Design Methodology and Analysis for E-Vehicles and Automotive

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Abstract: **The Electric Solar Vehicle is a multi-seater vehicle powered by 750 W BLDC hub motor. Undergraduate students of C.O.E.T. Akola from Mechanical Engineering Department, collaborated to design and fabricate a safe, high performance, cost efficient electric solar vehicle.**
Now a days, dealers of natural resources like fuel, coal etc. are facing a hard time to keep pace with the increasing demand. Therefore, to carry out this demand it is quite necessary to make a new exploration of natural resource of energy and power. Therefore, sunlight is now a days considered to be a source of energy which is implemented in various day to day applications. Solar energy is being used to produce electricity through sunlight. With the help of this technology, we aim to make solar energy powered car in our project. The main component to build a solar car is the solar panel. The solar cells collect a portion of the sun's energy and store it into the batteries of the solar car. Before that happens, power trackers convert the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. After the energy is stored in the batteries, it is available for use by the motor & motor controller to drive the car. We are going to use two set of batteries; one of which will get the electrical energy from the panel to drive the motor and another will be used as auxiliary power source which will provide required power to other electrical devices being used in the vehicle. A microcontroller can be used in this purpose which can switch to the fully recharged battery when it senses that another battery is empty or not providing enough power to drive the motor. Again, we used a complete circuitry to solve the problem of voltage fluctuation due to movement of the sun, earth or cloud etc. We used a voltage comparator, a relay circuit for and a transistor along with a diode for this purpose. Comparator compares the voltage of solar panel and the battery and then it provides the higher voltage to the transistor to activate the relay which provides the required and stable voltage to the car. However, after all these being proceeded, the motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels. Finally, an Arduino Circuit for Automatic Braking Alert System to infuse with safety of the vehicle and the passenger and to imitate the advanced technology of modern manufacturers.

Keywords: **Electric Solar Vehicle, BLDC hub motor, solar cells, solar panel, power trackers, auxiliary power, microcontroller, Automatic Braking Alert, voltage fluctuation, voltage comparator.**

I. INTRODUCTION

The purpose of the project is to build up interest towards energy efficient engineering, and enhance theoretical as well as practical knowledge along with management and team work of students. Our aim is to reduce the usage of organic fuel powered vehicle and design environment friendly electric power vehicle. A solar vehicle is primarily powered by direct solar energy. Photovoltaic cells (PVC) are installed on the Vehicle to collect and convert solar energy into electric energy. Made of silicon and alloys of indium, gallium and nitrogen, the semiconductors absorb light and then release it, producing a flow of electrons that generate electricity which charges the 48V battery connected to it, which runs the 750-Watt Brushless DC Motor to transmit power to drive the vehicle, using some arrangements the motor can run directly by the power generated through solar cells. The weight of the vehicle should be given proper attention. We are using Seamless Aluminium Pipes and the design is made such that vehicle has proper Power to Weight ratio and is of less weight and has high strength which is the foremost requirement of any solar vehicle.

At present situation Earth has limited amount of energy resources which is very soon going to extinct. Fortunately, population models have suggested that the world's population will probably level out at about two to three times the present numbers over the next hundred years. As the population is increasing the demands of people is also increasing. The question is whether the earth's resources are sufficient to sustain that population at a high standard of living for all. In this the key issue is energy. Now-a-days, dealers of natural resources like fuel, coal etc. are facing a hard time to keep pace with the increasing demand. At one hand, there are more cars or motor vehicles are dominating the transport medium, on the other hand these cars are being dominated by the fuel. As a result, the limited resources are being quashed by the producers and dealers to satisfy this need which is leading us to an uncertain future with having the scarcity of fuel and minerals. So, it is clear that present trends in energy consumption, especially oil, cannot be sustained much longer. Also, these are responsible for Global Warming, Environmental Imbalance, Ozone layer depletion etc. which in turn is a big threat to the future human race. Again, in view of the possibility of global warming, these resources are playing a negative role. Therefore, under this circumstance, it is quite necessary to make a new exploration of natural resource of energy and power. But why exploration when the resource is in front of our bear eye. It is effective, less expensive and above all, it is an endless source of energy. With greatly improved energy efficiency, a transition to this energy-based economy capable of sustaining the anticipated growth in the world economy is possible. This effective source is ―Solar Energy.

Solar energy is the energy provided by the sun. It is the radiant light and heat from the Sun, harnessed using a range of ever-evolving technologies such as solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial photosynthesis.

