

**STUDY OF GRID CONNECTED BUILDING INTEGRATED PHOTOVOLTAIC
SYSTEM AT THAPAR UNIVERSITY, CAMPUS**

**A Thesis Report Submitted In Partial Fulfillment of The
Requirements for the Award of Degree of**

MASTER OF ENGINEERING

In

Power System and Electric Drives

Submitted by

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July 2010

CERTIFICATE

I hereby certify that the work which is being presented in this thesis entitled, "STUDY OF GRID CONNECTED BUILDING INTEGRATED PHOTOVOLTAIC SYSTEM AT THAPAR UNIVERSITY, CAMPUS" in partial fulfillment of the requirements for the award of degree of Master of Engineering (Power System and Electric Drives) in the Department of Electrical And Instrumentation Engineering, at Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Mr. Souvik Ganguli (Asst. Professor) and refers other researcher's work which are duly listed in the reference section.

The matter embodied in this thesis has not been submitted for the award of any other degree to any other university.

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Abstract

The energy consumption in the world particularly in the industrialized countries has been growing at alarming rate. Fossil fuels which today meet major part of the energy demand are being depleted quickly. World has started running out of oil and it is estimated that 80% of the world's supply will be consumed in our life times. Coal supplies may appear to be large but even this stock may not last longer than a few decades. More over the pollution hazard arising out of fossil fuel-burning is become quite significant in recent years. Nuclear power has posed a number of problems and nuclear fusion is still a speculative technology. Thus we are forced to look for unconventional energy sources such as geothermal ocean tides, wind and sun. All unconventional energy sources have geographical limitations. But solar energy has less geographical limitation as compared to other unconventional energy sources because solar energy is available over the entire globe. There are so many ways to generate electricity from solar energy. One way is to generate electricity from solar energy is use photovoltaic cells; magic slivers of silicon that converts the solar energy falling on them directly into electricity. Large scale applications of photovoltaic for power generation, either on the rooftops of houses or in large fields connected to the utility grid are promising as well to provide clean, safe and strategically sound alternatives to current methods of electricity generation. Solar energy is set to play an ever-increasing role in generating the form, and affecting the appearance and construction, of buildings. The principal reason for this is that photovoltaic (PV) systems which produce electricity directly from solar radiation are becoming more widespread as their advantages become apparent and as costs fall. PVs are an advanced materials technology that will help us design buildings which are environmentally responsible, responsive and exciting. Thus our aim to examine all the necessary steps and key components needed to design and build a building integrated photovoltaic system its different types and advantages.

Organization of the Thesis

This thesis consists of five chapters. The first chapter discusses theory regarding introduction to energy, energy scenario for world and India. Also includes study of PV system and its different types . The second chapter is based on Building integrate photovoltaic system and its types. In the 3rd chapter deals with summary of work carried out by various researchers on solar photovoltaic system and objective of thesis is also identified. From Fourth chapter gives results and discussion. Fifth chapter deals the conclusions and the scope of further work.

List of Contents

Title	Page no.
CERTIFICATE	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
ORGANIZATION OF THE THESIS	iv
Chapter 01 : <i>Introduction with Photovoltaic system and types</i>	
1.0 Introduction	1
1.1 Energy Scenario	1
1.1.1 <i>World Energy Scenario</i>	1
1.1.2 <i>Energy Scenario in India</i>	2
1.1.3 <i>Status of renewable energy in India</i>	3
1.2 What is Photovoltaic?	5
1.3 How do Photovoltaic Work?	5
1.3.1 <i>Module</i>	6
1.3.2 <i>Load</i>	7
1.3.3 <i>Regulator</i>	7
1.3.4 <i>Inverter</i>	7
1.3.5 <i>Converter</i>	7
1.3.6 <i>PV array</i>	8
1.4 Different types of Photovoltaic Systems	10
1.4.1 <i>Stand-alone System</i>	11
1.4.2 <i>A hybrid PV system</i>	12
1.4.3 <i>Grid Connected System without battery storage</i>	13
1.4.4 <i>Grid Connected System with battery storage</i>	13
Chapter 02: <i>Building integrated PV system</i>	
2.0 Introduction	15
2.1 Building Integrated Photovoltaic	15
2.1.1 <i>BIPV terminology</i>	16
2.2 How long will the system last?	19
2.3 Sizing the array	20

2.3.1 <i>On-site use of energy</i>	20
2.3.2 <i>Contribution to the overall load</i>	20
2.3.3 <i>Contribution to the annual load</i>	20
2.3.4 <i>Available area</i>	20
2.3.5 <i>Budget</i>	20
2.4 Space required for BIPV system	20
2.5 How much energy do PV systems produce?	21
2.5.1 <i>Location</i>	21
2.5.2 <i>Tilt and Azimuth</i>	21
2.5.3 <i>Shadowing and temperature</i>	23
2.6 Electrical Characteristics	24
2.7 System Sizing	24
2.8 Design and construction	26
2.8.1 <i>Potentially high temperatures</i>	27
2.8.2 <i>Ventilation and modules</i>	27
2.8.3 <i>Use of the module heat</i>	27
2.9 Array mounting information	28
2.10 Available Systems	29
2.10.1 <i>Retro-fit</i>	29
2.10.2 <i>Flat roof</i>	30
2.10.3 <i>Semi integrated</i>	31
2.10.4 <i>PV Tiles (Re-roof)</i>	31
2.10.5 <i>Non-roof installation</i>	32
2.10.6 <i>Atrium systems</i>	33
2.10.7 <i>Awning and Shading systems</i>	33
2.11 Building-integrated PVs	34
2.12 Advantages of BIPV system	36
Chapter 03: Literature Review	
3.0 Introduction	38
3.1 Review of Earlier Work	38
Chapter 04: Results	

4.0 Objective	47
4.1 Solar Radiation Data & Calculation of Average Output April 2010	48
4.2 Load Calculation of different blocks	61
4.3 Roof Area of different Blocks	66
4.3.1 <i>Roof Area of E-block</i>	66
4.3.2 <i>Roof Area of F-block</i>	67
4.3.3 <i>Roof Area of B, C and D-blocks</i>	68
4.4 Energy Calculations	69
4.5 System Sizing	70
Chapter 05: <i>Conclusion and Future scope of work</i>	
5.0 Conclusion	71
5.1 Future scope of work	71
REFERENCES	72

List of Figures

Figure no.	Title	Page no.
Figure (1.1)	Power generation capacity in world by source, 2009	2
Figure (1.2)	Power generation capacity in India by source, 2009	3
Figure (1.3)	Working principle of a PV cell	6
Figure (1.4)	Module and array	8
Figure (1.5.1)	Series and parallel connection of modules	9
Figure (1.5.2)	Parallel connection of modules	9
Figure (1.5.3)	Series and parallel connection of modules 1	10
Figure (1.5.4)	Series and parallel connection of modules	10
Figure (1.6)	A simple PV system	11
Figure (1.7)	A stand-alone PV system	12
Figure (1.8)	A hybrid PV system	12
Figure (1.9)	A Grid Connected System without battery storage	13
Figure (1.10)	A Grid Connected System with battery storage	14
Figure (2.0)	Module and array	19
Figure (2.1)	Position of sun in winter and summer	22
Figure (2.2)	Effect of shadow on PV modules	23
Figure (2.3)	Retro fit system	30
Figure (2.3.1)	Flat roof system	31
Figure (2.3.2)	Roof with integrated tiles	32
Figure (2.3.3)	Atrium system	33
Figure (2.4)	Inclined roof	34
Figure (2.4.1)	Curved roof/wall	34
Figure (2.4.2)	Vertical	34
Figure (2.4.3)	Vertical with windows	35
Figure (2.4.4)	Inclined wall with windows	35
Figure (2.4.5)	Fixed sunshades	35
Figure (2.4.6)	Moveable sunshades	36
Figure (4.0)	Map of E –block	66

Figure (4.1)	Map of F –block	67
Figure (4.3)	Map of B, C and D –block	68

List of tables

Table no.	Title	Page no.
Table 1:	Status of renewable energy in India	4
Table 2:	Solar Radiation Data & Calculation of Average Output April 2010 (Time: 9 AM)	48
Table 3:	Solar Radiation Data & Calculation of Average Output April 2010 (10 AM)	49
Table 4:	Solar Radiation Data & Calculation of Average Output April 2010 (11 AM)	51
Table 5:	Solar Radiation Data & Calculation of Average Output April 2010 (12 NOON)	52
Table 6:	Solar Radiation Data & Calculation of Average Output April 2010 (1 PM)	54
Table 7:	Solar Radiation Data & Calculation of Average Output April 2010 (2 PM)	55
Table 8:	Solar Radiation Data & Calculation of Average Output April 2010 (3 PM)	57
Table 9:	Solar Radiation Data & Calculation of Average Output April 2010 (4 PM)	59
Table 10:	Peak Variation & Possible Plant Rating	60
Table 11:	Load Calculation for E-Block	61
Table 12:	Load Calculation for F-Block	61
Table 13:	Load Calculation for B-Block	62
Table 14:	Load Calculation for Link between B and C Block	63
Table 15:	Load Calculation for C Block	64
Table 16:	Load Calculation for Link between C and D Block	64
Table 17:	Load Calculation for D Block	65
Table 18:	Energy Consumption of Each Block	65
Table 19:	Energy generated from each Block	69
Table 20:	Solar Panel Specification	70
Table 21:	Number of Panels Required for each Block	70

List of Abbreviations

kW _p	kilo Watt peak
BIPV	Building Integrated Photovoltaic
MWh	Mega Watt hour
GW	Giga watt
MW	Mega watt
MT	Metric Tonnes
MU	Million Units
I(sc)	Short circuit current
V(oc)	Open circuit voltage
KVA	Kilo Volt Ampere

Introduction with Photovoltaic system and types

Chapter 01

1.0 Introduction

Energy plays a pivotal role in our daily activities. The degree of development and civilization of a country is measured by the amount of utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization and industrialization. The world's fossil fuel supply viz. coal, petroleum and natural gas will thus be depleted in a few hundred years. The rate of energy consumption increasing, supply is depleting resulting in inflation and energy shortage. This is called energy crisis. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. All unconventional energy sources have geographical limitations. but Solar energy has less geographical limitation as compared to other unconventional energy sources because solar energy is available over the entire globe, and only the size of the collector field needs to be increased to provide the same amount of heat or electricity. This document provides the details of photovoltaic cell and its applications.

1.1 Energy Scenario

The present energy scenario is discussed under categorical division of World, India and Punjab.

1.1.1 World Energy Scenario

Global economic recession drove energy consumption lower in 2009 – the first decline since 1982. World primary energy consumption – including oil, natural gas, coal, nuclear and hydro power – fell by 1.1% in 2009. Hydroelectric power generation increased by 1.5%.

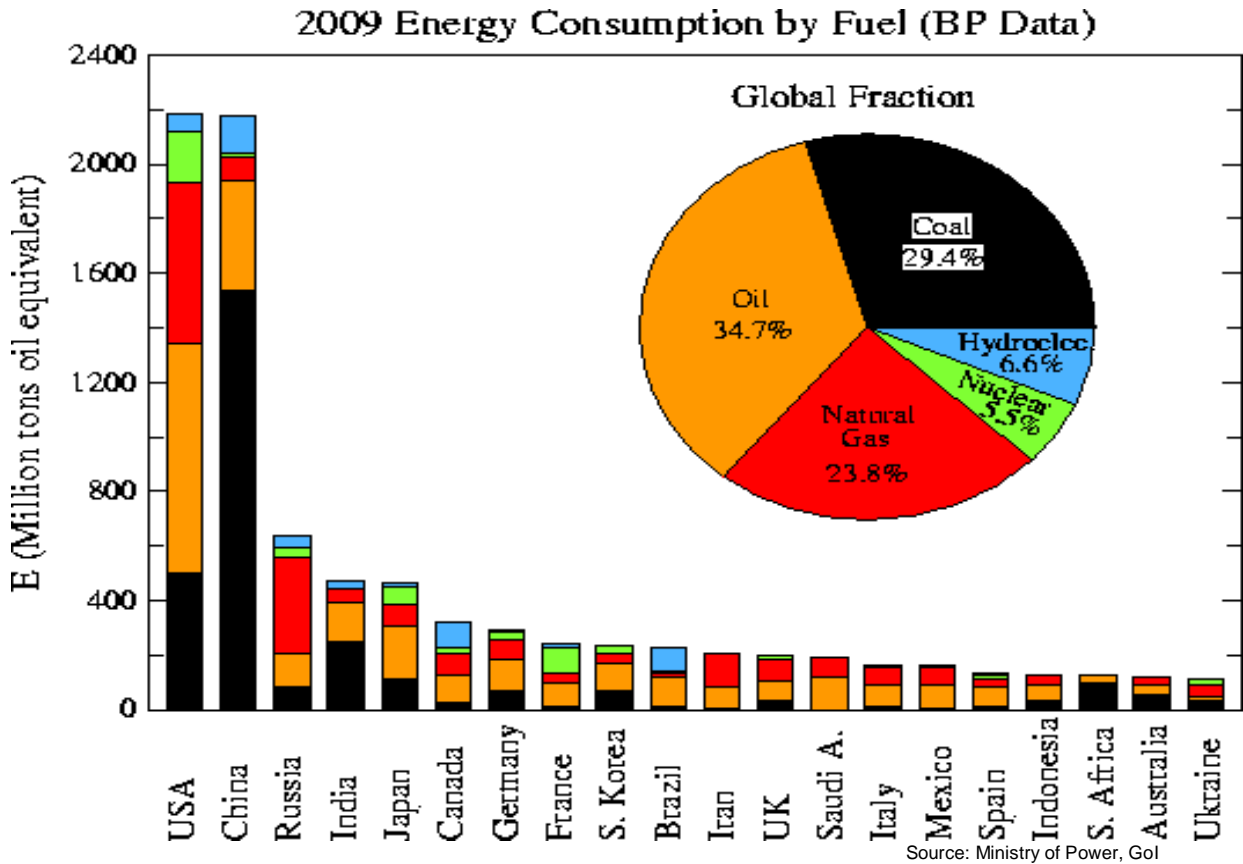
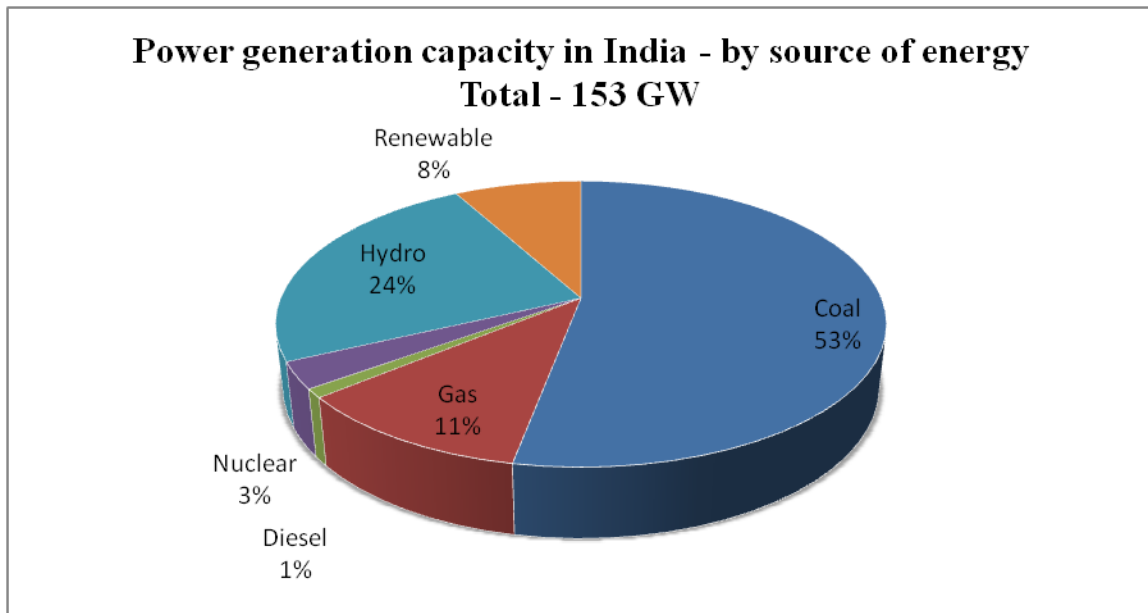


