Conceptual Modeling and Fabricating Solar Operated Portable Vacuum Cleaner For Domestic Use

B.Logesh[1], V.Aswin Kumar [2], G.Elangovan[3], R.Kuppuraj[4], P.Nagaraj[5]
[1]Assistant Professor, Dept of mechanical Engineering
[2, 3, 4, 5]Dept of mechanical Engineering
[1, 2, 3, 4, 5] Sree Sakthi Engineering College, Tamilnadu, India.

Abstract- *"SOLAR ENERGY"-the word has a deep meaning. Solar energy is a form of heat and radiant light from the source of sun that winded up using a range of ever evolving greener technologies such as solar thermal energy, solar heating and photovoltaic. It is an important source of renewable energy. From this whole ocean of solar energy, we have intended to build a basic Solar operated portable vacuum cleaner. The concept that emerged in our mind was to develop a product that would be useful to most of the people, so we decided to design and build a capable of vacuuming the floor of a room or area without any energy loss other than just starting and sometime operating the unit thus saving valuable human time.*

In this project the vacuum cleaner is operated by using solar energy, which is useful in cleaning our home, Industries and with little modifications can be used in agricultural field. The project is comprised of basically three modules, which handles all the basic functionalities of the project. The modules which we have integrated in this project are the solar panel and controller part, Battery and the Vacuum Cleaner.

Keywords- Portable Vacuum Cleaner, Solar Cells, Pressure Fan, Photovoltaic Cell, Hardwired Control Unit, 12 V batteries.

I. INTRODUCTION

A vacuum cleaner, also known as a sweeper, is a device that uses an air pump (a Centrifugal force in all but some of the very oldest models), to create a partial vacuum to suck up dust and dirt, usually from floors, and from other surfaces.

The dirt is collected by either a dust bag or a cyclone for later disposal. Vacuum cleaners, which are used in homes as well as in industry, exist in a variety of sizes and models small battery-powered hand-held devices, wheeled canister models for home use, domestic central vacuum cleaners, huge stationary industrial appliances that can handle several hundred litres of dust before being emptied, and self-propelled vacuum trucks for recovery of large spills or removal of contaminated soil. Specialized shop vacuums can be used to suck up both dust and liquids.

This project focuses on developing an easily portable solar operated vacuum cleaner based on the principle of solar energy. Basically a photovoltaic cell is attached to the vacuum cleaner and the battery is also fixed with it. Due to less weight of the photovoltaic cell and battery it is very easy to handle and possible to kept in any places. So that it can clean floor, wall, tables and ceiling.

When we sip soda through a straw, we are utilizing the simplest of all suction mechanisms. Sucking the soda up causes a pressure drop between the bottom of the straw and the top of the straw. With greater fluid pressure at the bottom than the top, the soda is pushed up to your mouth. This is the same basic mechanism at work in a vacuum cleaner, though the execution is a bit more complicated. Here we'll look inside a vacuum cleaner to find out how it puts suction to work when cleaning up the dust and debris in your house. As we'll see, the standard vacuum cleaner design is exceedingly simple, but it relies on a host of physical principles to clean effectively

A vacuum's suction is caused by a difference in air pressure. A fan driven by an electric motor (often a universal motor) reduces the pressure inside the machine. Atmospheric pressure then pushes the air through the carpet and into the nozzle, and so the dust is literally pushed into the bag. It's a job that is seemingly never finished and even if you clean them once a week, you will still find debris, dust, dander, and hair on their surfaces. This frustration with cleaning floor surfaces is one of the reasons why a vacuum cleaner was finally developed.

Portable vacuum cleaners working on the cyclonic separation principle. Cyclonic cleaners do not use filtration bags. Instead, the dust is separated in a detachable cylindrical collection vessel or bin. Air and dust are sucked at high speed into the collection vessel at a direction tangential to the vessel wall, creating a fast-spinning vortex. The dust particles and

other debris move to the outside of the vessel by centrifugal force, where they fall due to gravity.

II. END USER / CUSTOMER REQUIREMENTS

Looking at the present scenario, we have proposed the idea of building vacuum cleaner that eliminates the human efforts for cleaning. The vacuum cleaner has an ability to suck the unwanted papers, sand and dust by using solar power. These types of vacuum cleaners are very easy to produce in homes. It is also called homemade vacuum cleaner. The vacuum cleaner should be made from the basic cost effective materials like Solar panel. Battery, dc motors, etc.

