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Senior Design Project Report

Team 8: Solar Technology

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Abstract

All over the world there is significant increase in the usage of solar energy. Several automobile companies now have their project works dealing with solar power to run vehicles, as an alternative to using fuel. Solar cars harness the energy from the sun, converting it into electricity. That electricity then fuels the battery that runs the car's motor. Photovoltaic Cells (PVCs) are the components in the solar paneling that convert the sun's energy to electricity. They are made up of semiconductors, usually made of silicon, that absorb the light. The sunlight's energy then frees electrons in the semiconductors, creating a flow of electrons. That flow generates the electricity that powers the battery or the specialized car motor in solar car. The main component of a solar car is its solar array, which collect the energy from the sun and converts it into usable electrical energy.

In this project, the solar cells collect a portion of the sun's energy and stores it into the batteries of the solar car. Before that happens, power trackers convert the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. After the energy is stored in the batteries, it is available for use by the motor & motor controller to drive the car. The motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels.

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We would like to thank Dr. Wael Al-kouz for his tremendous effort in helping and guiding us through this journey. He was a great example and a source of knowledge that we always went to when we faced difficulties. In addition, we would like to express our gratitude to the dean of Engineering College Dr. Jamal Nayfeh and the chairman of the Mechanical Engineering Department Dr. Faramarz Djavanroodi for their continuous support. In addition, we would like to extend our thanks to all of PMU faculty in the department of mechanical engineering especially Dr. Mohamed Elmehdi Saleh who is the instructor for this course and who always answered our questions with a great attitude.

List of Acronyms (Symbols) used in the report:

Symbol	Defenition
F_{total}	Total force
$F_{friction}$	Friction force
F_{drag}	Drag force
$F_{acceleration}$	Acceleration force
m	mass
g	Gravity acceleration
μ	Friction coefficient
ρ	density
C_D	Drag coefficient
A_{cross}	Cross sectional area
V	velocity
a	acceleration
P_{total}	Total power
V_{max}	Max speed
$P_{requried}$	Required power
A_{panel}	Area of single panel
P_{panels}	Power output of panels

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Chapter 1: Introduction

1.1 Project Definition

This project is intended to design solar panels that are capable of providing enough power to run a solar car that is solely dependent on solar energy and batteries. The main challenge is to find out how much power is needed and how to provide that power using solar panels. Another challenge is to calculate the total area of all panels and see if we can fit the panel on the solar car.

1.2 Project Objectives

1) Design and install the most efficient Solar Panel, with the correct dimensions and precisions in order to run a fully solar-powered automobile.

2) To design a solar panel to transfer a constant 750Watt to the dc motor.

3) The main objective of the solar car is to reduce the dependency on fossil fuels and use renewable energy as an alternative.

4) Using the knowledge of engineering economy in order to calculate the total cost of the project.

5) For the solar panels to be able to provide enough electrical energy for the whole system to function in a persistent manner.

1.3 Project Specifications

According to PMU requirements, the design parameters are:

- Maximum mass = 400 kg
- Maximum speed = 70 km/h = 19.45 m/s
- Dimensions of the car: length = 5 m, width = 2 m, height = 1.5 m
- Batteries used 12 kWh (total)
- Total area of solar panels = 5 m^2

Chapter 2: Literature Review

The journeys for a consistent, protected, spotless, ecological well disposed of fuel is ceaseless. Carbon-based powers, for example, petroleum products are impractical and dangerous to our condition. A portion of the options is sustainable power sources that incorporate all fuel types and vitality transporters, not quite the same as the fossil ones, for example, the sun, wind, tides, hydropower, and biomass. Among these components, sun-oriented vitality is favored since it could give the cleanest feasible vitality to the longest term of time – the following barely any billion years. Because of its endless advantages in ecological, monetary social angles frameworks, turns into the world's fast developing vitality innovation. It can be said that the main constraint to sunlight-based force as a vitality source is our comprehension of creating productive and practical innovation which can actualize it. Not one thing in existence is liberated from cost yet imagine a scenario where we could figure out how to execute free rides. For sure it would be awesome if our vehicles could keep on running without us burning through billions on petroleum products consistently and to manage normal dangers that their ignition abandon. If we could drive a sun oriented controlled vehicle, that auto dream would work out as expected. Sun oriented vehicles would harness vitality from the sun through sun-based boards. A sunlight-based board is a bundled, associated get together of sun-based cells, likewise called photovoltaic cells which are strong state gadgets that can change over sun powered vitality straightforwardly into electrical vitality through quantum mechanical advances. They are silent and contamination-free with no turning parts and need the least upkeep. The power in this manner created would then fuel the battery that would run these engines. In this way we would get an electrically determined vehicle that would go on "free" vitality with no destructive outflows, that can use its full force at all paces, and would have next to no support cost.

