Fabrication of a Locally Designed Solar-Powered Wheelchair

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Abstract
Powered assistive technology has greatly restored ambulation of patients or persons with physical disability or impairments. Recharging the battery of the electrically powered wheelchairs can be challenging due to inadequacy of conventional energy sources in the developing nations. Due to WHO considerations, the work designed a solar powered wheelchair that is user- and environmentally-friendly. The main factors considered for the design were the weight, speed, cost, durability, width and height of the wheelchair. Two 24volt DC gear motors; two 12volt, 36AH batteries; and a solar panel of 18volt, 80 watt capacity were used among other electronic components to achieved the device. The microcontroller (atmega32) maximum consumable current is 200mA and it served as the processor. The inclusion of the ultrasonic obstruction monitoring sensor, solar panel roof and the recommended average speed of 1.79m/s made the vehicle safe for distant outdoor use. Its control commands included start/ stop, front, back, left, and right. The battery is recharged by the solar panel. The relatively low-cost solar powered wheelchair is proven to be an efficient mobility aid, improving life quality, and the dignity of the elderly and others with mobility difficulties arising from pathological disabilities and accident-related injuries.

Key words: Fabrication, Locally-designed, Solar powered, Wheelchair, Disability

1. Introduction

There is a great need to meet the challenges encountered by persons living with disabilities which has brought about activity limitations and participation restrictions. For this cause, so many devices and systems have been developed, geared towards solving the issues of activity limitation and participation restrictions in order to restore the hope of individuals living with disabilities. The aspect of technology concern with the development and application of these devices and systems is referred to as assistive technology, and such devices are called assistive devices. Assistive technology device means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability [1].

Some of these devices that assist individuals living with physical disabilities are the mobility aids for people with walking difficulties under which the wheelchair falls. Among others such as clutches, walking canes, mobility scooters etc.

There remains a vast need for quality wheelchairs around the world. The World Health Organization (WHO) estimates that 10% of people with disabilities (around 111 million) require a wheelchair and only about 5% – 15% have access to an appropriate one, suggesting that the unmet need is approximately 95 million wheelchairs [2, 3, 4].

A wheelchair is a chair with wheels to help people move around. It is used by individuals who have impairments that limit their ability to walk. It

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typically consist of a seat supported on two large wheels attached towards the back of the seat and two small wheels (casters) in front near the feet, a good braking system, footrests and a cushion [5, 6]. The user moves by pushing with his/her hands circular bars on outside of the large wheels, known as the hand-rim or push rings.[6] The manual wheelchair has the disadvantage of requiring much effort for propulsion or dependency on an assistant for movement, hence the need for powered wheelchairs.

A powered wheelchair (PW) is a motorized wheelchair propelled by means of an electric motor powered by batteries rather than manual power [7]. The motors used to drive powered wheelchair or electric wheelchairs run on batteries. As a result, they have a relatively limited travel range and require frequent recharging [5].

A common problem faced in the developing countries is the scarcity and depletion of energy resources, so solar power eco-friendly energy resource can be an alternative to electrically driven vehicles to a massive amount. Rated solar radiation power received by the earth surface is (global radiation flux) 1000 W/m² (AM 1.5, sun at about 48 °C from overhead position) [8].

The users are the most knowledgeable about their own physical, social and cultural needs [9]. There are two classes of powered wheelchairs and powered mobility scooters. Manual wheelchairs and Class 2 vehicles are those with an upper speed limit of 4 mph (6 km/h) [10]

Considering the aged and disabled individuals in our locality, they cannot propel themselves on a manual wheelchair neither can they afford a foreign electric powered wheelchair that will still suffer redundancy, thus less effective due to power supply interruptions in our rural settlement. This project therefore considers a solar powered wheelchair for its advantage of less stress, greater independency of the user, and high efficiency.

The solar powered wheelchair is a motorized wheelchair propelled by means of electric motors powered by a rechargeable battery recharged by solar energy. They can also be used not just by people with traditional mobility impairments, but also by people with cardiovascular and fatigue based conditions.

