Savings of Electricity Consumption Cost in Commercial Sector of Bangladesh

A. Hasib Chowdhury, Nahid-Al-Masood, Manjurul Alam Fuad, Md. Asad Uz Zaman, and Ridwanur Rahman

***Abstract*—Solar Photovoltaic (PV) system can be a pragmatic and affordable solution for providing the large scale electrical load in any commercial place. This will reduce the load consumption from national grid as well as this form of Renewable Energy (RE) is totally environment friendly. This paper presents the savings of electricity consumption cost in commercial sector of Bangladesh by supplying the lighting load with solar PV system. In Bangladesh, presently total electrical demand is about 6000 MW and 15% of it, that is, about 900 MW is commercial load. Approximately 11% of the commercial load, that is, 100 MW is used for lighting purpose in Bangladesh. Through economic analysis, it is found that in next 25 years, $ 122.4 million and $ 156.6 million can be saved for day long supply of lighting load and peak hour supply of lighting load, respectively, by using solar PV system in commercial sector of Bangladesh.**

***Index Terms*—Commercial load, payback period, solar PV system, savings of cost.**

I. Introduction

The quality of human life is intimately associated with the availability of energy resources. At present, the worlds' energy consumption rate exceeds 6000 GW. This is expected that energy demand will grow rapidly in the next decades due to the increase in demand from the developing countries. As Bangladesh is one of the developing countries with population of over 164.4 million, it is going through a huge energy crisis in recent years. Due to rapid change in climatic conditions of the world, RE sources are becoming popular day by day. Solar PV system is one of the sustainable and environment friendly RE sources. The commercial use of solar power has gained enormous acceptability over the last decade. Bangladesh is situated between 20.300 – 26.380 north and 88.040 – 92.440 east which is an ideal location for solar energy utilization. Here daily average solar radiation varies between 4 – 6.5 kW/m2. Maximum amount of radiation is available on the month of March – April and minimum on December – January. There is a good prospect of harnessing solar power in Bangladesh. In Bangladesh the residential use of solar power is increasing at a considerable rate. But the rapidity is really slow in commercial sector. If the solar PV system is implemented in commercial sector, the energy crisis of Bangladesh will be reduced to a great extent.

A number of investigations associated with the design of solar PV system and savings of electricity consumption cost have been reported in literature. The design, control and modeling of an isolated solar PV energy generating system are presented in [1]. The successful application of off- grid solar PV system has reached the electricity demand and improved the living condition of local people in the remote area in Inner Mongolia [2]. A novel system based on integration of solar power generator with grid for optimal utilization of energy by minimizing the power drawn from grid is introduced in [3]. To promote the solar PV installation, a large-scale PV system installed in the Main Stadium of the 2009 World Games has been investigated for the design of selling price of PV power generation in [4]. A detailed economic calculation on the cost of electricity production by a 1 kWp grid-connected organic photovoltaic system has been performed in [5]. The design method for the appropriate selection of a stand-alone photovoltaic power system for residential application in the absence of utility power supply is shown in [6]. Modeling of a combined photovoltaic and thermal energy system is presented in [7]. A comparative analysis of solar PV street lighting system in three different lamps is illustrated in [8].

Energy-saving technologies have become more readily available for residential purposes. Such technologies can be classified into two broad categories: energy generation systems and consumption reduction solutions. A more direct method of reducing home electricity costs would be to reduce consumption. It is observed that Compact Fluorescent Lamps (CFLs) are four times less expensive to run than incandescent light bulbs. The use of CFLs, coupled with a smart lighting system that automatically shuts off when not in use, results in around 7% reduction of total electricity consumption at home [9]-[11].

Lighting contributes the highest amount of electricity usage in a building. Generally, lighting consumes 20% – 50% of the total electricity consumption [12], [13]. The efficient and effective use of lighting can offer major energy and cost saving. An energy efficient lighting system design without sacrificing the visual comfort and quality of lighting is presented in [14]. Replacement of older fixtures with new luminaries can greatly improve efficiency and save a significant amount of cost in electricity consumption cost.

