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Promoting Sustainable Development: Solar Energy for the Urban Building Application

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Abstract*-This paper proposes the use of sustainable energy systems based on solar energy to provide solutions to utility challenges in urban areas of Bangladesh. Perennial power outages are poorly-developed basic power infrastructures in Bangladesh. The urban area is the major electrical energy consumption area in the country. This paper proposes the adaptation of building sustainable energy in the urban area. These changes will stimulate industrialists and promoters who will get encouragement to invest into the project in Bangladesh. An analysis is presented design and calculation of PV system in the building. The proposed strategies show the reduction of electricity demand, energy infrastructure development and promote sustainable development sharing solar energy in residential and commercial building in Chittagong town.*

Keywords: building energy, Chittagong, solar PV System, electricity demand, sustainable development

1. INTRODUCTION

The pace of urbanization has gained a new momentum in the city of a country by adopting on smart city development where technology and sustainable development are the forefront of city growth. Buildings are proportionally increasing with urban growth. The millions of people are concentrating in the townships every year for job, livelihoods, security and for better facilities. New residential building, shopping mall, grocery shop, educational institutions, offices and hospitals are growing and the demand for electricity is rising at an alarming rate. Buildings are responsible for approximately 40% of the total energy consumption [1]. Most of this energy is for the provision of lighting, heating, cooling, air conditioning and water supply in the city of country. Indeed, there is no alternative way to reduce energy demand except implementing efficient and sustainable energy technology to stand out in the pace of urbanization.

Country's energy demand is rising along with urban growth. Bangladesh electricity demand rose about 90% in 2013 by the last decade (Fig.1). About sixty percentage of population is getting electricity from national grid of Bangladesh. The current energy system

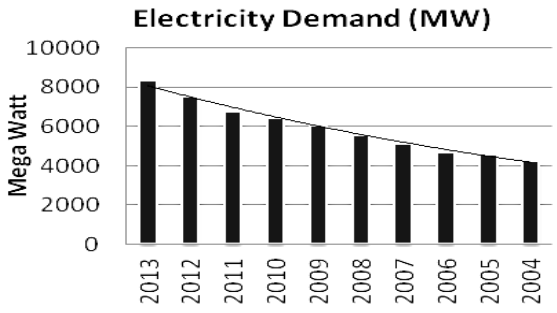

Fig.1: Energy Demand growth curve 2013-2004 [2]

is largely dependent on fossil fuels, which negatively impact air quality and contribute significantly to carbon emissions. But in the rural area of Bangladesh, Solar Home System (SHS) and Solar Irrigation Pump (SIP) are running successfully. Till now, 3 millions SHS have been installed with aggregated capacity of about 135MW in different rural location in Bangladesh [3]. The international community recognizes Bangladesh's SHSs as the fastest growing solar power dissemination program in the world. Now-a-days centralized based off grid solar plants (Mini-Grid Project) are installing in various rural area (islands and villages) of Bangladesh. It envisions having 10% power from renewable energy sources by 2020 in Bangladesh [3]. But according to Renewable Energy Policy of Bangladesh, the renewable energy application should not be disparity in between the urban and rural areas for electrification and development [4]. It is adequate time to promote sustainable development through solar energy in the urban area for tie together to satisfy the renewable energy policy of Bangladesh.

Bangladesh is a semi-tropical region lying in Between $20^0 34`$ and $26^0 38`$ North latitude, $88^0 01`$ and $92^0 41`$ East longitude part of South Asia gets abundant sunlight year round. The annual average bright sunshine duration is about 6.8 hours a day [5] and annual daily average solar radiation is 4-5.5 kWh per square meter. The Chittagong city is surround by rich natural resources such as- mountainous terrain, the Karnaphuli river and the Bay of Bengal which can be termed as the ``Divine Gift`` for the city. The geographical coordinates of Chittagong is 22.29^0 north latitude and 91.82^0 east longitudes and elevation above sea level 7m which is an ideal location of harnessing solar power in Chittagong.

