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Designing Solar Three-Wheeler for Disable People

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Abstract—Mobility of the physically disabled or crippled people is a great concern of the society. It is really difficult to realize the problems and sorrows of a physically disabled/crippled person who is partially or fully dependent on others or confining himself in a wheel chair with limited mobility. This paper provides idea of currently available three-wheelers for disabled people and proposes a new improved design of a solar powered three-wheeler suitable for countries like Bangladesh which is an under developed country with huge disabled/crippled people from war, accidents and diseases. This three-wheeler is operated by solar power and suitable for outdoor use. Solar power option enables the disabled people to use it at any place, even in remote areas where there is no electricity. A general survey had been conducted on disabled people using wheel chairs and manual three-wheelers and the opinions of the experts working with the disabled people are also taken in to consideration to identify the needs and requirement for designing the solar three-wheeler. The proposed solar three-wheeler is meant to match and exceed the conventional three-wheeler's facilities with a more intelligent and efficient design. A solar panel to produce solar electricity, a battery system for preserving electric power, an efficient motor, cushion seat, all terrain tires are used for this solar three-wheeler. Due consideration and attention is given to better maneuverability, effective use of solar energy, biomechanics and comforts, increased suspensions, all terrain traffic ability, ease of use etc. while designing this solar three-wheeler for physically disabled people of the country.

Index Terms— Design, Solar three-wheeler, Disabled people

1 Introduction

A lot of difficulties and hassles involved with the mobility of the physically disabled people in the society. It has been observed that physically disabled people are basically using some assistive devices like, crutches, artificial limbs or legs etc. and manual wheel chairs or three-wheelers for their day-to-day movements. But, these wheel chairs or three-wheelers are crude or of inefficient in design; not very much suitable for outdoor use or common terrain in the country like Bangladesh. Undoubtedly these manual wheel chairs or the three-wheelers are the blessings for crippled people but in the question of humanity, it is just "to add insult to injury". Because, commonly found manual wheel chair or three-wheeler has a basic problem that the occupant must use physical force to turn the wheels. This action is physically stressful, can result in muscle and joint pain and degradation, torn rotor cuffs, repetitive stress injury, and carpal tunnel syndrome; which causes secondary injury or further disability[3].

Again, Use of conventional energy sources and rapid development of the present world have some bad impacts on the surroundings and environment, like depleting limited energy resource, damage of ecosystem, environment pollution, global warming and so on. As a result, Designing for Environment (DFE) is the crying need of the time and it is very much necessary to develop environment friendly equipment or transport for better living, for better world.

Considering the overall prevailing situation, development of a solar three-wheeler for disabled people is a vital effort where solar energy and its advantages are taken into account. A solar three-wheeler could be a stand-alone system; it will be self-operated and independent in nature, using unending solar energy from the sun. It is powered by solar energy from attached solar panel at top, exposed to sunlight. It can take us off the grid; can be used in a place where there is no electricity.

The transport idea concerned here is a solar power operated three-wheeler with light structure of moderate height-width and weight, which suits to Bangladeshi terrain. Also due emphasis is given to biomechanics, comforts, safety etc. while designing the seat for the solar three-wheeler. These features give greater stability, better maneuver ability, better mobility and comforts over the available manual three-wheelers. In a sense, a solar three-wheeler can be the complete solution for the transportation of physically disabled people of the country. Use of available resources (for components such as pipes for chassis/body, wheels, bearing etc. from the local market) and simplicity in designing result cost economy. The battery used, motor and solar panels are also very much available in the markets. All these features make the solar three-wheeler a very cost effective and environment friendly transport for the daily use of the disabled people.

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2 PRESENT SCENARIO

Since the liberation war of Bangladesh in 1971, a large number of people have become disabled and vulnerable to the country. The prevalence of disability is believed to be high for basic reasons relating to over population, extreme poverty, illiteracy, social security, lack of awareness of traffic rules and above all lack of medical/health care and services. By latest, the numbers of disabled people are increasing rapidly due to increasing rate of road accidents and other relevant diseases [1]. In the present social hardship, other family members often fail to pay proper attention and care to the disabled people. So, their lifestyle improvement and independency is very much important and urgent too.

Although disability is a major social and economic phenomenon in Bangladesh, there is very little reliable data available on this issue, especially in the absence of a comprehensive national survey on disabiled persons. Basing on some data collected by the prevailing NGOs and international organizations, it is commonly believed that almost 10% of the total populations of Bangladesh are disabled and 2.5% of which are crippled or physically disabled [2]. Presently available wheel chairs are basically for indoor use or short distance movement and the manual three-wheelers for outdoor use. But those are not very suitable for use and having lot of technical drawbacks.

