A SOLAR POWERED CAR

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TEAM NAME- Solaree@bncet

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1. Solaree@bncet

   ME/EC/EE

   B.N.College of Engineering and Technology

   suryavanshianantsingh@gmail.com

   +918418826770

BRIEF DESCRIPTION ABOUT THE PAPER-

This paper is primarily based on our solar car. It contains review work along with the research done by team members in order to maximize the efficiency and throughput of the vehicle. The laggings and the losses in different stages are identified and defined along with the necessary remedies required. All n all, this paper drives the basic and necessary information required to build a powerful car that charges itself on its RUNWAY.

1. ABSTRACT

Its known non-renewable sources that we are using for energy are going to get exhausted; hence the renewable energy is the need of hour. The electric solar vehicle is a step toward nature friendly alternative to fossil fuels. The basic principle of an electric solar car is to make use of the solar energy by trapping it in solar cells and using it to charge a battery. This battery is used to drive the electric motor which acts as an engine for the car and gives the basic movement of forward and backward to the car, to control the motor speed an electrical tapping rheostat is provided. This is done to break the flow of current when the vehicle is supposed to be stopped suddenly. This whole idea is a way to save fossil fuel for our future generations. In this report a basic idea of construction and working of a solar vehicle with little complexity is discussed. This report also includes the technical and physical details of all the equipments that are being used in the construction of electric solar vehicles. The electric equipments included are solar panels, solar charge controller, BLDC motor, motor controller, batteries and speed control while the mechanical equipments include steering system, braking system, suspension system. This report also covers the aspect of most common problems faced in the designing and construction of the vehicle. This reports main focus is on the electrical and mechanical systems commonly used in an electric solar vehicle. The aim of this report is to construct an electric solar vehicle which is easy to construct, economical and less complex in working.

2. INTRODUCTION

Currently we use fuel and gas powered vehicles, due to which there is an increase in environmental pollution which can be limited by putting a check on the release of greenhouse gases into the environment. Every vehicle these days uses fossil fuels to power them and emit carbon monoxides as the fuel doesn't burn completely. The emitted hydrocarbons and harmful nitrogen oxides combine in sunlight to produce ozone. Ozone in the atmosphere closer to surface contributes to smog and causes respiratory problems. Air pollutants emitted from cars contribute to problems such as cancer, asthma, heart disease, birth defects and eye irritation. Keeping in mind the disastrous effects of the poisonous gases emitted due to vehicles, the best possible solution is to replace these vehicles with eco-friendly electric vehicles. Solar electric vehicle is one of the fancy ideas in the modern day world. The present day world's best idea of reducing the pollution and limiting the use of fossil fuels is using and finding the all possible alternatives to non renewable energy sources. There are many ways of building an electric vehicle. Some of the ways in which this problem is addressed is by charging the batteries using electricity vehicles. Charging the batteries is done using solar panels which are kept in an appropriate place. Directly using the solar panels on the vehicle to run the motor is a limited approach as a large number of panels are required to run a high capacity motor. Considering all these, this report concentrates on using solar panels on the vehicle to charge a high capacity battery.

3. CIRCUIT DESIGN AND SIMULATION

The electrical system is the main part of any solar vehicle. The solar panel is mounted on top of the solar vehicle where the concentration of sunlight is large. The solar panels are connected to the solar charge controller which is manufactured according to the required ratings. The solar charge controller takes the power from the solar panel and stores in the battery. The charge produced by the battery is controlled by the solar controller.

The motor controller is used to control the motor. The solar charge controller regulates the power by which the motor runs; the motor controller controls the working of BLDC motor. Speed control of the motor, lights, horns is also done by adding system to the motor controller. The protection system is also used in which fuses and MCB's are used.

