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A Review and Comparative Analysis of Solar, Electric and Gasoline Lawnmowers: An Extensive Study

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Abstract

A review on solar, electric and gasoline powered grass cutting machine comprises of a panel of photovoltaic cells, an electric motor and a rechargeable battery pack has been studied. This review discusses about the designing, analysis and fabrication of lawn mowers that play a vital role in day-to-day life. Furthermore, paper elaborates different technical implementations related to lawn mowers such as variation in blade angles of grass cutting machine and cutting rate of grass, speed and turning radius of machine that lead to the more flexible working of lawn mowers. The renewable energy resources such as solar energy from solar panel can be used for charging the battery and used for driving the remote controlled machine. A review also includes the environmental issues of gasoline grass cutting systems that affect the environment and deteriorate the quality of the atmosphere. The research on direct current electric grass cutting machine leads to ascertain the advantages over the gasoline machine. Furthermore, electric and solar powered remote controlled lawn mowers are trying to take over the conventional gasoline and manual lawn mowers. Remote controlled mowers need complicated circuits that are also discussed in the paper. The results revealed that solar cells can produce 175 watts under the normal sun condition in case of solar powered lawn mower. Moreover, it was surveyed that approximately 50,000 U.S. people were injured by lawn mower cutting blades that leads to the quest of novelty in the safe usage of machines and devices in household applications.

Keywords: *Lawnmowers, Solar/ Electric/ Gasoline lawnmowers, Remote operated lawnmowers*

1. Introduction

A lawn mower is a machine consists of variety of components such as blades, rotor and motor used in household applications in order to cut the grass up to some particular height that can be varied according to the design criteria of mower blades. The mowers run by electric source and comprising rotating cutters were emerged in early nineties. Edwin Beard Budding invented the first type of lawn in 1830 which used the basic idea of a local cloth mill and operated for trimming cloth. The same idea to trim the grass was carried out by cutting wheel made of cast iron and mounted to the shaft. Ransoms of Ipswich started manufacturing the Budding's lawn mower by 1832 which is today's largest manufacturer of lawn mower. Thomas Green developed a new kind of lawn which ran by chain drive and called 'silensmessor' because of low level of noise. By the end of 19th century, the heavy powered mowers were running the market. In 1919, the first gasoline powered motor was invented by Colonel Edwin George.

Nowadays, newest technologies are utilized and hover concept is used to lift the mower to different regions incorporate with catalytic converters in order to reduce the air pollution. In order to shut down all the problems, the RC-SOLAR type of mower is currently employing in grass cutting machine. Mowers are broadly used in gardening, agriculture, sports and public. The gasoline powered machines are the ones that causes health hazards and produces noise pollution and vibration. Moreover, it affects the human health irreversibly. It is a big concern for the public users because an average lawn mower works for around 8-9 hours. In workplaces and job locations, the care is taken by the authorities but for public, it becomes a worried situation because the sound level of irritating noise produces by the mower is greater than 85 decibels.

The main purpose of the paper is to summarize the literature review of different technologies pertaining to the lawnmowers running on gasoline, solar and electric power. Furthermore, the designing, fabrication and review result discussions are also studied.

2. Literature Review

An extensive literature study is carried out on grass cutting lawn mowers in order to emphasize on different designing, analysis, application and safety aspects of view.

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In the study of McCoy [1], the combination of solar cells was connected in an array and arranged in parallel or series connection so that desired amount of current and voltage could be drawn. It was claimed that the maximum amount of current without increasing voltage across the terminal was obtained by arranging the group of cells in the parallel connection. The array was divided into groups that included three-four cells in each. This arrangement was used to charge the battery in a rapid manner and this rapid charging was because of diode which provided electrical separation and that prevented the current to flow from battery to the solar cells. Every group of the solar panels had its own diode. This diode separated each group from other group of solar panels.

In the study of Paytas [2], the lawnmower was designed that was operated by the electric motor. The lawnmower batteries were either charged by electric power source or by solar energy by exposing it to the sunlight. In the design, the pairs of solar panels joined by the ridge of the panels was raised above the electric motor. The solar panels consisted of plurality of solar cells that produced required voltage and current. The voltage regulator at the charging outlet was connected to control current flow with respective battery. Voltage regulator was required to maintain the safe charging as additional voltage or current could be drawn from the solar cell. The electric clutch was used as electric brake which provided the opposite polarity when the safety bar was released.

