Overview of solar cars engineering essay

Renewable energy is vital in the world today as in the near future non-renewable sources of energy will become scarce. The solar powered car is a step in saving these non-renewable sources of energy. The basic principle of the solar car is to use energy that is stored in a battery during and after charging it from a solar panel. The charged batteries are used to drive the motor which serves as an engine and moves the vehicle in a reverse or forward direction.

Overview of Solar Cars

Advantages:

No longer needed to purchase gas or any other type of fuel

Solar cars have no regular expense besides maintenance and repairs

Doesn’t produce any greenhouse gas emissions so it is environmentally friendly

The use of solar cars as a combustion engine replacement will significantly reduce greenhouse emissions and improve air quality around the world

Solar cars produce no noise

Disadvantages:

Solar cars don’t have the same speed or power as a regular car that runs on gas

While sunlight is free, the creation of PV cells to capture that sunlight is expensive. Costs for solar panels are steadily declining (22% cost reduction per doubling of production volume).

The weather can directly affect the performance of the car, especially if it is dark outside

Possible system layouts

Fig. ure 1 : Basic block diagram representation of a solar vehicle

Source: Wamborikar, 2010. Solar cars are powered by the sun's energy. The main component of a solar powered car is its solar array or panel, which collects the energy from the sun and converts it into usable electrical energy. The solar cells collect a portion of the sun's energy and store it into the batteries of the solar car. Before that happens, a peak power tracker (maximum power point tracker) converts the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. Once the energy is stored in the batteries, it is available to be used by the DC motor and motor controller to drive the car. 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.

The primary energy source for a solar powered car is the battery. The battery has a number of individual batteries connected inside which are in series or parallel. Each battery is typically 6V or 12V, and multiple batteries are connected in series or parallel to acquire the optimum system voltage. A single battery is made from multiple cells contained within the battery housing. The overall battery voltage is chosen depending on the motor's EMF constant and the desired nominal driving speed.

In order to get the most efficient operation of the drive system, the battery voltage is chosen so that the motor controller can operate with minimal pulse width modulation at the maximum speed of the car. Nevertheless, the battery voltage, especially for lead-acid batteries, fluctuates considerably around the nominal battery voltage, from full charge to maximum discharge. This is why, the nominal battery voltage is chosen so that the lowest possible battery voltage is able to sustain a reasonable speed. An alternative solution to this problem is to put in a boost or buck converter in the motor controller so that a desirable speed can be obtained for any battery voltage.

Fundamentals and Application of Photovoltaics in Solar Vehicles

The bond model uses the covalent bonds joining the silicon atoms to describe semiconductor behaviour. In the figure below, it illustrates the bonding and the movement of electrons in a silicon crystal lattice.

Figure 2: Representation of covalent bonds in a silicon crystal lattice

Source: Wenham, 2007At low temperatures, the bonds are intact and the silicon behaves as an insulator. At high temperatures, some bonds are broken and conduction can occur by two processes: electrons from broken bonds are free to move and electrons from neighbouring bonds can also move into the ' hole' created in the broken bond, allowing the broken bond or hole to propagate as if it had a positive charge.

It is also possible to shift the balance of electrons and holes in a semi conductor (silicon crystal lattice by ‘ doping’ it with other atoms. Atoms with one more valence electron than the semiconductor are used to produce ‘ n-type’ material. Meanwhile, atoms with one less valence electron results in ‘ p-type’ material (Wenham, 2007). This can be seen in figure 3.

Figure 3:

Source: Wenham, 2007

Figure 4: Diagram of a P-N Junction

Source: Nave, 2005. A p-n junction is formed by joining n-type and p-type semiconductor materials. Since the n-type region has a high electron concentration and the p-type a high ‘ hole’ concentration, electrons diffuse from the n-type side to the p-type side. Similarly, holes flow by diffusion from the p-type side to then-type side. If the electrons and holes weren’t charged, this diffusion process would continue until the concentration of electrons and holes on the two sides were the same. However, in a p-n junction, when the electrons and holes move to the other side of the junction, they leave behind exposed charges on dopant atom sites, which are fixed in the crystal lattice and are unable to move. An electric field forms between the positive ion cores in the n-type material and negative ion cores in the p-type material. This region is called the “ depletion region” since the electric field pushes the free carriers out, hence the region is depleted of free carriers. A “ built in” potential (Vbi) is formed due to the electrified created at the junction.

Figure 5

Source: Wenham, 2007When sunlight falls onto the semiconductor material, photons with energy (Eph) lower than the band gap energy (Eg) interact insubstantially with the semiconductor, passing through it as if it were transparent. But, photons with energy greater than the band gap energy (Eph > Eg) interact with electrons in covalent bonds, using up their energy to break bonds and to create electron-hole pairs which can then move about independently. Also, higher energy photons (red light) are absorbed closer to the surface of the semiconductor than lower energy photons (blue light).