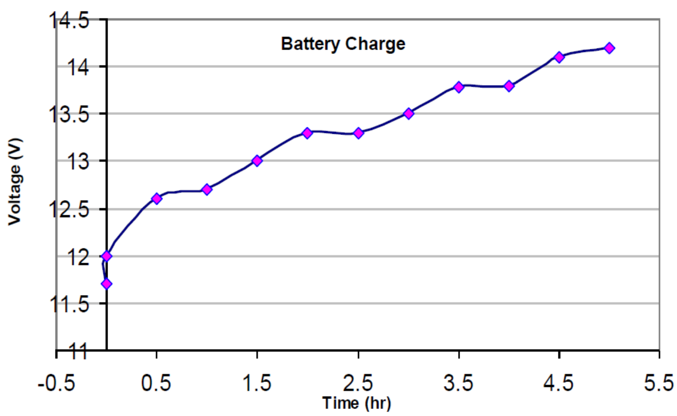

Figure 1: Charging of battery

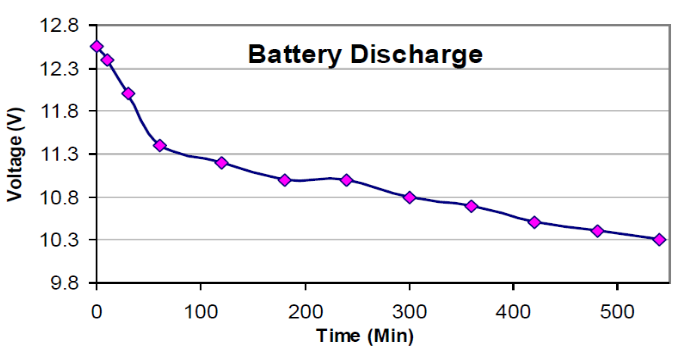

Figure 2: Discharging of battery

The wiring of the electrical system must be done properly to ensure safety. Copper wires are used because they have the highest electrical conductivity. Physical quantities like temperature; sunlight etc cannot be determined by the MATLAB software. It is important to maintain a point where maximum power can be derived.

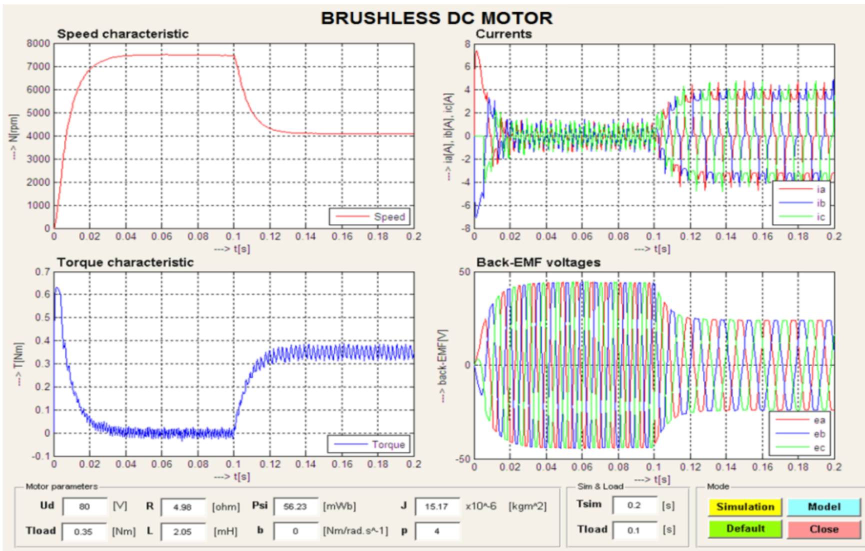

Figure 3: BLDC Motors characteristics

MPPT is used for maximum power point tracking point. This is the best method for maximum power tracking. The power from the photo voltaic cells is not sufficient to run the motor so a dc to dc converter is to be used. It is also called as boost chopper or step up chopper.

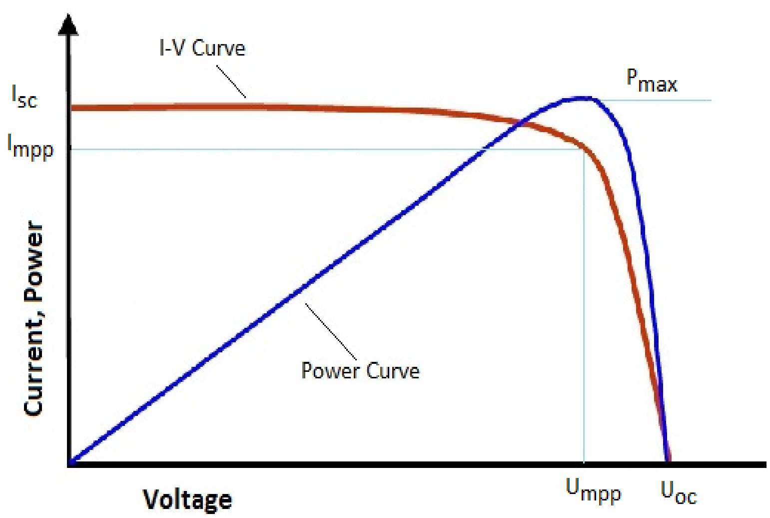

Figure 4: V-I Curve and I-V Curve for MPPT

4. CHASSIS DESIGN

4.1 SELECTION OF MATERIAL

From the survey the best chassis material were found, Stainless Seamless Pipe graded 5S, 10S, 40S, 80S. From the above material Stainless Seamless Pipe graded 5S was decided for use, as its weight, cost and availability satisfies our requirement. The chassis was modeled with circular hollow sections. Primary members are having a diameter of 1.315 inch and thickness of 1.65 mm with an amounting weight of 1.30 Kg/m.

