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ENERGY DEMAND OF DECENTRALIZED STP AND APPLICATION OF SOLAR PV MODULES

Pratima Singh

Department of Natural Resources, TERI University, New Delhi, (India)

ABSTRACT

The study focuses on the potential of solar photovoltaic (PV) for meeting the power requirement of a decentralized sewage treatment plant (STP) in Delhi. Average daily electrical energy consumption of the STP is estimated for designing of solar PV module. Green house gas emission (GHG) due to use to electrical energy is estimated by using the factors provided by CEA for north India (0.81 kgCO_2eq/kWh). The energy demand of the STP is found to be 362.04 kWh/day for the year 2015. Electrical equipments with the total daily energy consumption of 183.24 kWh/day are used for estimating the designing of solar photovoltaic modules, with area requirement of 316.19m^2. The on-site rooftop space availability for the installation of solar modules is available and hence 100% application of solar PV is possible. Total 50.6% of conventional energy is replaced by the application of solar PV module and same amount of GHG emission reduction can also be achieved.

Keywords*: *Decentralized STP, Energy Consumption, GHG Emission, Solar Photovoltaic, Sustainable City

I. INTRODUCTION

Power sector plays a major role in contributing to economic development of a country. Increasing energy consumption has become matter of concern due to decreasing fossil fuels and exhausting global reserves of coal and petroleum. This concern has been shared with most of the developing nations around the globe and India is not an exception to it. Apart from increasing the economic growth of the country, use of exhaustible fossil fuel has done nothing but help in increasing the environmental damage. India is also leading the path of economic growth by focusing on the change of power sector by establishing the Regulatory Commissions in 1998 under the Electricity Regulatory Commission Act 1998 to bring change in the electricity sector by promoting competition, increasing the efficiency and economy in the activities of the electricity industry [1]. The alarming challenge of increasing population and decreasing natural resources has drawn our focus to application of sustainable source of energy - renewable energy. By inclusion of renewable energy in the energy mix would not only decrease the dependence on the grid connection but would also increase the reliability of the system in terms of efficiency and less carbon emission.

Renewable energy especially solar photovoltaic (PV) has been used in many small industrial sectors (small-scale industries) in India and across the globe [2]. Electricity from solar PV is considered to be the most appropriate solution for energy source for sustainable future, the world can have. Presently, solar PV market is growing at an annual rate of 35-40% [3]. At present, the world energy consumption is 10 terawatts (TW) per year, and is projected to be about 30 TW by 2050 [4]. Use of solar PV modules for electricity generation could help in stabilizing the carbon content in the atmosphere emitted due to use of fossil fuels while generating electricity. The use of renewable energy is inevitable if India as the nation needs to reduce its carbon emissions looking to the fact that nearly half of the country's carbon emission comes from the power sector [1].

One of the major sectors, which need to be looked upon for the use of renewable energy, is sewage treatment systems. Sewage treatment systems are growing at a rapid pace due to population growth and not so proper sanitation facilities with low coverage. Above this, there is no proper inventory for the forms of energy used for the treatment of wastewater at sewage treatment plants (STPs). There is need to decide on substitute energy source before we exhaust our natural resources. The wastewater treatment consumes huge amount of electrical energy (60-70%) of the total energy consumed [5]. If this conventional electrical energy could be substituted by solar energy, the indirect CO_2 emission would significantly reduce and dependence on the grid electricity would also be minimized. Solar PV has been effectively and efficiently used at the decentralized level and has been well established in the literature for decentralized small scale industries. However, the application of PV solar cells for decentralized STPs has not been looked upon yet and needs to be considered for bringing change in the urban management scenario for changing climatic conditions. Decentralized system, due to its modular behaviour has the capacity of vast coverage in remote areas and can be good option against the large centralized system with huge sewage networks. The STPs designed at decentralized levels use electrical equipment's ranging from 0.05 kW to 180 kW capacities. Therefore this study looks into feasibility of solar PV application at small-scale decentralized STPs and the possibility of application of solar PV.

II. AVAILABLE SOLAR PV MODULES

Different companies manufacture solar PV modules like LANCO, EMMVEE, Vikram Solar, and TATA Solar, Indosolar, etc. in India and like Sun Power, Mitsubishi, Quasira, Panasonic, and Heat technology to mention few across the globe. Opting foreign companies for the application of PV modules would not be feasible looking into the cost economics. Hence, Indian companies have been selected for the can be easily available and cost effectiveness. After analysing the module efficiency and the surface area of all the available modules of various companies, it was found that PV modules of Vikram Solar Company have the best module efficiency of 16.2 and active surface area in range of 0.112 to 1.71 m^2. Hence, for all the calculations of the study the PV modules of Vikram Solar Company have been considered.