III. DESIGN REQUIREMENT FOR VACUUM CLEANERS

The performance of a vacuum cleaner can be measured by several parameters:

1) Airflow, in litres per second [l/s] or cubic feet per minute (CFM or ft³/min)
2) Air speed, in metres per second [m/s] or miles per hour [mph]
3) Suction, vacuum, in Pascal [Pa] or inches of water
4) Other specifications of a vacuum cleaner are:
5) Weight, in kilograms [kg] or pounds [lb]
6) Noise, in decibels[dB]
7) Power cord length and hose length (as applicable)

A. Suction

The suction is the maximum limit of pressure difference that the desired pump can produce. For example, a typical pump for domestic model will have a suction of about negative range of 20 kPa. It states that the lower the pressure that can be inside the hose from normal atmospheric pressure (about 100 kPa) by 20 kPa. Higher suction rating will results in designing a more powerful cleaner.

B. Input power

The power consumption of a vacuum cleaner, in watts, is often the only figure stated. The rated power input indicates only the consumption of electricity it will not indicates the effectiveness or efficiency of the cleaner.

C. Output power

The amount of input power that is converted into airflow at the end of the cleaning hose is sometimes stated, and is measured in air watts: the measurement units are simply watts. The term "Air" indicates us clearly that it is an output power neither being input electrical power.

IV. COMPONENTS OF VACUUM CLEANERS

COMPONENTS USED AND THEIR SPECIFICATIONS:

1) 12V DC Motor
2) Solar panel or photovoltaic
3) Control unit
4) 12V 1.3AH / 20HR Battery
5) Vacuum suction cleaner.

A. DC MOTOR

DC Motor is any of class of rotary electrical machines that converts the direct current electrical power into mechanical power. The 12V DC Motor is more than enough to produce the required vacuum inside the Vacuum cleaner. The DC Motor is fixed on the backside of the vacuum cleaner. The wings are mounted on the front end of the motor. A simple DC motor has a stationary set of magnets in the stator and an armature with one or more windings of insulated wire wrapped around a soft iron core that concentrates the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be several parallel current paths. The ends of the wire winding are connected to a commutator.

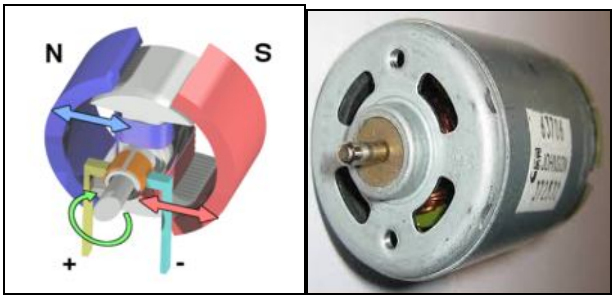

Fig.1.a. Internal view of DC Motor Fig.1.b. External view of DC Motor

B. SOLAR PANEL OR PHOTOVOLTAIC

Solar panel refers to a panel designed to absorb the sun's rays as source energy for generating electricity and heating. The most common use of solar panel is solar water heating system. The solar panel size 15 x 15 x 3 CM is suitable for charging the 12V battery. A photovoltaic (PV) module is a packaged; connect assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power

under standard test conditions (STC), and typically ranges from 100 to 365 watts.

The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. Depending on construction, photovoltaic modules can produce electricity from a range of frequencies of light but usually cannot cover the entire solar range (specifically, ultraviolet, infrared and low or diffused light). Hence, much of the incident sunlight energy is wasted by solar modules, and they can give far higher efficiencies if illuminated with monochromatic light.

Therefore, another design concept is to split the light into different wavelength ranges and direct the beams onto different cells tuned to those ranges. This has been projected to be capable of raising efficiency by 50%. Scientists from Spectra lab, a subsidiary of Boeing, have reported development of multi-junction solar cells with an efficiency of more than 40%, a new world record for solar photovoltaic cells.

Fig.2. Solar Panel Connected with Battery

C. CONTROL UNIT

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric battery. It may also prevent completely draining a battery, performance controlled discharges depending on the battery technology, to protect the battery life.

The term “Charge controller” “Charge regulator” may refer to either a stand – alone device, or to control circuitry integrated with in a battery pack, battery- power device. Some charge controllers / solar regulators have additional features, such as low voltage disconnect (LVD), a separate circuit which powers down the load when the battery becomes overly discharged.

A. HARDWIRED CONTROL UNIT

Hardwired control units are implemented through use of sequential logic units, featuring a finite number of gates that can generate specific results based on the instructions that were used to invoke those responses.

Hardwired control units are generally faster than micro programmed designs. Their design uses a fixed architecture it requires changes in the wiring if the instruction set is modified or changed. This architecture is preferred in reduced instruction set computers (RISC) as they use a simpler instruction set.

