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E. M., Onuabuchi, J. U., Ekeopara, R. Sule, O. Ayanbisi, S.A. Akinwumi, O.C. Olawole, E. Ogunwale

Department of Physics, Covenant University, Ota, Ogun State, Nigeria

emmanuel.onuabuchi@stu.cu.edu.ng
joseph.ekeopara@stu.cu.edu.ng
rasidi.sule@covenantuniversity.edu.ng
oluwasegun.ayanbisi@covenantuniversity.edu.ng
oluwasayo.akinwumi@covenantuniversity.edu.ng, orcid.org/0000-0001-5373-1067
olukunle.olawole@covenantuniversity.edu.ng, orcid.org/0000-0003-0961-2823
emmanuel.ogunwale@covenantuniversity.edu.ng
Corresponding email: rasidi.sule@covenantuniversity.edu.ng, rasidi.sule@gmail.com

Abstract. Solar powered lawn mower has offered a more convenient way of trimming the lawn due to the advancement in its technology. As the world gradually moves towards green technology, research has geared towards making solar powered mover readily available, efficient, and economical. However, few reports were available on the effect of grass types on battery voltage drop. In this paper, solar powered lawn mower was structured into phases which include, power supply phase, Arduino phase, motor phase and integration of the components. The 550-motor was sufficient to produce the required torque needed to drive the solar panel mower. The average efficiency of the solar panel was found to be 93 %. The battery voltage drop was investigated upon cutting different types of grasses to determine the rate at which power is dissipated in the solar powered lawn mower. The voltage drop of 0.34 V was recorded when cutting stubborn grass while that of soft grass was found to be 0.17 V. Rain sensor was incorporated to provide the user with a notification via Buzzer whenever raindrops are detected.

Keywords: Solar lawn mower; Solar panel; Arduino Uno; rain sensor; DC motor

1. Introduction

Management of lawn can be a very challenging task, especially, when one has a large lawn area to cover. Lawn mower is a machine used to maintain and cut grass in outdoor areas such as parks, playgrounds, golf course and private garden [1]. It is used to trim the grass to a uniform height especially in the football pitch where grass affects the spin of the ball. Generally, lawn mowers operate on gasoline, electric and solar as sources of energy [2] Gasoline powered lawn mowers have been widely used due to their availability [3]. But new environmental protection policy has made it less attractive due to their carbon emission, noise and cost of engine maintenance. Electric lawn mower would have been an alternative to gasoline due to the absence of noise, portability and eco-friendly. However, the high cost of electricity and epileptic power supply has made it undesirable [4].

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Recently, effort has been geared towards the use of solar energy due to its environmentally friendly, absence of noise and wiring [4, 5]. The choice of solar powered lawn mower was not limited to the reduction in carbon emissions but rather lower operational expenses of the machine due to the abundant energy from sunlight [6, 7]. Solar powered lawn mower uses a photovoltaic panel to generate the energy required to propel the mower [8, 9]. The solar panel installed on the mower frame collects sunlight and converts it into electrical energy that is used to drive the motor [10, 11].

Despite the advantages of solar powered lawn mowers, its major setback is that it's weather dependent which means if there is no sufficient solar radiation its operation would be interrupted. Different approaches could be employed to enhance the practical application of solar powered lawn mowers. The energy generated from solar radiation can be stored in batteries for future use [10]. Also, weather monitoring devices such as temperature, rain or humidity sensors could be integrated into the lawn mower control system. There has been several research on solar powered lawn mowers, but few reports were available on the effect of grass on battery voltage drop. In this work, effort was made to develop a solar lawn mower and to investigate its performance on different grass with respect to the battery voltage drop.

2. Materials and Method

This section highlighted the design of the framework, components selection, fabrication of the body frame, programming of the Arduino used in controlling the movement, conducting performance tests, assessing cutting efficiency and energy consumption of the mower.
Figure 1 shows the block diagram of the interconnection of the units in the system.

