FEASIBILITY STUDY HIGHLIGHTING THE BENEFITS OF SOLAR POWER OVER GRID POWER FOR CLASSROOM LOADS

A Thesis submitted in partial fulfillment of the requirements for the degree of

B.Sc. in Electrical & Electronic Engineering

By

Sharzana Reza

ShadmanSakibPatwary

Rashik Ahmed

Supervisor

Dr. AKM Abdul Malek Azad
Associate Professor, EEE Department

Department of Electrical and Electronics Engineering,
BRAC University

April, 2013

DECLERATION

We do hereby declare that the thesis titled “feasibility study highlighting the benefits of solar power along with grid power for classroom loads” is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

Date:

Supervisor

____

Dr. AKM Abdul Malek Azad
Associate professor,
Department of Electrical and Electronics Engineering

____

Sharzana Reza
Student ID: 09221042

____

ShadmanSakibPatwary
Student ID: 09221222

____

Rashik Ahmed
Student ID: 09221226

ACKNOWLEDGMENT

Firstly, we would like to express our sincere and firm gratitude and pay a lot of thanks to our honorable thesis supervisor **Dr. A K M Abdul Malek Azad**, Associate Professor, Department of Electrical and Electronic Engineering (EEE), BRAC University; for his supportive guidance, feedback, inspiration and encouragement that made it easier for us to finish the thesis work properly in proper time. And we also thank each and every other individual without whose contribution this project couldn't be completed.

ABSTRACT

Electricity is a very important factor in developing the economy and the standard of living of a country. Bangladesh largely depends on natural gas and hydro power stations to generate major portions of power. The country lacks behind than its expected production capacity. Though many power generation units have been added to the national grid to solve the power crises issue, it's not yet enough. High demand and increasing need of power have created challenge for the power stations to meet the demand. From that concept of renewable energy such as solar energy, this thesis has aimed to launch a cost effective solar based system in one of the classrooms of the university, UB 20903. Here it's mainly to run a fixed amount of loads, such as solar dc stand fans and LED lights, by using solar panel connected directly along with national grid using a controller device. This whole system was represented in the form of a prototype, where a 75 watts panel and a power supply representing grid power was used to connect to seven led lights and one dc fans through a controller. And based on this prototype,working and calculations was carried outfor the cost effectiveness and the feasibility of setting up of such project in reality. Use of software like HOMER was also shown for calculation validation. Taking initiative of such project two needs can be fulfilled. First of all is the reduction in the overall cost of huge current bill per year at a satisfactory level which would be a bright finding for BRAC University. Secondly, according to Bangladesh perspective it would be green process that may bring a very highlighting positive result in economic and environmental prospect.

TABLE OF CONTENT

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

Energy is one of the most important components required to eradicate poverty, realize socio-economic and human development but the energy that the world is widely dependent on right now, that is, fossil fuel like Natural gas, Coal and Oil is being depleted at a high rate. So the world is observing a major transition in the energy sector. It is shifting its dependence to Renewable Energy sources. The sustainable energy transition is a central topic in debates across Europe and within countries [1]. From the field of transition studies, it becomes clear that energy transition is not only a buzzword but a fundamental process of structural change [1]. As we are entering this transition, fundamentally new demands are being placed upon existing decision making structures and regulatory frameworks [1]. Renewable energy is energy that comes from resources which are continually replenished such as sunlight, wind, rain, tide, waves and geo thermal heats [2]. About 16% of global final energy consumption comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity [2]. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly. The share of renewables in electricity generation is around 19%, with 16% of electricity coming from hydroelectricity and 3% from new renewable [2]. Among all the renewable energy sources, solar and wind has attained most popularity but for countries like Bangladesh which are in the developing stage and where the amount of open land accessible to high winds is less, their only option is to rely on solar energy which is accessible everywhere indiscriminately.

Radiations from the Sun that can produce heat, generate electricity, or cause chemical reactions. Solar collectors collect solar radiation and transfer it as heat to a carrier fluid [3]. It can then be used for heating [3]. Solar cells converts solar radiation directly into electricity by means of the photovoltaic effect [3]. The energy transmitted from the Sun [3]. The upper atmosphere of Earth receives about 1.5×10^{21} watt-hours (thermal) of solar radiation annually [3]. This vast amount of energy is more than 23,000 times that used by the human population of this planet, but it is only about one two-billionth of the Sun's massive outpouring—about 3.9×10^{20} MW [3]. Solar research and technology development aim at finding the most efficient ways of capturing low- density solar energy and developing systems to convert captured energy to useful purposes [3]. Government of Bangladesh (GOB) has issued its Vision and Policy

Statement in February 2000, to bring the entire country under electricity service by the year 2020 in phases, in line with the direction of the Article 16 of 'The Constitution of the People's Republic of Bangladesh,' to remove the disparity in the standards of living between the urban and rural areas through rural electrification and development [4]. The government plans to implement a mega project of setting up 500 megawatts solar panel-based power installations with financial support of the Asian Development Bank (ADB) [5].

1.2 Literature Review

In order to complete this paper work appropriately different source of findings and studying is done. Calculations are very much based on the general techniques as used often considering all present conditions and values. Basically Internet web source is used to find and research on all recent updates on solar based systems, which helped to get a clear view on the project in detail. Few journals and paper works of IEEE especially of solar projects help to determine the steps of approach to work. The project is mostly based on the prototype that will be shown later in the chapters. The special homer software is used to validate the calculation. This software determines the economic feasibility of a hybrid energy system optimizes the system design and allows users to really understand how hybrid renewable systems work. For this project homer showed the economic feasibility of using both panel and grid connection at the same time.

1.3 Objective and system overview

The prime objectives of this thesis work are focusing on the use of both the solar power and the grid power at the same time, to power the loads of one of the classroom of BRAC University, UB20903. This is possible by the use of a controller circuit that will combine both the powers achieved in such a way so that the maximum amount of power that be receive will be from the panels and the rest combining the necessity will be the grid power. The measure of feasibility and the payback time of the project is the main goal. In this thesis work we implemented the whole project in to a prototype, which is concentrated onto a 75 watts panel and a power supply which represents the grid power through a controller which identifies the controller circuit, and these together running around 7 led lights and a 1 dc stand fan. Here these loads were adjusted in such a way so that a full load power is drawn from the 75 watts panel and power supply will keep on adjusting the rest of the required current. The block diagram shows the system overview of the thesis considering the prototype.

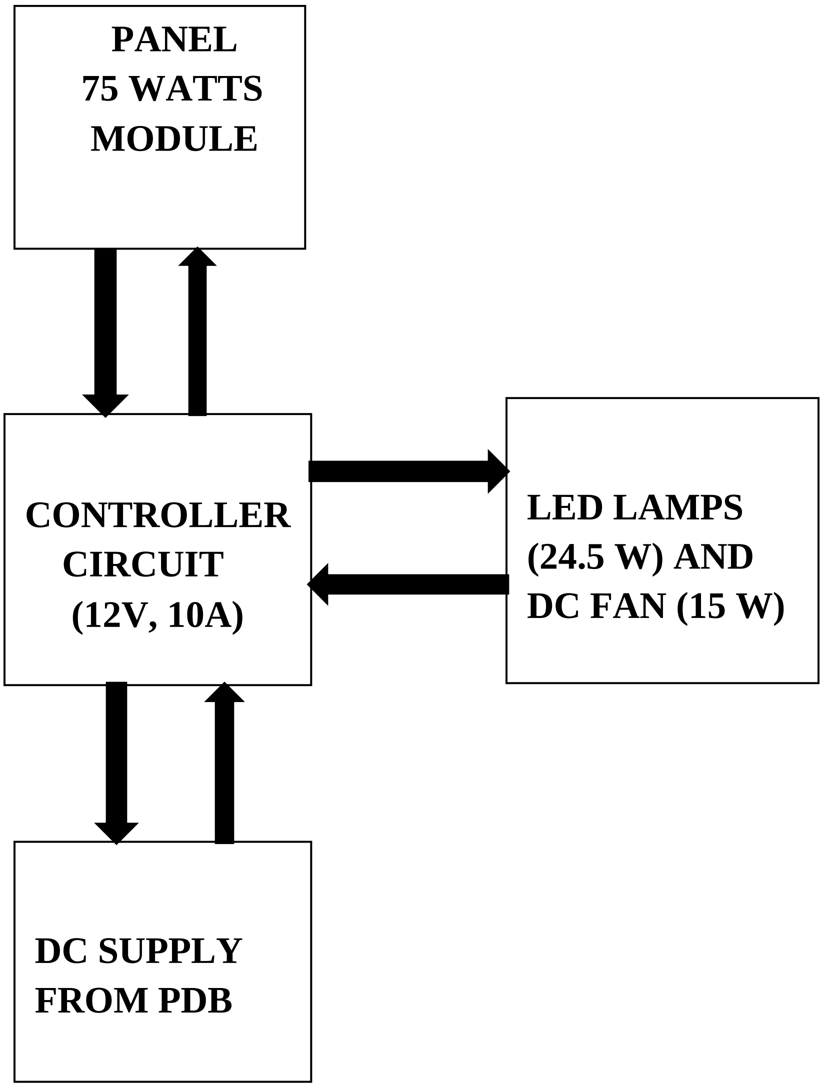


Figure1.1: Block diagram of system overview

1.4 Chapter Overview

The rest of the dissertation is organized as following:

Chapter 2: Component Description

This chapter describes the components that were used to complete the thesis work. Each of the components has some specific features which can be very effective in this sort of projects. Such as solar panels, led and fluorescent tubes, dc stand fan, controller circuit, power supply etc. Each of them is explained with detail description and diagram for better knowledge.

Chapter 3: Luminous Flux Test of Fluorescent and Led tubes

This chapter deals with the lumen test of both the fluorescent and led tube. A proper method along with description is thoroughly described. A brief overview on detail calculation of replacing the fluorescent tube lights with the led tube lights is included. Tables and calculations and figures gives more better knowledge to understand the ways of determination. For proper understanding and implementation of the thesis work this chapters has a great impact on the next upcoming chapters.

Chapter 4: The Design of Prototype System and Analysis of Data Taken

This chapter is the heart of this thesis that shows the actual data and further analysis of it in various ways. It consists of data table and different graphs and bar chart that describes how effective can this thesis be, if it's performed in reality.

Chapter 5: Panel Calculation and Use of Homer software

This following chapter will be divided into two parts. First part contain the basic calculations that will verify the total number of panels required as well as the specifications of the panels that will give the best output for the class room loads. And the second part of the chapter will talk about the "HOMER" software which will give the validation of the system calculation as well as the percentage of energy share by grid and solar panel.

Chapter 6: Payback Calculation

This chapter is the main focus and result of the thesis project that shows the calculations and verification of the money that can be saved by BRAC University and the time that is required to overcome the initial cost in introducing the project in reality. It consists of all the calculations based on the actually present rate of electricity, and the cost of all the primary products that will be required.

Chapter 7: Conclusion and Future Work

In this last chapter the main result of this dissertation is summarized, and some concluding remarks and identifies potential directions for future work has been given.

CHAPTER 2

COMPONENT DESCRIPTION

2.1 Introduction

To work with solar renewable energy we need to have idea about some of the basic elements of solar based system. Each of the components has some specific features which can be very effective in this sort of projects. There are huge works, research, thesis, implementation, design consideration and improvement utilizing all these solar components are going on around the world as well as in our country. This chapter deals with all the components that we used or can be used for future modification.

2.2 Solar Panel

Solar panels are devices that convert light into electricity. They are called "solar" panels because most of the time, the most powerful source of light available is the Sun, called Sol by astronomers. Some scientists call them photovoltaic which means, basically, "light-electricity"[6]. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications [7]. There are different types of solar panels are available in the market. For this classroom project its prefered to use the mono crystalline silicon solar panel, of 100 watts, nominal voltage (Vmp) 17.2V, nominal current (Imp) 5.8A, open circuit voltage (Voc) 21.6V, short circuit current (Isc) 6.46A, number of cell 36, weight 8.65 kg, power tolerance 3%.

2.2.1 Mon crystalline silicon solar panels – The Most Efficient

These are also known as “mono silicon” or “single silicon” panels and are the best in terms of efficiency. Because they’re more efficient than other types of panels, you don’t need as many panels to generate the same amount of electricity. That makes them especially useful in certain cases, like when part of your roof is shaded and you have a smaller surface area to work with [8].

Figure 2.1: Mono crystalline Panel

2.2.2 Polycrystalline silicon panels – Less Efficient but Less Expensive

This type of panel doesn’t contain as much silicon as mono crystalline panels (that isn’t at all apparent from the name, which means ‘many’ vs. mono, which means one). They’re also called multi-silicon, multi crystalline, or ribbon panels. Since they don’t have as much silicon, they’re a little less efficient, though other aspects of their design can help improve efficiency. They’re usually a little less expensive than mono crystalline panels [8].

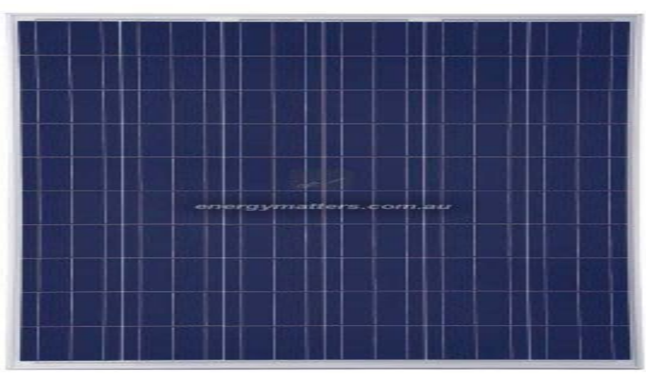


Figure 2.2: Polycrystalline Panel

2.2.3 Building integrated photovoltaic (BIPVs) – The Most Expensive

These are designed to be part of a building, rather than something that's added on. Solar shingles are one example of BIPVs; they're made to look like regular roofing tiles (sometimes called 'solar roofing tiles'), which some people prefer. Unfortunately, they're very expensive, and much less efficient than other types of solar panels. They also don't last as long. Because other types of solar panels are better options right now, BIPVs aren't as widely available as the other types of solar panels [8].