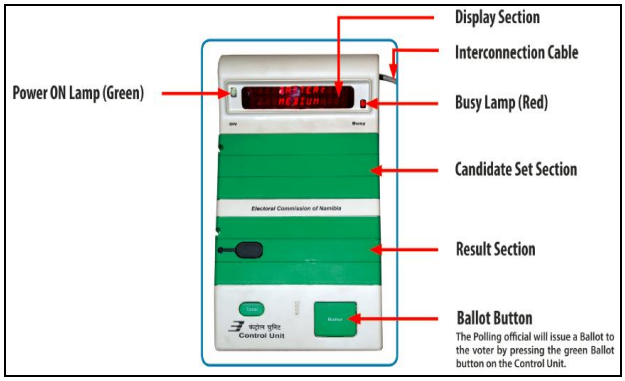

Fig.3. Hardwired Control Unit

D. BATTERY

The battery is a device which is used to store the energy and it will supply the constant supply to the DC motor. The lead acid rechargeable battery is suitable for this project.

The 12 volt battery is more common than most people know. In fact, the majority of people don’t even know what 12 volt is. It’s funny when a person finds out that their car or truck is a live operating 12v dc system and they say, I’ve heard of 12 volt but never knew what it was. Power supply: A 12V DC rechargeable battery is used for all the components of the robot as power source.

Batteries convert chemical energy directly to electrical energy. A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing anions and cations.

Fig.4. 12V Lead Battery

V. CONCEPTUAL CONSTRUCTION OF VACUUM CLEANERS

It may look like a complicated machine, but the conventional vacuum cleaner is actually made up of only six essential components: an intake port, which may include a variety of cleaning accessories an exhaust port, an electric motor, a fan, a porous bag, a housing that contains all the other components

When we plug the vacuum cleaner in and turn it on, this is what happens: The electric current operates the motor. The motor is attached to the fan, which has angled blades (like an airplane propeller). As the fan blades turn, they force air forward, toward the exhaust port (check out How Airplanes Work to find out what causes this). When air particles are driven forward, the density of particles (and therefore the air pressure) increases in front of the fan and decreases behind the fan.

This pressure drop behind the fan is just like the pressure drop in the straw when we sip from our drink. The pressure level in the area behind the fan drops below the pressure level outside the vacuum cleaner (the ambient air pressure). This creates suction, a partial vacuum, inside the vacuum cleaner. The ambient air pushes itself into the vacuum cleaner through the intake port because the air pressure inside the vacuum cleaner is lower than the pressure outside.

As long as the fan is running and the passageway through the vacuum cleaner remains open, there is a constant stream of air moving through the intake port and out the exhaust port. But how does a flowing stream of air collect the dirt and debris from your carpet? The key principle is friction.

VI. WORKING OF SOLAR CELL, BATTERY AND HARD WIRED CONTROL UNIT

A. WORKING OF PHOTOVOLTAIC CELL

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells.

The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connectors' type to facilitate easy weatherproof connections to the rest of the system. Modules electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals.

Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated. Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way. The amount of power produced by the solar panel is based on the weather conditions.

There are many practical applications for the use of solar panels or photovoltaic. It can first be used in agriculture as a power source for irrigation. In health care solar panels can be used to refrigerate medical supplies. It can also be used for infrastructure. PV modules are used in photovoltaic systems and include a large variety of electric devices:

1) Photovoltaic power stations
2) Rooftop solar PV systems
3) Standalone PV systems
4) Solar hybrid power systems

B. WORKING OF CONTROL UNIT

The charge controller or solar control unit is an electronic device which is used to indicate the power in the battery. The control unit must have a light indicator to indicate whether the battery is charged or not. The connections are made correctly to the solar panel to absorb energy and send the correct amount of power to the battery.

C. WORKING OF BATTERY

An battery is a rechargeable battery that supplies electrical energy to a motor are lead-acid type and provide 12.6 volts of direct current, nominally 12 V. The battery is actually six cells connected serially.Low-maintenance or maintenance-free: In the past, batteries required maintenance in the form of electrolyte refills. Modern batteries retain their fluid for the life of the battery.

A weakness of these batteries is that they are very intolerant of a deep discharge, for example when the car battery is completely drained by leaving the lights on. This coats the lead plate electrodes with sulphate deposits and can reduce the battery's lifespan by a third or more.

