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Making lightweight, high efficiency durable solar panels using Tefzel® sheets and theoretical estimation of solar irradiance

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Abstract— **Solar energy is a massive source of energy and can be tapped in many ways. Monocrystalline solar cells are one of the most efficient and are conventionally used with a tempered glass front sheet. This restricts the application and feasibility as the panels become very heavy and rigid. The use of Tefzel® sheets as alternative to the tempered glass decreases the weight of the panels by 5 times and makes them less rigid, increases the efficiency due to higher transmissivity of the Tefzel® sheets without compromising on the durability. We have made and tested 1-Watt and 3-Watt panels with monocrystalline solar cells using Tefzel® CLZ 500 sheets from DuPont. The power generated has been tested and compared with theoretical values using MATLAB.**

Index Terms— **monocrystalline;Tefzel®;MATLAB.**

I. INTRODUCTION

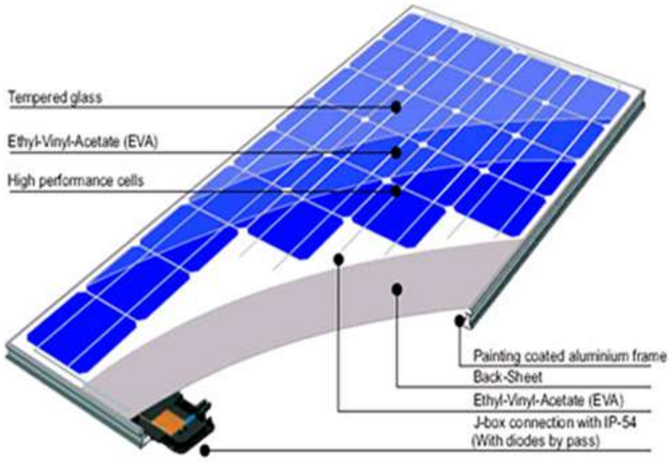
We are part of a team of students working on a Solar car project in Manipal Institute of Technology. We have successfully made and tested our car for about 200km,we had used a LiFePo4 battery pack and monocrystalline solar panels with a tempered glass front sheet. We had to compromise on the aerodynamics of the car due to the rigidity of the panels. The efficiency of the panels also came down greatly because of the weight of the solar panels. The weight of the panels alone was 80kg.This time, we are in pursuit of making a commercial Solar Electric Vehicle. We want to make custom high performance solar panels so that we do not have to compromise on the aerodynamics of the car and the weight can also be greatly reduced, thereby improving the overall efficiency of the car.

II. PROPOSED SOLUTION

After a lot of study and research,we decided to use Tefzel® sheets as front sheets for the solar panels.Dupont Tefzel® ETFE film is a transparent,thermoplastic film that can be heat sealed,thermo formed,metallized,laminated and used as a hot melt adhesive.Tefzel® sheet is ideal for using it as the front sheet for the solar panels due to their hight transmissitivity and low weight.

A. *Problems with conventional solar panels,using tempered glass frontsheet*

This is the layout of a solar module with tempered glass frontsheet.



Tedlar is used as the backsheet and tempered glass is used as the frontsheet.The tempered glass is very heavy due to which the panel weight comes to around 0.08kg/Watt.It is also very rigid and hence the application of these panels is limited.

B. *Properties of Tefzel® sheets*

DuPont Tefzel® ETFE fluoroplastic film CLZ 500 has a thickness of 125 micrometers and an area factor of 4 m^2/kg. It has a melting range of 260-280^{0}C and is heat sealable. It has superior anti-stick and low frictional properties, high resistance to impact and tearing. It is inert to outdoor atmosphere and has high transmittance. Hence this sheet is ideal for the purpose as it greatly reduces the weight and improves the efficiency of the panels. The main constraint by using this is that strength and stiffness is not provided to the panel because of the flexibility of the sheet. This can be overcome by using a hard and stiff back sheet. We used PCB as back sheet and this provided the strength and toughness to the panel. Using these materials,the weight will come down to around 0.015kg/Watt.

