ISSN No:-2456-2165

Development of Solar Powered Electric Wheelchair for Physically Challenged Persons

Ohaneme Cletus Ogbonna
Department of Electronic and Computer Engineering
Nnamdi Azikiwe University Awka, Nigeria

Ufoaroh Stephen Uchenna
Department of Electronic and Computer Engineering
Nnamdi Azikiwe University Awka, Nigeria

Nnebe Scholastica Ukamaka
Department of Electronic and Computer Engineering
Nnamdi Azikiwe University Awka, Nigeria

Obioma Peace Chibueze
Department of Electronic and Computer Engineering
Nnamdi Azikiwe University Awka, Nigeria

Abstract:- Persons with disability face many physical challenges, including nerve and muscular degeneration, reduced motor function and balance, impaired mobility, and so on. This research work proposes a solar power-assisted wheelchair for the differently disabled low income persons living in developing countries like Nigeria. This paper envisages an electric wheelchair that is cost effective, sustainable and efficient in terms of energy consumption. This wheelchair is designed especially for the paraplegics and aged people with an aim to make them more independent. The major components of the model are: the mechanical structure, the solar panels, the DC motor, and the control circuitry. The solar panels serve the dual purposes of providing shelter for the user and also providing the electrical energy that powers the electric motor. A prototype of the proposed model was produced and tested for the design goals

Keywords:- *Paraplegics, Wheelchair, Solar Panel, Electric D.C. Motor, Microcontroller, Deep-Cycled Battery)*

I. INTRODUCTION

In various homes, the presence of paraplegics have become source of worry to the parents/relations and members of the society especially as it concerns their movements. Wheelchair is a vehicle developed to aid patients' mobility as well as moving physically challenged people from one place to another with the help of attendee or by means of self propelling. Direct Current (DC) motors can also be deployed to provide the driving force for a wheelchair. Hence, in recent times, the prevalence loss of limbs in the society due to accidents, health problems, wars and age, this work has provided developed Solar Power Electric Wheelchair (SPEW) for paraplegics to alleviate their mobility being experienced when using clutches or manually operated wheelchairs. In this paper, the SPEW that meets up with the users' needs was designed and developed using electric motorized wheelchair to initiate the movement and the microcontroller that controls the movement on a press of buttons. The source of propelling force to provide the needed power was provided by the solar panel. The solar panels serve the dual purposes of providing shelter for the paraplegic and also providing the electrical energy that powers the electric motors. Various mechanical components/parts of the wheel chair are designed and constructed, and other designed electrical driving circuits are coupled to the wheelchair to arrive at the completed work. In this work, Prototypes was produced and tested, while validation of the prototype was carried out after test to ensure that the usage was found to be satisfactory. From the test carried out, it was found that the developed wheelchair is affordable, durable and alleviates the problem associated with the movement of the users (physically challenged). The constructed wheelchair is capable of providing cost effective and easily operated system that alleviates the mobility problems experienced by physically challenged persons in Nigeria and beyond. Some electronic devices are installed for changing directions while in motion and facility for keeping plate while eating food, reading and keeping water bottle was also provided. It will also serve for both indoor and outdoor purposes. For the indoor purpose, it can be deployed in hospitals for patients whose ailment cannot allow walking, and for the outdoor purpose, the paraplegics are the target.

Therefore, wheelchair is considered an essential device that can help to alleviate the problem of mobility, living quality, and dignity of the elderly and those with mobility difficulties arising from physical disabilities, accident-related injuries, and other sources. However, existing wheelchairs can be categorized as manual, electric-powered, or power-assisted depending on their mode of propulsion. There are indications that very low percentage of those in need of wheelchairs can afford the exorbitant ones. Therefore, the need to solve this problem lies in designing developing a low cost that can be locally accessed with less difficulty by target users. This is the idea behind the design and construction of a Solar-powered microcontroller-based wheelchair for paraplegics and other impaired persons. The work also solves the problem which the indoor and outdoor movement the physically challenged may be experiencing by providing a medium-power, easy-to-control electric wheelchair, [1].

