DESIGN AND FABRICATION OF FLEXIBLE SOLAR PANEL

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ABSTRACT:

Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and mostabundant renewableenergysourceavailable,andtheU.S.has some of the richest solar resources in the world. Solar technologies can harness this energy for a variety of uses, including generating electricity, providing light or a comfortable interior environment, and heating water for domestic, commercial, or industrial use.

As solar increases in popularity across the world, more investments are being funneled into the developmentofsolarcelltechnology.Thegoalisto continuallyimprovesolarcellefficiency,whilealso making these cells durable and applicable to everyday situations like powering your phones, vehicles, clothing, and other smartdevices.

Thin-filmflexiblephotovoltaicsarepavingtheway to low-cost electricity. Current conversion efficiencies under standard conditions are the3-15 % range, but in real applications the overall productivity is high. These new photovoltaic technologies are ready to provide cheap, clean electricity to the 2 billion people who lackaccessto the grid as well as to energy-eager companies and families in the developed world facing the increasingcostsofelectricitygeneratedusingfossil fuel resources. This Review focuses on recent achievements in the area of flexible solar cells, highlights the principles behind the main technologies,anddiscussesfuturechallengesinthis area.

INTRODUCTION:

As the world's interest in sources of clean and efficient energy increases and oursupply of oil and natural gas inevitably decline, taking a critical look at renewable energy assets to ensure ourfuturehasneverbeenmoreimportant.Thereare various sources of renewable energy,but one renewable asset that could meet our energy needs for many years to come is solar power. So weshould make the shift to solar.

There are many reasons to take advantage of the free and abundant power of the sun. The first andforemostreason,however,isthatutilizingsolar energy to power our planet is better for the environment than burning fossil fuels to generate the energy we need. Ironically, coal, oil and gasthe fossil fuels we have relied on in the past are early beneficiaries of solar energy because they were formed hundreds of millions of years agofrom decomposing plants. Those decomposing plants first grew using the light from the sun (a process called"photosynthesis").

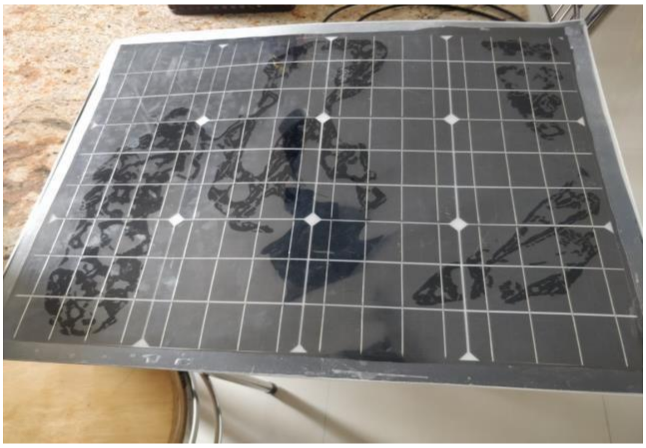

Fig 1. Flexible solar panel

But, burning the fossil fuels that come from these decomposed plants negatively affects our environment because the process releases carbon dioxide and other gases – called greenhouse gases – that trap heat within the Earth's atmosphere.Too muchofthesegreenhousegasesthatarereleasedby the burning of fossil fuels is contributing global climatic changes. So, the number one reason for making the shift to solar energy is that capturing energy from the sun does not create greenhouse gases.

According to the Union of Concerned Scientists, the burning of fossil fuels during the last 150 years has increased atmospheric carbon dioxide levelsby 25 percent. Levels of methane and nitrous oxide have also increased. The presence of ever-increasing amounts of carbon dioxide in our atmosphere essentially traps the sun's heat within the Earth's atmosphere rather than allowing it to escape into space, thereby contributing toincreases in temperatures around the globe both on land and sea. New research, for example, indicates that half of Australia's Great Barrier Reef has vanished in the past 27 years due to increases in ocean temperatures as a result of climate change. A key factor involved in the steep decline of the Reef is the problem of coral bleaching due to rising ocean temperatures. Capturing energy directly from the sun does not increase temperatures onEarth.

