

Technical and Economic Analysis of Different Solar Photovoltaic Materials for Electric Vehicle: A Review

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Abstract— In today's world the renewable energy is vital in near future. The renewable sources that we are using are going to get exhausted. The electric solar vehicle is a step in saving these renewable energy resources. The basic principle of electric solar vehicle is to use solar energy that is stored in battery during and after charging from solar panels. The charged batteries are used to drive the motor which serves here as an engine. Technical and economic analysis of different type of existing solar panels is given in this review paper. These available existing solar panels are: monocrystalline, polycrystalline and thin film solar panels. In future, this idea may help protect our fuels from getting extinguished.

Keywords: Solar Panels, Efficiency, Motor, Motor Controller

I. INTRODUCTION

Greenhouse gas emissions and exhaustion of natural fossil resources have become serious global issue in recent years. Global warming is rising rapidly with the increasing rate of usage of the conventional vehicles for the public and personal transportations. Main component of the conventional vehicles is the internal combustion engine (IC-engine) which takes oil for propulsion [37].

Oil used in conventional vehicles is produced from the burning of the fossil fuel that is liable for the CO₂ emission. Due to the increasing rate of oil burning in the conventional vehicles, 25% of CO₂ of all the carbon-dioxide are emitted in the atmosphere from the conventional vehicles only (Rui et al., 2011).

Therefore, it is also forecasted that the oil will be depleted in all around the world by 2038 (Ehsani et al., 2010). So that, there is a spacious need to move on the electric vehicles to reduce the dependency on the oil based conventional vehicles and the CO₂ emission in the atmosphere as well.

In year 1900, that time approx 4200 automobiles were on the road, out of which 22% gasoline powered, 40% steam powers and 38% were electric [27].

We all know that the fuel prices rising steadily day by day especially the petrol. Again the reason behind rising pollution is due to vehicles in metro cities and urban areas [36][50]. An effort is being made to search some other alternative sources of energy to overcome with the pollution problem, as we all know it's not affordable to purchase vehicles for middle or all class of society.

Keeping this into the mind, an alternative solution being introduced as electric vehicle for economically poor people as well as to provide a solution for the environmental pollution was in progress [37].

Due to global warming and energy supply security challenging all world in terms of global economy and environment. To boost regional economic development and

to overcome this energy supply renewable energy technologies are being explored.

The major source of the greenhouse gas emissions and fossil-fuels consumption is transport. Pollution from transport vehicles affects the human health also contribute environmental problems but climate change due to CO₂ emissions so ideal transport should be pollution free and with zero emission [7].

Many research and development actively conducted by government agencies, academic institutions, and related industries on protection of environment, carbon emission energy efficiency and energy conservation on electric vehicles [7]. Electric energy source is alternative energy source over internal combustion engine [7].

Our aim is to analyze with respect to the techno economical comparison of different solar panels for a low cost solar powered electric vehicle that would meet the requirements of the global customer.

The electric solar vehicle does not have effect on the environment. Therefore, it can be a better option for fulfilling the escalated vehicle demands. As their demand is increasing continuously electric solar vehicle will become the predominating sources of energy. Electric vehicle is more reliable due to their ecological supremacy and the development of smart grids that are certainly the future of electrical power systems.

Electric vehicle can be set in motion by electric motors and extract power from the electric source as compared to gasoline powered vehicles; electric vehicles are more durable and mechanically simpler. They are much more energy saving produce completely no tail pipe emissions as well as requires less maintenance.

Electric solar vehicle is an approach towards influencing the young minds about more and more utilization of sources like electric and solar energy to drive a vehicle. Solar combine technology used in the aerospace, bicycle, agriculture, domestic applications, alternative energy and automotive industries.

The solar energy is collected using photovoltaic cells and converted into electrical energy to drive the vehicle. Through the vehicle runs on battery that drives motor. Solar energy is basically used to recharge the batteries but at the time of complete discharge solar power can also be used independently to drive motor.

II. OVERVIEW

A. Historical Development in the Electric Vehicles:

The first successful attempt to store electrical energy was made by Alessandro Volta in Italy in 1800 [42]. In the 80's various scientists worked towards the electric vehicle invention [38].

The electric motor was developed by Michael Faraday in 1821. He invented a wire rod which carries an

electric current which supplied by a Volta pile would rotate around a fixed magnets if the one end of wire rod was unconstrained by allowing it to hang in a bath of mercury [22] [42].

Faraday discovered electromagnetic induction in 1831, so demonstrating the intimate relationship between magnetism and electric current and laying the foundation for electrical and electronic technology. Also including electric motors and generators for electric cars [22] [42].