This paper presents the savings of electricity consumption cost in commercial sector of Bangladesh. In what follows, the detailed economic analysis and total savings in electricity consumption cost presented chronologically.

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A. Hasib Chowdhury and Nahid-Al-Masood are with the Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh (e-mail: nam_039@yahoo.com, nahid@eee.buet.ac.bd).

Manjurul Alam Fuad, Md. Asad Uz Zaman, and Ridwanur Rahman are with the Department of Electrical, Electronic and Communication Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh.

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II. Availability of Solar Energy in Dhaka City

Bangladesh is situated between 20.30^0 – 26.38^0 north and 88.04^0 – 92.44^0 east which is an ideal location for solar energy utilization. Dhaka is the capital of Bangladesh which is situated at 23.71^0 latitude and 90.40^0 longitudes. Monthly solar insolation and daily average bright sunshine hours in Dhaka city are presented in Table I and Table II, respectively.

TABLE I: Monthly Solar Insolation in Dhaka

Month	Solar insolation (kWh/m^2)
January	3.16
February	4.46
March	4.88
April	5.28
May	5.46
June	4.22
July	4.42
August	4.18
September	3.74
October	5.53
November	3.92
December	3.17
Average	4.37 kWh/m^2

TABLE II: Bright Sunshine Hours in Dhaka

Month	Maximum (hours)	Minimum (hours)	Mean (hours)
January	9.9	7.5	8.7
February	10.7	7.7	9.2
March	10.1	7.5	8.8
April	10.2	7.8	9
May	9.7	5.7	7.7
June	7.3	3.8	5.55
July	6.7	2.6	4.65
August	7.1	4.1	5.6
September	8.5	4.8	6.65
October	9.2	6.5	7.85
November	9.9	7	8.45
December	10.2	7.4	8.8
Average	9.13 hours	6.03 hours	7.58 hours

III. Data Collection and Analysis

In order to collect the commercial load data, a field survey is carried out. Since Dhaka, the capital of Bangladesh, is the load centre of the country, the commercial places are selected within Dhaka city for survey. The following places are selected.

(1) Bashundhara City, (2) Mouchak Market, (3)New Market, (4) Eastern Plaza, (5) Nahar Plaza, (6) Mutalib Plaza, (7) Karnafuly City Garden, (8) Aarong, (9) Eastern Plus, (10) Shimanto Square, (11) Eastern Mallika, (12) Twin Tower Shopping Complex, (13) Metro Shopping Mall, (14) Orchard Plaza, (15) Rapa Plaza, (16) Orchid Plaza, (17) Alpona Plaza, (18) Multiplan Centre, (19) Bishal Centre, (20) Baitul Mukarram Market, (21) Stadium Market, (22) Navana Shopping Centre, (23) Rajlaxmi Plaza, (24) Royal Plaza, (25) Rajmoni Ishakha Shopping Complex, (26) Capital Market, (27) BCS Computer City, (28) Palwel Super Market, (29) Farmview Super Market, (30) Mascot Plaza, (31) Palwel Carnation, (32) Pink City, (33) Navana Baily Star, (34) Dhaka City Corporation Market, (35) DCC Market, (36) Police Plaza Concord, (37) North Tower, (38) Grand Plaza, (39) Chadni Chawk Market, (40) City Heart Shopping Centre, (41) Gausia Market and (42) Navana Shopping Centre.

The lighting loads for the above commercial places are calculated. A numerical example to calculate the lighting load is presented below.

Shimanto Square Shopping Complex has 180 shops in total. Out of them, 54 shops are high load consumers and the others are moderate load consumers. Table III shows the total lighting load of Shimanto Square.