Figure 1.1: Power generation capacity in world by source, 2009

1.1.2 Energy Scenario in India

By end of year 2008, India had power generation capacity of about 152 GW. Even with such an installed base, about 17% of the villages in India are non-electrified, which would translate to about 450 million. With a growing economy, the demand for power is growing at about 6% every year and the peak load demand is expected to reach 176 GW by 2012.

The Indian power sector is highly dependent on coal as a fuel, with 53% of the total installed capacity being coal based generation. Given the current scenario, coal consumption by the power sector is likely to reach levels of 173 mn Metric Tonnes by 2012. According to the Ministry of Coal, the existing coal reserves are estimated to last for another 40-45 years. [22]



Source: Ministry of Power, Govt

Figure 1.2: Power generation capacity in India by source, 2009

About 11% of the total power is sourced from oil & gas. Apart from automobiles and industry, the power sector is the largest importer of oil & gas in India. For 2008, the total oil imports accounted for 7% of the GDP.

India's per capita consumption of energy is far lower than that of the world average. Even with such a low per capita consumption, during the year 2008-09, the power deficit is about 11% in total demand and a deficit of more than 12% in peak load demand. This clearly signifies that the available fuel is not sufficient to meet the rising demand for energy of India.

1.1.3 Status of renewable energy in India

In the present scenario, renewable resources emerge as the best alternative. At present, renewable energy accounts for about 11% of India's installed generation capacity of 152 GW. Much of this capacity is wind-based (about 11 GW), with the share of solar power being only about 6 MW. India is blessed with an abundance of non-depleting and environmentally friendly renewable resources, such as solar, wind, biomass, hydro and cogeneration and geothermal. Wind energy sector, which has shown tremendous growth in the recent year, dominates the renewable energy sector in India.

No.	Source/ System	Achievements during 2009-10 (up to 31.12.2009)	Cumulative achievements during 2009-10 (up to 31.12.2009)
A. Grid Interactive Renewable Power			
1.	Biomass power (agro residues)	131.50 MW	834.50 MW
2.	Wind power	683 MW	10925.00 MW
3.	Small hydro power (up to 25 MW)	129.15 MW	2558.92 MW
4.	Cogeneration- bagasses	253.00 MW	1302.00 MW
5.	Waste to energy	4.72 MW	65.01 MW
6.	Solar power	3.10 MW	6.00 MW
	Subtotal (in MW) (A)	1204.47 MW	15691.43 MW
B. Off Grid/ Distributed Renewable Power			
7.	Biomass power / cogen. (non bagasses)	39.80 MW	210.57 MW
8.	Biomass gasifier	4.10 MWeq.	109.62 MWeq.
9.	Waste to energy	3.91 MWeq.	37.97 MWeq.
10.	Solar PV power plant & street lights	0.086 MWp	2.39 MWp
11.	Aero generator/ hybrid system	MW	0.89 MW
	Subtotal (in MW) (B)	47.876 MWeq.	361.44 MWeq.
	TOTAL (A+ B)	1252.346 MW	16052.87 MW

Table 1: Status of renewable energy in India.

India has an abundance of solar radiation, with the peninsula receiving more than 300 sunny days in a year. PV is progressively becoming more attractive, than other renewable sources of power, as its cost declines. The various factors leading to decline in cost includes setting up of large scale plants, integration across the value chain, declining cost of raw material, reducing material consumption and higher efficiency of modules.

1.2 What is Photovoltaic?

Photovoltaic (PV) are solid-state, semi-conductor type devices that produce electricity when exposed to light. The word photovoltaics actually mean "electricity from light." Many hand-held calculators run off power from room light, which would be one example of this phenomenon. Larger power applications for this technology are also possible.

1.3 How do Photovoltaic's Work?

Photovoltaics are the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons [20]. When these free electrons are captured electric current results that can be used as electricity. The photoelectric effect was first noted by a French physicist, Edmund Becquerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel Prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications.

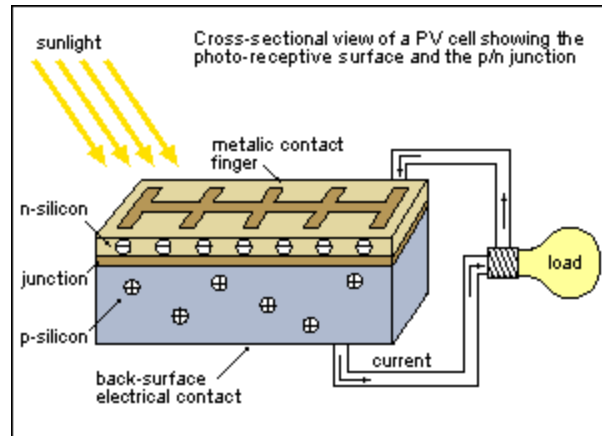


Figure (1.3) Working principle of a PV cell.

The diagram above illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current -- that is, electricity. This electricity can then be used to power a load

1.3.1 Module

Commercial PV product containing interconnected solar cells; Modules come in various standard sizes and can also be custom-made by the Manufacturer. These modules comprise a series of interconnected PV cells, laminated between glass and a back-sheet and held within a rigid aluminum frame. PV modules are usually the most cost effective solution and can be combined to form an array of the correct size for your building and electricity demand.

1.3.2 Load

It is the component responsible to absorb this energy and transform it into work. The diversity, amount and complexity of the behavior of the loads that could be connected to a photovoltaic system make difficult to be modeled.

1.3.3 Regulator

It is the element to protect the battery against to risking situations as overloads and over discharges. The theoretical formulation of the model can be simple, although it is necessary to consider the peculiar discontinuities of the model and the interperformance with the rest of the analyzed models.

1.3.4 Inverter

The inverter allows transforming the DC current to AC. A photovoltaic installation that incorporates an inverter can belong to two different situations, based on the characteristics of the alternating network:

- An isolated system, where the inverter is the element of the network and has to feed the set of loads.
- The inverter is connected to the public network, to which it sends the energy generated by the system.

The model must be able to include both situations.

1.3.5 Converter

The positioning of a converter between the panels and the batteries will improve the whole photovoltaic installation, allowing different controls from the system. Depending on the applied regulation, the panels will contribute to the maximum energy given to the system or the optimal energy for their operation, assuring an efficient charge of the battery.

1.3.6 PV array

Group or string of connected PV modules operating as a single unit. In order to provide useful power for any application the individual solar cells must be connected together to give the appropriate current and voltage level. The electrical output of a single cell is dependent on the design and the semiconductor material chosen, but is usually insufficient for most applications in order to provide the appropriate quantity of electrical power a number of cells must be electrically connected.

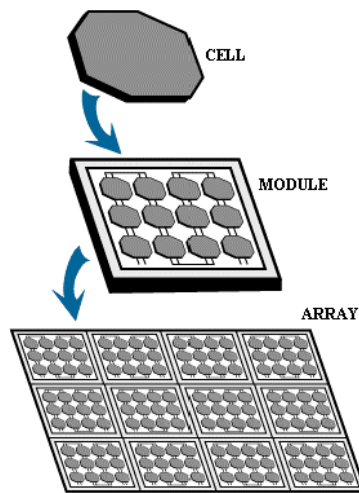


Figure (1.4) module and array.

There are two basic connection methods: series connection, in which top connection of each cell is connected to the back contact of the next cell in the sequence, and parallel connection in which all the top contacts are connected together, as are all the bottom contacts. In both cases this results in two electrical connection points for the group of cells.

The diagrams given below show the series and parallel connection of several modules:

A 12 V system using four 6 V PV modules

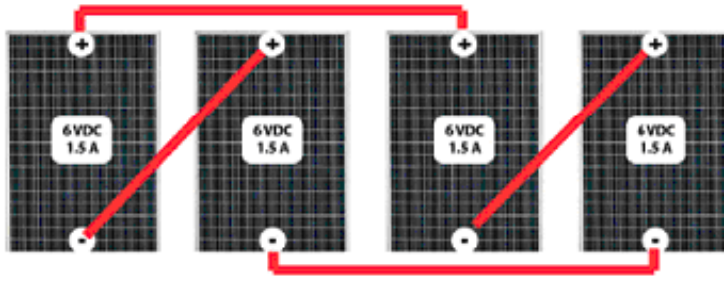


Figure (1.5.1) Series and parallel connection of modules.

Total voltage = 12 V

Total current = 3 A

To generate the correct voltage for the circuit in the example:

1. Two sets of two panels are connected in series (positive to negative). The voltages add together and increase to 12 volts.
2. These two groups of two panels are connected together in parallel (positive to positive, negative to negative). The voltage remains at 12; however, the current of the two groups of panels adds together bringing the final amperage (current) to 3.

Some more examples of series and parallel connections of module:

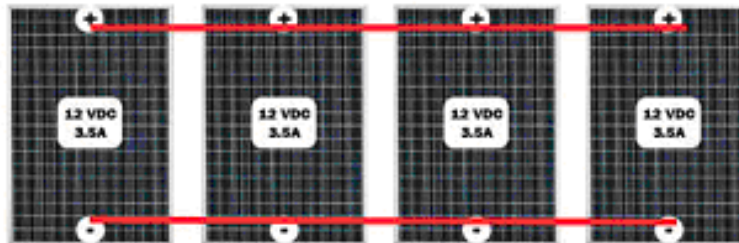


Figure (1.5.2) Parallel connection of modules.

Total voltage = 12 V

Total current = 14 A

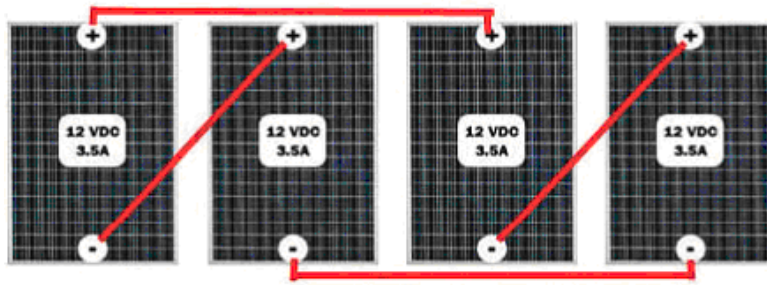


Figure (1.5.3) Series and parallel connection of modules.

Total voltage = 24 V

Total current = 7 A

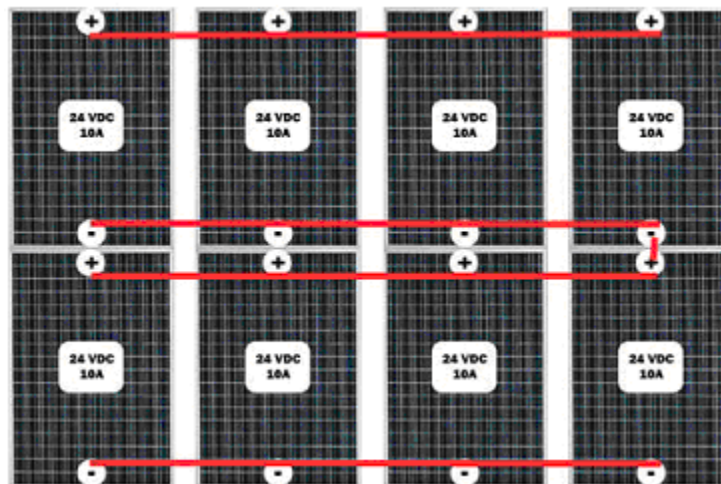


Figure (1.5.4) Series and parallel connection of modules.

