Solar Powered Electric Vehicle

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Abstract*—These days the world has changed a great deal. This prompted revolution in a transportation sector. Oil utilization on the planet increments, just as oil production declines. Use of coal, petroleum, diesel emanates plenty of contaminated gasses, this results in ill-advised parity of O3 development, Global warming and climatic changes, and so forth. So now the world is exchanging their transportation framework totally dependent on electrical and electronic as a force source. This anticipated need to contribute an innovation that supports Green energy; consider this circumstance we could improve and use solar energy to charge electric vehicles by utilizing solar panels that are executed in the vehicle. This Paper is totally outfitted with clarifications, for example, advanced structural design, analysis, their capacity, disadvantages of this innovation, and productivity of our vehicle.*

All in all, the majority of the commercial electric vehicles are accessible in alternating current (AC), it is pointless with regards to battery stockpiling, and need to do a lot of tasks to store, however losses are viewed as additional. Inbuilding direct current drive impact productivity. Actualizing BLDC motor requires less consideration and low support.

Keywords*— BLDC Motor, Controller, Hybrid Technology, Solar Panel, Performance Experiment.*

1. INTRODUCTION

Energy is the most basic necessity for human endurance. People are subject to energy and convert energy from fossil fuels. We use energy from these hotspots for creating power, running automobiles and so forth. In any case, to be more or less it has various disservices, that they are not eco-friendly and they are expendable. To manage these issues of fossil fuel, we have to invite a non-conventional source of energy. Solar powered vehicles are electric vehicles which are controlled by sun-oriented energy that is received by solar panels which are embedded on the outside of the vehicle. Fundamentally, photovoltaic cells and modules convert the solar energy straightforwardly into electrical energy. Solar panels are made up of semiconductors, usually silicon, that absorb the light. The sun's energy liberates electrons in the semiconductors, making a progression of electrons. That flow produces electricity that controls the battery and the particular motor in solar vehicles.

Considering every one of these variables gives us another imaginative thought. We have structured and fabricated an Electrical vehicle that sudden spikes in demand for solar energy [5].

2. SOLAR IRRADIANCE AND SCOPE

The measure of solar energy is amazing: the 89 petawatts of sunlight arriving at the Earth's surface is just about multiple times more than the 15 terawatts of normal electrical force devoured by people [3]. A pictorial perspective on the possibilities of photovoltaics is given in Fig -1, where the zones characterized by the dim circles could give more than the world's absolute essential vitality request (expecting a change proficiency of 8%). The applications extend from the power station, satellites, rustic jolt, structures to sun oriented roadways, and, obviously, transport. In Fig -1 shows the average solar irradiance.

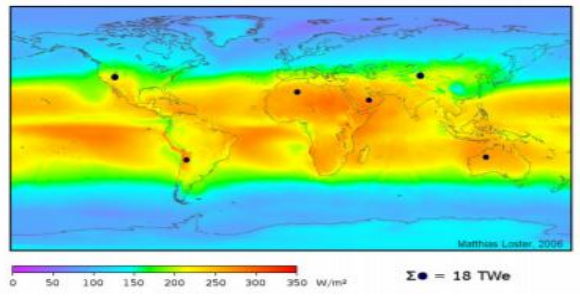

Fig -1: Average solar irradiance (W/m2) for a horizontal surface (Wikipedia).

Hybrid Electric Vehicles (HEV) have developed to modern development, and speak to now a sensible answer for significant issues[2], for example, the decrease of vaporous contamination in urban drive just as the energy sparing necessities the level of charge of the armada is relied upon to develop essentially in one years from now [1]. Fig -2.