An operating electric motor had been introduced in Paris in 1832 by British scientist William Sturgeon and in 1835 a small motor by Francis Watkins in London. The motor was operated by bar magnet which was mounted on a shaft rotating inside stationary coils of wire. In which the electric current was successively switched by contacts on the shaft [42].

History of the electric vehicles is started with the invention of crude electric carriage in 1832 by Robert Anderson [22] [42].

By year 1835, a small-scale electric car was invented by two colleagues Professor Sibrandus Stratingh (Netherlands) and Christopher Becker (German). The car was energized by non-rechargeable primary cells [22][38].

Very first locomotive was fabricated by chemist Robert Davidson in the year of 1837 in Scotland which run on electricity. Later he built a larger locomotive.

In 1840 a patent was presented for rails in England and in 1847 it was submitted in United States [2].

This locomotive was exhibited at the Royal Scottish Society of Arts Exhibition in 1841 [22].

Using an iron or a zinc primary battery it was possible to drive a road vehicle, in this case a four-wheel truck. First time in 1873 R. Davidson introduced in Edinburgh [42].

Electrification of a main line was built in London in 1880 and it has 4 mile (6kms) stretch of the altimore Belt Line. Andreas Flocked created a four wheeled Electric Vehicle in Germany [38].

In May 1881 Siemens & Halske AG produce a suburb of Berlin, Germany. [22]

The world's first passenger-carrying trolley bus operated in Bielathal, near Dresden, in Germany in 1901. And buses were in service in 1911 in Leeds and Bradford in Britain [22].

In September 1885, the Blackpool Tramway, was opened. In many cities the first world war trams were used throughout the world. [22].

In 1888 first electric car was constructed by Andreas Flocken in Germany [2]. Rocket-shaped electric vehicle presented by Jamais Contente in 1889 [2].

In New York City, first electric vehicle was designed at Pope Manufacturing Company in early 1897 which later becomes the largest cars mass production company in the USA [38].

In 1899, James Contents from Belgium, France designed the Electric Vehicle whose average was around 67 miles/ 100 km / hour [38].

At the starting of the 20th century, electric road vehicles must look a strong contender for future road transport [22]. Performance wise, the electric cars were preferred to their IC or steam-powered rivals so the electric

vehicle is relatively more reliable and started instantly, whereas IC engine vehicles were at the time unreliable, smelly and needed to be manually cranked to start so electric vehicle much better than IC engine vehicle [22]. IC engine proved that it is more attractive option for powering vehicles as the self-starter for the IC engine (invented in 1911) had arrived [22]. Battery was the main reasons for the greater success to date of IC engine vehicles. Batteries take much time to recharge even enough electrical power is available there is a minimum time, normally several hours, required to recharge a battery whereas petrol can be put into vehicle in approx 5-10 minutes[22].

There are some new batteries in market which will take less time to recharge them less than 1 hour, but still it consider very longer as compares to fill a tank with petrol. Also the batteries are so expensive, they have a limited life (, typically 5 years) so electric vehicle is likely not only to have a limited range. Electric vehicle is more expensive then IC engine vehicles of similar size and similar build quality [22].

Gasoline cars were cheaper in cost and able to retard over a wide distance. Still in 1912, the production of electric vehicles was counted in a huge number and the cost of the sold electric vehicles was just two times the cost of a gas-supplied vehicle. [22] [42].

In 1950, in the advancement of the electric vehicle's technology, the Henney Kilowatt - a new electric car was manufactured with 36-volt and 72-volt configuration. [22].

In 1955 the history of the electric solar vehicles is started with the world's first solar powered electric car was introduced by William G. Cobb of General Motors Corporation. That time all automobile was run by gasoline engines. He showed the car in auto expo which was held in Chicago, Illinois where Cobb's Sun-mobile introduced the field of Photovoltaic's. It was small to drive and was only 15 inch long modal [2][22][38] [42].

The Sun Mobile had 12 selenium cells on top of balsa wood body. The cells were connected series parallel combination. The combination of series parallel cells converted the sun light energy into electric energy, which in turn ran a small low inertia electric motor. The motor run on 1.5 volts and rotated at 2000 rpm.

The wiring for the solar cells to the electric motor was by standard No. 20 insulated stranded copper wire. As a result the car has not futuristic capabilities because the solar cells ran at their 100% capacity and those only produces 12HP, which was not enough to run an average automobile. But the concept was proved that Sun light alone can make a vehicle run [46].

The first solar car which a person could drive was In 1962 Vintage modal 1912 baker electric car and which was converted by the international rectifier company [46].

In 1958 it was retrofitted with solar panels by Charles Escoffery for the International Rectifier Corporation. Company didn't show this modal until 4 years later. That time the panel cost was \$20,000 which in today's currency would by approximately \$161,700. Approx 10,640 individual solar cells were mounted on the rooftop of the 1912 Baker. It could run for three hours average speed of 20 miles per hour (32 km/h) [46].