Inadditiontocontributingtoglobalclimatechange, burning fossil fuels also pollutes the air, leading to negativehealtheffectsforbothpeopleandanimals.

Solar energy does not create nor contribute tothese environmental problems. There are emissions associated with manufacturing, transporting and installing solar energy systems but once installed, solar energy does not cause pollution. Making the shift to solar energy is an important step infighting climate change and the gradual warming of our planet. The average residential solar system offsets about 100,000 lbs. of carbon dioxide in 20 years – theequivalentofdrivingacarfor100,000miles.In addition, because there are no moving parts involved in most applications of solar power, there is no associated noise. Solar is a quiet and clean source ofenergy.

Solar energy is becoming more and more popular because the evidence of the negative impact of the burning of fossil fuels on our environment is too clear to ignore. It is critical that we invest in the technologies and infrastructure needed to support solar energy use around the world. In some places, this is beginning to happen. More and more people are paying attention to what is happening to the Earth.

The International Energy Agency's Trends inPhotovoltaic Applications report, with data provided through 2014, indicates which countries are generating the most power from solar. What's surprising about this list is that relatively tiny countries are on it: Germany, Japan, and Italy.

Exposure to the carbon dioxide produced by burning fossil fuels can cause headaches and increase the risk of heart disease. According to GreenEnergyChoice.com, more than 2.5 million metric tons of carbon dioxide are produced just by power plants each year. Sulphur oxides produced when burning fossil fuels create sulphuric acid when these oxides combine with water vapour. As thisacidaccumulatesinlakesandstreams,itmakes the habitats uninhabitable for plants and animals. Solar energy does not create negative chemical reactions when generated orused.

Burning fossil fuels also results in thermal pollution. The process of burning any substance generates heat, and this heat is often released into lakes and streams when the water that they contain is used as a coolant. The increased temperatures in these lakes and streams upsets the ecosystem, causing some species' populations to increase and others to decrease.

LITERATURE REVIEW:

The different researches were carried out on the solar power generation the utilization of solar energy required system. The literature carried out with categorization of the different system and stone was follows:

AbhayaSwarupwasdevelopedamodelforenergy management of PV based energy system. This model has been mainly proposed to raise thepublic awareness and education levels of solar systems in an interesting and entertaining way. The results indicate that the problems with PV systems were not due to PV array and instead it was due to the performance of the batteryunits.

Vivek Kapil have developed an Artificial Neural Network (ANN) model for designing PV systems for remote areas and presented the influence of various parameters on the design of PV systems. The results of ANN model showed a variation of 5% as compared to other models with more reliability and accuracy. The application of solar power is varied and the scope of PV systems being employed even in domestic applications appears to be bright.

Bhattacharya developed a simplified design approach and economic appraisal of a solar PV system.InthismodelthePVarrayandbatterybank sizes for a standalone PV system were estimated. Also a cost comparison of the standalone PV system with a PV diesel hybrid system was presented. The results indicate that the hybrid systems were cost effective than standalone systems for a givenlocation.

Kushite Kaushik developed a knowledge based model for the design of standalone solar photovoltaic system. This approach combined both the site and array characteristics as a single parameter, referred to as an equivalent unit array output.

Hamid Marafia studied the feasibility of photovoltaic technology for power generation and presented comparative economic analysis of power generation with a conventional gas turbine. The results indicate that the solar photovoltaic systems are not economical as compared with a conventional gas turbine. However, it was concluded that PV systems could become economical when the system cost reduces to below $2.50 per peak Watt with conversion efficiency above 20%.

Mohanlal Kolhe has analysed the economic viability of a standalone solar photovoltaic system with the most likely conventional alternative system i.e. a diesel powered system for energy demand through sensitivity analysis of life cycle costcomputation.Theanalysishasbeencarriedout fortheenergydemandfordifferentkeyparameters, suchasdiscountrate,dieselfuelcost,dieselsystem lifetime, fuel escalation rate, solar isolation, PV arraycostandreliability.Theresultshowedthatthe PV powered systems could be a cost effective optionatadailyenergydemandupto15kWheven under unfavourable economicconditions.

