CHAPTER 1
INTRODUCTION

Energy is fundamental to the quality of our lives. Nowadays, we are totally dependent on an abundant and uninterrupted supply of energy for living and working. It is a key ingredient in all sectors of modern economies. The energy production in our modern industrialized society is still mainly based on non renewable resources and lead to their exploitation. As the world's energy demand rises, it is very important to find an alternative solution for producing power. Since electricity cannot be stored in large amount, their production and usage is of great importance. It will be more efficient if we use the renewable resources for production of electricity. Solar power is an alternative solution that will hopefully lead us away from exploiting our non renewable resources.

An efficient system which makes use of the solar power for our needs is the aim of our project. Such a multipurpose system should satisfy all the power requirements of the equipment connected to it. Since the power available is a varying one, our system should consider all these variations and generate a constant required output.

The project aims at efficiently converting solar energy into electrical energy, and this is used to drive the loads connected. Then there exist a suitable switching section which is used to use main AC supply in case of insufficient power from the solar panel due to climatic changes. Both the power supplies must be regulated for getting a constant output. The loads connected to the output are a battery charging circuit and a household LED lighting system.

The designing of such a system involves the calculation of the power output from the solar panel and the power needed for driving the loads connected. The regulators used in the system should also be selected such that we get an efficient amount of power at the output. Considering all these facts we are aiming at designing a system which can be widely implemented in households for saving the non-renewable energy sources.

CHAPTER 2

SYSTEM OVERVIEW

2.1 MOTIVATION

Energy is most important in everyone's life whether we notice it or not. It is one of the most problematic issues in the world. Exploitation of non renewable resources for energy production leads to large number of environmental issues. So the need of utilizing renewable resources to reduce energy crisis is the main motivation for us. Solar energy is available in large amounts every day. So production of electricity from this will help to utilize solar power efficiently to reduce energy scarcity. We are trying to design a system which can work efficiently and continuously to drive the loads. To achieve this, we include a switching circuit that connects the loads to the main AC supply in situations of insufficient power from the solar panel. So it will generate power for a long period of time if properly protected and requires less maintenance.

2.2 NEED ANALYSIS

What is the main goal of the project?

To design and implement a multipurpose solar energy system, which efficiently converts solar energy into electricity to drive the loads connected to it.

What is the relevance of the project?

The project is highly relevant since it generates electricity from the renewable source of energy. So the usage of non-renewable resources can be reduced. Since we are depending on the solar radiation for power production, it reduces the pollution caused by the usage of fossil fuels. The large amount of radiation from the sun can be efficiently used to generate large power.

What is the benefit of the project?

The main benefit of such a system is that it replaces power production from the non-renewable resources and can produce large amount of power from renewable resources with low maintenance cost. The output of such a system will give peak values during summer seasons in which our country faces severe water scarcity.

What is the reason for selecting this topic?

The need of utilization of renewable energy resources to reduce energy crisis is the main motivation for us. Solar energy is available in large amounts every day. So production of electricity from this renewable source will help to utilize solar power efficiently. Thus the project is selected to reduce the use of non renewable energy resources and creating a new and more efficient electricity generating system.

Whether does such a system exist in the market? If yes what is the speciality of this system?

Solar energy converting systems are available nowadays. Because of high cost, low efficiency and non availability of power all the time they are not implemented widely. Since our system uses switched mode regulator instead of linear regulator it works efficiently. To drive the loads continuously, a switching circuit that switches the loads to main AC supply in case of insufficient power from the solar panel is additionally implemented.

What are the essential needs of the project?

- It should be efficient to convert the solar energy.
- It should regulate the highly varying output of the solar panel
- It should provide power necessary to drive the loads continuously
- It should use main AC supply if solar panel cannot provide sufficient power

What are the main requirements of the project?

- Solar photovoltaic source
- Regulators
- Battery Bank
- Switching circuit

What are the considerations while selecting the solar panel?

The panel should have sufficient power rating for satisfying the requirements of the loads connected to it. Amorphous silicon panels are usually selected, since they are comparably less costly and have less dependence on temperature variations.

