A CASE STUDY OF BIPV APPLICATION TOWARDS GREEN BUILDING

Arshi Sana Noor¹, Fatimah Zohra², Safa Perween¹,*, Tuba Fatima¹

¹Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi, India
²Faculty of Law, Jamia Millia Islamia, New Delhi, India

*Corresponding author. E-mail: perween.safa.sp@gmail.com

Abstract. This paper focuses on the reduction of dependency on conventional sources of energy. The main aim of this paper is to do analysis of conversion of the current building into a green building using solar panels to harness solar energy and reducing the dependency on the conventional source. A workshop in Mumbai is considered for the calculation of heat load using MS EXCEL heat load calculation sheet. U-factors for different components of the buildings such as walls, roofs, window panes are taken from ASHRAE table. Other factors such as equipment load, light load, fresh air per person, occupancy etc., are also taken into consideration. Heat load is calculated for each room separately and then summed up for the entire building. This cooling demand of current building was met by conventional electricity supply. Photo-Voltaic modules are incorporated to the building to harness the solar energy and meet some of the cooling demands of the building and thus reducing its dependency on conventional source. To convert the current building into a Green building, several LEED criteria are considered and reduction in the cooling demand of the existing building is achieved by thermal insulation of walls and roofs and glazed window panes.

Keywords: Green building, BIPV, Cooling Load, ASHRAE

1. Introduction

Industrializations and rapid population growth has affected our natural resources, which are exhaustible. These resources are being consumed at an alarming rate. There is an urgent need to think about alternative sources of power. In this paper we have utilised solar power and tried to convert the present building into green building. The sun provides an unlimited source of power around the world. Solar power has become a positive energy source. It reduces carbon footprint. A workshop in Mumbai is discussed in this paper. The building has two floors above the ground floor and a basement. The total area to be air conditioned is 7037 sq ft. There is a control cell on the ground floor. On the first floor there is a drawing office and two cabins. The third mezzanine accommodates classrooms, recreation room, IT cell, three NDT labs, and a dining hall. This paper focuses on different ways of reducing the energy demand ie., cooling demand of the building with the help of different kinds of insulation. On grid solar system is used to utilize solar energy.

Thus due to reduction in energy demand, we can reduce the dependency on conventional sources
and reduce global CO2 emissions which causes global warming. The cooling load and energy consumption of this building is calculated and compared with that of its green building design. LEED v4.1 O+M – EXISTING BUILDING rating system is used to find the leed points of the converted green building.

1.1. Literature review
We collected research papers from internet and periodicals to gather information for our study. We reviewed them and found that the following three are the broad areas of interest in our paper:
1. Green Buildings
2. Active and Passive Buildings
3. Heat load calculations
These three areas are discussed thoroughly in further sections.

1.1.1. Green buildings
Avinash Shivajirao Pawar in 2012 discussed that using high-efficiency windows and insulating walls, ceilings, and floors, a building can be converted into green building. Passive solar building design can also be implemented in houses. S.Selvendran has described the green building concepts and building orientation etc. Jack C.P. Cheng, Moumita Das in 2014 has presented building information modeling (BIM) which provides building code checking and building energy simulation. Yiqun Pan, Rongxin Yin, Zhizhong Huang in 2007 has presented energy simulation models for China Code building, and ASHRAE budget building. He redesigned current building with energy simulation software EnergyPlus. Warren L. Paul, Peter A. Taylor in 2007 has argued that “green” buildings have a lot better indoor environmental quality compared to that of a conventional buildings resulting in a more satisfying workplace for the building’s occupants and, which in turn, increases the productivity of the workforce.

1.1.2. Active and passive buildings
Ji Eun Kang in 2004 has discussed the various ways to reduce cooling load of a school building in Korea. He has cross-compared the impact of passive and active approaches. Suresh B. Sadineni, Srikant Madala, Robert F. Boehm (2011) has proposed building end energy demand can be reduced by implementing approaches like passive solar walls, green roofs, photovoltaic roof, thermal roof insulation etc. Carlos Ernesto Ochoa, Isaac Guedi Capeluto in 2007 suggested that the evaluation of energy performance and visual comfort can be done with the help of computer energy modelling in three parametric series which includes the active components, approach of smart passive design and the combination of them.

