

DEVELOPMENT OF A SOLAR ASSISTED LAWNMOWER

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Abstract

A lawn mower is a machine that uses one or more revolving blades to cut a grass surface to an even height. There are several drawback experience in both mechanical and electrical operated lawn mower such as noise, shortage and high cost of fossil fuel, and the effect of emission of poisonous gases from the burnt fuel into the atmosphere. This necessitated the use of the abundant solar energy from the sun as a source of power to drive a lawn mower. This project aimed at developing a solar assisted lawnmower. The solar powered lawnmower comprises of alternate current (ac) motor, a rechargeable battery, solar panel, a stainless steel blade, control switch and deck on which other components of the mower were attached. Mowing is achieved by the alternate current motor which provides the required torque needed to drive the stainless steel blade which is directly coupled to the shaft of the motor. The solar powered lawnmower is operated by the switch on the board which closes the circuit and allows the flow of current to the motor which in turn drive the blade used for mowing. The battery recharges through the solar charging controller. The solar powered lawnmower machine was tested on three different grass field containing stubborn grass, spear grass and elephant grass to ensure the functionality of all components and the cutting efficiency of the machine was found to be 88.4, 94 and 85% respectively. This machine tends to proffer solution to environmental pollution caused by lawn mowers powered by internal combustion engines and also, it can be easily carried around to mower any form of grasses. It also extend the cutting hour beyond the insolation hour due to inclusion of battery in the system.

Keywords: Lawn, Inverter, Mower, Photovoltaic cell, A/C Motor.

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Introduction

A lawn mower is a ground keeping device that make use of one or more rotating blades to cut a grass surface to an even height. Grasses are leaves, which might either be herbaceous plants or monocotyledon plants that grow from the ground in various areas of our environment (Pratik *et al.*, 2014). Lawn maintenance and landscaping remain one of the most important constraints from keeping clean and fresh looking gardens and yards (Ogiemudia *et al.*, 2016). In the past, cutting of grasses in the

schools, sports track, or field, industries, hotels, public centers, etc. was done by sickle, hand shear and cutlass, this method of manual cutting is tedious, time consuming, also inaccurate in cutting level.

The first lawn mower was invented in 1830 by Edwin Beard Budding who obtained the idea after watching a machine in a local cloth mill which use a cutting cylinder mounted on a bench to trim clothes for a smooth finish after weaving. There are primarily two types of

mowers, namely (i) the reel mowers, and (ii) the rotary mowers (Satwik *et al.*, 2015).

The blades may be powered either by hand, by pushing the mower forward to operate the mechanical blades, by an electric motor, by solar power or a small internal combustion engine to spin the blades.

A lawn mower is a machine consisting variety of components such as blades, rotor and motor used in household applications in order to cut the grass down to some particular height that can be varied according to the design criteria of mower blades. An extensive literature study is carried out on grass cutting lawn mowers in order to emphasize on different designs, application and their results.

Nowadays, with evolving mechanical technologies, innovations of cutting grasses has been adopted using gasoline engine type of lawn mower in keeping our environment clean in place of manual method, the latter system emits gasses which contaminate the atmospheric air, heavy to maintain, noisy, shortage and high cost of fossil fuel to runs the system necessitated the need for development of an alternative system that could be run on renewable energy.

Development of mower that will be fully powered by renewable energy addressed a number of issues of gasoline engine powered lawn mower. It generates no noise, poisonous emission generated by gasoline engine into the atmosphere are eliminated. It also eliminates down time by frequent trips to the gas station for fill-ups and danger associated with gasoline spillage. Solar powered lawn mower can be described as the application of solar energy to power an electric motor which in turn rotates a blade which does the mowing of a lawn. The solar powered lawnmower is based on the same principle that other early inventions of lawn mowers works on. The difference is just the application of the energy source. It uses the photovoltaic panel to generate the energy needed to power the mower (Tanimola *et al.*, 2014).

Basil (2013) designed a lawn mower made up of an induction motor, a battery, and alternator, two collapsible blades, and a link mechanism. Speed of blade shaft is increased by an arrangement of a speed multiplication pulley system mounted on a steel platform. The power and charging system comprises of an alternator which charges the battery while in operation. The use of collapsible blades and incorporation of an alternator for recharging the battery make the design unique such that no engine is involved. Overall, it is a cordless electric power mower with 89.55% cutting efficiency. The major weakness of the machine is that the battery discharges easily due to the power drawn by the motor and there is need for a more efficient means of charging it other than the alternator.

