The International Journal of Soft Computing and Software Engineering [JSCSE], Vol. 3, No. 3, Special Issue:
The Proceeding of International Conference on Soft Computing and Software Engineering 2013 [SCSE'13],
San Francisco, CA, U.S.A., March 1-2, 2013
Doi: 10.7321/jscse.v3.n3.130 e-ISSN: 2251-7545

Simulation of a Building Integrated Solar PVT- Roof System

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***Abstract*—The present photovoltaic solar cell (PV) converts solar energy into electricity with efficiency, of less than 20%. Photovoltaic thermal (PV/T) system consists of PV module along a heat removing passage to remove the heat below the PV. Also PV/T systems can provide simultaneously electricity and heat, and hence can serve dual purpose. In this paper comparative study of three roof models are discussed -1) Conventional roof: Conventional roof is taken as a base case which is made up of concrete.2) roof with photovoltaic, 3) roof with photovoltaic thermal (PV/T). The electricity consumption for each system is computed using EQUEST software. Also estimation of carbon di-oxide emission is compared in each case done for each system.**

Key words:photovoltaic solar cell, EQUEST, electrical consumption.

I. INTRODUCTION

A. BACKGROUND

Solar energy is the promising source of the future earth. It lies in the fact of how we tap it at a reasonable cost. The light energy can be converted into electrical energy via a solar photovoltaic cell. The current popular technology converts solar energy into electricity and heat separately [1]. A significant amount of research and development work on the photovoltaic/thermal technology has been done since the 1970s [2].The integration of photovoltaic modules in buildings allows one to consider a multifunctional frame and then to reduce the cost by substitution of components [3]. The photovoltaic modules have been deployed to provide electricity in various types of buildings across the world and the recent development on photovoltaic/thermal concept offered an opportunity to increase overall efficiency by making use of waste heat generated in the PV module [4]. It is a well-known fact that the rising demand in electricity and with the depletion of conventional fuels, the research technologies are focusing towards a sustainable solutions utilizing solar energy which would be available till the end of the Universe. The rationale for the development of PVT systems is that in recent years the cost of silicon solar cells has fallen rapidly and improvements in efficiencies have also been realized, during the same time period the cost of solar thermal systems has remained relatively static and efficiencies have remained steady [5].Typical PV modules can only convert 10–20% of solar radiation to electricity while some part is reflected back to the sky and the reminding solar energy will be transformed into heat.[6]. Further, the UK government intends to set zero carbon targets for new non domestic buildings by 2019[7]. These standards are expected to assist the UK government significantly in reducing CO2 emissions from buildings and to achieve the 2050 target of an 80% reduction in carbon emissions compared to the 1990 baseline as set in the Climate Change Act 200 [8]. It was reported by Zondag et al (2002) that hybrid PVT systems are more efficient than conventional solar thermal or solar photovoltaic collectors per unit area [9].

B. LITERATURE REVIEW

From the literature review, it is clear that PV/T collectors are very promising devices and further work should be carried out aiming at improving their efficiency and reducing their cost, making them more competitive and thus aid towards global expansion and utilization of this environmentally friendly renewable energy device [10].The review research suggested that further works could be undertaken to (1) develop new feasible, economic and energy efficient PV/T systems; (2) optimise the structural/geometrical configurations of the existing PV/T systems; (3) study long term dynamic performance of the PV/T systems; (4) demonstrate the PV/T systems in real buildings and conduct the feasibility study; and (5) carry on advanced economic and environmental analyses. This review research helps finding the questions remaining in PV/T technology, identify new research topics/directions to further improve the performance of the PV/T, remove the barriers in PV/T practical application, establish the standards/regulations related to PV/T design and installation, and promote its market penetration throughout the world [11].

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C. OBJECTIVE

The aim of the present study to simulate and evaluate the performance study of three roof models: system I: Conventional roof is taken as a base case which is made up of concrete system; System II: Roof with photovoltaic; System III: Roof with photovoltaic thermal (PV/T). The electricity consumption for each system is computed and compared using EQUEST software. The estimation of carbon di-oxide emission in percentage for each system is computed and compared.

II. DESCRIPTION OF THE SYSTEM

The room of floor area 800 sq. ft. is considered for the present study. It has having flat concrete roof with single pane and a single door for exit as shown in Figure.No.1. The room is used as a dining hall with occupancy of four members. The window to wall ratio is considered to be 30% . . The circulation of the air inside is of the atmospheric conditions in three cases. The three system simulated and compared are discussed in section2.1, 2.2 & 2.3 respectively.

A. SYSTEM I CONVENTIONAL ROOF

The base case is made up concrete roof and is designed according to ASHRAE 9.0. It is similar to the conventional room with a single pane and door.

B. SYSTEM II ROOF WITH PHOTOVOLTAIC PANEL

The simulated model of the dining hall for the system II is done using EQUEST software in which the. PV panel is placed on the building integrated roof system. The electricity produced is either used for lighting the dining hall considered or to heat the water used for various purposes.