The constructed wheelchair consists of both electronic and electromechanical sections. The electronic section comprises of a microcontroller Integrated Circuit (IC) which receives input commands from buttons on a keypad, processes them, and issues out appropriate control signals. Also included is a charge controller that charges and also prevents the battery from overcharging beyond a certain predefined level. The electromechanical section comprised of two worm-geared, brushed DC motors with their Relay switches. One DC motor takes care of the forward/reverse direction of the rear wheel while the other is for the left/right direction of the front wheel. The frame of the wheelchair is made of a chair of light weight metallic steel sheet material. It is fabricated by welding to fix and support the battery and control circuitry. Also, provision is made for the spare tyre to be fixed at the back of the seat of the wheelchair in the event of emergency.

This work is relevant in the hospital and for the paraplegics with the following benefits:

(1) Minimal effort is needed to control the wheelchair because it uses a simple keypad so that patients find it to be user friendly.
(2) With the solar powered electric wheelchair, the user does not have to depend on someone else to push the chair around thereby allowing the user the independence of moving about.
(3) The power of the solar powered wheelchair makes it easier for paraplegics to move up or down relatively low hills with less energy expended and without any assistance from attendee.
(4) When using a manual chair to travel to far distance, it is required that the user takes into consideration how much energy that is needed to travel to and fro the destination.

Therefore, with this type of developed solar powered electric wheelchair, which is only limited by the amount of power stored in the installed battery, the solar panel provides charging capability on the battery while moving especially in outdoor environment.

II. LITERATURE REVIEW

The history of wheelchair dates back to 1595 when it was invented for the King of Spain called Philip. In 1655, Stephen Farfler built a self-propelling chair on a three wheel chassis as shown in the works as reported in [1]. There are several other outstanding evolutions which wheelchair underwent until recently when serious researches were undertaken to automate the wheel chairs thereby making it more user friendly, cheap and portable.

One of the most outstanding of them is where different types of sensors were deployed in the development of solar powered wheelchairs as reported in the work of [2] as smart wheelchair. The smart wheelchair as it was called by the authors consists of PIR sensors, ultrasonic sensor and accelerometer which was designed to serve people who has difficulties in walking, people who are partially blind (50%-60%), people who are aged having muscular problems and people who are paraplegic and quadriplegic. This wheelchair is the combination of all wheelchair such as automatic wheelchair, electric wheelchair, solar wheelchair e.t.c., hence the name multipurpose wheelchair. Because of its peculiarity, it can be inferred that a low income paraplegic cannot afford it. The maintenance cost may also be high. It is therefore necessary to produce a more affordable wheelchair which will serve an average and lower income earner such as the one we are proposing here.

Before then, [2] and [3] developed a solar powered wheelchair capable of assisting the physically challenged in their mobility. In their works, the authors showcased the wheelchair with a user-selectable manual/electric propulsion mode and auxiliary solar power supply system.

Traditional manual wheelchairs induce a greater oxygen consumption and a higher respiratory exchange ratio and therefore beneficial to the user's health when properly used. However, the gross mechanical efficiency of such wheelchairs (i.e., the ratio of the external power to the metabolic power) is just 2 to 13.8 percent, depending on the injury, the propulsion technique, the adjustments made to the wheelchair interface (e.g., the seat height), and the intensity of the exercise taken, [4]. Thus, this low mechanical efficiency, coupled with high physical strain imposed on the movement of the user, may result in fatigue or even strain-induced injuries in the worst-case scenario. As a result, the design and development of electric powered wheelchairs (EPWs) or power-assisted wheelchairs has attracted increasing attention in recent decades, [5] as reported by [4].

Compared with Manual Wheelchairs (MWs), Electric-Powered Wheelchairs (EPWs) have several important advantages, including reduced user effort and a lower risk of strain-induced injuries. However, present EPWs still have many disadvantages including a long charging time, a large physical size, a heavy weight, and a high expense. They are also the most inconvenient to maintain because of the wear and tear that occurs in many mechanical part and deterioration of electrical components when constantly put into use.