Energy is produced in Sun by nuclear fusion during a series of steps called the proton-proton (PP) chain, converting hydrogen to helium. The core is the only part of the Sun that produces an appreciable amount of heat through fusion about 99%. Hydrogen nuclei in Sun's core fuse together to form helium nuclei and release energy, this process is called nuclear fusion. In this state, some 120 million tons of matter--mostly hydrogen are converted into helium on the sun every minute, with some of the mass being converted into energy. The size of the sun determines its temperature and the amount of energy radiated. Electromagnetic energy from the sun comes to Earth in the form of radiation. The sun radiates energy equally in all directions, and the Earth intercepts and receives part of this energy. The power flux reaching the top of the Earth's atmosphere is about 1400 Watts/m2. This measure simply means that on the average, one square meter on the side of the Earth facing the sun receives energy from the sun equal to that from fourteen 100-Watt light bulbs every second. The Earth receives 174petawatt of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to the space while the rest is absorbed by the clouds, oceans and land masses. The spectrum of solar light at the earth‘s surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet. Yet this amount of energy is very much to utilize for useful work.

II. PROCESS OUTLINE, DATA CONCEPT & SEMANTICS

The Process

1. Preliminary data collection of the existing solar technology and its analysis.
2. Assessment and locating suitable applications and niche areas for the technology.
3. Comparing different applications zones and locating the most probable areas where a four-wheeler vehicle with the respective technology will work.
4. Identifying the existing vehicles and their characteristics in these selected scenarios for which the vehicle has to be designed.
5. User study through scenario building in the areas where the vehicle is to be used.
6. Developing a design brief.
7. Basic anthropometric requirements and an ergonomic study.
8. Initial ideation and concepts.
9. Concept generation, -over all form -structure.
10. Form exploration through semantic study of the object.
11. Final concept selection and variations.

The Solar Rickshaw

The introduced prototype and its features are as follows:

1. Self-sufficient on solar energy
2. Capable of a speed of 25- 40 km/h.
3. Capable of climbing up hill on an average inclination of 15 deg to 30 deg.
4. One seater.

Individual Constituent parts Of Prototype

1. Solar panels- 85-Watt BP solar panels placed on the roof and
2. Motor- Lynch motor, which offers the best efficiency greater than 90 % and has a weight of only 9 kg. At 12 Volts the motor can run at 2.5 KW approx. 4 HP
3. Batteries- The batteries mainly store the excess power from the solar panels to give backup for night hours use. They also supply the initial torque to start the motor. The batteries are 2 x 12 Volt Exide sealed traction, deep discharge batteries.
4. Solar Controller- the solar controller is like a fuse which regulates the current from the panels to the motor.
5. Running gear- Bicycle wheels with spokes have been used and on later versions stronger wheels will be used. A differential is incorporated in the back axle and 3 speed Strum archer gears used in the drive system.
6. Brakes Hydraulic disc brake are fitted to front wheels.

Design Criteria for Improving Solar Rickshaw as proposed by the team.

1. Ideal balance between weight and stability.
2. Seating to be more comfortable.
3. 18” of room between seat and floor.
4. Wider wheels for more stability.
5. Better suspension.
6. Efficiency of motor suitable for higher gradients.
7. Aero dynamic body
8. Road clearance
9. Passenger cover for monsoon
10. Seat belt and safety features

Concept development

1. “Inside out to Outside in” approach form well integrated with material and structure and complimentary to the overall functional requirements, interior elements with certain level of flexibility, innovation and convenience.
2. Exploring attributes like:

a) unconventional
b) sporty,
c) light,
d) dynamic,
e) extrovert,

3. Experiments with lighter materials like metal sections (M.S and aluminium), fibre reinforced plastics and aluminium sheets keeping in mind the main constraint of accommodating surfacing surface area of 4'x 7' (14 sq. feet).

