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Design and Feasibility Analysis of Building Integrated PV (BIPV) System: Case Study in Bahir Dar University Lecture Halls Building

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Abstract Building Integrated Photovoltaic System (BIPV) is the integration of Photovoltaic (PV) into the building envelope in the top, the facades and or may be used for the building which is built already without PV integration. That is installing or hanging of PV panel in different positron of the building. When the building is integrated with PV panel, it is used as a construction material and again save extra area requirement of installation and at the time it generates the required amount of energy for the habitants of the building is to get from free natural solar energy. Integrating BU in photovoltaic system is the aim to save the large power cost without taking large area for the installation of the photovoltaic panel since the university occupied by large number of students, workers and staffs members. The total estimated cost of initial investment for materials such as PV panels, battery, charge controller, inverter and like is $63,040. It is estimated as BIPV system total cost in the 25years life time is $176,815 which lower than that of the total national grid electricity cost by $40, 185.2 using in HOMER software implementation.

Keywords: *BIPV, battery, HOMER software, inverter, PV panel*

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1. Introduction and Literature Review

Building Integrated Photovoltaic System (BIPV) is the integration of Photovoltaic (PV) into the building envelope. BIPV system is designed to provide savings in roof construction materials & electricity costs reduces consumption of fossil fuels, emission of ozone depleting gases, and add architectural interest to the building. Building Integrated Photovoltaic System often has lower cost than PV systems requiring separate place, dedicated, mounting systems. Building Integrated Photovoltaic System is a compilation of beneficial components like thin-film or crystalline, transparent, semi-transparent, or opaque, a charge controller, a power storage system, power conversion equipment, backup power supplies and appropriate support and mounting hardware, wiring, and safety disconnects. For assorting the wonderful features in one system, we are established ourselves in the markets. The parts of PV system include the parts of figure as shown below. It may be connected to national grid if necessary if there deficiency and efficiency of system and the overall system configuration shown in Figure 1 below.

Generating electricity with a photovoltaic (PV) system has many advantages over other energy generating sources. Photovoltaic systems are sustainable, Solar electricity can also displace fossil fuel use with many environmentally friendly, and is quiet, light and require minimal maintenance (except seasonal cleaning) as they have no moving parts and with long life time about 20-30 year having special treated glass, to protect the cells and provide long years of service for the panels. PV systems are made up of modules (panels), which give the system flexible to be expanded or reduced to suit any given application. Solar cells can be connected in series or parallel in virtually any number and combination. Therefore, PV systems may be realized in an extraordinary broad range of power: from mill watt systems in watches or calculators to megawatt systems for central power production. Building power supply systems are usually in the range of several kilowatts of nominal power. Thus it may be used as connection to an electric grid or "stand-alone" systems. The versatility of PV panels gives numerous possibilities for their integration into new and existing building structures.

Building Integrated Photovoltaic (BIPV) is an application where solar PV modules are integrated into the building structures. The integration could be made by either installing the PV modules on top of existing structures (as shown in Figure 2 below) or by using the PV modules as part of the building materials. The PV modules could also be used as building elements (facades, roofs, walls, glass), and as non-building elements (sunscreen, sunshade). Modem commercial building facades often cost as much as a PV façade which means immediate or short-term payback for the PV system. Depending on the type of integration, the PV modules may also provide shading or noise protection. Here again, the costs for replaced conventional means for these purposes may be deducted from the initial PV cost.

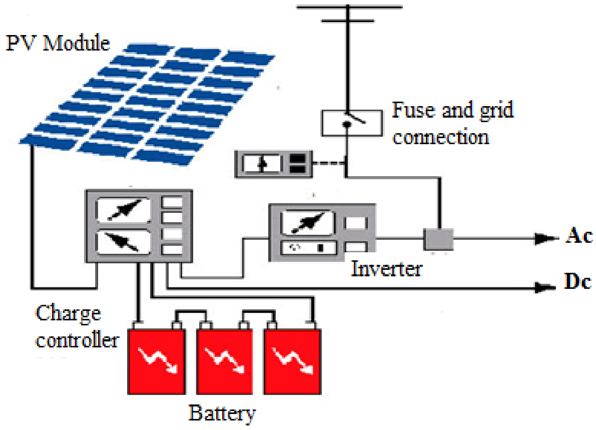

Figure 1. Configurations of PV system

Figure 2. PV Panel on top of house after built and integration during built on direction of solar

BIPV application will result in the production of quality electricity very close to the demand points. This will directly improve energy efficiency and reduce electrical distribution and transmission losses and system simplicity.