In 1977, blue bird solar car was built by Prof. Ed Passerini of Alabama University. It was a prototype full scale

vehicle. It was supposed to move from solar energy without the use of a battery. The Bluebird was exhibited during Knoxville, TN 1982 World's Fair [46].

In 1974 an Englishman Alan Freeman first started to think about using solar panels to power an electric motor on a boat. After one year he developed Solar Craft 1. He developed a prototype after 4 year for solar car initially made out of plywood because these developments the car was fitted with a fiberglass body and given a aerodynamic shape.

In 1979 he invented the solar car. Solar car was a 3-wheeler with a solar panel on the roof. Road tax dropped to zero for electric vehicle so in 1980, Alan registered and insured the car, and was able to be the first to legally drive a solar car on the road. His simple design is practical, effective and economical. Freeman's car probably couldn't be used efficiently in Britain due to the low levels of sun, but could be more successfully somewhere like the Mediterranean [46].

In 1980, at Tel Aviv University, Arye Braunstein and his colleagues created a solar car in Israel. Solar panels were mounted on the hood and on the roof. The Citicar solar has a series parallel combination of 432 cells creating 400 watts of peak power. It uses 8 batteries each having 6 volts (48v) each to store the photovoltaic energy. It has weight of 1320 pounds solar and able to reach up to 40 mph with a maximum range of 50 miles [46].

The Quiet Achiever was the world's first practical long-distance solar-powered car powered entirely by photovoltaic solar cells, it was also known as the BP Solar Trek.

In December 1982, the car was driven by Hans Tholstrup and Larry Perkins, performed the first manned transcontinental journey using only solar power, traversing Australia from west to east, travelling over 2,500 miles (4,000 kilometers) in under 20 days. By contrast, gasoline/petrol powered car took 30 days to do the same trip.

Greg Johanson and Joel Davidson invented the Sunrunner solar race car in 1984. The Sunrunner holds the official Guinness world record for the fastest "Solely Solar Powered Vehicle" in Bellflower, California of. On July 1, 1984 Sunrunner achieved 24.7 mph in the Mojave Desert of California and final top speed of 41 mph was officially recorded for a "Solely Solar Powered Vehicle" (without battery) [2][38].

In 1987, the GM Sunraycer completed a 1,866 mile trip with an average speed of 42 mph and in November 1987 Sunraycer won the inaugural World Solar Challenge in a race across Australia [20]. GM Sunraycer was 19.7 feet long, 6.6 feet wide and 3.3 feet high and has a weighs 390 pounds and had gross weight of 573 pounds with driver. Average speed of the vehicle was 41.6 mph during 44.9 driving hours over 1950-miles race. It's was made of aluminum tube space-frame chassis with body of composite sandwich material. It contains solar array of about 90 square-feet to power 3 KW, 4 HP magnequench brushless DC-Motor.

A team of six drivers took turns in the car during the race, one driver at a time. They covered a 1,950-mile route over 5 1/4 days in a combined daytime running time of 44 hours at an average speed of 41 mph.

In 1991, the Electric Vehicle had a new turn when General Motor launched their few commercial vehicles with EVI & PSA. For as long as solar-powered cars have been in

existence, so have solar rally races and challenges. The Sun Favor took part in various solar challenges, which are often sponsored by education and research institutions. It raced into 2nd place in the FIA Electro-Solar Cup in Suzuka (1992) , and also won the "Most Outstanding" award at the Asahi Solar Car Rally in Kobe (1992). Last but not least, it made a noteworthy finish at the most well-known solar race which travels across Australia, the World Solar Challenge, coming in 12th position (1993).

In Japan 1997, The Toyota Launched Prius" it was the first hybrid commercial car in which 18,000 of them were sold in the first year.

Vehicle electrification was again back in the market with both public and private sector. In 2004-2010, the oil prices started touching skyline Nissan launched its battery-Electric Vehicle Leaf.

In 2011, Autolib launches its Electric Vehicle with target & stock of 3,000 vehicles and the global stock of overall Electric Vehicle reaches up to 50,000 in the last 4 years. The Nissan Leaf was awarded as, European Car of the year" award. In 2012, the plug-In Hybrid Electric Vehicle Chevrolet Volt outsells 50% of car models in the US. The Global Electric Vehicle stocks now reached up to 180,000 all around the world.

B. Recent Developments in Electric Vehicle:

For automobile industry electric vehicles are the solution for the big environment issue in India. As the population of worlds increasing fast, it is necessary to maintain the environmental balance to survive the human race. Our Indian government took some initiatives to promote the electric vehicle.