Steel Type	Nominal Pipe size (inches)	Outside Diameter (inches)	Wall Thickness (mm)	Weight (Kg/m)
5 S	1 inch	1.315	1.65	1.30
10 S	1 inch	1.315	2.77	2.09
40 S	1 inch	1.315	3.38	2.50
80 S	1 inch	1.315	4.55	3.24

Table 1: Steel grades and comparison

4.2 DESIGN PROCEDURE

The wheel base and track width were decided according to the mounting position of solar panel and the comfort of driver. The design was compact keeping in mind the safety parameters.

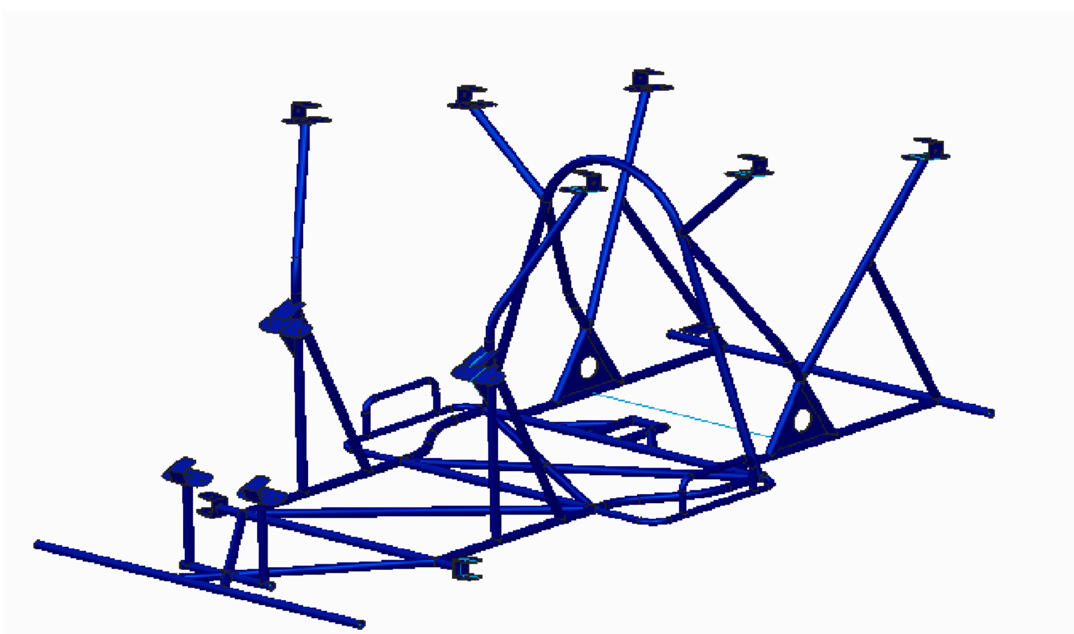

Figure 5: Basic design

The above figure shows the preliminary design of chassis .The mass obtained was approximately 40 kg when mass properties were analyzed. A number of iterations were made so as to reduce the chassis weight and obtain maximum strength and rigidity. Solar panel supports were redesigned, proper sizes of chassis material was done depending upon its use. Instead of being compact there was a lot of available driving space. All these things are solved and chassis design is finalized as shown in figure.

Figure 6: Finalized design

The complete assembly of the Solar Vehicle Designed is shown in the figure below.

Figure 7: Complete design

5. Results and Analysis:

5.1. Computer Aided Designing

Chassis was designed in CAD/CAE software. Strength and safety is our prime focus. In order to fulfill our requirement a static analysis was also performed. Static analysis was done using Solid-Works.

5.2. Front Impact

Initially, the load of motor and driver were given on the chassis along with the fixed bearing positions on the wheels. In accordance of the industrial standards the impact time of 0.2 sec was considered. For the final analysis of the chassis all the loads including the driver, wheels and the steering were included.

