Modelling and Simulation of Building Integrated Photovoltaic (BIPV) System for Energy Efficient Buildings

Arshdeep Singh
Electrical and Instrumentation Engineering Department
Thapar University
Patiala

Prasenjit Basak
Electrical and Instrumentation Engineering Department
Thapar University
Patiala

Jasvir Singh, Mohammad Shehzad
Electrical Engineering Department
Bhai Gurdas Institute of Engineering and Technology
Sangrur

ABSTRACT
To meet the increasing energy demand microgrid which can work in both grid connected as well as islanded mode of operation might play an important role. With the help of microgrid, solar energy which is freely available can be utilized to fulfill the energy demand of buildings. This paper proposes a building integrated photovoltaic (BIPV) system for energy efficient buildings. Solar power is the clean and abundantly available among the other renewable energy resources. It can be utilized in the best way using BIPV technology. In this paper the load demand of a building in Punjab (India) and the power output of photovoltaic system have been studied with the help of Matlab Simulation software.

Keywords
BIPV, BAPV, PV, Microgrid

1. INTRODUCTION
The indentation of growth and advancement of a nation can be estimated by the quantity of deployment of energy by the population. Due to increase in population the demand and consumption of energy is increasing rapidly. The conventional energy resources will be depleted soon in few hundred years [1]. To meet the future energy requirements it is necessary to develop the renewable sources of energy. The non-conventional energy sources present in the universe having some limitation for their use most of them are geographic limitations. Other renewable energy resources have more geographical limitations than solar because it is available in abundance over the whole universe. In urban area, decentralized photovoltaic (PV) power production plays a significant role [2]. Building-integrated photovoltaic (BIPV) was comes into picture during 1991 in Germany [3].This technology provides an organized design, solid structure and power generation system for buildings [4, 5]. BIPV elements can be easily integrated into the building by replacing the building material [6]. Today the researchers are focused on efficiency improvement and heat emissions by this system. For facades the mechanical ventilation is less advantageous than the natural ventilation [7]. The research paper [8] provides the environmental outline of BIPV system. It has been found that two-inlet BIPV is better than one inlet system and efficiency of BIPV system can be enhanced by 7.6% using semi-transparent crystalline silicon PV modules [9].

Building Integrated Photovoltaic (BIPV) systems are considered as the functional parts of the building's construction which act as an electrical energy source. This technology includes the components that replaces the tiles shingle, slate and metal roofing. This will improve the appearance of the building along with power generation [10, 11]. Building Applied Photovoltaic (BAPV) systems the components are not the parts of building itself. These are the extra components which are installed on buildings only for power generation.

BIPV and BAPV can differentiate by the extent of tightness between the PV system and the building. In case when the photovoltaic arrays are tightly integrated then BAPV converts to BIPV [12].

2. ADVANTAGES OF BUILDING INTEGRATED PHOTOVOLTAIC CELL
The cost of the PV roof can be compensated against the cost of the building's roof elements replaced by it [13]. Power is generated from the available solar energy that is free of cost which would otherwise to be purchased from utility grid. It can operate in grid connected mode which enhances the reliability as compared to the stand alone system. Moreover there is no need of extra land [14].

3. SIMULATION OF BIPV
Our aim of study is to check whether BIPV/BAPV based buildings are feasible in Punjab or not. So, in order to fulfill this aim the building of Sukham Memorial Central Library at Bhai Gurdas Institute of Engineering and Technology Sangrur is selected with geographical parameters as latitudes 30.2457963 longitudes 75.8420716. The building of the library consists of glass at the outer walls. The existing building can be transformed to BIPV/BAPV buildings by minor amendments. By utilizing the area of south facing wall and rooftop a PV system of capacity more than 30 KW can be installed, but here the capacity of PV system is taken as 25 KW.

With the installation of PV system will makes financial benefits through power generation from solar energy and potentially sell electricity back to grid. It also enhances the social values of the building by making it go green.

The load demand of the library for 24 hours on 8th April 2015 is taken. Also the solar radiation data for same date has been taken from Thapar University weather station. It has been assumed that solar access might be similar for Sangrur as these two locations are only 45 Km apart. With the help of Matlab-Simulation the load demand of the building and the power output of photovoltaic system are analyzed.

3.1 Simulation of PV Array

Enough power cannot be generated through single module to fulfill the load demand. PV array consists of the combination of the number of solar panels those convert solar energy to electricity. The power output of a PV array can be calculated using following equation [15]:

$$P_{PV} = P_{STC}/G_{ING} (1+K (T_C - T_r)) \quad (1)$$

where: P_{PV}-Output power of the PV system, P_{STC} - maximum power of PV system at Standard Test Condition (STC),G_{ING} - Incident Irradiance, G_{STC}- Irradiance at STC 1000 (W/m^2), T_r -Reference temperature, T_c -Cell temperature, k-Temperature coefficient of power. The maximum power of PV (STC) array in present case is:

P_{STC} = 25KW,

K= 0.0167

3.2 Weather conditions

Weather conditions like temperature and light intensity with their deviation with time are required for mathematical modeling of PV system in matlab [16]. These parameters were taken on 8th April 2015 to meet the load demand of the building on same day. The variation of temperature and solar radiation with respect to time is shown in Figure 1and 2. The solar radiations are calculated on hourly basis as the average of the April month.