2. Design Methodology

2.1 Materials Used

- Iron pipe for the frame
- 2 of 24V 150W DC gear motor
- Gauge 18 sheet metal
- 2 Large spoke wheels
- 2 Small wheels (0.18m in diameter and thickness of 0.04m)
- 2 of 12Volts, 36AH lead-acid battery18volt, 80watt solar panel
- Electronic components

2.2 Design Consideration

The main factors that are considered for the design of the wheelchair are weight or load, speed, width and height of the wheelchair. The design is use-centered design to accommodate individual of different body size and body mass.

2.3 Block Diagram of the Electrical System Model

This is a block diagram of the system model comprising of mainly the electrical components and the solar power supply. These components are encased in the mechanical components of the model as seen in Figure 1.

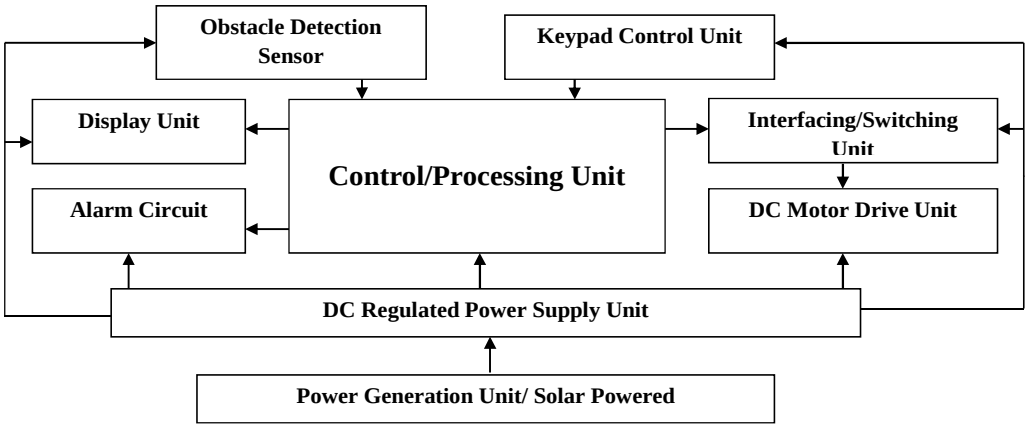

Figure 1: Block diagram of the main electrical system model

2.4 Calculations

Maximum Wheelchair Speed

Diameter of wheel = 0.30metre

Circumference (in meters) = $\pi \times d$ (diameter in meter)

Circumference = 3.142 x 0.30 = 0.94meter

Taking maximum wheelchair speed on load to be 6.0km/h [10].

Maximum Speed = 6.0km/h. (maximum wheelchair speed for safety)

Speed = 100.2m/min. $Speed = \frac{6.0 \times 1000}{60 \times 60} = 1.67m/s$

$$Revolution\ per\ minute = \frac{Speed\ (inmeterpermimute)}{Circumference\ (inmeter)}$$

$$RPM = \frac{100.2}{0.94} (\text{required revolution per minute of the motor under load})$$

RPM = 106.6 (rpm)

RPM = 107 (round figure)

Power of DC motor in Watts

Power = W/t =Fd/t = F . V (Force X Velocity)

Power (watts) = Total weight x g x speed x gradient [11]

Gradient = slope (assume 3%) [8].

where, Total weight = 150kg

(Person = 70 kg, weight of the system = 80 kg)

Speed = 6.0km/h = 6000 / 3600 m/s = 1.67 m/s

Power = 150 x 9.81 x 1.67 x 0.03 = 73.7watt (approximately 74watt)

Therefore power required is 74 watt (for single motor).

Using 2 motors requires double power [8].

As we are using 2 motors, power required is 148W, approximately 150watt.

Thus, a 24volt150 W motor will be enough for the wheelchair.