1.1.3. Heat load calculation
Kulkarni, Sahoo and Mishra in 2011 has worked for the optimization of the cooling load for a classroom from the study it is deduced that incorporating false ceiling, ceramic tiles on roof and reflective clear glass are good retrofitting option, and an approximate 17.6–19.8% reduction in cooling load and the emission of CO2 can be achieved, Gaurang Tripathi and Ankur Kumar has in this study calculated cooling load for a tutorial room located in Ghaziabad City with the help of Cooling load temperature difference (CLTD) method which came out to be 3.558TR. Mohammad Azhar Kareem in 2016 has done a comparison of hand calculation against the hap programs for calculating cooling load for buildings. The cooling load for Refrigeration and Air conditioning Engineering Department building in Erbil was calculated. The total cooling load for the Air conditioning of the building by hand calculation requirement is 95.7 TR. and total cooling Load for HAP programs requirement is 93.6 TR.
Cooling load of building can be reduced by using intelligent systems.

1.2. Scope of work
The boiler workshop is selected for the comparative analysis between normal building and green building or solar building. The summer load, monsoon load, dehumidified CFM and required CFM are calculated using the MS Excel program. The required U factors are taken from ASHRAE table. The present building is then converted to green building by employing energy efficiency measures such as solar panels, high efficiency HVAC systems with smart controls. Green buildings are the buildings which reduce the negative impacts on the environment and produce a positive impact. The thermal characteristics of building, natural ventilation and daylighting are improved to minimize internal loads. For example, the use of insulation in the walls, roofs, glazed window panes and effective sun control can effectively reduce cooling load. The ultimate objective is to make use of renewable energy resources and minimize requirements of refrigeration. Solar power is a boon which can reduce the consumption and dependency on conventional fossil fuels and is also quite economical.

1.3. Objective
The main objective is to minimize the end energy demand of a building by reducing its cooling demand and by integrating PV modules to the building i.e., BIPV.

2. Analysis

2.1. Cooling load of present building
The cooling load calculations are carried by the CLTD (cooling load temperature difference) method suggested by ASHRAE for the workshop in Mumbai.

*Table 1: Design conditions of current building*

| Conditions          | Value                        |
|---------------------|------------------------------|
| U Factor of Wall    | 0.36 Btu/hr-Sqft-F           |
| U Factor of roof    | 0.32 Btu/hr-Sqft-F           |
| U Factor of Glass   | 1.1 Btu/hr-Sqft-F            |
| Lightning Load      | 2w/sqft                      |
| ACPH                | 1                            |
| Equipment load      | 150W/workstations            |
| DBT (Summer)        | 95F                          |
| DBT (Monsoon)       | 85F                          |
| WBT (Summer)        | 83F                          |
| WBT (Monsoon)       | 82F                          |
| RH (Summer)         | 60                           |
| RH (Summer)         | 88                           |

Desired indoor temp=CLTD= outdoor temp- indoor temp= 75deg Celsius Heat
Transfer = U* CLTD* Area
Area is obtained by the detailed design data of the building.
U-factor is taken from ASHRAE table. We have calculated the cooling load of building by entering various inputs like area, U factors, occupancy, light and equipment loads, ACPH, RH to the MS EXCEL heat load calculation sheet. The total cooling load for the building came out to be 49 TR.

2.2. Green Building

2.2.1. Conversion of present building into green building
Workshop is a kind of light industrial building. So we are considering LEED v4.1 O+M – EXISTING BUILDING rating system for the different criteria of green building. These criteria are:

Location and transportation- The building is suitably situated in Mumbai. Transportation of raw material will be much easier and cheaper.

Materials and resources- Materials are obtained from natural, renewable sources to reduce the costs of transportation. Materials are procured by looking at their Life Cycle Analysis (LCA) of durability, recyclability and waste reduction. The portland cement is replaced by industrial waste like fly ash and slag.