What is the use of regulator in the system?

The output from a solar panel varies over a wide range according to the solar radiation. So we need regulator in the system to regulate the voltage into a specific desirable range.

Solar radiations change according to the climatic variations. What can be done to overcome this power scarcity?

To overcome such cases a switching circuit is added to connect the load with main AC supply. When the output from the solar panel is not sufficient, the switching is done.

What should be the loads connected to the system. How are they chosen?

A household mainly contains the lighting systems. Suitable number of LEDs should be selected according to the plan of the house. Each room requires different intensities of light which should be taken accordingly. Mobile charging circuit is also a basic need. So such a system should also be implemented.

What are the requirements for each room in a house?

Centre hall	400lmn	6W
Kitchen	400lmn	6W
Room	300lmn	3W
Bathroom	200lmn	3W

Why are LEDs suitable for lighting system?

LEDs offer the following advantages when used as light sources in lighting.

- Long and predictable lifetime
- Reduces maintenance costs
- Reliability
- Reducing energy consumption and light pollution
- Small package size
- Flexible, flat and compact lamp design

- Quick turn on / off
- No problem with hot ignition
- Turn on / off without time delay
- Easy lamp recycling
- Higher light output even at low temperatures

From the advantages listed above, the use of LEDs as a light source offers many possibilities to improve the quality of lighting.

What can be done to get a maximum output from the panel?

The panel should be placed at regions were maximum radiation can be obtained. It should also be placed in the direction facing the radiation. It can be achieved through tracking the sun. The solar panel should be placed such that sufficient air passage is available for cooling.

2.3 WISH SPECIFICATION

Output current	:	2A
Output voltage	:	12V
Charging time of battery	:	6 Hours
Battery backup	:	4 Hours

Work in all climatic conditions.

Less dependence on main AC supply

2.4 SPECIFICATION

Output current	:	2A
Output voltage	:	12V

Requirement of loads:-

3W LED bulb	:	12V, 250mA
6W LED bulb	:	12V, 500mA

Mobile battery charging	:	5V, 292mA

LED Lighting System	Charging time of battery	:	7.6 Hours
	Battery backup	:	3.9 Hours

2.5 TIME PLAN

2.6 BLOCK DIAGRAM

2.6.1 BLOCK DIAGRAM DESCRIPTION

This is the simplified block diagram of the system used for converting solar power into useful form of electricity. Such a system consists of a solar panel for capturing and converting the solar energy. The output of the solar panel varies over a wide range according to the intensity of incident light. This system contains a DC-DC converter to regulate this output to a specific range. This regulated output is stored in a battery bank and is used for the power requirements of the loads connected. A household LED lighting system and a mobile phone battery charger are used as the loads of this system. Apart from usual system, it has an additional section that is used for switching the loads with the main AC supply. The 230V main AC supply is rectified and regulated. The regulated output is then connected to the switching circuit.

Detailed description of each block is as follows.

Solar panel

A solar cell or photovoltaic cell is a device that converts light directly into electricity by the photovoltaic effect. When light is incident on the cells the barrier between p-n junction breaks and the current begins to flow. Assembles of cells are used to make solar panels, solar modules or photovoltaic arrays. These modules are connected serially or parallel to get the required output. For the efficient dissipation of heat generated in the module it is mounted at a small height from the ground. Our system uses amorphous solar panel, because the crystalline cells have a large temperature effect on them which reduces their efficiency drastically.

DC-DC converter

The DC-DC converter converts the input DC voltage to an output voltage wherein the output is regulated for variations in input voltage. Linear regulator or switched mode regulator can be used for this purpose. Because of high efficiency as compared to the linear regulators, switched mode regulator is used. It can be buck converter, boost converter, or buck boost converter according to the output of solar panel and the required regulated output.

Battery bank

For the purpose of storing the regulated voltage from the converter a rechargeable battery bank is required. Due to high reliability, low cost and better storage capacity lead acid battery is used as storage device. Compared to other cells they are easily available. For the better working and long life of batteries, a battery charging control circuit is used.

