Design and Development of Smart Solar Grass Cutter

Firas B. Ismail, Nizar F.O. Al-Muhsen, Fazreen A. Fuzi, A. Zukipli

Abstract: ***From the time immemorial, the sun is the major source of energy for life on earth used for heat and lighting. Nowadays, solar energyhas been known as a renewable energy source. It is an alternative energy to that of fossil fuel and it can be collected from the renewable resources such as sun, wind and hydro. This paper introduces a new development of grass cutter, named as Smart Solar Grass Cutter, by usingsolar irradiance as a primary energy source with the presence of a solar panel. This grass cutter prototype is developed to reduce air pollutant and improve the current design specifically the blade position based on the previous studies. With current technology, this new prototype is designed as remotely controlled grass cutter using Arduino UNO. Smartphone is used as the remote controller. After developing an established prototype, the design analysis is carried out to bevalidate with the theoretical values to ensure that the prototype can be safely used. The Smart Solar Grass Cutter can operate more than two hours when the used battery is fully charged. Based upon the results, the Smart Solar Grass Cutteris reliable with high efficiency of the system compared to the previous studies. Therefore, it can be concluded that the prototype is reliable and environmentally friendly.***

Keywords: Smart Grass Cutter, Solar Grass Cutter, Smart Solar System.

I.INTRODUCTION

The conventional grass cutters have been widely used recently by workers in the gardening and agricultural industries. However,the manual handled grass cutters are consuming a lot of energy and producing air pollution which can directly affect the workers' health. The conventional grass cutters are also creating a high level of noise and vibration which can cause serious health issues such as grip strength, decreased hand sensation and dexterity, finger blanching or 'white fingers' and carpal tunnel[1].In order to address these issues, a new design of a grass cutter machine has been proposed. This device can be fueled by solar energy and smartly controlled, which has been named as a Smart Solar Grass Cutter that has three main systems which are smart control system, solar system, and the grass cutter.

According to the national air space association (NASA), there is a 1.361 kW/m^2 of solar irradiance received at the top of Earth's atmosphere[2].

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Approximately 1.8/10MW amount of power from the sun has been interrupted by the planet Earth,which is thousands of times larger than the present global consumption rate of the energy. This has motivated the governments, researchers and power industries to increase their investments in the renewable energy industry aiming to utilize more this clean energy and relief the global warming.Many researchers have proposed new designs of autonomous and non-autonomous solar grass cutters[3, 4].Moreover, a fewfully automated designs using sensors to detect obstacles and avoid any harm or injuries have been also proposed[4, 5].Patil S.M. et al. proposed a solar grass cutter called Smart Solar Grass Cutter with Lawn Coverage [5]. The proposed design aimed to develop an automatic grass cutting machine that could beremotely controlled, andable to charge the used batteries while the solar powered grass cutter is operating during daytime. Dilip B.P. et al. used several sensors in their prototype design providing the proposed solar grass cutter the capability to avoid the unnecessary objects and/or obstacles in the field during operation [6].

Asha N. et al. proposed a programmable robot that is able to work either autonomously or wirelessly using an Android Smart phone via Bluetooth from a safe distance[7]. The grass cutter can cut the grass according to preset shapes while the blade was able to be adjusted to maintain the different length of the grass. The robot is a dual powered with a Hybrid Solar panel and Lithium Ion rechargeable battery.This programmable robot is used to decorate the lawn and encourage the implementation of the renewable energy resources. Ulhe P.P. et al. [8]fabricated and modified the solar grass cutter that can be used to cut the different grasses with different applications. A remote-control unit was added to help the unskilled persons to operate it. The used battery in the designed grass cutter can be charged by using solar panels regardless of the operating conditions.An AC charging system and spiral cutting blades were used to increase the cutting efficiency. Amrutesh P. et al. [9]designed a solar grass cutter by implementing a linear blade and Scotch Yoke mechanism. The cutter was coupled with PV panels installed at 45 degrees angle and Lithium-ion battery as the power supply. The used solar charger has automatically controlled the charging from the solar panels when it was required.However, the authors found that the Scotch Yoke mechanism did not produced the expected efficiency.Solar based automatic grass cutter was fully automated grass cutting robotic vehicle powered by solar energy introduced by Gaikwd Y.M. et al.[10]. The device was capable of fully automated grass cutting without the need of any human interaction. The working principle of this project is the micro-controller moving the motors in the forward direction if there is no obstacle detected and vice versa if the sensor detects any obstacle.Smart is related to current technologies where the researchers want to integrate the current technologies into their daily life.