Torque = force x radius

(Total weight = 150 kg)

Weight (on each wheel) = m x g = 75 x 9.81= 735.75 Newton

Diameter = 0.3m, so radius = 0.15m

Torque = force x radius= 735.75 x 0.15 = 110.36Nm

2.5 Design Specifications

2.5.1 Specifications

Weight capacity: 150Kg

Maximum speed: 6.0Km/h (1.67m/s)

Motor: DC 24V, 150W (times 2)

Battery: 12volt, 36AH (times 2)

Rear wheel drive

Four wheels on the ground.

2.5.2 Dimensions

Table 1: Dimensions of the solar powered wheelchair

Dimension	***Length (m)***
Overall height	1.45
Overall width	0.63
Overall length	1.20
Seat height	0.48
Seat depth	0.05
Backrest height	0.50
Backrest width	0.04
Arm rest height	0.18
Arm rest length	0.34
Thickness of front wheel	0.05
Thickness of back wheel	0.04
Diameter of front wheel	0.20
Diameter of back wheel	0.30

2.6 Program Flowchart

Figure 2: Program Flowchart

2.7 Complete Circuit Diagram of the System

Figure 3: Complete circuit diagram of the system

2.8 Description of Different Sections of the System

2.8.1 Power Supply Unit

The system power supply consists of a DC voltage. The output voltage supply is +5V DC and +24V DC which is what the discrete components including the microcontroller demands for proper functionality. The power supply got its source from two 12V DC batteries in series. The battery powers the entire system including the DC motor drive. The battery is being recharged with the solar panel.

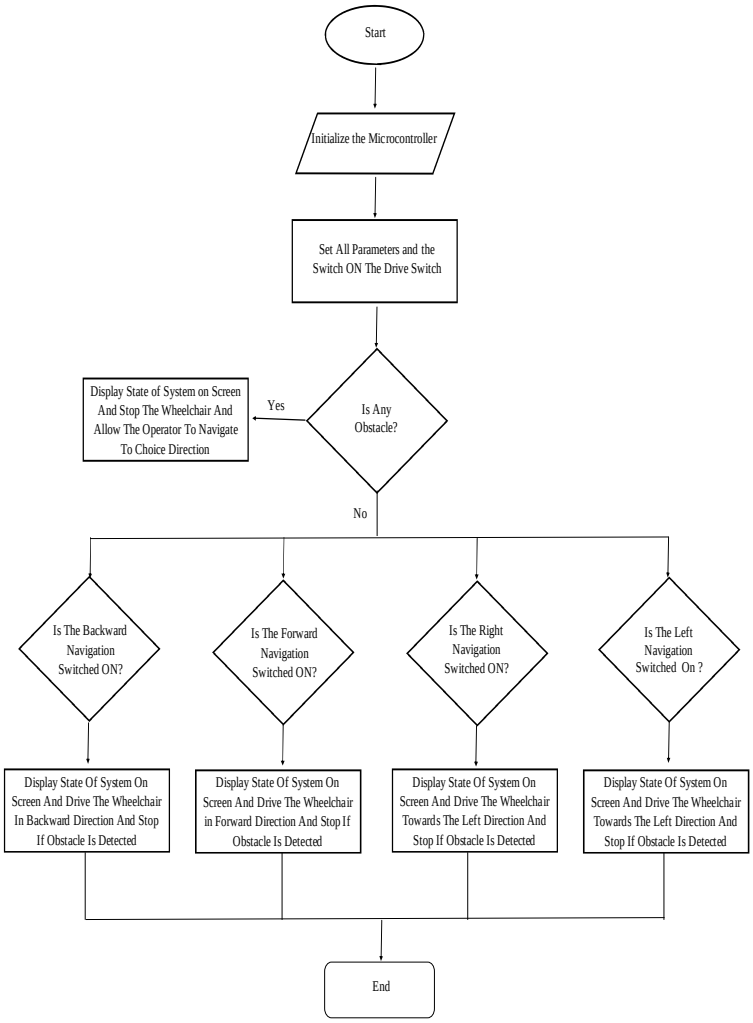

Figure 2: Program Flowchart

2.8.2 Obstacle Detection Sensor

The obstacle sensor uses ultrasonic sensor to detect obstruction within a stipulated distance. If the sensor senses obstacle, it directly sends signal to the microcontroller which takes decision based on the received signal.