2.2.4 Thin film panels – Prepare to cover everything

This type of panel uses thin, light weight layers of a photovoltaic material (like cadmium telluride or amorphous silicon, for example). They're cheaper than other types of solar panels and are better able to work in hot weather. They're not efficient, so you'd need many, many more of them to make the same amount of electricity. They're used in huge projects, like a 10MW plant in the desert near Las Vegas, but they're not really the best option for someone's household roof [8].

Figure 2.3: Thin Film Panel

2.3 Controller Circuit

A controller circuit will be considered the backbone of this thesis work. This controller limits the rate at which the current will be delivered to the loads. Here these loads were adjusted in such a way so that a full load power is drawn from the 75 watts panel and power supply will keep on adjusting the rest of the required current. This mechanism important because it will control the amount of current flow. For thesis prototype this device initially was not made as it requires more cost, so in place of it a charge controller was used without the battery port terminal. Its functions in the similar pattern as seen in several test results and give a good relevant output.

Charge controllers are specified by both amperage and voltage. One will need a controller that matches the voltage of the solar panel array and battery bank (usually 12, 24 or 48 VDC). And one should make sure that the solar charge controller has enough capacity to handle the current (in amps) from the solar panel array [9]. For this prototype project it require a charge controllers of each 10 A, 12V, power 120 Watts.

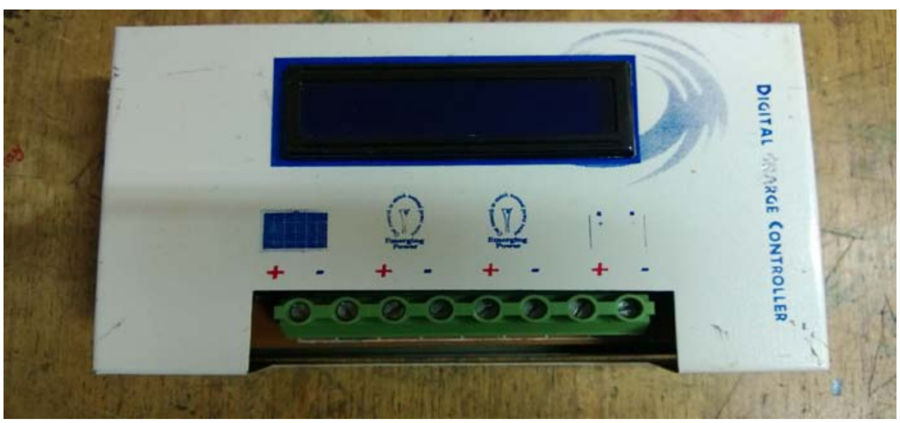


Figure 2.4: Charge Controller

2.4 Solar DC stand fan

Fans are nearly ideal solar powered loads. It is specified of 15 watts, 12 V. They can run directly off DC, (as with all of the following products). Basically solar powered fans run when they are needed the most - when the sun is shining. During summer months, the attic temperatures can reach 150F. High temperatures cause an increase in temperature in the living space and an increase in energy consumption by air conditioning equipment. Forced ventilation will circulate cooler air through the attic space and lower the temperature. Fan and solar module combinations allow daytime ventilation and air circulation anywhere the sun shines. They are great for greenhouses, kennels, barns and attics where AC power is not available. The solar module runs the fan at full power in full sun and at a slower speed in overcast weather. Operation is automatic. When the sun shines on the solar module, the fan begins to operate [10].

Figure 2.5: Solar DC Stand Fan

2.5 DC Led Tubes

Rapid developments in solar cells, LED lighting and energy storage are creating great opportunities for solar-powered solid-state lighting. Solar electric lighting systems do in fact connect to a truly "infinite" power source - the sun. However, as we all know, this source is intermittent. In the case of solar outdoor lighting, the power source is inversely related to the load (the lights turn on when the sun goes down). This relationship leads to an important conclusion; the system must rely on energy storage (e.g. batteries), unless it remains connected to grid. LEDs produce directional beams of light, up to 90% of which is usable for ambient lighting and 70% of which is useable for task lighting. For our purpose we planned to use led tube of 12V, rated power 3.5 Watts, rated current 290mA and luminous flux 330 lm.

Figure 2.6: DC LED Light

There is a rising demand on the energy sector for rapid industrialization, urbanization, high population growth, increasing food production, rising standard of living etc. In this regard solar energy can play a vital role. To implement this system in our country we have to deal with its components. Thus we can make sure of an effective solar system.

.

CHAPTER 3

LUMINOUS FLUX TEST OF FLUORESCENT AND LED TUBE

3.1 Introduction

In this chapter a clear overview of the lumen test is discussed. A proper method along with description is thoroughly shown. A brief overview on detail calculation of replacing the fluorescent tube lights with the led tube lights is clearly defined. Tables and calculations and figures are thoroughly described. For proper understanding and implementation of the thesis work this chapters has a great impact on the next upcoming chapters.

3.2 Lumen

The lumen is the SI derived unit of luminous flux, a measure of the total "amount" of visible light emitted by a source [11]. Luminous flux differs from power (radiant flux) in that luminous flux measurements reflect the varying sensitivity of the human eye to different wavelengths of light, while radiant flux measurements indicate the total power of all light emitted, independent of the eye's ability to perceive it [11]. A lux is one lumen per square meter [11].

The lumen is defined in relation to the candela as, 1 lm = 1 cd·sr [11].

The lumen can be thought of casually as a measure of the total "amount" of visible light in some defined beam or angle, or emitted from some source [11]. The number of candelas or lumens from a source also depends on its spectrum, via the nominal response of the human eye as represented in the luminosity function [11].

The difference between the units lumen and lux is that the lux takes into account the area over which the luminous flux is spread. A flux of 1000 lumens, concentrated into an area of one square meter, lights up that square meter with an illuminance of 1000 lux [11]. The same 1000 lumens, spread out over ten square meters, produces a dimmer illuminance of only 100 lux. Mathematically, $1\ lx = 1\ lm/m^2$ [11].

3.3 Luminous Flux Test

Determination of the total luminous flux from a light source can be done by placing the source in the centre of an imaginary hemisphere and measuring the illuminance from the source at different locations (meridian angles,θ and parallel angles,ϕ) of the hemisphere. This allows illuminance measurements for a small zone (*dA*) on the surface of the hemisphere and enables determination of the luminous flux in that area. The total luminous flux emitted from the source can then be determined by summing up the luminous flux of individual zones on the surface of the sphere/hemisphere.

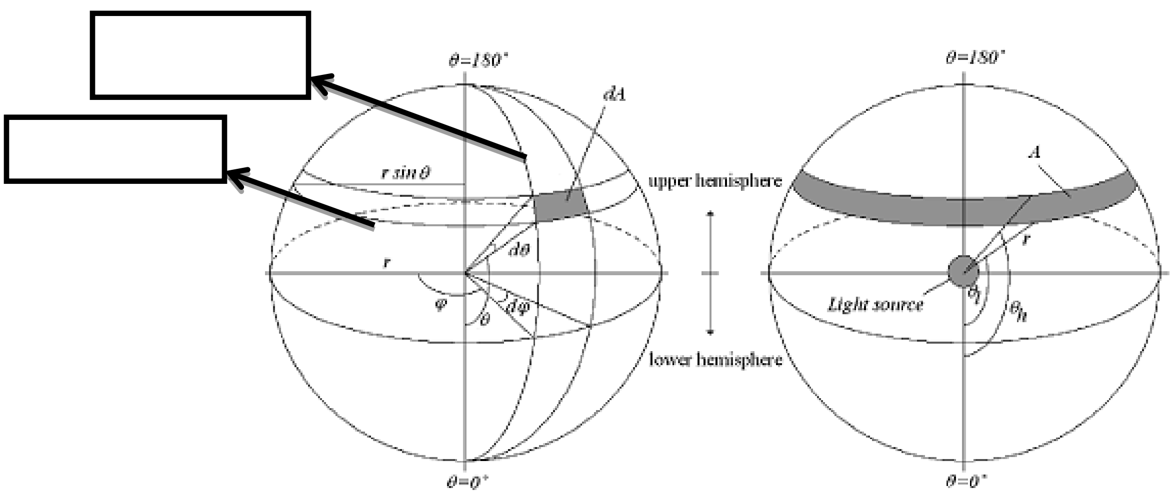


Fig3.1: Imaginary hemisphere for lumen test

θ (Meridian angle) is the angle between the plane on which the LED is mounted and the photometer head.

ϕ (Parallel angle) is the angle between the reference axis of the plane and the line along which the photometer head is rotated.

3.3.1 Procedure of Luminous Flux test

The following describes the procedure used at the laboratory of BRAC University for measuring the illuminance of a led tube or a fluorescent tube over the surface of a hemisphere.

a. The LED tube or the fluorescent tube is placed on a highly reflective plane that has a radius of 1m or more from the center of the lamp.
b. Illuminance readings are measured by a lux meter and recorded for a certain meridian at different parallels from 0̊ -90˚ at 15˚ intervals at a fixed distance of 1m from the center lamp.

c. Step 2 is repeated for 0˚-90˚ meridian angles at 10˚ intervals.
d. An average illumination for each meridian interval is calculated.
e. The illumination, E (θ, ϕ) is put into equation (1) to calculate the total luminous flux.

$$\Phi_V \text{ (lumen)} = r^2 \int_{\theta=0}^{\theta=\pi/2} \int_{\emptyset=0}^{\emptyset=2\pi} E(\theta, \emptyset) \operatorname{Sin}(\emptyset)\, d\emptyset\, d\theta \qquad \ldots\ldots(1)$$

3.4 Luminous Flux Test of a Fluorescent Tube

	Meridian Angle θ	Parallel angle ϕ	0	15	30	45	60	75	90		
	Angle in degree of point of measurement	**Measurement interval in degree**	**Illuminance (lux)**							**Average Illuminance on the meridian angle E_0 (θ,ϕ) (lux)**	**Illuminance on the meridian interval E_I (θ,ϕ) (lux)**
	90		18	18	18	18	18	18	18		
		90 - 80								17.214	2.990
	80		18	17	16	14	16	17	17		
		80 - 70								16.143	2.718
	70		18	15	17	15	15	15	16		
		70 - 60								15.857	2.506
	60		19	18	17	15	14	14	14		
		60 - 50								15.357	2.193
	50		16	16	17	15	14	13	13		
		50 -40								13.857	1.708
	40		15	14	14	13	12	11	11		
		40 - 30								12.214	1.221
	30		14	14	13	12	11	9	8		
		30 - 20								10.286	0.758
	20		12	11	11	10	8	6	5		
		20 - 10								8.357	0.377
	10		12	11	10	8	6	4	3		
		10 - 0								7.786	0.118
	0		13	11	11	8	8	3	1		
		Total Illuminance on a meridian line for one-eighth of the hemisphere (lux)									**14.590**
		Total luminous flux over the surface area of 2m radius hemisphere Φ_V (lumen)									**733.482**
		Luminous efficacy (lumen/watt)									**66.680**

Table3.1: Luminous flux test of a fluorescent tube.

As procedure stated above the following meridian and the parallel lines are marked with proper measurement tape. Each detail points that are mentioned above in the luminous test procedure are properly done. Soon after that the test with the fluorescent tube that is present in the class room was carried off. It's of following specification 18 watts, 2ft and 50 Hz. As per mentioned the rated lumen of this specific tube at rated power was given 1050 lux. Due to some inconvenience in the light holder the test couldn't be performed in the maximum power output, rather the tested conditions are found to be different in lab. It's mentioned down in table no 3.2.

Test conditions		
Input voltage	220	V
Input current	0.05	A
Input Power	**11**	**W**

Table3.2: Test conditions of fluorescent tube

By calculating the total illuminance on a meridian line for one-eighth of the hemisphere was found to be 14.590 lux. And the resulted lux was further put in the equation (2) and total luminous flux over the surface area of 2m radius hemisphere, Φ_V was deduced to be 733.482 lumen.

$$\Phi_V = \{14.590 \times 2 \times \pi \times r\hat{}2\} \times 2 \qquad \ldots\ldots (2)$$

$$\text{Luminous efficacy} = \Phi_V \,/\, \text{input power} \qquad \ldots\ldots (3)$$

Finally the luminous efficacy was further calculated from equation (3) which was **66.680 lumen per watt**. This luminous efficacy is very important for lumen test; because in whatever input power the test is performed the luminous efficacy will remain same. So for maximum rated power that is 18 watts the luminous flux was found to be **1200.2427 lumen**, which is similar to the rated lumen that was mentioned earlier.