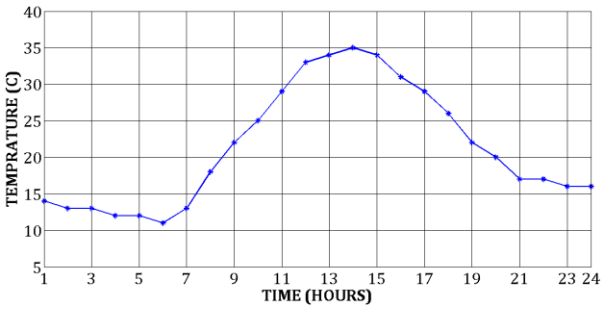

Figure 1. Temperature variation with time

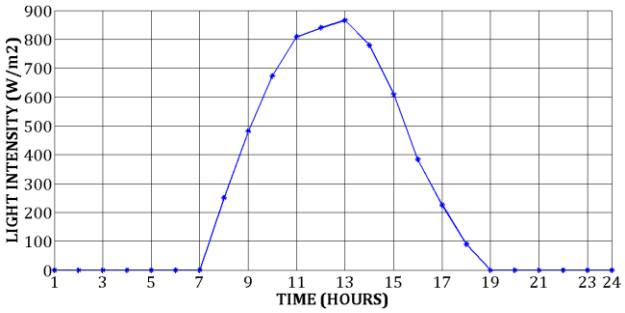

Figure 2. Light intensity variation with time

4. RESULTS AND DISCUSSION

Figure 3 shows the simulation results of the power output and load demand. It validates that there is less power consumption during first working hours of the day and the output power of the PV system is higher than the consumption. After 8 am the output power of PV system increases and at the same time the load is also increasing. During the mid of the day the power output power from the PV system is much higher than the requirement.

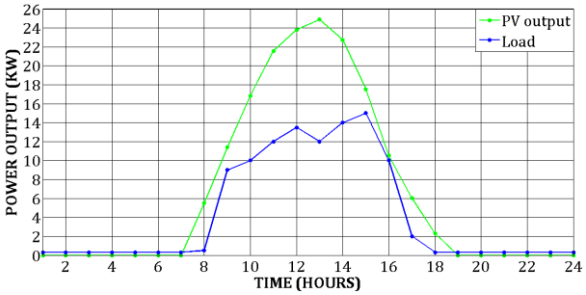

Figure 3. Power output and load demand.

At 16th hour from figure 3 it has been found that the power output as well as the load demand is comparably same. In the last working hours the load demand starts decreases to very low value but at that time generated power also decreases but still more than the demand. The surplus power can be stored for night time load as well as can be shared with the other neighboring building. The output power is surplus almost every hour during day time. This shows that the building can generate power more than its demand by utilizing the solar power falling on its own area. There is no need of extra land for PV system installation. However the output may be different for any other day due to weather effect. It may become less then demand due to clouds.

5. CONCLUSIONS

Due to the increase in the demand of energy, the major area of concern is to utilize the renewable energy resources. Among those solar energy is playing very important role. There is sufficient solar access is available at our site Sangrur. BIPV system can fulfill the load demand of the building without extra land requirement. Integration of PV system on buildings will make them able to generate power for their requirement. It will reduce the overall load on utility grid and transmission lines. This will also optimize the power system by reducing the losses with increased efficiency. From the simulation result, it has been found that BIPV integrated building in Punjab can fulfill its load demand for 24 hour. BIPV system can play an important role for designing of energy efficient building and this type of buildings can be designed in Punjab because of good solar access availability.

More research efforts are required to compare the BIPV and BAPV's capital and maintenance cost in order to get the favorable outcomes.

6. REFERENCES

[1] Bentley, R. 2002. Global oil & gas depletion: an overview. Energ policy .3 (Feb. 2002), 189-205.

[2] Sechilariu, M. 2013. Building integrated photovoltaic system with energy storage and smart grid communication. IEEE T Ind Electron. 60 (April 2013) 1607-1618.

[3] http://publications.lib.chalmers.se/records/fulltext/68151.pdf

[4] Joachim, B. 2001 Building-integrated PV modules. Sol Energ Mat Sol C. 67 (March 2001) 345-354.

[5] Tripanagnostopoulos,Y. 2002. Hybrid photovoltaic/thermal solar systems. Sol Energy.72 (March 2002) 217-234.

[6] Sharma, S. (2016). Performance enhancement of a Building-Integrated Concentrating Photovoltaic system

using phase change material. Sol Energ Mat Sol C. 149 (May 2016) 29-39.

[7] Agathokleous, R. A. 2016. Double skin facades (DSF) and building integrated photovoltaics (BIPV): A review of configurations and heat transfer characteristics. Renew Energ. 89 (April 2016) 743-756.

[8] Lamnatou, Chr. 2015. Life cycle energy analysis and embodied carbon of a linear dielectric-based concentrating photovoltaic appropriate for building-integrated applications. Energ Buildings. 107 (Nov. 2015) 366-375.

[9] Yang, T. 2015. Experimental investigation of a two-inlet air-based building integrated photovoltaic/thermal (BIPV/T) system. Appl Energ. 159 (Dec. 2015) 70-79.

[10] Chow, T. 2003. Building-integrated photovoltaic and thermal applications in a subtropical hotel building. Appl Therm Eng. 23 (Nov 2003) 2035-2049.

[11] Pantic, S. 2010. Modeling of energy performance of a house with three configurations of building-integrated photovoltaic/thermal systems. Energ Buildings.42 (Oct 2010)1779-1789.

[12] Peng, C. 2011 Building-integrated photovoltaics (BIPV) in architectural design in China. Energ Buildings. 43 (Dec 2011) 3592-3598.

[13] Peng, C. 2011. Building-integrated photovoltaics (BIPV) in architectural design in China. Energ Buildings. 43(Dec 2011) 3592-3598.

[14] http://dspace.thapar.edu

[15] Singh, Arshdeep, and Prasenjit Basak. "Foundations and Frontiers in Computer, Communication and Electrical Engineering."

[16] http://www.timeanddate.com