources by 2020. The energy conversion efficiencies of commonly used Si-based-solar cells are only 10-14% instead of 50%. It is important to take initiatives for fabrication of advanced solar cells and then assemble solar modules from solar cells through public-private

partnership (PPP) rather than importing the whole components.

Following conclusions can be drawn with regard to promote the SPV and solar thermal systems:

- Import duty and taxes shall be withdrawn on PN panels, Pumps, Auto trackers, Inverters, charge controllers, batteries and other related raw materials and chemicals.
- Attempts shall be taken to fabricate solar cells from Si-wafers locally and then to assemble PV panels from locally produced solar cells in order to reduce the cost dramatically
- More companies should come forward to produce solar batteries locally rather than monopolize in the business
- Academic activities need to be strengthening through introduction to undergraduate programs, Master programs, short courses and training programs in the field of renewable energy technologies.
- More promotional activities on solar technology and its economic aspects in the print and electronic media should be carried out.

7. References:

1. Islam, Md. Shafiqul, National Seminar on Prospect of energy Auditing and Alternative Energy to meet the present energy crisis in Bangladesh, MIST, 09 October 2010, Dhaka.

2. A.M. Azizul Haq, M.A.R. Sarkar and M.A. Hossain, Renewable Energy for Sustainable Development, Bangladesh Context, 3rd International Conference on Renewable Energy for Sustainable Development, IEB, Dhaka, Bangladesh, 2.4-October (2003).

3. Islam, M.A. Utilization of Renewable Energies in Bangladesh, Shakti: Energy Web Site of Bangladesh.http://shakti.hypermart.net

4. http://www.iea.org/co2highlights