While the installation of PV panels on flat and tilted roofs is perhaps the most popular example of its application in buildings, the integration of PV into facades also offers tremendous potential and transparent module to front face of the building as exemplified in Figure 3. Integrating PV into new and existing architecture offers great possibilities for the design of energy efficient and ecologically sound buildings, without compromising comfort or aesthetics.

In addition to design benefits, PV integration offers a number of cost benefits. Integrated PV panels generate electricity and acts as part of the building fabric. This combined function can result in costs savings where the cost of traditional building fabric is comparable to that of the PV panels. Also, no additional land or separate support structure is required, giving further cost advantages.

Currently, a typical PV system currently produces electricity at approximately four times the cost of conventionally produced electricity. However, the cost of producing electricity from PV has fallen by over 50% in the last ten years as a result of constant improvements in PV technology, integration techniques and increased production volumes. With this downward trend set to continue against a background of rising oil prices, the economic benefits of PV will continue to rise.

Building Integrated PV helps designers to meet goals of sustainability and reduced emissions while maintaining or improving comfort. The synergy between integrated PV's main functions of on-site energy generation and forming part of the building fabric, along with increasing cost competitiveness makes integrated PV an especially attractive option.

Due to specific task cooperation of many different experts, such as architects, civil engineers and PV system designers, work together is necessary. According to how and where such systems are built, whether into the facade or in the roof, the following BIPV systems are recognized:

- Facade or roof systems added after the building was built.
- Facade integrated photovoltaic systems built along with an object.
- Roof-integrated photovoltaic systems built along with an object.
- "Shadow-Voltaic" - PV systems also used as shadowing systems, built along with an object or added later.
- PV panel is installed on the top of already built building to get power.

Figure 3. Large transparent module - glass/glass laminate for front surface

Ethiopia is located in the eastern part of Africa between 3^{o} to 15^{o} north and 33^{o} to 48^{o} east and has abundant solar energy resources. Ethiopia located near the equator its solar resource is obviously of significant potential to use solar energy. The national annual average irradiance is estimated to be 5.2 kWh/m2/day with seasonal variations that range between the minimum of 4.5 kWh/m2/day in July to a maximum of 5.6 kWh/m2/day in February and March.1 The solar resource is relatively lower in the most populous Northern, Central and Western highlands of the country while the rift valley regions, Western and Eastern lowlands of the country receive higher annual average irradiance well above 6 kWh/m2/day.

The Ethiopian solar PV use is still at an early development stage with an estimated installed capacity of 5 MW. Growth during the 1990s was under 5 % but has reached 15-20 % during the last few years, primarily driven by the telecom market that constitutes 70 % of installed capacity [1].

The PV system installed in Ethiopia is in major case for telecommunication service in rural area of Ethiopia. Thus using of building integrated system is not more developed in our country. However, the cost of PV system is competitive with diesel burn power system; Ethiopia is still t the initial area in the use of PV system. Different nongovernmental organizations are working to promote the use of PV system in Ethiopia.

Many countries like German, Chine, and Australia the world growth is rapidly increasing in use and manufacturing photovoltaic module in different structure.

It is more convincible to get comfortably and the beauty of the building and at the same time to get the required amount of energy from natural solar energy. Using of BIPV in building is also good to increase the power potential of the country. It should be the great mission of engineers, architectures, and PV designers.

Bahr dar is one the regional capital cities of Ethiopia which is located at latitude 11.56o and longitude 37.4o and having average solar radiation is between the minimum 5.02 kWh/m²/day in July and maximum is 6.59 kWh/m²/day in month of April.

A. Problem statement

Bahir Dar University uses large quantity of electric power at student dormitory area, staffs office, cafeteria, workers and student lounge, workshops, computer labs, lecture rooms, and also energy for air conditioning. For two compasses, there is large quantity of money wastes to run these all areas of power requirement. In addition, there an interruption of work when light has gone.

To minimize these problems, by integrating the university building with PV panels without taking of large area of panel installing is currently will be the best solution. Ideally, the orientation of a photovoltaic panel must face south towards the equator, roofs and the windows in the direction to solar radiation to be integrated with transparent PV panels, size to get the required amount energy from PV panel.