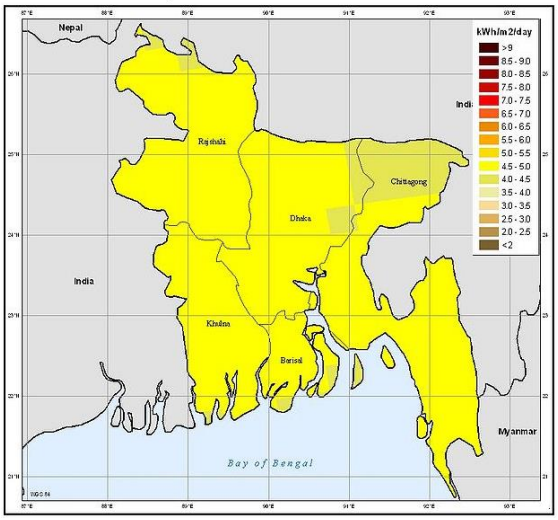

Fig. 2: Global Horizontal Insolation of Bangladesh [6]

Solar energy is the ultimate suitable option other than alternative sources in urban areas, especially in Chittagong. BPDB now supplies 750 Megawatts (MW) electricity against per day demand of 850 MW in Chittagong and the demand may increase to 4000 MW by 2021 [7]. Thereafter, there is no large solar project in the city of Chittagong. Some solar PV systems have been installed on the roof top of building in Chittagong according to authority rules of PV system capacity should have installed 3% and 7 % of the total load in residential and commercial space respectively [8]. And there is no any solar street light on the road of Chittagong City except CEPZ. But in the Chittagong city, hills, sea and river side, buildings, road, flyovers, commercial places, schools and colleges are potential places in urban area to yield energy from sun for appliances of commercial and residential buildings.

The Paper focused on the potential of solar energy for Building energy share in places of Residential places, office, educational institution, Shop & Shopping mall in Chittagong city of Bangladesh. It also identifies the factors of solar feasibility and the opportunity of solar system in the urban area. The proposed strategies show the reduction of electricity demand, energy infrastructure development and promote sustainable development to share solar energy in residential and commercial building in Chittagong town as well as trying to stimulate industrialists and promoters for investment approach to sustainable development.

2. ENERGY CONSUMPTION IN BUILDING

Globalization, improvement of living condition and life style, growing industrialization raise energy needs to consumption. Globally, buildings are responsible for approximately 40% of the total annual energy consumption in both residential and commercial. Most of this energy is for the provision of lighting, heating, cooling and air-conditioning, computer, printer and Xerox machine in the both residential and commercial building. Lighting contributes the highest amount of electricity in a building. Generally, lighting consumes 20% –50% of the total electricity consumption [9].

Residential buildings containing more than one dwelling unit are called a duplex, apartment building to differentiate them from 'individual' houses. Single-family residential buildings are most often called houses or homes. The commercial building sector is a mix of office buildings, retail stores, warehouses, schools, hotels, theatres, churches, etc. The commercial buildings sector's main characteristic is its energy demand, especially for space heating, air conditioning, and lighting. Dwellers and users are using various type of electrical and electronic gadgets depend on their lifestyle and income in the residential and commercial buildings. The common appliances used most in building are lighting: Incandescent/Fluorescent Tube/CFL/LED, Cooling system: Ceiling Fans/Exhaust Fan/Pedestal Fan/Table Fan/ window type AC/Split type AC, Television, Refrigeration, Computer, Laptop, Micro Oven, Washing Machine, Photocopiers and Grinding Machine etc.

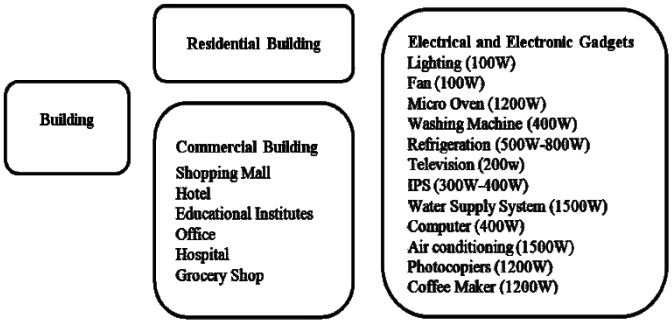

Fig. 3: building types and average capacity of appliances

Energy Consumption of electricity varies on capacity or power of electrical and electronic appliances and operating hours. All electrical appliances have the wattage listed somewhere on the appliance. Energy consumption and cost of operation can be determined multiplying by operating hours and price of unit (KWh) electricity. For example, a cooling system air conditioner lists 1500 as the wattage, operating time 5 hours so energy consumption is 7500Wh which is equal to 7.5 units (KWh). If per unit cost is 7.00 BDT, cost of operation will be 52.5 BDT to operate.