Tasla Motors took some initiative for the electric cars production in California in starting of 2004. Tesla Motors manufactured his first electric car using a - Tesla Roadster in 2008. It has travelling range of 320 kms in a single charge. Renault presented Renault Fluence Z.E. electric car in Denmark and Israel with interchanging the battery technology. They sold almost 1000 and 400 units of Renault Fluence Z.E. cars in Israel and Denmark countries respectively. In July 2009 Mitsubishi Motors inaugurated Mitsubishi i-MiEV in Japan and in Europe in December 2010 [2] [38].

Mahindra group launched the "e20" model of electric car in India in 2013 to meet the company's "5cs" framework: Clean, convenient, connective, clever, and cost effective. e20 can be charged via a common 15 amp outlet or using solar panels. Various manufacturers have also entered in the market to boost sustainability benefits of different electric car models [31][44].

From one of the startups Aether Energy which started in 2013, started by two friends Tarun Mehta and Swapnil Jain. The Company has an online purchase mode with the vehicle delivered directly to the end customer's home. They launched 2 models, 340 models & 450 models with price 111,230 and 123,230, INR respectively. In which other one 450 is one of the powerful vehicles constructed of frame Aluminium material and a motor rating of 5.4 kW (7.2) B.H.P Brushless DC electric motor with 2.4 kWh and has a acceleration of 40 km/h in just 3.9 seconds and attain a top speed of 80 km/h. It has travel range up to 75 km in a single

charge. And it has some of other features like it contains a 7-inch touch screen which receives on the air updates and it gets connected to the user Smartphone for GPS and driving updates.

In 2014-2015 (16,000) EV were sold by the Society of Manufacturers of electric vehicle and 25,000 units were sold including 21,000 2-Wheelers and 4,000 4-Wheelers.

Around 37.5 % growth was seen in the EV market in the year of (2015-2016). Also, this study revealed that the 8% sold vehicle were 4-Wheelers and 92% were 2- Wheeler Electric Vehicle sold in our country. by the year 2020 the Society of manufacture of Electric Vehicle also pointed out an ambitious target of reaching 5-6 million vehicles on road [3] [38].

As per the data held by a survey in 2017 revealed in India that Gujarat has the most Electric Vehicle (4,330), West Bengal secured second rank with sale figure of (2,846) Electric Vehicle, Utter Pradesh(2,467), Rajasthan (2,388), and Maharashtra with (1,926) units respectively.

Indian Railroads started first solar based fuelled diesel electrical numerous unit train from the Safdarjung rail line station in Delhi in 2017. The train runs from SaraiRohilla to Farukh Nagar [31]. A total of 16 sunlight based boards, each creating 300 Wp, are fitted in six mentors. The sunlight based boards achieve out 17 units of intensity in a day which empowers the lighting framework in the mentor. By sparing an approximated 1.2 lakh kilo liter of diesel consistently, the railroads spare a use of INR 672 crore for each year [31]. The sunlight based force likewise helps in limiting 2.7 lakh huge amounts of carbon dioxide outflow every year [44].

In year 2017-2018 the union budget allocated inr 795 crore for evolving electric vehicle. 2/3 of the market of the electric vehicles was acquired by 3-wheelers which are e-rickshaw and e-auto rickshaw in 2018.

According to a study by Naiket et. al (2019), the capa-buses (super capacitor), the electric vehicles have been worked alongside with the electric transports to investigate the electrified transportation structure in the Guwahati [31][44].

Students from Lovely Professional University have developed India's first driverless solar powered electric bus [31]. The bus uses renewable energy which delivered to electric motor. With this set up, the bus can manage to reach a top speed up to 30kmph and can transit up to 70 km per single full energy [31] [44].

Aether Energy has created a various charging station in Bengaluru. It Charges Aether 450 to 80 percent in 2 Hours 40 minutes 100% in 4 hours 18 minutes, recently other energy received 50 million investments by Sachin Bansal company founder of (Flipkart). To increase the electric vehicle production in India in the upcoming year [38].

In december 2020 sales of EV grow up to 15% compared to November 2020 according to a report, the government of India issued Rs. 600 crore budget for development of electric vehicles. Pandemic situation became normal sales went again up to 40% by April 2021. It is expected to be reached at 2.10 million US dollars by 2026. E-bike market also faces the some downfall due to COVID-19 pandemic [38].

According to the IEA's Global EV Outlook 2020, the number of electric cars on the road at the end of 2019 had

already risen to 7.2 million. The fact that the technology has already progressed to the point where a practical car with three passengers on board, powered by a relatively cheap solar array can average 75 km/h long distance is an eye-opener, forcing us to start looking differently at what we have come to think of as 'the motor car' [15].