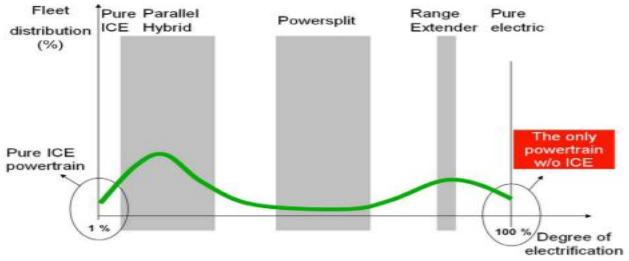

Fig -2: Degree of electrification. Vision 2025

3. DESIGN AND ANALYSIS

The preeminent motivation behind the plan is to accomplish less weight and achieve ideal on-street execution without settling on the driver's security, reliability and durability. With respect to the plan, driver's security and ergonomics have been given top priority. This calls for weight decrease and better vehicle execution to the detriment of expanded expenses. During the conceptualizing stage, several design ideas were considered and the optimum solution at every stage was pursued, Various design and analysis software's such as Solidworks, Catia, Ansys, and Solidworks Electrical were utilized to help carry the vision to reality into an effectively usable advanced medium that is appropriate for design creation, analysis and optimisation. The picked design is a rounded space outline made out of a blend of two arrangements of cylindrical members. The primary members are made altogether of 1.25" O.D and 1.65 m. The material for the members was picked as AISI 4130 (Chromoly) Steel since it offers high elasticity, incredible pliability, high effect quality, erosion opposition and great weldability at a sensible cost and accessibility. Design is shown in Fig -3

Fig -3: Vehicle design

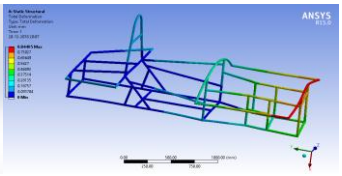

Fig -4: CAE (Total deformation)

4. CAE ANALYSIS

The CAE software utilized for analysis was Ansys. The three-dimensional geometry which was created in SolidWorks was brought into Ansys and different investigations like Front effect examination, rollover examination, and wheel knock were performed. All these investigations depended on the conditions that we would be involved with the vehicle building and riding, whereas remote loads were given accordingly. The hard focuses were fixed and the remainder of the heaps were appointed by the G-Force counts. Shown in Fig -4. Parameters of vehicle is provided in the Table -1.

Table -1:

PARAMETERS	DIMENSIONS
Length*Breath*Height	2432*1384*1441 (mm)
Wheel base * wheel track	60 & 44 (inch)
Vehicle weight	140kg

5. BLOCK DIAGRAM

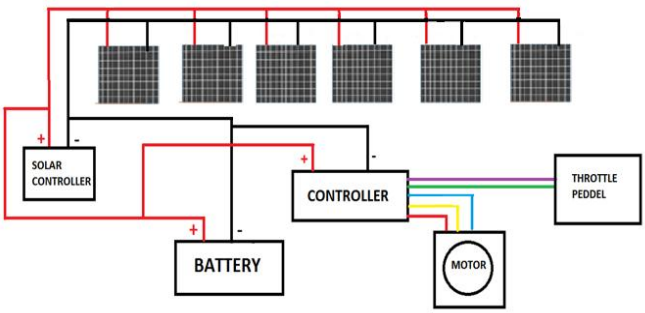

Fig -5: Overall Block Diagram

Figure-5, shows an overview of the working of solar vehicles. Sun is the main source of energy for the vehicle. Photo-voltaic cells use daylight as a wellspring of energy and generate direct current. Arrays of a photovoltaic framework gracefully supply power to electrical equipment. The electrical energy is put away as batteries for later use through the MPPT controller. Batteries flexibly supply the power to the controller which spits the necessary power for the BLDC motor. The shaft of the motor is connected with the rear wheel of the vehicle utilizing chain sprocket. At first batteries are completely energized and thereafter they are charged by panels. This aids in finishing the charging-discharging pattern of the batteries, which is significant for legitimate working of batteries.

6. CIRCUIT DIAGRAM

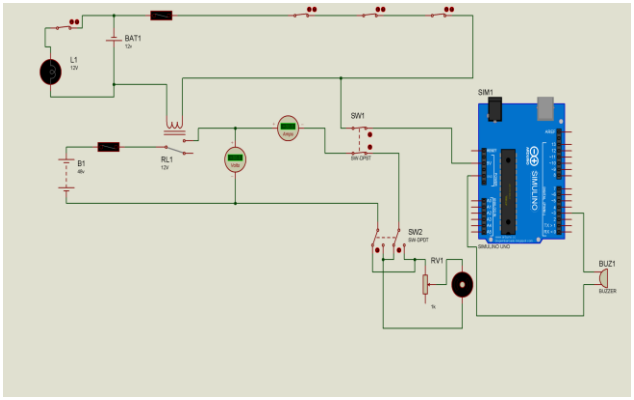

Fig -6: Circuit Diagram

Overall circuit diagram of a solar vehicle is presented as a MATLAB design, shown in figure -6, which gives the complete electrical design (panels circuits are excluded). Electrical rating of the components is detailed below in Table -2. Working stage of the vehicle begins from the battery(B1-48V), which is directed to the controller using a fuse to ensure safety. Relay is introduced between the circuit for ease of accessibility and safe practise. Controller drives the BLDC motor by providing and distributing the required power supply. Speed of the motor is varied by using the throttle pedal which is inbuilt in the controller