In the works of [6], a wheelchair which gave several options to the user (physically challenged) and attendee by providing the ease of defecation, cleaning and changing of clothes was produced. In their work, adjustable back rest, arm rest, leg rest and foot rest was included to provide comfort for the patients while resting. The adjustable arm rest provided was for the ease of shifting the patient/user from chair to the bed or to the vehicle. Besides, alarm facility was provided to inform the attendee that there is the need for his/her presence to the patient.

The Geographical Position System (GPS) and Global System for Mobile Communication (GSM) modules that play a role of identifying the position of the wheelchair was deployed in the electric wheelchair designed and produced by [7]. The idea was useful to the person who takes care of the physically challenged to know the exact location of the user at any point in time. This is achieved with the help of ardiuno which receives signal power from the battery with voltage regulator because ardiuno, GPS and GSM modules require less power compared to the motors and other assemblies. Also, a mobile application was created in order to view the disabled position through Google maps. In addition, the authors focused on converting the wheelchair into semi/complete stretcher model using motorized scissor jack.

Joystick was also provided to steer the wheels in a particular direction.

[8] in their paper showed the designed and implemented a low cost solar powered wheelchair for physically challenged people using surface Electromygraphy (sEMG) technique. In this technique, the raw sEMG signals are collected from the upper limb muscles, processed, characterized and classified. The direction of movement of wheelchair is extracted from the classified signal, and the accuracy of the extracted EMG signals was found to be high. The sEMG signal acquired was related to the movement of hand and forearm which was pre-processed, filtered and amplified and then fed to a microcontroller which produced the driving pulses necessary for the motors to drive the wheelchair.

Another model of solar powered wheelchair equipped with solar trackers was developed by [9], so as to track the path of the sun rays and make maximum possible use of the available solar energy. The developed model was a three-wheeler system which is manually handled and is solar assisted. It is a standalone system which was self-operated and independent in nature, using an unending solar energy from the sun. It consists of a solar panel to produce electricity, a battery system for preserving electric power, efficient motors, and cushion seat, all terrain tires were used for the solar three-wheeler system, [9] and [10].

In the work of [11], the vehicle (wheelchair) was controlled using microcontroller Integrated Circuit (IC) which receives input command from buttons on a keypad, processes them and issues appropriate control signals for the directional movement of the wheelchair. It consists of both mechanical and electrical sections.

In the works of [12] and [13], solar powered motorized wheelchair was developed for patient handling thereby relieving patient and nursing staff from a lot of physical discomfort. The vehicle would be helpful for many of mentally disabled as well as physically challenged thereby not making the affected user but to rely on any external help. The wheelchair takes input from the user through joystick and deciphers the motion into power to the wheels to move the user in the preferred direction.

In summary, the developed electric wheelchair is cost effective to provide necessary assistance to the paraplegics and other disabled person so that their sufferings is minimized.

III. METHODOLOGY

The work is implemented using the following stages

(1) Construction of the mechanical system (skeleton of the wheelchair)
(2) Design of the power section (solar power system)
(3) Design of the control system
(4) Provision of the braking system and other accessories such as upholstery, alarm system (horn), e.t.c.
(5) Assemblage of the complete solar-powered wheelchair

(A) Calculations (Electrical/Electronic Designs)

It is assumed in this work that the user is expected to weigh between 80kg and 100kg. However, it is also expected that the wheel chair will weigh about 70kg. Then, the total weight of the wheelchair including the person (using 100kg) is 170kg.