In the study of Lucas et al. [3], the hybrid lawnmower was introduced which could be run by either direct current (DC) or alternating current (AC) power supply. A 60 volts DC supply was provided from the battery pack to the motor with a hybrid AC/DC controller which acted as step down controller or power inverter. The full bridge rectifier was used to rectify the current from AC to DC. The mower could be run in two modes such as conserve and boost mode. An additional 6 volt battery was provided to hybrid AC/DC controller that increased the speed of blade motor when switched to boost mode. Furthermore, when the mower was switched to the conserve mode, the battery life was prolonged.

In the study of Thomas et al. [4], a lawn mower was designed which had both AC and DC motors. Both motors were connected by gear and clutch arrangement which could be run together or separately. When AC motor was powered, DC was permitted to the free wheel by the clutch assembly mechanism. When the grass was dense, both the AC and DC motors were powered. Both AC and DC motors drove the gear through their association with the clutch assembly. In the design, three gears were used which were arranged in the way that they were always in the contact with one another and the driven clutch plates were in the motion all the times. AC and DC motor were mounted adjacent to each other.

In the invention of Milshtein et al. [5], a solar electric powered lawnmower was designed which was controlled electronically to minimize the energy consumption. Change of grass density or any other change of a load to the blade was sensed by a controller and was fed-back to the circuitry. Clean energy, low noise, no pollution, no energy cost, safe operation and low maintenance was added as benefit to the prototype to reduce its cost. Lawnmower was operated by set of batteries and solar panels. The direction of the blade could be changed so that mower could throw grass in different direction. The DC motor was selected to provide maximum efficiency of 81%-84% at the low possible current. Batteries were selected to provide high energy density (30 W- hour/kg). In this design, conventional solar cells were used with the efficiency of 14%. Solar cells were able to produce 175 watts under the normal sun condition. The machine required 24 volt and 10 ampere of current where solar cells were able to produce only 6 ampere of current.

In the study of Wassell [6], a solar powered lawn mower was designed which was contained an electric motor, a rechargeable battery and photovoltaic cells panel that was attached on the handle of the lawn mower. A solar powered lawnmower was compared and studied with the gasoline powered lawnmowers from the effectiveness point of view. Both the mowers were compared and concluded that the solar powered mowers were more efficient, noiseless and had minimum energy cost. As it was solar powered, no air pollution was caused as gasoline mowers produced a lot of noise and affected the environment.

Shukitis et al. [7] researched the methodology which solved the problem while lifting and lowering the deck. There was a problem with the force used to ‘quick lift’ of the deck. In this design, a solution was given which reduced a force of 22 pounds for lifting and lowering and for ‘quick lifting’, a lever system was used, that enabled the mower to lift till the maximum height.

In the study of Atkins [8], the relation between the slice (blade that cuts in one rotation of the rotor) and push (the forward travel) was reviewed. It was discussed that, if the slice to push ratio was more, then the amount of grass cut was more and when the knife or blade was sharp, then more was the cutting action. In the study, the blades were arranged on helices around the cylinder and slice to push

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ratio was determined by the helix angle. It was also investigated that the design and ergonomics of different blades that were used in meat cutting, cylinder lawnmowers, and scythes greatly reduced the force required to cut the grass.

In the study of Sujendran et al. [9], a survey was done regarding the health effects of the lawn mower. It was discussed that lawn mowers produced a noise that was greater than 80 decibels with inclusion of the motor. Therefore, an additional muffler was assembled to the design by which the noise level was reduced by an amount of 7-10 decibels (dBs). The amount of grass cut and the area of grass cut were calculated by assuming some of the data with the help of path algorithm. The relation between the vibration and the noise caused by different types of lawn mower were studied. The conclusion was made that the lawn mower was smart when all the problems related to health and the technical issues were checked.

In the study of Tanimola [10], a survey was done between the lawn mowers that used renewable and non-renewable resources as the energy input. The effects of gas emitted from lawn mower to the land, air and humans were studied. The selection parameters of different parts that were used for the lawn mower were discussed and the comparison was made with the other types. It also tested the mower in four different types of grass i.e. elephant grass, stubborn grass, spare grass and carpet grass on a same area where the time parameter were noted side by side. It was concluded that the mower was 93% efficient and with a good field capacity but there was no significant difference seen on the height of grasses with a 5% confidence level.