TABLE III: Total Lighting Load of Shimanto Square

Consumer class	Average lighting load (w/ft^2)	Occupied space (ft^2)	Total load (W)
High load consumer	11.27	12182	137291.1
Moderate load consumer	4.03	28426	114556.8
Total lighting load			251847.9 W

In Bangladesh, presently total electrical demand is about 6000 MW and 15% of it, that is, about 900 MW is commercial load. Approximately 11% of the commercial load, that is, 100 MW is used for lighting purpose in Bangladesh [15].

IV. System Design and Economic Analysis

In order to evaluate the electricity consumption cost in commercial sector of Bangladesh, two separate steps are executed. At first step, a Light Emitting Diode (LED) system supplied by solar PV modules is designed to illuminate the commercial places. At second step, the economic analysis is performed. The steps are presented in what follows.

A. System Design

After the field survey it is observed that the commercial places can use LED lights with a flat consumption of 1.5 W/ft^2. A sample design of LEDs in Shimanto Square Shopping complex, supplied by solar PV system, is illustrated below.

Total area for the shops in Shimanto Square Shopping Complex is 40,609.73 ft^2. So the total lighting load consumption using LED lights of Shimanto Square Shopping Complex is approximately 61 kW. A standalone PV system shown in Fig.1 is selected to supply the LED lights. The designed system of Fig.1is expected to run for the period of 25 years.

A standalone system does not have any connection to the electricity grid. Standalone systems vary widely in size and application. If the load is to be supplied independently of solar irradiation, the generated power is stored and buffered with a battery. A charge controller may be incorporated in the system to avoid battery damage by excessive charging or discharging and optimizing the production of the cells or modules by Maximum Power Point Tracking (MPPT). However, in simple PV systems where the PV module voltage is matched to the battery voltage, the use of MPPT electronics is generally considered unnecessary, since the

battery voltage is stable enough to provide near-maximum power collection from the PV module.

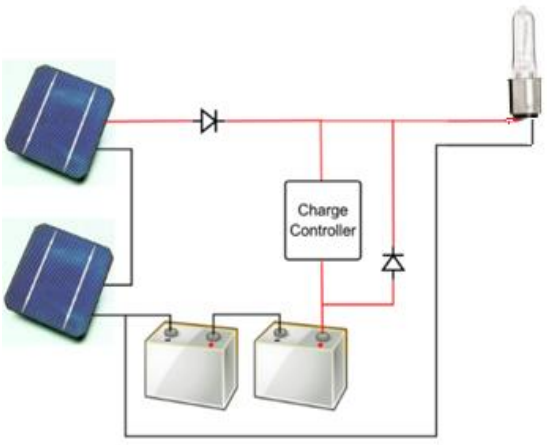

Fig. 1. Standalone PV system.

A standalone PV system is simple because the output from a PV module is always DC. Battery backup is used for continuing power supply against irregular solar irradiation charge controller is used to keep the battery safe from overcharging.

B. Economic Analysis

Since a standalone PV system is chosen, there is no need to use inverters. The required equipments are PV modules, batteries, charge controllers, mountings and other accessories. Economic analysis is performed for two different patterns of use, the day long supply and the peak hour supply of lighting load of commercial places. The detail analysis is presented below.

(a) Day long supply: For day long supply, the system of 61 kW load is simulated for 10 hours per day and 6 days per week where the daily load requirement is assumed to be constant. A 96 V, 80 A charge controller is chosen for system because it is fairly available in the local market. Table IV shows the total cost of day long supply of commercial load using solar PV system. Note that the charge controllers must be replaced in every 2 to 3 years. So the cost associated with it increases.

TABLE IV: TOTAL COST OF DAY LONG SUPPLY

Equipment	Quantity	Cost ($)
PV modules	655	237341
Batteries	240	268235
Charge controllers	17	17117
Structure and installation	Once	127059
	Total expense	$ 649752

The present lighting load of the considered system (Shimanto Square Shopping Complex) is approximately 251 kW. In a year, approximately, the total working days of the shopping complex are 300 days as the off-days include the weekly as well as various holidays. The lights are used for 10 hours every day. The unit energy cost is $ 0.051/ kWhr. So, the total cost of energy consumption using grid supply is about $ 38403.