III. SELECTION OF STP, ESTIMATION OF ENERGY CONSUMPTION AND GHG EMISSION

Out of twelve small-scale decentralized STPs surveyed in Delhi, India, one decentralized STP was considered to check the feasibility of renewable application. This STP is located at a commercial institution. The design capacity of the STP is 300 m^3/day with average daily inflow of 250 m^3/day (TABLE 1). The STP uses extended aeration (EA) process for treatment. It has treatment units such as screen chamber, equalization tank, extended aeration tank, final settling tank, sand filter, activated carbon, chlorination unit and sludge drying bed. For the application of solar PV modules, the electrical energy demand of all the electrical equipment's in different units of STP was studied and estimated using method provided in [5]. Field visits and one-on-one interaction with the STP officials were conducted to estimate the total energy consumption of STP. The capacities of the electrical equipments were also crossed-checked from the treatment unit user manuals. The field observations included the number of different electrical equipment's present, their rated power and duration of operation for the daily energy demand. The STP was monitored for duration of a week to know the average working time of all the electrical equipments. The green house gas (GHG) emission of the STP due to use of electrical energy was calculated by using the emission factor of 0.81 $kgCO_2eq/kWh$ [6].

Table 1 Physical characteristics of the STP

Parameters	m^3/day	Inlet flow (mg/l)	Outlet flow (mg/l)
Design capacity	300	-	-
Operating capacity	250	-	-
PH	-	6.5	7.5
BOD	-	400	17

IV. DESIGN METHODOLOGY FOR SOLAR PV SYSTEM

Design of the solar PV consists of module sizing, inverter sizing, battery sizing, and module circuit design. The design involves the determination of capacity and size of various components to be used in PV system. The designing of the solar PV consists of the location of installation, amount of sunlight available, number of load to be connected, number of hours of usage for each load, available modules in the market and the efficiency, peak watt of the module etc. [6].

4.1 Estimation of design electrical load

Design load required the estimation of amount of electricity required by the load (electrical equipments). Energy consumed by a load in a given day is calculated by using methodology discussed in [5]. The electrical load of decentralized STP as provided in TABLE 2 was found to be 362.04 kWh/day.

4.2 Estimation of inverter size

The inverter is selected to supply the desired power to the load. Inverted is selected with power capacity higher than the total connected load. By taking into account the efficiency of the inverter, the required input to the inverter is calculated using (1):

$$\text{Inverter capacity} = \frac{\text{Total wattage of load (Wh)} \times 100}{\text{Efficiency}} \quad \text{.. (1).}$$

Inverter efficiency is considered as 93% [7]. Inverted takes DC input power and converts it into AC output power. In this paper the estimated power rating of the inverter is considered as 400VA. The standard value of inverter available in the market is 400VA with 12 volts DC input and 230 V AC input.

4.3 Estimation of battery size (E_d)

The battery sizing is carried out after the inverter sizing has been done. The inverter has some loses as the efficiency is less than 100%. Therefore, the battery selection is done in a way that they not only supply the power but also energy required by the load and should also be able to supply the loss of energy by the inverter. In order to size the batteries, several other parameters were considered like (1) system capacity of the battery (2) depth of discharge (DoD) and (3) number of autonomy days. The DoD of the batteries indicates the amount of total change that could be used. If the DoD is 50% means that only 50% of the battery charge could be used. In solar PV, the deep discharge batteries are used with DoD in the range of 50% to 60%. The batteries in standalone system store energy to provide power during the non-sunshine days. The numbers of cloudy days for which we need to supply energy are referred to as autonomy days. This means that whatever capacity we have estimated after DoD needs to be increased to store extra energy for the number of autonomy days. In this study autonomy days is taken as 2 for Delhi. The battery capacity is calculated using (2) and number of batteries using (3):

$$Capacity\ of\ battery\ (Ah) = \frac{Energy\ input\ to\ inverter \times No.of\ days\ of\ autonomy}{DoD \times System\ voltage} \quad \text{....... (2).}$$

Number of batteries:

$$\text{Total number of batteries} = \frac{\text{Total Ah capacity required}}{\text{Ah capacity of one battery}} \quad \text{.. (3).}$$

Where, Ah capacity is calculated using (2).

Ah capacity of battery is assumed as 150Ah

4.4 Estimation of PV module size

Daily energy supplied by the PV module is calculated using (4):

$$\text{Energy from PV module (Wh)} = \frac{\text{Total energy (Wh)}}{\text{Battery efficiency (0.90)}} \quad \text{... (4).}$$

The numbers of modules and their power rating to supply required energy to the system needs to be estimated. To estimate the number of modules required, we need to know the amount of solar radiation (sunshine hours) availability of the location where PV module is installed. Typical daily solar radiation of India varies from 4 to 5 hours/day. For Delhi the solar radiation varies from 4.8 to 5.0 kWh/m^2/day [1]. The PV module power is calculated using (5).

$$\text{SPV module wattage (W) or Wp} = \frac{\text{Daily energy to be supplied by SPV module (Wh/day)}}{\text{Equivalent daily sunshine hours (5)}} \quad \text{........... (5).}$$