circuit to vary the resistance. Forward and Reverse of the vehicle is achieved by switching the controllers FNR circuit. Voltmeter and Ammeter are connected across the primary circuit to examine the voltage and current consumption of the vehicle. Buzzer is an electrical device used to alter during the vehicle starts. Buzzer is completely controlled by the Arduino board which stops the buzzer sound within 3 secs after alert.

Additionally, all the electrical components other than the tractive system are powered by a secondary battery (BAT1-12V). This secondary battery is used to supply power to the relay (RL1), ammeter, voltmeter, buzzer, horn, bake light and other lighting systems. Fuse is also used in the secondary connection to ensure safety and are provided with ON/OFF along with the three kill switches at the varied location in the vehicle for emergency stop.

7. Electrical Components

Different kinds of electrical components were implemented in the solar powered electric vehicle. A rundown of these parts' usage with their range and the specific quantities that were required for making a solar vehicle is discussed in the following table.

Table -2:

Components	Range	Quantity	Type
Battery	48V, 100Ah	1	Li-ion
Motor	48V,2kW	1	BLDC
Controller	24-72V, 0-180A	1	Closed loop
Solar Controller	48V, 40A	1	MPPT
Solar module	150Wp 70Wp 35Wp 20Wp	2 1 2 2	Flexible Mono-crystalline
Relay	48VDC, 200Ah	1	2Z contact form
Wire Harnesses	16mm^2 (High voltage) 2mm^2 (Low voltage)	Approx. 5meter Approx. 8meter	copper
Battery	12V	1	Lead acid

Furthermore, some other electrical components were used in the vehicle some are.

- Voltmeter, Ammeter to measure the voltage and current consumption,
- Brake light, Buzzer, Horn were used for driver comfort and safety.

8. COMPONENTS IN DETAIL

8.1 Battery:

A battery is a device comprising of at least one electrochemical cell with an external connection that gave power to electrical devices. At the point when a battery is providing electric force, its positive terminal is the cathode and its negative terminal is the anode.

- Number of cells in battery =546 cells
- Cells in Parallel connection = 42 cells
- Cells in Series connection = 13 cells
- Number of cells in Rows = 42 cells
- Number of cells in Columns = 13 cells
- Current rating of single cell = 2.4 amps
- Voltage rating of single cell = 3.7 volts

Charging and Discharging time:

V=48V, I=100Ah

Charging time = rated current/applied current
= 100/15
= 6.6 hours(approx.).
Discharging:
Motor power consumption=2000watts

Discharging time = total power/motor power
= 4800/2000
= 2.4 hours(approx.)

8.2 Motor:

A brushless DC electric motor, also known as synchronous DC motor, are simultaneous motor fueled by direct flow (DC) power by means of an inverter or exchanging power flexibly which produces power through substituting flow (AC) to drive each period of the motor by means of a closed-loop controller. The controller gives the pulse of current to the motor windings that control the speed and torque of the motor.

- Voltage rating of motor: 48V
- Power rating of motor: 2000W
- Torque at maximum speed: 6.3Nm
- Rated Speed: 3000rpm

8.3 Controller:

A controller is a device which control the performance of an electric motor. A motor controller may incorporate a manual or programmed implies for beginning and halting the engine, choosing forward or turn around a pivot,

choosing and managing the speed, directing or restricting the torque, and securing against over-load and electrical issues.