F = m*a
F=m*g*4(where 4g of force is calculated from Impulse momentum equation)
F=210*10*4
F=8400N (without driver analysis)

F=280*10*4
F=11200N (with driver analysis)

5.3. Front Impact Stresses

Max Equivalent Stress 292.79 MPa
Max Deflection 0.9411 mm
Factor of Safety 1.19

5.4. Side Impact

To keep the vehicle stable it was considered to be static for the analysis simplicity. The impact force was measured by applying load equivalent to 3g force on the right side in order to counterbalance forces. Time of impact considered is 0.2seconds as per industrial standards.
F = m*a
F= mg *3 (where g is acceleration constant due to gravity)
F= 210*10*3
F =6300 N

5.5. Analyzed values

Max Equivalent Stress 338.38 MPa
Max Deflection 1.7335 mm
Factor of Safety 1.03

5.6. Rear Impact

For the safety reasons the 4g force has been calculated for the rear impact. Time of impact considered is 0.2 seconds as per industrial standards. The load was applied at the rear end on the chassis during the analysis.

F = m*a
F= mg *4
F= 210*10*4
F =8400 N

5.7. Rear End Analysis

Max Equivalent Stress 270.42 MPa
Max Deflection 1.0198 mm
Factor of Safety 1.29

6. Selection Process

6.1. Suspension system

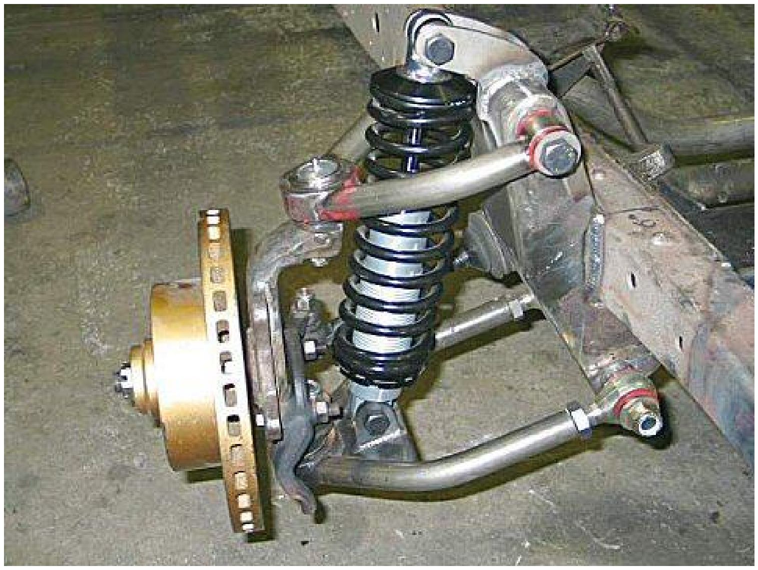

Figure 8: Wishbone suspension

In automobiles, a double **wishbone** (or upper and lower A-**arm**) **suspension** is an independent **suspension** designed using two (occasionally parallel) **wishbone**-shaped **arms** to locate the wheel. Each **wishbone** or **arm** has two mounting points to the chassis and one joint at the knuckle.

6.1.1. Advantages

- Double wishbones have better performance.
- The double suspension system is much more rigid and stable than other suspension systems.

6.1.2. Demerits

- There are many parts in this system, and thus any of them may malfunction.
- The body roll over will be heavy if one wheel hits a bump.

6.2. STEERING SYSTEM

The controlling behavior of a vehicle is influenced by the performance of its steering system. The track consisting of sharp turns so the stability of the system and the response time (feedback) are vital factors in deciding the vehicle's run. The Worm and Sector mechanism Rack and pinion and the Re-circulating ball mechanism were among our options to go with. In this report, on consideration of mounting ease, simplicity in design and considering that our vehicle is of the compact category; rack and pinion is chosen over the others. A practical picture is shown in the fig. below. The rack and pinion being a simple system can be easily maneuvered and the defect (if any) can be spotted and taken care of very easily. Moreover the steering wheel and other relevant apparatus are placed in such a way that it provides easy entering and exit of the driver. The composite error in the gear increases the torque required to rotate the steering wheel by the driver. Rack and pinion steering system has a very few moving parts, lighter in weight and economical. It converts the rotational motion of the steering wheel into the linear motion needed to turn the wheels. It provides a gear reduction, making it easier to turn the wheels. Re circulating steering system is used in heavy vehicle but for solar car the rack and pinion would be the good choice. In this steering system we can change the steering ratio according to our desire like 12:1, 6:1, 10:1 etc. which will really increase the efficiency of our solar car.