(1) *Power of the Electric Motor*

It is important at this juncture to calculate the power that should be used to drive the wheelchair which will be provided by the electric motor. This can be determined according to [3] as follows;

$$Power\ (Watts) = Total\ weight \times gravitational\ force(g) \times assumed\ speed \times assumed\ gradient \quad (1)$$

Where,

$$Totalweight = 170kg$$

$$gravitationalforce(g) = 9.81m/s$$

$$assumedspeed = 5kmp = 5 \times \frac{1000}{3600} m/s = 1.38m/s$$

$$assumedgradient(slope) = 3\%$$

Therefore, the total power to be delivered is

$$Power = 170 \times 9.81 \times 1.38 \times 0.03 = 69.04\ watt$$

Therefore, the power required is approximately 70 watts (for single motor). Since there are two DC motors for the wheelchair, then the power required is approximately 140 watts.

Thus a 24 Volt 140 W motor was enough to propel the wheelchair

(2) The Battery System

The system voltage is 24 Volts, and Power is 140 watts, then the load current (I_L) is

$$I_L = \frac{power}{voltage} = \frac{140}{24} = 5.83\ Amps$$

It was estimated that the wheelchair shall be run for 8 hours continuously per day. Then the load current that provided for the wheelchair is computed using

$$LoadCurrent = 8 \times 5.83 \times 1.2 = \frac{55.96Ah}{day} \approx 60Ah/day$$

Assume 10% overall loss in the system,

$$Batterysize = 60 \times 1.2 = 72\ Ah/day$$

Energy required for the motor

$$= Vit = 60 \times 24 = 1440\ Wh/day$$

Therefore, 60 Ah/day, 24 Volt power was required for the system

(3) Solar Power Supply

(i) Solar Panel

The Solar Power supply comprises of the solar panel and a charge controller.

The block diagram of the solar-based power supply system for the wheelchair is as shown in figure 1

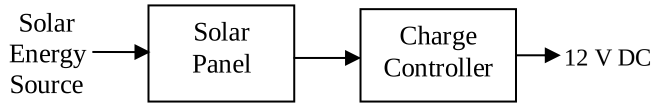

Figure 1: The block diagram of the solar-based power supply

The solar panel is responsible for converting solar energy to electricity which is capable of charging the battery while the charge controller is responsible for preventing the battery from overcharging.

The specifications of the solar panel used are as shown in Table 1.

TABLE I. SPECIFICATION OF SOLAR PANEL

S/N	*Parameters*	*Values*
1.	Power (W)	100 Watts
2.	Open Circuit Voltage (Voc)	21.6 V
3.	Short circuit current (Isc)	6.46 A
4.	Maximum Power Voltage (Vmp)	17.2 V
5.	Maximum Power Current (Imp)	5.81A
6.	Cell Type	Polycrystalline
7.	Frame Type	Silver
8.	Junction Box	Yes
9.	Length	41.81”(1062mm)
10.	Width	26.57”(675mm)
11.	Depth	1.18” (30mm)
12.	Weight	19.62 lb (8.9 Kg)
13.	Connector	MC4 Pigtails 900mm

The charge controller performs two-position control capabilities in which it compares an analogue or variable input with reference input and generates a digital output. In this case, the controller operates as a comparator. Hence, it compares the variable input signal corresponding to the battery voltage level to the fixed reference input signal and generates an output.