3.5 Luminous Flux Test of a Led Tube

Meridian angle θ	Parallel angle ϕ	0	15	30	45	60	75	90		
Angle in degree of point of measurement	**Measurement interval in degree**	**Illuminance (lux)**							**Average Illuminance on the meridian angle $E_0(\theta,\varphi)$ (lux)**	**Illuminance on the meridian interval $E_I(\theta,\varphi)$ (lux)**
90		17	17	17	17	17	17	17		
	90 - 80								17.643	3.064
80		20	21	16	20	15	19	17		
	80 - 70								18.429	3.103
70		21	19	20	20	16	17	17		
	70 - 60								17.214	2.720
60		19	17	16	15	14	15	15		
	60 - 50								15.214	2.173
50		18	15	16	16	13	13	11		
	50 -40								14.857	1.832
40		19	15	14	14	17	10	17		
	40 - 30								13.357	1.336
30		18	14	12	14	7	10	6		
	30 - 20								10.571	0.779
20		10	15	13	10	6	7	6		
	20 - 10								9.714	0.438
10		13	12	15	9	11	5	4		
	10 - 0								7.643	0.116
0		1	1	5	6	9	5	11		
	Total Illuminance on a meridian line for one-eighth of the hemisphere (lux)									**15.561**
	Total luminous flux over the surface area of 2m radius hemisphere Φ_V (lumen)									**391.150**
	Luminous efficacy (lumen/watt)									**74.081**

Table 3.3: Luminous flux test of a led tube

The lumen test of a led tube is carried out in the same manner like the lumen test of fluorescent tube light. The test conditions are as following in table.

Test conditions		
Input voltage	12	V
Input current	0.44	A
Input Power	**5.28**	**W**

Table3.4: Test conditions of a led tube

By calculating the total illuminance on a meridian line for one-eighth of the hemisphere was found to be 15.561 lux. And the resulted lux was further put in the equation (2) and total luminous flux over the surface area of 2m radius hemisphere, Φ_V was deduced to be 391.150 lumen. Finally the luminous efficacy was further calculated from equation (3) and found to be 74.081 **lumen per watt.**

This test results is used for calculating how many led tubes will be required to replace one fluorescent tube.

No of led tubes required=

$$\boldsymbol{total\ luminous\ flux\ of\ fluorescent\ tube \div total\ luminous\ flux\ of\ one\ led\ tube}$$

=1200 lumen $\div$ 391.150

= 3.067

≈ 3 Led tubes

3.6 Luminous Flux Test of Three Led Tubes

Meridian Angle θ	Parallel angle ϕ	0	15	30	45	60	75	90		
Angle in degree of point of measurement	**Measurement interval in degree**	**Illuminance (lux)**							**Average Illuminance on the meridian angle E_0 (θ,ϕ) (lux)**	**Illuminance on the meridian interval E_I (θ,ϕ) (lux)**
90		55	55	55	55	55	55	55		
	90 - 80								54.286	9.428
80		55	56	54	50	54	53	53		
	80 - 70								52.571	8.853
70		54	52	53	51	52	49	50		
	70 - 60								49.643	7.844
60		52	52	51	48	44	44	43		
	60 - 50								45.286	6.468
50		44	44	45	44	43	41	39		
	50 -40								38.500	4.746
40		41	38	40	33	32	28	27		
	40 - 30								31.214	3.122
30		37	37	32	29	24	21	18		
	30 - 20								24.857	1.832
20		31	27	26	22	19	14	11		
	20 - 10								18.214	0.822
10		21	22	21	15	12	8	6		
	10 - 0								10.500	0.160
0		8	7	6	6	6	5	4		
	Total Illuminance on a meridian line for one-eighth of the hemisphere (lux)									**43.274**
	Total luminous flux over the surface area of 2m radius hemisphere Φ_V (lumen)									**1087.737**
	Luminous efficacy (lumen/watt)									**86.328**

Table3.5: Luminous flux test of three led tubes.

As seen above in table number 3.5 the lumen test of three led tube was performed using the same procedure. The test conditions are shown down in table 3.6.

Test conditions		
Input voltage	12	V
Input current	1.05	A
Input Power	12.6	W

Table3.6: Test conditions of three led tubes

By calculating the total illuminance on a meridian line for one-eighth of the hemisphere was found to be 43.274 lux. And the resulted lux was further put in the equation (2) and total luminous flux over the surface area of 2m radius hemisphere, Φ_V was deduced to be 1087.737 lumen. Finally the luminous efficacy was further calculated from equation (3) and found to be 86.328 lumen per watt. Finally we can conclude that the total luminous flux for three tubes yield 1087.737 lumen which is equivalent to one fluorescent tube of lumen 1050 lux.

Our main focus is to replace the fluorescent tubes with the led tubes in the classroom UB0923 based on the luminous flux.

Total luminous flux in classroom based on fluorescent tube = no of fluorescent tubes × Luminous flux per tube

$= 36 \times 1200$

$= 43200$ lumen

Luminous flux of one led tube= total luminous flux of three led tubes ÷ no of led tubes taken

$= 1087.737 \div 3$

$= 362.579$ lumen

No if led tubes required for the classroom= Total luminous flux in classroom based on Fluorescent tube÷ Luminous flux of one led tube

$$= 43200 \div 362.579$$

$$= 119.146$$

$$\approx 120 \text{ Led tubes}$$

In concluding it can be summed up that 36 fluorescent tubes of 18 watts, 2 ft. each can be replaced with 120 led tubes of 3.5 watts, 1 ft. which will give out the equivalent lumen required. In the next preceding chapters we will see how this result achieved is used in for further calculations.

CHAPTER 4

THE DESIGN OF PROTOTYPE AND ANALYSIS OF DATA TAKEN

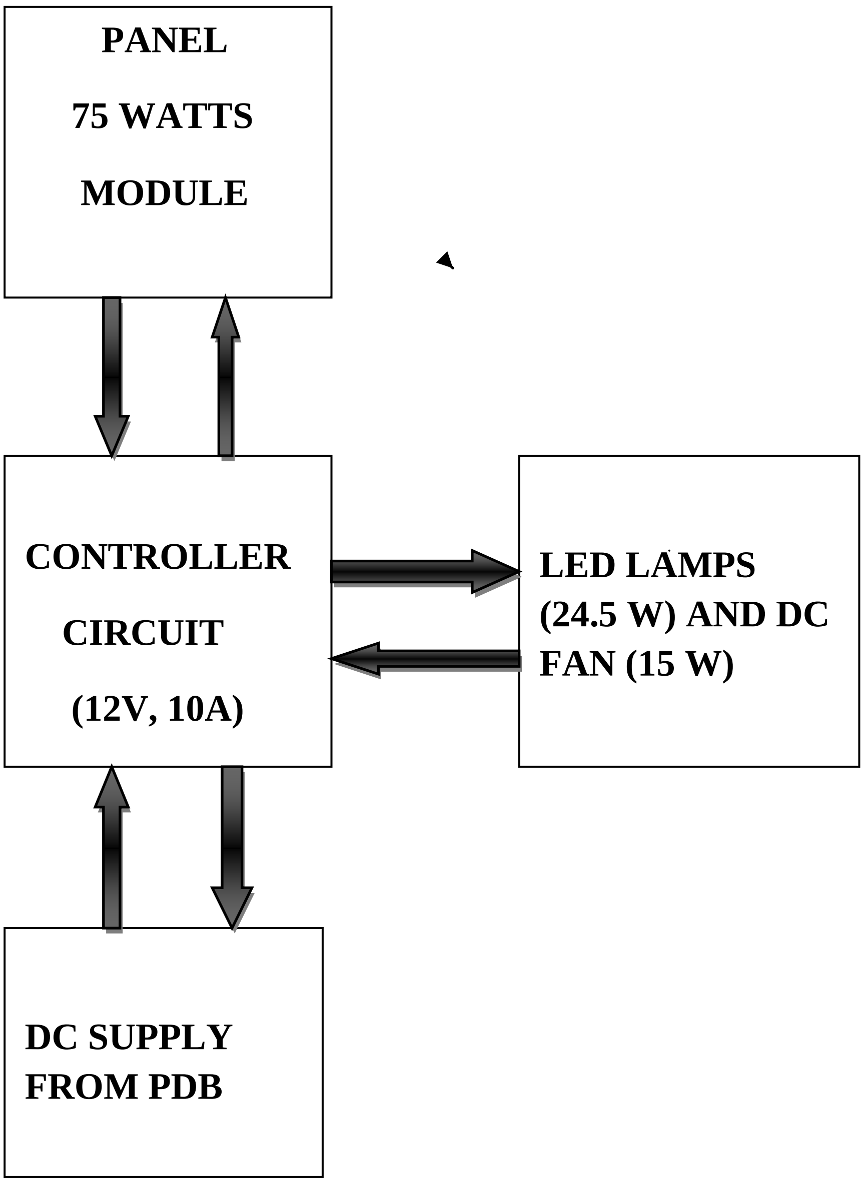
4.1 Introduction

Energy has become one of the most significant ingredients to eradicate poverty. Thus the world is giving more emphasis on renewable energy sources such as solar energy. Our country has serious shortage of electrical energy. In this regard, our project can hold promises of contribution towards the growth of the power sector in Bangladesh. The primary aim of our project is to decline electricity consumption from the national grid. The project focuses mainly on replacing the existing lights and fans with low energy DC LED lamps and DC fans respectively in one of the classrooms of BRAC University.

4.2 Operating System

The subject classroom has 36 lamps each of 18W and 1050 lumen. Lumen is the measurement of the total amount of visible light emitted from a source. These lamps can be replaced by LED lamps of 330 lumen each. To match the existing lumen approximately 120 LED lamps are required for the whole classroom along with 4 DC stand fans of 15W each. Therefore to implement the whole project firstly a prototype system was designed and tests were carried out on 75W system with 7 LED lamps (total of 26.83W) and 1 DC fan of 15W. The test was performed using a controller with the inputs of DC power source and the solar panel. This test was accomplished in the month of March. The relevant block diagram of the prototype test is given below.

4.2.1 Block Diagram of Prototype Design



This designed block diagram is shown previously, but in this chapter the main implementation and detail analysis is carried out.

4.2.2 Load Specification and Data table

LED lamps = 26.83W

For 12V system,

Current in LED lamps = 26.83W/12V = 2.235A

DC fan = 15W

For 12V system,

Current in fan = 15W/12V = 1.5A

Total current = 1.5A + 2.235A = 3.735A

Total power = LED lamp power + fan power

= 26.83W + 15W

= 41.83W

Figure 4.1: Prototype setup design

Figure 4.2: Close view of the Led tubes connected to Dc power supply

Eventually this experimented was done throughout a whole day on 23rd of March, 2013 according to the block diagram of the prototype project. Data was taken starting from 9:30 am to 4:50 pm using loads of DC LED lamps and the DC fan. Throughout the experiment the panel voltage, grid voltage, and panel current, grid current, current of fan, current of lights and voltage of the overall loads were measured. The figure 4.1 and 4.2 shows how the prototype was set up in the roof top of BRAC University. The suitable data for this prototype project is given below.

From the above experimental data from 9:30 am till 5:00 pm, some of the relations amongst various parameters that are given in table 4.1 and 4.2 have been portrayed.

	Input									
Time	Panel Voltage(V)	Panel Current(A)	Panel Power(W)	Grid Voltage(V)	Grid Current(A)	Grid Power(W)	Total Input Current(A)	Total Input Power(W)	Panel % Share	Grid % Share
9:30	13.48	0.93	12.54	13.10	2.34	30.65	3.27	43.19	29.03%	70.97%
9:50	13.41	0.85	11.40	13.00	2.40	31.20	3.25	42.60	26.76%	73.24%
10:05	13.45	0.69	9.28	13.10	2.56	33.54	3.25	42.82	21.68%	78.32%
10:20	13.75	1.51	20.76	13.20	1.77	23.36	3.28	44.13	47.05%	52.95%
10:35	14.18	2.71	38.43	13.70	0.51	6.99	3.22	45.41	84.62%	15.38%
10:50	14.22	2.83	40.24	13.80	0.43	5.93	3.26	46.18	87.15%	12.85%
11:05	14.36	3.18	45.66	14.10	0.04	0.56	3.22	46.23	98.78%	1.22%
11:20	13.53	0.92	12.45	13.50	2.32	31.32	3.24	43.77	28.44%	71.56%
11:35	14.85	3.37	50.04	14.10	0.02	0.28	3.39	50.33	99.44%	0.56%
11:50	13.85	2.80	38.78	13.80	0.94	12.97	3.74	51.75	74.87%	25.13%
12:05	14.08	3.09	43.51	13.10	0.10	1.31	3.19	44.82	97.08%	2.92%
12:20	13.30	1.27	16.89	13.10	2.19	28.69	3.46	45.58	37.06%	62.94%
12:35	14.09	3.18	44.81	13.10	0.41	5.37	3.59	50.18	89.30%	10.70%
12:50	14.85	3.39	50.34	13.50	0.02	0.27	3.41	50.61	99.47%	0.53%
13:05	13.33	1.29	17.20	13.10	1.85	24.24	3.14	41.43	41.50%	58.50%
13:20	13.75	2.75	37.81	13.80	0.24	3.31	2.99	41.12	91.95%	8.05%
13:35	13.90	1.92	26.69	13.70	1.09	14.93	3.01	41.62	64.12%	35.88%
13:50	14.03	3.00	42.09	13.80	0.25	3.45	3.25	45.54	92.42%	7.58%
14:05	13.98	2.78	38.86	13.60	0.50	6.80	3.28	45.66	85.11%	14.89%
14:20	13.79	2.26	31.17	13.60	0.99	13.46	3.25	44.63	69.83%	30.17%
14:35	13.65	2.01	27.44	13.10	1.28	16.77	3.29	44.20	62.07%	37.93%
14:50	13.83	2.39	33.05	13.10	0.85	11.14	3.24	44.19	74.80%	25.20%
15:05	13.79	0.75	10.34	13.10	2.44	31.96	3.19	42.31	24.45%	75.55%
15:20	13.51	2.04	27.56	13.20	1.18	15.58	3.22	43.14	63.89%	36.11%
15:35	13.10	0.85	11.14	13.10	2.41	31.81	3.26	42.95	25.93%	74.07%
15:50	12.80	1.32	16.90	13.10	1.91	25.02	3.23	41.92	40.31%	59.69%
16:05	13.22	0.75	9.92	13.10	2.49	32.62	3.24	42.53	23.31%	76.69%
16:20	13.08	0.53	6.93	12.90	2.68	35.11	3.21	42.04	16.49%	83.51%
16:35	13.04	0.36	4.69	12.70	2.84	36.64	3.20	41.33	11.36%	88.64%
16:50	12.96	0.30	3.89	13.10	2.90	36.83	3.20	40.72	9.55%	90.45%
Average	13.71	1.87	26.03	13.34	1.40	18.40	3.27	44.43	57%	43%