Voltage regulator

Usually systems are connected to 230V, 50Hz main AC supply. A transformer, bridge rectifier and a 78xx series voltage regulator are used to convert this AC supply into the required fixed voltage.

Switching circuit

Switching circuit is used to switch the loads between the main AC supply and the storage bank. If the output of the solar panel is insufficient due to the climatic changes, loads are switched to the regulated output from the main AC supply. A DC relay is used to perform this task.

Load

The loads connected are a mobile battery charger circuit and household LED lighting system. The output from the switching circuit is directly passed to drive these loads.

CHAPTER 3

SYSTEM DESIGN

1. SOLAR PANEL:

1. The energy used by the loads

- Power requirement of the LED system = 6W(In kitchen)+ 6W(In centre hall)+ 3W (In bed room)+ 3W(In bathroom) = 18 watt
- Power requirement of the Mobile battery charger = 3.5 W
- Energy used by the system =4hr*6w (LED in kitchen) + 4hr*6w (LED in centre hall) + 1hr*3w (LED in bedroom) + 1hr*3w (LED in bathroom) + 3.5w*2hr (mobile battery charging) = 61WH.
- The total energy used by the loads is 61 WH.

2. The energy stored in battery

The light in the centre hall and kitchen should work about 4hr. Others should work for at most 1hr. Maximum usage of the charger will only be 2hr. So the battery should have a back up of 4hrs.

The required battery Watt Hour should be greater than 61WH. For a 12V battery the required Ampere Hour should be greater than 61WH/12V i.e. it should be greater than 5.1 AH. The battery capacity of the selected one, meeting the above requirement is 7AH.
Then, the Watt Hour of selected battery =12*7= 84WH.

3. The energy generated by solar panel

Energy required by the loads = 61WH
Exposing the solar panel for 6 hrs,

Energy obtained from one 10W solar panel= 60WH

It shows that a single panel is not enough. So two panels of 10W are selected.

The energy generated from two panels = 20W*6 Hrs = 120WH

Considering the natural system losses (i.e. loss by reflection, loss due to incomplete absorption, loss due to metal coverage, etc)

The obtained energy = 120*0.85 = 102WH

We only require 61 WH for operating the loads connected to our system. Applying a de-rating factor of 2, two 10W solar panel supplying energy of 102WH for exposing about 6 hours is sufficient for proper operation.

3.2 DC- DC CONVERTER

The peak variations of current and voltage are tabulated below.

INTENSITY(lx)	CURRENT(A)	VOLTAGE(V)	POWER(W)	
Sunny Day	698	1.12	20.85	23.35
	720	1.20	20.56	24.67
Cloudy day	256	0.96	16.90	16.19
	367	0.98	17.26	16.91

Maximum output voltage = 20.85V

Minimum output voltage = 16.90V

The tabulated data shows that the current and voltage varies over a wide range. So a regulator IC suitable to withstand these variations is required. For charging a 12V, 7AH sealed Lead acid battery, required voltage is 14.4V. So we have to regulate variable voltage from the solar panel into 14.4V.

The input output specifications of IC LM2576 buck regulator is given below.

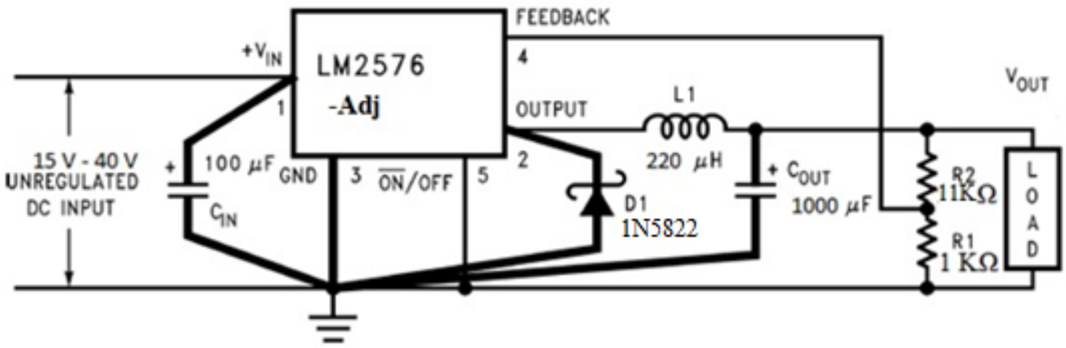
Electrical characteristics of IC LM2576 - adj:

Input voltage range :- $15V < V_{in} < 40V$

Output current :- $0.5A < I_{load} < 3A$

Output voltage :- 14.4V

Minimum charging current required by the 12V,7AH battery is about 700mA and the maximum current of this IC is 3A.So this IC can be used as a DC-DC converter.



Vout = Vref(1+(R2/R1)) where Vref = 1.23 V

R2 = R1((Vout/Vref)-1)

Take R1 = 1K

R2 = 1((14.4/1.23)-1) = 11KΩ

Inductor selection:-

- The inductor smoothens the load current.
- It should be of thick wire to handle the high output current.

Calculate inductor volt * microsecond constant

$E*T = (V_{in(max)}-V_{out})\ V_{out}/V_{in} * (1000/F_{(in\ KHz)})$

F=> Switching frequency of LM2576 = 52 KHz

$V_{in(max)}= 25$ V, $V_{out} = 14.4$ V

$E*T = 117.4$ V.uS

$I_{load(max)} = 3A$(since the maximum capacity of the regulator is 3A)

From the characteristics of LM2576 IC the inductor corresponding to the above values is 150uH. ie, L_1= 150uH.

Output Capacitor selection:-

- Capacitor decreases the output voltage ripple.
- As the circuit deals with a high current a low ESR aluminium electrolyte capacitor should be selected.

For stable operation,

$C_{out} > 13{,}300(V_{in(max)}/V_{out}*L_{(uH)})$ uF

>153.9uF

For getting an acceptable output ripple voltage and transient response it should be large enough. Select C_{out} = 1000uF ,25V electrolytic capacitor

Catch diode selection:-

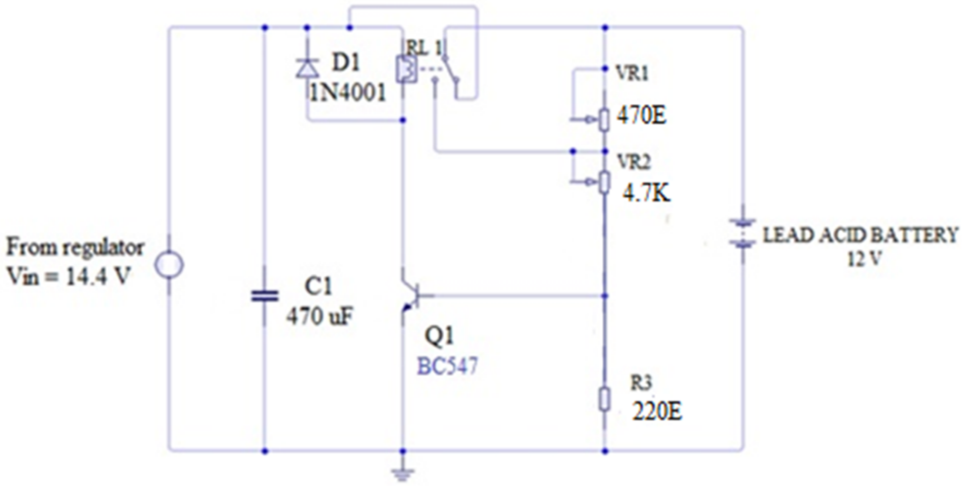
- It provides a return path for the inductor current when the switch to the load is open.
- The diode should have a current rating equal to the maximum current limit of the LM2576.
- The reverse voltage rating of the diode should be at least 1.25 times the maximum input voltage.
  Use a 60V 1N5822

Selection of input capacitor:-

- A 100 μF aluminium electrolytic capacitor located near the input and ground pins provides sufficient bypassing and stable operation.