III. IMPLEMENTATION

Our encapsulation procedure:
Different parts of a solar panel:
1)Pottant: The pottant is the material which melts and surrounds the solar panels and totally encloses the solar cells and the associated circuitry.We have chosen EVA as the encapsulate because it has good bonding characteristics with our front sheet and our backsheet(Tedlar).The solar panel must be supported mechanically either by a superstrate
2)FrontCover or Superstrate:The main use of the frontcover is to provide weathering protection for the entire panel and prevent or reduce moisture ingress,soil accumulation.We

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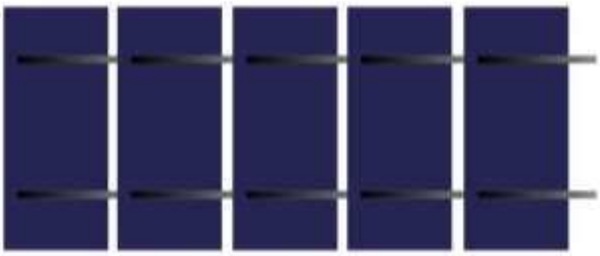
have chosen Tefzel® film as it is inert to outdoor atmosphere and has high transmittance. Hence this sheet is ideal for the purpose as it greatly reduces the weight and improves the efficiency of the panels.

3)BackCover or Substrate:The backcover material should be weatherable,mechanically durable,hard and tough.We have chosen tedlar as back cover as it has high level of reflectivity. Bypass diodes are placed in parallel with strings of 12 cells. When a particular cell is shaded,the corresponding string is bypassed and shading losses are minimized.

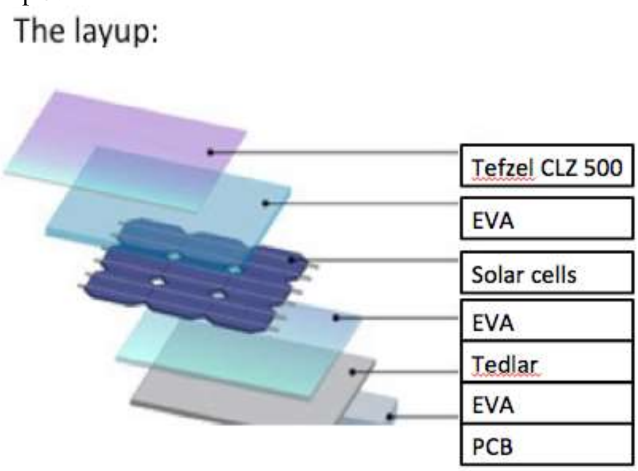
<u>The Procedure:</u>

Step 1:Stringing of Solar cells



Step 2:Arranging all the strings of solar cells and connecting them is series using bus bars

Step 3:



This layup was put in a lamination chamber and was adjusted to a time of 20 minutes and a temperature of 140^{0}C.We had first made a 3W panel and observed that there were wrinkles on the front sheet due to excess temperature and lamination time.For the next trial,we reduced the temperature to 130^0 C and the time to 18min.This resulted in improved results ithout any wrinkles on the front sheet.Below are the pictures of the 1-Watt and 3-Watt panel:

3-Watt panel

1-Watt panel

The second part of this project was to make a theoretical calculation of the amount of solar irradiance falling on the earth at a particular place and time. We achieved this using ASHRAE method.This method has been formulated solar irradiance data collected periodically over long periods of time.

ASHRAE(American Society of Heating,Refrigerating and Air-conditioning Engineers) has given a method for estimating the hourly global and diffuse radiation falling on a horizontal surface.According to this method,the global radiation reaching a horizontal surface on the earth is given by:

$$I_g = I_b + I_d \quad (1)$$

Where I_g =hourly global radiation
I_b =hourly beam radiation
I_d =hourly diffuse radiation

$$I_b = I_{bn}\cos(\boldsymbol{\Theta_z}) \quad (2)$$

I_{bn}=beam radiationin the direction of the rays
$\boldsymbol{\Theta_z}$ =angle of incidence on a horizontal surface

$$w=(12-(\text{timeofthe day}))*15 \quad (3)$$

w is the hour angle

$$\Delta=23.45*\sin((360/365)*(284+n)) \quad (4)$$

n is the day of the year

$$\cos\boldsymbol{\Theta_z}=(\sin ø*\sin\Delta)+(\cos ø*\cos\Delta*\cos w) \quad (6)$$