Total voltage = 48 V

Total current = 40 A

1.4 Different types of Photovoltaic Systems.

A photovoltaic system (or PVS) is a system which uses solar cells (arranged into solar panels) to convert sunlight into electricity [21].

A PVS consists of many components. These include solar cells, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output.

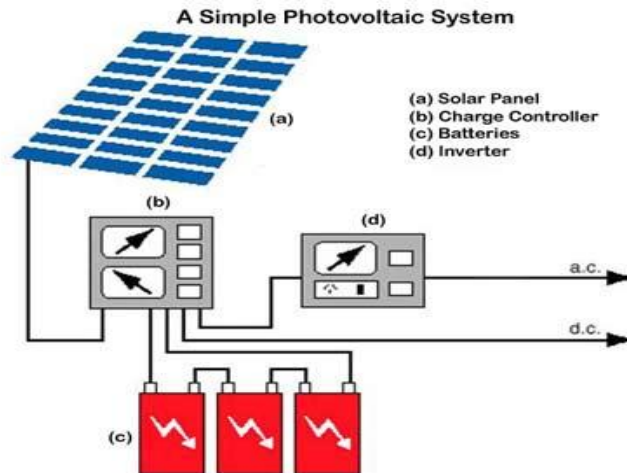


Figure. (1.6) A simple PV system.

Due to the low voltage of an individual solar cell, several cells are combined into photovoltaic modules (commonly called solar panels), which are then connected together into a photovoltaic array. The electricity generated can be used directly, stored or fed into a large electricity grid. A PVS may also be combined with domestic electricity generators to create a hybrid system. A photovoltaic system is generally designed in order to ensure the highest energy yield for a given investment.

Below we explore the different types of photovoltaic systems and their applications.

1.4.1 Stand-alone Systems

A standalone system does not have a connection to the electricity mains. Standalone systems vary in size from watches or calculators to remote buildings or spacecraft. If the load is to be supplied independently of insolation, the generated power needs to be stored using a battery. Where weight is not an issue (e.g. buildings) lead acid batteries are used.

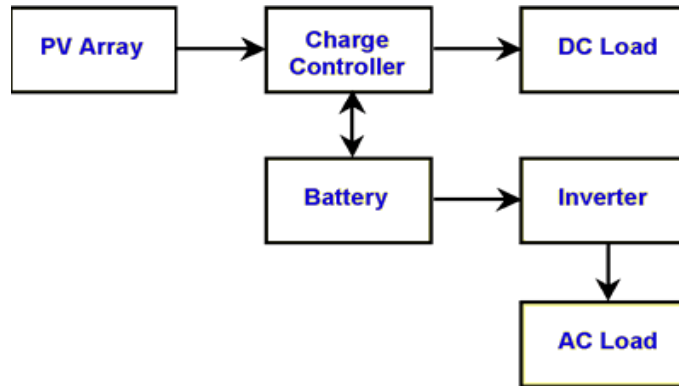


Figure (1.7) A stand-alone PV system.

A charge controller may be incorporated in the system to avoid battery damage by excessive charging or discharging.

In small devices (e.g. calculators, parking meters) only DC is consumed.

In larger systems (e.g. buildings, remote water pumps) AC is usually required. To convert the DC from the modules or batteries into AC, an inverter is used.

1.4.2 Hybrid System

A hybrid system combines PV with other forms of power generation, usually a diesel generator. Biogas is also used.

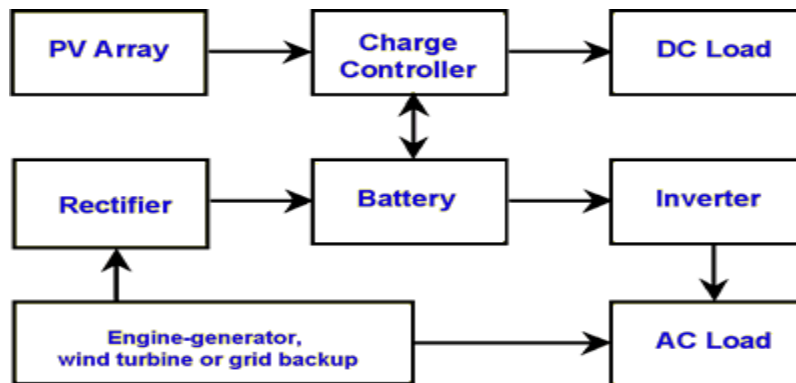


Figure (1.8) A hybrid PV system.

The other form of power generation is usually a type which is able to modulate power output as a function of demand. However more than one form of renewable energy may

be used e.g. wind and solar. The photovoltaic power generation serves to reduce the consumption of non renewable fuel.

1.4.3 Grid Connected System without battery storage

A grid connected system is connected to a large independent grid (typically the public electricity grid) and feeds power into the grid. Grid connected systems vary in size from residential (2-10kWp) to solar power stations (up to 10s of GWp).

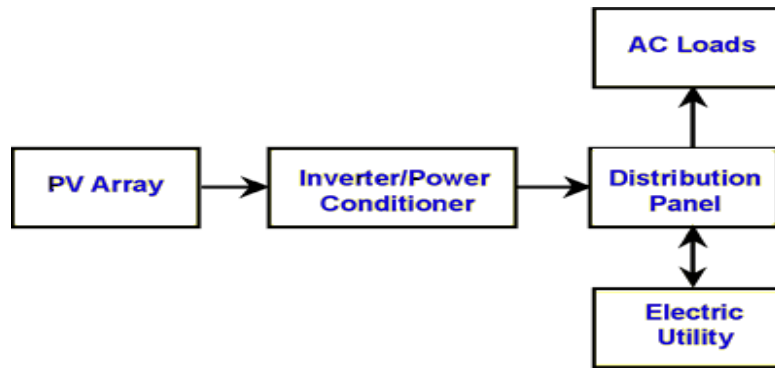


Figure (1.9) A Grid Connected System without battery storage.

This is a form of decentralized electricity generation. In the case of residential or building mounted grid connected PV systems, the electricity demand of the building is met by the PV system. Power is only fed into the grid when there is an excess.

The feeding of electricity into the grid requires the transformation of DC into AC by a special, grid-controlled inverter.

Most modules (72 crystalline silicon cells) generate about 160W at 36 volts. It is sometimes necessary or desirable to connect the modules partially in parallel rather than all in series. One set of modules connected in series is known as a 'string'.

1.4.4 Grid Connected System with battery storage

This type of system is extremely popular for homeowners and small business where back up power is required for stand by loads such as refrigeration, water pumps, lighting etc. normally system operates in a grid connected mode , supplementing the on-site load or sending excess power back to the grid while keeping the battery fully charged. In the

event the grid becomes de-energized, control circuitry operates the inverter from the battery to supply power to dedicated standby load only.

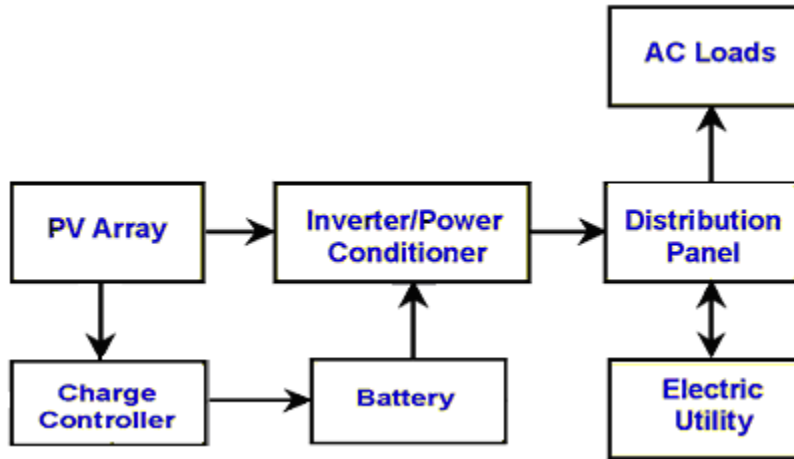


Figure (1.10) A Grid Connected System with battery storage.

Building integrated PV system

Chapter 02

2.0 Introduction

Solar energy is set to play an ever-increasing role in generating the form, and affecting the appearance and construction, of buildings. The principal reason for this is that photovoltaic (PV) systems which produce electricity directly from solar radiation are becoming more widespread as their advantages become apparent and as costs fall. PVs are an advanced materials technology that will help us design buildings which are environmentally responsible, responsive and exciting.

2.1 Building Integrated Photovoltaic's

Building-integrated photovoltaic (BIPV) electric power systems not only produce electricity, they are also part of the building. For example, a BIPV skylight is an integral component of the building envelope as well as a solar electric energy system that generates electricity for the building. These solar systems are thus multifunctional construction materials. The standard element of a BIPV system is the PV module. Individual solar cells are interconnected and encapsulated on various materials to form a module. Modules are strung together in an electrical series with cables and wires to form a PV array. Direct or diffuse light (usually sunlight) shining on the solar cells induces the photovoltaic effect, generating unregulated DC electric power. This DC power can be used, stored in a battery system, or fed into an inverter that transforms and synchronizes the power into AC electricity. The electricity can be used in the building or exported to a utility company through a grid interconnection. A wide variety of BIPV systems are available in today's markets. Most of them can be grouped into two main categories: facade systems and roofing systems. Facade systems include curtain wall products, spandrel panels, and glazing. Roofing systems include tiles, shingles, standing seam products, and skylights. Building-integrated, grid-connected systems have the following advantages:

- The cost of the PV wall or roof can be offset against the cost of the building element it replaces.
- Power is generated on site and replaces electricity which would otherwise be purchased at commercial rates.
- By connecting to the grid the high cost of storage associated with stand-alone systems is avoided and security of supply is ensured.
- There is no additional requirement for land.

1.1.1 BIPV Terminology.

Building-integrated photovoltaic (BIPV) is a relatively recent new application of Photovoltaic (PV) energy technologies. These are some of the basic terms used in Describing PV technologies, BIPV products, and their uses:

Antireflection coating: A thin coating of a material that reduces light reflection and increases light transmission; it is applied to the surface of a photovoltaic cell.

Balance of System (BOS): Non-PV components of a BIPV system typically include wiring, switches, power conditioning units, meters, and battery storage equipment (if required).

Bypass diode: A diode connected across one or more solar cells in a photovoltaic Module to protect these cells from thermal destruction in case of total or partial Shading of individual cells while other cells are exposed to full light.

Blocking diode: placed in series with a module or string of modules to prevent reverse current flow and protect PV modules. Conducts current during normal operation. Can be used to prevent discharge of batteries at night in stand alone systems.

Autonomy: a term used to describe the period the electrical load can operate with the given battery storage capacity in a PV system. Determined by the load current and the battery capacity from full state of charge to the load disconnect point, with no input from the PV array.

Battery and battery bank: an electrochemical energy storage and delivery system, used in PV system to store the energy produced by the PV array, and to provide back up to on site load or to feed the utility grid.

Conversion efficiency: Amount of electricity a PV device produces in relation to the amount of light shining on the device, expressed as a percentage. It is defined as the maximum power out put of the module/array divided by the irradiance and array surface area.

Maximum power current (Imp): the current output of a photovoltaic cell, module or array when operated at its maximum power point, corresponding with the maximum power voltage. (Vmp).

Maximum power voltage (Vmp): the maximum voltage output of a photovoltaic cell, module or array when operated at its maximum power point, corresponding with the maximum power current(Imp).

Maximum system voltage: the maximum rated voltage of a PV system, based upon the rated open circuit voltage of the array, and adjust for the lowest ambient temperature at the installation site. Used to determine acceptable ratings for electrical devices used in the system.

Nominal operating cell temperature: a reference temperature of a photovoltaic module or array, operating at an irradiance level of 800 W/m^2 , an ambient temperature of 20^0 C , a wind speed of 1.0 m/s, and with the module or array in open-circuit condition.

Curtain wall: An exterior wall that provides no structural support.

Encapsulant: Plastic or other material around PV cells that protects them from environmental damage.

Stand-alone: Remote power source separate from an electric utility grid; a Stand-alone system typically has a battery storage component

Grid-connected: Intertied with an electric power utility.

PV solar cell: Device made of semiconductor materials that converts direct or Diffuse light into electricity; typical PV technologies are made from crystalline, Polycrystalline, and amorphous silicon and other thin-film materials

Inverter: Device that transforms direct-current (DC) electricity to alternating current (AC) electricity at specified voltage and frequency. Can operate directly from PV array or battery.

Irradiance: the instantaneous solar power or rate of solar flux received at a unit surface area, generally expressed in units of watt per square meter. A typical peak value for irradiance at noon on a clear day is 1000 W/m^2

PV laminate: Building component constructed of multilayer of glass, metal or Plastic and a photovoltaic material.

Module: Commercial PV product containing interconnected solar cells; Modules come in various standard sizes and can also be custom-made by the Manufacturer. These modules comprise a series of interconnected PV cells, laminated between glass and a back-sheet and held within a rigid aluminum frame. PV modules are usually the most cost effective solution and can be combined to form an array of the correct size for your building and electricity demand.