In the residential and commercial building, there are no high voltage alternate current (HVAC) appliances. So It is technical feasibility to use sustainable energy sources (such as solar, wind) alternate to fossil fuels (grid such as gas, diesel) to make environment and energy security in the country.

3. SOLAR ENERGY OPPORTUNITY IN BUILDING

Solar energy is radiant light and heat from the sun harnessed using photovoltaic (PV) technology. PV panels use the photovoltaic effect to turn the sun's energy directly into electricity, which can supplement or replace a building's usual supply. The Photovoltaic (PV) system consists of the solar PV panel, charge controller, battery, inverter, DC and AC Load. The diagram describes the system components configuration (Fig. 4). The PV panel converts the energy from the sun light to electricity. The

PV panel connected to the charge controller which controls the charging and discharging system of the battery and uninterrupted flow of electricity to load. The inverter converts the produced DC electricity into AC electricity for the AC components. Solar panel inclination is at 22° facing south to obtain optimum energy output from the panels in Chittagong. The efficiency of the solar panel, Battery efficiency & depth of discharge (DOD) operation of the battery, high module temperature, dust settlement on PV modules and other factors which degrade the solar PV system performance and also decrease the amount of capacity (Ah) produced.

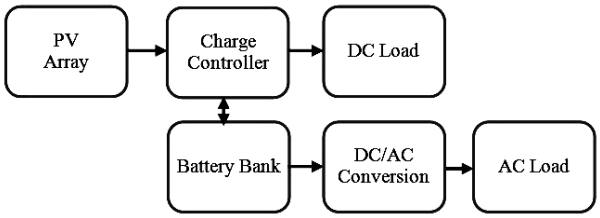

Fig.4: PV systems and common components

The stand-alone PV systems have various applications in rural and urban areas such as household electrification, water pump, battery charging & so on. PV system can supply electricity by using sun light wherever electricity needed in day time. Now-a-days, electricity demand of the urban area is gradually rising as well as load shedding. The paper presents application of solar energy such PV (Photovoltaic) system can be used various ways for the instant power supply during load shedding in the residential building and also this article shows how the daylight time is benefit to get direct solar electricity energy by solar PV system for the commercial building.

3.1 Replace IPS to Solar System

IPS (Instant Power Supply) is a power back-up system for continuous power supply during electricity failure. It is a built-in microprocessor based control unit and converter system that continuously monitors and controls the functions of the IPS. This is designed to meet emergency power requirements for home and office appliances like light, fan, television, etc. Total installed capacity of IPS is consuming huge electricity from grid that is about 150 MW in the residential sector of Bangladesh [10].

The working principal of Solar PV system is similar to IPS. Solar PV system stores DC energy in battery and when needed converts to AC for home usage. The main difference is IPS uses grid power to charge the batteries and PV system uses solar energy. Using solar panel to charge batteries will reduce the power shortage and energy demand from the grid. PV system instead of IPS will be more reliably and effectively. There are 3 ways to design Solar IPS, these are

a. Hybrid IPS System
b. Solar IPS System
c. Direct DC Supply Solar System

(a) Hybrid IPS system gets power from solar PV system as well as Grid. When weather is cloudy or rainy that time battery can charge from grid electricity. Here conventional IPS will be updated technologically even existence IPS could be improved by connecting power source option for PV system. In normal mood, system will always be connected with solar panel. But when solar panel current is low due to bad weather condition or unable to charge battery; controller will do switching to grid connection during charging. And load will be connected when load shedding occurs.

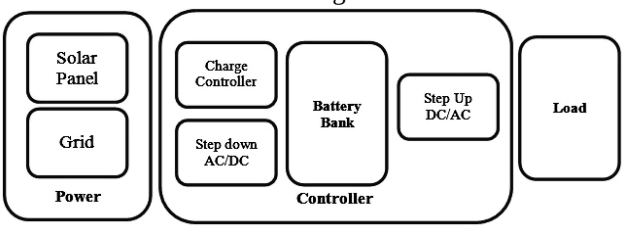

Fig.5: Hybrid IPS System

(b) Solar IPS System is same as IPS system, only it gets power from solar PV system instead of Grid sources. But it needs to design and calculate system size according to load. Maximum load of residential and commercial buildings are lighting and cooling (fan) load. So, solar PV system could be designed simplest way with inverter.