Lightyear One only consumes about 83 Wh/km (without air exertion) in the WLTP- cycle. That's half of what a Tesla Model S consumes, and a third of the Porsche Taycan's energy consumption. Depending on the number of kilometers the auto covers a day, and how important sun it catches, the true diurnal consumption can indeed drop to zero. The total area of the solar array is roughly 5 m². Lightyear One has 1000 km range in plug in charging and it has independently controlled by hub motors. Lightyear One can charges anywhere depending on the climate, you could yield between 6,000 to 11,000 kms of free, effortless, and clean range every year [15].

C. Electric Vehicle:

Basically, an electric vehicle consists of an electric motor which can be electrified from a battery [2][38]. A wide variety can be considered in the types of electric vehicles such as:

- Battery Electric Vehicles (BEVs) BEVs are also known as All-Electric Vehicles (AEV)
- Hybrid Electric Vehicle (HEV): HEVs are also known as series hybrid or parallel hybrid.
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle(FCEV)

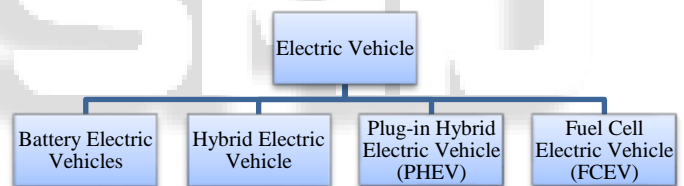


Fig. 1: Block diagram of types of Electric Vehicle

1) Battery Electric Vehicles (BEVs) :

Battery electric vehicle (BEV) basically consists of a battery for supplying electricity and energy storage to an electric motor through the controller [22]. The battery is normally charged from external power source mains electricity via a plug and a battery charging unit that can be either carried on board or fitted at the charging point or a charging station [38].

Motor controller will normally control the electric power which is supplied to the motor used in an electric vehicle speed in reverse and forward [2][4][38]. This controller is known as two quadrant controller. Controller controls the speed of the vehicle as forward and reverses. It is usually desirable to use a regenerative braking both to recoup energy and as a convenient form of frictionless braking. Regenerative braking is ravishing characteristic of the controller used in EVs [22]. Hence, battery of an EV can be recharged additionally also while the vehicle is operating through the regenerative braking mode [2][4][38].

The maximum distance traveled by the vehicle with a completely charged battery is called its range. Examples of BEV are Tesla Model S, Nissan Leaf, BMW i3, Mitsubishi iMiEV, Ford Focus EV, etc [4][38].

2) Hybrid Electric Vehicle (HEV):

A hybrid electric vehicle uses two or more power sources it is basically a combination of an internal combustion (IC) engine with an electric motor that is powered from both fuel and electricity which gives a very large number of variants – known as hybrid electric vehicle (HEV) [2][4][22][38]. Combination of an IC engine with a battery and an electric motor and generator is the most common types of hybrid vehicle. Batteries can be charged either when the HEVs operating through regenerative braking as maintain the down speed of the vehicles or from the IC-engine [2][4][38]. Batteries of the HEVs do not need to charge by plugging the vehicle into a power source at a charging. Toyota Prius is broadly used hybrid electric vehicle. In HEVs, batteries supply electricity to the electric motor and diesel/petrol propels for driving of the IC-engine. HEVs are better than both BEVs and PHEVs as it can be fuel economical and also can reduce the emission.

Some of HEV companies are Toyota Motor Corporation, Ford Motors, Volkswagen, General Motors, Hyundai Motors, Nissan Motor Corporation Ltd, Honda Motor Corporation Limited. Examples of HEVs are MG Hector, +, Toyota Camry, BMW 7, Lexus Series Toyota Glanza, MG Hector [4][38].

These HEVs differ according to their energy components and the driving range. The HEVs can be classified into three categories according to the connection between motor and the IC-engine as – series HEV, parallel HEV and combined HEV [22]:

- a) Series Hybrid Electric Vehicle: In a series HEV, an electric motor takes power either from battery or from an IC-engine coupled generator unit. The IC-engine energizes the generator to supply power to the motor. The generator charges the battery also when the vehicle is operating under regenerative braking mode [4][38].
- b) Parallel Hybrid Vehicle: In a parallel HEV, both an electric motor and an IC-engine are connected in parallel with a transmission system to the wheels. Battery can be charged during regenerating braking mode only [54]. It can't be charged when the vehicle is not in moving condition. In the parallel HEVs, the electric motor produces power less than the total power produced by the vehicle. The IC-engine have ability to generate more power than the electric motor [4][38].
- c) Combined Hybrid Electric Vehicle: Combined HEV is a combination of both series and parallel hybrid electric vehicles. It is also known as power split type of HEV. In this type of HEV, an IC-engine is engaged for driving of vehicle and for the charging of the battery as well. Combined HEV consists of double connection between the engine and the driving paths – electrical path and mechanical path. Therefore, the total power transferred to the wheels of the vehicle through both mechanical and electrical paths. [4][38].