Usha Bajpai developed a model to optimize the size of PV panel and battery in a standalone photovoltaic powered system. Optimization of PV system was done based on the cell area, efficiency, and cell power and array inclination. Hence this type of standalone PV power system can be more reliable, viable and acceptable. Similar work was also carried out by Philip (2003) on the studies of system design, installation and performance of a standalone wind-diesel power supply systems for remote applications. The result shows that the system performance was satisfactory.

Bernard F and E Esmond T. They have investigated on the concentrating solar energy receivers. In their study they have commented that the solar collectors can be classified into focusing type (concentrating toe) and Non-focusing type (non-concentrating type). The inventor has designed the concentrating type solar energy receiver comprising a primary parabolic reflector having a centre and a high reflective surface on a concavesideofthereflectorandhavingafixedaxis extendingfromtheconcavesideofthereflectorand passing through a fixed point of primary parabolic reflector and a conversion module having a reception surface. Non concentrating type solar collecting devices intercept parallel un-concentrated rays of the sun with an array of photovoltaiccells.

Coc Oko and S.N Nanchi

They have worked on optimum collector tilt angle for low latitudes. There are many factors thataffect thesolarradiationsfallingontheearth.Someofthe factors that affect the intensity of the extra-terrestrial solar radiation on the earth's horizontal and titled surfaces are clouds, dusts and shades. In designing the solar equipment the designer has to pay more attention towards harnessing the insolation to the optimum level for effective performance of the equipment. Determination of thetiltangleatlowerlatitudesisonesucheffortfor a country likeNigeria.

PROBLEM IDENTIFICATION:

The sun offers the most abundant, reliable and pollution-free power in the world. However, problems with solar energy, namely the expensive cost and inconsistent availability, have prevented it from becoming a more utilized energy source. Solar power makes up a tiny fraction of all power produced in India, North America, even thoughtherearevastregionsofthecontinentwhere there is an abundance of sunshine. To harvestmore of this free energy, we need to discover new materials, develop new production techniques and solve the problem of storing energy when the sun isn'tshining.

What is hampering solar power has everythingto do with cost. It is five to eleven times more expensive to produce electricity from the sun than it is from coal, hydro or nuclear sources. The first problem is with the cost of the technology:

- Solar panels use expensive semiconductor materialtogenerateelectricitydirectlyfrom sunlight. Semiconductor factories need 'clean' manufacturing environments and are expensive to build &maintain.
- The efficiency of solar cells currently ranges from around 20% up to a top rangeof around 40%, although this continues to improve.Therestofthesunlightthatstrikes the panel is wasted as heat. More efficient photovoltaic cells have been discovered (but these are still in relatively new and are expensive tomanufacture).

Itwilllikelytakedecadestodiscovernewmaterials andmethodsofmakingsolarpanelslessexpensive. How long it takes depends on how much time and money is invested into solar energy research both by government and privateindustry.

But even if the fundamental cost hurdles of the technology are overcome, there are still other issues:

- Installing solar panels on a house is expensive and requires experienced people. These systems used fixed solar panelssince alignment systems are too expensive forthe averagehomeowner(see:Howtodetermine the correct angle for solar panels). The initial investment outlay is a significant factor in why there is a lack of support for solar power fromconsumers.
- Giant solar farms have been built in desert regions and have reduced the installation cost since a larger economy-of-scale is created (parts, material & installation people are in one location). But these large, inexpensive tracks of lands are found far from cities where the power is needed. Expensive transmission lines are needed to bring the power to a distantmarket.
- Maintenance costs and time can add-up since every inch of asolar panel must be kept clean and clear of debris for them to operate at their most efficient. Their efficiency drops drastically even when a small portion is blocked by fallen debris or a film ofdust.