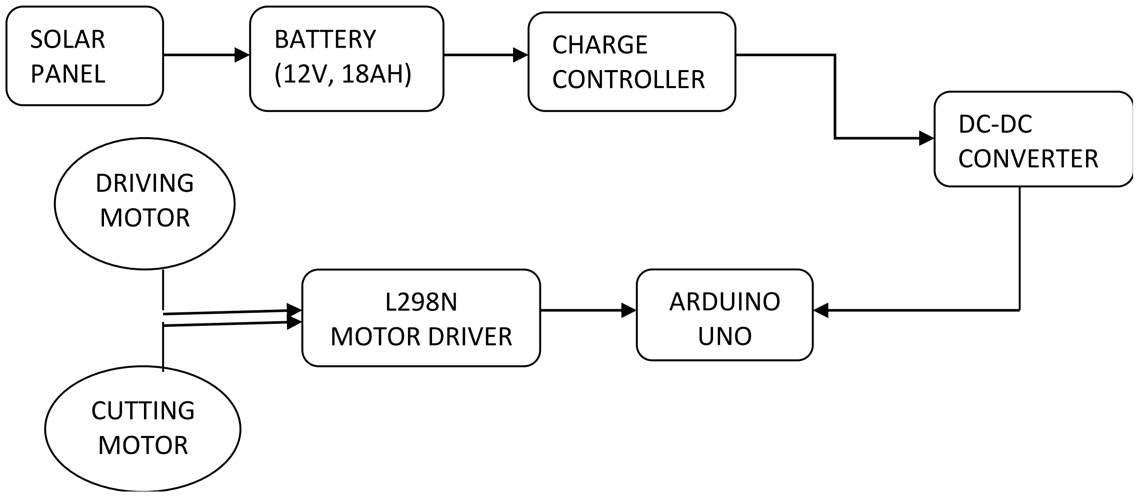

Figure 1: Block diagram showing the hardware components of the system.

2.1 Design and Components selection

The body frame of the solar lawn mower provides structural support and housing other components. It's usually made from materials such as Aluminium, Steel, or reinforced plastic composites that are lightweight, durable and can survive outdoor conditions. In order to support the size and weight of the components, the chassis was properly constructed, assuring adequate

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weight distribution, balance, and accessibility for maintenance. The body structure has a suspension mechanism that improves the stability and agility on difficult terrain. This feature keeps the cutting heights constant and guards against damage from extreme vibrations or impacts. Components like solar panels, batteries, and sensors were carefully mounted to secure optimal performance. Waterproof seals, gaskets, and cover materials were used to adequately protect internal parts from water, dust, and debris. The following components were used for the construction of a solar powered lawn mower.

- Solar panel
- Rechargeable Battery
- Solar charge controller
- Dc motor
- Arduino Uno
- Rain sensor
- Bluetooth module
- Cutter thread
- Wheels
- Buzzer
- Plastic box (water resistance)
- Relay
- L298l motor driver
- DC to DC converter

2.1.1 Power supply

Solar panel or photovoltaic (PV) panel converts sunlight into electrical energy. The solar lawn mower utilizes solar panels to capture sunlight and convert it into electrical energy.

This project was powered using a 12 V, 18 AH rechargeable battery which was enough to drive the mower and enable it to cut different types of grasses. It was used along with a DC-to-DC power converter to generate 9 V such that it can conveniently power the Arduino Uno and other devices connected to it. Solar panel along with a solar charge controller was used to charge the battery and to regulate the charging current in order to keep the solar mower in operation when solar radiation is poor. Figure 2 shows the picture of the solar panel, battery, and solar charge controller.