Also, we looked for three type of solar:

Table 1: Specification of Thin Film Flexible Solar PV panel

Sr. No.	Area	Power Outputs	Weight	Efficiency
1	4 mm^2	375 Watts	140 lb.	25%

Advantages

i. Thin film solar PV panels are easy to handle
ii. More flexible as compare to conventional solar panels that can be adjust every curved surface.
iii. Available as thin wafer sheets
iv. Economical as compare to traditional solar panels

Disadvantages

i. Flexible solar PV panels are less efficient as compare to conventional solar panels.
ii. The structure of flexible solar panels is complex.
iii. It cannot be also used for astronomical solar devices.

Table 2: Amorphous Flexible solar PV panel

Sr. No.	Area	Power Outputs	Weight	Efficiency
1	4 mm^2	350 Watts	135 lb	25%

Advantages

v. The cost of amorphous type flexible solar panel is very low as compare to conventional solar panel.

vi. Amorphous silicon flexible solar panel is much more uniform over large areas as compare to crystalline silicon solar panel.

vii. Amorphous silicon can be produced in a variety of shapes and sizes (e.g., round, square, hexagonal, or any other complex shape.

Disadvantages

iv. The efficiency of amorphous type flexible solar panel is very low.

v. The structure of flexible solar panels is not uniform.

vi. The life time of amorphous type flexible solar PV panel is shorter than as compare to crystalline solar panel.

Table 3: Specification of crystalline Flexible Solar PV panel

Sr. No.	Area	Power Outputs	Weight	Efficiency
1	4 mm^2	340 Watts	138 lbs.	25%

Crystalline Silicon Flexible solar PV panel

Flexible solar PV panel is one of more important solar PV panel which is widely used across the global due to its light weight. Flexible solar PV panels are weight less and are very useful due to its two characteristics; one is rapid transport and deployment in emergencies scenarios. Flexible solar PV panels are mostly used in various places such as caravans, vehicles and even used in aircraft busses. Flexible solar panels are mostly glued directly on the surface of structures or buildings.

Nowadays, several solar panels used which are made from silicon material that is primary element in the beach sand. There are generally two types of solar cells are widely used; one is polycrystalline and other is mono crystalline. In the both types of solar cells, the cells are made by cutting the wafers of silicon out of the block. After that these all cells are wired together to make panels which are generally in group of 60 or 70 cells. Schematic diagram of crystalline silicon solar PV panel is shown in fig. 1.

Figure 1: Schematic diagram of flexible crystalline solar PV panel

The individual wafers are thick enough that they aren't flexible. But it turns out that if you cut the wafers thin enough, they become fairly flexible while retaining their photovoltaic properties.

Advantages

viii. Crystalline silicon flexible solar panel is more efficient as compare to thin film solar panel.
ix. The requirement of space is concerned is economical. These solar cells are capable of producing the four times more electricity as compared to space, which is available.
x. Most of silicon solar cells have 25 years of warranty and it also offers a return on investment.

Disadvantages

vii. Dirty and polluted ambience can hamper the performance of these panels.
viii. The structure of flexible solar panels is complex.
ix. The basic shape of these silicon solar cells is cylindrical with rounded edges. The characteristics shape accounts its functional effectiveness, the structural feature leads to substantial wastage of original silicon.

Material used in thin film solar PV panel

Nowadays, crystalline silicon flexible solar PV panels generally made from crystalline silicon metals which are the crystalline form of silicon. Crystalline silicon is the dominant semiconducting material used in photovoltaic technology for the production of solar cells. These cells are assembled into solar panels as part of a photovoltaic system to generate solar power from sunlight.