In the study of Kamlukin et al. [11], the construction of a self-propelled lawn mower was discussed. The mounting points of different parts and assembly were discussed. The welding and their strength were also discussed. It concluded that, a good strength could be obtained by minimizing the number of welded parts. It comprised of stamped sheet steel having a forward end including an upwardly and forwardly inclined portion from an operator's foot rest which held all the mounting of the motor. Both the primary motors were supported by the mounting at the rear side of the stamped steel sheet.

In the study of Hythika et al. [12], a manually operated rotary lawn mower was discussed. The cost related issues were discussed by comparing the lawn mower for domestic purpose and public use. It also introduced a new type of mower that was the hover mower which could fly up to certain height. In this case, the deck lifting problem was solved as the mower could fly. There was no need of an extra motor for cutting grass as the hover blades had the rotary fans which acted as the cutting blades. The cost was also reduced, efficiency was improved and time of cut was reduced. It was concluded that the mower could cut any type of grass with an efficiency of 62% and also the energy requirements were lesser as compared to the other types.

In the study of Hicks et al. [13], a survey was done on the state of art in robotics to find out the capabilities, requirements and advantages of devices present these days. Several controlling modes of the remote control were studied. There were three distinct modes of the mower that were remote control, teach control and automatic operation. It also discussed the importance of the innovation required to establish a clear result by implementing the navigation system, obstacle avoidance and motion control. The safety issue was highlighted at most in the survey. It was surveyed that more than 50,000 people were injured due to the use of lawn mowers in the U.S.A which were mostly caused when a person encountered high speed blade of mower or by the object that was flung by the blade while cutting grass. An emergency stop condition was discussed which was an additional advantage for a condition of halting.

In the study of Fulton et al. [14], a detailed incident was investigated as it included the analysis of the product, ergonomics evaluation and it suggested the design criteria for future development. Ergonomics was the main discussion because this led to the accidents and it was solved by repeated trials and testing. The stages of investigation were discussed which included study related to the accidents, ergonomics assessments, comparisons of studies and discussion with the manufacturers. It also showed the performance criteria comparing the both petrol and electric lawn mowers. It demonstrated the characteristics of users, including aspects of their behavior and also had a significant bearing upon lawn mower safety. The approach of investigating created a more informed basis for decisions of future design of lawn mower.

In the study of John [15], it was reviewed that in order to produce a mechanical energy, a direct current motor was used that consumed electrical energy as its input. The energy was produced due to the interaction of current-carrying conductors and magnetic fields. Current or voltage was given as the input to the direct current motor and torque was the output. Self-initiated precise exchange force was utilized by the motor to control spin-waves. Sudden magnetic forces which were precisely located as well as directed were produced by the motor using the phenomena of self-initiated nonlinear magnetism.

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In the study of McNair et al. [16], a battery operated electric vehicles were examined that found that the sealed lead batteries were suitable power source for lawn mowers, but if their discharge voltage dropped below a certain limit then they could not be recharged, or normal life of the battery was drastically reduced. The point at which it happened depended to some extent on rate of the battery which further depended on the condition of its use. Current sensing devices had been used to disable the battery if the current was drawn above the certain limit from the battery. The objective was to control power supply system for battery powered machines. Control system was used for monitoring the voltage discharge levels of the battery and to disable it. It improved the battery life and the efficiency.

In the study of Gobler [17], a blade of a lawnmower was designed that contained a hump which was located near the end of blade but also provided with a space, adjacent transitional zone was merged into each hump and the hump was directed towards the non-cutting edges of the blade. The hump was able to increase the force of ejection of the grass and smooth rotatory motion of the blade was not influenced by the hump. Moreover, humps were integrated with the blade and the hump's highest point was placed with a space from the central region. The space was equal to the distance of cutting edges that were lowered below the central region.

In the study of Willsie [18], a lawnmower blade was designed that had improved blade bar which was flat and also slight twist was provided. A pivotal cutter discs was fitted on each end of the blade. Each end of the blade was fitted with blower elements which blew the grass. The design provided maximum throwing of cut grass from the housing of the mower during the blade rotation. To direct the cut grass into outward direction of the cutter discs, the blower elements were extended above the ends of the cutter discs. It facilitated the expulsion of the grass clipping beneath the lawnmower housing.

In the study of Lalonde [19], the blade assembly for lawn mower which produced efficient mulching of the grass was reviewed. The assembly was adapted to produce self-cleaning inside the shroud housing of the mower and the internal surface of the same housing. The grass was finely mulched and blown downward outwardly of the shroud housing of the lawn mower and kept the latter clean. The grass cuttings were blown downward and it avoided the raking and reduced the need for a lateral outlet in the shroud hosing. It also reduced the risks of injuries caused by obstacles which were flung outward, such as rocks, sticks, or by engagement of foot in the path of the rotating blade.