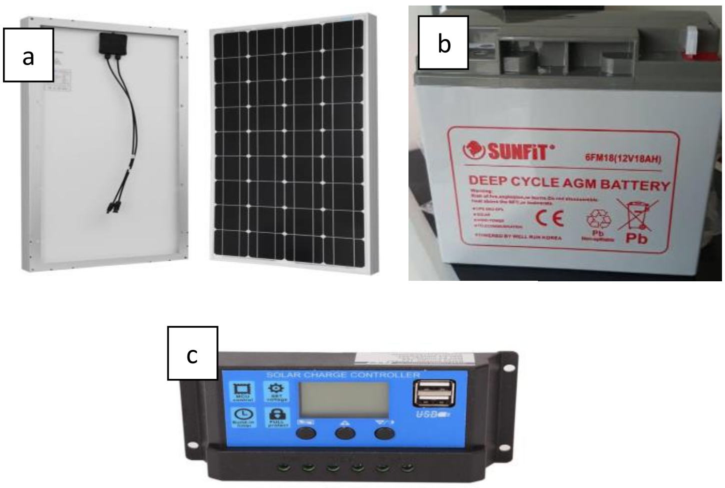

Figure 2: (a) Solar Panel (b) 12V 15AH Battery (c) Solar Charge Controller

2.1.2 DC Motor

A 550 motor was used for this project (parameters: Spur Gear, No-load Speed 95 RPM, Rated Speed 83 RPM, Rated Torque 53 Kg-cm, Max Power 50 W, and Weight 350 g, rated voltage is 12 V with a range of 6 to 12 V). The DC motor was carefully selected to produce the torque requirement to move the mower. The L298N motor driver was used to control and drive DC motors. It provides bidirectional control which allows motors to be driven in different directions.

2.1.3 The Arduino

The Arduino Uno is a microcontroller module that served as the brain for this project. The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller. The ATmega328 on the board comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. The board was programmed using the C programming language via a user-friendly Integrated Development Environment (IDE). The rain sensor was used to determine whether there is precipitation or moisture present.

2.1.4 Rain sensor

The rain sensor is used to determine precipitation or moisture. It was used with a buzzer. The buzzer gives signal once the rain sensor detects moisture.

2.1.5 Water resistance box

Water resistance was incorporated to protect electronic components from water, dust, and other environmental factors that could damage it.

2.1.6 Cutting thread

Majority of the mower constructed uses a blade as a cutting component. In this project, Teflon cutting thread was used instead of blade.

3. Results and Discussion

3.1 Efficiency of the solar panel

The efficiency of the solar panel is the amount of power it can generate at maximum intensity of the sun at different times of the day. The efficiency is dependent on the types of solar panel, the load, and the time of the day. The solar panel used for this project had a maximum power rating of 10 Watt and an open circuit voltage of 21.5 V. In order to ascertain the efficiency of the solar panel, the power output was calculated at various times of the day using current and voltage at load of 45 ohms, 5 Watt. Table 1 shows the power output at various times of the day. The results show that the solar panel power rating is sufficient to power the mower. On the other hand, the efficiency of the solar panel was examined by taking the output voltage of the solar panel under no-load condition. The readings were taken for different times of the day with one hour interval. The results obtained were shown in Table 2. Equation 1 and 2 was used to calculate the efficiency of the solar panel at load condition while Equations 3 and 4 were used to determine the efficiency under no load condition.

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Table 1: Experimental result for the power output at various times of the day

S/N	Time (s)	Current (A)	Volt (V)	Power (W) V×I
1	8:30	0.38	17.10	6.50
2	9:25	0.46	20.70	9.52
3	11:45	0.45	20.25	9.11
4	2:30	0.45	22.05	10.80
5	5:47	0.41	18.45	7.56
Average power				8.698

$$Power = Voltage * Current \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

Efficiency of the solar panel at load condition

$$Eff = \frac{Average\ Power\ output}{Pmax\ of\ the\ solar\ panel} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots..2$$

$$Eff = \frac{8.698}{10.8} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$Eff = 80.53\%$$

Table2: Experimental result for the output voltage at various times of the day.

S/N	Time of the day	Output Voltage (V)
1	8:00	17.65
2	9:00	18.01
3	10:00	18.67
4	11:00	19.45
5	12:00	20.50
6	13:00	21.30
7	14:00	21.25
8	15:00	21.02
9	16:00	20.82
10	17:00	21.3
	Average	19.997

The average output voltage (V) = $\frac{TOTAL\ \ VOLTAGE\ GOTTEN}{AMOUNT\ OF\ VOLTAGE\ GOTTEN} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$

= $\frac{199.97}{10}$ = 19.997 V

$$Efficiency\ E = \frac{average\ output\ voltage}{open\ circuit\ volatge\ of\ the\ solar\ panel} 100\% \quad \ldots\ldots\ldots\ldots\ldots 5$$

E = $\frac{19.997}{21.5}$ 100% = 93%

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3.2 Influence of grass types on battery voltage drop

Table 3 shows the results obtained from mowing carpet grass, soft grass and the stubborn grass with respect to battery voltage drop. The coverage area of each test sample is 3 m × 2 m which is equal to 6 m^2. The voltage drop of 0.34 V was recorded when cutting stubborn grass while that of soft grass was 0.17 V. The results show that the types of grass determine the rate at which the power is dissipated in solar powered lawn mowers.