III. METHEDOLOGY

1. **Technical specifications** which are followed from the existing prototype are: The basic chassis structure with permissible modification in the size of the Wheelbase. Over all mechanics of the vehicle constituting parts like motor, battery, controller and instrumentation remains unchanged.
2. **Minimum surface area** of the solar panels to be 2.4 square meters. The solar panels are currently 50cm x 120 cm, they can be broken into 3 parts of 50 cm x 40 cm (each panel containing minimum 12 cells.
3. **Minimum surfaces and skinning**: In order to increase higher visibility from inside to outside.
4. **Light weight** vehicle, which means under 350 kg kerb weight to be maintained approximately.
5. Designing a solar powered vehicle for locomotion in areas like non-academic in campus, entertainment parks, safari parks and exhibition areas, to be used by tourists, middle class families, executives and workers.
6. An **ergonomically designed** vehicle.
7. **Possibility of storage space** or collapsible area to generate extra storage floor area.
8. **Safety** of passengers. Safety here does not imply emphasis on collision safety rather safety of passenger from slipping due to inertia while moving and breaking and arresting the person in the sitting position if the vehicle topples.
9. **Strong and distinct visual identity.**
10. **Simple interface and minimal interior elements.**

Golden Rule for Trike Design

In Accordance to the Golden rule of TRIKE DESIGN, it appears to stem from HGJ's calculations on lateral stability. To ensure lateral stability for the situation of constant speed straight line motion, it is recommended that the three wheeled vehicles with two wheels on the front axle be designed so that its mass centre is located in the front third of the vehicle. The centre of gravity should be mounted as close to the two-wheel axle as possible to maximise rollover stability. The height of the centre of gravity should be less than half the track measurement and less than the distance to the front axle. If the centre of gravity is in the front half of the vehicle, the vehicle will be stable at all speeds, otherwise further calculation is necessary to determine the speed limit of lateral stability.

Lateral Stability: Depending on the value of the under steer coincident a vehicle may be either directionally stable at all speeds, or become unstable above a threshold speed (known as the critical speed).

Rollover Stability: A measure of a vehicle's tendency to tip over sideways when a lateral body force is applied (e.g., during cornering). Engineering design is all about compromise, and deciding on track, wheelbase and weight distribution is one big set of interrelated effects.

FOR A TADPOLE LAYOUT (2 WHEELS ON THE FRONT AXLE, 1 ON THE REAR)

Track: Wide track gives good lateral stability, though being wider than a bike; it limits the places that it can get through without being disassembled. On the road however, that extra width means passing vehicles are further away from the rider. A narrow track can allow a trike to ride through doorways, but makes it easier to tip over in the corners.

Wheelbase: A longer wheelbase gives a smoother ride with less pitching and allows greater braking performance, but gives a proportionally thinner trike, thus lowering the roll-over threshold. Shortening the wheelbase gives better lateral stability, but could pitch forward under heavy braking.

Centre of Gravity (CG): A rearward weight distribution improves directional stability under braking, but reduces lateral stability Having the weight distribution forward improves lateral stability, but reduces directional stability under braking (as load on the rear gets less) and at the extreme, lifting the rear wheel and tipping the nose to the floor.

FOR A DELTA LAYOUT

The effects are the similar, but in a different order. And the effect of reduced cornering stability with acceleration of a tadpole becomes reduced cornering stability with braking. The typical choice is to have a short wheelbase trike with a track that is narrow enough to fit through a doorway or between bollards on a path. But that's not the only solution, a long wheelbase, Short & Narrow vs. Long & Wide track trike is likely to mix much better with traffic because it takes 14 up more space on the road. It's still important to have a stable trike and this is how I 've gone about sizing it.

Stability: This isn't a lesson and there 's no quiz at the end, this is a reference. Normally when I read technical papers, I skip over the equations first time through. I begin stability calculations with an approximate wheelbase, track and centre of gravity position and then iterate through the calculations to refine them from there. Because the all three values have interrelated effects, there 's no clear reference value, so I prefer to work from a rough idea, check if it 's feasible and then refine it from there.

ATOMIC DUCK CONCEPT SIDE LAYOUT

From the side layout, the combined C.G looks to be about 0.4m above the ground and 1m ahead of the rear contact patch. This combination is vehicle and rider, where the rider 's C.G is approximately at the position of their navel when seated. The C.G for the vehicle will never be just at one point, because different mass riders, with or without luggage; will influence the exact position; so, I 'm using this as a guide. I 'm assuming the C.G lies on the centreline.