PV array: Group or string of connected PV modules operating as a single unit. In order to provide useful power for any application the individual solar cells must be connected together to give the appropriate current and voltage level. The electrical output of a single cell is dependent on the design and the semiconductor material chosen, but is usually insufficient for most applications in order to provide the appropriate quantity of electrical power a number of cells must be electrically connected.

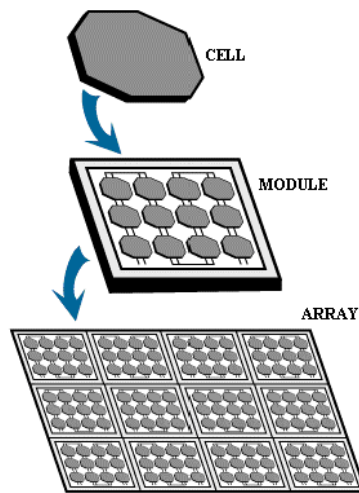


Figure (2.0) Module and array.

There are two basic connection methods: series connection, in which top connection of each cell is connected to the back contact of the next cell in the sequence, and parallel connection in which all the top contacts are connected together, as are all the bottom contacts. In both cases this results in two electrical connection points for the group of cells.

2.2 How long will the system last?

90% of specified power output after 10 years (at standard test conditions).

80% of specified power output after 20 years (at standard test conditions). [22]

2.3 Sizing the array

In sizing a grid-connected PV array there are a number of key points to keep in mind:

2.3.1 On-site use of energy:

For a given installation the more of the energy that can be used on site the better; this is principally because, given the current price differential between PV and grid electricity, using the energy on site makes more financial sense.

2.3.2 Contribution to the overall load:

Sizing is usually on the basis of a contribution to the overall load for the building rather than to meet a particular load (e.g. lighting).

2.3.3 Contribution to the annual load:

Usually sizing is to determine the contribution to the total annual load but one can also consider the contribution to the annual load during daylight hours.

2.3.4 Available area:

The available roof and facade area may restrict the array size, particularly in smaller installations such as houses.

2.3.5 Budget:

Often the available budget is the dominant constraint.

2.4 Space required for BIPV system.

There are many different ways of mounting PV. Generally, a 1kWp system requires approximately 8m² of roof space. If there is nowhere to mount your PV on a roof then we recommend a ground mounted PV system [22].

2.5 How much energy do PV systems produce?

The output from building-integrated PV installations is the output of the PV array less the losses in the rest of the system. The output from the array will depend on:

- The daily variation due to the rotation of the earth and the seasonal one (due to the orientation of the earth's axis and the movement of the earth about the sun).
- Location ie the solar radiation available at the site.
- Tilt
- Azimuth ie orientation with respect to due south
- Shadowing.
- Temperature.

For purposes of standardization and comparison, PV modules are tested in STCs of $1000\text{W}/\text{m}^2$ and 25°C . A high level of solar radiation achieved only in very sunny conditions [23].

2.5.1 Location

The out put of a PV array depends upon the solar asses on the site. Solar access, the incidence of solar radiation (insolation) that reaches a PV surface at any given time, determines the potential electrical output of a BIPV system [23].

2.5.2 Tilt and Azimuth

The orientation of the module with respect to the direction of sun determines the intensity of sunlight falling on module surface. Two main parameters are defined to describe this. The first is tilt angle, which is the angle between the plane of module and the horizontal. The second parameter is the azimuth angle, which is the angle between the plane of module and due south (or sometimes due north depending on the definition used). Correction of the direct normal irradiance to that on any surface can be determined using the cosine of the angle between the normal to the sun and the module plane.

The optimum array orientation will depend on the latitude of the site, prevailing weather conditions and the load to be met. It is generally accepted that, for low latitudes, the maximum annual output is obtained when the array tilt angle is roughly equal to the latitude angle and the array faces due south (in northern hemisphere) or due north (for the

southern hemisphere). For higher latitudes, such as those in northern Europe, the maximum output is obtained for tilt angles of approximately the latitude angle minus 10-15 degrees. The optimum tilt angle is also affected by proportion of diffuse radiation in the sunlight, since diffuse light is only weakly directional. Therefore, the location with a high proportion of diffuse sunlight, the effect of tilt angle is reduced.

However, although this condition will give the maximum output over the year, there can be considerable variation in output in season. This is particularly true in high latitude locations where the day length vary significantly between summer and winter. Therefore if a constant or reasonably constant load is to be met or, particularly, winter load is higher than the summer load, then the best tilt angle may be higher in order to boost winter output [24].

BIPV system's particular seasonal performance must be optimized. For example, a system might be designed to produce maximum power output only in the summer months in order to reduce peak electricity costs for air-conditioning loads; thus, the system should be installed at an optimum orientation and tilt for summer power output.

As we are on north of the equator therefore our system will perform optimally when oriented south and tilted at an angle 15 degrees higher than the site latitude.

However, although this condition will give the maximum out put over the year, there can be considerable variation in out put with season. This is particularly true in high latitude locations where the day length vary significantly between summer and winter.

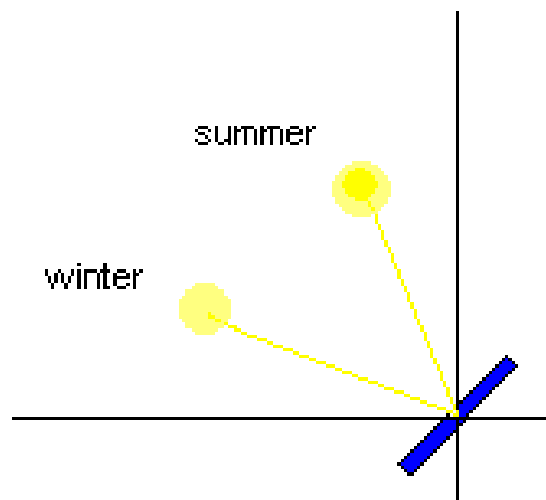


Figure (2.1) Position of sun in winter and summer.

2.5.3 Shadowing and temperature

Shadowing will depend on the geography of the site, neighboring buildings and self-shadowing by the architectural forms. The effects of shadowing can be mitigated somewhat through system design. For the present exercise no loss due to shading is assumed. The



Figure (2.2) effect of shadow on PV modules.

Performance of PV modules decreases with increasing temperature (the drop in performance is somewhat more marked for crystalline silicon than amorphous silicon). Designs for building-integrated PVs need to consider this from the outset in order to allow air to flow over the backs of the modules to maintain high performance. It is also likely to be necessary with all types of module to avoid unwanted heat gain into the space (which cause discomfort and increase any cooling load). The temperature of a Building-integrated modules can reach 20-40⁰C above ambient in conditions of high radiation. For each 10⁰C increase in cell temperature above 25⁰C the power output decreases by about 0.4-0.5%.

Typical temperature for PV modules in full sun at 20⁰C outdoor temperature is 50⁰C. This is a 30⁰C rise above outdoor temperatures. On the hottest day of the year, outdoor temperatures can reach 40-45⁰C in many locations. This means that the PV module will be operating at 75⁰C on the hottest day of the year (45⁰C+30⁰C =75⁰C). When exposed to high ambient temperatures and to bright sunlight these temperatures may routinely exceed 70⁰C (158⁰F) in many locations. Module interconnection conductors are available

with insulation rated for wet locations and a temperature rating of 90°C (194°F) or greater [23].

2.6 Electrical Characteristics

The pertinent electrical characteristics of a PV module or array are summarized in the relationship between the current and voltage. The amount and intensity of solar insolation controls the current (I); the temperature of the solar cells affects the voltage(V) of the PV module or array. Module I-V curves provide information designers need to configure systems that can operate as close to the optimal peak power point as possible.

2.7 System Sizing.

Choosing a BIPV type and sizing a system have three main components: energy loads, architectural or aesthetic considerations, and economic factors. To determine the desired power rating of a BIPV system for a building, the electrical requirements of the building should first be evaluated. The optimum power rating of the system can be calculated and sized, based on the portion of the building's electricity that will be supplied by the BIPV system. For example, an autonomous or off-grid building may require a large system with battery storage capabilities to provide 100% of the building's electricity requirements; a building owner desiring to reduce demand charges will require a small system that produces electricity only during peak utility charge hours. Architecturally, the size of the BIPV system is physically limited to the dimensions of the building's available surface area [25].

Amount of power required and the amount of surface area available can determine the type of PV technology that will be used. Each technology has an associated range of output in watts per square foot or per square meter and cost per watt. For example, systems made of amorphous silicon require a larger surface area but cost less than equivalent systems composed of single crystal solar cells. Therefore, in projects that have a limited budget but include a large south-facing facade surface area, amorphous silicon can be the most suitable BIPV technology. To achieve the appearance of a uniform surface area, less expensive "mock" or imitation PV panels can also be provided by the manufacturer. Once the building energy load requirement is determined, the watt-hour

method can be used to design the electrical system. An evaluation of seasonal climatic conditions and variations (temperature and solar insolation) and the available surface area will determine the number of modules that will satisfy the voltage and current requirement of the load.

After that, corresponding inverter requirements and BOS requirements can be specified. Electrical issues primarily involve the performance and reliability of the inverters. The variety available for BIPV systems includes single inverters, master-slave inverter configurations, modular inverters, and parallel independent or string inverters. A BIPV system is most vulnerable to a single-point failure where the power generated from the BIPV array must be transformed and synchronized through the inverter from DC to AC power and then fed into the building or an electric utility system. If the inverter fails, the entire system malfunctions. Today, most inverters are highly reliable. However, the practice of relying on only one inverter for a BIPV system in a commercial building is problematic. When BIPV systems are made up of a large series of interconnected strings, there is a technical difficulty in determining where a system has failed.

A BIPV system designed so that multiple inverters work together ensures greater system reliability. If one inverter malfunctions or requires maintenance, it can be disconnected from the array and the BIPV system can still operate. Cascading hierarchy "master slave" configuration includes one master inverter and multiple slave inverters that operate together for maximum efficiency. Modular, "micro," or "mini" inverters allow each module to be tested (each has its own address) through the use of a power line carrier signal injected into the building's electrical distribution system. This way, each unit's performance can easily be evaluated. Modular inverters also enable PV to be integrated into complex, geometric building designs. Modular inverters are desirable for commercial buildings because they operate independently. Shading one module will not interrupt the power output of the whole array. In single or multiple inverter systems, a number of modules are connected in series to achieve the voltage needed by the selected inverter. Shading any one module in this series can negate the output of the entire string.

One design issue related to the modular inverter is whether it will last the lifetime of the PV module. If the inverter has a lifetime of only 5 years and the BIPV facade lasts 25

years, replacing the modular inverter has an associated periodic cost, and access needs to be anticipated and designed into the project. The string inverter is the second generation of inverters for buildings. In Europe, one string inverter with the nominal power of 750 watts can connect as many as 10 PV modules in a series and be connected anywhere in the building's electricity distribution system. The flexibility, reliability, and increased efficiency offered by string inverters may further reduce the cost of BIPV systems. New AC modules are being equipped with individual AC mini-inverters mounted on the backs of the PV panels. They are at the early commercial stages of development in the United States and Switzerland.

One benefit of these is that they eliminate the need in the building for the high-voltage DC wiring associated with other BIPV systems. In regard to electrical safety issues, it is important to note that lightning ground faults, and power line surges can cause high voltages in otherwise low-voltage BIPV systems. National and international electric code regulations and building codes are being amended to include PV technologies and address fire and safety issues concerning BIPV design, installation, and maintenance.

2.8 Design and construction.

Firstly, in construction terms, building-integrated PV systems need to play the same role as the traditional wall and roofing cladding elements they replace. Consequently, they must address all the normal issues, for example:

- Appearance.
- Weather tightness and protection from the elements.
- Wind loading.
- Lifetime of materials and risks and consequences of failure.
- Safety (construction, fire, electrical, etc.).
- Cost.

In addition, there are a number of more particular aspects, often associated with being able to use the electricity produced, namely:

- Avoidance of self shading (as mentioned above).
- Heat generation and ventilation.

- Provision of accessible routes for connectors and cables.
- Maintenance.

If we look at heat generation and ventilation there are three aspects of particular interest:

- The effect of potentially high temperatures.
- The desirability of ventilating the back of the modules to improve efficiency.
- The possible use of the heat from the back of the modules.

2.8.1 Potentially high temperatures.

The potentially high temperatures associated with building elements specifically designed to capture the sun's radiation need careful consideration. The lifetime of materials, thermal movement, temperature cycling, suitability of electrical cables in high temperatures and so on need to be thought about carefully. In general, as long as the heat from PV modules does not build up and is removed by ventilation (normally, natural ventilation), there should not be a problem. In conditions of high radiation, say 700-750W/m², modules can reach up to 40⁰C above ambient, say 70⁰C but this will obviously depend on module design and building context. Higher temperatures can, however, occur and this should be discussed with the manufacturers when considering modules [23].

2.8.2 Ventilation and modules.

In above paragraph we pointed out the importance of adequate ventilation to keep the temperatures as low as possible to improve module performance. There are many ways of doing this, varying from ventilation gaps in rain screen cladding. To combining the module ventilation with the building ventilation. A rule of thumb is to provide an air gap of 100mm. However, at least one study indicates that performance is improved with gaps up to 200mm or more.

2.8.3 Use of the module heat.

The heat given off at the back of the panels is potentially of value during the heating season. It is possible to use it directly or to recover it by a system. However, an important question remains about the economical viability of doing so. This is particularly the case for highly energy-efficient buildings which often have very low space heating demands.