Table 3: Effect of cutting grass on battery voltage drop.

S/N	Sample Plot	Coverage Area (mm^2)	Battery voltage drop (V)	Time (s)
1	Carpet grass	6	0.29	300
2	Stubborn grass	6	0.34	300
3	Soft grass	6	0.17	300
4	Spear grass	6	0.21	300

3.3 Charging rate of the battery by solar panel

Generally, the time of the day, solar irradiance and meteorological changes are known to have a significant effect on the voltage output of the solar panel [12, 13]. Table 4 shows the rate at which the solar panel charges the battery to full voltage capacity. The battery voltage was recorded before charging with the solar panel. At 11: 25 a.m the battery was charged for 300 seconds and its voltage increased from 11.35 V to 11:38 V. It was observed that the battery voltage increased with the same interval from 11:25 to 11:40 am. The highest voltage from the solar panel was found between 12:00 noon and 12:10 pm. The battery was charged in 50 minutes with a total voltage of 0.65 V. Figure 3 shows the relationship between the voltage and time. It is obvious that other factors contribute to the output voltage of the solar panel as we observed fluctuation between the 11:40 pm and 12:10 pm which is the peak period. This result is reasonably consistent with Ismail et al. [7] report which found that high sunlight intensity might lead to less charging time.

Table 4: Average charging voltage of the solar panel

S/N	Time (s)	V_O (V)	V_1 (V)	V ($V_1 - V_0$) (V)
1	300 (11:25)	11.35	11.38	0.03
2	600 (11:30)	11.38	11.42	0.04
3	900 (11:35)	11.42	11.46	0.04
4	1200 (11:40)	11.46	11.51	0.05
5	1500 (11:45)	11.51	11.53	0.02
6	1800 (11:50)	11.53	11.57	0.05
7	2100 (11:55)	11.57	11.59	0.02
8	2400 (12:00)	11.59	11.64	0.05
9	2700 (12:05)	11.64	11.73	0.09
10	3000 (12:10)	11.73	11.78	0.05
Total	50min			0.62V

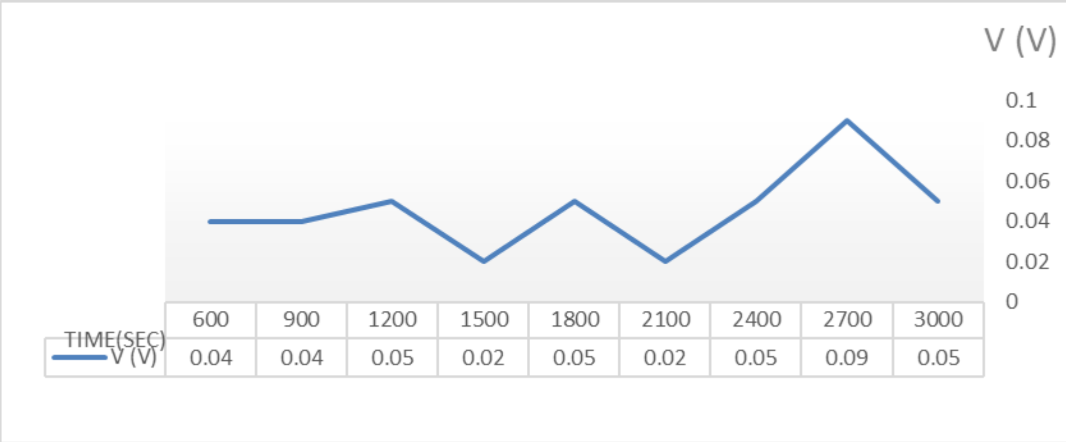

Figure 3: Plot of voltage (V) against time (s)

Where,V_0 is the battery voltage before charging, V_1 is the voltage after charging for some and V is the voltage difference.

4. Conclusions

Solar powered lawn mower with 12 V has been successfully developed as tested. The average efficiency of the solar panel was found to be 93%. The types of grass determine the rate at which the power is dissipated in solar powered lawn mowers. The output voltage of the solar panel depends on other factors as we observed fluctuation in battery voltage within a period of 5 minutes. The durability and efficiency of the Teflon thread during operation suggested that it is an excellent alternative to the blade in a lawn mower. However, further study is needed to enhance the robustness of the constructed lawn mower.

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