Tanimola *et al.*, (2014) designed a solar powered lawnmower which comprises of a DC motor, a rechargeable battery, solar panel, a stainless steel blade and control switch. Mowing is achieved by the D.C motor which provides the required torque needed to drive the stainless steel blade which is directly coupled to the shaft of the D.C motor. The battery recharges through the solar charging controller. The machine was tested in four different types of grass i.e. elephant grass, stubborn grass, spare grass and carpet grass on the same area where the time parameter were noted side by side and it was found to be highly efficient because of the components used with an efficiency of about 93%. The weakness of the machine is such that the operational time of the machine at battery full charge is low.

Satwik *et al.*, (2015) developed a lever operated solar lawnmower which has a spur gear displacement mechanism in which rotor blade height can be adjusted. Arduino board is used to control the speed of the motor manually and an anti-collision sensor is also placed in front of the machine to prevent collision. The weakness of the machine is such that the battery charging time is too long.

Mabesh (2014) reviewed and evaluated three (3) different types (solar, electric and gasoline)

of lawnmower and concluded that solar powered lawnmower has over 90% cutting efficiency, and produces no air pollution or noise as compare to internal combustion engine lawnmowers. They also concluded that the direction of sunlight falling on the solar panel can vary how the system is charged.

Richard (2010) developed a solar mower. A direct current (D.C) motor connected to the battery powers the blades and a photovoltaic panel is use to generate the energy needed to power the mower. Performance evaluation of the design was done on a field capacity of 1.11×10^{-4} ha/hr and an efficiency of 93% was obtained.

This paper aimed at developing a solar assisted lawnmower that explore the renewable energy source specifically solar energy which is clean, readily available, environment and user friendly and overcome the constraints experienced by the machines developed by previous researches.

Materials and Methods

Materials

The following materials were used for the construction of solar assisted lawn mower:

- Angle Iron
- Sheet metal
- Cable
- Galvanized pipe
- Stainless steel

Method

These are some of the methods employed in carrying out the project.

Main Component Part of Solar Lawn mower

- **Solar Panel:** This component collects and converts solar energy to electrical energy to charge the battery.
- **Control Switch:** This opens and closes the circuit during operation.
- **AC. Motor:** This is powered by battery through inverter which

converts electrical energy to mechanical energy which rotates the blades to effect cutting.

- **Inverter:** Inverter is an electronic device that converts DC voltage into AC voltage of required magnitude and frequency to operate the electric motor.
- **Charge Controller:** This limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against over voltage, which can reduce battery performance or lifespan.
- **Stainless Cutting Cutter:** This is the blade that cuts the grasses.
- **Deck:** This is the platform on which other components of the solar lawnmower are attached.
- **Battery:** It stores and transfers the required energy to inverter which converts direct current

Principle of Operation

As sunlight falls on the solar panel it is converted to electrical energy and stored in the battery. However, a charge controller is also installed alongside the battery to help prevent overcharging or over discharging of the battery. The battery therefore transfers the required energy to the electric motor. The electric motor converts the electrical energy into mechanical energy which eventually causes the cutter to rotate thereby producing the required cutting effect on the grass.

Design Consideration

The following factors were taken into consideration when designing to ensure economical, optimal productivity and ease of use of the developed solar assisted lawnmower machine

- i) Material selection
- ii) Functionality
- iii) Material availability
- iv) Cost and manufacturability

Figure 1 and 2 showed the conceptual design of the solar assisted lawnmower in isometric and orthographic respectively.