The payback period is defined as,

$$payback\ period = \frac{Total\ \exp ense\ of\ \ solar\ PV\ system}{Total\ \exp ense\ of\ \ grid\ system} \quad (1)$$

Using (1), the payback period for day long supply of lighting load is about 17 years.

(b) Peak hour supply: For peak hour supply, the system of 61 kW load is simulated for 4 hours per day and 6 days per week. Table V shows the total cost of peak hour supply of commercial load using solar PV system.

TABLE V: TOTAL COST OF PEAK HOUR SUPPLY

Equipment	Quantity	Cost ($)
PV modules	255	92400
Batteries	96	107294
Charge controllers	7	7706
Structure and installation	Once	49500
	Total expense	$ 256900

The peak hour rate of grid energy is $ 0.087/kWhr. Following the same procedure as of day long supply, the total cost of energy consumption using grid supply in peak hour is about $ 26205.

Using (1), the payback period for peak hour supply of lighting load is about 10 years.

C. Savings of Cost

From the economic analysis it is observed that the payback period of 251 kW system is 17 years and 10 years for day long use and peak hour use, respectively. It is expected that the designed solar PV system will run for the period of 25 years. So the consumers will get a free service of 8 years period and 15 years period for day long use and peak hour use, respectively. Table VI presents the savings of electricity consumption cost for 251 kW commercial load.

TABLE VI: SAVINGS OF COST

Pattern of use	Payback period (years)	Free service period (years)	Savings of cost ($)
Day long	17	8	307224
Peak hour	10	15	393075

The total lighting load in commercial sector of Bangladesh is 100 MW. Using Table VI, the total savings of electricity consumption cost in commercial sector of Bangladesh is $ 122.4 million and $ 156.6 million for day long use and peak hour use of solar PV system, respectively.

V. CONCLUSION

This paper investigates the savings of electricity consumption cost in commercial sector of Bangladesh by supplying the lighting load with solar PV system. In order to collect the commercial load data, field survey are carried out in different commercial location of Dhaka city. A test system, Shimanto Square Shopping Complex, is considered for design and simulation purpose. It is observed that the existing

251 kW load of Shimanto Square Shopping Complex can be replaced with 61 kW LEDs run by solar system. After the detail economic analysis, it is found that $ 307224 and $ 393075 can be saved for day long use and peak hour use of solar PV system, respectively.

In Bangladesh, presently total electrical demand is about 6000 MW and 15% of it, that is, about 900 MW is commercial load. Approximately 11% of the commercial load, that is, 100 MW is used for lighting purpose in Bangladesh. The paper clearly reveals that the total savings of electricity consumption cost in commercial sector of Bangladesh in next 25 years is $ 122.4 million and $ 156.6 million for day long use and peak hour use of solar PV system, respectively. Moreover the replacement of commercial lighting load with solar PV system will not only save the electricity consumption cost but also reduce the carbon emission from fossil fuel and will help in green and better living.

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A. Hasib Chowdhury completed hid B.Sc., M.Sc. and Ph.D. in Electrical and Electronic Engineering (EEE) from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, in 1992, 1995 and 2008, respectively. Currently he is serving as an Associate Professor in the Department of EEE, BUET. He has published more than 25 research papers on power system. His research interest includes optimization and stability of power systems, embedded system design and renewable energy.

Nahid-Al-Masood completed hid B.Sc. and M.Sc. in Electrical and Electronic Engineering (EEE) from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh, in 2008 and 2010, respectively. Currently he is serving as an Assistant Professor in the Department of EEE, BUET. He has published more than 24 research papers on power system. His research interest includes power system planning, modeling, security, reliability, economy and control.