In the study of Savazzi [20], a project was designed to construct and program an autonomous focus stacker that was used for the production of small 3D image with higher depth of field (DOF). Arduino was coded with C++ to control the electronics for stacking the images into final image as the process earlier was time consuming, expensive and error prone.

In the study of Yusoff et al. [21], the project was designed to control a robotic arm in which Arduino was used in order to control the mobile robotic arm wirelessly that performed various essential operation through the PS2 controller. Signal transmission was done on the bluetooth module from the PS2 controller to the Arduino.

In the study of Serrano et al. [22], a project was designed to control a wheelchair using a speech control system. In this project, Arduino coded with C++ language was used in the signal transmission for steering and driving the wheelchair with the help of speech and magnetic means of input.

In the project of Kadir et al. [23], a robotic arm was designed which was controlled by the Arduino that was interfaced with the internet with the help of Arduino Ethernet Shield. The robotic arm was able to be controlled from anywhere using the internet. The accuracy of the input to the output signal through the internet to Arduino was 97% to 99%.

In the review of Mohamaddana et al. [24], upper limb rehabilitation robot device was designed in which Arduino was used to drive the device consisting of scissors, lifts and armrest mechanism that allowed patient to perform upper limb rehabilitation during the stroke. Arduino controlled the device movement along XX, XZ, YY, YZ axis direction during the stroke.

In the literature of Hua et al. [25], a wireless monitoring, calibration and diagnosis interface was designed which used bluetooth module. It was designed to control fuel cell bus used in Olympic demonstration. For one year, fuel cell buses were operated in a fixed bus line as a public demonstration of environmental friendly vehicles. The measurement, monitoring and calibration devices were easy due to the use of fuel cell engines and electrified driving systems. So, the fuel cell city bus was controlled by the Bluetooth universal data interface.

In the project of Hsu [26], using a speech-recognition and blue-tooth microprocessor controlled system, an intelligent living-space system was designed which had automatic control system that could control every home-appliances in the house. The system constituted of two parts, one was a

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blue-tooth module remote control mechanism which was mounted on master controller module as well as on a slave receiver module, the other was design of the remote-controller with speech-recognition.

In the extensive review of Jeonga [27], a Bluetooth remote lock system was designed and utilized through a smartphone with the help of a dedicated Android application. The Bluetooth remote lock can be controlled using blue-tooth application on any Anroid device. The storing and managing of the lock information of any user was provided in real time in the database through a server that was built and managed by a server manager. The lock system was provided with password retrieving, adding, deleting, modifying, and purchasing own locks facilitated for users.

In the project of Ji et al. [28], an intelligent wheelchair was designed for the disabled person in which functions like user intention recognition, obstacle detection and avoidance, and situation awareness was installed. It used two cameras, 8 ultrasonic sensors, laptop computer and DAQ board. It allowed the user to control the wheelchair using their face movement with the help of images obtained from the camera. 8 ultrasonic sensors were used to detect the obstacle and avoid the collision.

In the study of Hermann et al. [29], the smart sensor based obstacle detection for high speed unmanned surface vehicle was designed in which an obstacle detection system was introduced to the high speed and agile unmanned surface vehicle with the speed of 30m/s. It detected the obstacle within the range of 175m with the help of radar and vision technologies.

In the study of Kima et al. [30], an obstacle detection system at the rear that used fisheye stereo camera consisted of HCT (hierarchical census transform) was designed in which hierarchical approach was used to improve efficiency of computation and to decrease the matching window size dependency. Computation time was reduced using compute unified device architecture. It also used colour and motion information for the moving things to be detected. It was resulted 12.51% better than other system and misdetection was 11.09% which was lower than other system.

In the study of Wanga et al. [31], a non-linear model predictive controller with obstacle avoidance for space robot was designed in which non-linear predictive control was introduced to approach the un-cooperative target in the space environment. In this project, an on-line quadratic programming (QP) procedure was used to obtain the control decisions in real-time. The design was provided with 7 degree-of-freedom (DOF) kinematically mounted on a 6 DOF free-floating spacecraft through simulation studies. The design was provided with Real-time trajectory tracking and collision avoidance that added effectiveness and potential to the proposed NMPC strategy for the space robot.