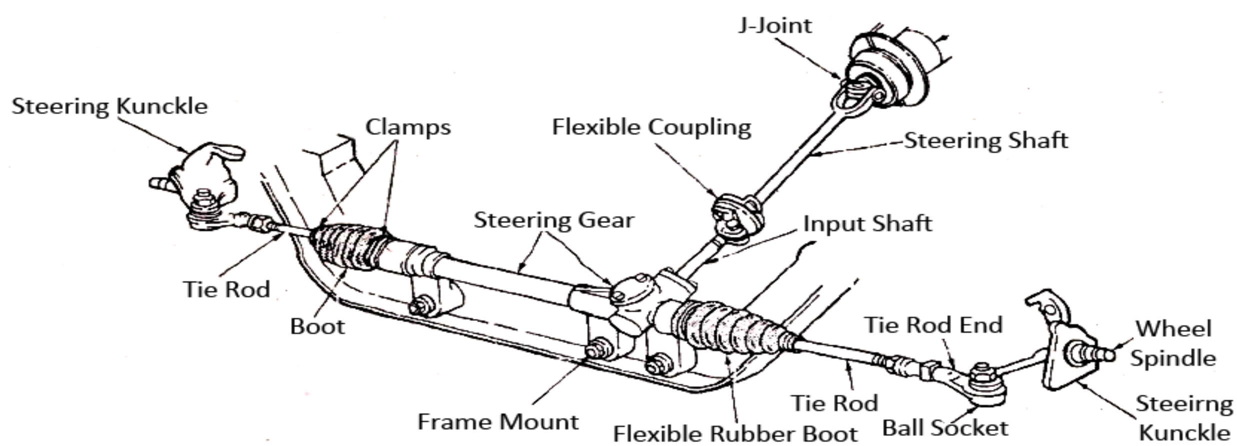

Figure 9: Steering system

6.2.1. Common Steering System Parts

All steering systems contain several common parts. Every steering system, no matter what type, will have a steering wheel, a steering shaft and column, a flexible coupler, universal joints, steering arms, and ball sockets.

These parts are discussed below.

6.2.2. Steering Wheels

The only part of the steering system the average driver is familiar with is the ***steering wheel.*** Older wheels are made of hard plastic, are larger in diameter, and are relatively thin when compared to modern steering wheels. The modern steering wheel is generally padded. Most steering wheels have two or three spokes or a large center section that connects the wheel portion to the hub. To prevent slippage, the steering wheel hub has internal splines, which match external splines on the steering shaft. Some shafts and steering wheels have a ***master spline,*** which is larger than the others. The master spline prevents the installation of the wheel in the wrong position. A large nut holds the hub to the steering shaft.

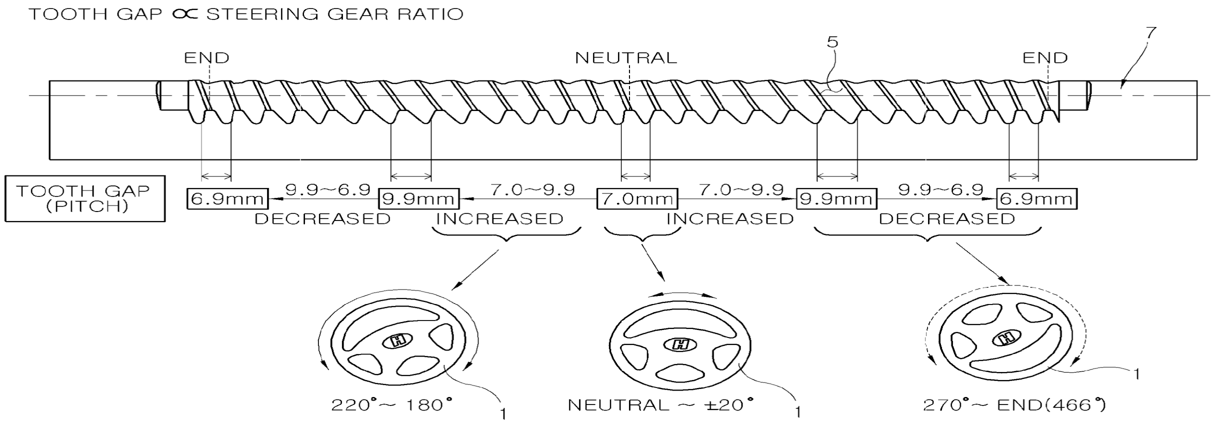

Figure 10: Steering Wheel

6.2.3. Steering Wheel Size

The steering wheel size has an effect on the effort expended by the driver to turn the vehicle. The larger the wheel, the less effort needed to turn it. This is due to the leverage exerted by the larger wheel.