(Such an office, when in operation during the day, may need no additional heat other than that from the occupants and other casual gains at external temperatures above 8C or 9C.) Obviously the simplest, least expensive ways of using the heat from the back of the PVs are most likely to be viable and to be adopted. Other possibilities of using the waste heat also exist. For example, PV panels could incorporate water pipes linked to space or domestic hot water systems but such other possibilities tend to be of greater cost and complexity.

Outside the heating season, or more precisely anytime the heat is not needed, it is important that it does not cause overheating and contribute to the building's cooling load. This requires consideration of the ventilation patterns in the building and thought should be given to ensuring that in windy conditions in summer heat from the modules does not lead to discomfort.

2.9 Array mounting information

Provide information on weight of array (pounds per square foot). This includes the weight of the modules and all panelizing hardware (e.g. modules, rails and associated hardware).

If array is roof mounted:

Provide information on roof structure(s) construction (truss or rafter size and spacing) and roofing material.

- i) Is the weight distribution of the system greater than 5 lbs. per square foot? If yes, engineering calculations may be required.
- ii) Is the roof structure more than 30 years old? If yes, specify rafter or truss size and spacing—engineering calculations may be required if non-standard.

Explanation: Sub point (i) refers to the broad inspection practice that allows additional layers of comp shingles as long as the weight is limited to no more than an additional 5 lbs/ft². This provides a conservative structural weight threshold without the need for a structural engineer to review the roof structure. Sub point (ii) refers to the fact that the code enforcement of roof structural elements has been much more consistent across the United States in the last 30 years. However, there may be many local jurisdictions who have been carefully reviewing roof structures for a much longer period of time. The local

jurisdiction should consider extending this limit based on the period that roofs have been consistently inspected.

iii) Identify roofing type (e.g. comp shingle, masonry tile, shake, etc...)

iv) Provide engineering details of PV panel mounting attachment to the roof framing members. Several well-engineered mounting systems are now available for installers to use. These designs often include detailed engineering specifications and details. Installers who use their own designs will need to provide their own details and engineering calculations with their design.

v) Identify method of sealing roof penetrations (e.g. flashing, sealed with urethane caulk, etc...).

2.10 Available Systems

- Retro-fit installation
- Flat roof installation
- Semi Integrated installation
- PV tile installation (Re-roof)
- Non-roof installation

2.10.1 Retro-fit:

Retro-fit means the PV modules are mounted on aluminum frame just above (max. 150mm) your existing roof [26]. There are a number of advantages to this type of system. There is minimal disturbance to the roof structure and is therefore one of the quickest and easiest ways of installing modules on a pitched roof. This also means the system is more easily removed, although these systems are not really designed to move house with you. It is modular and is therefore easy to add to or change. Also, it costs less than most other installation methods. Briefly, on tiled or slate roofs aluminum roof-hooks are fitted under the tiles. This is done in a number of different ways; fixing them to the rafters or securing them around the battens being just two. The tiles remain in their

original places. These roof-hooks then have aluminum rails fixed to them; the rails are what the PV modules themselves are fixed to. There are a number of different fixings available for modern commercial roofing materials. There are no real disadvantages to this installation method.



Figure (2.3) Retro fit system.

2.10.2 Flat roof:

There are many installation options with flat roofs; the simplest being pre-formed recycled PVC ‘boxes’. These ‘boxes’ are not actually fixed to the roof but are weighed down with ballast (min. 55kg each, depending on size and the height of the building) for stability. The advantages are that they are at optimum tilt angle and can be orientated exactly due south. They are also the cheapest and quickest installation method. The disadvantages are that they are quite heavy and they need quite a bit of room (1.5m approx.) between rows to avoid shading each other in times of low sun. If a new flat roof is required bespoke mounting brackets can be utilized to give strong mounting points for the modules. Ecovolt work with a partner who is a flat roof expert. This option is especially useful where there is a new dormer loft extension and space and/or load bearing are limited.



Figure (2.3.1) Flat roof system.

2.10.3 Semi integrated:

This method uses the same type of PV modules as retro-fitting, the difference being that where in a retro-fit your original roof stays in place, in a semi integrated system the tiles or slates are removed from the area in which the modules are to be fitted. These are then replaced with PVC undertrays which maintain the integrity of the weatherproofing and also become the fixing points for the modules. The modules will be much closer to the original line of the roof that in a retro-fit but will still be slightly proud.

Semi integrated systems are more expensive than the same size retro-fit system due to more specialized kit and the extra roofing work involved, they are however cheaper than an equivalent size re-roof with PV tiles.

2.10.4 PV Tiles (Re-roof):

PV tiles are the most elegant, neatest and aesthetically pleasing type of installation, but also the most expensive. A number of different types of tiles exist, most of which can be integrated with your existing tiles (some ordinary [non-PV] tiles have to surround the PV). In practice it is not often that the existing tiles can just be removed and replaced with PV tiles, or a roof can accept PV tiles without some re-battening. The best option is to remove everything and fit tiles that are designed to go with the PV.



Figure (2.3.2) Roof with integrated tiles.

2.10.5 Non-roof installation:

These are what they say, installations that are not on roofs. They can be ‘ground mounted’ i.e. bolted to a frame that sits on the ground, which has the disadvantage of taking up a lot of room, or pole mounted. Poles can either be static or motorized in order to take advantage of optimum positioning.

- Facade
 - Facades can be installed on existing buildings, giving old buildings a whole new look. These modules are mounted on the facade of the building, over the existing structure, which can increase the appeal of the building and its resale value. The BIPV system is designed to act as an outer skin and weather barrier as part of the building envelope. An example is a BIPV system used for rain screen over cladding. Glass BIPV products are typically used as facade systems. BIPV façade systems include laminated and patterned glass, spandrel glass panels, and curtain wall glazing systems. These BIPV products can displace traditional construction materials. Laminated glass is a standardized BIPV product. It is composed of two pieces of glass with PV solar cells sandwiched between them, an encapsulant of ethylene-vinyl acetate (EVA) or another encapsulant material, and a translucent or colored tedlar-coated polyester back sheet. It can also be made with only one piece of glass and a tedlar back sheet.

- Glazing

Semitransparent modules can be used to replace a number of architectural elements commonly made with glass or similar materials, such as windows and skylights. PV glazing functions to provide shelter, shading and electricity in one material. Like glazing, solar cladding can also be used in the place of other materials and can be made bespoke in order to fit the solar features of your site and electricity demand. Solar PV could be a good option if you are considering replacing part of a roof or building façade. In some cases solar materials may work out cheaper than conventional building materials or even offset their cost.

2.10.6 Atrium systems.

BIPV is a glass element that provides different degrees of shading and can be designed to enhance indoor thermal comfort as well as daylighting.



Figure (2.3.3) Atrium system.

2.10.7 Awning and Shading systems.

A variety of PV materials can be mounted onto a facade in aesthetic manner to serve as awnings.

2.11 Building-integrated PVs:



Figure (2.4) Inclined roof.



Figure (2.4.1) Curved roof/wall.



Figure (2.4.2) Vertical.



Figure (2.4.3) Vertical with windows.



Figure (2.4.4) Inclined wall with windows.



Figure (2.4.5) Fixed sunshades.



Figure (2.4.6) Moveable sunshades.

However roofs have a number of attractions as sites for PVs:

- They are often free from over-shadowing.
- The roof slope can be selected for high performance.
- It may be easier to integrate PVs aesthetically and functionally into a roof than a wall.
- This system can be easily removed therefore easy to add to or change.
- It costs less than most other installation methods.

2.12 Advantages of BIPV system

BIPV modules can be colorful and visually arresting. Using BIPV creates a strikingly futuristic building. Its flexibility is such that it can respond to the architect's imagination and result in a building that is both impressive and environmentally friendly. It improves the image of a building and increases the resale value. Advantages include:

- Photovoltaic modules can be integrated into the building envelope in a so-called "non ventilated facade", both on public buildings such as office complexes, production buildings, shopping centres or schools, and on private buildings such as indoor gardens or terraced houses. The modules replace traditional materials in new build and create an ambient inside temperate all-year round.
- Using photovoltaics in a building envelope replaces traditional building materials and building processes. For example using BIPV in roofing systems may replace batten and seam metal roofing, and traditional 3- tab asphalt shingles.

- Using photovoltaics cells for skylight systems in entrance halls, atria, or courtyards, can be both economical use of solar energy and an exciting design feature. BIPV cells have the advantage that their transparency can be varied so that if desired, the module can provide shade or be semi-transparent.
- Modules can protect against the weather, giving shade from the sun as well as protection from wind and rain. They also protect against lightning, being an electrical resistor.
- When the weather gets cold (or hot), non-ventilated modules act as thermal insulation through the sandwich construction of the modules themselves, the layer of air within the modules and the ray absorption by the crystalline silicon and thin film solar cells. This means that less energy is wasted by heat loss from the interior, reducing heating costs.

Literature Review

Chapter 03

3.0 Introduction

Energy plays a pivotal role in our daily activities. The degree of development and civilization of a country is measured by the amount of utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization and industrialization. The world's fossil fuel supply viz. coal, petroleum and natural gas will thus be depleted in a few hundred years. The rate of energy consumption increasing, supply is depleting resulting in inflation and energy shortage. This is called energy crisis. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. All unconventional energy sources have geographical limitations. but Solar energy has less geographical limitation as compared to other unconventional energy sources because solar energy is available over the entire globe, and only the size of the collector field needs to be increased to provide the same amount of heat or electricity. Solar energy is set to play an ever-increasing role in generating the form, and affecting the appearance and construction, of buildings. The principal reason for this is that photovoltaic (PV) systems which produce electricity directly from solar radiation are becoming more widespread as their advantages become apparent and as costs fall. PVs are an advanced materials technology that will help us design buildings which are environmentally responsible, responsive and exciting. In this chapter we will discuss different reviews on building integrated photovoltaic systems.

3.1 Review of Earlier Work

Several works are going on building integrated photovoltaic systems. Some of these are discussed below:

Bangyin Liu, Chaohui Liang and Shanxu Duan [1] presented Design criteria and converter topology for DC-Module-Based Building Integrated Photovoltaic System. They

had investigated the design criterion of photovoltaic module integrated dc-dc converter according demands and specifications of the system. They had also evaluated the performance and characteristic of the suitable converter topologies. Based on the evaluation results, a current-fed half bridge topology is selected for this application, and an experimental prototype was built and tested in the laboratory to verify the results.

A. J. Aristizábal, C.A. Arredondo, J. Hernández and G. Gordillo [2] introduced a system for monitoring the performance of PV power plant. They have used the Virtual Instrumentation concept the hardware based on the National Instruments SCXI system and as software the Lab view graphical programming package. The equipment is capable of real time signal measuring giving information about the performance of the PV power plant, as well as of the energy quality generated by it. The equipment can also be used for measuring ambient variables like solar radiation and ambient temperature and for analyzing the energy quality of conventional electricity grid supplied to typical loads in commercial and residential sectors. The equipment was used during one year for monitoring the performance and the energy quality of a PV power plant, interconnected to the local grid in order to test its performance and reliability. The results indicated that the reliability and the accuracy of the monitoring system were excellent. They also indicated the daily irradiation in Bogota for every month of year 2005. The behavior of the parameters percentage of the total harmonic distortion, harmonic components, frequency and voltage of the PV system, flicker and power factor are also reported.

Shaohong Wu, Dilip Kotak, Martin Fleetwood, Hiroshi Tomato [3] presented a distributed data acquisition and monitoring system using a multi-agent framework for a demonstration project for integrated energy application implemented in the National Research Council Canada, Institute for Fuel Cell Innovation. The physical energy system includes three major components: renewable energy source - a building integrated photovoltaic system; a hydrogen generator – an electrolyser and a hydrogen storage system. The previous proposed IDEA architecture and integration technologies have been validated in both their prototype project and industrial application project. Based on the IDEA system architecture and technologies used in these applications, their ongoing

development will focus on the development of a distributed coordination and control system and the virtual simulation environment, through which to enhance the physical systems increasing requirements on scalability and robustness.

E.W. Smiley and L. Stamenic [4] provide summary of the performance of Building Integrated Photovoltaic System in low irradiance. For the optimization of Building Integrated Photovoltaic (BIPV) systems the low irradiance efficiency of photovoltaic modules is important. They have used a 1kWp, grid connected array of PV modules for assessing the accuracy of an energy performance model developed for BIPV systems. They studied the variation in efficiency of a 1kWp, grid connected of PV modules integrated into the South facade of the BCIT Technology Centre in Burnaby, British Columbia, due to variation in irradiance. The algorithm for calculating power output of the photovoltaic array is derived from the ideal diode equation. An empirically derived parameter modifies the equation and the resulting model can be used to predict the performance of a variety of PV cell technologies at all irradiance levels.

With ever increasing concerns on environmental protection, the full utilization of inexhaustible solar energy is highly desirable. A new energy storage system is proposed by H.P. Kan, K.T. Chau and M. Cheng [5]. A new energy storage system is proposed which consists of a building integrated photovoltaic array, a DC-DC converter, a doubly salient permanent magnet (DSPM) motor drive incorporated with a high-speed flywheel, and an inverter. It has the advantages that the BIPV array is practically feasible in modern cities, while the DSPM motor flywheel offers high efficiency, long cycle life and environmental friendliness. The DSPM motor flywheel energy storage for BIPV system is newly proposed and avoid the use of environmentally harmful batteries. The PV power makes the system flexible in power usage, so that all powers in the system can be utilized in a cost effective manner. The MPPT of the PV array is based on the power equilibrium in the DC link and controlled by the DSPM motor load. Simulation results done by MATLAB have been provided to demonstrate the operation and effectiveness of the proposed system.