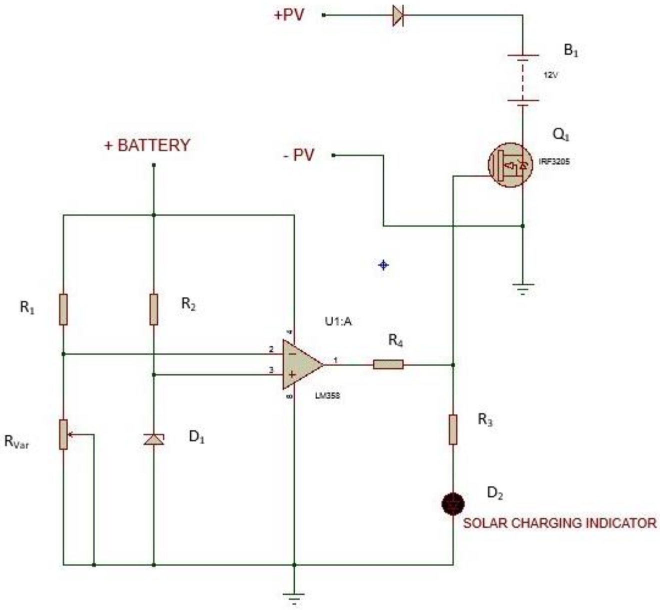

Figure 2: Circuit diagram of charge controller

The trigger circuit comprises of an actuator which is responsible for turning OFF or ON the charging of the battery through the solar panel. The circuit schematic is shown in figure 2.

In figure 2, the LM358N IC is configured as a voltage comparator. The fixed reference input was achieved using the zener diode. The value of the fixed reference signal is equal to the zener voltage (Va) rating of the zener diode. The potentiometer was used to calibrate the variable input signal in such a way that a little voltage over the fixed reference input voltage value (Va) corresponds to about 12V indicating a full battery was achieved.

(ii) Charge Controller Circuit Design:

The LM358N dual operational amplifier IC consist of two independent, high-gain, internally frequency-compensated op-amps, specifically designed to operate from a single power supply over a wide range of voltages. This uses one of the op-amps as a voltage comparator, comparing the varying battery voltage to a fixed reference voltage. From the LM358N datasheet, R_1 is calculated to limit the input current to the op-amp. Also, it was used in conjunction with the variable resistor R_{Var} to get a value corresponding to the battery voltage. Ohm’s law was used to calculate R_1 thus:

$$R_1 = \frac{V}{I} \qquad (2)$$

ISSN No:-2456-2165

Substituting values of I = $1.2mA$ and $V = 12V$, we have R_1 to be,

$$R_1 = \frac{12}{1.2 \times 10^{-3}} = 10 \times 10^3$$

$$R_1 = 10k\Omega$$

To obtain a value that determines the variable resistor range, we recall the voltage divider rule thus,

$$R_1 = \frac{R_{var}}{R_1 + R_{var}} \times V_1 \qquad (3)$$

Where V_2= voltage required at pin 2 of the LM358N and V_1= battery full voltage. Then making R_{Var} the subject of the formula in equation 3, we have that,

$$R_{Var} = R_1 \left(\frac{V_2}{V_1 - V_2}\right) \qquad (4)$$

As $R_1 = 10k\Omega$ from equation 3, $V_2 = 5V$ (less than 5.1VZenervoltage) and $V_1 = 12V$ (battery full voltage), R_{Var} is estimated thus,

$$R_{Var} = 10 \times 10^3 \left(\frac{6}{12-6}\right) = 10 \times 10^3\Omega$$

$$\therefore R_{Var} = 10k\Omega$$

Since $R_{Var} = 10\ k\Omega$, a $20k\Omega$ variable resistor was used.

Similarly, the resistor R_1 is chosen to be $10k\Omega$ to limit the input current to the op-amp to $1.2mA$. The 5.1V zener diode was chosen to set the reference voltage at pin 2 of the LM358N to 5.1V.

The resistors R_3 and R_4 are both used to limit the current flowing through the Light Emitting Diode (LED) D_2 and the gate of the transistor Q_1 respectively, thus they were chosen to be $1k\Omega$ each which limits the current to about $5mA$. The Source of the MOSFET is connected to ground while the Drain is connected to the positive terminal of the Solar Panel.

Power Supply from AC Source

The power supply circuit was responsible for converting the 220V AC mains supply to the 14V DC capable of charging the 12V battery. The block diagram is shown in figure 3.