So, without taking the large area of the PV panel for installation, the electric power cost is to be saved, the function stop when the light has gone is to be sustained by using of storage battery of PV system.

B. Objectives of the study

General objectives:

The objectives of integration of PV panel to the building is that the building use PV panel as building material save construction cost and to save extra area of the panel installation and as the same time the required amount of energy for the habitants of the building is to get from free naturally available solar energy.

Specific Objectives

This study seeks to produce a document that comprises PV system energy use of by applying of PV panel to the buildings of Bahir Dar University that is already constructed without integrating the front face windows and the roofs with PV panel. However, still it has large top area to install the PV panel to get large enough power from sun for each blocks of the building.

- To investigate solar energy potential of Bahir dar, Ethiopia
- To Design PV system for model lecture room of university, BDU
- To design system components such battery, inverter, charge controller, wire, etc.
- To study feasibility of PV system relative to nation grid electric energy.

2. Solar Radiation

The sun is a sphere of intensely of hot gaseous matter with a diameter of 1.39 x 10^9 m and is on the average 1.5 x 10^{11} m center to center distance from the earth. This distance compares to about 12000 times the earth's diameter. The eccentricity of the earth's orbit is such that the distance between the sun and the earth varies by 1.7% [2]. The sun has an effective blackbody temperature of 5777 K. The radiation emitted by the sun and its spatial relationship to the earth result in a nearly fixed intensity of solar radiation outside the earth's atmosphere, often referred to as extraterrestrial radiation. The values for this solar constant found in different literature may vary slightly due to the measurement techniques or assumptions for necessary estimations. The World Radiation Center has adopted a value of 1367 W/m^2; the solar power reaches the earth of 1m^2 area when the sun is perpendicular to the area and with an uncertainty in the order of 1%. Compared to fossil fuels, the energy density of the solar radiation is relatively small. The total amount of incident radiation, however, is 6500 times larger than the world's energy demand. Even if only the land-covered part of the earth's surface is considered, the sun could still supply 1900 times our worldwide energy demand.

A. Solar Radiation in Bahir Dar, Ethiopia

Bahir Dar lies nearly to the equatorial region at 11.56^{o}N (11°33'36"N) and 37.37^o E (37°22'12"E). The climate is governed by the regime of the north-east monsoons which blows alternatively during the course of the year. The north-east monsoon blows from approximately October until March. Ambient temperature remains uniformly high over the country throughout the year. An average ambient temperature is between 18.81°C to 23.45 °C. The area has a relative clearness index between 0.48-0.69.

The monthly average daily solar radiation in Bahir Dar 5.02-6.59 kWh/m²/day with low wind speed usually around 4.5m/s.

Table 1. SURFACE METEOROLOGICAL DATA OF BAHIR DAR, ETHIOPIA (NASA)

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insulation, kWh/m²/day	5.76	6.20	6.48	6.59	6.26	5.74	5.02	5.04	5.67	5.87	6.01	5.67
Clearness, 0 - 1	0.68	0.67	0.64	0.63	0.60	0.55	0.48	0.48	0.56	0.62	0.69	0.69
Temperature, °C	21.10	22.43	23.45	22.46	21.39	19.00	17.92	17.90	18.81	20.29	20.56	20.56
Wind speed, m/s	4.14	4.28	4.13	4.07	4.10	5.09	4.98	4.21	3.50	3.06	3.83	4.09

3. Analysis of a Building Integrated Photovoltaic (BIPV) System

BIPV systems should be approached to where energy conscious design techniques have been employed, and equipment and systems have been carefully selected and specified. They should be viewed in terms of life-cycle cost, and not just initial, first-cost because the overall cost may be reduced by the avoided costs of the building materials and labor they replace. Design considerations for BIPV systems must include the building's use and electrical loads, its location and orientation, the appropriate building and safety codes, and the relevant utility issues and costs.

A. Photo voltaic PV specifications and design

Photovoltaic panels manufactured in different textured material and that make it most flexible to different activities applications. That is accordingly types of cover glassing material, it may be flexible to use as curved, transparency for front window area, and it may be rigid hard for standalone outside installed. Photovoltaic, in its simplest terms, means the conversion of sunlight into electrical energy directly.