Tymandra Blewett, Margaret Horne and Robert Hill [6] proposed a method to avoid shadowing of building integrated photovoltaic systems. Shadowing decreases the output power of module by high performance losses, often much higher than originally estimated. In urban areas shading cannot be avoided and therefore methods to accurately predict PV facade and/or roof system shading patterns must be developed. By utilizing a Heliodon, normally used by architects to predict natural interior lighting effects, accurate seasonal shading by surrounding structures can be assessed on a 3D scale model of the proposed PV array. In order to test this Heliodon Prediction Method they have made comparisons between photographs of the shading on both the model of and actual Northumberland Building PV Facade in the UK. A study of the Northumberland Building's annual shading has been undertaken and photographs taken under Heliodon conditions. Two days were chosen for each month of the year and then hourly photographs taken for each of those days. These photographs have been examined throughout the past year in order to establish accuracy for such a prediction method.

Ricardo Ruther, Paulo Knob, Hans Georg Beyer, Marcelo M. Dacoregio and Alexandre A. Montenegro [7] observed the operation over five years of a 2 kWp grid-connected, double junction a-Si BIPV installation in Brazil. In September 1997 LABSOLAR, at Universidade Federal de Santa Catarina, installed the first grid connected, thin-film, building-integrated PV system in Brazil. In this fully monitored installation, irradiation levels, temperatures and electrical performance data are measured and logged continuously. They have shown results on the continuous operation over five years of this system. The fully monitored PV array operates satisfactorily at a high performance ratio of 82% AC and 92% DC, averaged over 60 month's period. In the stabilized state their results demonstrate that the a-Si PV module performance is independent of the solar cell operating temperature. They have also shown that a considerable amount of the incident solar energy at the site occurs at high irradiation levels ($\geq 1000 \text{ W/m}^2$), which justifies recommendation of over sizing the inverter with respect to the PV array in warm and sunny climates.

H. MauNs, M. Schmid, B. Bliersch, P. Lechner and H. Schade [8] presented summary of amorphous silicon (a-Si) module incorporation for building-integrated photovoltaic systems. The thin-film technology based on amorphous silicon (a-Si) offers a range of attractive features that are ideally suited for building-integrated photovoltaic installations (BIPV). Solar modules can be designed for roofs and facades, and thus perform various functions, namely electricity generation, thermal insulation, shading, and even satisfy aspects of architectural design. Semitransparent modules are also available that exhibit a color-neutral see-through effect. Compared to other PV technologies, a-Si modules show only a minor reduction in power output at elevated temperatures and at lower light levels. They had also describe the factors affecting the cost of a BIPV system and some examples of BIPV system.

Bangyin Liu, and Shanxu Duan [9] proposed a multi-energy hybrid BIPV system and its corresponding energy management strategy to balance the energy of the power sources and loads in the stand-alone operating BIPV system. The dc-module-based BIPV system has some advantages it has better system monitor than ac-module-based system, and is of potential interest in building integrated generation system utilizing multiple sustainable energy sources. The energy storage system or other distributed generation systems, such as wind and fuel cell system, can be extended easily by connecting to the dc bus according to demand. In order to maintain an uninterrupted voltage across critical loads when the grid is failure, the dc-module-based BIPV system must be operated in both grid-connected mode and stand-alone mode. It is difficult to guarantee the balance of energy under the stand-alone operating condition due to the randomness of solar energy and building load. They purposed a multi-energy hybrid BIPV system comprising PV, wind, aqua electrolyzer and fuel cells, to solve this problem, and an energy management strategy is adopted to coordinate the energy flow among the power sources and load. The simulation results are presented to verify the availability of the proposed system.

In Hong Kong, a number of medium-scale Building Integrated Photovoltaic systems were completed in last few years. Edward W. C. LO [10] presented the concepts and benefits of BIPV system several major cases of completed or ongoing BIPV systems in Hong

Kong. The development directions in the near future for Hong Kong were also discussed. These BIPV projects included government building, commercial building, schools, institutional building. The power rating the BIPV system for each project is in the order of tens of kilowatts. Most of these BIPV systems are grid-connected type to eliminate the bulky and troublesome battery banks. Some of these projects are retrofitting on existing buildings, while some are parts of a new building. He gave details of these PV systems including system configurations, design considerations, protections, grid-connection interfacing, power quality issues, their performance, technical difficulties encountered, and experience gained.

In contemporary buildings, Building energy management system (BEMS) is becoming the essential part in monitoring and control the energy consumption within the building. King-hang Lam, Josie Close and Edward WC Lo [11] presented a BIPV dynamic model. They proposed the construction of dynamic model, its applications as building energy management system and Decentralized grid structure are given. The building-integrated photovoltaic system requires some sort of energy storage or supplement to supply the similarly intermittent load demand. It can be achieved by connecting the PV generated electricity to the utility grid, or by energy storage device like battery. Either of these to certain extent affects the electrical network stability if not designed properly. Artificial intelligence plays an important role to promote energy efficiency and system stability. With the precise knowledge of the efficiency characteristics of different PV technologies the simulation of dynamic model of energy output from a BIPV system can be achieved as an indispensable part of the building energy management system (BEMS) in providing necessary control mechanism for the energy demand within the building. When the effect of exposure to weather on the system performance is considered as well, the dynamic model shall be able to adjust itself over time when the system components are degrading and the weather patterns changing.

G. J. Yu, J. H. So, Y. S. Jung and G. H. Kang [12] observed the performance of a 15kW building integrated photovoltaic system installed in Korea Institute of Energy Research (KIER). A 15kW grid connected building integrated photovoltaic (BIPV) sunshade

system and monitoring system are installed in Korea Institute of Energy Research (KIER) was observed for one year and the performance of BIPV sunshade system is analyzed and evaluated to observe the overall effect of meteorological conditions on their operation characteristics for monitoring period by field test. And the cause of loss factors generated by field test are also compared and reviewed. On the basis of these performance results of BIPV sunshade system, to establish utilization technology such as performance improvement, Reliability and stability of PV system and generating problems due to grid-connected of PV system, evaluation, analysis and optimization technologies for PV system will be planning to develop and confirm the validity.

Kazuya Yosliioka, Tadashi Saitoh and Toshikazu Yamamura [13] presented the performance monitoring of a building-integrated PV system located in an urban area in Kobe, Japan. The building has 3 rated power of 76kW array consisting of sub-arrays installed on the north, south and west walls and north and south roofs. The field data acquisition has been continued since June 2001. Monitoring results were reported on the building integrated PV system introduced for MINAMI Tradc Building in Kobe, Japan. The system has been operating without any trouble to date. In addition to the performance monitoring, simulation for produced DC energy was carried out using PVFORM with METPV data for Kobe to compare between the both each other. Monthly energy output semis to mainly depend on the length of daytime for each month. But it was found that the weather conditions, seasonal sun elevation and constructions around the system have also an effect on system energy performance.

J. de la Casa, P. J. Phea, I. Aguilera, G. Almonacid and J.M. Anguita [14] presented some solutions to be considered during the design in order to make the measurements, monitoring and maintenance tasks easier. They analyze general conclusions about how the design of a photovoltaic installation can affect the maintenance and evaluation tasks when using just classic parameters. Due to the sole use of classic parameters, it is more difficult to make an effective monitoring of the installation actual operation and suitable maintenance tasks. This situation worsens when the grid connected PV system is a medium power system, a high power system or has a centralized inverter. These

conclusions are the result from the experience lived during the design; implementation, evaluation and maintenance of a 200-kWp photovoltaic plant integrated at the Jaen University Campus.

Chang Ying-Pin and Shen Chung-Huang [15] presented the effects of the solar module installing angles on the output power. The output power increment of photovoltaic cells is mainly based on two factors. One is decreasing the cell modular temperature and the other is increasing the cells received solar illumination intensity. The former can be simply achieved by maintaining a proper radiating space between the modules and the ground. They theoretically calculated the solar orbit and position at any time and any location.

T. Yamawaki, M. Kondo, A. Nakajima and Y. Tawada [16] presented the power generating behavior of thin-film silicon hybrid solar cell systems in Japan. Thin-film silicon hybrid (a-Si/poly-Si stacked) solar cell modules whose conversion efficiency is around 10% have come into market since April, 2001. Field data of several BIPV system applications of thin-film silicon hybrid solar cell for about two years are presented, and compared with that of a-Si PV modules.

M. Posnansky, S. Gnos [17] presented the importance of hybrid PV building integration. An extensive utilization of photovoltaic's for future electricity generation and for hybrid generation of electricity and thermal energy is possible, when PV-panels are designed to become a part of the building envelope itself. The technology of hybrid PV-building integration with multifunctional PV-building elements is advantageous. Various successfully realized hybrid PV-roofs and PV-facades are milestones in this respect and they demonstrate, that the combined conversion of solar radiation into electrical and thermal energy in facades and roofs is of great interest where heating or warm water is required.

R. Alonso, P. Ibáñez, V. Martínez, Román E., Sanz A. [18] presented an innovative perturb, observe and check algorithm for partially shaded PV systems. The performance

of every photovoltaic (PV) module constituting a PV system can be slightly or strongly different from each other. This factual functioning of PV systems results in some new effects to bear in mind, including the appearance of new peak power points on the output P-V characteristic. They have proposed a new Maximum Power Point Tracking control method consisting of a traditional Perturb & Observe (PO) algorithm but improved with a second stage able to detect these anomalies on the PV generator curve.

Ashraf M. Hemeida, Gaber Shabeeb [19] presented assessment of photovoltaic power system in Aswan city. The paper presents a feasibility of applying a photovoltaic PV power system in Aswan city. Different residential loads were considered to examine if the proposed system can carry out the whole load of large blocks of building. The Five parameters solar cell model is used in this study to determine the performance of solar modules. The inverter efficiency is considered as linear function of input power.

Conclusion

PVs are an advanced materials technology that will help us design buildings which are environmentally responsible, responsive and exciting. This document provides the details of BIPV technique, necessary steps to be taken into account while designing a BIPV and connecting it to a grid. System and design issues are also provided. It also provides the details of size of the system. The effect of temperature and shadowing on out put of a PV array is observed.

Results

Chapter 04

4.0 Objective

Solar energy is set to play an ever-increasing role in generating the form, and affecting the appearance and construction, of buildings. The principal reason for this is that photovoltaic (PV) systems which produce electricity directly from solar radiation are becoming more widespread as their advantages become apparent and as costs fall. PVs are an advanced materials technology that will help us design buildings which are environmentally responsible, responsive and exciting.

Our aim is to design a Roof Based BIPV system in Thapar University, Patiala which can meet the load of class rooms in Blocks B, C, D, E and F approximately during class hours. We have estimated an amount of energy that can be generated by using roof area of these blocks. We have assumed in our study that the lights and fans remained switched on for about 6 hours during the normal classes. We have not taken into account the load of the different labs of the above mentioned blocks.

4.1 Solar Radiation Data & Calculation of Average Output April 2010

Table 2: Solar Radiation Data & Calculation of Average Output April 2010 (Time: 9 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		481.25	68.81875		
02.04.2010		498.125	71.231875		
03.04.2010		505	72.215		
04.04.2010		480.625	68.729375		
05.04.2010		499.375	71.410625		
06.04.2010		528.75	75.61125		
07.04.2010		575.625	82.314375		
08.04.2010		413.75	59.16625		
09.04.2010		509.375	72.840625		
10.04.2010	14.3%	511.875	73.198125	2034.443125	67.81477083
11.04.2010		499.375	71.410625		
12.04.2010		444.375	63.545625		
13.04.2010		551.25	78.82875		
14.04.2010		555	79.365		
15.04.2010		569.375	81.420625		
16.04.2010		514.375	73.555625		
17.04.2010		501.25	71.67875		

18.04.2010		343.75	49.15625		
19.04.2010		239.375	34.230625		
20.04.2010		479.375	68.550625		
21.04.2010		432.5	61.8475		
22.04.2010		450.625	64.439375		
23.04.2010		483.75	69.17625		
24.04.2010		316.875	45.313125		
25.04.2010		565.625	80.884375		
26.04.2010		531.25	75.96875		
27.04.2010		451.25	64.52875		
28.04.2010		479.375	68.550625		
29.04.2010		511.875	73.198125		
30.04.2010		302.5	43.2575		

Table 3: Solar Radiation Data & Calculation of Average Output April 2010 (10 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		672.5	96.1675		
02.04.2010		693.75	99.20625		
03.04.2010		685.625	98.044375		
04.04.2010		651.875	93.218125		
05.04.2010		721.875	103.228125		

06.04.2010		719.375	102.870625		
07.04.2010		772.5	110.4675		
08.04.2010	14.3%	660.625	94.469375	2778.221875	92.60739583
09.04.2010		644.375	92.145625		
10.04.2010		724.375	103.585625		
11.04.2010		679.375	97.150625		
12.04.2010		612.5	87.5875		
13.04.2010		733.75	104.92625		
14.04.2010		721.25	103.13875		
15.04.2010		752.5	107.6075		
16.04.2010		678.75	97.06125		
17.04.2010		678.125	96.971875		
18.04.2010		291.875	41.738125		
19.04.2010		601.875	86.068125		
20.04.2010		627.5	89.7325		
21.04.2010		343.75	49.15625		
22.04.2010		605.625	86.604375		
23.04.2010		668.125	95.541875		
24.04.2010		613.75	87.76625		
25.04.2010		728.75	104.21125		
26.04.2010		684.375	97.865625		
27.04.2010		646.25	92.41375		
28.04.2010		616.25	88.12375		