Water Efficiency- The use of water use is minimized by utilization of greywater and harvesting rainwater water for various purposes. Low flow showerheads, self-closing or spray taps, low-flush toilets and waterless composting toilets are some of the water efficient appliances that reduce water wastages.

Indoor Air Quality- The pollutants of main concern when assessing IAQ, are the airborne contaminants, which usually affect humans through inhalation. The contaminated (biological and chemical) air adversely affects the human beings inhaling that polluted air. Formaldehyde is usually present in adhesives and furniture of our homes. Volatile Organic Compounds (VOCs) have very low boiling temperature and is found in vapour state at room temperatures in products like paints, solvents, adhesives, carpets etc. These contaminants effect the human health adversely by causing dizziness, headache, fatigue, irritation and other chronic problems.

We can reduce these problems by installing a proper ventilation system which would allow the flow of fresh air into the building, getting rid of toxic gas by using advance exhaust system and, avoiding products which contain these contaminants.

Energy and atmosphere- Sunlight is a non perishable energy resource and the energy created by it is much more than our consumption. The whole world has the access to the solar energy unlike the natural resources which are randomly present and unevenly distributed and vary all across the world. The photovoltaic cells are used to convert the solar energy into electrical energy. Solar energy being a renewable energy is also environmental friendly and does not causes any pollution and can considerably reduce the energy generating costs.
Figure 1: On grid solar system

Specification of Single PV Module:
Maximum Power = 350W
Open Circuit Voltage = 46.40 V
Short Circuit Current = 9.80 A
Dimensions = 1960 mm * 960 mm
Maximum System Voltage = 1000 V

Solar Power Plant Scheme: Required
Load = 100 kW
So to install 100 kW the pattern of PV module
No of inverters = 3 (each three phase solar inverter)
No of Array = 1
No of strings = 9
No of Optimizers = 144 of 700 W each
No of PV module = 288 of 350 W each
So Area required = 288 \times 1960 \times 990 \text{ mm}^2 = 558.8352 \text{ m}^2 \text{ So area} = 558.8352 \times 10.7639 = 6055.09 \text{ ft}^2

String Arrangement and Load Calculations
One optimizer is connected with two plates which are connected in parallel with each other but all optimizers in a string are connected in series so Voltage of each optimizer = 46.40 V
Power of each optimizer = 700 W
Current through each optimizer individually = 700/46.40 A = 15.086 A
As each string have 16 optimizers so the total voltage through each string = 46.40 \times 16 \text{ V} = 742.4 V
Current remains same in series so current through each string = 15.086 A
Power through each string = Voltage \times Current = 742.4 \times 15.086 = 11200 W
This means that each phase have 11200 W power and as each inverter have 3 phase/string therefore power through each inverter = 11200 \times 3 W = 33600 W
As the number of solar inverters are 3 so the total plant power = 33600 \times 3 W = 100800 W \approx 100 \text{ kW}

**Building Envelope** - The building envelope includes exterior and interior walls, floors, ceiling and roofs which is a medium of heat transfer in the building. The energy loss or transfer depends upon the thermal resistance of the different components of the envelope. The U value of the Wall and Roof for proposed green building is 0.122 Btu/hr-Sqft-F and 0.061 Btu/hr-Sqft-F and this can be achieved by using R-13 and R-15ci thermal insulation respectively. The U value for the glazed glass will be taken 0.6 Btu/hr-Sqft-F. Ventilation is improved and extra fresh air is supplied. CFM per person is taken as 22 (previously 17) and CFM per sqft is taken 0.08 (previously 0.06). The cooling load is again calculated using these factors and we found that cooling load is decreased by 15%.