Accomplishing this conversion requires panels with cells that meet certain specifications, sometimes referred to as solar panels, which release free electrons when stimulated by sunlight. Those free electrons produce the electrical current which is either used immediately as electricity or is stored in batteries for use at a later time

Cell specification: One specification of a photovoltaic panel refers to the cells located in the panels that generate electricity. The cells, normally 30 to 40 in a typical panel, depending upon construction and size, consist of a semiconductor material, generally silicon shaped in thin wafers or ribbons with a positive side and a negative side. The sunlight striking the positive side activates the electrons in the negative side with an electric current as the end result. A panel's specifications can request crystalline silicon in either a single crystal or more than one: polycrystalline. Either crystalline produces the same result. New technology uses amorphous silicon which is less expensive but not as efficient for use in large panels.

Physical construction specification: According to Naturals Energy, photovoltaic panels consist of translucent material, normally special treated glass, to protect the cells and provide 25 years of service for the panels. Each panel, or module, is connected to other panels to form an array. The panel weighs just over 28 pounds with a dimension of 4 feet 10 inches in length by 2 feet 2 inches wide by 1.4 inches thick. The panels function in temperatures ranging from 40 degrees below zero to 185 degrees Fahrenheit with humidity of up to 100 percent.

Energy specification: The maximum power, peak power or energy that a panel can generate depends upon the panel. The number of actual watts, measured in kilowatts, a panel generates over time varies depending upon the hours of sunlight.

Selected panel is specified as: Photovoltaic Mon crystalline Silicon module of 230W suitable both for installation in PV systems integrated then in big parks having of its flexibility. The number of the cells is 60 and the max system voltage DC is 1000V. The JSTY230M-96 photovoltaic module is IEC 61215.

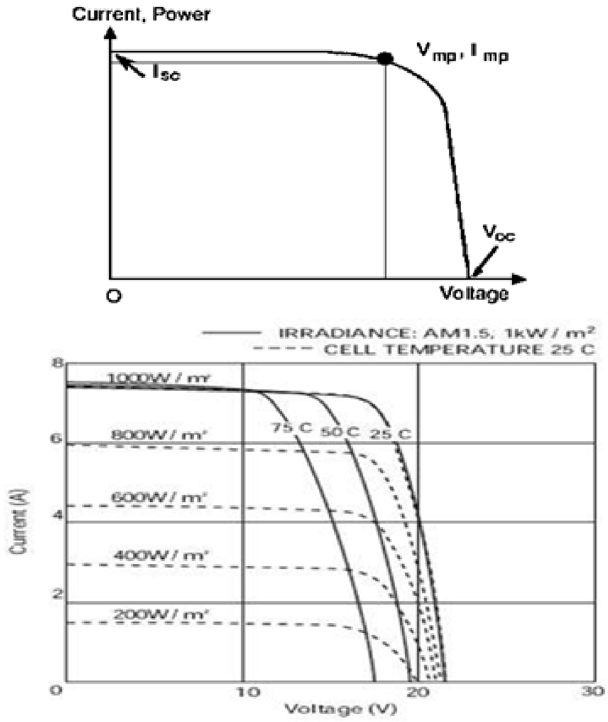

Figure 4. PV Voltage current characteristic curves

Technical data

Type: JSTY230M-96; Module efficiency: 13.5%; Cell efficiency: 15.80%; Nominal voltage: 48VDC; Power peak: 230W; Vm: 48V; Im: 7.60A; Voc58.6V; Isc: 5.15A; Power output tolerance: -0/+5W; Electrical parameters tolerance: +/- 6%; Dimension: 1575×1082×50mm

Figure 5. dimensional description if the panel (Source: http://www.alibaba.com/product)

Loads determination

Determine power consumption demands: The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows: Calculate total Watt-hours per day for each appliance used**.** Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances. Calculate total Watt-hours per day needed from the PV modules: Multiply the total.

To get total university load and total energy demand, taking the sample of one building of the university. For simplicity, since all the building of university is similar, I decided taking a sample of one building. Therefore, from consecutive of the buildings the first one building is selected at the left side of the workers staffs' gate.