Technology is helping the human being to work less however receiving more outputs, save their time, ease their works. The human can take the advantages of current technologies to improve life quality as well as reduce the negative effects of the new technologies on the planet Earth. In this study, solar energy was used as a main power source to the proposed solar grass cutter. The proposed grass cutter combined the use of automation and manual in which it used sensors or remote controller to move. This proposed study is mainly to improve the current grass cutter design especially the position of the blade using the latest possible technologies.

II.METHODOLOGY

Design Identification

To design a Smart Solar Grass Cutter, some parameters need to be considered such as the components to be used in the project, the position of the components, the structure of the main body, the advantages and disadvantages of the design and the safety factors. The Smart Solar Grass Cutter is able to operate autonomously or non-autonomously. Other than that, the important factor is the efficiency. The materials and components selections including the positions are crucial to achieve a better efficiency.

This Smart Solar Grass Cutter is a simple design which is optimizing the usage of materials. The overall dimensions are depending on the size or the dimensions of the solar panel. Three motors are used for rear tires and the blade. The height of the roof is depending on the height of the battery. The rubber rotating wheel is used as the front tires as it will automatically change the direction depending on the rear tires. One motor is implemented for each rear tire. The design is cost effective and compatible to the main objectives. Starting from the hand sketch, the prototypeis designed in multidimensional using SolidWorks software. Dimensions of the design are very important and need to be accurate and precise to enhance the safety factor. Full dimensions are listed in Table 1.

Table. 1 Prototypedimensions

Part	Dimension (mm)
Roof	380 x 280 x 5
Bottom part of the body	480 x 280 x 5
Wall of the body	280 x 120 x 5
Front wheel	D 50
Rear wheel	D 150

Arduino microcontroller known as the brain of the prototype and PV panels are the main power supply. The PV panel supplied the absorbed energy to the battery through the solar charge controller. The solar charge controller protected the battery from overcharge as well as to maintain the battery performance. During autonomous mode, the ultrasonic sensor was detecting the obstacle. The sensor transfers the information to the microcontroller regarding the detected obstacle then the microcontroller will act, and the grass cutter will change the direction. If non-autonomous mode is used, Bluetooth module will be used to connect the Smart Solar Grass Cutter with the smartphone. The grass cutter will be controlled by using the smartphone and the direction is depending on the requirement. The microcontroller will be programmed to ensure both motors at the rear wheels will be having the same speed when it is required. If the grass cutter is needed to move to the right direction, the left motor will be having a higher speed compared to the right motor and vice versa.

From the hand sketching and digital design of Smart Solar Grass Cutter was created and shown in Figure 3. The Arduino Board, Bluetooth module and other electrical components are included in circuitry. Two DC motors were used for rear wheels and the third motor was used for the blades.The front wheels are made of rotating rubber tires located below the main body. The selection of the used materials and components are very important to produce a reliable and effective design of smart solar grass cutter.