In the project of Li et al. [32], a mechanical fault recognition of extra high voltage circuit breaker was designed which was able to recognize the mechanical fault when extra high voltage was encountered. The monitoring condition was realized with the help of improved Support Vector Machines. The recognition methods were ANN and LibSVM. These methods were compared on their recognition accuracy and the result was obtained that LibSVM was more efficient than ANN. Genetic Algorithm (GA) was used to improve the algorithm of LibSVM.

In the study of Kazem [33], an applicability of auxiliary contacts (A. Cs) in circuit breaker (CB) online condition assessment was tested. On the basis of the results, timing of A. Cs was easy-to-access and easy-to-measure. The investigations were established upon measurements carried out on sixty CBs (72.5 kV, SF_6) under healthy and faulty conditions. The new approach was conducted through an adaptive neuro-fuzzy inference system (ANFIS). The feasibility and applicability of this method in CB condition assessment was verified against the experimental measured data.

In the project of Sadi et al. [34], an operation which was the combination of static var compensator (SVC) and suitable reconnecting of circuit breakers (CBs) for the power system transient stability was performed and studied. Matlab software was used for simulation. The study resulted from single-line-to-ground and three-line-to-ground was that SVC and optimal reconnecting of CBs could enhance the transient stability of system if the permanent fault was detected at different points of the power system. It also concluded the better performance than that of other combined operations.

In the literature study of Soliman [35], low sensitivity to frequency change power system digital voltmeter was designed. The certain correction factor (CF) was imposed during the measurement process and there was no change in meter readings with the change in frequency. The least error squares algorithm was used as the parameter estimation algorithm to estimate the system parameters. Furthermore, the corresponding voltage phase angle as well as the voltage phasor magnitude was included. The technique could be applied for non-sinusoidal voltage waveforms as well as sinusoidal waveforms. The project

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resulted that the errors was reduced with the use of LES algorithm due to the change in system frequency.

In the project of Horenstein [36], a non-contacting voltmeter to measure an isolated surface charge was designed in which surface potential was measured without physical contact. It adjusted its own probe potential and zero-field condition was enforced at its probe. Field around the probe consisted of two superimposed components when an isolated charge distribution was measured. First one was equal to the field that was caused due to the measured charge distribution and a probe that was grounded and the other component was equal to the field of the probe that was energized due to the absence of the charge distribution. The resulting potential of the probe depended on the magnitude of the charge measured, physical geometry of charge, the probe geometry, and the probe position relative to the distribution of charge.

In the project of Sandhu [37], a low cost integrating digital voltmeter used for pulsed nuclear magnetic resonance signals was designed which was used for measurement of the amplitude of the transient signal in pulsed nuclear magnetic resonance. The unit was self-contained, cheap and could be easily built. A digital readout of the amplitudes was provided by the design but only could be used with the help of tape punch. It could also be used as a direct current voltmeter.

In the study of Pandeya et al. [38], a verification of electric potential measurement model which was non-contacting was done using contacting electrostatic voltmeter. In place of non-contacting measurement model, an ultra-high input impedance voltmeter was used. A very low input capacitance 10^{-15} F, and very high input resistance Tera ohms was provided which resulted no charge transfer from the measured object to or from the instrument. An experiment gave the correlation between the non-contacting and contacting measurement model.

3. Conclusions

Some of the important conclusions on comparing the solar, electric and gasoline lawn mowers are summarized as follows:

- Solar powered mowers are more efficient, noiseless and no pollution when compare with gasoline mowers that produce a lot of noise and affect the environment.
- The muffler can be installed in order to reduce the noise of motor as low as 7-10 decibels.
- Lawnmower is 93% efficient on elephant grass, stubborn grass, spare grass and carpet grass and with a good field capacity but there is no significant difference seen on the height of grasses within a 5% confidence level.
- The robotic arm is able to control from anywhere using the internet. An accuracy of 97% to 99% from input to the output signal through the internet to Arduino can be attained in case of remote controlled lawnmowers.
- Maximum amount of current can be drawn without increasing voltage across the terminal by arranging group of cells in parallel connection.
- The amount of charging during operation varies as per different direction of sunlight which reaches the solar panel and the solar panel should be perpendicular to the sun ray to obtain maximum output.
- The cutting effectiveness of the blade can be increased by improving the slice to push and to obtain good strength. Furthermore, there should be minimum welding joints in the design.

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