Table 2. LOADS TYPES OF A SINGLE BUILDING

Loads types	No. Of units of single building	Rated power (W) of unit load	Rated power output(W)	Hours used / day	KWh / day
Room bulbs	10*3*4=120	36	4320	12	51.84
Outdoor bulbs	6*3=18	36	648	12	7.76
Toilet bulbs	6*3=18	36	648	12	7.76
Presentation projector and student mobile charge	4*3=12	60	720	10	7.2
Steps bulbs	2*3=6	36	216	12	2.55
fans	3*4*3=36	35	1980	24	47.52
Total	198	---------	8,532	----------	124.63

The buildings are similar and all are south face oriented and the top area is approximately in 5^0 inclinations. Each building is 52 m long and 10m wide. Each room contains 10 florescent bulb and 3 fans of total 12 rooms of the building in three floors. The value of loads of a sampled single room is listed in Table 2.

By assuming fudge factor of 1.3 the daily energy usage of the house with the above utilities will be, Daily Energy Usage =1.3 x 124.63= 162.019kWh/day.

And the annual energy demand is calculated by multiplying the above daily energy usage by the number of days in the year that those equipments are used. Annual Energy Demand of the house= 365 days/yr x 162.019kWh/day and Annual Energy Demand of the university building will be 59136.9kWh/year.

Sizing of the PV modules

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (WP) produced depends on size of the PV module and climate of site location. We have to consider "panel generation factor" which is different in each site location. For Thailand, the panel generation factor at least greater than 3 is assumed to be 3.43 in this specific design.

This discussion illustrates the various assumptions and tradeoffs you need to make when designing a PV system. We begin by analyzing our electrical load requirements and minimizing these loads. Then, if cost were not an issue, we could over-design the system, assuming worst-case scenarios for solar insulation, and choosing the optimum battery discharge level. In this way we could attempt to make the system fail-safe. As our resources are not infinite, we chose to design a smaller system with the understanding that it could fail during poor conditions.

Load size: the sum of all loads=Total power is=124.63 kwh/day (from Table 2).

Daily Power Demand

Inverter efficiency loss factor= 1.3(for the energy lost by the system).

Total PV panel energy needed: 1.3 X 124.63 kwh/day = 162.019kwh/day.

Inverter DC input voltage = 48V.

Amp-h/day used by AC loads: The total PV panel energy needed divided by inverter DC input voltage.

$$= \frac{162.019\text{kwh / day}}{48\text{v}} = 3375.39\text{Amh / day}.$$

Array sizing:

Battery Charge/Discharge Compensating Factor = 1.2

$$3375.39\text{Amh / day}x1.2 = 4050.475\text{Amh / day}.$$

Average Sun Hours/ day in Bahir dar is: SH = 5.8*.

$$\text{Total Solar Array Amps} = \frac{4050.475\text{Amh / day}}{5.8\text{SH}}$$

=698.35Ams

Table 3. SPECIFICATION OF INVERTER.

Specifications XW6048	XW9048(Xantrex inverters)
Nominal DC Input Voltage	12VDC
AC Output Voltage	120/240 VAC
Nominal Frequency	60 Hz
Continuous Power @ 25C	6000W
Efficiency (peak)	95%
Maximum Charging Rate	100 amps
Cost	$4,500.00

Optimum Amps of specified Solar Module Used = 7.6 Amps

$$\text{Total number of modules required:} = \frac{698.35\text{Ams}}{7.6\text{Amps}}$$

= 91.89 Modules/building ≈92 modules.

The area of a single panel is: 1.65m*0.99=1.64m^2

And the total area needed for 285 modules is: 92*1.64=150.88 m^2.from the total top building area is 52*10=520 m^2, so it is enough area to get the required power to the building.

Note: The number of modules for a single room is much greater because the loads work for 10 hrs of a day and more that it is reading space of students, so it is better if the system is connected to the grid or it should be hybrid with other power generation system.

B. Inverter sizing

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

So, for 8.532KW total power appliance required, 30% more wattage is 11.091KW capacity of inverter required.

Therefore four similar inverter of XW9048 (Xantrex inverters) type are used in series connection to attain 48V of nominal voltage of battery. The power carrying capacity of the inverters is 12,000W so it is greater than the power carrying capacity require of the inverter of the system.

C. Battery sizing

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and maximum cloudy days to be assumed 1 to 4 days. To find out the size of battery, calculate as follows:

Assumptions

- The maximum cloudy day to be assumed is 2 days.
- Battery loses in deep discharge is 50%
- The efficiency of battery is 90%.