Table 4.1: Input values of the prototype

Time	Output				
	Load Voltage(V)	Light Current(A)	Fan Current(A)	Total Output Current(A)	Total Output Power(W)
9:30	13.10	2.05	1.16	3.21	42.10
9:50	12.90	2.07	1.12	3.19	41.14
10:05	13.10	2.09	1.14	3.23	42.27
10:20	13.08	2.08	1.16	3.24	42.31
10:35	12.96	2.08	1.16	3.24	41.93
10:50	12.90	2.08	1.17	3.25	41.86
11:05	12.99	2.08	1.21	3.29	42.71
11:20	12.51	2.07	1.14	3.21	40.17
11:35	12.91	2.07	1.16	3.23	41.73
11:50	12.66	2.07	1.17	3.24	41.03
12:05	12.79	2.07	1.18	3.25	41.53
12:20	12.66	2.07	1.09	3.16	39.95
12:35	12.61	2.07	1.13	3.20	40.33
12:50	12.61	2.07	1.25	3.32	41.89
13:05	12.54	2.07	1.12	3.19	39.96
13:20	13.06	2.07	1.13	3.20	41.75
13:35	12.91	2.06	1.13	3.19	41.21
13:50	12.94	2.07	1.13	3.20	41.37
14:05	13.06	2.07	1.12	3.19	41.60
14:20	13.28	2.06	1.12	3.18	42.26
14:35	13.32	2.06	1.14	3.20	42.65
14:50	13.68	2.06	1.14	3.20	43.80
15:05	12.98	2.06	1.09	3.15	40.91
15:20	13.34	2.04	1.14	3.18	42.38
15:35	13.33	2.06	1.11	3.17	42.20
15:50	13.12	2.05	1.14	3.19	41.91
16:05	12.70	2.05	1.12	3.17	40.25
16:20	13.13	2.05	1.10	3.15	41.39
16:35	13.98	2.04	1.09	3.13	43.81
16:50	12.71	2.05	1.09	3.14	39.85
Average	12.995	2.064	1.138	3.202	41.608

Table 4.2: Output values of the prototype

4.2.3 Data Analysis through Graphs and Bar charts

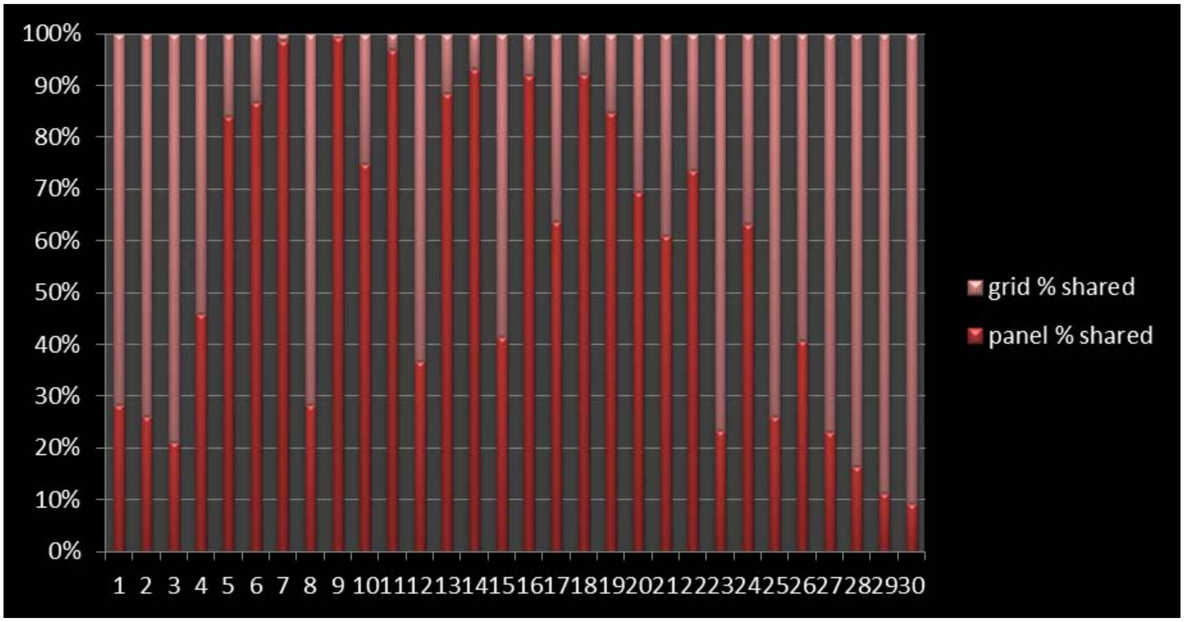


Figure 4.3: Percentage Input of current share

From the above figure 4.3 the shared amount of input currents can be observed. At 11:35 am, panel shared almost 99.41% current and the highest amount of current shared by grid was recorder 90.42% at 4:50 pm. These values are portrayed on the above graph.

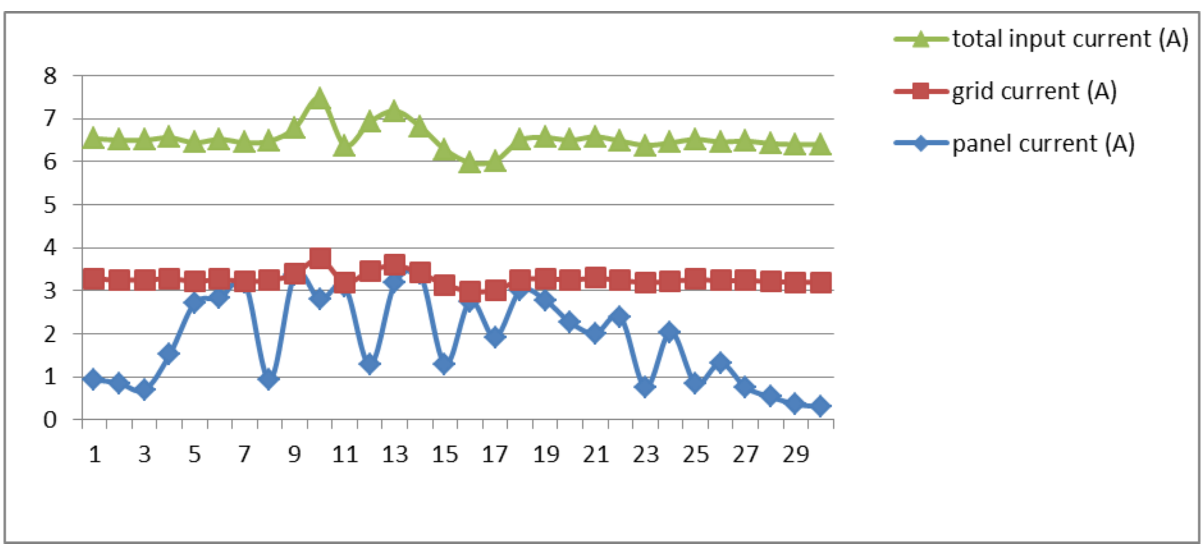


Figure 4.4: Input current shared

From the above figure 4.4 it can observed that the highest amount of total input current was 3.59 A which was recorded at 12:35 pm according to the experimental data. The highest amount of panel current was recorded 3.39A at 12:50 pm and highest amount of grid current was recorded 2.9A.

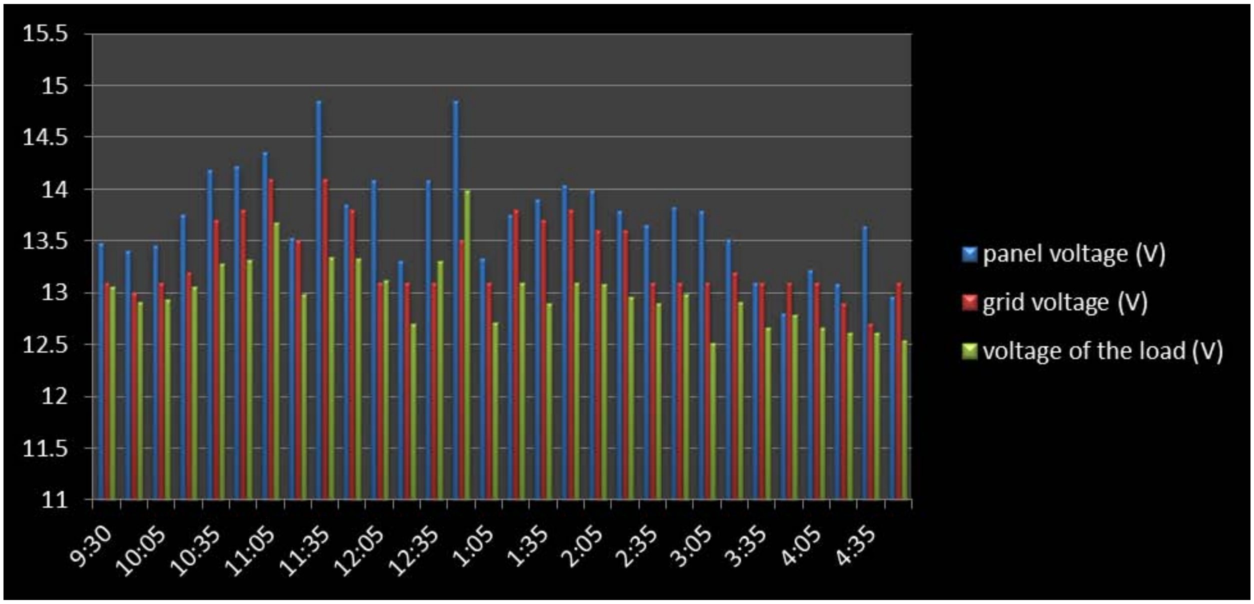


Figure 4.5: Relation among the voltages of panel, grid and load

From the above figure 4.5 it can be illustrated that, the maximum voltage of the panel was 14.85V at both 11:35 am and 12:50 pm. Thus the maximum voltage of the load was recorded 13.98V at 12:50 pm.

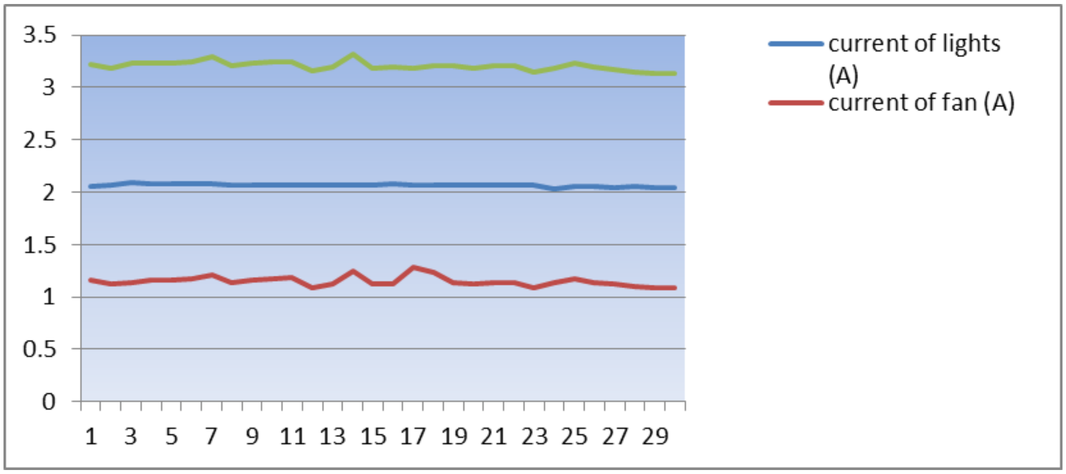


Figure 4.6: Output load currents

From the figure 4.6 it is visible that the current of fan is almost constant. The maximum output current was recorded 3.32A from the experimental data at 12:50 pm.

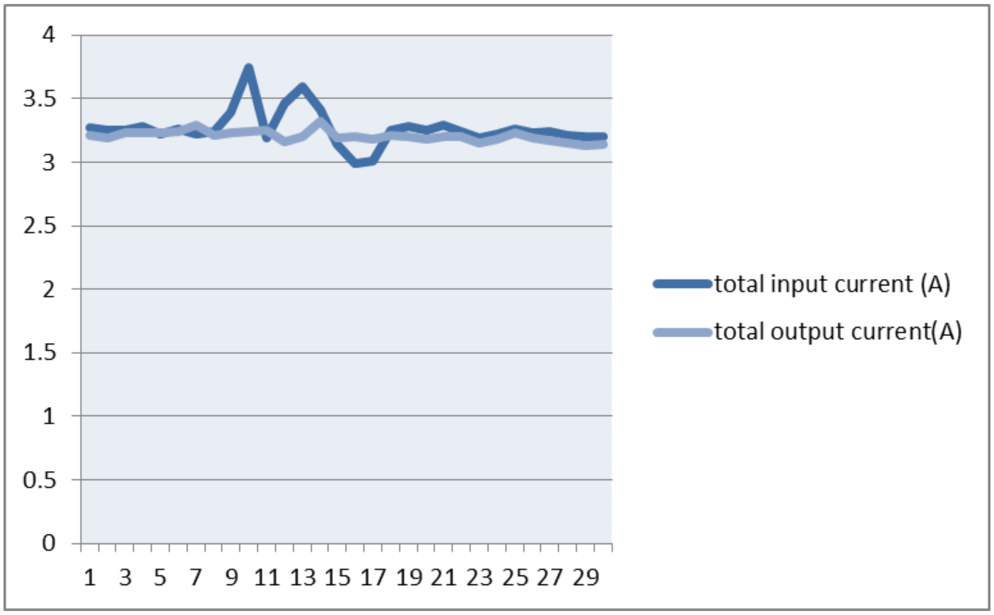


Figure 4.7: Total input and output current.

