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An Review on Solar Vehicles Requirements and Investigation

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Abstract—As per the rapid growth of population, the energy demand is also increasing and usage of fossil-fuels intended to find an alternative energy source solution for automobile industry. A solar energy is an abundant source of energy is considered to be better option to overcome such challenges. The major aim of this work is to provide a broad review on solar vehicles requirements, which supports solar energy to drive the electric vehicle. The electric solar vehicle have no emission that means it will not any effect on our environment. The solar vehicle consist of solar panels, battery, motor, cast body and etc. Also some other mechanism should be considered to optimize the efficiency of energy and cost effectiveness.

IndexTerms— Solar Energy (SE); Photovoltaics (PV); Solar Panels; Solar Battery.

I. INTRODUCTION

In present scenario, the demand of energy has increased across the world, whereas the decrement in natural resources with respect to population growth is the major problem. Therefore, more energy is needed to withstand the present human growth. In 2015, 91% of world energy demand comes from non-renewable resources (coal, natural gas, oil and nuclear) and rest 9% comes from renewable resources (wind, hydro and solar) [1]. The solar energy is produced through the sun light and it is radiant energy source, which also has been used by humans by very ancient era at several range of evolving methods. The technologies of SE includes solar PV, solar architecture, solar heating and solar power that can be used to resolve major world problem. In according to International energy agency [2], the SE could deliver a 3rd of the worldwide energy demand at after 2060, which will cause to reduction of CO_2 at low levels. The solar technologies are generally categorized on the method of capturing such as active solar and passive solar. The technique of active solar refer to the solar terminal accumulators and PV system in order to harness the SE, whereas, the technique of passive solar includes providing sun light to the building with property of light dispersing. According to global energy report [3], from the year of 2012 to 2016, the capacity of SE has tripled and now 1.3% global energy has provided by SE.

In this paper, we are going to discuss the SE usage in order to drive the vehicle, because it is a renewable resource of energy so it competitive to fossil fuels energy resources. Development of vehicles are done for fast transport and the combustion engines are found in several type of application from cane-harvesters to the scrubland generator. The PV module can be associated in series or parallel to get the high required power.

In order to make electric vehicle cost effective, batteries and power converters has been used. The vehicle with gasoline fuel emits high amount of nitrogen oxides, carbon monoxide, CO_2 gas and the traces that having lead, so it is very harmful for the environment and the compounds are affecting steady harm to greenhouse effect and ozone layer. As we know the active solar methods uses the PV panels in order to convert sunlight to useful drive power, the charge controllers are used to direct this obtained solar panel power to the batteries. The charging process is done in accordance to the battery state, in order to evade extra charging and discharging. The equipment's like battery, charge controller, power converter, motor, solar panel and etc. can enhance the vehicle efficiency.

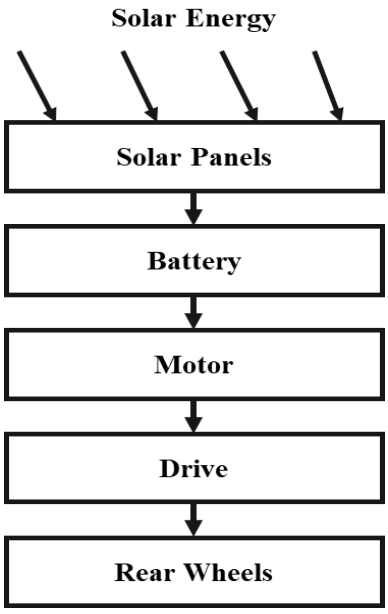

Figure 1: Energy Flow diagram of solar vehicle

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Figure 1 shows the energy flow diagram of solar vehicle, where several components can be used to deliver better drivability, also an efficient accumulation of energy to drive the vehicle [4]. In electric vehicle, the foundation for holding body and engine of vehicle is very important just like other type of vehicle. Also the braking systems, transmission and, steering are made of by rubber pads, axle and spring. While considering the solar panels, which generally contains n-type and p-type silicon's that used to accumulate sun energy from the sun-rays. The PV cells commonly made up of semi-conductor type materials, which has capability to convert solar spectrum radiation to the electric currents. Commonly the PV cells are made of using silicon, and it having two different types; thin-film and crystalline type.