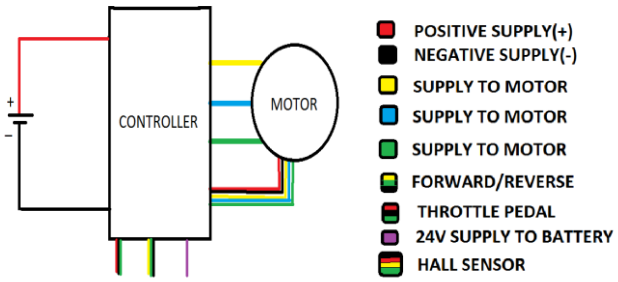

Fig -7: Controller Connections

8.4 Relay:

A relay contactor is an electrically-controlled switch utilized for exchanging an electrical power circuit. A contactor is regularly controlled by a circuit which has a much lower power level than the exchanged circuit, for example, a 12-volt curl electromagnet controlling a 48-volt motor switch.

- Insulation resistance: 100Mohm Min
- Dielectric strength between contacts: 200VAC
- Between coil and contacts: 1500VAC

8.5 SOLAR CONTROLLER:

An MPPT charge controller, or maximum power point tracker is an electronic DC to DC converter that improves the match between the solar (array) cluster (PV panels), and the battery bank. To lay it out plainly, they convert a higher voltage DC yield from solar panels and down to the lower voltage expected to charge batteries just as comparatively give power legitimately to the motor utilizing a controller to drive a vehicle.

8.6 Solar Module:

Photovoltaic modules utilize light energy (photons) from the Sun to produce power through the photovoltaic effect. A solar module is typically an arrangement associated with, an adequate number of solar cells to give required standard voltage and power. A single solar module can be appraised from 3 watts to 300 watts. As a matter of fact, a solitary PV cell produces an exceptionally small sum that is around 0.1 watt to 2 watts. In any case, it isn't functional to utilize such a low power unit as a building square of a framework. So, the required number of such cells are joined together to frame a reasonable financially accessible solar unit which is known as solar module or PV module.

In Fig. 6 the patterns for the productivity of photovoltaic cells have appeared. The vast majority of today PV panels, with multi-crystalline silicon innovation, have efficiencies somewhere in the range of 11% and 18%, while the utilization of mono-crystalline silicon permits to expand the changing productivity of about 4%. The response to multi-intersection cells, with the utilization of materials as Gallium Arsenide [9] and to concentrating advancements [9], has permitted to arrive at 40% of cell productivity. Anyway, the expense of these last arrangements is still unreasonably high for a mass application on vehicles.

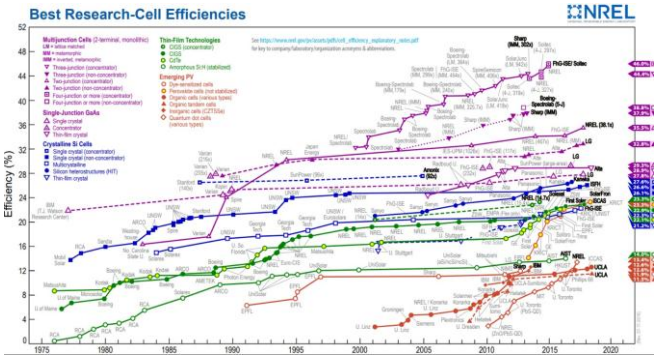

Fig -8: Efficiency of photovoltaic cells.

The vehicle is totally designed dependent on the driver's wellbeing however maximum priority given to utilize the upper surface of the vehicle to gather solar beams. The panel ought to be mounted so that it gets the greatest sunbeams with the goal that it gives its most extreme proficiency. The vehicle is mounted with a solar panel in 360 degrees of the vehicle, it assists with getting the most extreme measure of intensity, a voyaging bearing of the vehicle won't be a serious deal to gather sun-powered energy. In light of the compelled and streamlined structure, adaptable panels were prescribed to utilize, usefully it gives a weight decrease to the vehicle. As the vehicle has a board power rating of 480wp with a shifted voltage appraised panel. Panels in a vehicle are associated with an arrangement and equal approach to get an ideal yield of 48V, associations are clarified as a pictorial portrayal in beneath. In fig -9.