Because the vehicle is mostly symmetrical and the rider sits across the centre. The wheelbase is 2.5m. This gives some luggage space, low, behind the seat while still allowing enough leg length for a 99th percentile rider. Total height of the Atomic Duck then is around 1m with 0.2m ground clearance. The roll-over point is the limit value of lateral stability. When the roll-over point is reached, there is zero load on one wheel, and even the slightest extra sideways load will cause the trike to roll over. Obviously, this is not a good thing to have happen when riding. So, it 's important to make sure that the roll-over value is higher than any lateral loading that is likely to occur. For an idea of possible lateral accelerations, I turned to my trusty Blue Book (Bosch Automotive Handbook), which suggested for a road vehicle, that a 0.42g lateral acceleration has a 0.01% probability of occurrence—equivalent to occurring once every 10,000 journeys. Lateral accelerations above 0.6g are possible, although designing to values approaching 0.8g means rollover shouldn't occur except for the most extreme accident conditions. On calculating the roll-over point using accelerations at the centre of gravity. The accelerations give rise to body forces (braking/acceleration and cornering) that act through the C.G. For clarification, the force due to longitudinal acceleration and the lateral, centrifugal cornering force don't actually exists, they are pseudo-forces and valid in these calculations because I'm using a reference frame that is static to the vehicle.

IV. DESIGN AND CALCULATIONS

1. The solar vehicle must be manufactured within INR 80,000.
2. The vehicle must have a wheelbase of at least 1168.4 mm (46 inches).
3. The smaller track of the vehicle (front or rear) must be no less than 75% of the larger track.
4. 2-inch suspension travel (1 inch Jounce & 1 Inch Bounce).
5. Tyres and wheels: using three wheels then there should be two wheels on the front.
6. Material: use only seamless pipe.
7. The ground clearance with the driver aboard must be minimum of 50.8 mm (2 inch) of static ground clearance under the vehicle at all times of the competition.
8. Impact bumper: Should be an impact bumper on front and rear side of the vehicle.
9. Jack Points: must be two jack points on the vehicle
10. Ergonomics: Driver must be able to exit to the side of the vehicle in no more than 5 seconds.
11. Driver Visibility: must have a minimum field of vision of two hundred degrees (200°) (a minimum one hundred degrees (100°) to either side of the driver).
12. Push rod: Detachable push rod is mandatory for all the team. Push rod should have the capability push as well as pull the vehicle.
13. Steering system: The steering wheel must be mechanically connected to the wheels.
14. The break circuit: It must have hydraulic circuits such that in the case of a leak or failure at any point in the system.
15. Motor: Teams have to use motor of power 1 kW maximum and operating voltage is restricted to maximum 48 Volts at any point of the circuit.
16. Batteries: Batteries should have maximum of 48V and 50ah all the time of event.

V. INNOVATION

Automatic Brake Alert

Automatic Brake Alert is an automobile safety feature designed to reduce the severity of an accident. It uses radar sensor to detect an imminent crash. Once the detection is done, this system provides a warning to the driver when there is an imminent collision or take action autonomously. Major components of ABA are:

- Infrared Transceiver: An infrared transceiver is a device which is capable of both sending and receiving infrared data.
- Arduino Uno Microcontroller Interface: Arduino is a single-board microcontroller, intended to make it easier to build interactive objects or environments. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32bit Atmel ARM. Current models feature a USB interface, 6 analogue input pins, as well as 14 digital I/O pins that accommodate various extension boards.

Arduino Sketch (program for the ABA):

This helps to have an external programmer (e.g., an AVR-ISP, STK500, or parallel programmer), you can burn sketches to the Arduino board without using the bootloader. This allows you to use the full program space (flash) of the chip on the Arduino board. So, with an ATmega168, you'll get 16 KB instead of 14 (on an ATmega8 you'll get 8 KB instead of 7). It also avoids the boot loader delay when you power or reset your board.

Objectives of ABA:

The objective of this device is to alert the driver to apply brakes in situations where the velocity of the vehicle is high enough to not allow the vehicle to stop within a distance which is necessary to avoid collision. The device will determine the relative velocity between the vehicle and the object in front of it (which may be another vehicle). It will sound an alert if this relative velocity suddenly increases. It will be triggered at a distance that is sufficient for the vehicle to stop to prevent collision.