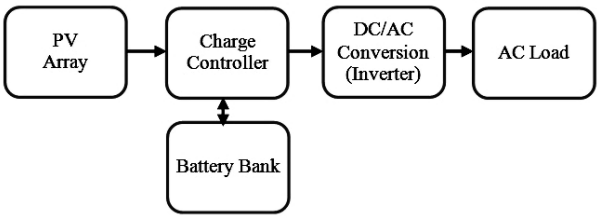

Fig.6: Solar IPS System

(c) Direct DC supply solar system will reduce the system cost and longevity supply to appliance. It can work both way to load and charging battery in day time. Nowadays DC appliances (light and fan) are available in market. It is also needed to design and load calculation for system.

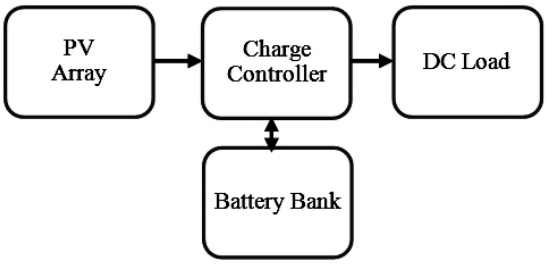

Fig.7: Direct DC Supply Solar System

3.2 Solar Energy in Commercial Building

A commercial building is a building that is used for commercial use. Commercial buildings account for a significant fraction of the total energy consumption in the city. The most of commercial building is operated in daylight time. Academic building, Hospital, Office and other and other kinds of non-profit buildings, companies and organizations are considered to be commercial, as well as industrial zone and warehouse where common

loads are lighting and cooling (fan) system.

Figure 8 shows solar global irradiance time duration in a day which does synchronous with working hour. So, commercial places are ideal places for use of solar PV modules for the reasons. Most of the operation of commercial space takes place in the day time, which is in synchronous with the availability of sun light and it is easier to generate small scale power with solar PV system without storage even it is suitable DC supply.

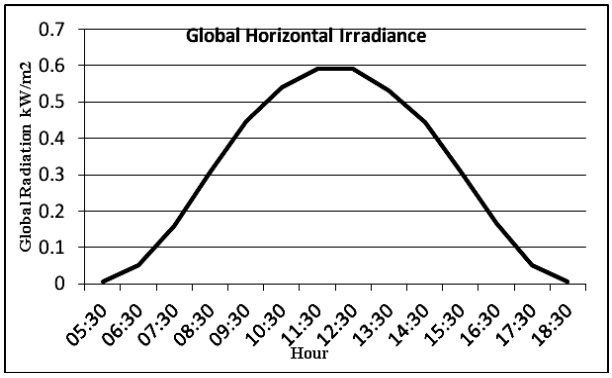

Fig.8: synchronous with sun hour and operation time of commercial building [11]

4. SYSTEM DESIGN AND SIZING

A PV system design and sizing depends on the level of details used in components capacity and following two stages decision and design of engineer or designer: approximate design and precise design [12]. The approximate deign is prepared with assumptions of component performance, solar radiation data, seasonal variation and performance of PV panel etc. The precise design is attention to accurate design of all factors. At first, most of design engineers mostly look at approximate design. A hypothetical system design and calculation procedures are discussed in below:

Table 1: Load estimated per day

Appliances	Watts	Qty	Hrs/Day	Watt-Hrs
CFL	20	2	6	240
Fan	80	2	6	960
others	50	1	3	150
Total	250W			1350Wh

1) Load Calculation: The total energy consumption is 1350Wh for the load of 250W at system voltage 12V and load current (250 ÷ 12) = 20.82A.
2) Required Battery Bank: The deep cycle battery (Lead acid battery) recommended for the solar PV system. Deep cycle battery is specifically designed for to be discharged to low energy level. Days of autonomy determines supply the battery power to number of days that the system needs to operate. Battery sizing calculates as follows:

Battery Capacity (Ah) =

$$= \frac{\text{Total enrgy consumption per day x day of autonomys}}{0.85 \times 0.6 \times \text{system battery voltage}}$$

$$= \frac{1350x2}{0.85x0.6x12} = 441.18Ah$$

Here Considered Battery efficiency 85% and Depth of Discharge (DOD) 60% which is determined by battery manufactured, 2 days of autonomy. So, battery selected 100Ah and 12V so battery bank will be designed parallel with 5 batteries and total capacity is 500Ah.
3) PV Array Sizing:
Average daily sunlight duration = 6 hours
Consider daily power consumption duration = 5 hours
Total load current= 20.82A

$$\text{Battery charging current} = \frac{500x0.85}{48} = 8.85A$$

Daily Battery is needed power = (8.85 × 6) = 53.1Ah
Daily power is needed for load = (20.82 × 5) = 104.1Ah
Daily Total power needed = [(53.1+ 104.1) × 1.2]
= 188.64 ≈ 190Ah (here 1.2 is the correction factor)

Considered PV module is $100W_p$ which at maximum power point (V_m and I_m) would be about 18.77V and 5.35A respectively.