The main problem with solar power that has stifled its use is the fact that energy production only takes place when the sun is shining. Large storage systems need to be developed to provide aconstant and reliable source of electricity when the sun isn't shining at night or when a cloud goes overhead. When solar panels are not producing energy, it takes longer to recoup their installation and maintenancecost.

Intherarecaseyou arehavinganissue,diagnosing solar panel problems can seem challenging. For instance, you may notice that your system isn’t producing its original power, but you might not know why. Extreme variances in performance are usually due to one of severalissues.

1. Wiring Is Loose

Loose wiring can cause unexpected electrical issues. Remember that your solar panel system includes a specific network of wiring, linking individual PV cells to each other, to home solarbatteries and to inverters. Because of this, there are many places where connections might fail.
To correct wiring faults, you should talk to an expert. Installers with electrical experience use meters and other tools to pinpoint problems. They can also disconnect faulty parts to keep them from damagingothersectionsofyoursystem.Ifyouhave used an experienced installer they most likely installed monitoring. Monitoring allows them and you to see the performance of your system on your smartphone, often on a panel by panel basis. This makes the troubleshooting of your system fairly simple.

2. System Is Overheating

One simple way to tell if your panels have temperatureproblemsistocheckforheatfade.This occurs when excessively high temperatures (exceeding upper 90s) cause your panels to underperform. This is common and not necessarily an indication of faulty panels. If heat fade is the underlying issue, you may notice that you receive less power during the hottest times of theday.
Often, instead of the whole system getting too warm, high temperatures could just affect certain sections of your panel installation. These areas might wear down faster than others.

There are also certain panel manufacturers that perform better in high heat than others. The

Panasonic HIT panel is an example of one. These panels have thin layers of material that sandwich the monocrystalline layer, making them more efficient in higher temperatures. Keep this in mind when selecting your panels.

3. System Is Dirty orDamaged

The most common performance issue is caused by something as simple as dirt. From dust and pollen to leaves and other debris, Mother Nature has a knack for reducing panel efficiency. These environmental problems may seem minor, but they can stop your system from generating as much power as it should. Cleaningisaneasyfix,andisbestdoneonaregular basis. Since shade from soiling can lower your output by about 5 percent each year, it pays tohose off your panels two or three times a year. This is usually sufficient, unless you live in a particular dustyarea.Ifcertainsectionsofdirthavehardened, use a soft push broom to remove it or simply hire a cleaning crew. Working with experts also lowers yourchancesofinjuringyourselfonaladderorwet roof. What about cracked PV cells and other physicaldamage?Itispossibleforapaneltosustain a small crack and still function normally. The glass is laminated and stronger than you may think. However,inmostcases,thatcrackwillgrowlarger over time, causing the performance to drop. When this occurs, you would need to have an installer replace the brokenpanel.

OBJECTIVE OF WORK:

The main objective of work is

1. To reduce the installationcost.
2. Toimprovetheefficiency,improvethequalityof life and alleviate rural poverty in the un-energized and off-gridareas.
3. Toimprovetheflexibilityofsolarpanelbyusing thesiliconwafersmustbesliceddowntojustafew micrometers wide.
4. Using these ultra-thin silicon wafers gives solar panels unique properties includingflexibility.
5. To increase the speed of light in the upper layer which means EVA sheet when compared to the glass layer.

OPERATIONS PERFORMED:

1. SOLDERING:

Soldering is a process in which two or more items are joined together by melting and puttingafillermetal(solder)intothejoint,thefiller metal having a lower melting point than the adjoiningmetal.Unlikewelding,solderingdoesnot involve melting the work pieces. In brazing, the work piece metal also does not melt, but the filler metal is one that melts at a higher temperature than in soldering. In the past, nearly all solders contained lead, but environmental and health concernshaveincreasinglydictateduseof lead-freealloys for electronics and plumbingpurposes.