From the above figure 4.7 it's clear that the total output current and the total input current are fairly constant. The highest amount of input current and the output current are 3.59A and 3.32A respectively.

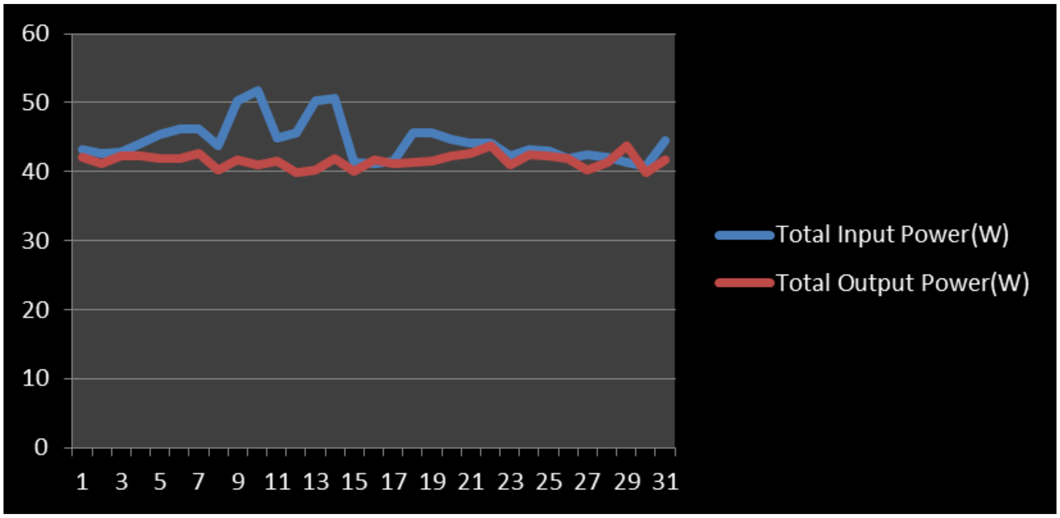


Figure 4.8: Total input and output power.

From the experimental data it can be further determined that at 11:50 am the maximum total input power was recorded 51.75W. From the above figure 4.8 it's observed that at a specific period almost around 50% of the overall power is delivered by the total input power. On the other side it's visual that the maximum total output power was 43.81W at 4:35 pm.

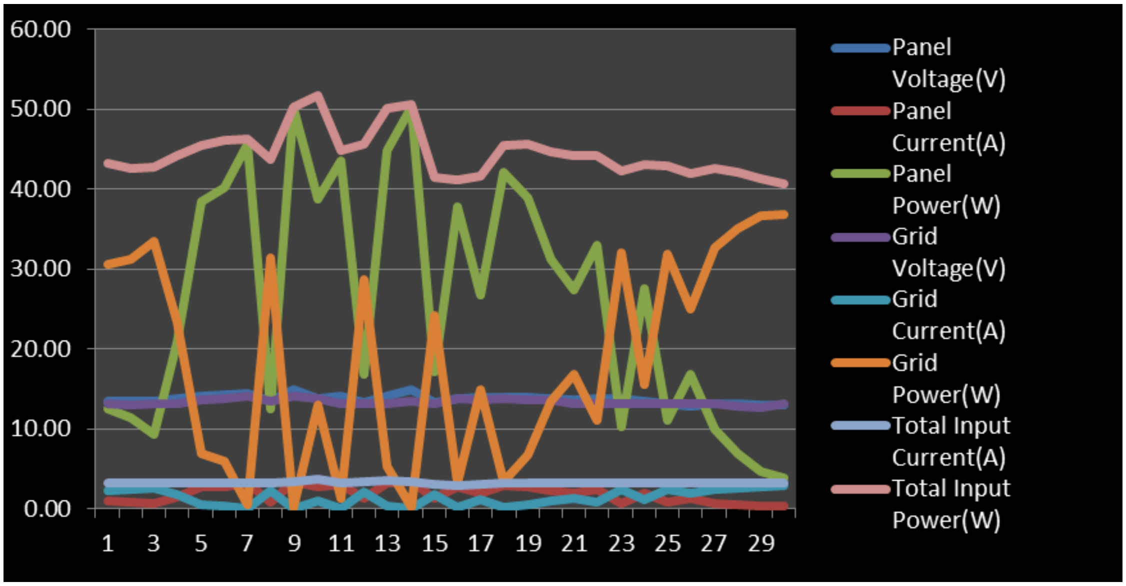


Figure 4.9: Relation between overall input and output parameters

From the figure 4.9 it can be observed that the total input and output currents are almost constant. Difference between total input and output power is visible in the figure.

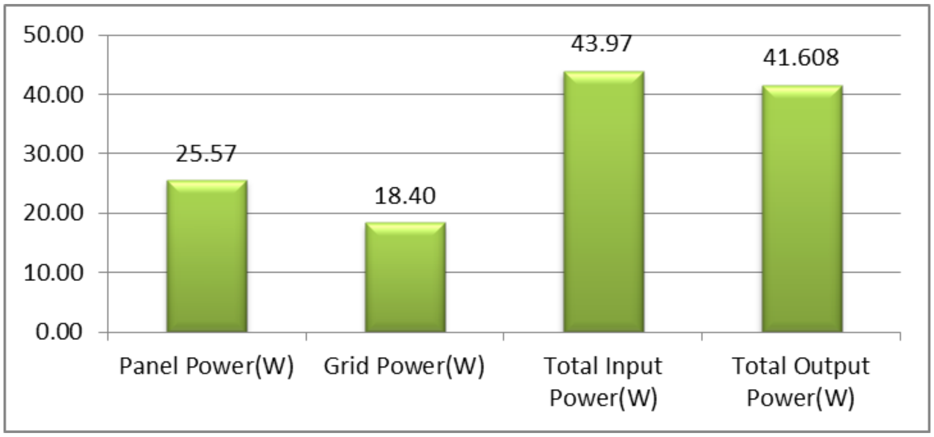


Figure 4.10: Average Power

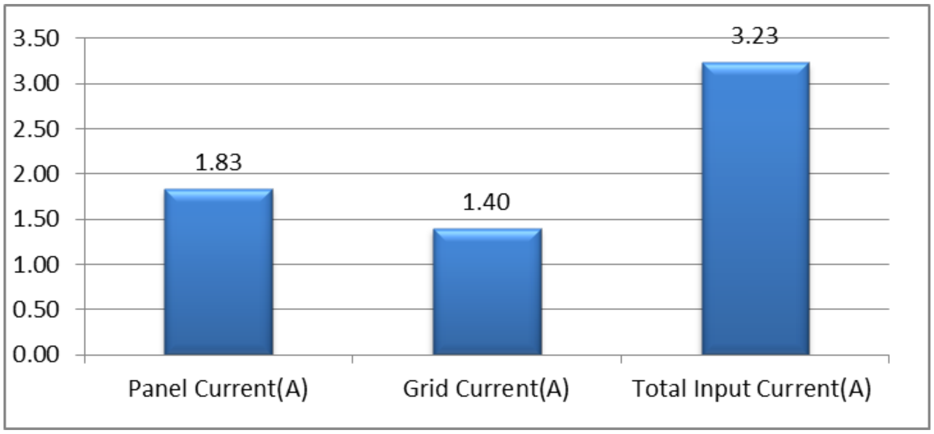


Figure 4.11: Average Input Current

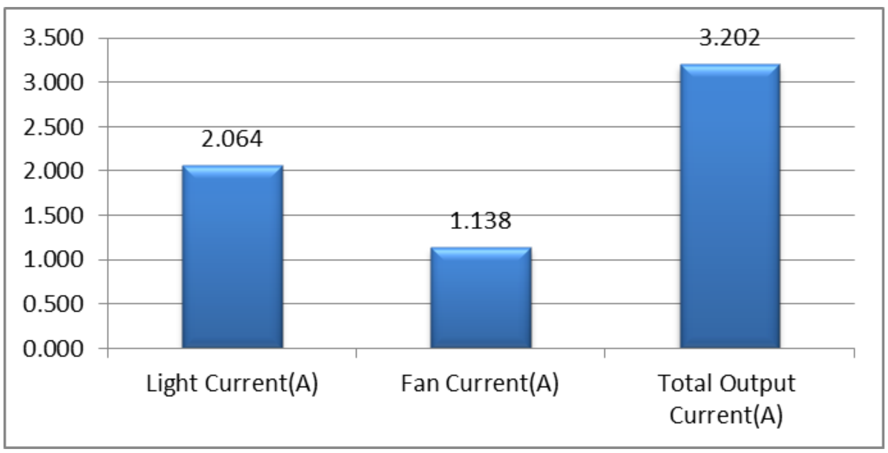


Figure 4.12: average output current

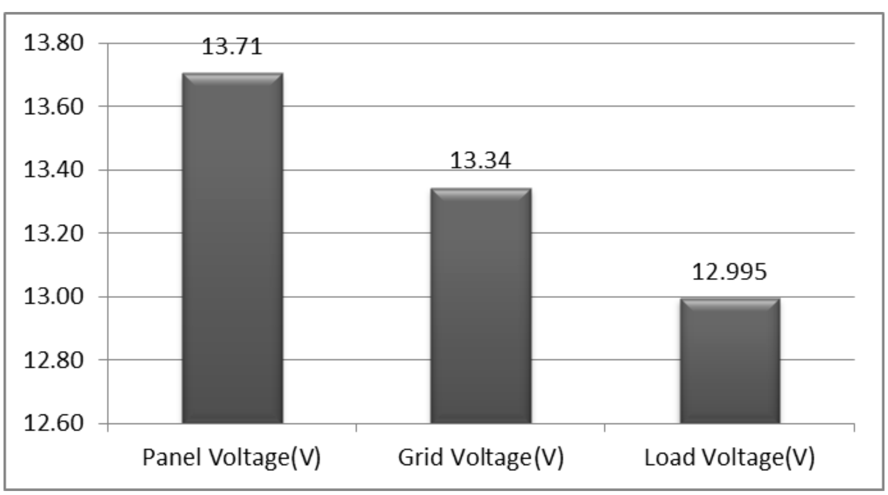


Figure 4.13: Average Voltage

At the “Load specification” part it was determine the total load power or output power that was 41.83W whereas in the prototype experiment it was found that the total output power was 41.66W. From the experimental data we have determined the average value of panel percentage shared and grid percentage shared. Those values are 56.42% and 43.55% respectively. The total energy supplied by the system throughout the whole day was 312.42Wh; among which 136.06Wh (43.55%) was supplied by the national grid and the rest 176.36Wh (56.42%) was supplied by the PV module. Assuming constant conditions for the whole month of March, the average total load supplied by the panels would be 48.675 KWh, which was around 379.17 taka (saved). On the contrary the total load supplied by the national grid would be 37.552 KWh.

4.3 Technical Part of Data Analysis

Hours/month	Jan		Feb		Mar		Apr		May		Jun	
Time	Panel	Grid	Panel	Grid	Panel	Grid	Panel	Grid	Panel	Grid	Panel	Grid
5:30	0.00	561.00	0.00	561.00	1.11	559.89	5.53	555.47	18.80	542.20	21.01	539.99
6:30	3.32	557.68	8.85	552.15	32.07	528.93	72.98	488.02	117.21	443.79	102.84	458.16
7:30	63.03	497.97	102.84	458.16	163.66	397.34	218.95	342.05	278.66	282.34	221.16	339.84
8:30	193.52	367.49	280.87	280.13	351.64	209.36	391.45	169.55	448.95	112.05	354.96	206.04
9:30	331.74	229.26	468.86	92.14	540.74	20.26	561.00	0.00	561.00	0.00	460.01	100.99
10:30	454.48	106.52	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	546.27	14.73
11:30	546.27	14.73	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00
12:30	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00
13:30	534.10	26.90	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	552.90	8.10
14:30	419.10	141.90	561.00	0.00	561.00	0.00	561.00	0.00	561.00	0.00	498.72	62.28
15:30	260.97	300.03	390.35	170.65	416.89	144.11	444.53	116.47	463.33	97.67	363.81	197.19
16:30	103.95	457.05	193.52	367.49	225.58	335.42	262.07	298.93	284.19	276.81	237.75	323.25
17:30	11.06	549.94	40.91	520.09	60.82	500.18	79.62	481.38	102.84	458.16	102.84	458.16
18:30	0.00	561.00	0.00	561.00	2.21	558.79	4.42	556.58	12.16	548.84	18.80	542.20
Daily average (W/day)	248.75	312.25	306.51	254.49	328.55	232.45	346.11	214.89	363.73	197.27	328.79	232.21
Wh/day	3482.52	4371.48	4291.20	3562.80	4599.71	3254.29	4845.56	3008.44	5092.15	2761.85	4603.06	3250.94
% Share	44.34%	55.66%	54.64%	45.36%	58.57%	41.43%	61.70%	38.30%	64.84%	35.16%	58.61%	41.39%