6.2.4. Steering Columns and Shafts

The steering shaft is installed in the steering column. Bearings are generally used to hold the shaft in position. The shaft and column assembly is usually removed and replaced as a unit. However, individual parts are often replaced without removing the shaft or column.

6.2.5. Shaft Design

Modern steering shafts are made of two sections of steel rod. One section is hollow and the other is solid. The solid section slides into the hollow section.

6.2.6. Rack-and-Pinion Construction

The body of a rack-and-pinion steering gear is usually an aluminum casting. The rack is often held to the vehicle body or frame by two U-shaped brackets that are bolted in place. Other units are bolted directly to the vehicle with a series of bolts and nuts that pass through holes in the rack body and the vehicle's frame. The pinion assembly is a hardened steel gear supported by bearings at the top and bottom. The rack is also made of hardened steel and moves in slide bearings. Seals keep the steering gear lubricant from leaking out of the rack-and-pinion assembly.

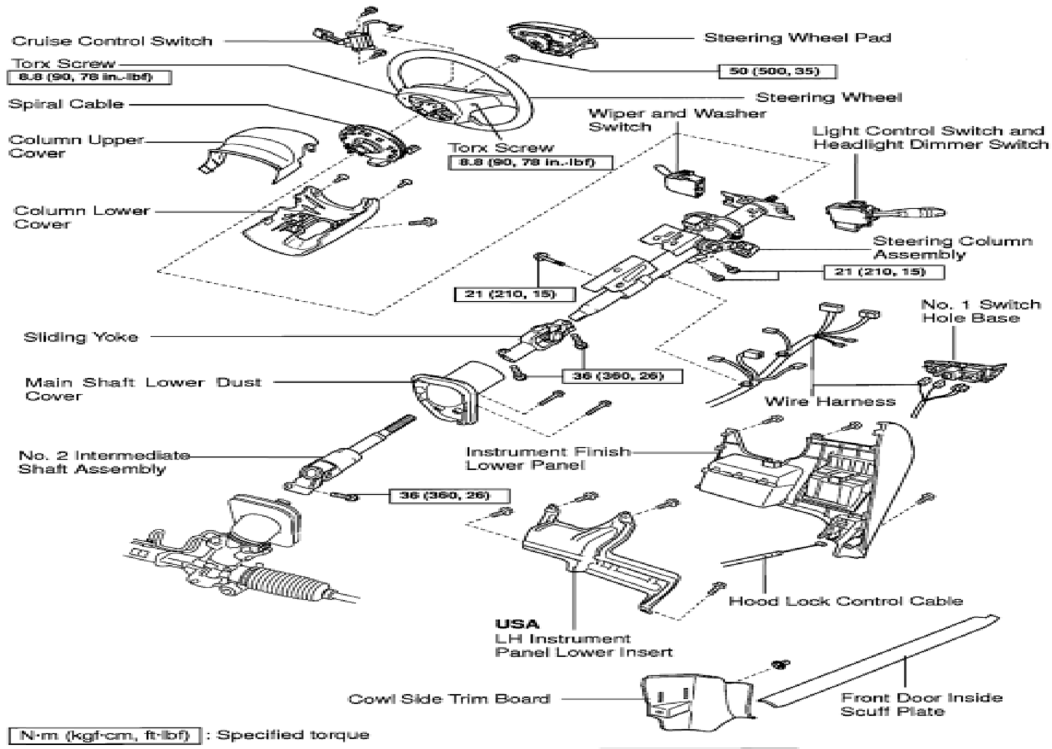

Figure 11: Rack and Pinion assembly

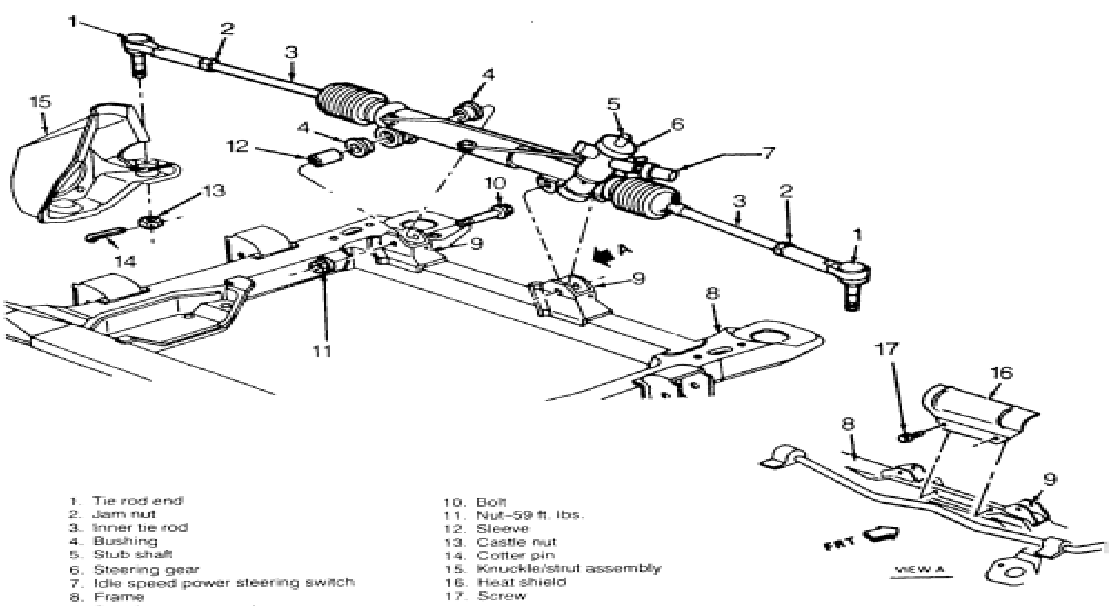

Figure 12: Rack and Pinion assembly

6.2.7. Rack and Pinion steering system

Steering is the collection of components, linkages, etc. which allows any vehicle (car, motorcycle, bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function. The primary purpose of the steering system is to allow the driver to guide the vehicle.
The most conventional steering arrangement is to turn the front wheels using a hand– operated steering wheel which is positioned in front of the driver, via the steering column , which may also be part of the collapsible steering column design, to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles.

6.2.8. Rack and pinion steering mechanism

The mechanism consists of-
1. Rack
2. Tubular casing
3. Pinion
4. Track rod
5. Ball and socket joint
6. Adjusting screw

The rack is housed in Tubular casing. The casing is supported on the frame near its ends. The ends of rack are connected to the track rod with the help of ball and socket joint. The pinion shaft is carried in the plain bearings housed in casing. The pinion is meshed with rack and clearance is adjusted with adjusting screw.