Program Logic:

The instantaneous relative velocity of the vehicles will be calculated by time averaging the difference of two consecutive readings of distance. This velocity will be compared with a table of _Minimum real velocities 'and corresponding _Braking distances '. The alarm will be triggered if this relative velocity exceeds the velocity corresponding to the current distance between the vehicle and the object

Safe-Speed Setting

Safe-speed setting (SSS) is an electronic device to have a proper control on vehicle propulsion and also helps the vehicle for better performance. It controls the performance of motor under every possible condition. Major components of SSS:

- Digital speedometer
- A feedback control circuit (on-off control or proportional control)
- A comparator

Functioning of SSS:

- The speed setting in terms of voltage is input to the comparator
- An output from the digital speedometer will be fed to the comparator
- The comparator decides if the vehicle velocity exceeds or is below the set velocity
- The comparator output controls: a relay that will switch the motor - or - a potentiometer that will control the speed of the motor

Electrical System Protection and Diagnostic

It is a simple circuit for protecting and monitoring the health of the electrical system of the vehicle (electric drive and auxiliaries).
Monitored aspects: -
Battery health indication (Percentage charge)

- Motor protection (overload tripping and Low voltage cut-off) with by-pass option.
- 'Live-body 'detection and warning.
- Electric throttle malfunction and auxiliary electric throttle.

Components:

- For battery health indicator: a 5-LED indication via analogue circuit
- For motor protection: an MCB of appropriate rating
- For Live-body: a sensitive LED indication via appropriate circuit
- For electronic throttle malfunction: LED indication for loose connection

Advantages:

- Quick localization of fault in the vehicle
- Decreases potential of damage to equipment
- Cost effective as it cuts expenditure on spare parts
- Physical safety of personnel
- Easy to repair the vehicle as exact cause is made known

Electric Assist

An electric assist requires the addition of an electric motor to a modified rickshaw frame, as well as energy storage in rechargeable batteries. Other necessary components include a throttle and controller of some sort, in order to incrementally change the motor output (depending the method of assist), as well as a method of charging the batteries. While a working electric assist could be extremely beneficial to drivers, there are a number of constraints which limit design and feasibility. Cost of the system, for instance, could easily become prohibitively expensive for drivers in India, and the monsoons mean that any system would have to be very robust and weatherproof. In addition, ability to do local manufacture and repair is an important consideration when beginning to outsource parts like batteries and motor systems.

Mechanical Assist

A power assist system could also be accomplished with some form of mechanical energy storage. Potential energy storage mechanisms include a flywheel, compressed air, and a spring. There are a number of different forms that this system could take. A strong spring, for instance, could capture energy while the rickshaw coasts down hills, or store energy while stopping the rickshaw (akin to a regenerative brake), and release it later to give the driver a boost when starting up again. With compressed air, a tank of compressed air could power pistons or a compressed air engine in order to assist the driver. In both cases, however, there are a number of challenges with energy capacity and efficiency of the mechanical storage; the energy captured in a spring from coming to a stop would not be enough to start the rickshaw up again, due to numerous losses in the system. As with any system, exposure to weather could have a serious effect on a mechanical system. Despite its challenges, a mechanical system would alleviate a number of the problems with a purely electric assist. Batteries are particularly expensive, and inexpensive batteries often last for only a few years. The high cost of the 8 system, plus the added costs of occasional battery replacements, could make the system too expensive for the rickshaw community to afford. And while a simple mechanical assist could be a better solution, the amount of power needed for a useful electric assist could be difficult to achieve with mechanical energy storage

VI. Analysis Of the Model & Specifications

S.W.O.T ANALYSIS

Strength

Light weight and durable chassis.

We have manufactured our roll cage chassis with aluminium alloy composites for light weight and high strength and durability. We have also done high grade aluminium welding for joining the chassis parts to make a robust and stable chassis for better dynamic stability of the vehicle. We have also used alloy wheels for more light weight material. Also, we have tried to reduce as much extra materials from the vehicle as possible. Our vehicle body is also made of Fibre sheets which are ultra-light weight. But this doesn't reflects on the strength of the vehicle nor on its dynamic stability and vehicle is durable at any extreme conditions.

Run directly on Solar Energy

We have specially concentrated on the fact to run the vehicle directly on solar power on full load with best performance and speed of the vehicle. We have been successful in designing and manufacturing such vehicle which is capable of running directly on solar power. We have 6 solar panels which is sufficient to drive a powerful electric hub motor to take an average load on 50-80 kg mass. This is a great achievement from the future point of prospective.

Weakness

Not ideal for long rides

One of the demerits of this vehicle is that it is not manufactured for very long-distance rides since its design is neither that comfortable for long rides nor it is suitable keeping in mind the weather and constant need of solar power. We can easily switch to battery mode which is being charged on the go with those solar panels and is stored for use when the intensity of the solar power is not enough for driving the vehicle. Thus, we get a limit to the power stored in the batteries which limits from not suitable for very long rides.