3.3 BATTERY CHARGING CONTROL CIRCUIT

The regulator voltage should be stored efficiently for driving the loads. Different types of batteries are available in the market. Because of high reliability, low cost and better storage capacity lead acid battery is used as storage device. Compared to other cells they are easily available. For the better working and long life of batteries, a battery charging control circuit is used.



When battery is fully charged the voltage across the battery is 13.8V and when discharged it is 11.4V. So the charging control circuit should be designed so as to sense this voltage and switch off the charging. For this purpose a relay controlled circuit is used. Here when the battery is fully charged the base voltage of the transistor is sufficient to turn on it. Now the relay is activated and the charging process is cut off. When the battery voltage is less than 13.8V the transistor turn off and again starts the charging process.

A DC relay of 12V is chosen.

If the battery is fully charged the voltage across the battery = 13.8V

Now the charging should be cut off and the relay is on the normally open position.

So (13.8*R3)/(VR2+R3) = 0.7V

Choose R3= 220Ω

VR2 = ((13.8*.22)-(.7*.22))/0.7

=4.12K

Use a preset of 4.7K.

During charging, if the battery is fully charged it shows 14.4V across the battery. To cut off charging the base voltage of the transistor should be greater than or equal to 0.7V.

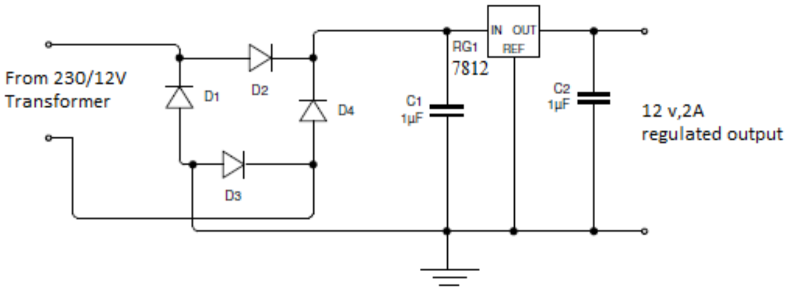
So (14.4*.22)/(.22+4.12+VR1) = 0.7V

VR1 = 185Ω

Use a preset of 470Ω.

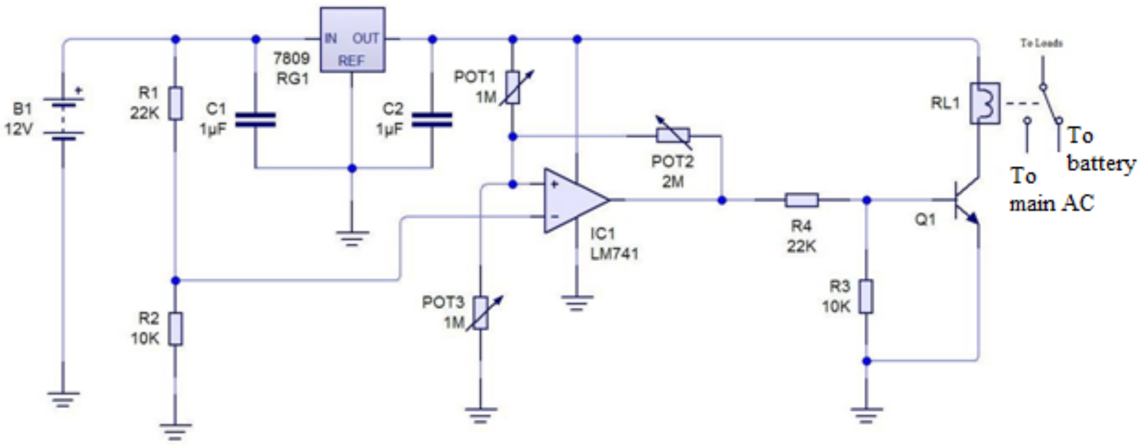
4. VOLTAGE REGULATOR

A 230/12V, 2A transformer, a bridge rectifier and a 7812 regulator IC is used. The capacitors are for avoiding ripples in the input and output voltages of the IC and are chosen as C1= 0.1uF & C2= 0.1uF. Diodes selected are four 1N5822 to withstand the 2A current.