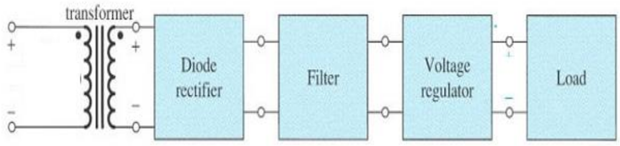

Figure 3 Power supply unit from AC source

The Transformer is wound in such a way as to accept 220V AC mains at its input and step the voltage down to 24V AC at its output. This 24V is still alternating and is rectified by the bridge rectifier contained within the Bridge (Diode)

Rectifier Circuit: The rectified 24V is still pulsating in the positive sense and is then smoothened by a smoothening capacitor connected in shunt before being regulated by the voltage regulator. The regulator gave a regulated output of 14V dc which was then suitable for charging the battery. The rectifier circuit is as shown in figure 4.

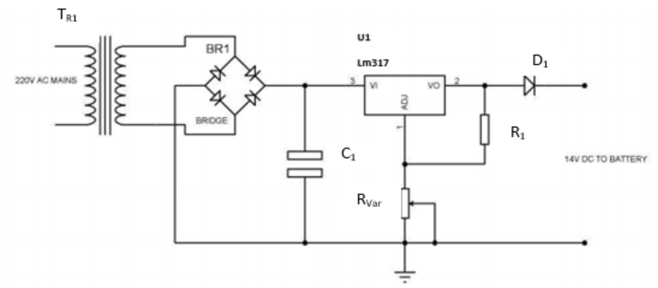

Figure 4: Power supply circuit from AC source

Power supply design:

In order for the regulated voltage to be 14V, the secondary voltage of the transformer need was made to be above 14V. In other words, 14V should be the root-mean-square (rms) value. Then recall that,

$$V_{rms} = \frac{V_t}{\sqrt{2}} \qquad (5)$$

Where V_t secondary voltage of the transformer and V_{rms} is the rms value. Then if 14V was the assumed rms value, then V_t from equation 5 becomes,

$$V_t = V_{rms} \times \sqrt{2} = 14 \times \sqrt{2} = 19.78 \cong 20 \qquad (6)$$

Thus, from the calculation, the secondary voltage of the transformer is 20V. But since the nearest transformer value is 24V, therefore, 220V/24V was used for the construction.

The capacitor connected in shunt (smoothening capacitor) is used to remove ripples from the pulsating rectified DC voltage. The value of capacitor C is estimated using,

$$C = \frac{0.5 \times I}{V_r \times F} \qquad (7)$$

IV. RESULTS AND DISCUSSION

At the conclusion of the research work, a well designed, constructed and tested prototype of a solar assisted wheelchair with different sub units as produced was assembled as shown in Plates 1, 2, 3 and 4.

Plate 1: Rear tyres, of the wheel motors and steering

Plate 2: Back tyre of the wheelchair

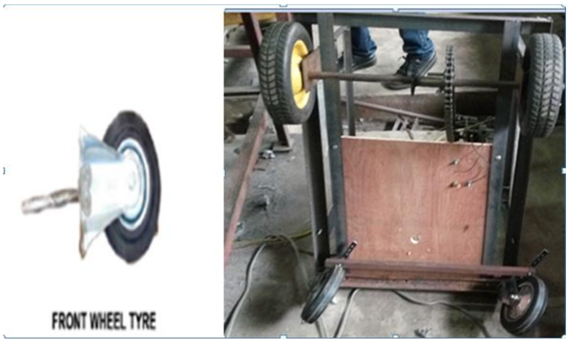

Plate 3: Front wheel mounted on the platform

Plate 4: A complete prototype solar powered wheelchair

V. CONCLUSION

In the work, a wheelchair Solar-Powered electric wheelchair which is of a low-cost alternative to the current market offerings was developed and produced. The attempt made in constructing a Solar Powered Electric Wheelchair using off the shelf components was successful. The performance of the wheelchair showed the indigenous infrastructure and the capabilities of the wheelchair. The Recharging capacity of the battery through the solar panels was satisfactory. The desired functionality of the Steering Mechanism was satisfactorily achieved. The wheel chair is capable of providing an uninterrupted journey of 8KM that can take up to 4 hours continuously to accomplish. Thus, the attempt made in fabricating the Solar Powered Wheel chair was successful.