The capacity of battery Ahs to:

$$= \frac{\text{Total load(Kwh / day)*days of autonomy}}{\text{(0.50*0.90*nominal voltage of battery)}}$$

$$= \frac{124.63\frac{\text{kwh}}{\text{day}}*2\text{day}}{0.50*0.850*48v} = 12,218.3 \text{ Amh.}$$

So, the recommended battery capacity should to carry this system rated voltage 48V and 12,218.3 Amhra. For that high value of Amhra require of the system and there is no single battery, thus small batteries connected in series that is for two days autonomy rate. Since the nominal voltage of PV panel is 48V, 2V small batteries are connected in series 24 small batteries and four batteries connected in parallel are used to 48V nominal volt of the PV panel 12,218.3Amhr of the battery requirements and totally 28 batteries are used. In the sizing of PV panel above, the calculation is that half panels are in parallel so; the output voltage of the module is 48V. This using of small batteries rather using of single large battery is good for cost efficiency.

Figure 6. AGM Marine and Leisure Battery (Source: http://www.hoppecke.com/products)

Specification of battery:

- Nominal Battery Voltage: 6V.
- Solar Charging Current: 0 to 20 Amps continuous.
- Recommended Battery Capacity: hrs autonomy is 2500Amph Hours
- Absolute maximum PV input voltage (not sustained): 30.3 VDC
- Photovoltaic Panel Voltage Ratings: 12V Nominal (17-24V Open Circuit Voltage, 56-68 cells typical).
- Absolute 100% maintenance-free
- Installation in any place, even with difficult access

D. *Solar charge controller and wire sizing*

Solar charge controller sizing

The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array.

For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3 for safety margin for the increase of current with conditions like temperature, solar intensity.

Solar charge controller rating is total short circuit current of PV array x 1.3.

Therefore the amperage of charge controller the total wattage of the system divided by the nominal voltage of the panel and result is multiplied by a safety margin (30%).

For 9,432W wattage and 48V of nominal voltage of the system;

Short cky current of charge controller (Isc) =short ckt current of array (Isca)*safety margin (25-30%) Isca short circuit current of PV:

$$\text{Isc} = \frac{8,532\text{W}}{48v}$$
$$= 177.75\text{Amp}*1.3$$
$$= 231.1\text{Amp.}$$

The charge controller needs for this system the capacity of at least 231.1Amp and 48V, the same as the nominal voltage of the battery. Its high value of current of system number of charge controllers are used since there is no charge controller of greater current of 70A. So, there are four 60A charge controllers connected in series to be used.

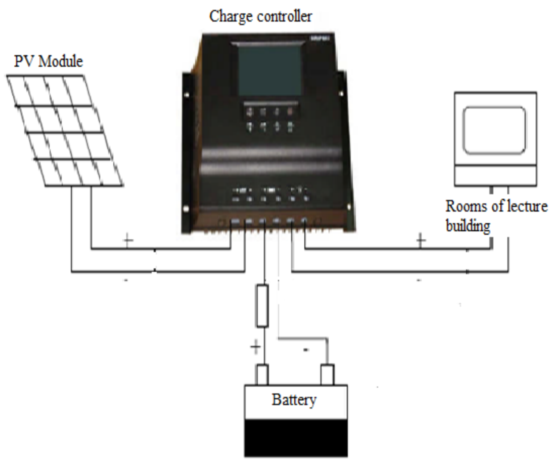

Figure 7. Charge controller system configuration.

Wiring sizing

Selecting the correct size and type of wire will enhance the performance and reliability of your PV system. The size of the wire must be large enough to carry the maximum current expected without undue voltage losses. All wire has a certain amount of resistance to the flow of current. This resistance causes a drop in the voltage from the source to the load. Voltage drops cause inefficiencies, especially in low voltage systems (12V or less). There are several different types of wire available depending on how and where it will be used. For example, there are wire types designed for resistance to sunlight exposure, high temperatures and direct burial. Specify wiring that will withstand the worst conditions.

A voltage drop greater than 5% will reduce this necessary voltage difference, and can reduce charge current to the battery by a much greater percentage. Our general recommendation here is to size for a 3-7% voltage drop. If you think that the PV array may be expanded in the future, size the wire for future expansion. Your customer will appreciate that when it comes time to add to the array.