5. SWITCHING CIRCUIT

The switching circuit is used to connect the loads to regulated output from the Main AC in cases of insufficient power from the battery. The system uses a Schmitt trigger based comparator and a relay for the switching purpose. When the battery voltage is sufficient the output of the Schmitt trigger is high and the relay is active. In this condition the loads are connected to the battery voltage. When the battery voltage becomes insufficient the Schmitt trigger output will be low and the relay switches the loads to the Main AC supply.



The Vcc of the Schmitt trigger is 9V. To provide two positive thresholds for switching a variable resistance of 1MΩ is connected from the non-inverting terminal of op-amp to Vcc. The loads get sufficient power from the battery above 11.4V and insufficient power below

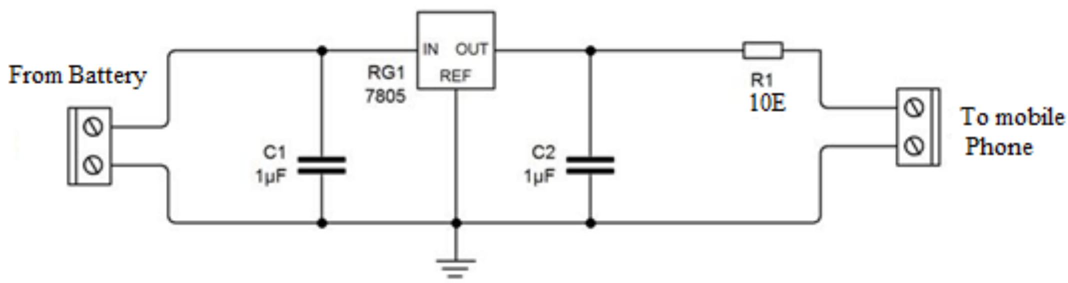
10.6V. So the two thresholds are set as 10.6V and 11.4V by adjusting the resistors pot1, pot2 and pot3.

Choose pot1 = 1MΩ, pot2 = 2MΩ and pot3 = 1MΩ

R4 = 22k and R3 = 10K are selected to turn on or turn off the transistor accordingly.

3.6 MOBILE BATTERY CHARGING CIRCUIT:

One of the loads connected is a circuit for charging mobile batteries. A mobile battery needs 4.5 V and 180-300mA. The circuit shown below provides these specifications for mobile charging.



CHAPTER 4

SYSTEM INTEGRATION

4.1. CIRCUIT DIAGRAM

4.2 PCB LAYOUT

REGULATOR

BATTERY CHARGING CIRCUIT AND SWITCHING CIRCUIT

4.3 PRODUCT PHOTOGRAPH

4.4 OPERATING SEQUENCE OF INSTRUMENT

1. Place the solar panel such a way that it gets maximum sun light by adjusting its height and angle.

2. Keep the battery in a region of low temperature.

3. Switch on the loads that are required.

CHAPTER 5

CONCLUSION

5.1 RESULT

Experimental results using a 10W solar panel for different days and time are tabulated below

Day 1

Time	Voltage(V)	Current(mA)	Intensity(lx)
10 am	19.6	498	440
11 am	19.40	515	400
12 pm	20.00	583	760
2:50 pm	19.56	493	403
3:40 pm	19.41	430	316

Day 2

Time	Voltage(V)	Current(mA)	Intensity(lx)
10 am	20.17	498	549
11 am	17.89	313	242
12 pm	19.5	606	606
1 pm	20	580	745
2 pm	19.73	512	520
3:10 pm	17.2	501	490

Day 3

Time	Voltage(V)	Current(mA)	Intensity(lx)
10 am	19.6	498	444
12 pm	19.18	514	466

1 pm	19.75	530	602
2 pm	19.41	515	405
3 pm	17.26	290	221

Day 4

Time	Voltage(V)	Current(mA)	Intensity(lx)
10:30 am	19.3	542	490
11:30 am	19.27	563	530
1 pm	19.7	570	634
2 pm	18.64	279	307
3:30 pm	16.9	250	32 6

According to the observed readings variations of different parameter are plotted.