Power outputs & weight of thin film solar panels for 4 mm^2 area

Dimensions of solar panels directly depend on the power outputs and weight of solar panels. So, the dimensions such as size, weight and power outputs play a vital role for the selection of solar panels which is to be installed for domestic as well as commercial purpose. The average power outputs and weight of the 4 mm^2 area of flexible crystalline silicon solar panels are 340 watts and 138 lbs. with efficiency 25%. Details of crystalline silicon solar PV panels are shown in table 1.

PV Cells and the Influence of Internal Resistance

According to Gang Yang, silicon solar cells maximum power is simulated under different radiation. The internal resistance of the maximum power is also simulated. The results justify the nonlinear output characteristic of the silicon solar cell and the test prove to be effective in determining the most applicable load to balance the maximum power of the cell. Also, he proves that the internal resistance is the key factor to the maximum power and fill factor of the solar cells.

Cost-effective Si-based solar cells

According to Shafiqul Islam, basic building blocks of a solar panels. There are nine companies manufacturing in Bangladesh. Solar modules of the nine companies are about 80-90MWp annually. He found that about 55-60% of the total module cost depend on the solar cells. The quality of the solar cells depends on the cost-effective power. The cost of the solar cells around USD2.5-USD1.2 per Wp. Cost will change depend on the brand. Several solar cells of 150×150 mm^2 sizes and 200 micrometers thick. The paper addresses the challenges and potentialities in fabricating the quality based crystalline solar cells using slightly p-doped Si-wafers and chemicals in order to adopt technology so as to reduce the cost of solar modules

Performance of Rooftop Solar PV System

According to Karthik Atluri, the paper study the performance of 5KW rooftop solar PV system with crystalline solar cells. On this test, 15%efficient glass was covered by crystalline solar cells with a temperature co-efficient of a power as 0.47 %/°C is chosen. The system was mounted on a tilt angle close to latitude is tested using National Renewable Energy Laboratory (NREL). The results show the 5 kW PV system generates an annual energy of 7658 kWh with a capacity factor of 17.5 %. The cost value of the energy is also estimated to be around RS. 34457.

Silicon solar cells: toward the efficiency limits

Photovoltaic (PV) transformation of solar powered vitality begins to give an appreciable contribution to power generation in numerous nations, with over 90% of the worldwide PV showcase depending on solar based cells dependent on crystalline silicon (c-Si). The present effectiveness record of c-Si solar cells is 26.7%, against an intrinsic limit of ~29%. Ebb and flow research and creation patterns target expanding the proficiency, and decreasing the cost, of industrial modules. Right now, survey the principle ideas and theoretical approaches that allow calculating the efficiency limits of c-Si solar cells as a function of silicon thickness. For a given material quality, the ideal thickness is dictated by an exchange off between the contending needs of high optical assimilation (requiring a thicker retaining layer) and of effective carrier collection (best accomplished by a slim silicon layer). As far as possible can be determined by understanding the vehicle conditions in the presumption of ideal (Lambertian) light catching, which can be accomplished by embeddings appropriate photonic structures in the sun powered cell engineering. The impacts of extraneous (mass and surface) recombination's on the transformation productivity are examined. We additionally show how the fundamental ends and patterns can be portrayed utilizing moderately straightforward logical models. Prospects for overcoming the 29% limit by means of silicon/perovskite tandems are briefly discussed.

SOLBIANFLEX SR Company in Italy

The monocrystalline high efficiency SR cells are sandwiched by two licensed metallic grids. The grid on the front is carefully tailored to optimize the current harvesting, while the one behind the cell offers strong mechanical support. The grids essentially form a double shield that acts as a conducting reinforcement to the solar cell. Extreme crack and bend tolerance are built in, enabling novel crystalline silicon architectures. A guaranty of high efficiency and unmatched durability in flexible solar panels.