The power converters are used to convert solar spectrum energy to the electric currents and it placed in between the solar panel and battery. It get input from the solar panel in the form of energy and stores it in battery, the stored energy is further used to drive the vehicle in order to get the required speed. Here, battery is very important component, which helps vehicle to drive not only in sun light but also in the night time due to his capability of energy storage that stored in the day time. In electric vehicle, DC electric motor has used that also known as ECMs (i.e.,electronically commutated motors)are synchronous type motors. It powered through a DC electric basis by an integration of switching power supply that also used to generates AC electric signal in order to run the motor.

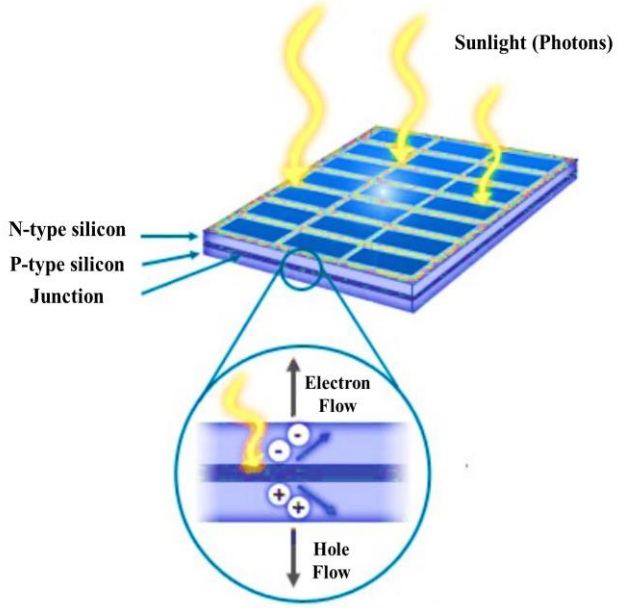
II. SOLAR DOMAIN REQUIREMENTS AND INVESTIGATION

Solar cells & panels for maximum Electric Power

PV solar panels are generally known as solar panels, which used to generate electricity but not the solar thermal accumulators. Also a PV cell (i.e., solar cell) is semiconductor device, when the sun light falls above it produces electricity [5], where it convert the solar radiation beam into the electricity. Figure 2 describe the PV effect and it's clearly shown that the cell is built of two semiconductor layers. Whenever, the light fall on the solar cell, it absorbed through silicon atoms and take count as energy, later on the energy maximize the electrons so that the electrons present in the material allows them to pass easily inside the material. Moreover, free electrons are open under an electric field so it can able to move only at single direction that produce the electric current. In according to [6] 90% of world's PV are based upon the some silicon variation, the PV modules have three types such as; Mono-crystalline, Thin-films and Poly-crystalline.

Mono-crystalline PV cells

This type PV solar cells are built of using silicon ingots, which generally in cylindrical shape. In addition, the cost factor and performance of single mono-crystalline PV cells can be optimized by cutting four sides of cylindrical ingots in order to create silicon wafers.A mono-crystalline PV panels comes with several advantages and disadvantages. Advantages, these are space efficient, durability is high and because it made of high grade silicon material, so it have high efficiency rate. Disadvantages, if the panel is covered partially (with the snow, dirt or shade), so it can cause circuit problem. The cost of mono-crystalline PV panels are slightly high and it tends to be more effective if the weather is warm.



. **Figure 2: Photovoltaic effect**

Polycrystalline PV cells

The polycrystalline silicon is also known as poly-silicon and multi crystalline silicon, which was initially introduced in 1981. Polycrystalline solar panels do not need the Czochralski method like the mono-crystalline PV panels. In this raw silicon material is melted and it decanted in a square frame, afterwards is cooled out and shaped into a perfect square size.

The preparation method of polycrystalline silicon panels is cost effective or lower cost and simpler, compare to mono-crystalline PV panels this generates less silicon waste. But the polycrystalline PV panels have lower heat tolerance as compared to the mono-crystalline PV panels.

The poly-crystalline PV panels have 13% to 16% efficiency, due to its lower purity of silicon. Therefore, it is not much efficient like the mono-crystalline PV panels and it also have lower space efficiency. So it is required to cover more surface area to get same outcome obtained by mono-crystalline PV panels in less area. Though, it does not mean to be that every poly-crystalline PV panels performs lower than the mono-crystalline PV panels.

Thin-film PV cells

The thin-film PV cells are manufactured by depositing one or some thin type PV metallic layer onto a substrate. There are several types of thin-film PV cells and it can be characterized via deposited PV material onto the subrate such as; amorphous silicon, cadmium telluride, copper indium gallium selenide and organic PV cells.