Fig 2.Soldering process

Soldering filler materials are available in many different alloys for differing applications. In electronics assembly, the eutectic alloy with 63% tin and 37% lead (or 60/40, which is almost identical in melting point) has been the alloy of choice. Other alloys are used for plumbing, mechanicalassembly,andotherapplications.Some examples of soft-solder are tin-lead for general purposes, tin-zinc for joining aluminium, lead-silver for strength at higher than roomtemperature, cadmium-silver for strength at high temperatures, zinc-aluminium for aluminium and corrosion resistance, and tin-silver and tin-bismuth for electronics.

A eutectic formulation has advantages when applied to soldering: the liquidous and also the Solidus temperatures are the same, so there is no plasticphase,andithasthelowestpossiblemelting point. Having the lowest possible melting point minimizes heat stress on electronic components during soldering. And, having no plastic phase allows for quicker wetting as the solder heats up, and quicker setup as the solder cools. A non-eutectic formulation must remain still as the temperaturedropsthroughtheliquidusandsolidus.

temperatures. Any movement during the plastic phase may result in cracks, resulting in an unreliable joint.

2. LAMINATION:

Lamination is the technique/process of manufacturing a material in multiple layers, so that the composite material achieves improved strength ,stability, sound insulation,appearance , or other propertiesfromtheuseofthedifferingmaterials.A laminate is a permanently assembled objectcreated using heat, pressure,welding orgluing.

Solar panel lamination ensures the longevity of the solar cells of a module as they need to be able to withstand outdoor exposure in all types of climate for periods of 25 years and more. Solar modules need to convert sunlight to electricity at an acceptable cost throughout their lifetime. The encapsulation of the solar cells through lamination is a crucial step in traditional solar PV module manufacturing. Improper lamination can lead to prematurefailureofthesemodules.Theknowledge of complete lamination process not only helps in making a better product but also lessens losses like cell breakage, air bubbles and delamination, which mostly occurs due to incorrect processing parameters.

Fig 3. Laminating process

The lamination process encapsulates solar cells in between a number of substrate layers including top and bottom protective layers. These layers are knownasa"lay-up"andthismethodologyhasbeen successfullyemployedforoverdecades.JohnKirk, MD, J-Flex notes that the most common shared module lay-ups is tempered glass as thetransparent top layer; followed by a layer of encapsulant; the interconnected solar cells; another layer of encapsulant and finally a layer of U.V. stable film as the bottom layer.

Even today, the most common way to laminate a solar panel is by using a lamination machine notes Sinovoltaics. This old-fashioned method has many disadvantages, but is used by the large majority of solar panel manufacturers.

Themajorityofmodulelaminatorsfollowthisthree step process for proper melting and curing of the encapsulant (EVA) and achieving a good quality lamination,itincludesa)heatingofthemodulelay- up to required temperatures to perform the EVA cross-linking step. b) Create vacuum t to remove the air and avoid bubble formation. The time of applyingavacuumaswellastherateofevacuation can be varied to optimize the process and hencethe end-result.

Reducingthepressuretooearlyoratahighratewill result in significant outgassing of the additives in theEVAlikeadhesionpromotersand/orstabilisers, and hence result in a decreased quality of the PV modules,whereasapplyingthevacuumtoolatewill lead to air inclusion and hence unwanted bubble formation. c) Application of pressure to ensure a good surface contact and adhesion between the different layers of the pvmodule.

During the process of lamination the prepared 5-layer module is placed in the lamination machine and heated to maximum135°C for a period of approximately 20 minutes. The final product that comes out is completely sealed; the lamination is now ready to protect the solar cells for at least 25 years. Excessive EVA and TPT during the lamination are discarded, and the junction box is attached. Finally the laminate can be framed.

PROCESS DEVELOPED:

The lamination cycle is an empirically determined sequence of events. The main objective is to determine the shortest sequence which produces a good lamination without negative effects to any of the laminate components. The most critical part of the lamination cycle is the part prior to plastic melt of the sheet encapsulant. The amount of time the assembly is under vacuum, the time at which pressure is applied, the temperature when pressure isapplied,andthedurationandquantityofpressure all affect the quality of the lamination. As the polymerization reaction is irreversible, the thermal treatmentstepiscrucialinthesolarcells encapsulation process. It is a decisive step for the quality of the module and for its lifetime. If a default(break,shortcircuit,stringmoving)happens during the polymerization, the module will be rejected.Thelaminationcycleisperformed.Itstarts with the introduction of the laminate stack (cells andtheencapsulantmaterials)inthelowerchamber where the temperature is kept constant at 100◦C. The upper chamber is under vacuum (0.1 mm Hg). The lamination operation is conducted in two phases.