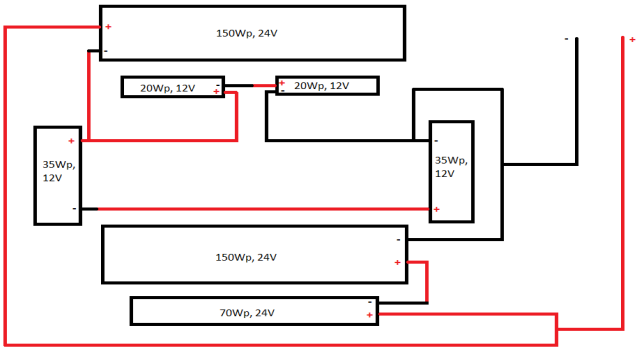

Fig -9: Panel Connections (as the way connected in vehicle)

9. OPERATIONS INVOLVED IN VEHICLE

The solar module mounted on the surface of the vehicle is utilized to charge the batteries through a charge controller. It gives a yield of 48V. The batteries are at first completely energized and afterward they are associated with a solar module for charging [4]. This assists with keeping the battery charged consistently. This is additionally done, as the effectiveness of the solar module is just 15%. Thus, under this condition the battery gets completely energized. While panels may get a normal 7 hours of sunshine for each day, the normal pinnacle sun-hours may really be more like 3 or 4hours. Consequently, the panel is mounted to the point that most extreme yield might be acquired. As the supply is given through the controller to the motor it takes a high starting current to propel the wheel to move in forward direction. The vehicle is around 180kg including the driver, it can reach up to 60km/h speed at the greatest. The batteries get charged consistently from the solar panel thus it gives the ceaseless run to the vehicle. Vehicle is totally relying upon the driver's power on the throttle pedal to shift speed. As the speed differs the heap current likewise fluctuates. So, the speed variety must be low to keep the battery alive for the most extreme term of time. For halting the vehicle, brake pedals were given in the vehicle; from there on the disc brakes ought to be applied. The disc brakes can be applied in a split-second during emergency however this ought to be maintained a strategic distance from as this could harm the motor and furthermore produce pointless back emf. The normal battery back-up is around last for more than two and half hours. A secondary battery is used in the vehicle to power an auxiliary electrical device like voltmeter, ammeter and so for.

10. VEHICLE TESTING

The complete static report of the vehicle was studied, and the vehicle was taken to the dynamic testing after the technical inspection. The testing of the vehicle involves acceleration, braking, cross test, solar endurance, suspension and endurance test. All testing was carried out under the rule mentioned in rulebook SUVC-2018[7]. The test and their results are discussed below. All the test was carried out for the 3 times. Tabulation below the result shows the number of test and its result.

Note: All test was carried with a same driver with an approximate weight of 50Kg.

10.1 Acceleration Test:

In the acceleration test. Vehicle was taken to a track which was 85 meters in distance included with 10 meters for the braking test. In this acceleration vehicle was allowed to move at full throttle to achieve a maximum speed. Timing was recorded from the timer. This allows us to measure the acceleration timing of the vehicle. In addition, the braking test was carried at the same time. Braking track line begins at the end of the acceleration track. Braking track was around 10 meter in distance. Vehicle was supposed to stop in the track with a complete locked wheel without any rotations. Acceleration and braking tracks are shown in fig -10.

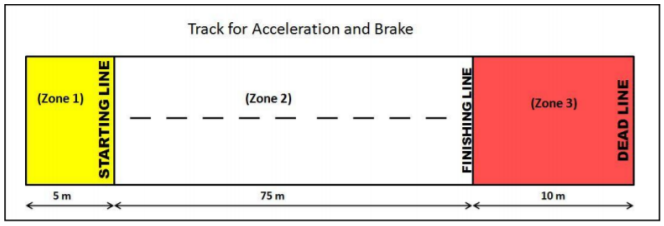

Fig -10: Acceleration and Braking Track

10.1.1 Result:

With the high-performance, vehicle could able to cover a 75 meters distance in 11.46 seconds. Vehicle completely stopped at a smartest distance of 6.54 meter with locked wheel.

Table -3:

Test Rounds	Time (sec)	Braking Distance (m)
Round 1	12.01	6.54
Round 2	11.54	6.72
Round 3	11.46	6.86

10.2 Cross Test:

Cross test is designed to test the vehicles steering and cornering. This test had a lot of sharp turns in the track. Driver have to drive the vehicle in this zone. Zone 2 consists of plain dumber or concrete road in which cones will be placed. In this cross test, the design of the vehicle was also tested, it would show the mistakes made in the design to increase the space for panel. If the size of the panel increases or extend beyond the vehicle design would hit the cone. But it was assured only with the qualified driver. Cross test track is shown below in the fig -11.