Features

- High tolerance to cracks and bending thanks to the double shield protecting the cell
- Flexible and lightweight (2.2 kg/m2)
- Completely waterproof and resistant to salt water
- Thin (less than 2 mm)
- IEC 61215 and IEC 61730 certified
- Adaptable to any battery: from 5 to 48-volt, lead-acid or lithium

	SR 160 L	SR 160 Q	SR 144	SR 108	SR 72 L	SR 72 Q	SR 62
Maximum power [W]	160	160	144	108	72	72	62
Length Y [mm]	1523	1046	1364	1046	1364	728	1205
Width X [mm]	683	996	683	683	365	683	365
Thickness [mm]	2	2	2	2	2	2	2
Weight [kg]	2.40	2.40	2.10	1.70	1.20	1.20	1.10
Max power Voltage Vmp [V]	18.6	18.6	16.7	12.6	8.4	8.4	7.2
Max power Current Imp [A]	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Open circuit voltage Voc [V]	23.0	23.0	20.4	15.3	10.2	10.2	8.9
Short circuit current Isc [A]	9.0	9.0	9.0	9.0	9.0	9.0	9.0
NOCT [°C]	45 ± 2	45 ± 2	45 ± 2	45 ± 2	45 ± 2	45 ± 2	45 ± 2
Operating temperature [°C]	-40/+85	-40/+85	-40/+85	-40/+85	-40/+85	-40/+85	-40/+85
Temp. coeff. Pmax [%/°C]	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
Temp. coeff. Voc [%/°C]	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27
Temp. coeff. Isc [%/°C]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Columns x Rows (cells n°)	4x9 (36)	6x6 (36)	4x8 (32)	4x6 (24)	2x8 (16)	4x4 (16)	2x7 (14)
Maximum system voltage [V]	1000 V	1000 V	1000 V	1000 V	1000 V	1000 V	1000 V
Maximum reverse current [A]	12 A	12 A	12 A	12 A	12 A	12 A	12 A
Safety class	A	A	A	A	A	A	A

Figure 2: SOLBIANFLEX SR Solar Panel Features.

Dimension of thin film single junction

There has been a lot of enthusiasm for building up a slim film sun-based cell since it is lightweight and adaptable. The GaAs meager film sun-oriented cell is a top contender in the flimsy film sunlight-based cell showcase in that it has a powerful transformation proficiency

(PCE) contrasted with that of other slight film sun-based cells. There are two normal structures for the GaAs sunlight-based cell: n (producer)- on-p (base) and p-on-n. The previous performs better because of its high assortment proficiency in light of the fact that the electron dispersion length of the p-type base locale is any longer than the opening dissemination length of the n-type base district. In any case, it has been constrained to create profoundly productive n-on-p single-intersection GaAs slender film sun powered cell on an adaptable substrate because of specialized deterrents. We researched a straightforward and quick epitaxial lift-off (ELO) technique that uses a pressure beginning from a Cr/Au bilayer on a 125-μm-thick adaptable substrate. A metal mix of AuBe/Pt/Au is utilized as another p-type ohmic contact with which a n-on-p single-intersection GaAs slender film sun-oriented cell on adaptable substrate was effectively manufactured. The PCE of the manufactured single-intersection GaAs slim film sun-oriented cells arrived at 22.08% under air mass 1.5 worldwide brightening.

Power system of thin film single junction

The point of the examination is to apply a strategy normally used to decide the proficiency of multi-intersection nanoheterostructure III–V sunlight based cells by investigation of the dim current-voltage (I–V) qualities to such a capricious semiconducting material as formless silicon. a-Si:H and a-Si:H/μc-Si:H p-I-n structures without a light-dissipating sublayer or an antireflection covering are examined. The consequences of estimations of the dim I–V attributes exhibit that the voltage reliance of the current has a few exponential parts. The transformation productivity of sunlight-based cells (SCs) is determined for each segment of the dim I–V trademark. This yields a reliance of the potential SC effectiveness on the age current thickness or on the photon transition. The watched understanding between the information got from the test attributes and consequences of figuring can be viewed as good and adequate, accordingly the strategy recommended for estimation and investigation of dim I–V qualities and tried before on SCs dependent on crystalline III–V mixes gets a widespread nature. The examination of the attributes of p-I-n formless silicon structures and the estimation of potential efficiencies, in view of this investigation, broaden the creators' comprehension of this class of gadgets and make it conceivable to improve the innovation and photoconversion proficiency of SCs of this sort.