3) Plug-In Hybrid Electric Vehicle:

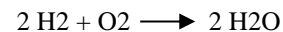
Plug-In Hybrid Electric Vehicle is a combination of gasoline or diesel engine with an electric motor and a large rechargeable battery system. But the real difference of P-

HEV from the Hybrid Electric Vehicle is that the battery in PHEV can be plugged – in and recharged from a specific power station. As the other source in PHEV, the range of the vehicle is increased up to 35 miles [4][38].

The PHEV is often a cleaner energy source as compared to the other vehicle as when it is operated on electric mode there is no tailpipe /harmful emission by this vehicle. Also, they help in saving fuel economy as they use less gas than normal vehicle so; driving a PHEV is economical and saves a lot in fuel in a year as compared to traditional vehicle. Example of few PHEV is BMW i8, Cadillac ELR, GM Chevy Volt, Ford Fusion Energy, Toyota Prius [4][38].

4) Fuel Cell Electric Vehicle:

A vehicle which is powered by electric energy from the fuel cells is known as fuel cellelectric vehicle (FCEV). A vehicle which is powered by electric energy from the fuel cells is known as fuel cell electric vehicle (FCEV). Fuel cell is a power supplying device that was discovered in 1840. The fuel cell generates electricity by using hydrogen as a fuel in a battery. The hydrogen fuel is mounted on one electrode as anode and oxygen as air is filled on another electrode as cathode. Both electrodes are immersed in an acidlectrolyte. So that, a chemical reaction occurs for the fuel cell that is given as-



A fuel cell electric vehicle introduces to the different sorts of fuel cells based on the electrolyte used in it i.e. polymer electrolyte membrane fuel cells, solid oxide fuel cells, phosphoric acid fuel cells, molten carbonate fuel cells and direct methanol fuel cells etc.

D. Electric Solar Vehicle:

The solar energy is collected using photovoltaic cells and converted into electrical energy to drive the vehicle. Through the vehicle runs on battery that drives motor. Solar energy is basically used to recharge the batteries but at the time of complete discharge solar power can also be used independently to drive motor. The basic configuration of a solar drive system is based on an electric motor embedded into a wheel (in order to eliminate power transmission losses), a rechargeable battery and solar cells equipped with Maximum Power Point Trackers (MPPTs) [4][19][38].

The Electric Solar Vehicle powered by BLDC motor which collaborated to design and fabricates a safe and high performance, cost efficient electric solar vehicle.

These days consumers of gasoline and diesel powered vehicle facing a hard time to keep pace with the increasing demand. So we need to explore natural source of energy and power. Sunlight is considered a best source of energy which implemented in various day to day applications. With the help of this technology we can use this energy in our daily transportation life. Main component in solar car is the solar panel. In solar panel the cells converts the solar energy into electric energy and by the help of charge controller it stores in the batteries of the solar car. After that this stored energy used by electric motor of the car.

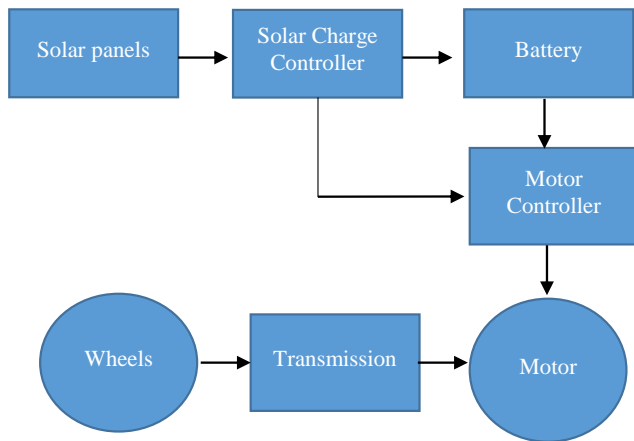


Fig. 2: Block diagram of Electric Solar Vehicle

1) Solar Panel:

Solar panels is the main part of any solar system installation, it is major part of the system [2][4].The solar panels return investment cost compared to another component in PV system installation. And the return of investment for PV system depends mainly on the energy output performance of PV panels. The PV panels normally operated into low conversion efficiency due the some factors of degradation. PV panel temperature considered as critical issues when forecasting energy production and long-time high temperature working conditions of PV panel can cause irreversible degradation of its electric output power and the high temperature caused by waste heat generated due to the absorption of solar irradiance. Only up to 20% of the incident solar energy is converted to electricity from the radiation falling onto a PV panel and the remaining major part is converted to heat [44].