ACKNOWLEDGEMENT

We acknowledge the Tertiary Education Trust Fund (TETFUNF) of Nigeria for the funding the project that led to the production of this paper. We also acknowledge the departments of Electronic and Computer Engineering and Mechanical Engineering for providing the laboratory facility where the entire designed and constructed work were accomplished.

REFERENCES

[1]. (IEEE, 2015).

[2]. Weijun Tao, Junyi Xu and Tao Liu, “Electric-powered wheelchair with stair-climbing ability”, International Journal of Advanced Robotic Systems July-August 2017: pp 1–13

[3]. Siddharth M. Ahluwalia, Nivin Venghese T., Nayan S. Patil, Mayur R. Sarbhukan Soheb Khan U.K. Pathan, Akshay S. Jaiswal, Iliyas S. Jaiswal, Iliyas Khan H.K. Pathan and Tosik Y. Khalik, “Design and Fabrication of Sensor Assisted Solar Powered Wheelchair” International Journal of Engineering Trend and Technology, Vol. 46 No. 2, April 2017, pp 71-74.

[4]. Chi-Sheng Chien, Tung-Yung Huang, Tze-Yuan Liao, Tsung-Yuang Kuo and Tzer-Min Lee, “ Design of Solar Power-Assisted Manual/Electric Wheelchair”, International Journal Rehabilitation Research and Development (JRRD), January 2014, Vol. 51 No. 2, pp 1411-1425.

[5]. Arun Manohar Gunam, P.S.V. Ramana, Raghuveer Dontikurti, “Solar Powered Wheel Chair: Mobility for Physically Challenged”, International Journal of Current Engineering and Technology, Vol. 2 No. 1 March 2012, pp 211-214.

[6]. Ding D. and Cooper R 2005, Electric Powered Wheelchair”, IEEE Control Systems 2005, Vol. 25 No. 2 pp 22-34.

[7]. M. H. Muhammad Sidik, S. A. Che Ghani, M. Ishak, W. S. W. Harun, N. Daud, “A Review on Electric Wheelchair

[8]. Innovation to Ease Mobility and as a Rehabilitation Tool for Spinal Cord Impairment Patient", International Journal of Engineering and Technology (IJET), Vol. 10 No. 3 June-July 2018, pp 803-815.

[9]. Swapna P., Sharmila B., and Darshan Y, "Electric Wheelchair for Physically Challenged", International Research Journal of Engineering and Technology, Vol. 3, Issue 5, May 2016, pp 1090-1094

[10]. Kaiser M. Shamim, Zamshed Iqbal Chowdhury, Shamim Al Mamun, Amir Hussain, Mufti Mahmud, IEEE Symposium Series on Computational Intelligence 2015, pp 833-836.

[11]. Snehal G. Bali, Amit Kushwala, Pralik Dhate, Chetan Nandanwar, and Sandesh G Ugbade, "Fabrication of Solar Powered Tricyle for Handicaped Person", International Journal of Innovative Research in Science and Technology, Volume 1 Issue 10, March 2015, pp 169-173.

[12]. Islam Shahidul Md, Zaheed Bin Rahman and Nafis Ahmed, "Desidning Solar Three-Wheeler for Disabled People", International Journal of Scientific and Engineering Research", Vol. 3 Issue 1, January, 2012, pp 1-7.

[13]. Stephen Uchenna., Azubuike Aniedu, Omego Samuel-Henry Nnamonu and Nnaeto Godson Okechukwu, "Design and Construction of Battery-Powered Microcontroller-Based Whweelchair", African Journal of Computing & ICT, Vol. 8 No 3 Issue 2 October, 2015, pp 153-162

[14]. Kiran N. Ravi and Chiranjeevi A., "Solar Powered Motorized Wheel Chair", International Journal of Innovative and Emerging Research in Engineering (IJIERE) Vol. 4 Issue 3, 2017, pp 164-169.