Jul		Aug		Sep		Oct		Nov		Dec	
Panel	**Grid**	**Panel**	**Grid**	**Panel**	**Grid**	**Panel**	**Grid**	**Panel**	**Grid**	**Panel**	**Grid**
12.16	548.84	7.74	553.26	3.32	557.68	0.00	561.00	0.00	561.00	0.00	561.00
95.10	465.90	72.98	488.02	64.14	496.86	50.87	510.13	34.28	526.72	12.16	548.84
218.95	342.05	199.04	361.96	182.46	378.54	186.88	374.12	173.61	387.39	107.26	453.74
392.56	168.44	318.47	242.53	335.06	225.94	358.28	202.72	366.02	194.98	262.07	298.93
484.34	76.66	478.81	82.19	481.02	79.98	523.04	37.96	541.84	19.16	422.42	138.58
556.22	4.78	561.00	0.00	536.31	24.69	538.52	22.48	561.00	0.00	529.68	31.32
561.00	0.00	561.00	0.00	536.31	24.69	561.00	0.00	561.00	0.00	550.69	10.31
561.00	0.00	561.00	0.00	537.42	23.58	539.63	21.37	561.00	0.00	540.74	20.26
556.22	4.78	533.00	28.00	487.66	73.34	448.95	112.05	561.00	0.00	471.07	89.93
511.99	49.01	500.93	60.07	425.73	135.27	357.17	203.83	416.89	144.11	341.69	219.31
411.36	149.64	393.66	167.34	310.73	250.27	230.01	330.99	225.58	335.42	202.36	358.64
269.82	291.18	255.44	305.56	181.35	379.65	84.04	476.96	63.03	497.97	59.71	501.29
118.32	442.68	98.42	462.58	49.76	511.24	6.63	554.37	1.11	559.89	2.21	558.79
19.90	541.10	8.85	552.15	1.11	559.89	0.00	561.00	0.00	561.00	0.00	561.00
340.64	220.36	325.02	235.98	295.17	265.83	277.50	283.50	290.45	270.55	250.15	310.85
4768.93	3085.07	4550.34	3303.66	4132.37	3721.63	3885.03	3968.97	4066.36	3787.64	3502.07	4351.93
60.72%	39.28%	57.94%	42.06%	52.61%	47.39%	49.47%	50.53%	51.77%	48.23%	44.59%	55.41%

Table 4.3: monthly average hourly power distribution

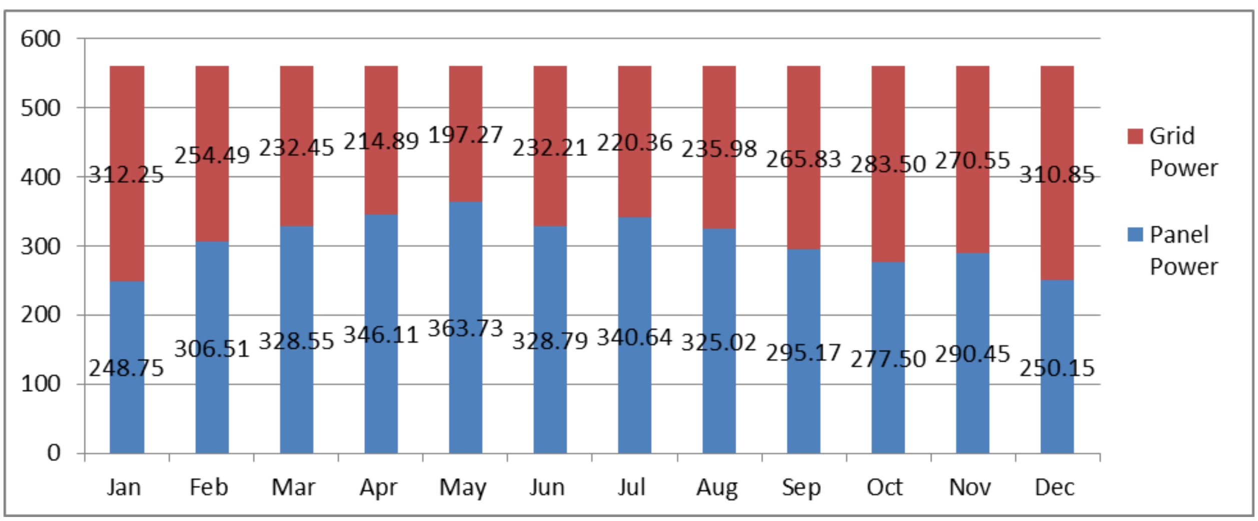


Figure 4.14: Daily average power distribution between panel and grid

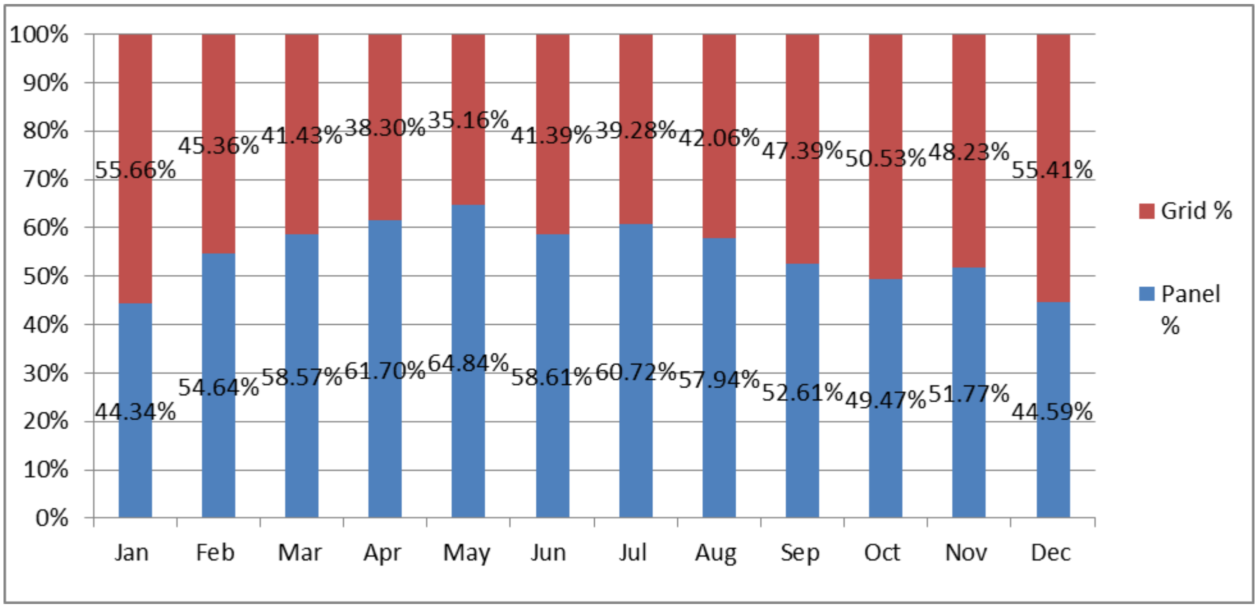


Figure 4.15: Monthly average percentage share by grid and panel

From both the above figure 4.14 and 4.15 shows us that the monthly power and percentage shared by grid is less in most of the month than panel share. This proves that quite much solar power can be achieved for the class room loads.

The experiment discloses that more than 55% of the electricity bill can be saved only in the month of March. Our primary target of the project was to save a good amount of electricity from the grid. Thus by the experiment it has been successfully showed that above 55% of electrical energy can be saved from the national grid.

CHAPTER 5
PANEL CALCULATION
AND USE OF HOMER SOFTWARE

5.1 Introduction

This following chapter will be divided into two parts. First part contain the basic calculations that will verify the total number of panels required as well as the specifications of the panels that will be give the best output for the class room loads. And the second part of the chapter will talk about the "HOMER" software which will give the validation of the system calculation. To bring up a quality result the Global Horizontal Irradiance that is known as the GHI will be considered in our calculations.

5.2 Global Horizontal Irradiance

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground [12]. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF) [12]. DNI is solar radiation that comes in a straight line from the direction of the sun at its current position in the sky [12]. DIF is solar radiation that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions [12]. On a clear day, most of the solar radiation received by a horizontal surface will be DNI, while on a cloudy day most will be DIF [12].

Hours/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5:30	0	0	1	5	17	19	11	7	3	0	0	0
6:30	3	8	29	66	106	93	86	66	58	46	31	11
7:30	57	93	148	198	252	200	198	180	165	169	157	97
8:30	175	254	318	354	406	321	355	288	303	324	331	237
9:30	300	424	489	521	561	416	438	433	435	473	490	382
10:30	411	573	629	666	681	494	503	514	485	487	580	479
11:30	494	672	712	751	727	532	548	537	485	520	614	498
12:30	518	701	722	764	711	543	570	535	486	488	573	489
13:30	483	646	657	693	641	500	503	482	441	406	510	426
14:30	379	528	541	553	577	451	463	453	385	323	377	309
15:30	236	353	377	402	419	329	372	356	281	208	204	183
16:30	94	175	204	237	257	215	244	231	164	76	57	54
17:30	10	37	55	72	93	93	107	89	45	6	1	2
18:30	0	0	2	4	11	17	18	8	1	0	0	0
Daily average (kWh/m2-day)	3.16	4.46	4.88	5.28	5.46	4.22	4.42	4.18	3.74	3.53	3.92	3.17

Table 5.1: Monthly average hourly GHI [13]

5.3 Panel Calculation for the Class Room

Average hourly irradiation	540.32	Wh/m2
Percentage irradiation	54.03%	
Derating due to dirt down to	95%	
Guaranteed output	97%	
Panel power	100.00	W
Max Panel current	5.80	A
Available power	49.79	W
Available current	4.15	A
System voltage	12.00	V
Power needed	528	W
Current needed	44	A
Panels Needed	11	

Table 5.2: Number of panels required

lights	120	
light power	3.50	W
total light power	420.00	W
fan	4	
fan power	15	W
total fan power	60	W
total power	480.00	W
Safety Factor	10%	
power	48	W
Total power	528	W

Table 5.3: Total load power

From the previous chapter we got to know that we can replace the 36 fluorescent tubes of 18 watts, 2 ft. each with 120 led tubes of 3.5 watts, 1 ft. which will give out the equivalent luminous flux. As shown in table 5.3 to complete the total load calculation we would need 4 fans of each 15 watts.

Total power = (Number of lights $\times$ watts of each light) + (No. of fans $\times$ watts of each fan)

= (120 $\times$ 3.5) + (4 $\times$ 15)

= 480 watts

Adding 10% safety factor to the total power, 10% of 480 watts is 48 watts, to be just in safe hands makes total power to be **528 watts.**

Average hourly irradiation is calculated from **10.30am to 14.30pm** for one whole year. So the average irradiation is found to be 540.32 Wh/m2 from table 5.1. Then the percentage of irradiation is taken by dividing the average irradiation by 1000.

Percentage irradiation = 540.32 Wh/m2 $\div$ 1000

=**54.03%**

Taking in consideration of the percentage deteriorating due to dirt is 95% and the guaranteed output of the panel is 97%. So, theoretical output power of a 100 watt panel is 49.79 watts in real.

Available Output power = 100 watts $\times$ 52.03% $\times$ 95% $\times$ 97%

= **49.79 watts**

The maximum current of a 100 watt panel is 5.80 watts and the system voltage is 12 volts. So, in order to find the output current we would need to divide the available output power by the system voltage.

Available output current = 49.79 watts $\div$12 volts

= **4.15 Amps**

Finally the current required to run the project is 44 amps which can be calculated by dividing the total power by the system voltage.

Current needed = 528 watts ÷12 watts

=**44 Amps**

We can now reach to the findings of the number of panels required, by dividing the required current needed for the whole classroom to the available output current by a 100 watt panel.

Number of panel = 44 amps ÷ 4.15 amps

= 10.60

≈ **11 panels**

So we can finally say that if we use 100 watts panel then we would need **11 panels** to run the full load in the classroom.

5.4 Homer Software

The HOMER energy modeling software is a powerful tool for designing and analyzing hybrid power systems, which contain a mix of conventional generators, combined heat and power, wind turbines, solar photovoltaic, batteries, fuel cells, hydropower, biomass and other inputs. For either grid-tied or off-grid environments, HOMER helps determine how variable resources such as wind and solar can be optimally integrated into hybrid systems. HOMER determines the economic feasibility of a hybrid energy system optimizes the system design and allows users to really understand how hybrid renewable systems work (14). For our project homer showed the economic feasibility of using both panel and grid connection at the same time.

In the following unit first all components that were required were entered. Such as total led load power, total dc fan power, panel, grid power and controller which is represented as converter in homer software. Then the specifications were mentioned in each of the components, such like panel wattage and total cost. Load wattage, cost, and time slot of the load distributions. Controller specification and cost and grid off peak and peak costs were also included. The next following figures will show the screen shots of how things were obtained in homer software.