The open circuit voltage (VOC) of a solar cell is the voltage measured when there is no current passing through the cell. The top side of the solar cell is of negative voltage and the bottom is positive. The open circuit voltage is independent of the size of the solar cell, and is determined by the materials the cell is made of (refer to Appendix 2). The short circuit current (ISC) of a solar cell corresponds to the current measured when the solar cell is short circuited (Fig. 2. 11), the voltage equals 0. The electric current ¬, ows from the bottom (+) of the cell to the top of the cell (-) when the solar cell is under illumination (refer to Appendix 2). In advanced solar cars, they include a Maximum Power Point Tracking (MPPT) which maximizes the amount of current going into the battery from the solar array by lowering the panel's output voltage which increases the charging amps to the battery. The maximum power output of a solar cell is at the maximum power point (MPP), where the product of voltage and current is a maximum (refer to Appendix 2).

When solar cells are connected in parallel, the output current is the sum of the currents from the individual cells, and output voltage remains the same to that of a single cell (proven by data, refer to Appendix 1). When solar cells are connected in series, the output voltage is the sum of the voltage from each cell, where the output current stays the same (proven by data, refer to Appendix 1). Therefore, the optimum alignment for solar cells on a solar car would be in series. This is because the MPPT needs more voltage as it extracts the solar cell's output voltage in order to maximize the amount of current going into the battery.

Source: Blimpy, 2010.

How a solar cell works

Figure 6: A diagram of a solar cell.

Source: Lollini, 2010. The photovoltaic effect used in solar cells allows direct conversion of light energy from the sun into electricity, by the generation and transport inside a semiconductor material, of positive and negative electric charges, through the action of light. This material features two regions, one exhibiting an excess of electrons, the other an electron deficit, resistively referred to as n-type ' doped' and p-type ' doped. When the two are brought into contact with the silicon, excess electrons from the n-material diffuse into the p-material. The initially n-doped region becomes positively charged and the initially p-doped region is negatively charged. An electric field is thus made between them, tending to force electrons back into the n-region and holes back into the p-region. Then a p-n junction is setup and by placing metallic contacts on the n and p regions, a diode is acquired. When the p-n junction makes contact with light, the photons having energy equal to or higher than the width of the forbidden band or band gap yield their energy to the atoms, where each photon causes an electron to move from the valence band to the conduction band, leaving behind a hole, also able to move around the material thus, giving rise to an electron-hole pair. If a ‘ load’ is to be positioned at the cell’s terminals, electrons from the n-region will migrate back to the holes in the p-region, by way of the outside connection, giving rise to a potential difference- an electric current passes.

Importance of Correct System Design and Sizing / Non-shading

The main point that should be kept in mind while making a solar vehicle is the mounting of the solar panel. The panel should be mounted in such a way that it receives maximum sun rays so that it gives maximum efficiency. Since the sun is at a different angle to the ground all the, so the solar panels need to be directed according to this positioning. The ideal situation is when the sun’s rays are colliding with the panels at a perpendicular angle of 90°(proven by data, refer to Appendix 4). This maximizes the amount of energy hitting the panels and being produced. The two factors that affect the angle as such are controlled by the orientations (north, south, east, and west) and the angle of the panels from the ground.

The main feature of any solar is its array of solar cells. An ideal solar cell would be made of expensive gallium arsenide which are nearly 30% efficient. However a cheaper alternative can be used such as ultra pure monocrystalline silicon which can reach efficiencies of over 20%. Selecting the solar cell with higher efficiency means the less surface area needed so the solar vehicle is able to carry less weight and travel at a faster speed.

Therefore, it'd be recommended to use a small solar panel with a high efficiency rate so then sizing is not important.

For maximum power efficiency in a solar powered car, the solar panels should be in full contact with the sun's rays. If a single cell is somewhat shaded by even a small object, it can create a power drop as much as 50%. This is because the cells in a panel are connected in a series string, so if one cell is shaded, then the rest don't work properly (proven by data, refer to Appendix 5). To reduce the effects of shading, the strings are usually kept short and paralleled as much as possible. Having lots of parallel strings is good, because whatever currents are generated can be added together, while the voltage of each string remains relatively similar with or without light. Voltages of parallel strings are taken as the average voltage of each string. An example of how a module might be wired is shown below.

Source: Sanghster, 2006.

Safety Issues

Since the solar powered car is run by a DC motor, there are safety issues with direct current. If a person is electrocuted, electric currents can produce severe burns in the body, particularly at the points of contact to the circuit, as the electrical power dissipates across the body's resistance. Electric shock can only occur when contact is made between two points of a circuit, and when a voltage is applied across a victim's body. Since direct current moves in one direction through a conductor, it has the tendency to incite muscular tetanus, even at low voltages. Victims are often unable to let go of a DC conductor because of the continuous motion and stable voltage. Also, DC electricity tends to make the heart stand still.

Conclusion

It is essential that the design of solar cars are efficient, safe and takes into account the specific requirements and limitations. For example, in order for the solar car to run on solar power it needs a lot of power and an optimum angle needs to be decided to maximise this power output. It is best to use a MPPT to maximize the current going into the battery and to choose an efficient solar array or panel. This being said, the solar car can have a significant impact on the reduction of unhealthy greenhouse gas emissions and help prevent global warming. We need to make use of solar powered cars so that we can reduce our dependence on fossil fuels.