The thin-film PV cells module technique have efficiency of 7 to 13% depends upon the prototypes and generally the production modules process at 9% efficiency. In future, the efficiency of thin-film PV cells can go up to 10 to 16%.

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It is simple produce when the demand is more, which make this cheaper to produce as compared to crystalline type PV cells. The homogeneous exterior makes it look more attractive, also it can built flexible that allows to use in several other applications. Shading and high temperature have lower effect at the performance of thin-film PV cells. Whereas, the space is not a big issue, the thin-film PV cells is consider to be best option.

The effects of solar radiation and temperature on the efficiency of PV panels has discussed in [7]. Here, they have considered poly-crystalline, mono-crystalline, and amorphous silicon material for the numerical evaluation. As per the experiment conducted in the paper, the solar cell performance for considered material is majorly varies according to the solar cell standard condition. However, mono-crystalline PV cell have shown enhanced performance compared to other considered PV cells. In present days, the commercially used PV cell materials are poly-crystalline silicon, mono-crystalline silicon, and amorphous based thin-film silicon. The mono-crystalline solar cells shows high adaptation efficiency and more space efficient, but it have slightly more price. Therefore, in order to develop efficient and cheap PV devices, the research is progress in various thin-film technologies.

Customized Dimension of Solar cell/panels

The thumb rule is used to compute the generate power on the vehicle, while theoretically each of the square meter can produce 1 kilo-Watt (kW) electricity at most. Whereas, there are several factors that limits the generation of electricity by the PV panel such as weather conditions, location and etc. Panel efficiency is computed at optimal condition, also checked when the panel gets hot and some other circumstances.

While a car driving on the road is not a suitable condition to arrange the PV panels optimally to the sun and cannot avoid shading effect, etc. There are lots of disadvantage in order to generate electricity by solar car driving on the road. Consequently, 1 kW per square meter is the maximal amount in theoretical computation, in practice solar car would not generate that much amount of power.

There are also some significant limit, if we consider 1 kW per square meter as a number of fact. In general, electric car on the road will consumes 50 kW, 100 kW or more than that. The Tesla top end model cars have capacity S-3 seconds 0-60 miles per hour, etc., would need a lot more generated electric power than that. The solar electric vehicle have a battery pack and it supply appropriate 50+ kW as per the speed demand on the highway. The solar cell are not much capable to provide this amount of power by itself.

If we consider that the battery have the capacity to drive electric car for 100 miles and have appropriate PV panels to recharge it on some reasonable time. Then, the 30 kW battery that recharge in one hour is considered to analyze the dimension of solar panels is required for the fast charging

- 30 kW array cell requires 1 hour recharge
- 20 kW array cell requires 1.5 hour recharge
- 15 kW array cell requires 2 hour recharge
- 10 kW array cell requires 3 hour recharge
- 5 kW array cell requires 6 hour recharge
- 1 kW array cell requires 30 hour recharge

Battery Systems

In electric vehicle, solar with storage options is come with more complicated specifications of product. The battery system is one of the most important evaluation parameters that done by round-trip efficiency, depth of discharge, warranty, power & capacity rating and manufacturer.

Power & Capacity

The total amount of electricity capacity that a battery in solar vehicle can store in terms of kW-hours (kWh). Majority of the home solar type batteries are built to include multiple number of batteries in it, so it can provide extra capacity in solar and storage system. While considering the bigger battery is does not mean to give more required power at the moment, it depends upon the power rating that given to the battery.

A power rating in solar batteries is calculated in terms of electricity amount that a battery can provide in one time and it measured in terms of kW. A low power rating and high capacity solar battery may deliver a low electricity power, which is compatible with few type of applications and runs for a long interval of time. A high power rating and low capacity solar battery could able to run few hours the entire home.

Depth-of discharge (DoD)

In general, the solar batteries has need to have some amount of charge, it not allowed to completely discharge due to some chemical composition. If 100% of a battery is used, then the life of the battery become significantly short. The DoD of battery shows the battery capacity amount that has used. Majority of the battery manufacturers specify the maximal DoD in order to provide optimal performance. Example, DoD of 90% at 10kWh battery, means we can make use of 9 kWh of battery charging. Therefore, the higher number of DoD means that the utilization of battery capacity is more.