- <u>Variation of current in a day</u>

- <u>Variation of current with variation in light intensity</u>

<u>Observations</u>

▲ As the light intensity increases, current obtained from the panel increases.

▲ Average power = 9.92W

▲ Maximum voltage = 20.17V

▲ Minimum voltage = 16.9V

▲ Maximum current = 606mA

▲ Minimum current = 250mA

▲ Maximum current is obtained between 10am and 3pm.

▲ When two solar panels are connected in parallel,

Maximum voltage = 20.85V

Maximum current = 1.21A

Experimental results using buck regulator

- Variation of output current for various capacitors

Capacitor(µF)	Output voltage(V)	Output current(mA)
220	14.6	120
320	14.6	140
430	14.6	490
470	14.6	300
550	14.6	490
570	14.6	510
800	14.6	520
1000	14.6	550

▲ Maximum current is obtained for 1000µF.

- Variation of output current for various inductors

Inductance(µH)	Output voltage(V)	Output current(mA)
91	14.6	950
106	14.6	950
142	14.6	940
215	14.6	910
300	14.6	840

▲ Maximum current is obtained for 106µH.

Experimental results using buck regulator for different days and time are tabulated below

Day 1

Time	Voltage(V)	Current(mA)
10 am	14.6	898

11 am	14.6	1.15
12 pm	14.6	1.23
2:50 pm	14.6	893
3:40 pm	14.6	830

Day 2

Time	Voltage(V)	Current(mA)
10 am	14.6	898
11 am	14.6	613
12 pm	14.6	1.06
1 pm	14.6	1.30
2 pm	14.6	912
3:10 pm	14.6	861

Day 3

Time	Voltage(V)	Current(mA)
10 am	14.6	898
12 pm	14.6	914
1 pm	14.6	1.30
2 pm	14.6	868
3 pm	14.6	490

Day 4

Time	Voltage(V)	Current(mA)
10:30 am	14.6	982
11:30 am	14.6	1.03
1 pm	14.6	1.27
2 pm	14.6	479
3:30 pm	14.6	450

- ▲ Average current from the regulator = 920mA
- ▲ Time required to fully charge the battery = AH/ current =7/0.920=7.6 hours.
- ▲ Current required by loads = 292mA (for mobile battery charger)+ 2*250mA(for 3W LED)+2*500mA(for 6W LED) =1.792A

Output power (W)

- ▲ Battery backup = AH/current=7/1.792=3.9 Hours

Experimental set up to find the efficiency of the regulator

LOAD (Ω)	INPUT			OUTPUT			EFFFICIENCY (%)
	V (V)	I (A)	P (W)	V (V)	I (A)	P (W)	
11.4	20.40	1.04	21.22	14.6	1	14.6	68.80
13.6	19.68	0.980	19.28	14.6	0.900	13.14	68.15
16.6	20.05	0.890	17.84	14.6	0.800	11.68	65.47
20.7	20.00	0.770	15.40	14.6	0.700	10.22	66.36
24.2	19.80	0.700	13.86	14.6	0.600	8.76	63.41
28.8	18.98	0.600	11.39	14.6	0.500	7.3	64.09
36.6	19.64	0.490	9.62	14.6	0.400	5.84	60.70
45.8	20.65	0.400	8.26	14.6	0.320	4.67	56.54

- ▲ Average efficiency of the regulator is 64.19%.

5.2 ERROR ANALYSIS

The system uses switched mode LM2576 with an expected efficiency of 75%.The battery charging time was designed to be 6hrs.When the battery is fully charged the panel should be automatically disconnected from the battery. The loads consist of two 3W LEDs, two 6W LEDs and a mobile battery charger. The whole system of loads consume a total current of 1.792A.

Almost all specifications were obtained. The efficiency of buck regulator is 64.19%.The capacitor designed for LM2576 was 680uF but a 1000uF was needed to get the sufficient current.

APPENDIX