Batteries are typically made of six galvanic cells in a series circuit. Each cell provides 2.1 volts for a total of 12.6 volts at full charge. Each cell of a lead storage battery consists of alternate plates of lead (cathode) and lead coated with lead dioxide (anode) immersed in an electrolyte of sulphuric acid solution. The actual standard cell potential is obtained from the standard reduction potentials. This causes a chemical reaction that releases electrons, allowing them to flow through conductors to produce electricity. As the battery discharges, the acid of the electrolyte reacts with the materials of the plates, changing their surface to lead sulphate. When the battery is recharged, the chemical reaction is reversed: the lead sulphate reforms into lead dioxide. With the plates restored to their original condition, the process may be repeated.

Table.1. Lead Battery Specifications for solar panel with capacity limit and dimensions

Name	IEC number	ANSI/NEDA	Manufacturer designations	Capacity (Ah)	Dimensions (mm)
4.5 Volt	3R12, 3LR12	3R12, 3LR12, 4.5v	G3LR12, 1289/AD28, 210, GP312S, MN1203, 3336	3 – 4.8	67 × 62 × 22
6 Volt, Spring fitting	4R25X, 4LR25X	908AC, 908C, 908CD, 908D	EN1209, EN529, MN908, EV90, EV90HP, GP908, PJ996	12 – 26	115 × 68.2 × 68.2
6 volt, Screw fitting	4R25Y, 4LR25Y	915A	EN528	26	109.5 × 66.7 × 66.7
6 Volt, double	4R25-2, 4LR25-2	918A	EN521, MN918, GP918S, GP918G, 918/1231	52	125.4 × 132.5 × 73
7.5 Volt	5LR25-2	903AC	EN715, PC903	43	97 × 184.2 × 103.2
12 Volt	8R25	926	EN732, PC926	7.5	125.4 × 136.5 × 73

VII. FABRICATION OF SOLAR VACUUM CLEANER

A. ARRANGEMENTS OF THE COMPONENTS

The fan which is used to produce pressure difference is initially attached to the 12V DC motor. The motor arrangement with fan is fixed on the back side of the vacuum cleaner.

The vacuum cleaner is placed in centre of the sheet metal. Battery is placed Left side .The whole setup is covered with the metal sheet. Control unit is fixed outside the sheet metal arrangement. Handle is fixed in the top of the setup. Solar panel is fixed in opposite side of the Handle.

B. Design layout

The design layout consist of a square shaped sheet metal will act as a base for the portable vacuum cleaner.The proper dimensions are marked with respect to the vacuum cleaner size and battery size.

The solar panel or photovoltaic size of 15 x 15 x 3 CM is attached on the bottom surface of the sheet metal layout.

The control unit or charge controller is fixed on the left surface of the sheet metal arrangement.

The vacuum cleaner and battery are fixed inside the sheet metal arrangement.

C. FABRICATION

First the 12V DC Motor which is located on the backside of the vacuum cleaner, the positive terminal is connected to the switch and switch to battery.

The negative terminal of the motor is directly connected to the battery.

The positive and negative terminals of the Battery are directly connected with the terminals of the charge controller.

The positive and negative terminals of the P+ and P- are connected with the solar panel or photovoltaic cell for absorbing the energy and send it to the battery.

Fig.5. Fabricated portable Vacuum Cleaner

VIII. CONCLUSION

The solar operated portable vacuum cleaner can be made by using simple components and parts. The word portable means it will be easily available and handling is easy. While cleaning the surfaces the vacuum cleaner is in straight position. Similarly while charging the battery the whole setup is turned 180 degree and the solar panel will be charged during the vacuum cleaner is in opposite side of the sheet metal arrangement.

In this project the vacuum cleaner is operated by using solar energy, which is useful in cleaning our home, Industries and with little modifications can be used in agricultural field.

It can be used in industrial cleaning where in it reduces human contact to harmful chemicals and industrial waste. It reduces the necessity for having a maid to clean our houses Used in agricultural operations for instance, in the recovery of grain dust from silos.

The same concept can be extended to cars as well where robots move automatically according to dimension of car and clean it.

This technology integrated with high power drier could be used to dry up cricket field if there is a shower in the middle of play reducing the delay in drying the field

IX. FUTURE SCOPE AND RECOMMENDATIONS

The portable vacuum cleaner may be fixed on the movable wheeled vehicle and by fixing some sensors on the front and backsides of the vehicle will create the automatically operated solar vacuum cleaner in future.

The vacuum cleaner on the robotic arm could be replaced by hand like structure that can lift things from one place to another. Scheduler: Allows the user to program the Robot to clean at certain times automatically.

Home base: The Robot automatically returns to and docks here for recharging.

Virtual Wall: Used for keeping the Robot out of designated areas. Voice controlled locomotion of robot instead of button control.

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