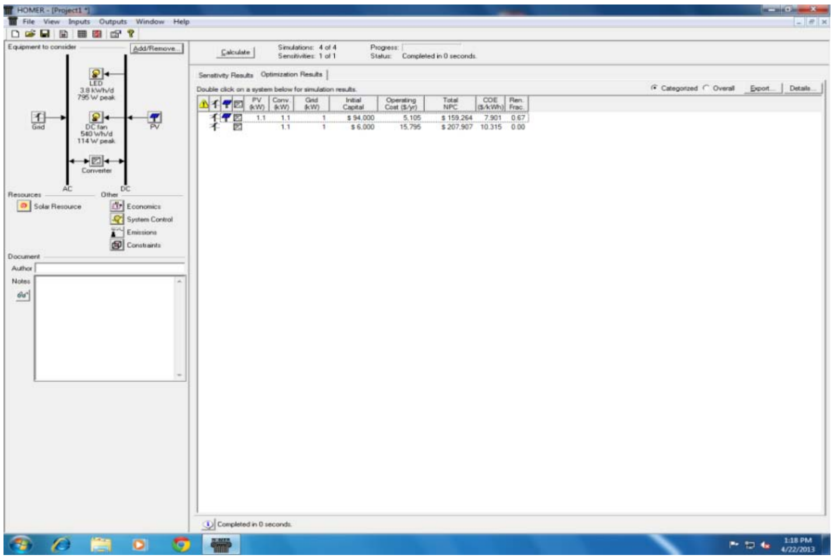


Figure 5.1: Setup of the system in Homer software

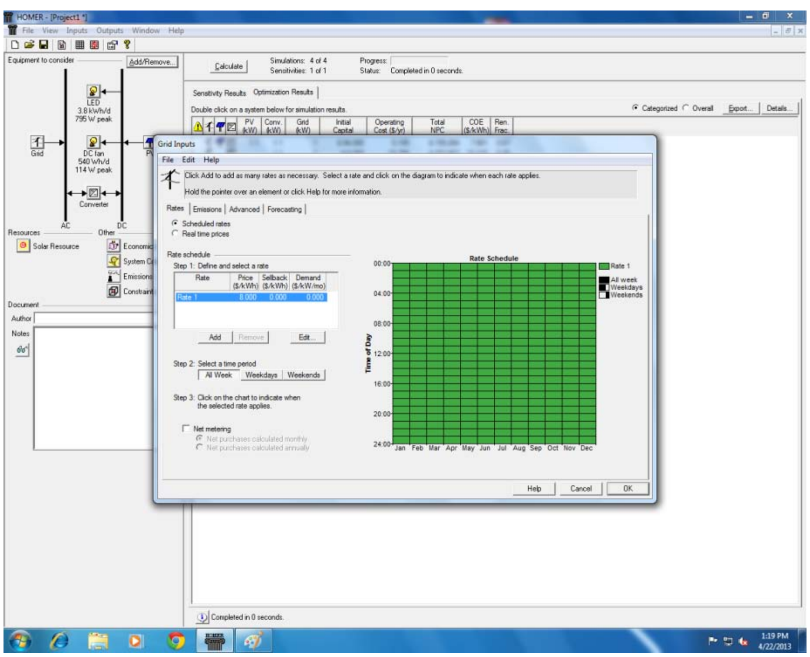


Figure 5.2: Grid input rates.

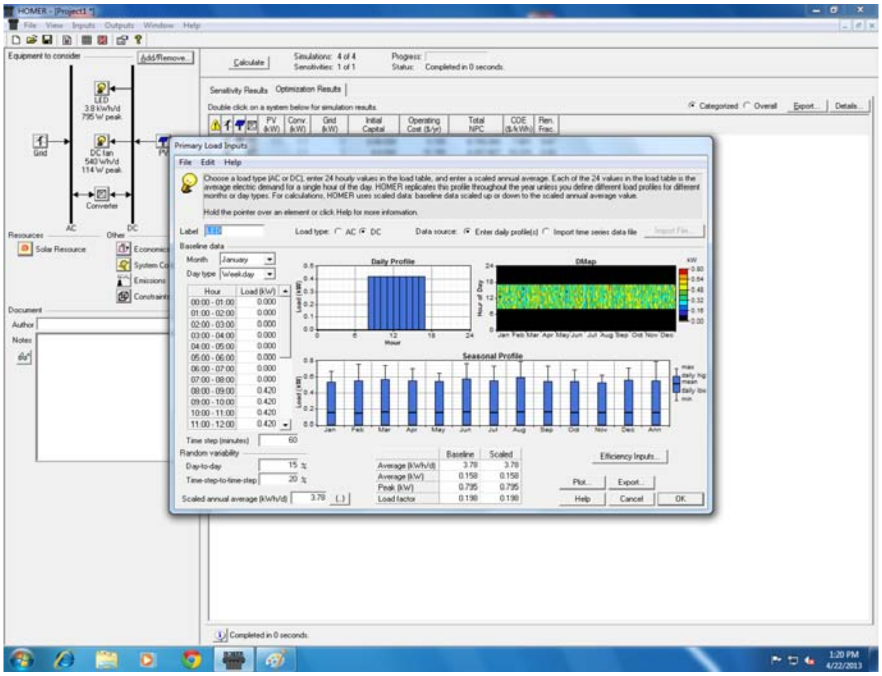


Figure 5.3: Led load input along with the time schedule

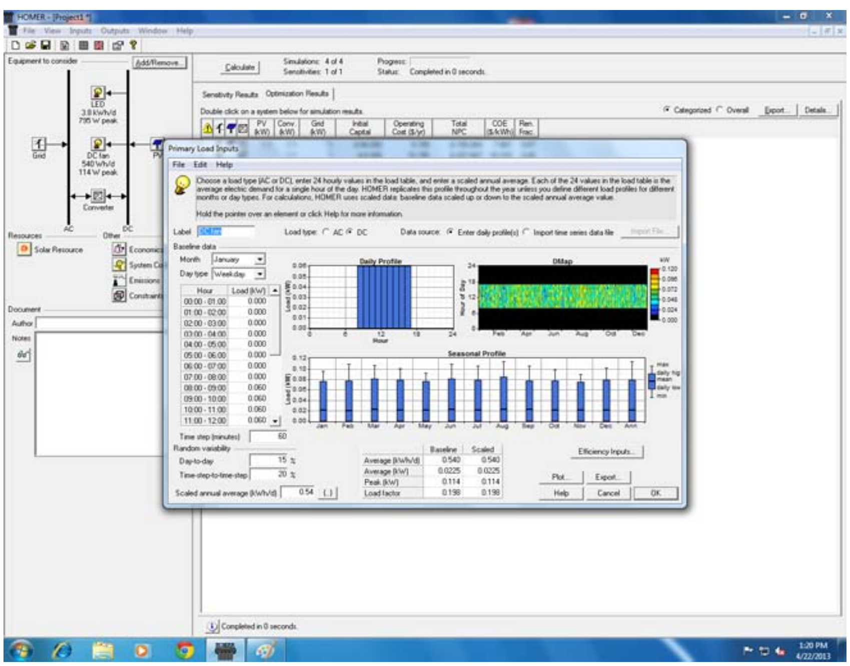


Figure 5.4: Dc stand fan load input along with the time schedule

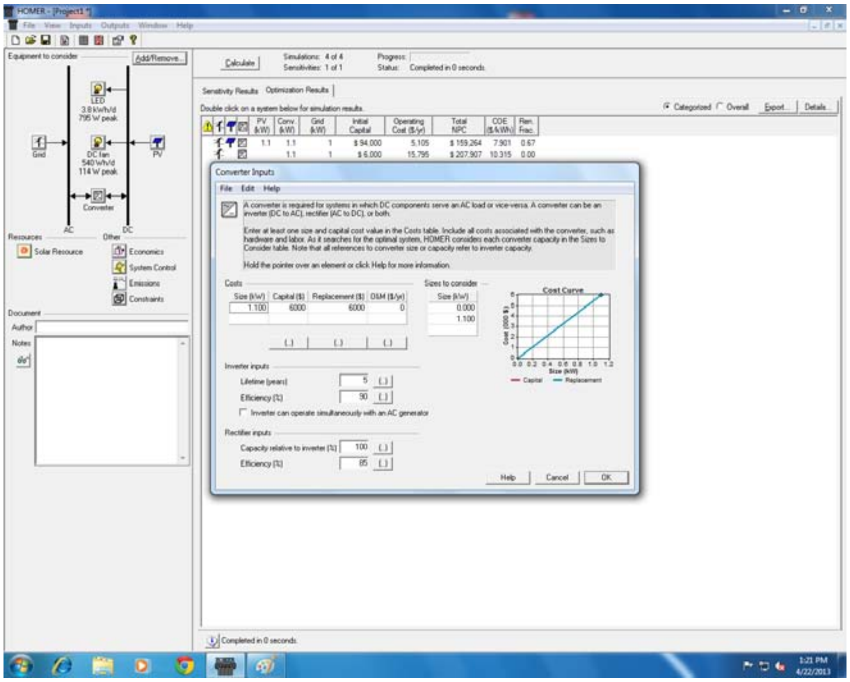


Figure 5.5: set up of the converter and its cost rating

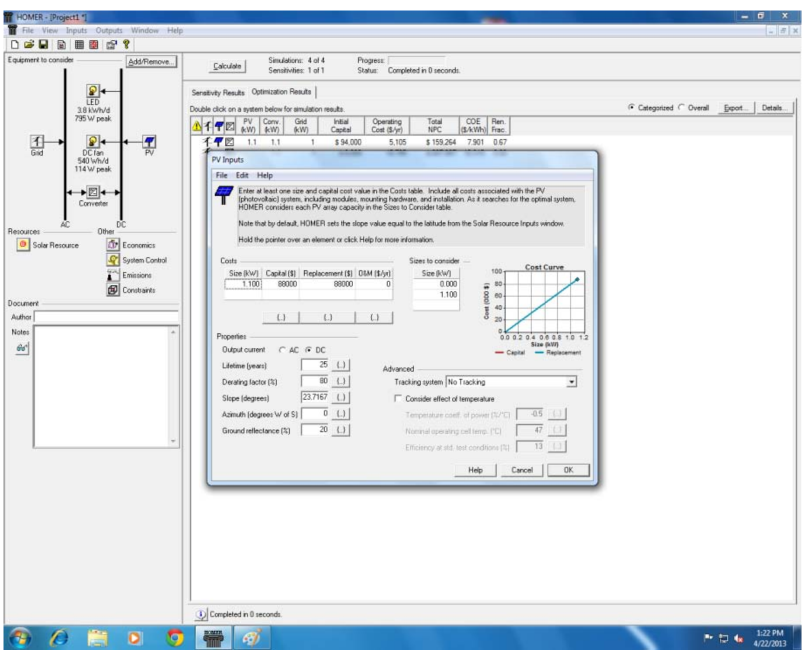


Figure 5.6: Wattage and cost of panel for the project

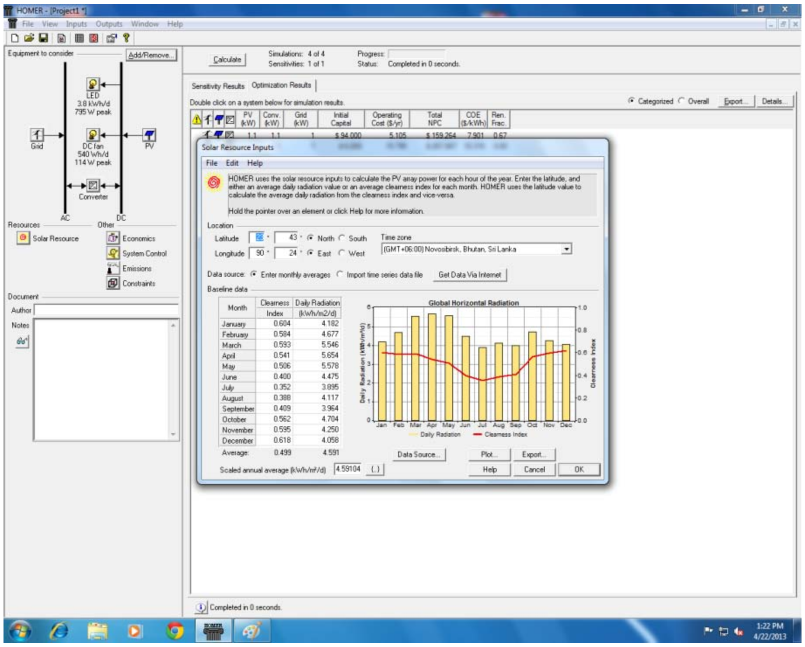
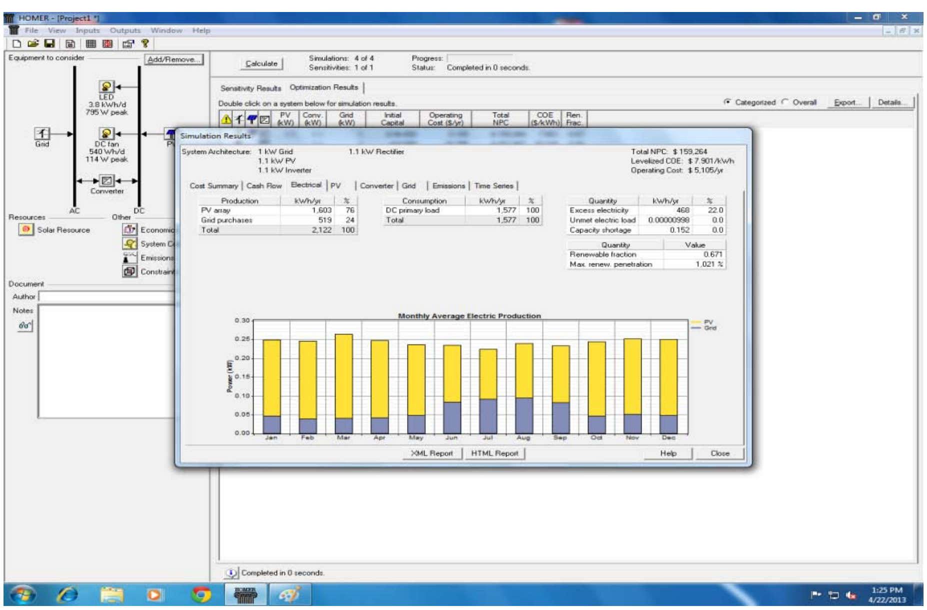


Figure 5.7: solar data achieved via internet

After putting all as following homer does the calculation of the payback as well as the feasibility study of the system. And according to homer it's been seen that solar panel shares 76 percent whereas grid shares 24 percent of the energy throughout the year. And it's achieved that this system in reality will be feasible and will come with much better output.