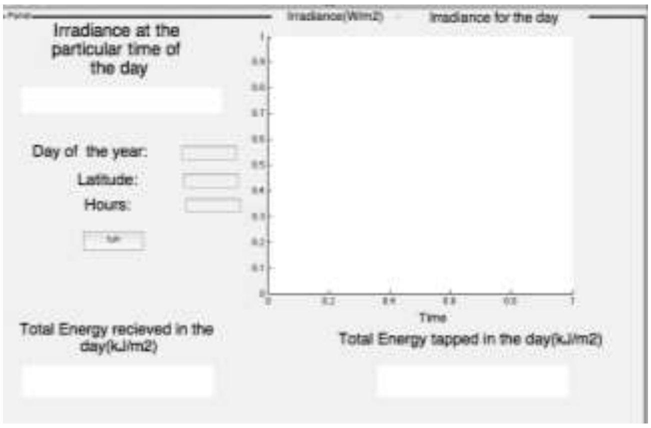
ø is the latitude of the place

$$\text{Irradiance}(W/m^2)=(A*\exp(-(B/\cos\boldsymbol{\Theta_z})))*(\cos\boldsymbol{\Theta_z} + C) \quad (7)$$

The constants A,B and C are obtained from this table:

DAY	A	(W/m^2)	B	C
January	21	1202	0.141	0.103
February	21	1187	0.142	0.104
March	21	1164	0.149	0.109
April	21	1130	0.164	0.120
May	21	1106	0.177	0.130
June	21	1092	0.185	0.137
July	21	1093	0.186	0.138
August	21	1107	0.182	0.134
September	21	1136	0.165	0.121
October	21	1136	0.152	0.111
November	21	1190	0.144	0.106
December	21	1204	0.141	0.103

These calculations were simulated on MATLAB to make a graphical user interface to estimate the amount of solar irradiance at a particular place at a particular time.This is an image of the graphical user interface:

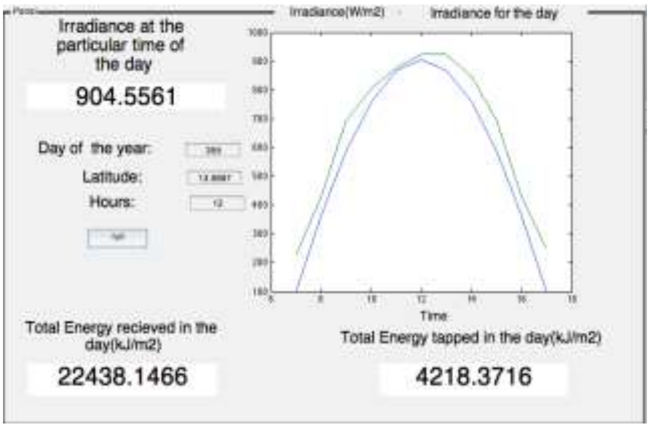


We need to enter the day of the year,latitude and time of the day to get the graph of solar irradiance for the entire day.
We also get an estimate of the amount of solar energy received throughout the day.From this, we calculated the amount of energy which will be tapped using solar cells of efficiency 18.8%.

IV. RESULTS

To compare the theoretical values of irradiance calculated by ASHRAE method with the practical readings and test the performance of the panel we made using Tefzel® sheets,we measured the irradiance hourly on 20th December 2013.The irradiance can be calculated by measuring the short circuit current of the solar cell.(The rated I_{sc} is at $1000W/m^2$)the irradiance is given by

$$(I_{sc(measured)}/I_{sc(rated)}*1000)\ W/m^2 \quad (8)$$



On MATLAB,we plotted the irradiance calculated on an hourly basis, by ASHRAE method (blue in the graph) and also plotted the practical reading (green in the graph) of the solar panel.We can observe that the theoretically calculated readings almost coincide with the practical readings and the performance of method in estimating the amount of Solar Irradiance is verified.

The 1-Watt and 3-Watt panels were tested on an irradiance tester in the factory where a flash of irradiance of 1000 W/m^2 is incident on the solar panels and the corresponding volage,current and power is measured.The panel outputs were 2.93W and 0.99 W respectively.

ACKNOWLEDGMENT

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