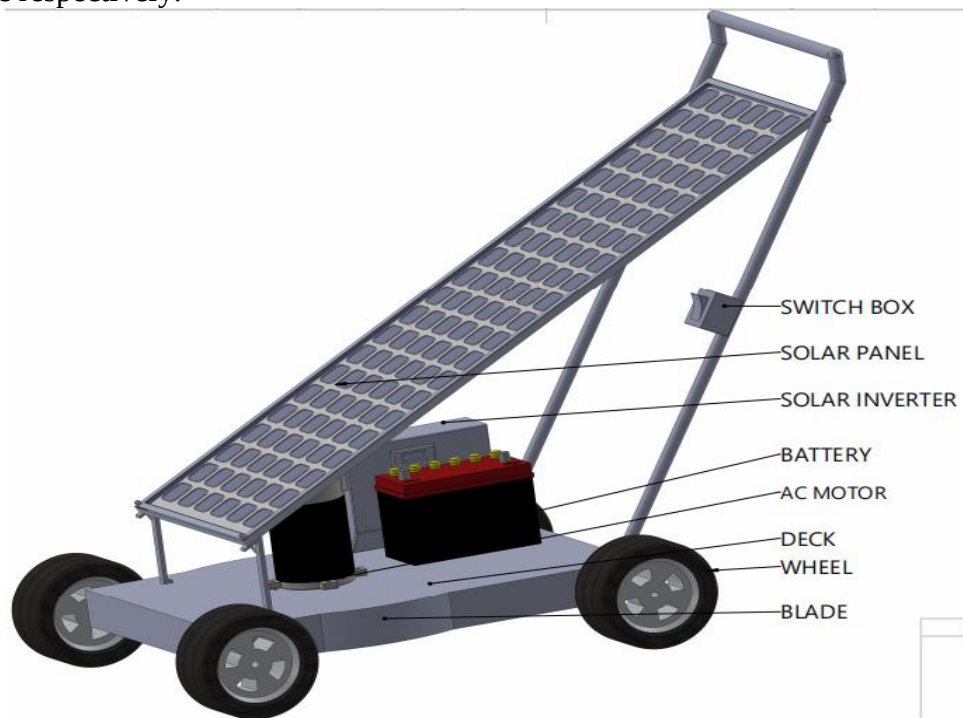


Figure 1: Isometric Projection of a Solar Assisted Lawnmower

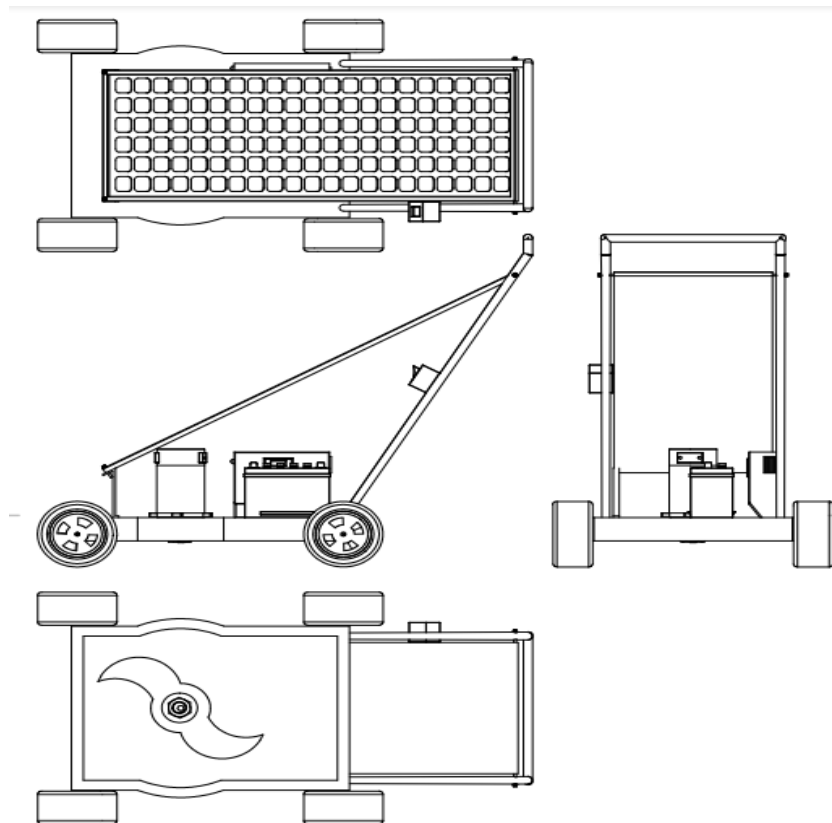


Figure 1: Orthographic Projection of Solar Assisted Lawnmower

Design Calculations

Power selection

The force required to cut grass by a sharp object should not be less than 10Newtons (Mogaji *et al.*, 2020), this is subjected to factors such as: the height of the grass, type as well as grass density in the area.

However, a slightly bigger force will be required (or selected) for high efficiency. Therefore, the force required to cut grass should be greater than 10 Newton.

A stainless steel was used in the construction of the cutting blade because of its strength and weight which can transmit same speed as that of the motor or a little less cause of friction.

Length of blade = 0.420m

Breadth of blade = 0.03m

Thickness of blade = 0.003m

Speed of motor, N = 3000 rpm

Density = 7850 kg/m³

Acceleration due to gravity g = 9.81ms⁻²

1) Area of the blade:

$$\text{Area} = \text{Length} \times \text{Breadth}$$

$$\text{Area} = 0.420 \times 0.030$$

$$= 0.0126 \text{ m}^2$$

2) Volume of blade

$$\text{Volume} = \text{Area} \times \text{Thickness}$$

$$= 0.0126 \times 0.003$$

$$= 3.78 \times 10^{-5} \text{ m}^3$$

3) Mass of blade

$$\text{Mass of blade} = \text{density} \times \text{volume}$$

$$= 7850 \times 3.78 \times 10^{-5}$$

$$= 0.2967 \text{ kg}$$

4) Force on blade

$$\text{Force} = \text{mass} \times \text{acceleration due to gravity}$$

$$= 0.2967 \times 9.81$$

$$= 2.91 \text{ N}$$

5) Torque required to turn the blade

$$\text{Radius of the blade} = \text{diameter} / 2$$

$$= 0.420 / 2$$

$$= 0.21\text{m}$$

$$\text{Torque} = \text{Force} \times \text{Radius}$$

$$= 2.91 \times 0.21$$

$$= 0.611 \text{ Nm}$$

6) Determination of angular velocity

Universally, angular velocity (ω) is given as:

$$\omega = 2\pi N / 60$$

$$\text{where } N = 3000\text{rpm}$$

$$\pi = 3.142$$

$$\omega = 2 \times 3.142 \times 3000 / 60$$

$$= 314.2\text{rad/s}$$

7) Power generated at the blade

The power P developed is the product of torque and angular velocity.