1. In the first, the air inside the lower chamber is removed during 5 minutes. The pressure is then set at 0.1 mm Hg and maintained at this value during both the lamination and the polymerizationcycles.

2. In the second phase, the upper chamber is filled with air to provide pressure on the module. During thisstep,thecombinationofthelowerchamberair-pumpingandthepressureappliedbythemembrane allows to drive out the residual air and moisture present in thelaminate.

And meanwhile, the module is heated and theEVA melts and surrounds the electrical circuit forming sealstotheglassfrontandbacksheetofthemodule. Note that additional EVA material is added at the module perimeter to ensure complete sealing ofthe moduleedges.Thecuringisdoneat156◦Candlasts 15 mm. The EVA resin polymerization occurs during this step. The EVA crosslinks forming a chemical bond which hermitically seals themodule components. At the end of this step we get a compact structure, the photovoltaic laminant. After cooling at 100◦C, the lower chamber is at the atmospheric pressure and the upper chamber is at mm Hg. This is “the long cycle” of the encapsulation process which is conducted completely in thelaminator.

FABRICATION PROCESS EVALUATION:

In order to evaluate the fabrication process developed, we have fabricated module using four inches square monocrystalline silicon solar cells. Each module consist of 12 electrically series-connected cells. These current well-matched solar cellsarearrangedinthreestringsof4cells.Atfirst, we have conducted moisture and heat tests of the EVA to be sure that the thermal treatment parameters lead to a sufficient EVAcuring.

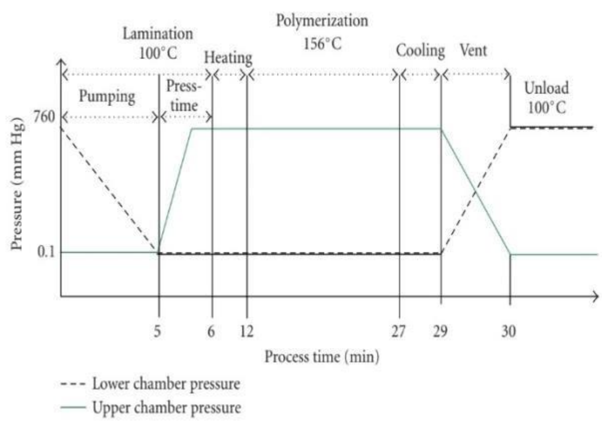

Fig 4. Fabrication process

WORKING PRINCIPLE:

All types of solar panels follow a basic layout that consists of a series of layers that work together to allowelectronstoflowthroughafunctionalcircuit. The cathode is the conductor closest to the side of thep-typesemiconductorlayer,andisusuallymade from a metal in a grid like pattern, although our cathode is a solid metal film of Au/Pd. Below this layer lies the two semiconductor layers. The semiconductors are typically separated into two layers, called n and p type semiconductors, n standing for negative and p forpositive.

Usuallytoobtainthetwolayersofasemiconductor the material will need to be doped. There are also materials that act as intrinsic n or p type semiconductors that do not need to be doped. Doping introduces a small amount of an alternate element into the main semiconductor material. To make the n type layer of the semiconductor the element that is introduced into the main structure has more valence electrons to create free electrons andtheptypesemiconductorlayerhaslessvalence electrons, in order to create vacancies ("holes") for the free electrons to occupy.

These are the layers where the charge is separated and transported. These layers can consist of a variety of materials which differ in many of the major types of solar cells that exist today. A commonexampleiscrystallinesiliconinwhichone layerisdopedtopromotechargemovementandthe other layer is doped to become a charge receiver. The back-contact acts as the anode and finishes off the circuit. The anode layer of thin film solar cells is especially important in flexible solar cells, because it can often be the limiting flexible layer. Two of the primary options are IndiumTin Oxide

(ITO)andAluminumDopedZincOxide(ZnO-Al).