### 3. Results And Calculations
The calculated results are shown in Table 2. The summer and monsoon load of present and proposed green building are compared in the table. The summer load is reduced by 15.13%.

| Building type   | Summer TR | Power(KW) |
|-----------------|-----------|-----------|
| Present building| 46.6      | 163.85    |
| Green building  | 38.7      | 38.95     |

Table 2: Power consumption of present and green building.
Table 3: LEED Criteria.

| S.No. | Criteria                      | Max LEED points | LEED Point achieved |
|-------|-------------------------------|-----------------|---------------------|
| 1     | Location and transportation   | 14              | 8                   |
| 2     | Sustainable sites             | 3               | 1                   |
| 3     | Water efficiency              | 15              | 10                  |
| 4     | Energy and Atmosphere         | 35              | 24                  |
| 5     | Material and Resources        | 9               | 6                   |
| 6     | Indoor Air Quality            | 22              | 15                  |
| 7     | Building Envelope             | 2               | 1                   |
| **TOTAL** |                                | **100**        | **65**              |

If we are able to extract the above points out of the maximum as listed in Table 3 the building could be certified as gold category.

Thus the present building is converted to green building by working on the various criteria of green building. The major changes were seen in the energy consumption by the application of BIPV. Further the load is substantially reduced by insulating walls, roofs and using glazed window panes. To increase the overall building efficiency, the location, transportation, material selection, recycling used water and other factors can be taken into consideration to achieve a good LEED rating.

4. Scope Of Future Work
We have used solar panel to harness solar energy and utilize it to generate electricity. The maximum efficiency of a solar panel is almost about 23 percent and the average efficiency falls between the 15 to 18 percent range. The efficiency could be increased by adopting following measures:

1. By reducing reflectance of the solar cells and thus increasing its efficiency.  
2. By controlling temperature of solar cells by water cooling.  
3. By dividing solar spectrum into smaller junctions and thus raising its efficiency.

5. References

[1] Kulkarni K., P.K. Sahoo and Mishra M., 2011, “Optimization of cooling load for a lecture theatre in a composite climate in India” Energy and Buildings.
[2] Avinash Shivajirao Pawar, 2012, “Green Buildings”, Journal of Engineering Research and Studies.
[3] S.Selvendran,”Review on Green Building Concepts & Techniques”, 2017, International Research Journal of Engineering and Technology.
[4] Suresh B. Sadineni, Srikanth Madala, Robert F. Boehm, 2011, “Passive building energy savings: A review of building envelope components”, Renewable and Sustainable Energy Reviews
[5] Prof. Deepak Kumar Yadav, Aviral Srivastava, Ayush Chauhan, Gaurang Tripathi, Ankur Kumar, “Cooling Load Estimation of a Room”, 2017, International
Research Journal of Engineering and Technology

[6] Hai-xiang Zhao, Frédéric Magoulès , 2012, A review on the prediction of building energy consumption” Renewable and Sustainable Energy Reviews

[7] Warren L. Paul, Peter A. Taylor”, 2007, A comparison of occupant comfort and satisfaction between a green building and a conventional building “Building and Environment

[8] Tesoriero, R., Gallud, J. A., Lozano, M., and Penichet, MAY 2008, “V. M. R. Using Active and Passive RFID Technology to Support Indoor Location-Aware Systems” IEEE Transactions on Consumer Electronics.

[9] Yiqun Pan , Rongxin Yin, Zhizhong Huang,2008, “Energy modeling of two office buildings with data center for green building design”, Energy and Buildings.

[10] Carlos Ernesto Ochoa, Isaac Guedi Capeluto,,” 2008, Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in a hot climate”, Building and Environment.

[11] Ji Eun Kang , 2004,“A case study on passive vs. active strategies for an energy efficient school building” 8th Conference of the International Forum on Urbanism.

[12] Mohammad Azhar Kareem ,2016 “Comparison between Hand Calculation and HAP programs for estimating total cooling load for Buildings” ZANCO Journal of Pure and Applied Sciences.

[13] Jack CP Cheng, Moumita Das , 2014 , “A BIM-based web service framework for green building energy simulation and code checking” Journal of Information Technology in Construction.

[14] Suresh B. Sadineni, Srikanth Madala, Robert F. Boehm , 2011 “Passive building energy savings: A review of building envelope component” Elsevier Journal.

[15] Turgay Coskun, Cihan Turhan, Zeynep Durmuş Arsan, 2007 Gülden Gökçen Akkur, “The importance of internal heat gains for building cooling design” Journal of Thermal Engg.