Daily output each PV Module = (5.35 × 6) = 32.1Ah
No. of module = (190 ÷ 32.1) = 5.919 ≈ 6 PV Modules
So, 6 PV Modules will be connected in parallel.

4) Size of charge controller depends on current (load) of total solar array (20.82+8.85) = 29.67A and considers 90% efficiency. So charge controller size = (29.67 ÷ 0.9) ≈ 33A at 12V or greater.

5) Size of inverter = (250 ÷ 0.85) = 295W ≈ 300W (consider inverter efficiency 85%).
Above design and calculation would be considered for any type PV system design.

5. SUSTAINABLE AND SOLAR ENERGY

Ever increasing demand could place significant strain on the current energy infrastructure and potentially damage world environmental health by CO, CO_2, SO_2 and NO_2. Today requires long-term potential actions for sustainable development. In this regards, renewable energy resources appear to be the one of the most efficient and effective solutions since the intimate relationship between solar energy and sustainable development.

Bangladesh has major problems with energy crisis, persisting poverty and environmental degradation. The producing electricity of 99% fuel is natural gas, furnace oil and diesel in Bangladesh. It is the alarming problem to contribute large amount of CO_2, NO_2 and green house gases in environment of Bangladesh. The demand of electricity is rising day by day with access to electricity with 62% of Bangladesh [13] where the per capita use is only 234kWh [14] and the grid emission factor (GEF) is 0.67 ton CO_2/MWh for the electrical system according to national technical committee in Bangladesh [15]. Moreover, the people who are connected with the national grid are experiencing frequent load shedding. Promoting solar energy in the urban area will help to

increase percentage of access to electricity in Bangladesh as well as will make strong power infrastructure and energy security of the country. The small amount of solar energy contribution is not enough to save the degradation environment health in urban and rural area of Bangladesh. In research, it is found that taking 10%-12% contribution of solar energy, the emission of the CO_2 gas will be 22821679 metric tons which will reduce up to 21% in the year 2033[16].

Most the people of Bangladesh are using IPS or diesel generator as a backup power system to get rid of the power shortage problem. PV system can use for the same purpose. Here using the PV system the initial cost may rise a little but for rest of the life we will be generating electricity for free of cost. Most of the PV modules come with 20-25 years guarantee and battery with 3-5 years. IPS is consuming total 129102 MWh per year which is contributing 86498 ton CO_2 emission in environment. Apart this, Most of the commercial and residential buildings are using diesel generator at 1.3 ton CO_2/MWh diesel gen-set emission factor [11]. So, Solar PV system can be reduced mentionable amount of CO_2 emission from building in the urban area.

Indeed, in the power sector of Bangladesh needs sustainable and efficient solution to make relationship among electricity demand, environment and sustainable energy. And solar energy helps to ensure the economic development of the country and to improve the standard of living of the people through sustainable and environment friendly investment.

6. CONCLUSION

This paper shows the solar energy share in the building to reduce the grid electricity demand by replacing IPS to PV system in urban area and revealed mentionable saving electricity consumption and environmental degradation through IPS unit from national grid. Apart this, this paper discusses electrical and electronic appliances in building and PV system design and calculation which help to do design manually. So solar can satisfy urban building loads in cases of load shedding and solar daylight do synchronous with working hour in commercial buildings that will be very helpful to fight the power shortage and minimize the electricity demand and energy saving project in the urban area.

There is strong scientific evidence that the average temperature of the earth's surface is rising. This is a result of the increased concentration of carbon dioxide and other GHGs in the atmosphere as released by burning fossil fuels. Therefore, an effort has to be made to reduce fossil energy use and to promote solar energy, particularly in the building sector. Energy use reductions can be achieved by minimizing the energy demand. Moreover, it is important to have smooth change over from the conventional electrical system to solar PV system. As well as industrialist will be stimulated to invest sustainable development project. This makes the sustainable development of Bangladesh.

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