EXPERIMENTAL WORK:

Voltage of each cell = 1.8 v

Amperes of each cell = 0.25A

Open circuit voltage V_{oc} = 1.8×12 = 21.6 v

Short circuit current I_{sc} = 0.25×12 = 3 A

Voltage at max power V_{mp} = 19 v

Current at max power I_{mp} = 2 A

$$\text{Fill Factor} = \frac{I_{mp} \times V_{mp}}{I_{sc} \times V_{oc}}$$

$$= \frac{2 \times 19}{22 \times 3}$$

$$= 0.57$$

Max Power = $V_{oc} \times I_{sc} \times FF$

= 22 × 3 × 0.57

= 37.6 W/hour

Consider peak hour = 5 hours

For 1 hour of sunshine the load is = 37.6 W

For peak hour, the load will be = 5 × 37.6

= 188 W

CASE–STUDY:

- In order to run a 50W DC motor for 1 hour then the output power willbe

  = 50 × 1hr

  = 50W
- In order to run a 55W table fan for 1 hour then the output power willbe

  = 55 × 1hr

  = 55W
- Inordertoworkawaterpurifierof15litres, it requires 25W of power for 2 hours then the output power willbe

  = 25 × 2hrs

  = 50W
- Generally the mobile chargers are having a powerof5W.Soweareconsidering2chargers whichwillbe10Wforcharging1hourthenthe output power willbe

  = 10 × 1hr

  = 10W

∴ The total consumption of power for running of these items are

= 50+55+50+10 = 165W

$$\text{Efficiency } \eta = \frac{P_{out}}{P_{in}} \times 100$$

Where P_{out} = Peak load or total output power

P_{in} = Input power

P_{in} = Sun rays striking the earth at

=1000W/m^2.

$$\eta = \frac{188}{1000} \times 100$$

= 18.8 %

RESULT AND DISCUSSION:

As we tested the flexible solar panel for a range of 5 hours that is from 10 am to 3 pm ,we found that the efficiency of the solar panel about 15.6%.If we compare to the theoretical value , we found that there is 3.2% loss of efficiency . The above results was calculated by testing 250w dc reduction gear motor which can be operated upto 24 v.

As per the experiment, we found that the peak voltage and current is obtained to be 19v and 2A . As we found the flexible solar panel can be bend upto 30° so that It can be applied on yacht, cars, train roofs, sky scrappers etc .

CONCLUSION:

The flexible solar panel can be a very good option to generate electricity. It is light in weight when compared to rigid solar panel. It is non-dependent on weather conditions. As compared to rigid solar panel it is less in cost. To contrast, the lifespan of the flexible solar panel is low due to the flexibility purpose. It's efficiency is comparatively low with concentrated solar system technology.

FUTURE SCOPE OF THE WORK:

Innovation in solar technology continues to improve the efficiency, size and cost, makingit morepervasivethroughoutthesociety.Thetrendis learning towards incorporating solar into more buildingsbeyondpanelsplaceduupontheroof.Cool applications include solar shingles, solar film,solar roadways, and solarwindows.

Other innovations being explored are the solar orb, solar cars (commercially available), solar balloons, nanowires,andworkingwiththeinfraredspectrum.

Intheimmediatefuture,siliconsolarcellsarelikely to continue to decrease in cost and be installed in large numbers. In the United States, these cost decreasesareanticipatedtoincreasethesolarpower produced by at least 700% by 2050. Meanwhile, research on alternative designs for more efficient and less expensive solar cells will continue. Years fromnow,wearelikelytoseealternativestosilicon appearing on our solar farms and rooftops, helping to provide clean and renewable sources of energy. These improvements have and will continue to be made possible by increasing bulk manufacturingof solarcellsandnewtechnologiesthatmakethecells cheaper and more efficient.

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