The numbers of crippled/ disabled people are quite alarming but the numbers of wheel chair or three-wheeler users are not big and mostly found them in hospitals and residents, especially in urban areas. It is revealed from the survey that the numbers of present wheel chair/three-wheeler users are negligible in all over the country. It happens because the presently available wheel chairs or three-wheelers are manual and not very suitable for outdoors use or for the roads around the country. The roads even in the cities are not very smooth or there is no lane for wheel chairs/ three-wheelers. Most of the cases the roads are very rough and narrows with some other limitations. Commonly Bangladesh has plain land and roads in the villages are of rough condition where peoples are moving with their bicycles, rickshaws etc. City roads are better where people move by rickshaws, auto- rickshaws, busses, taxi-cabs, cars etc.

There are some NGOs like, Centre for Disability Development (CDD), Centre for Rehabilitation of the Paralyzed (CRP) etc. working for the physically disabled people and producing some manual wheel chairs and three-wheelers, somehow suitable for outdoor use. But again the problems remain, as the users need to use the physical force to drive it. Photographs of the presently available wheelchairs and three-wheelers in Bangladesh are shown in Figure 1.

(a) Wheelchair (b) Three-wheeler (c) Three-wheeler

Figure 1. Different types of available wheelchair and three-wheelers

The common size and basic dimensions of the presently available wheel chairs and three-wheelers are shown in Table 1.

Table 1: Basic dimensions of the presently available wheel chairs and three-wheelers

Wheel chair	**Three-wheeler**
Length:97 cm	Length:145 cm
Width:56 cm	Width: 97 cm
Height:71 cm	Height: 86 cm
Rear Wheel Dia.:51 cm	Rear Wheel Dia. :68cm
Front wheel Dia.:15cm to 20cm	Front Wheel Dia.:68cm

The main problems with the presently available three-wheelers are that these are manual, needs physical force to drive it; causes secondary injury such as upper extremity repetitive strain injuries, vibration exposure injuries, pressure ulcers, accidental injuries etc. There are lots of technical drawbacks of this manual three-wheeler too. However, the main drawbacks can be pointed as; crude or of inefficient design, biomechanics are not well considered, lack of safety measures, over weight and size, not suitable for outdoor use and no shed for protection to the user against adverse environment like sunshine, rain etc.

3 PROSPECT OF SOLAR THREE-WHEELER

Scarcity of energy is a common problem in all over the globe due to lack of conventional energy sources. So, Eco-friendly renewable energy like solar power can be the alternative and solve the power problem to some extent. Availability of solar energy radiation is the most vital consideration for designing and development of a solar system or solar equipment at any location on the earth. Rated solar radiation power received by the earth surface is (global radiation flux) 1000 W/m² (AM 1.5, sun at about 48 ° from overhead position). Availability of solar energy radiation in all over the country is very much encouraging for developing a solar three-wheeler for disabled people in Bangladesh. The geo-location of Bangladesh is in favor of receiving highest amount of solar radiation round the year. It is situated between 20.30-26.38 degrees north latitude and

88.04 - 92.44 degrees east, which is an ideal location for solar energy utilization. Solar radiation mapping shows that the daily average solar radiation varies between 4-6.5 kWh/m². Maximum amount of radiation is available on the month of March-April and minimum on December-January [5].

The researches have been going on to produce solar car, solar plane and so on. In the transportation sector, the use of solar energy faces different problems, such as the limited space for panel, batteries, transmission problems etc. Many in the world attempted to carry out the idea of a solar car, jointly forming as association and establishing a yearly race for solar powered cars, in different county each year. These works show the design parameters for a solar car only and no significant achievement yet for a suitable solar three-wheeler for disabled people.

Since the solar power system suits well with the minimal power consumption, the development of the solar three-wheeler would be very much feasible as it as mini transport needs comparatively smaller power for the power system. A 100 W solar panel is good enough to support the daily power requirement. However, the most challenging part of the solar three-wheeler project is to use the limited solar energy effectively, maximize its efficiency and ensure suitability/traffic ability on our terrain. Successful implementation of the project will depend on how successfully and exactly the problems are indentified.

4 Designing The Solar Three-Wheeler

Designing of the solar three-wheeler has two major parts/aspects. Firstly, Designing the three-wheeler and it's components from mechanical and biomechanics point of view and secondly, incorporation of solar power system to the improved manual three-wheeler to achieve automation. Drawbacks of the available manual three-wheelers as well as needs and requirements from the disabled people (users) are seriously considered while making definite improvement in designing. Effective use of limited solar energy (due to limited space/module), energy storage and power requirement (load) are also seriously considered to balance and optimize the solar power system of the solar three-wheeler.