6.2.9. **Working of Rack and pinion steering system**:

Its objective is to convert the rotational motion of the steering wheel to linear motion of the rack. While the driver turns the steering wheels the steering column rotates with the steering wheel, and other end of steering column is connected to pinion gear by means of universal joint and it rotates the pinion gear on the rack which consists of teeth in it. The linear motion in rack is converted in to tie rod, which is connected to the rack rod on both end which is connected to the wheels by the means of stub axle. In the normal steering system for example ambassador old model, the driver have to turn the steering wheels 4 or 5 full turns to turn the vehicle from full left to full right, so here the driver have to give more effort to turn the steering wheel but the steering wheel is easy to turn only if the number of turns are more. It is due to low number of teeth in rack rod and smaller radius pinion gear. When we use the pinion gear with higher or greater radius and more no of rack teeth, their is no need to turn more rotation of steering wheel, but it is hard to turn in this case.

6.2.10. Dimensions of steering system:

- 6:1 Ratio pinion assembly
- 2.5Kg

- Rack length=14 inch
- Rack travel= 4 inch
- Lock to lock turn=1.5
- Rack and pinion length=40-50 inch
- Steering column=27 inch
- Lower steering shaft=4.92 inch
- Angle between steering column and base of the vehicle=40 degree
- Height of steering wheel from the base of the vehicle=13 inch
- Steering wheel diameter=12inch
- Tyre diameter=18 inch
- Tyre width=5 inch

7. Regenerative braking system

Regenerative braking system is the way of slowing vehicle by using the motors as brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat the motors act as generators and return some of it to the overhead wires as electricity. The vehicle is primarily powered from the electrical energy generated from the generator. This energy is stored in a battery, and used by an electric motor that provides a motive force to the wheels. The regenerative braking when applied on the vehicle becomes a way to obtain more efficiency instead of converting kinetic energy to thermal energy through frictional braking; the vehicle can convert a good fraction of its kinetic energy back into charge in the battery using the same principle as an alternator.