2.8.3 Control/Processing Unit

This unit monitors and controls the behavior of the entire system. Each sections of the entire input channel sends signal to the control/processing unit, then the control/processing unit accepts and interprets the accepted signals and takes its decision through the alarm section. Microcontroller (atmega32) maximum consumable current is 200mA

2.8.4The Alarm Unit

The alarm circuit serves as an interpretation medium for the wheelchair user in the occurrence of obstacle. It produces beep signal any time an obstacle is detected. If microcontroller receives an obstacle signal sent by the obstacle sensor, it sends output to the buzzer by blinking it continuously without stopping until the wheelchair is driven out of the obstacle position.

2.9 Operation of the System

The microcontroller receives instruction from the control channel. Once the start button of the control unit is pressed, the microcontroller first automatically Scan the system to note if there is any obstacle. In the absence of any obstacle, the microcontroller gives a go ahead other. The controller unit comprises of five different command buttons (Start, Front, Back, Go Left and Go Right Button). Each of these buttons determines the movement direction of the Wheelchair. If the wheelchair detects obstacle while on motion, the wheelchair automatically stops and allow the user to navigate to the choice direction.

The microcontroller monitors the command buttons to note the next operation. The power section of the system uses solar energy as the source of recharging the battery. Two batteries of 12V 36AH

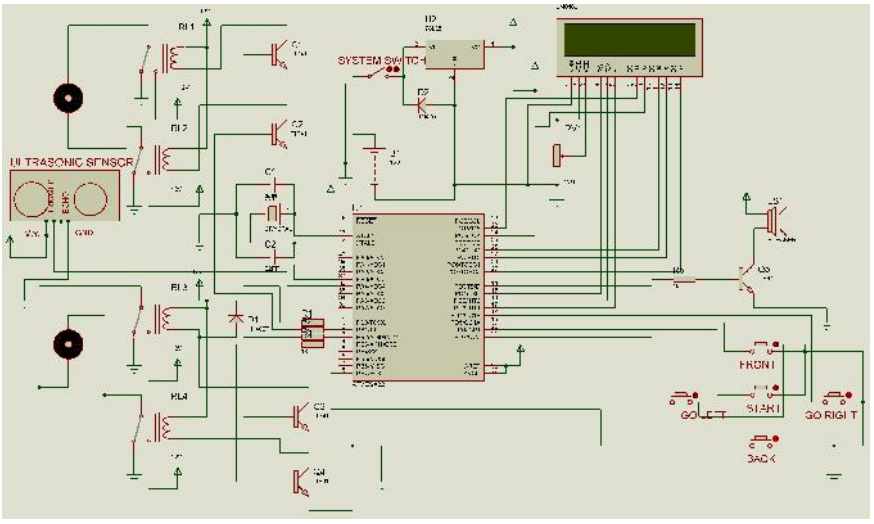

Figure 3: Complete circuit diagram of the system

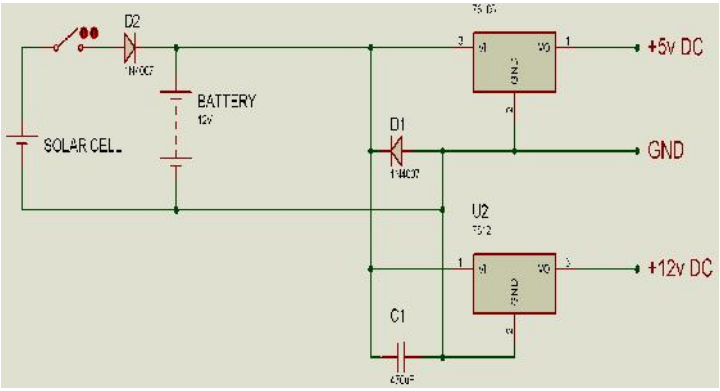

Figure 4: Power Supply Unit

connected in series was used to power the entire system after passing through the voltage regulator which determines the final output voltage. The system uses A Liquid Crystal Display module as a medium of visualizing the entire system behavior. This enables easy communication between the user and the system.