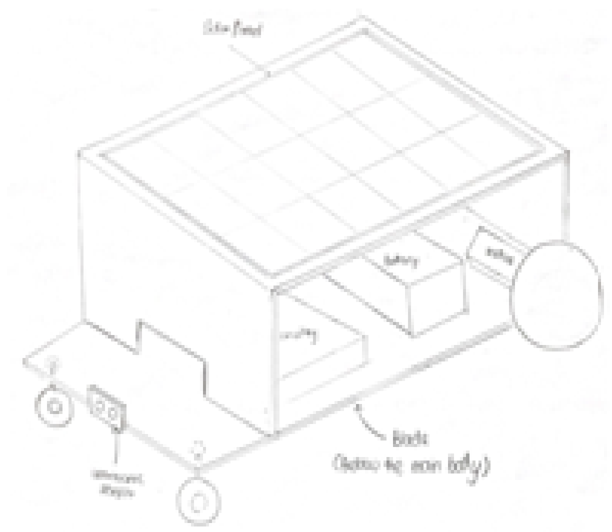

Fig. 1 Hand sketch design

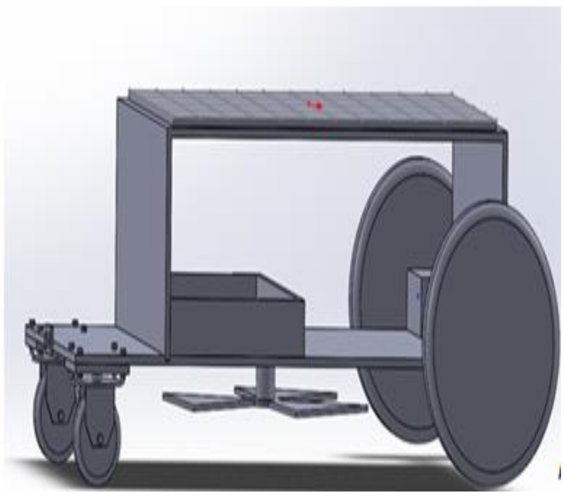

Fig. 2 3D design using SolidWorks

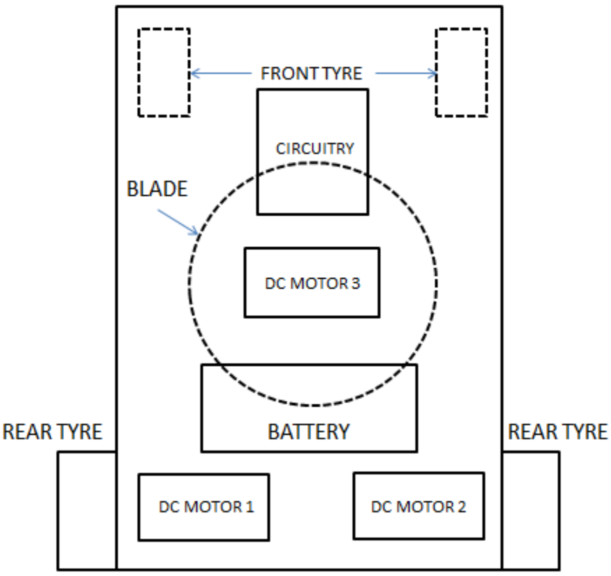

Fig. 3 Schematic diagram of the smart solar grass cutter

Table. 2 Smart Solar Grass Cutter material selections

Materials selection	Descriptions
Solar panel	PV panel of 12V and 10W
Solar charge controller	Pulse Width Modulation (PWM) regulator
Battery	7AH Li-ion
Arduino microcontroller	Arduino UNO board
Motors	DC motor (rear tires) 12V 1100RPM motor (blades)
Motor driver	MDD10A motor driver
Bluetooth module	HC-05 type

Design Calculation

In the numerical simulation, a model was implanted with unlimited variations to produce complex scenarios. These capabilities allow the analysis and understanding the interaction of each element in the system. Firstly, the design of the model must be developed. The model represents the system itself, whereas the simulation represents the operation of the system over time[11]. To conduct a simulation and fabrication, a design calculation is introduced and applied. The dimension of the blade is important as the calculation of weight required the volume Eq. (1). The volume can be obtained from the multiplication of the length, width and the thickness of the blade.

$$W = mg \quad \textbf{(11)}$$

The weight calculation of the blade is important to calculate the blade power. The blade power can be obtained by multiplication of the torque and angular velocity as shown in Eq. (2). The weight of the blade is used to calculate the torque. The calculation of the blade power is important to check the power consumption and the motor selection. The power of the motor was selected to be higher than the blade power to ensure that the motor is able to rotate the used blades.

$$P = T\omega = Fdx\frac{2\pi \times N}{60} \quad \textbf{(22)}$$

Based on the Eqs. (1) and (2), the calculated weight and power of the blade are 0.7N and 9.33W respectively. These values are used to calculate the total power consumption. Eq. (3) is used to calculate the value of the power consumption by both rear motors and the supplied power by the solar panel as well as the rechargeable battery.

$$P = IV \quad \textbf{(33)}$$

A single motor of the rear wheel is having 12V of rated voltage and 1.2A of rated current. By implementing Eq. (3), the power consumption of one motor is 14.4W. Therefore, the total power consumption is 28.8W for both rear wheels. However, the designed model is not using motors and blade. Therefore, an estimation of power consumption for one motor is 10W. As a result, the total power consumption of the whole system is 55.8W.

Theoretically, the total possible operation duration is calculated based on the values obtained from Eq. (1) to (3). A battery is taking up to 8.43 hours to be fully recharged. In this model, the battery used is 12V and 7Ah, thus the battery is able to supply 84Wh to the proposed prototype. Therefore, the total operation duration is 2.6 hours which the solar panel able to supply for 1.1 hours and the battery is supplying 1.5 hours.

$$\eta = \frac{P_{out}}{P_{in}} \quad \textbf{(44)}$$

However, the most important part of any design and development of a project is the system efficiency. The efficiency is required to prove the reliability of the systems. To sum up, it is important to show the improvement of new prototype compared to the previous studies. In the efficiency calculation, it is necessary to calculate the used power and supplied power by the system.

Circuit Connection

The Smart Solar Grass Cutter is using circuit connection to run the system. Connections were designed using Fritzing Software. Based on Figure 4, the solar charge control, battery, step down voltage regulator, Arduino UNO microcontroller, HC-05 Bluetooth module, MDD10A motor driver, motors and switch were connected to each other. To avoid any damage in the electrical appliances, the connection of the wires must be carried out by using the software first and then it must be simulated to avoid any possible in the circuit.