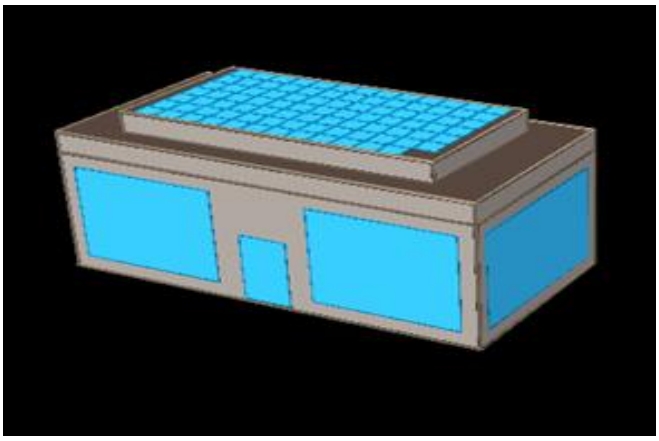

Figure 1. Simulated Model of Dining Hall with PV Integrated Roof Top System with technical specification

Technical Specifications of the roof:

Total no of arrays – *7*

Total no of panels – *350*

Wattage of each panel - *80 Wp*

Panel efficiency - *14%*

Total no of cells in each panel - *36*

Total Installed Capacity - *24 kWp*

Total Cost - *Rs 72,00,000/-*

Energy Generation - *30600 kWh/yr*

The specification of the room is as follows:

External Wall - 0.121 W/sq m K,

Roof - 0.061 W/sq. m K

Floor - 0.350 W/sq. m K

Window to Wall Ratio -30%

Glass (Single pane) -1.22 W/sq. m K

C. SYSTEM III ROOF WITH PHOTO-VOLTAIC THERMAL ROOF

In system III, the water is heated by sending it below the passage of PV panel and the roof. The electricity produced is utilized in lighting the hall and the hot water formed is used in low temperature application such as cooking, bathing, etc. For example solar water heaters convert incident solar radiation into thermal energy, which is typically utilised, for domestic, commercial or industrial purposes (photo thermal conversion); solar photovoltaic generate electricity a hybrid of these technologies is known as a solar photovoltaic-thermal collector. PVT solar systems combine photovoltaic and solar thermal components into one unit with a simultaneous provision of electric power and heat [12].

III. COMPUTATION

Computation of the performance is done using EQUEST software. EQUEST consists of DOE-2 derived engine. DOE-2 is the most widely recognized and respected building energy analysis program in use today. EQUEST provides very accurate simulation of such building features as shading, fenestration, interior building mass, envelope building mass and the dynamic response of differing heating and air conditioning system types and controls. EQUEST also contains a dynamic day lighting model to assess the effect of natural lighting on thermal and lighting demands.

IV. RESULT

The electricity consumed and the Co_2 emissions for the three models were compared and the analysis was made.

A. ELECTRICITY CONSUMPTION

Figure 2.shows the comparative electrical consumption in kWh per year for the three systems considered. From the

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result arrived it is seen that the total electrical consumption in dining hall using PV/T system is less (around 8,535 kWh less) when compared to the base case (conventional roof) system. The graph shows that the electrical consumption for cooling, and in heating hot water is more than in conventional rooftop systems. Also it shows the decrease in electrical consumption used for heating the water which otherwise is met by the hot water sent in cooling the PV panel in case of PVT. Hence, the total electrical consumption in dining hall using PV/T system is less (around 6,680 kWh less) when compared to the PV system.

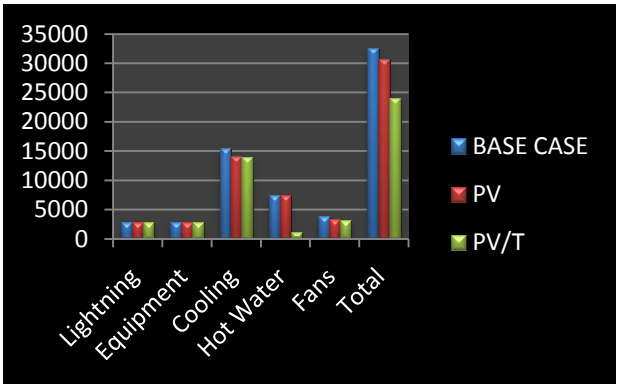

Figure 2. Electrical consumption in kWh for three cases considered

To overcome this problem, PVT systems are introduced. The water passes over the PV back surface preventing the panel from overheating. Also hot water demand can be met using PVT system. This hot water can be used for low temperature application such as cooking, bathing, washing, etc. Thus it decreases the load on the power plant sectors.

B. CO_2 EMISSION (TONS PER YEAR)

The Stern Report (14) has highlighted the rationale for the deployment of low carbon technologies to stabilize global greenhouse gas emissions at 550 ppm CO_2eq (15). Fig.3. shows the % carbon emission in tons per year in three cases.

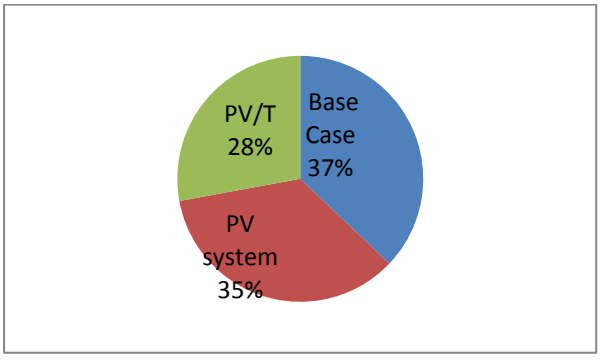

Figure 3. Percentage Co_2 emission

CO2 emission in percentage for a year shows that around 2% of CO_2 emission can be reduced by using PV and 9% of CO_2 emission can be reduced using PV/T system.

V. CONCLUSION

Simulated result shows that using PV/T system we can cut down the load of the electricity bill and hence can be practiced as a sustainable solution towards conserving electricity especially in all rural households where grid connectivity is not cost effective solution. Also this PV/T roof-top system will be a boon in the place where huge power cuts occur during day time. Also implementing this system will reduce the carbon emissions considerably.

VI. FUTURE WORK

The air could be used as the working fluid and heated such that the circulation rate could be faster and heat removal rate would be higher. The heated air could be used in space heating by which significant energy could be save which is the need of the hour.

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