2.10 Testing

2.10.1 Obstacle Detection Test

The wheelchair was driven and obstacles were placed in front at different points. At about 2 meter distance to each obstacle, the buzzer was triggered. The user has to navigate to a different direction.

2.10.2 Functionality Test (Test on Load)

The wheelchair was driven by five persons of body weight 40kg, 55kg, 62kg, 70kg and 80kg respectively. Each person was allowed to travel a distance of 10meters and stopwatch was used to read the time taken for the distance covered. A slight decrease in speed with increasing load was observed. The result of the test is shown in Table 2.

3. Results and Discussion

3.1 Project Result

This solar powered wheelchair has been designed and fabricated with locally available materials like iron pipe, dc gear motors of 24volts, 2 rechargeable battery of 12volt capacity, 18volt solar cell, wheels and casters.

A right hand key-pad drive mechanism is provided including an ultrasound obstacle detector. The speed is limited to 6.0Km/h (1.67m/s) for safety purpose.

Recommended maximum user weight is 80kg. The battery voltage is display on the screen to give information on when to switch 'ON' and switch 'OFF' the solar power.

The solar assembly of the wheelchair is dismountable for easy transportation of the solar powered wheelchair in vehicle.

The picture of the fabricated solar power wheelchair is shown in Figure 5.

3.2 Functionality Test of the locally produced solar powered wheelchair

The results of the functionality test is shown in Table 2.

Figure 5: Picture of the Fabricated Solar Powered Wheelchair (back and front views)

Average speed of the wheelchair on load (user weight of 40kg to 70kg)

(2.09+1.85+1.76+1.67+1.57) / 5 = 8.94/5

Average wheelchair speed = 1.79m/s

3.3 Relationship between User Weight and Speed of the Wheelchair

The relationship between speed and user weight is shown

Table 2: Results of Functionality Test (Test on Load)

S/No	User Weight (kg)	Distance Travelled (m)	Time Taken (s)	Speed (Distance/Time) (m/s)
1	40	10	4.78	2.09
2	55	10	5.41	1.85
3	62	10	5.68	1.76
4	70	10	5.99	1.67
5	80	10	6.37	1.57

in Figure 6. The speed of the wheelchair is inversely proportional to the weight of the user as observed in Figure 6..

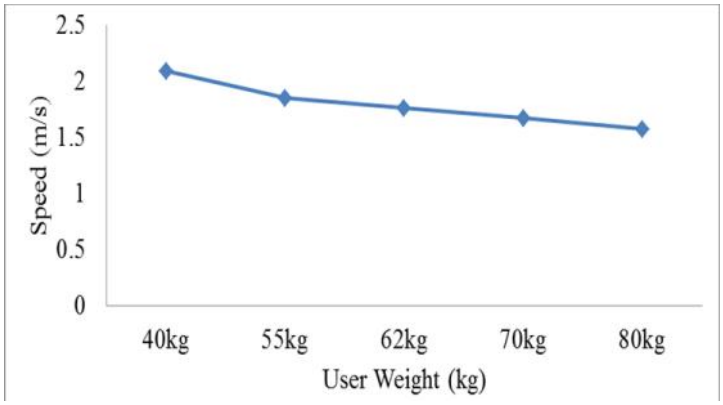

Figure 6: Graph Showing Relationship of the Wheelchair Speed against User Weight

3.4 Discussion

About 10% of the global population, i.e. about 650 million people, have disabilities [12]. Studies indicate that, of these, some 10% require a wheelchair [6]. There are needs for efficient mobility of those living with walking disabilities in order to maintain the dignity of the elderly people. Also, those suffering from ailments resulting in fatigue and pain can also benefit from a powered wheelchair [13]. In addition, improving educational results for children with disabilities is an essential element of our national policy of ensuring equality of opportunity, full participation, independent living, and economic self-sufficiency for individuals with disabilities [1]. Meanwhile, the available wheelchairs in Nigeria have no provisions for independent disabled persons with visual impairment in places with poor electricity supply. This necessitates the local design and fabrication of this solar powered wheelchair with ultrasonic obstacle detector.