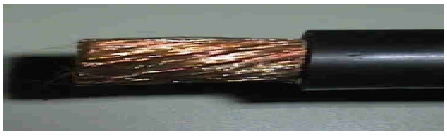

Figure 8. Typical PV wire system (Source: http://www.altestore.com)

Voltage Drop Index (VDI) (a reference number based on resistance of wire) and is determined as follows:

VDI = (AMPS x TOTAL LENGTH)/(%VOLT DROP x VOLTAGE)

For our system of the amperage of the load is (AMPS) is 393Aps and voltage of system is 24V.

Assumptions:

- Total length of wire in the building is 110ft
- Selecting of Aluminum wire for no long distance and voltage drop 3%.

$$\text{VDI} = (231.1\text{Amp x } 110\text{ft}) / (5 \text{ x } 48\text{V}) = 105.92.$$

So the area of wire in aluminums multiplying by 1.7 thus 180.064.5ft and is equal to 54.89mm^2 therefore it be according of standard table the cross-sectional area to be 55 mm^2 [7].

E. Investment cost estimation and prices of parts and HOMER optimization

The cost of system installation to integrate the buildings of BU is first getting the total cost for a single building PV installation cost, and then multflying with the total number of the university buildings which are good south equator oriented. Some investments cost like time depend and massive needs to be assumed since there is no data. Since the number of string is on there is no need of fuse protection. The quantity and cost of the parts are summarized in table below.

Table 4. INVESTMENTS COST

No	Items	Quantity	Unit price ($)	Total price ($)	Remark
1	PV panel	92	425.5	39146	Monocrystalline
2	Supporting bars and joining	..	….	3000	Square bars
3	Wiring of system and fixing structure	…	0.65/ft	1144	Insulated Al Ø55 mm2 wire
4	Storage battery	28	27.5	770	AGM Deep cycle solar battery
5	Charge controller	4	245	980	
6	Inverter	4	4,500.00	18,000	XW9048(Xantrex inverters)
8	Total $63,040.00				

The total investment cost of PV system in integrating to single building of university including new wiring is in the current price is $63,040.00 as shown in table-IV above.

Estimation of Price of Electricity of single building of university

Current Electric Tariff Structure of Ethiopian Electric Power Corporation The electric tariff for domestic use is summarized with the following Table 5.

Table 5. TARIFF OF ELECTRICITY OF EEPCO [9]

Tariff Category	Differentiation	Birr/kWh	€/kWh
Domestic (single building)	First 50kWh	0.2730	0.0273
	Next 50kWh	0.2921	0.0292
	Next 100kWh	0.4093	0.0409
	Next 100kWh	0.4508	0.0451
	Next 100kWh	0.4644	0.0464
	Next 100kWh	0.4820	0.0482
	Above 500kWh	0.5691	0.0569

Calculating the annual expense to the conventional system:

The first 50kWh =0.02730 x 50 = 1.365
Next 50kWh =0.02921 x 50 = 1.461
Next 100kWh =0.04093 x 100=4.093
Next 100kWh =0.04508 x 100=4.508
Next 100kWh =0.04644 x 100=4.644
Next 100kWh =0.04820 x 100=4.820
Used 500kwh = 20.8905 €

The remaining electricity price is obtained by subtracting the 500kWh demanded value and multiply it with 0.0569 €/kWh.

54136.9 x 0.0569 = 3364.9€= 4837.04$.

So the total amount of money that is needed per year is 3385.81€.

<u>Annual Production</u>

According to above section, this power system can produce a net energy

Production of 59136.9kWh/year (the annual energy demand of single building of university).

<u>Specific Energy Costs</u>

Using a simple Net Present Value calculation method the dynamic specific costs is estimated. To arrive at the unit cost per kWh, total average value KWh divides the total investment cost. For the life of 25 years of the system installation:

- Total Pessimistic KWh is-0.8*25 years*59136.9kWh/year =1182738.7 kWh
- Total Optimistic KWh is-1.20*25years*59136.9kWh/year =1774107 kWh
- Total average KWh is – 25years*59136.9kWh/year =1,478,422.5 kWh
- Total investment cost is – 24 years*0.1*$63,825/year +$63,825=$217,000.2.

The investment cost, the maintenance and operation cost of system first year is zero and for each years the project life is assumed 10% of the initial cost.