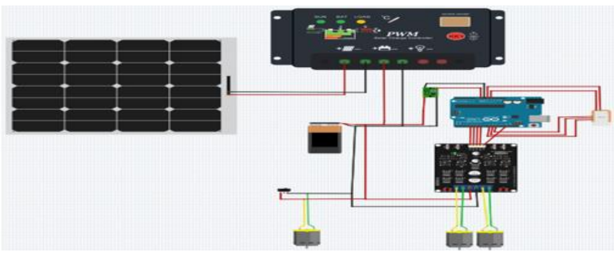

Fig. 4 Overall circuit connection

The similar connections are carried out in Proteus Design Suit (PDS). However, there is a difference in the use of the motor driver. The real motor driver used for the system is MDD10A dual motor driver, but it is not available in Proteus library. Thus, different motor driver is chosen to achieve an approximate result of this simulation. The coding also is changed according to the pins number.

III.RESULTS AND DISCUSSION

Stress-strain Analysis

Based on the calculated design value, the whole prototype body is numerically analyzed by using SolidWorks software to analyze the stress-strainof the selected material for this part which is MS Plate. To perform the simulation, a fixed geometry is set at the bottom (green arrow) as shown in Figure 5. Then an estimated 10N external forces is applied on the top of the roof of the grass cutter, as shown in Figure 6. The value is based on the mass of the solar panel and weight of the roof material.

Since the prototype is able to withstand all the forces in the stress-strain analysis, it can be concluded that the prototype is mechanically reliable. However, as shown in the Figure 5, there are few red colors on the wall of the body due to the weight of the solar panel. It is important to conduct a further stress-strain analysis to smoothen the process of the prototype fabrications without having any possible failure.

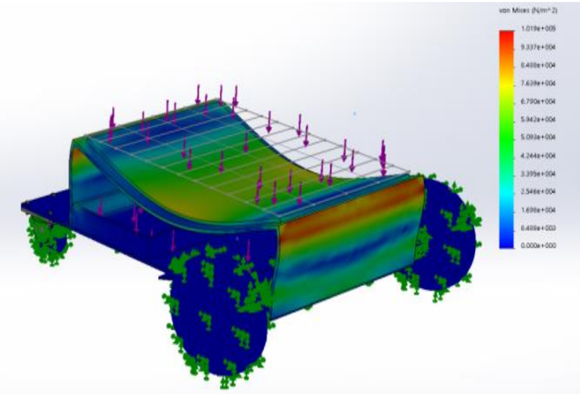

Fig. 5 Stress-strain analysis by SolidWorks

Fig. 6 Prototype of smart solar grass cutter

Design Analysis

Thesmart solar grass cutter is consuming a total power of 55.8W while the supplied power is 59.76W. By adopting these two values into the Eq. (4), the efficiency of the system is 93.37%. It is found that the efficiency of this prototype is improving by around 37% compared to the previous study [12].

Table. 3 Experimental result

Test	Test 1	Test 2	Test 3
Fully charge (hours)	7.8	7.9	8.1
Total operation time (hours)	2.2	2.0	2.3

According to Table 3, three tests have been conducted totest on the operating hours of the fully charged prototype and charging time. It can be seen that there are three different results which are depending on the unpredictable factor such as the weather.Due to the high intensity of the sunlight, the grass cutter may consumethe solar power directly instead of the battery which led to extend the operating time. Other than that, the charging time is affected by the intensity of the sunlight. High sun light intensity might lead to less charging time. However, the battery itself also can be considered as one of the factors. For example, the drained battery which is 10% capacity might take longer charging time compared to 30% capacity battery. Based upon the theoreticalvalue, the total time for 12V 7Ah battery to be fully charge is 8.43 hours. In conclusion, the proposed prototypeis taking shorter time to be fully rechargedaccording to the three sets of experiments as shown in Table 3. Therefore, the Smart Solar Grass Cutter can be a reasonable replacement the conventional grass solar cutter.

IV.CONCLUSIONS

A workable smart solar grass cutter prototype is focusing on therenewable energy as the primary sources of energy has been successfully fabricated with high working efficiency. Therefore, it can be concluded that the developed design of the proposedSmart Solar Grass Cutter has achieved the mainobjectives and it can be further developed by industry. Smart Solar Grass Cutter is able to reduce the air pollution and also it is auser-friendlydevice. The grass cutter is suitable to be used for small application due tothe shortest operating time,but it is notsuitable for tall height grasses.For future work, there are few recommendations can be made to develop a better device. Instead of using polycrystalline solar panel, it is better to used mono-crystalline solar panel due to the high efficiency. The motor for the blade should have both high speed and torque. Higher capacity of rechargeable battery can lead to more operating time. Lastly, few types of blade to be considered to cut different types of grasses.

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