As a result, the accumulated heat energy increases the PV panel operating temperature, hence leads to drop in its electrical efficiency. Under STC, the conversion efficiency of the PV panel is decreased by about 0.40 - 0.50 % for each degree rise in temperature. However, all data rarely meet the real sun conditions, as that depends on the specific climatic conditions of each location [2][4][22][38][44].

There are three types of solar panels mainly we have:

- a) Polycrystalline
- b) Monocrystalline
- c) Thin Film

a) Polycrystalline

Polycrystalline solar panels have simpler structure and the making is easy and it is also a cost effective panel. The heat tolerance of polycrystalline solar panels is much lower when compared to mono crystalline solar panels [36].

Polycrystalline solar cells are blended together from multiple pieces of silicon. Smaller bits of silicon are molded and treated to create the solar cell. Hardly any raw material is thrown out during manufacturing so this process is very useful [33] and the blended makeup of the cells gives poly panels their iconic blue color. If we look at them up close, we'll see the texture and color is uneven due to the way the cells are made.

b) Monocrystalline

Monocrystalline solar panels contain cells that are cut from a single crystalline silicon ingot. Each cell is made from a

single piece of silicon so the composition of these cells is purer. As a result, mono panels are slightly more efficient than poly panels. Monocrystalline panels also perform better in high heat and lower light environments, which means they will produce closer to their rated output in less than ideal conditions [4].

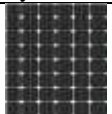


However, monocrystalline cost more to produce and that higher cost are passed on to the buyer. Mono panels are a bit more expensive than poly panels of the same wattage. The manufacturing process for mono panels is also more wasteful than the alternative. Mono panels are cut from square silicon wafers and the corners are shaved off to make the distinct cell shape.

c) Thin film

There is a third type of solar panel technology, called thin film panels, which are usually deployed for large-scale utility projects and some specialty applications. Thin film solar panels are totally different than monocrystalline and polycrystalline solar panels. The majority of solar panels deployed today are made from either monocrystalline or polycrystalline solar cells. Thin film panels are created by depositing a thin layer of conductive material onto a backing plate made of glass or plastic.

Thin film panels are a new technology which is ideal for houses with shading issues and requires more space. Aesthetically the panels appear as a flat sheet with no lines that run through the panels. Thin Film solar panels are less efficient when compared to monocrystalline and polycrystalline solar panels, and do not seem to be making any steady improvements in the next decade.

Thin film panels typically don't see use in residential installs because they're much less efficient than mono or poly panels. With roof space at a premium, residential customers go with more traditional crystalline silicon panels to maximize production from the space available to them.

Item	Mono - crystalline	Poly - crystalline	Thin-film
Apperance			
High Temperature performance	Mono - Crystalline panels does not perform good at high-temp. (Drops 10-15%)	Poly - crystalline panels does not perform good at high temperature (Drops 20%)	Good in cool as well as high temperature conditions (0% drops)
Temperature Coefficients	0.003-0.004/K	0.0042-0.0045/K	0.0022-0.0025/K
Material	Pure silicon	Melted silicon crystals	Variety of materials
Efficiency	24.4%	19.9%	18.9%
Bending strength	Higher	Lower	Higher

Manufacturing Carbon Footprint	38.1g CO ₂ -eq/kWh	27.2g CO ₂ -eq/kWh	21.4g CO ₂ -eq/kWh
Dislocation density (cm ⁻²)	<10 ³	10 ³ ~10 ⁹	<10 ¹⁵
Iron impurity	Lower	Higher	Higher
Oxygen impurity	Higher	Lower	Lower
Macro-structure	Chamfer/No spots	No chamfer/Spots	No chamfer/no Spots

Table I: Technical analysis of different photovoltaic materials

In the table I technical analysis of different photovoltaic materials has been shown. Pure silicon is used in mono crystalline and melted silicon crystal material is used in poly crystalline and in thin film variety of materials is used [19]. As we can see that the high performance of the monocrystalline panel is not much better than the poly crystalline and the thin film solar panels. Oxygen impurity is higher in mono crystalline whereas in poly crystalline and thin film they both have lower oxygen impurity. Bending strength impurity is higher in mono crystalline whereas in poly crystalline and thin film they both have lower bending strength [29].