29.04.2010		670	95.81		
30.04.2010		526.875	75.343125		

Table 4: Solar Radiation Data & Calculation of Average Output April 2010 (11 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		808.75	115.65125		
02.04.2010		808.75	115.65125		
03.04.2010		801.25	114.57875		
04.04.2010		770.625	110.199375		
05.04.2010		861.25	123.15875		
06.04.2010		857.5	122.6225		
07.04.2010		913.75	130.66625		
08.04.2010	14.3%	809.375	115.740625	3333.776875	111.1258958
09.04.2010		820	117.26		
10.04.2010		862.5	123.3375		
11.04.2010		819.375	117.170625		
12.04.2010		733.125	104.836875		
13.04.2010		866.25	123.87375		
14.04.2010		881.875	126.108125		
15.04.2010		866.875	123.963125		
16.04.2010		791.875	113.238125		

17.04.2010		803.75	114.93625		
18.04.2010		543.75	77.75625		
19.04.2010		589.375	84.280625		
20.04.2010		737.5	105.4625		
21.04.2010		642.5	91.8775		
22.04.2010		710.625	101.619375		
23.04.2010		786.25	112.43375		
24.04.2010		830	118.69		
25.04.2010		876.875	125.393125		
26.04.2010		825.625	118.064375		
27.04.2010		765.625	109.484375		
28.04.2010		683.75	97.77625		
29.04.2010		780	111.54		
30.04.2010		464.375	66.405625		

Table 5: Solar Radiation Data & Calculation of Average Output April 2010 (12 noon)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		840	120.12		
02.04.2010		860.625	123.069375		
03.04.2010		866.875	123.963125		

04.04.2010		846.25	121.01375		
05.04.2010		928.125	132.721875		
06.04.2010		927.5	132.6325		
07.04.2010		961.875	137.548125		
08.04.2010	14.3%	838.125	119.851875	3517.531875	117.2510625
09.04.2010		845.625	120.924375		
10.04.2010		798.75	114.22125		
11.04.2010		871.875	124.678125		
12.04.2010		811.25	116.00875		
13.04.2010		921.25	131.73875		
14.04.2010		920	131.56		
15.04.2010		940.625	134.509375		
16.04.2010		856.875	122.533125		
17.04.2010		842.5	120.4775		
18.04.2010		528.75	75.61125		
19.04.2010		571.25	81.68875		
20.04.2010		778.75	111.36125		
21.04.2010		452.5	64.7075		
22.04.2010		735	105.105		
23.04.2010		866.875	123.963125		
24.04.2010		866.875	123.963125		
25.04.2010		923.125	132.006875		
26.04.2010		880	125.84		

27.04.2010		795.625	113.774375		
28.04.2010		708.75	101.35125		
29.04.2010		828.125	118.421875		
30.04.2010		784.375	112.165625		

Table 6: Solar Radiation Data & Calculation of Average Output April 2010 (1 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		865.625	123.784375		
02.04.2010		839.375	120.030625		
03.04.2010		857.5	122.6225		
04.04.2010		817.5	116.9025		
05.04.2010		914.375	130.755625		
06.04.2010		883.75	126.37625		
07.04.2010		907.5	129.7725		
08.04.2010	14.3%	806.25	115.29375	3451.036875	115.0345625
09.04.2010		881.25	126.01875		
10.04.2010		780.625	111.629375		
11.04.2010		829.375	118.600625		
12.04.2010		793.75	113.50625		
13.04.2010		897.5	128.3425		
14.04.2010		892.5	127.6275		

15.04.2010		883.125	126.286875		
16.04.2010		851.25	121.72875		
17.04.2010		843.75	120.65625		
18.04.2010		543.125	77.666875		
19.04.2010		551.25	78.82875		
20.04.2010		746.25	106.71375		
21.04.2010		534.375	76.415625		
22.04.2010		687.5	98.3125		
23.04.2010		900	128.7		
24.04.2010		857.5	122.6225		
25.04.2010		905	129.415		
26.04.2010		854.375	122.175625		
27.04.2010		775.625	110.914375		
28.04.2010		720	102.96		
29.04.2010		779.375	111.450625		
30.04.2010		733.75	104.92625		

Table 7: Solar Radiation Data & Calculation of Average Output April 2010 (2 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		780	111.54		
02.04.2010		702.5	100.4575		

03.04.2010		753.75	107.78625		
04.04.2010		740.625	105.909375		
05.04.2010		731.25	104.56875		
06.04.2010		798.125	114.131875		
07.04.2010		816.25	116.72375		
08.04.2010	14.3%	678.75	97.06125	3087.37	102.9123333
09.04.2010		800.625	114.489375		
10.04.2010		625.625	89.464375		
11.04.2010		736.25	105.28375		
12.04.2010		746.875	106.803125		
13.04.2010		805	115.115		
14.04.2010		781.875	111.808125		
15.04.2010		783.125	111.986875		
16.04.2010		741.25	105.99875		
17.04.2010		746.25	106.71375		
18.04.2010		704.375	100.725625		
19.04.2010		598.125	85.531875		
20.04.2010		634.375	90.715625		
21.04.2010		450.625	64.439375		
22.04.2010		626.875	89.643125		
23.04.2010		818.125	116.991875		
24.04.2010		750	107.25		
25.04.2010		785.625	112.344375		

26.04.2010		755.625	108.054375		
27.04.2010		685.625	98.044375		
28.04.2010		665	95.095		
29.04.2010		695.625	99.474375		
30.04.2010		651.875	93.218125		

Table 8: Solar Radiation Data & Calculation of Average Output April 2010 (3 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		609.375	87.140625		
02.04.2010		491.25	70.24875		
03.04.2010		578.125	82.671875		
04.04.2010		576.25	82.40375		
05.04.2010		566.25	80.97375		
06.04.2010		620.625	88.749375		
07.04.2010		639.375	91.430625		
08.04.2010	14.3%	540	77.22	2301.2275	76.70758333
09.04.2010		610	87.23		
10.04.2010		405	57.915		
11.04.2010		563.75	80.61625		
12.04.2010		555.625	79.454375		
13.04.2010		626.875	89.643125		

14.04.2010		615	87.945		
15.04.2010		623.125	89.106875		
16.04.2010		526.875	75.343125		
17.04.2010		583.125	83.386875		
18.04.2010		573.75	82.04625		
19.04.2010		450	64.35		
20.04.2010		488.75	69.89125		
21.04.2010		340	48.62		
22.04.2010		466.875	66.763125		
23.04.2010		631.25	90.26875		
24.04.2010		588.125	84.101875		
25.04.2010		611.25	87.40875		
26.04.2010		583.125	83.386875		
27.04.2010		416.875	59.613125		
28.04.2010		511.25	73.10875		
29.04.2010		371.875	53.178125		
30.04.2010		328.75	47.01125		

Table 9: Solar Radiation Data & Calculation of Average Output April 2010 (4 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m²)	Output (Watt/m²)	Total Output (Watt/m²)	Average Output (Watt/m²)
01.04.2010		383.75	54.87625		

02.04.2010		215.625	30.834375		
03.04.2010		378.125	54.071875		
04.04.2010		373.125	53.356875		
05.04.2010		367.5	52.5525		
06.04.2010		396.875	56.753125		
07.04.2010		430	61.49		
08.04.2010	14.3%	223.125	31.906875	1380.933125	46.03110417
09.04.2010		395.625	56.574375		
10.04.2010		361.875	51.748125		
11.04.2010		366.25	52.37375		
12.04.2010		367.5	52.5525		
13.04.2010		418.125	59.791875		
14.04.2010		393.125	56.216875		
15.04.2010		411.25	58.80875		
16.04.2010		335.625	47.994375		
17.04.2010		310.625	44.419375		
18.04.2010		295	42.185		
19.04.2010		253.75	36.28625		
20.04.2010		334.375	47.815625		
21.04.2010		221.25	31.63875		
22.04.2010		276.25	39.50375		
23.04.2010		422.5	60.4175		
24.04.2010		390.625	55.859375		

25.04.2010		397.5	56.8425		
26.04.2010		383.75	54.87625		
27.04.2010		120	17.16		
28.04.2010		258.125	36.911875		
29.04.2010		172.5	24.6675		
30.04.2010		3.125	0.446875		

Table 10: Peak Variation & Possible Plant Rating

Months	Peak Output (Watt/m²)	Average Peak Output (Watt/m²)
September	102.9467593	
October	98.17016204	
November	71.46425	
December	56.93546	94.66075866
January	60.228025	
February	96.72928571	
March	115.8357661	
April	117.2510625	

4.2 Load Calculation of different blocks

Table 11: Load Calculation for E-Block

Room No.	Fans	Tube Lights	Power Plugs	Total Load
E-101	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-102	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-103	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-104	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-105	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-106	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-107	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-108	$6 \times 80 = 480 \text{ W}$	$10 \times 40 = 400 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	1.88 KW
E-201	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-203	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-204	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-205	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-206	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-207	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-208	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-209	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-210	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-211	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W
E-212	$5 \times 80 = 400 \text{ W}$	$8 \times 40 = 320 \text{ W}$		720 W

Table 12: Load Calculation for F-Block

Room No.	Fans	Tube Lights	Power Plugs	Total Load
F-102	$9 \times 80 = 720 \text{ W}$	$12 \times 40 = 480 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-103	$9 \times 80 = 720 \text{ W}$	$12 \times 40 = 480 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-104	$9 \times 80 = 720 \text{ W}$	$12 \times 40 = 480 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-105	$9 \times 80 = 720 \text{ W}$	$12 \times 40 = 480 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-106	$9 \times 80 = 720 \text{ W}$	$12 \times 40 = 480 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-107	$6 \times 80 = 480 \text{ W}$	$16 \times 40 = 640 \text{ W}$	$1 \times 1 = 1 \text{ KW}$	2.2 KW
F-201	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-202	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-203	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-204	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-205	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-206	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-207	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W
F-208	$9 \times 80 = 720 \text{ W}$	$14 \times 40 = 560 \text{ W}$		1280 W

Table 13: Load Calculation for B-Block

Room No.	Fans	Tube Lights	ACs	Computers & Accessories	Coolers	Power Plugs	Total Load
B-106	12 × 80 =960 W	12×40 =480 W					1440 W
B-107	5 × 80 =400 W	6 × 40 =240 W					640 W
B-108	1 × 80 =80W	2 × 40 =80 W					160 W
B-108A	1 × 80 =80W	2 × 40 =80 W					160 W
B-109	5 × 80 =400 W	6 × 40 =240 W					640 W
B-110	1 × 80 =80W	2 × 40 =80 W		1 × 300 =300W	1 × 200 =200 W		660 W
B-111	5 × 80 =400 W	10 × 40 =400 W					800 W
B-201	8 × 80 =640 W	7 × 40 =280 W		8 × 300 =2400W	3 × 200 =600 W	1 × 1 =1KW	4.92 KW
B-202	9 × 80 =720 W	7 × 40 =280 W	1×2 =2KW	8 × 300 =2.4KW	1 × 200 =200 W	1 × 1 =1KW	6.6 KW
B-203	8 × 80 =640 W	8 × 40 =320 W		10 × 300= 3KW	2 × 200 =400 W	1 × 1 =1KW	5. 36 KW
B-204	1 × 80 =80W	2 × 40 =80 W					160 W
B-205A	1 × 80 =80W	2 × 40 =80 W					160 W
B-205	2 × 80 =160 W	2 × 40 =80 W		1 × 300 =300W			540 W
B-206	2 × 80 =160 W	8 × 40 =320 W	1×2 =2KW	1 × 300 =300W			2.78 KW
B-207	2 × 80 =160 W	2 × 40 =80 W		1 × 300 =300W			540 W
B-208	2 × 80 =160 W	2 × 40 =80 W		1 × 300 =300W			540 W
B-209	4 × 80 =320 W	4 × 40 =160 W		4 × 300 =1200W			1360 W

Table 14: Load Calculation for Link between B and C Block

Room No.	Fans	Tube Lights	ACs	Computers & Accessories	Coolers	Power Plugs	Total Load
L-107	1 × 80 =80 W	2 × 40 =80 W		1 × 300= 300 W			460 W
L-107A	1 × 80 =80 W	2 × 40 =80 W		1 × 300 = 300W			460 W
L-108	2 × 80 =160 W	3 × 40 =120 W		1 × 300 = 300W			580 W
L-109	2 × 80 =160 W	8 × 40 =320 W	1×2 =2KW	1 × 300 = 300W			2.78 KW
L-110	1 × 80 =80 W	2 × 40 =80 W					160 W
L-111	1 × 80 =80 W	1 × 40 =40 W					120 W
L-111A	1 × 80 =80 W	2 × 40 =80 W		1 × 300 = 300W			460 W
L-112	1 × 80 =80 W	1 × 40 =40 W					120 W
L-112A	1 × 80 =80 W	1 × 40 =40 W					120 W
L-208	2 × 80 =160 W	2 × 40 =80 W			1 × 200 =200 W		440 W
L-208A	2 × 80 =160 W	6 × 40 =240 W		2 × 300 = 600W		1 × 1 =1KW	2 KW
L-209	2 × 80 =160 W	2 × 40 =80 W		1 × 300 = 300W			540 W
L-211	2 × 80 =160 W	2 × 40 =80 W		1 × 300 = 300W			540 W
L-212	2 × 80 =160 W	2 × 40 =80 W		1 × 300 = 300W			540 W
L-213	2 × 80 =160 W	2 × 40 =80 W		2 × 300 = 600W			840 W
L-214	2 × 80 =160 W	2 × 40 =80 W		1 × 300 = 300W			540 W