$$\text{Power} = \text{Torque} \times \text{angular velocity}$$

$$= 0.611 \text{ Nm} \times 314.2 \text{ rad/s}$$

$$= 191.98 \text{ W} = 0.19\text{KW}$$

To convert kilowatt to horsepower

$$\text{Since } 1\text{kw} = 1.3596 \text{ hp}$$

Therefore: 0.19 KW is equivalent to 0.3hp

8) Motor Size

In-order to have a smooth grass cutting, a motor power of not less than 628.3W (0.84hp) having 3,000 rev/min rotational speed and cutting force of 10.5N was recommended (Tanimola, 2014).

Therefore, for design purpose 1hp AC motor was used for this project, so that it provides the required torque in order to cut all types of grasses effectively and also to increase the efficiency of the machine.

9) Cutting efficiency

$$\text{Cutting Efficiency} = \frac{\text{Portion cut by lawnmower}}{\text{Portion of lawn}} \times 100$$

10) Battery Size

Available 12V, 220Ah battery was selected for greater efficiency.

To determine the battery capacity:

$$\text{Power factor} = 0.8$$

$$\begin{aligned} \text{Design power} &= \frac{\text{Current} \times \text{Voltage}}{\text{power factor}} \\ \text{Current (I)} &= \frac{\text{Power} \times \text{P.f}}{\text{Voltage}} \\ &= \frac{750 \times 0.8}{12} \\ &= \frac{600}{12} \\ &= 50\text{A} \end{aligned}$$

The battery was expected to discharge after;

$$= \frac{220}{50A} \text{ hours}$$

$$= 4.4\text{hrs}$$

11) Solar panel

Although, the required power to charge the chosen battery full in 5hrs sunshine;

$$= \frac{\text{Load} + \text{energy losses}}{\text{sunshine hours}}$$

$$= \frac{750 + (25\% \text{ of } 750)\text{Watt}}{5\text{hrs}}$$

$$= \frac{937.5\text{watt}}{5\text{hrs}}$$

$$= 187.5W$$

A solar panel 250W was selected for effective charging.

11) Inverter sizing

Since the load is 750W (electric motor)

$$\text{Inverter sizing} = 30\% \text{ of } 750W + 750W$$

$$= (225 + 750) W$$

$$= 975W$$

A 1.5KVA inverter was selected

13) Charge controller

$$\text{i.e Charge controller} = \frac{\text{PV array size/}}{\text{Battery Current}}$$

$$= \frac{220}{50}$$

$$= 4.4A$$

For efficiency and effectiveness due to cold temperatures 25% of the result was added to it.

$$= 1.25A + 4.4A$$

$$= 5.65A$$

Therefore, a 10A charge controller was selected.

Result and Discussion

The machine was tested on three different grass field containing stubborn grass, spear grass and elephant grass. Three trials were carried out consecutively on each field and average experimental results obtained were presented in table 1 where the efficiency of the machine on stubborn, spear and elephant grasses were 88.4, 94 and 85% respectively. The elephant grass field took considerable longer time to cut as compared to the stubborn and spear grass. The difference in cutting time observed indicates that the elephant grass is a much tougher grass and requires more energy to achieve, whereas spear grass are much easier grasses to cut. Plate 1 showed the fabricated solar assisted lawnmower machine which explores renewable energy.



Plate 1: Fabricated solar lawnmower

Average results from mowing different type of grasses

Sample Plot	Area of Lawn (m2)	Average Height before cut (mm)	Average height after cut (mm)	Average time taken(mins)	Efficiency (%)
Stubborn grass	50.00	44.20	5.80	87.00	88.40
Spear grass	50.00	47.00	3.00	65.00	94.00
Elephant grass	50.00	42.50	6.70	82.00	85.00

Conclusion

Design, fabrication and performance evaluation of the solar assisted lawnmower was carried out. The efficiency of the machine on stubborn, spear and elephant grasses was discovered to be 88.4, 94 and 85% respectively. Test showed that the lawnmower performed differently on the three grass fields as the time it took to cut each grass varied from one grass to another due to the variation of toughness of the grass species tested. From the result, machine is easy to operate, generates no noise, eliminates environmental pollution caused by internal combustion engine powered lawn mower and also taps into the potentials of the renewable energy.

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