Item	Mono - crystalline	Poly - crystalline	Thin-film
Size	It requires very less area to produce same amount of power	It requires less area to produce same amount of power	wide range of products design from flexible, and require more area, light durable
cost	It has more expensive crystalline silicon and two time more costly as compared to thin film solar cells -typical module price/ Wp : Rs 75-100	It is cheapest crystalline silicon and two time more costly compared to thin film solar cells -typical module price/ Wp : Rs 50-75	Cheaper and 50 % less expensive than crystalline silicon -typical module price/ Wp : Rs 40-55
life span	Longest	Moderate	Shortest
Weather efficient	Tend to more efficient in warm weather	Enough efficient in warm weather	Tend to less efficient in cold weather
residential situation	useful for residential situation	useful for residential situation	not useful for residential situation
warranties	25-40 years	25-30 years	15-25 years

Table II: Economical analysis of different photovoltaic materials

2) Solar Charge Controller:

It is an electronic converter which determines the best output power that solar panel can put out to charge its corresponding battery. Solar charge controller is stable ratio of the current from the solar panel to the battery. Because of change in solar radiation, change output is varying time to time of the solar panel [36]. Thus charge controller looks at the output of the panels, and compares into the battery voltage [36]. Thereby higher voltage DC output down to the lower voltage required to charge its respective battery. It takes best power and converts it to voltage to get maximum ampere into the battery [36]. The efficiency of modern MPPT is around 93-97% efficient in the conversion. Typically get a 20 to 45% power gain in winter and 10-15% in summer. Actual gain can vary widely depending weather conditions, temperature, battery state of charge, and other factors.

3) Motor Controller:

The motor controller is used to control the motor voltage and change voltage rating with the time to provide the motor. Motor controller changes voltage DC to AC. It is a multifunctional device and basically called the brain of the electric vehicle. It provides signals to all electronics components like accelerator, display panel, brakes, etc. It receives voltage from the battery and supplies power from that battery to the motor on receiving the accelerator signal when it activates. When battery voltage is too low that time protects the battery from over discharge and shut down the motor

4) Battery:

A battery consists of two or more electric cells connected together. It consists of positive and negative electrodes in an electrolyte. It has the chemical reaction between the electrodes and the electrolyte which generates DC electricity. The chemical reaction can be reversed by reversing the current and the battery returned to a charged state in the case of secondary or rechargeable batteries [22]. In the electric vehicles, the electric motors are engaged instead of the engine. These electric motors are powered from the battery placed in the electric vehicles. An electric motor is used for converting electrical energy into mechanical energy to move the wheels of the EVs. The electric motors provide a maximum torque at low speed with high efficiency at low cost.

The battery in an Electric Vehicle is the main fundamental source of power for the propulsion in an Electric Vehicle. The reason for which the batteries were considered as a source of power in an Electric Vehicle was due to their relatively high energy to the weight and size ratio, specific power and energy density [47]. In recent developments, the battery's weight and size is readily decreased and the vehicle's performance is improved. The rechargeable batteries have Lead-Acid, Zinc-Air and molten salt batteries. In the recent Electric Vehicle industries, the majorly used battery types are Lithium-Ion & Lithium polymer battery, due to their high electrochemical potential and high energy density compared to weight ratio [19]. In general, there are four types of batteries used in an Electric Vehicle [2].

5) Motor:

The electric motor is a main part of the electric vehicle. It converts the energy supplied by the battery into mechanical energy to provide traction power to the wheels. It is the motor with the controller that determines the characteristics of the propulsion system and the ratings of the power devices in the power converter [26][27].

Many types of electric machine technologies have been introduced for automotive propulsion. These mainly include induction, permanent magnet (PM), switched reluctance, and axial gap machines. Either induction or PM machines is used in the commercially available electric and hybrid vehicles for propulsion. Automotive manufacturers and suppliers have significantly improved the electric machine technologies to be used in electric and hybrid vehicles [26][27][36][38].

The BLDC motor has higher efficiency (greater than 75%) and higher life time compared to Brushed DC motors. Hence conventional motor driver drives the BLDC with respect to the supply from lead acid battery. The initial current of the BLDC motor is 8Amps (Approx.) [36][47].

6) Throttle:

A device which is used for acceleration of the vehicle and maintain the speed of the vehicle. Whenever the throttle is an action, at that time throttle is converted signal and signal is supply to the controller. Controller is supplied signal to motor, and motor starts acceleration.

III. CONCLUSION:

The concept of the solar electric vehicle is essentially simple. Electric solar vehicle consists of an electric battery for energy storage, an electric motor and a controller. The battery of the vehicle is normally recharged from mains electricity via a plug or Solar panels. Monocrystalline modules have good esthetic value because of ordered lattice structure, uniform color and no spots. Monocrystalline requires very less area to produce same amount of power whereas polycrystalline and thin film require more space for the same amount of power. The investment cost of monocrystalline modules, polycrystalline modules and thin film modules tend to be consistent, but the monocrystalline module has the advantage of weak internal resistance, good quantum efficiency under weak sunlight; therefore, monocrystalline modules are superior to polycrystalline and thin film in both appearance and power performance.

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