Selection of PV modules: Many PV modules are available in the market ranging from 10Wp to 300Wp. In order to find the number of PV modules, the total PV module power required is divided by the single PV module available in the market.

$$\text{Total number of PV module} = \frac{\text{Total estimated module power}}{\text{Power of single module}} \quad \text{.. (6).}$$

V. RESULTS

Energy demand of all the units of STP is provided in (TABLE 2). The estimate peak power requirement (electrical energy) of all the electrical equipment's at the decentralized STP is found in the range of 4.44 - 178.8 kWh/day. The total electrical energy use of decentralized STP is 362.04 kWh/day (TABLE 1). The energy requirement of the electrical equipment's depends on the daily total sewage inflow at the STP. The working capacity of the STP is not fully utilized as the daily inflow of the plant is lower than the design capacity of the

STP. Hence the maximum average inflow has been considered for estimating the total electrical energy, to help in the designing of PV modules. The total electrical energy use by the blowers used in the extended aeration unit was high and hence was excluded from the designing process of solar PV modules. Therefore, electrical equipment's having electrical load less than 150 kWh capacities have only been considered for the application of PV modules. Moreover, considering the compact spaces the decentralized STPs are build in, the area required for installing PV modules is not available, which is a major concern.

Table 2 Electrical load of centralized and decentralized STP

Electrical equipments of decentralized STP	Number of appliance	Numbers	kW	Hours/day	kWh/day
Raw water transfer pump	Motor	1	2.24	12	26.88
Pump to aeration tank	Pump	1	2.24	12	26.88
Blower	Pump	1	7.45	24	178.8
RAS pump	Motor	1	1.49	24	35.76
Chemical dosing pump	Dosing pump	1	0.37	12	4.44
Filter feed pump	Filter feed pump	1	3.72	12	44.64
Effluent transfer pump	Motor	1	3.72	8	14.88
Transfer pump for cooling	Pump	1	3.72	4	29.76

In the STP, 50.06% of the electrical energy used by the electrical equipments could be replacement by the renewable source of energy (after excluding the blowers used in extended aeration unit). The specifications of the various components involved in the designing of the solar PV modules are mentioned in TABLE 3.

Table 3 Specifications for designing solar PV modules

Parameters	Quantity
Load	183.24 kWh/day
Solar inverter capacity	197 kWh
Battery bank capacity and number of batteries	65677.4 Ah and 438 batteries
Solar PV modules	24 V - 842 panels
Total area required	316.19m^2

The total area required for installation of these panels required is estimated as 316.19 m^2. The total roof top area available at the institution building of the STP is 650 m^2, which will allow the installation of solar PV modules for the estimated load. The total GHG emission from the STP is estimated to be 293.25 $kgCO_2eq$/day which after the se of solar PV modules can be reduced to 144.82 $kgCO_2eq$/day.

The range of electrical energy replaced by solar PV in other decentralized STPs of Delhi is found in the range of 8.8% to 100% respectively. Consequently, same amount of CO_2 emission reduction is also observed from the treatment plants. If all the decentralized STPs in Delhi were installed with solar PV modules, there could be huge reduction in the dependence on grid energy. This will help to reduce the amount of GHG emission from the sewage treatment system. Due to power cut problem the decentralized STPs also use diesel generators to operate the plants. The total emission due to use of diesel fuel can be completely eliminated with the application of solar PV modules at the STP. Therefore, application of solar PV modules will not only help in reduction of GHG but also decrease the reliability of the system on conventional grid.

VI. CONCLUSION

Grid connected energy is the fastest growing sector with solar PV modules. With life span of almost 25 years makes the use of solar panels more suitable for multiple applications. The study analyses the application of renewable energy for decentralized STP in Delhi. The study intends to check the share of conventional grid energy that can be substituted by the use of solar PV. The study estimates the total energy of the decentralized STP as 362.04 kWh/day. The study considered electrical equipments less that 100 kW capacity for designing the solar PV module at the STP. It was estimated that 50.06% share of electrical energy can be substituted by application of renewable energy –solar PV. The application of solar PV will reduce the emission due to use of conventional electrical energy by 50%, making the total emission as low as 0.2 $kgCO_2eq/m^3$ of sewage treated. Substitution of grid electricity by solar energy by almost 50% can make huge difference in the waste sector and this integration of the solar energy with grid will not only help to decrease the reliability on the grid but also help to reduce the environmental burden and make the system more sustainable.

With India planning to achieve ambitious target of using renewable energy, this study will help the urban planners and policy makers to focus on the sewage treatment sector to create a more reliable and efficient system. This will lead to development of sustainable environment and creating better future urban growth. Shifting the energy economics from cola based electricity generation to use of solar PV modules is required and can change the dynamics of country like India and help achieve the millennium goals. Combination of energy efficiency, energy conservation and renewable energy in the wastewater sector will make the city more manageable and will lead toward a smart city.

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