This work locally designed and fabricated a solar powered wheelchair as an efficient mobility aid to the elderly ones and individuals living with walking disabilities in rural settlements and in the less privileged homes, at relatively affordable price. Its speed is within the UK range [10].

From the functionality test, the solar powered wheelchair is proven to be an efficient mobility aid for people living with walking disabilities and the elderly ones. It overcomes the problem of dependency or requiring much effort for propulsion as with manual wheelchairs. Electric powered wheelchairs were invented to solve the problem of dependency and effort for propelling a manual wheelchair but not efficient for longer distances and with frequent need for recharging. The motors used to drive electric wheelchairs run on batteries. As a result, they have a relatively limited travel range and require frequent recharging [5].

Ahluwaliahad rightly stated, "Solar power eco-friendly energy resource can be an alternative to electrically driven vehicles to a massive amount" [8]. In addition, this solar powered wheelchair solve the problem of propelling effort by the user, alleviates dependency or the need for an attendant and as well eliminates the frequent need of recharging the battery with the unreliable electric power supply in the rural or poorer areas. Solar powered wheelchair is more efficient for outdoor movements of the disabled as the battery is continuously recharged by solar energy when necessary and thus the wheelchair runs outdoor, nonstop.

The solar assembly of the wheelchair is dismountable for indoor use or for easy transportation of the solar powered wheelchair in a bigger vehicle.

From the functionality test, the solar powered wheelchair can carry any person up to a maximum of 80kg body weight with recommended speed [10].

There are certainly different models and types of wheelchair which is being used widely in the current environment. But everyone has its own limitations over one another [14, 15]. The advantages of this locally designed solar powered wheelchair over the available ones in Nigeria, include that this solar powered wheelchair is designed for independent indoor and outdoor movements of the mobility impaired. The solar panel also provides shelter for the user against rain and the heat of the sun during outdoor mobility. In addition, the Ultrasonic technologies (Electronics Travelling Aids, ETAs) device added to the wheelchair will assist the blind and physically challenged peoples [16]. This ultrasonic obstacle detector enhances the safety of the wheelchair and the safety of the user, hence this relatively cheaper vehicle is quite safer compared to other available manual or powered wheelchairs in Nigeria. This local fabrication enhances regular and relatively cheaper servicing / maintenance which is necessary for reducing breakdowns, repairs, occurrence of adverse events (e.g. accidents) and improving reliability [16, 17, 18]. This wheelchair is safe, strong, durable and appropriate for the local environment in which they will be used, according to WHO [6].

4. Conclusion and Recommendation

The fabrication of this locally designed powered wheelchair with bio-friendly alternative energy supply, obstruction detector and shelter provides a more efficient independent mobility aid for persons living with walking disabilities and for aged or fatigued individuals in order to restore or maintain their dignity. Users can give five (5) command signal to the wheelchair which is start/stop, front, back, left and right. The ultrasonic sensor enhanced the safety of the wheelchair by detecting obstacle and sounding an alarm to call the attention of the user in case of distraction.

Comparatively, the movable solar powered wheelchair is efficient for outdoor distant movements as the battery is continuously recharged by solar energy when necessary. The solar assembly is dismountable for easy transportation of the wheelchair in bigger vehicles.

The vehicle is therefore recommended as a prototype for mass production in order to provide an efficient mobility aid for persons living with walking disabilities and the elderly or weak ones. This wheelchair is considered essential for improving the mobility, living quality, and dignity of the elderly and for those with mobility difficulties arising from physical disabilities and accident-related injuries.

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