Performance varies with weather conditions

As discussed earlier our vehicle runs directly through solar power effectively. We have another limitation in terms of the climatic conditions. As we know that sun ray's intensity is not uniform throughout the day time and is absent in the night time. So that limits our vehicle's performance at different time of the day. Also, the vehicle is not effective at times of cloudy environment or rainy season.

Opportunities

Eco – Friendly Vehicle

Our vehicle is totally environment friendly vehicle in all respect. The materials used in the overall manufacturing of the vehicle is made of recyclable materials. The vehicle doesn't emits any hazardous polluting gases. I neither uses electricity for charging of the vehicle since indirectly electricity production also causes lots of environmental issues. It charges the vehicle directly through solar power on the Go.

Efficient use of solar energy radiated to Earth.

A lot of sun's rays are emitted to earth surface and atmosphere. Most of these rays and energies are wasted due to no use of them. By running our vehicle directly via solar energy give a best way of optimum utilization of this solar energy for running our vehicles.

Awareness towards a clean, green & sustainable future.

Our next but most important motive is to get a clean green and sustainably future. If we preserve our no renewable conventional sources of energy now, the only it is useful for future generations.

THREATS

Varying weather conditions.
Uneven Roadways.

S T P ANALYSIS

SEGMENTATION

Geographic

We are focusing in both urban and rural parts of India but to have our manufacturing hub and initial launch in Orissa since Orissa is the only area/state in India to receive highest intensity of solar rays.

Demographic

India is the world largest country with youngsters (below 30) having formal technical knowledge.

We plan to develop the service sector of India by using the labour force available in India for expanding from Light Motor Vehicle to Heavy Duty Vehicle.

Psychographic

People of India are very concerned regarding the cost factor.

Inspiring the labour force to go for non-conventional sources of energy because it's a necessity right now as we are reaching the point when we will be out of petroleum products.

Society's style statement is going to get affected too. In other words, when the neighbour is going to have a solar car, it's natural in India that people will get curious and they would want to have one such type of car as well.

TARGET
Target audience comprises everybody who are eligible to drive, that is, youth, elders, Male/female.

POSITIONING
1. Using the unique concept of running the vehicle only with solar energy but not batteries
2. It is a burning topic of today‘s debate on fuel scarcity.
3. Inspiring the youth for sustainability of conventional resources
4. Expanding from Light Motor Vehicle to Heavy Duty Vehicles and we initiate it from Orissa

CONCLUSION
1. The above results, discussions as well as mechatronic design for an electric solar vehicle concludes the followings:
2. A three-wheeled low-cost electric solar vehicle (ESV) for lower income strata of developing countries is feasible and practicable.
3. Our ESV, a single-seated vehicle powered by 750 W BLDC hub motor can be a good choice for Indian market.
4. A multivariate technical group has enriched the design and fabrication of our EVS, for which it stands with higher safety, high performance as well as cost-efficient electric solar vehicle.
5. The dynamic stability of our ESV has been successfully done through maintaining the CG in the front half of the vehicle which in turn taking care for lateral and rollover stability as well.
6. Our design for wide track, longer wheel base and forward weight distribution system improves lateral stability of the ESV, which also reduces directional stability under braking (as load on the rear gets less) and at the extreme, lifting the rear wheel and tipping the nose to the floor.
7. During designing a special attention was given to reduced cornering stability with acceleration of a tadpole which becomes reduced cornering stability with braking.
8. Use of Buck Boost Converter in the EVS improve the efficacy of its power system including effective recharging facilities.
9. Safety and Ergonomics consideration in design including Driver’s seat design, incorporation of lock nut for motor, suspension, steering, braking and transmission etc. strengthen the acceptability of consumers in Indian road ways.
10. Application of Automatic Brake Alert in our design strengthens the safety aspects of the ESV which will reduce the severity of any accident. This is our special innovation in this project.
11. The attempt in using a Safe-speed setting (SSS), an electronic device to have a proper control on vehicle propulsion, was also successful for the ESV.
12. Use of aluminium alloy pipes for light weighted chassis with durable strength, use of Ergonomically designed vehicle interior, running on direct solar power without battery source, use of several advanced electronic devices like kinetic Energy Recovery System, Automatic Brake Alert system, Distance measuring system, Solar panel Heat sensors, Advanced Cooling system etc. have strengthen the vehicle as an advanced ESV in global market.
13. It is an economically viable, low budgeted ESV costing only within INR 80,000,
14. **The present eco-friendly ESV, ‘SOLWAVER’ can be a choice for future generation consumers.**

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