Supply of thin film single junction

From sun-based cell application perspective, this section audits the parts of hydrogenated undefined silicon (a-Si:H) based materials. Lance and LeComer made the initial a-Si:H films with gleam release by breaking down hydrogen containing gases, for example, SiH4, in which hydrogen particles end the Si dangling bonds and decrease the imperfection thickness altogether. The decrease of deformity thickness lead to the plausibility of doping a-Si:H to shape N-type and P-type films and made it conceivable to make p-n intersection, which is the establishment of slender film silicon-based electronic gadgets, for example, sun oriented cells and flimsy film transistors. From that point forward a few strategies have been created to store a-Si:H materials and gadgets. From sun oriented cells perspective, a-Si:H is one of the helpful materials with a few remarkable properties: (1) high retention coefficients in the unmistakable range permitting to utilize a slender safeguard layer, (2) enormous region uniform statement for ease large scale productions, and (3) affidavit on different remote substrates for unbending and adaptable sun powered modules. The principle hindrance of a-Si:H is the lower transporters versatility and lifetime than the precious stone copartners, which bring about the lower vitality discussion proficiency in a-Si:H sun-based cells than c-Si sunlight based cells. Also, the purported Staebler-Wronski impact causes a light-instigated corruption in a-Si:H sun powered cell effectiveness. Throughout the years, a-Si:H science and innovation have been very much created driving by the applications in slight film silicon photovoltaic (PV) sun powered vitality and enormous zone show ventures. In the PV applications, a-Si:H sun-oriented cell has been one of the most significant advances for the purported second-age PV sun powered vitality. In any case, with the huge cost decrease of poly-Si and c-Si sun powered boards over the most recent couple of years, a-Si:H PV industry has been contracted to the sideline and can just give items in the specialty advertise. Luckily, new application as the surface passivation layer on c-Si to shape a-Si:H/c-Si heterojunction sun-based cells gives a-Si:H another life in the PV business.

Custom made if there Flexible panel of thin film single junction

The base material is aluminum oxide, aluminum nitride, quartz, also
Precision, line accuracy ±2.5μm, minimum line width and spacing 20μm
, the Frequency range is DC～110G
Thin-film attenuator, High frequency to 26GHz, low standing wave, high attenuation accuracy
, and a Hybrid integrated signal circuit.

Cost of thin-film solar

The current cost of the thin-film solar cells ranges from $0.50 to $1.00/watt. Many manufacturers have set a target to bring down the cost under $0.70/watt of peak power. It will be cost-effective for residential users to have solar panels at their home, particularly compared with the traditional solar panel, where the average price per watt for solar panels is between $2.58 to $3.38 silicone cell

Safety

GaAs contains both gallium and arsenic. Gallium is said to have been found as non-toxic. However, many sources find this information to be non-conclusive. Contact with Gallium may cause skin diseases such as skin irritations or even dermatitis. On the other hand, arsenic, which is both a toxic chemical and carcinogen, has been found to be stable in this compound. Due to this, arsenic does not put its users in any immediate danger. It can also pass through the digestive system with negligible arsenic absorption.
As stated earlier, GaAs thin-film solar cells have reached nearly 30 percent efficiency in laboratory environments. However, they are still relatively expensive to produce. The cost has been a major constraint in the way of expanding the market for GaAs solar cells. They are commonly used for spacecraft and satellites.

Thin Film Multi-Junction Solar Cells

Multijunction photovoltaic cell is a type of solar cell or photovoltaic cell characterized by high efficiency in converting solar energy into electrical energy. The multi-link cell consists of several thin layers prepared using the so-called layering by the flow of molecules. While a type of semiconductor is characterized by an energy space that allows it to absorb a certain color of light, that is, it has the ability to absorb a limited part of the spectrum of