The specific energy cost or cost of electricity is now calculated as dividing the total average cost of the system to total investment cost:

$$= \frac{\$79{,}143}{1478422.5\text{kWh}} = 0.0535\$/\ \text{kWh} = 0.0389€/\text{KWh}.$$

F. Result and discussion

The current electricity price in Ethiopia is 0.0569€/kWh which is greater than that of the designed system since the life cycle of the system is long time. Thus, the design of PV panel to the university building is best alternative in the case of cost; although production of electricity in Ethiopia is done by EEPCO which is a government corporation the electricity price is low, it is find as BIPV system is the best option to minimize year to year cost of public electricity. In the cost comparison of grid electric use for the lecture hall buildings of the university and BIPV system, the cost grid electric price is greater than that of the total initial materials cost of PV system. It can save $153,960.2 in the 25 year life which is twice the material cost of PV system.

HOMER Implementation of the system

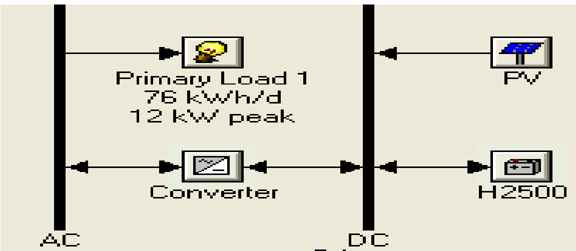

Figure 9. HOMER implementation of standalone system

The price of the PV system and its installation are important factors in the economics of PV systems. These include the prices of PV modules, the control unit, the inverter, and all other auxiliaries. The cost of installation must be taken into consideration. For the present PV system, the life cycle cost (LCC) will be estimated as:

$$LCC = IC + OM + R - S.$$

Where:

- IC- is the initial capital cost,
- OM- is the operation and maintenance cost
- R -is the repair and replacement cost and
- S- Is the salvage value. In this paper, all the costs.

The initial cost of the system of calculated value is little less than that of the HOMER optimization value is that increasing and decreasing of number of parts, operation, and maintenance, and repair cost.

PV (kW)	H2500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
20.03	112	11....	$61,198	9,044	$176,815	0.558	1.00	0.15

Figure 10. Optimizations result of HOMER

The cost results of the system are shown in Figure 11 below; the initial capital cost is $ 61,198 where the replacement cost is $1,290, and total operation and the maintenance cost is considered as $115,050, thus total cost of the system in life is $176,815.

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	39,146	0	0	0	0	39,146
Hoppecke 20 OPzS 250	4,052	1,290	0	0	-723	4,619
Converter	18,000	0	115,050	0	0	133,050
System	61,198	1,290	115,050	0	-723	176,815

Figure 11. HOMER life cycle cost of the system

Therefore, the total 25 years life cycle cost of the system is $176,815 that is quite good monetary require that need to use of natural solar energy for lighting, air conditioning and charging of student mobiles and laptops relating to the electric cost of the grid connection use the same life time years. The total money in using national grid electricity is $217,000.2 which can save $40,185.2. It is lower than that of the total electricity cost in the life of 25 years thus the BIPV for the university lecture hall buildings is feasible in relative to that of using national grid electricity.

4. Conclusion and Recommendation

Energy is the crucial aspect that need for the stepping up the standards of life, as it is increasing with time the energy consumption is also increasing rapidly. Thus the technology of energy production is also increasing thus the investigation of study and many methods of energy production are invented. Among these inventions one is BIPV which is using of PV panel on the surface of the building to get electricity.

The BIPV system introduction to the surface area of the building is the best science for the architectural beauty of the building and in addition to get the required power for the dwellers of the building. Although there no wide use of BIPV system in our country Ethiopia, the use of panels integrate to the building is clear and convincible idea for both power generation and construction material save. Ethiopia has solar energy habit, but is still not utilized and the system of utilization is not developed well.

This project provides full data for the using of PV panel integration on the tops of each well solar oriented blocks of the university. Types and quantity of the accessories and system configuration and total the investment cost is also estimated. According to the total energy demand single reference building of university, the required amount of energy from PV is determined.

For the total life time of the system, the initial investment cost and comparison made with public grid electricity power cost of EEPCO either by using analytical calculation and HOMER software.

All the systems calculated only to use solar PV for lighting and rooms comfort, and others it is good if the system is grid tied or other system aided for the system optimization. Anyone who interested to modify or going with related work of this study, can make base or reference to it.

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