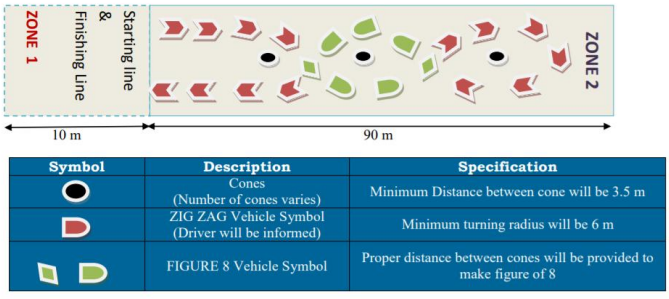

Fig -11: Cross Test Track

10.2.1 Result:

Vehicle covered a complete distance without hitting any cone in a timing record of 1.21 minutes. This testing was not only depended on vehicle condition but also depend on driver's ability in driving. Fortunately, with a talented driver, cross test took place with a good result.

Table -4:

Test Rounds	Time (min)
Round 1	1.26
Round 2	1.34
Round 3	1.21

10.3 Suspension Test:

Suspension test is designed to check suspension of Vehicle. Thus, it will have a lot of obstacles alike on Indian Roads. The track will be off-road and have bumps, sharp turns, small hill climbs, etc. This test would be designed in such a way that actually to test vehicles capabilities; it would be very challenging as well as inspiring. Track used to carry out the test is shown below in fig -12.

Note: Tracks were not exactly same as in the picture but, the check post was almost it seemed to be similar which were filled with stones, woods and some artificial hurdles.

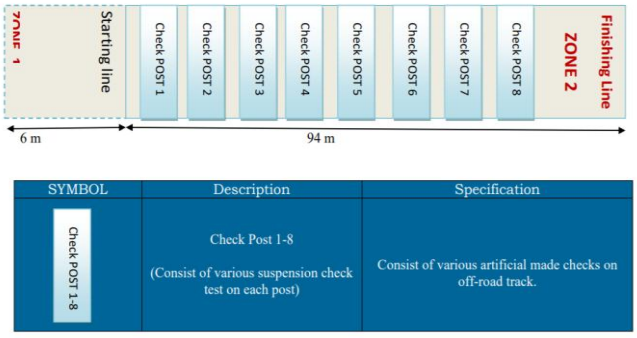

Fig -12: Suspension Track

10.3.1 Result:

Vehicle drove under a lot of struggles and hurdles to reach the finishing line. It took a minimum timing of 40 seconds to complete the suspension test in a track.

Table -5:

Test Rounds	Time (sec)
Round 1	59
Round 2	43
Round 3	40

10.4 Solar Endurance Test:

Solar Endurance test would be the most important test among the all other test. In this test, battery connections had removed. In vehicle, solar panels had directly connected to the controller to power the motor. In this test vehicle had to run completely in a solar power without any internal or external means of source.

This test took place in a two way, at first vehicle had to run in a straight path of road to cover an assigned distance, secondly vehicle had to run with an external load or weighted carrier of almost 80 kg. Track used for the solar endurance test is pictured below in the fig -13.

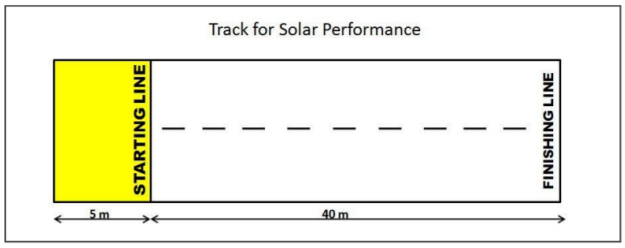

Fig -13: Solar Endurance Track

10.4.1 Result:

Vehicle requires of torque to move at initially, test conducted during the mid of the day during the time between 12:00 – 01:00 p.m. With the maximum power vehicle covered a distance in a desired time of 2.26 minute without any external load. As well as similarly it took almost 3.15 minutes to cover the same distance with an external load of 80kg. It was the ultimate result test. At the beginning vehicle were left in the sunlight for 5 minutes.