Round-trip efficiency

A round-trip efficiency of the battery defines the energy amount that can use as an energy amount percent that it procured to store. As taking example, electricity of 5 kWh in a battery can get only 4 kWh of output electricity, so the battery has 80% of round-trip efficiency (i.e., four kWh/five kWh = 80 %). Therefore, the higher amount of round-trip efficiency means that the battery have more economic outcome.

Battery life & warranty

The ability in order to hold a charge in a battery will decrease gradually as per the usage time increases. Therefore, the solar battery is also come with warranty period just like the mobile phone batteries, where it guarantee a several number of years or cycles of useful lifespan. As we already know that performance of battery decreases over time passes, therefore the mostly manufacturers provide the guarantee for certain amount of time. Thus the long lasting capacity of solar battery depends upon the battery brand and how much considerable power capacity it will drop over the time.

Manufacturer

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There are many company (from big company to start-up companies) are manufacturing and developing the solar battery system. The majority of big automated firm entering the storage market has an extensive history of manufacturing product, so maybe they will offer much advanced technique. While coming to the start-up firm, may provide much advanced technique but may not able to provide long-term functionality of battery. So choosing battery from the start-up firm and big automated firm is completely depends upon the priority and choice, whereas the associated guarantee with battery will give a proper additional guidance to make the decision of choice.

Solar Battery Lifespan

The usual lifespan for solar battery is from 5 to 15 years, but if we are taking some solar batteries in present then it should be of 25 to 30 years for PV system. Though, the lifespan of PV panels has improved considerably in some past years and it is probable that the PV batteries will tends to suit as per the market demand as the growing solutions of energy storage.

The proper maintenance of solar battery have the considerable effect on lifespan of PV battery. Temperature is the major parameter that effect the solar batteries, so it is required to protect the battery from sweltering or freezing temperatures. Whenever, the solar batteries drops down to 30° F, it need more voltage in order to get maximal charge, when the battery is overheated it required minimization of charge. In order to overcome this issue many battery manufacturers such as Tesla come up with feature of temperature moderation. The earth-sheltered enclosures can be consider to be other solution, however the efforts of quality maintenance is best optimal solution that impact on lifespan of solar battery.

Charging Type

As per application of electric vehicle charging, it can be separated into two type of charging such as static and dynamic charging. Both are important way to transfer the power from battery to car. With the minimum driver participation, the static charging can able to replace the function of plug-in charging, also it overcome safety related issues like as electric shock and trip hazards.

The plug-in charging suffers from major disadvantages - range and cost. Though to increase the range the electric vehicle is required to charge frequently or to have much larger battery system that also increases the weight and cost burden. While it is also not possible to charge electric vehicle more frequently. Therefore, dynamic charging system comes into a picture, which is very capable technique and can overcome the problem related to cost and range of electric vehicle. However, it is not an only solution for future electric vehicle charging system. There are some technique - in-motion method [8] and roadways powered [9]. The several other static and dynamic techniques has discussed in [10], also there are lots of research has been going on to enhance the battery charging system.

Air Cooling System in Electric vehicle

During the summer, the temperature inside the vehicles are more under the hot-sun, which causes more energy in order to power the air-conditioner. In present, there is no such efficient method to overcome this issue while maintaining environment friendly and energy saving mode.

The renewable energy application such as phase-change based heat energy [11], mechanical energy [12], solar energy [13], acoustic energy [14] and magnetic energy [15] has been widely studied in some recent years. However, there are some cooling technique that uses renewable source of energy such as magnetic cooling, geo-thermally heated cooling, thermo-acoustic cooling and phase-change cooling technique. However, these type of cooling process have widely deliberated for the several applications, but little more effort is required in research to apply these technologies to effectively cool the vehicle cabins. As per the higher accessibility, the phase-change based heat and solar energy are considered to be more effective for cooling the vehicle cabin [16]

III. CONCLUSION

The emission of greenhouse gas is the major environmental issues that comes from vehicle transportation and it also increasing day by day. In this paper, we have provided a review on solar vehicles requirements and the parameters that need to be investigate further. Here, different type of solar cells and panels have discussed in order to maximize the electric power requirements, also the customized dimension of solar cell. In addition, battery system is considered to be most important part in solar vehicle for that several evaluation parameters has discussed such as round-trip efficiency, depth of discharge, warranty, power & capacity rating and manufacturer. Furthermore, it is require more development and research in the field of solar vehicle.

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