electromagnetic waves and reduce its efficiency when absorbing others. Therefore, the semiconductor layers are chosen so that they collectively absorb all the spectrum waves efficiently, thereby generating more electricity.
That is, in a multi-link cell, each layer absorbs one or two colors of the spectrum that passes through it so that it absorbs the greatest amount of light in its entirety and converts it into electricity.
Multi-link solar cells were invented for the first time and used to power satellites, as their high efficiency compensated the prohibitive expense of preparing them.
These cells are also currently used on Earth in photovoltaic complexes, and the combination of high efficiency and concentration in use has led to competition from silicon solar panels.
This technology is now also used on the Mars Opportunity and Spirit rovers, which were sent to Mars in 2004 and are still in operation.
The combination of straight conductive photovoltaic cells consisting of gallium phosphide indium GaInP and gallium arsenide GaAs and p-n junctions are good solutions for use and demand is increasing. During the period between December 2006 and December 2007, the price of high-purity gallium increased from $ 350 to $ 680 per kilogram. The price of germanium metal has also increased from $ 1,000 per kilogram to $ 1,200. These materials are used to provide the crystals needed for these cells.
A type of solar cell - Gallium Arsenide Tri-Link - was used in cars traveling during the "World Solar Challenge" race to exploit the sun and won the first prize four consecutive times from 2005 to 2007.
In 2009, a company announced that it had increased the efficiency of the three-link photovoltaic cell to 35%, an increase of 15% over its predecessor.
Spectrolab has devised what is called a concentrator solar cell, which converts solar energy into electricity with an efficiency of 7 and 40%, which is considered a world record, and it costs about $ 3 per watt. The cost of electrical energy is provided from 8 to 10 cents per kWh.
The efficiency of polynomial photovoltaic cells during the eighties of the last century has reached only 16%, then its efficiency penetrated the 30% limit in 1994.

Product Characteristics

Model No.	AE P6-72 315W	AE P6-72 320W	AE P6-72 325W	AE P6-72 330W	AE P6-72 335W	AE P6-72 340W
Warranty						
Product Warranty	12 Years					
Power Warranty	30 Years of 80% Output Power					
Electrical Data at STC						
Maximum Power (Pmax)	315 Wp	320 Wp	325 Wp	330 Wp	335 Wp	340 Wp
Voltage at Maximum Power (Vmpp)	36.73 V	36.81 V	36.89 V	36.97 V	37.05 V	37.09 V
Current at Maximum Power (Impp)	8.56 A	8.69 A	8.81 A	8.93 A	9.04 A	9.17 A
Open Circuit Voltage (Voc)	45.76 V	45.81 V	45.85 V	45.89 V	45.93 V	45.97 V
Short Circuit Current (Isc)	9.28 A	9.31 A	9.34 A	9.37 A	9.41 A	9.44 A
Panel Efficiency	16.23 %	16.5 %	16.7537 %	17.01 %	17.26 %	17.52 %
Power Tolerance (Positive)	+3 %	+3 %	+3 %	+3 %	+3 %	+3 %

Figure 3: Thin film multi-junction solar panels electrical data.

Multi-Junction Solar Panel

Multi-junction solar cells are solar cells with multiple p–n junctions made of different semiconductor materials. Each material's p-n junction will produce electric current in response to different wavelengths of light. The use of multiple semiconducting materials allows the absorbance of a broader range of wavelengths, improving the cell's sunlight to electrical energy conversion efficiency.

Traditional single-junction cells have a maximum theoretical efficiency of 33.16%. Theoretically, an infinite number of junctions would have a limiting efficiency of 86.8% under highly concentrated sunlight.

Currently, the best lab examples of traditional crystalline silicon (c-Si) solar cells have efficiencies between 20% and 25%, while lab examples of multi-junction cells have demonstrated performance over 46% under concentrated sunlight Commercial examples of tandem cells are widely available at 30% under one-sun illumination, and improve to around 40% under concentrated sunlight. However, this efficiency is gained at the cost of increased complexity and manufacturing price. To date, their higher price and higher price-to-performance ratio have limited their use to special roles, notably in aerospace where their high power-to-weight ratio is desirable. In terrestrial applications, these solar cells are emerging in concentrator photovoltaics (CPV), with a growing number of installations around the world.