Table -6:

Test Rounds	Time (min) Without weight	Time (min) With weight
Round 1	2.44	3.26
Round 2	2.31	3.20
Round 3	2.26	3.15

10.5 Endurance Test:

Endurance test was designed to test the overall efficiency of the solar car. This endurance test was carried out in two different ways, which were static and dynamic.

In a static test vehicle was uplifted in a frame and applied a constant throttle until the battery dried.

In a dynamic test, the vehicle had to be driven for 2 hours continuously. A specific track was made up to 2.5km and allowed a driver to repeatedly drive on that track. This

dynamic test track also had some hurdles to test the vehicle condition while running.

Note: Endurance test was planned to be carried out until battery dies. But occasionally the motor, controller and battery attain a maximum temperature during the experiment, so time was limited to 3 hours. Fig -14 shows the model endurance track.

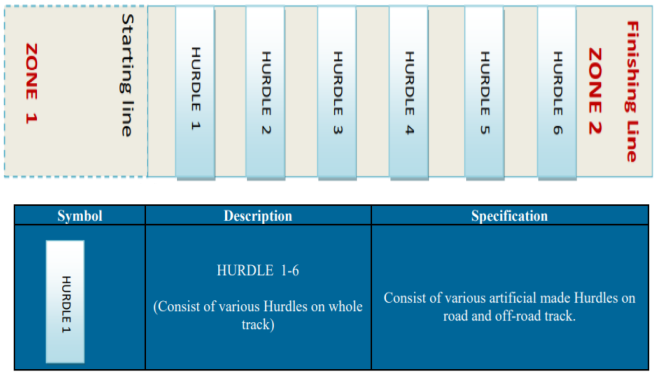

Fig -14: Endurance Track

10.5.1 Result:

In a static endurance test a vehicle took almost 2 hours and 34 minutes to get completely drained condition of battery. During this test battery and motor got a high temperature. But it was maintained by applying constant throttle.

In a dynamic endurance test a vehicle covered almost 23 laps within two hours, in a nutshell it covered around a distance of 69 kilometer without any interval for driver and vehicle. At the end of the test it was observed that the vehicle had a minor issue in front left-side disc brake. Over heating in motor. Controller and battery. Voltmeter showed a voltage of 36V at the end of the endurance test.

11. CONCLUSION

The integration of photovoltaic panels in solar powered vehicles is getting progressively practical, because of the expanding armada charge, to the expansion in fuel costs, to the advances regarding PV panel innovation, and to the decrease in their expense. Solar electric Vehicles may therefore represent a valuable solution to face both energy saving and environmental issues. Of course, these vehicles cannot represent a universal solution, since the best harmony among advantages and expenses would rely upon mission profile: specifically, huge decreases in fuel utilization and outflows can be acquired during average use in urban conditions during working days. Additionally, the integration with solar energy would likewise add to diminish battery reviving time, a basic issue for Plug-in vehicles, and to add an incentive for Vehicle to Grid applications. Putting a solar panel on an existing electric vehicle might be only the initial phase: so as to expand their advantages, re-plan and enhancement of the entire vehicle-powertrain framework would be required. Specific consideration must be paid in amplifying the net force from solar panels, and in embracing propelled answers for power hardware. Also, these vehicles would require explicit answers for energy management and control, with further developed look-ahead abilities. The reception of moving rooftops for leaving stages and the utilization of solar panels on windows and horizontal sides would upgrade solar commitment, past the traditional fixed board on the vehicle rooftop. Besides, these arrangements would decrease the hole between solar commitment at low and high scopes, so expanding the expected market of these vehicles. Intriguing open doors are likewise identified with conceivable reconversion of ordinary vehicles to Solar Powered Electric Vehicles, by methods for packs to be dispersed in the reseller's exchange. The points of view about cost issues of solar vehicles are empowering. Anyway, as it occurs for some, developments, full monetary attainability couldn't be prompt, and a money related help from governments would unquestionably be fitting. Be that as it may, the ongoing and to some degree unforeseen business achievement of some solar powered electrical vehicles demonstrates that there are reasons for trust that a noteworthy number of clients is as of now ready to go through some more cash to add to spare the planet from contamination, atmosphere changes and asset exhaustion. Running vehicle is show in fig -15.

12.ACKNOWLEDGEMENT

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Fig -15: Running Vehicle

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