Table 15: Load Calculation for C Block

Room No.	Fans	Tube Lights	ACs	Computers & Accessories	Power Plugs	Total Load
C-103	3 × 80 =240 W	4 × 40 =160 W	1 × 2 = 2 KW		1 × 1 =1KW	3.4 KW
C-104	5 × 80 =400 W	6 × 40 =240 W				640 W
C-105	1 × 80 =80 W	2 × 40 =80 W				160 W
C-105A	1 × 80 =80 W	2 × 40 =80 W				160 W
C-106	1 × 80 =80 W	1 × 40 =40 W		1 × 300 =300W		420 W
C-107	1 × 80 =80 W	1 × 40 =40 W		1 × 300 =300W		420 W
C-108	2 × 80 =160 W	3 × 40 =120 W		1 × 300 =300W		580 W
C-109	2 × 80 =160 W	8 × 40 =320 W	1 × 2 =2KW	1 × 300 =300W		2.78KW
C-110	1 × 80 =80 W	1 × 40 =40 W				120 W

Table 16: Load Calculation for Link between C and D Block

Room No.	Fans	Tube Lights	Computers & Accessories	Coolers	Total Load
1	2 × 80 =160 W	8 × 40 =320 W	2 × 300= 600W	1 × 200 =200 W	1280 W
2	2 × 80 =160 W	8 × 40 =320 W	2 × 300 =600W	1 × 200 =200 W	1280 W
3	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W
4	2 × 80 =160 W	8 × 40 =320 W	2 × 300= 600W	1 × 200 =200 W	1280 W
5	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W
6	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W
7	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W
8	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W
9	2 × 80 =160 W	8 × 40 =320 W	2 × 300 = 600W	1 × 200 =200 W	1280 W

10	$2 \times 80 = 160 \text{ W}$	$8 \times 40 = 320 \text{ W}$	$2 \times 300 = 600 \text{ W}$	$1 \times 200 = 200 \text{ W}$	1280 W
11	$2 \times 80 = 160 \text{ W}$	$8 \times 40 = 320 \text{ W}$	$2 \times 300 = 600 \text{ W}$	$1 \times 200 = 200 \text{ W}$	1280 W

Table 17: Load Calculation for D Block

Room No.	Fans	Tube Lights	Total Load
D-201	$11 \times 80 = 880 \text{ W}$	$12 \times 40 = 480 \text{ W}$ $14 \times 10 = 140 \text{ W}$	1500 W
D-202	$11 \times 80 = 880 \text{ W}$	$12 \times 40 = 480 \text{ W}$ $28 \times 10 = 280 \text{ W}$	1640 W
D-203	$5 \times 80 = 400 \text{ W}$	$20 \times 10 = 200 \text{ W}$	600 W
D-204	$5 \times 80 = 400 \text{ W}$	$22 \times 10 = 220 \text{ W}$	620 W
D-205	$6 \times 80 = 480 \text{ W}$	$16 \times 40 = 640 \text{ W}$	1120 W
D-206	$11 \times 80 = 880 \text{ W}$	$28 \times 40 = 1120 \text{ W}$	2000 W
D-207	$6 \times 80 = 480 \text{ W}$	$11 \times 40 = 440 \text{ W}$	920 W

Table 18: Energy Consumption of Each Block

Name of Block	Total Load (KW)	Energy Consumption per day (KW-hr)	Energy Consumption per month (KW-hr)
E	22.96	137.76	3030.72
F	23.36	140.16	3083.52
B	27.46	164.76	3624.72
Link between B & C	10.7	64.2	1412.4
C	8.68	52.08	1145.76
Link between C & D	14.08	84.48	1858.56
D	8.4	50.4	1108.8

4.3 Roof Area of different Blocks

4.3.1 Roof Area of E-block

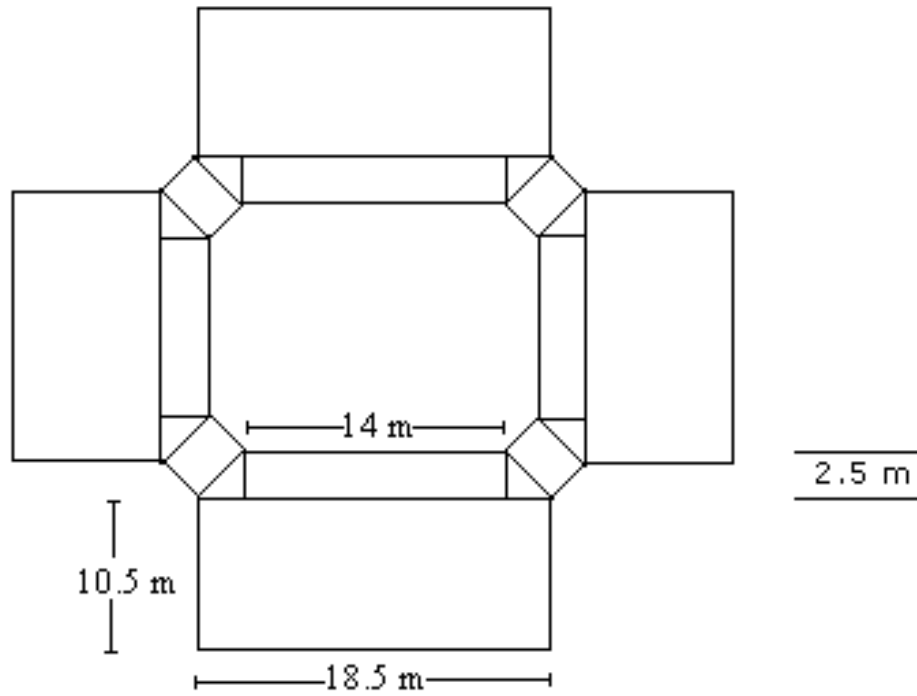


Figure (4.0) Map of E -block.

$$\text{Total roof area} = (14 \times 2.5 \times 4) + (10.5 \times 18.5 \times 4) = 917 \text{ m}^2$$

4.3.2 Roof Area of F-block

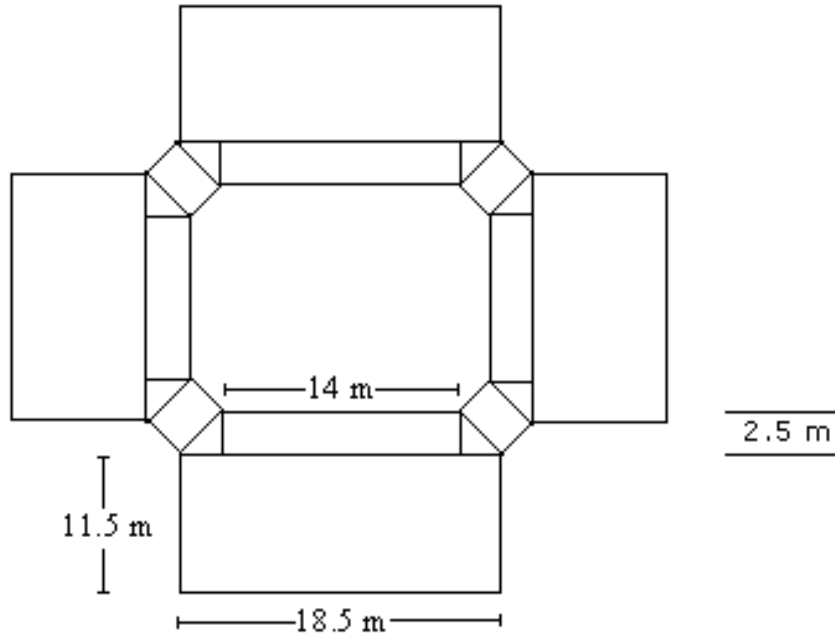


Figure (4.1) Map of F –block.

$$\text{Total roof area} = (14 \times 2.5 \times 4) + (11.5 \times 18.5 \times 4) = 991 \text{ m}^2$$

4.3.3 Roof Area of B, C and D-blocks

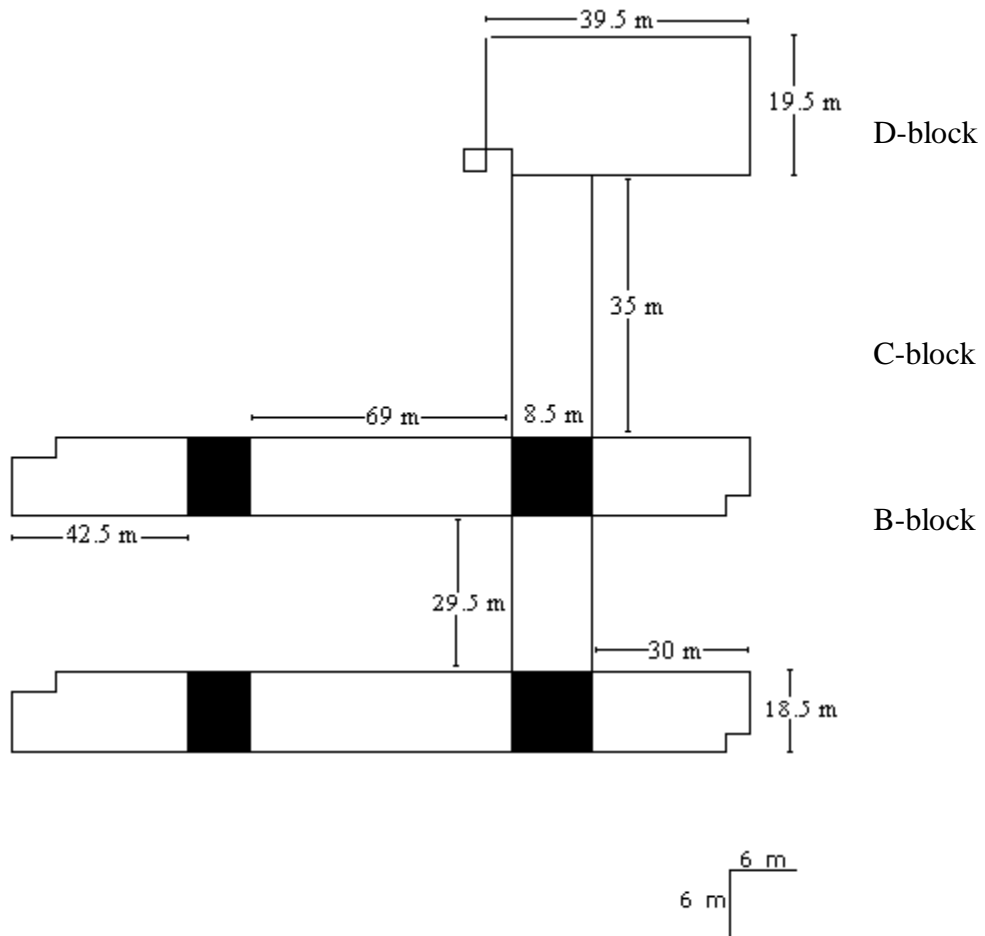


Figure (4.3) Map of B, C and D –block.

Area of B-block = 519 m^2

Area of C-block = 519 m^2

Area of D-block = 734 m^2

Area of link between B and C blocks = 250 m^2

Area of link between C and D blocks = 297 m^2

4.4 Energy Calculations

Table 19: Energy generated from each Block

Total energy generated from each block = Effective area × Average peak output

Name of Block	Available Area (m²)	Effective Area (m²)	Average Peak Output (W/m²)	Possible Plant Capacity (KW)	Energy Generated per day (KW-hr)	Energy Generated per month (KW-hr)
E	917	733		69	414	12420
F	991	792		74	444	13320
B	519	415		39	234	7020
Link between B and C	250	200	94.66075866	18	108	3240
C	519	415		39	234	7020
Link between C and D	297	237		22	132	3960
D	734	587		55	330	9900

4.5 System Sizing

Table 20: Solar Panel Specification

Watt	180 Watt
Voltage	24 Volts
Current	5.4 A
Type	Polycrystalline
Efficiency	14.3%
Temperature	25 deg c

Table 21: Number of Panels Required for each Block

Name of Block	Number of Panels Required	Number of Panels Connected in Series in one String	Number of Strings Connected in Parallel
E	384	32	12
F	420	35	12
B	216	27	8
Link between B and C	100	20	5
C	216	27	8
Link between C and D	125	25	5
D	306	34	9

Conclusion and Future scope of work

Chapter 05

5.0 Conclusion

There is sufficient solar access available at our site (Patiala) to meet with the load requirement. Also in class rooms the load is day time only and there is large amount of roof area is available. The entire area is free from shadow. Hence there is no need to install the system at any other place except roof. The roof is made of concrete and ordinary tiles, the upper layer is made of ordinary tiles and inner layer is made of Concrete. The retro-fit PV installation technique can be applied at our site. There are a number of advantages to this type of system.

We have estimated the energy that can be generated in April 2010 by using 80% of the total roof area of every block. From above calculations it is clear that the estimated energy generation per day for blocks E and F is almost double. The estimated energy generation per day for blocks B, link block between B and C blocks and link block between C and D blocks is more then the energy requirement of these blocks. The estimated energy generation per day for C block is four times then the energy requirement of this block and for D block it is six times. By connecting these blocks with a grid the excess energy can be supplied to the hostels.

5.1 Future scope of work

To design a roof based BIPV system we need the readings of average solar radiation of all the months in a year. In future we will calculate the number of PV arrays and cost of the system which can meet the load demand of all class rooms .We have find that the E, F, B and C–blocks has a large area and estimated energy generation is more then the energy requirement of class rooms of these blocks. In starting we have not taken into account the air-conditioners connected in D block and the load of labs in C block. In future we will include the load of labs in C block and air-conditioners of D block.

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