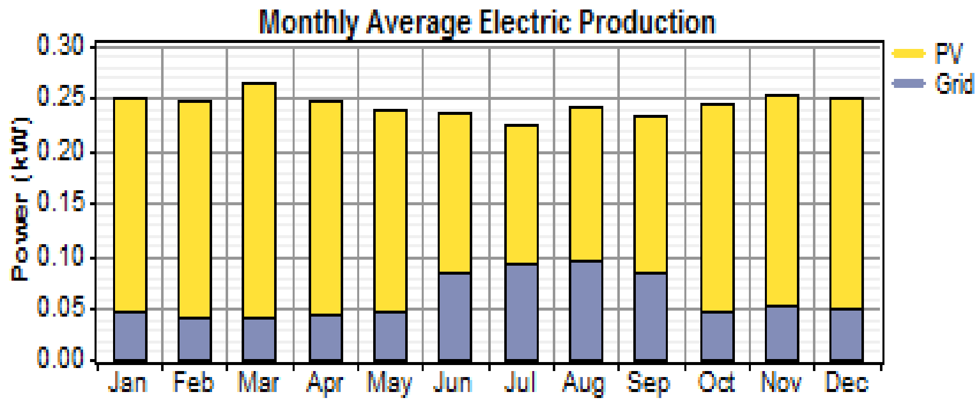


Figure 5.8: Monthly average electricity production for Classroom loads

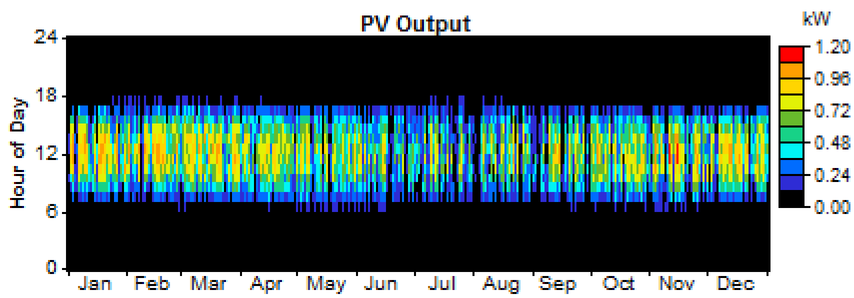


Figure 5.9: PV output throughout the year in Dhaka

This chapter came up with the actual number of panels required for the project and also showed the use of homer software. In term of software use it's shown that the project is feasible enough to implement in reality, and in the next preceding chapter the payback years will be shown through calculation.

CHAPTER 6

PAYBACK CALCULATION

6.1 Introduction

This chapter is the main focus of the thesis project as well as the most important chapter among all that shows the calculations and verification of the money that can be saved in introducing such a project. It consists of all the calculations based on the actually present rate of electricity, and the cost of all the primary products that will be required.

6.2 Tariff

According to DESCO in present the cost of per unit electricity of commercial and office category, in Bangladesh is as following down in table 6.1. As the project timing are upon the timing slot from morning 8am till 5pm, the off peak time will be considered in all our following calculations.

Type of rate	Cost	Unit	Timings
Off peak rate	7.22	taka/kWh	11pm to 5pm
peak rate	11.85	taka/kWh	5pm to 11pm
flat rate	9.00	taka/kWh	~

Table 6.1: Type of rates and the per unit electricity cost according to DESCO

6.3 Monthly Expense Estimation

If a month is considered to have 30 days, then there are 4 Fridays that is an official holiday. Therefore we have total 26 working days. So if we take the time slot from 8pm to 5pm, then we have total **234 hours** of load duration.

Total load hours per month= no of working days × total load hour duration per day from 8am to 5pm

= 26 × 9

= 234 hours per month

6.3.1 Cost Calculation on Existing AC Loads

Existing or present load	Units	Unit Rating(W)	Power (W)	Energy per month (KWh)	Cost Taka
Fluorescent tubes	36	18	648W	151.63kWh	_
Fans	4	55	220W	51.48KWh	_
Total loads	_	_	868W	203.11KWh	_
loss	_	10%	86.80W	20.31KWh	_
Total	_	_	954.80W	223.42KWh	_
Cost per month (taka/month)	_	_	_	_	1613.12 taka
Cost per month + VAT 5% (taka/month)	_	_	_	_	1693.77 taka
Total cost per year (taka/year)	_	_	_	_	**20325.26 taka**

Table 6.2: total load in KWh and cost of grid electricity per year in existing system load

The above table 6.2 describes about the existing loads that are present in UB0923. Total 36 fluorescent tubes of 18 watts each and 4 fans of 55 watts each are available in present. The total loads sum up to be 868 W, and considering 10% loss the sum becomes 954.80 W. Thus power per month is 223.42 KWh.

Furthermore the total cost that is required to give on electricity bills per year can be deduced. The expanded calculations are shown as following.

Cost per month = power per month on existing loads × off peak rate

= 223.42 kWh × 7.22 taka

= 1613.12 taka per month

5% VAT of cost per month = (1613.12÷100) ×5

= 80.656 taka

Adding 5% VAT on cost per month = 80.656 + 1613.12

= 1693.11 taka

Total cost per year = cost per month (including VAT) × 12

= **20325.26** taka per year

6.3.2 Cost Calculation on DC 'Loads When Panel Not Connected

New setup with DC loads	Units	Unit Rating(W)	Power (W)	Power per month (KWh)	Cost (Taka)
LED tubes	120	3.5	420W	98KWh	-
DC Fan	4	15	60W	14.04KWh	-
Total	-	-	480W	112.32KWh	-
Loss	-	10%	48W	11.23KWh	-
Total power	-	-	528W	123.55KWh	-
Cost per month (taka/month)	-	-	-	-	892.05 taka
Cost per month + VAT 5% (taka/month)	-	-	-	-	936.65 taka
Total cost per year (taka/year)	-	-	-	-	**11239.77 taka**

Table 6.3: Total loads in KWh and cost of grid electricity per year in new replaced dc loads

The above table 6.3 discusses about the new dc loads that will be place in the classroom which was mentioned in previous chapters. 120 led tubes of 3.5 watts each and 4 dc fans of 15 watts each will be required. The sum of the loads will be 480 W, and considering 10% loss the sum becomes 528 W. Thus power per month is 123.55 KWh.

Cost per month = power per month on existing loads × off peak rate

= 123.55kWh × 7.22 taka

= 892.05 taka per month

5% VAT of cost per month = (892.05÷100) ×5

= 44.60 taka per month

Adding 5% VAT on cost per month = 44.60 + 892.05

= 936.65 taka per month

Total cost per year = cost per month (including VAT) × 12

= **11239.77** taka per year

Total saving per year over grid= Cost per year on ac loads (existing loads) – cost per year on dc Loads (without solar power)

= **20325.26 - 11239.77**

= 9085.48 taka per year

6.4 Cost Calculation on DC Loads When Sharing both Grid and Panel Current

Table 4.3 is the monthly average hourly power distribution shown, which is very important for the next following calculations. Here the percentage share between panel and grid power is shown.

Month	Share	Percentage Share (%)	Energy (KWh)	Cost (taka)
January	Panel	44.34	54.78	395.53
	Grid	55.66	68.77	496.51
February	Panel	54.64	67.51	487.41
	Grid	45.36	56.04	404.63
March	Panel	58.57	72.36	522.47

	Grid	41.43	51.19	369.57
April	Panel	61.70	76.23	550.39
	Grid	38.30	47.32	341.65
May	Panel	64.84	80.11	578.40
	Grid	35.16	43.44	313.64
June	Panel	58.61	72.41	522.83
	Grid	41.39	51.14	369.22
July	Panel	60.72	75.02	541.65
	Grid	39.28	48.53	350.40
August	Panel	57.94	71.59	516.85
	Grid	42.09	51.97	375.19
September	Panel	52.61	65.00	469.31
	Grid	47.39	58.55	422.74
October	Panel	49.47	61.12	441.29
	Grid	50.53	62.43	450.75
November	Panel	51.77	63.96	461.81
	Grid	48.23	59.59	430.23
December	Panel	44.59	55.09	397.76
	Grid	55.41	68.46	492.28

Table 6.4: Cost share between panel and grid

Table 6.4 shows us a relation between the percentage share (of panel and grid) and the cost for every month in a whole year. And with the equation 1 and 2 we can find the total cost that can be saved due to panel current and the cost that BRAC University will need to pay every month due to grid current share.

Cost Saved by panel = (Energy per month in KWh÷100%) × Percentage shared by panel× Off peak rate cost ………………equation (1)

Cost for grid share = (Energy per month in KWh÷100%) × Percentage shared by grid× Off peak rate cost ………………equation (2)

For example for January:

Cost saved by panel = (123.55 KWh ÷ 100%) × 44.34% × 7.22 taka

= 395.53 taka

Cost for grid share = (123.55 KWh ÷ 100%) × 55.66% × 7.22 taka

= 496.51 taka

Same way for the rest of the following months the same equations are used and values are achieved as shown in the table 6.7.

Total money saved by panel current per year = 393.53 + 487.41 + 522.47 + 550.39 +578.40 +

522.83 + 541.65 + 516.85 + 469.31 + 441.29 + 461.81 + 397.76

= **5885.72 taka per year**

Finally, adding 5% VAT on the total cost saved per year makes the grand total to be **6180 taka per year.**

Total cost on grid electricity = 496.51 + 404.63 + 369.57 + 341.65 + 313.64 + 369.22 + 350.40 +

375.19 + 422.74 + 450.75 + 430.23 + 492.28

= **4818.83 taka per year**

Again adding 5% VAT to the total cost on grid electricity make the grand total to be **5059.77 taka per year,** which BRAC University will have to pay.

Finally we can find the actually cost that BRAC University can save per year due to this project, is by subtracting the amount of money that BRAC University is providing now due to existing load from the amount of money that BRAC will give after the projected is completed. This cost is the main cost that can lead us to the payback calculation, which is the main heart of this thesis.

Therefore, total cost saved = per year cost due to existing load – per year cost due to grid

Electricity

= **20325.26 – 5059.77**

= **15265.48 taka per year**

6.5 Payback Calculation

Items	Unit	Power (W)	Unit Per price (taka)	Total price (Taka)
Panel	11	100	80	88000
LED tubes	120	3.5	500	60000
DC Fan	4	15	4000	16000
Controller	5	120	1200	6000
Total				170000/=

Table 6.5: System set up cost for whole project

Finally if we divide the total amount of money for the setting up the system by the total cost saved by per year than we can estimate the number of year required for BRAC University to overcome this investment.

Number of payback years = total set up cost of the project ÷ the saving per year

= 170000 / 15265.48

= **11.14 years**

So in concluding, we can see that either way round we can come to a very successful point. And we can say that it will take almost 11 years for BRAC University to overcome the investment that will be used for this project.

CHAPTER 7

CONCLUSION AND FUTURE WORK

In concluding part of this thesis work it can be state that the result that was found was successful one to implementing the project in real. The initial target of the project of creating a cost effective feasible system in the classrooms of BRAC University was fulfilled. This thesis work tried to make an overall assessment of all the parameters that can be retrieved from the system. Eventually we derived the amount of cost that can be saved due to the contribution of the solar panel per year.

Further modifications can also be done in future with the controller device and with the payback calculation. And in future work this project can be implemented in real which will be a bright finding of BRAC University. For panel section thin film panels can be used instead of mono crystalline panels. If someone wants to utilize these thin film panels as windows then it's possible to decline the temperature of that specific room. Thus we can decline the power consumption inside the room.

REFERENCES

[1] Jan Coen van Elburg and Derk Loorbach. “A Transition Perspective on Regulation and Renewable Energy" [Online]. Available: http://www.europeanbusinessreview.com/?p=7757

[2] (2013, April, 23). “Renewable Energy”(Wikipedia) [Online]. Available: http://en.wikipedia.org/wiki/Renewable_energy

[3] “Solar Energy” [Online]. Available: http://www.answers.com/topic/solar-energy

[4] (2008, November, 6). “Renewable Energy Policy of Bangladesh” (final) [Online].

Available: http://www.pv-expo.net/BD/Renewable_Energy_Policy.pdf

[5] Unb, Dhaka. (2011, May, 15) “Target 500 MW Solar Project”(The Daily Star) [Online]

Available: http://www.thedailystar.net/newDesign/news-details.php?nid=185717

[6] “What are Solar panels?” [Online]. Available: http://www.qrg.northwestern.edu/projects/vss/docs/power/1-what-are-solar-panels.html

[7] (2013, April, 22). “Solar Panels” (Wikipedia) [Online]. Available: http://en.wikipedia.org/wiki/Solar_panel

[8] “Different types of solar panel” [Online]. Available: http://solarenergyfactsblog.com/different-types-of-solar-panels/

[9] http://www.altestore.com/store/Charge-Controllers/Solar-Charge-Controllers/c892/

[10] “Solar dc cooling fans & Kits” [Online]. Available: http://aessolar.com/catalog/applications/fans.htm

[11] (2013, April, 9). “Lumen” (Wikipedia) [Online]. Available: http://en.wikipedia.org/wiki/Lumen_(unit)

[12] "What is Global Horizontal Irradiance?" [Online]. Available: http://www.3tier.com/en/support/solar-prospecting-tools/what-global-horizontal-irradiance-solar-prospecting/

[13] Jannatul Ferdous, Md Sanzidul Islam, Nabila Sharkar, Bonny Amin Khan, A.Azad "Performance Improvement of SHWS by Increasing Thermal Efficiency Using Insulation Materials and Optimum Position of Solar Collector"

[14] https://www.homerenergy.com/

LIST OF TABLES