Regenerative braking can improve energy usage efficiency and can extend the driving distance of electric vehicles. Innovative regenerative braking system of EV driven by BLDC motor is recommended. To improve the performance of electric vehicles, the regenerative braking system has been developed. It utilizes the electric motor, providing negative torque to the driven wheels and converting kinetic energy to electrical energy for recharging the battery or power supply.

Figure 13: Original image of BLDC motor

The dissipation of kinetic energy during braking, by an electric or hybrid vehicle can be recovered advantageously by controlling the power electronics for total energy management onboard the vehicle. Therefore, regenerative braking is an efficient technology to improve the efficiency of electric vehicles. Research indicates that substantial energy savings are in fact achievable, from 8% to as much as 25% of the total energy used by the vehicle, depending on the driving cycle and its control strategy. Particularly, this additional energy recycling can be achieved without addition of any extra components. Regenerative braking is a two-step process involving the motor/generator and the battery. The initial kinetic energy is transformed into electrical energy by the generator and is then converted into chemical energy by the battery.
There are two ways to coordinate the regenerative torque of the motor and the friction torque of the hydraulic unit: Parallel and Series. In parallel braking, the regenerative torque of the motor is exerted on the driving axle directly in addition to the friction torque, while series braking allows independent modulation of the hydraulic brake torque of each axle according to the regenerative torque, and thus potentially more kinetic energy can be recovered than with parallel braking.

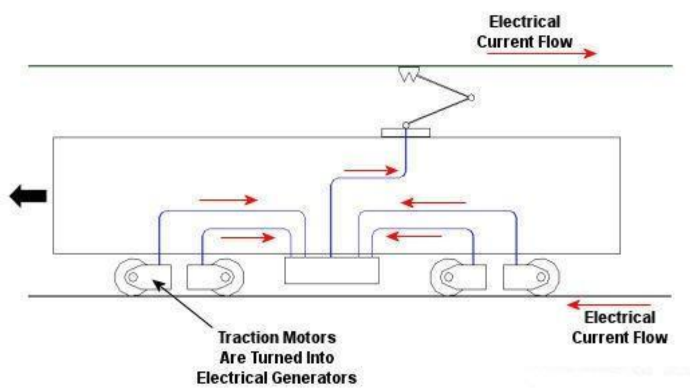

Figure 14: Model of regenerative braking system

8. ASSEMBLING

For assembling, the requirement is a well equipped workshop which has a welding and electric cutting machine to cut pipes, plates and solid rods while a drilling machine is needed to drill into metal with different bits. The step by step procedure of assembly can be found below

- The Mechanical simulation is done on CAD software. This simulation is useful to maintain the mechanical properties of the vehicle according to the standards.
- Accumulate the mechanical materials nuts and bolts, members, spanners, screwdrivers, grease, rack and pinion steering, brake set, wheels, brake pedals, acceleration pedal, seats etc.
- Accumulate all the electrical equipments like BLDC motor, motor controller, solar panels, MPPT solar charge controller, batteries, and required quality of electric wires in abundance. It is also advised to get a soldering set, wire stripper DC voltmeter and ammeters to measure the current and voltages.
- Mark two circular rods of equal length for both front and rear axles, fix the braking system with nut and bolt, fix two pedestals from both sides of the axle and fasten it tight

without horizontal movement. Weld two solid circular plates perpendicular to the axle at both ends of the axle which fit exactly to the rims of the wheels. Mark holes on the plates, drill them and fasten the wheels to the axle. Weld two small metal parts in the forward direction with holes.

- Attach both the front and rear axles to the chassis with the pedestals with nut and bolt. Also connect the rack and pinion steering set to the front axle by bolting the two ends to the small metal parts with holes and fix the base of the steering to the main body.
- Mount the solar panels on top of the vehicle. It is advised to use some insulators under the panels to reduce heat and noise while travelling.
- Complete the wiring of all the electrical equipment with safety measures where ever necessary. Do not short any wires.

9. Troubleshooting

Practical and theoretical analysis has certain differences. The appropriate measures must be taken into consideration. The controllers, wire losses including heat loss, energy produced by virtue of inertia of wheel, solar losses, battery losses, lack of efficiency in transmission are all the major causes of the deviation. Some abrupt losses in mechanical parts also contribute to the deviations. Most of these issues require a proper look up and look after.

10. Conclusion

In accordance with the specifications provided by ISIE and the requirements made by us, we have achieved the final design with all its analysis and will successfully build an efficient and powerful car that charges itself on its RUNWAY.

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