The theoretical efficiency of MJ solar cells is 86.8% for an infinite number of p-n junctions, implying that more junctions increase efficiency. The maximum theoretical efficiency is 37, 50, 56, 72% for 1, 2, 3, 36 p-n junctions, respectively, with the number of junctions increasing exponentially to achieve equal efficiency increments. The exponential relationship implies that as the cell approaches the limit of efficiency, the increase cost and complexity grow rapidly. Decreasing the thickness of the top cell increases the transmission coefficient. As of 2010, the cost of MJ solar cells was too high to allow use outside of specialized applications. The high cost is mainly due to the complex structure and the high price of materials. Nevertheless, with light concentrators under illumination of at least 400 suns, MJ solar panels become practical.

Chapter 3: System Design

According to PMU requirements, the design parameters are:

- Maximum mass = 400 kg
- Maximum speed = 70 km/h = 19.45 m/s
- Dimensions of the car: length = 5 m, width = 2 m, height = 1.5 m
- Batteries used 12 kWh (total)
- Total area of solar panels = 5 m^2

In order for the car to move itself, it needs to overcome three forces: friction force, drag force, and acceleration force. Using the balance of forces:

$$F_{total} = F_{friction} + F_{drag} + F_{acceleration}$$

$$F_{total} = (m * g * \mu) + \left(\frac{1}{2} * \rho * C_D * A_{cross} * V^2\right) + (m * a)$$

Knowing that the acceleration due to gravity is around 9.81 m/s^2, drag coefficient is about 0.35, mass density of air is 1.2 kg/m^3, and the coefficient of friction is around 0.01, we can assume that frontal area of the car A_{cross} is 1.2 m^2.

Due to the heavy traffic in Saudi Arabia, we can assume that the acceleration time needed to reach the maximum speed is about 60 seconds. Thus, the acceleration becomes:

$$a = \frac{V_{max} - V_0}{t} = \frac{19.45\frac{m}{s} - 0\frac{m}{s}}{60\ s} = 0.3242\ m/s^2$$

The total force then becomes:

$$F_{total} = [\left(400kg * 9.81\frac{m}{s^2} * 0.01\right) + \left(0.5 * 1.2\ \frac{kg}{m^3} * 0.35 * 1.2m^2 * \left(19.45\frac{m}{s}\right)^2\right) + (400kg * 0.3242\frac{m}{s^2})] = 264.25\ N$$

According to the following equation, the maximum power needed is equivalent to the total force multiplied by the maximum speed:

$$P_{max} = F_{total} * V_{max}$$

Using the maximum speed of 19.45 m/s and the calculated total force, the maximum power needed becomes:

$$P_{max} = 264.25\ N * 19.45\frac{m}{s} = 5140\ W = 5.14\ kW$$

Since the batteries used in this project require an amount of energy equivalent to 12 kWh, the energy transferred from the solar panels to the battery needs to be around 12 kWh.

Assuming that the average sunny period in Saudi Arabia is 13 hours a day (during summer), the required solar panels output becomes:

$$P_{requried} = \frac{(12\ kWh)}{13\ h} = \ 0.923\ kW\ = 923\ W$$

The solar panels used in this project are 320 W (per panel) and the dimensions of each panel are 1672*991*35mm. Therefore, the area of a single panel becomes:

$$A_{panel} = (1.672\ m) * (0.991\ m) = 1.657\ m^2$$

Since the total area available for solar panels in this project is 5 m^2, the number of panels we need to use is:

$$number\ of\ panels = \frac{total\ available\ area}{area\ of\ a\ single\ panel} = \frac{5\ m^2}{1.657\ m^2} = 3.018\ \approx 3\ panels$$

Therefore, the power output of the solar panels becomes:

$$P_{panels} = (3) * (320\ W) = 960\ W$$

Since the power required by the batteries is 923 W, the solar panels will be able to provide that amount.

Chapter 4: Conclusions and Future Recommendations

4.1 Conclusions

- We need to use solar technology in order to save our planet
- There are 3 types of solar panels: monocrystalline, polycrystalline, thin film
- For this project we used 320W monocrystalline solar panels
- Force, power, and total area of solar panels were calculated
- Recommendation and advice were given to future students

4.2 Future Recommendations

- Start planning as early as you can (you don’t know what could happen)
- Communicate effectively with other teams
- Choose the solar panel type that satisfies your project’s needs
- Consider different manufacturers
- Choose a product with good warranty
- Account for shipping time
- Keep up with your advisor and instructor

8. References

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