4.1 Design Phases

The overall designing of the solar three-wheeler is done through different phases as: recognition of the needs, definition of problem, synthesis, analysis and optimization, evaluation and presentation Firstly, the demand or requirements from the disabled people are identified. Then the human requirements are translated to technical requirements, which include all the specifications or characteristics for the solar three-wheeler to be designed. Then the solar three-wheeler under design has been analyzed to whether it complies with specifications. Once complied, then it was optimized and leaded to a successful design. Sometimes, the analysis may reveal that the system is not an optimum one. In evaluation phase, testing of the solar three-wheeler is done and finally it is presented to others.

4.2 User's Needs And Requirements

A general survey had been conducted among disabled people who are using wheel chairs and manual three-wheelers. They had been interviewed on some specific questions and their problems/needs had been investigated and identified. They came out with their problems, requirements, opinions as well. Basically these are the requirements from the physically disabled persons using manual wheel chair/three-wheelers. The opinions and advices of the experts working with the disabled people are also taken in to consideration. Their overall needs and requirements can be described as: the three-wheeler should be power driven to avoid physical force, it can be used at any time either in day or night, having lighter weight with better safety and stability, easy to control and better maneuverability in case of narrow space/roads, comfortable, all terrain traffic ability/mobility and suitable for indoor as well as outdoor use, having available solar power to drive the three-wheeler in average15~20 km distance per day, able to protect the user from the adverse environment like sunshine, rain etc., having availability of spares, ease of maintenance and finally cheaper price.

4.3 Design Considerations

Design considerations refer to some characteristics, which influence the design of the element or, perhaps the entire system. The strength of each element, its dimension and geometry are important design consideration from the mechanical point of view. As a transport for the physically disabled people the overall safety, stability, reliability, control, comforts etc are a very much important and taken in to consideration while designing it. However, the general points of consideration during the designing of the solar three-wheeler are: simplicity, strength, stability, safety, corrosion and wear, weight, size, flexibility, ease of control, modularity, efficient extraction of solar energy, effective use of solar energy and energy storage, all terrain tires for all terrain traffic ability/mobility, increased suspensions, biomechanics and comforts and cost.

4.4 Different Parts/Components Of The Solar Three-Wheeler

The main components of the solar three-wheeler are: Chassis/Frame, Wheels, Body, Seat, Solar panel mounting frame, Solar Panel, Charge controller, Battery, Motor, Chain, Steering System, Speed Controller, Break System, lights etc.

4.5 Mechanical Design

The Chassis/Frame of the presently available three-wheeler is heavy and wheels are of big sizes. So while designing, unnecessary weight is reduced to meet the requirement. Comparatively smaller wheels are selected; keeping in mind that the weight of the solar three-wheeler should be as low as possible and must have required strength. The solar three-wheeler chassis is designed by using steel pipes reinforced with angle bars where necessary. The chassis can withstand necessary loads as well as absorbs shocks. The overall length and width are also reduced to some extent. Finally, the chassis is made by steel pipes having 19 mm diameter with 2 mm thickness. Reinforcement in bends etc. is done by 19 mm×19 mm angle bars as necessary. To avoid accidents and ensure safety, the sharp edges, bends etc. are rounded. Total weight of the loaded solar three-wheeler (with a person) will be 150 kg. Four iron pipes (Steel ASTM-A36) are to bear the load as frame/chassis and the maximum static deflection of the used pipes will around 0.66 mm, which is acceptable. Due to shock, these pipes will also deflect more and act as a shock absorber.

Figure 4: Design of the proposed solar three-wheeler

Overall road condition including bumps, pot-holes etc. around the country is duly considered while choosing the wheel as well as it's size. All the three wheels are of equal size having the diameter of 40 cm each. All terrain tires are used for better traffic ability. The body of the solar three-wheeler is made of pipes, steel sheets of minimum possible thickness and woods for lighter weight. Two leaf springs are added to the rear axle for better suspension. An adjustable waterproof cushioned seat is attached with the chassis. The solar panel is set on the top (over head) with panel mounting frame made of light steel pipes duly attached to the main frame/chassis. While modeling; sharp edges, bends, nails are avoided to avoid accidents and ensure better safety. The basic size and dimensions of the solar three-wheeler are set to: Length: 132 cm, Width: 86 cm, Height: 137 cm with the ground clearance of 20 cm as shown in Figure 4.

A normal handle bar decorated with brake lever, accelerator, switches etc. and attached with front wheel is used here as steering. The speed of the solar three-wheeler is controlled by accelerator through continuous change in voltage by a twist throttle. Due to voltage change the motor power also changes and thereby speed is controlled by increasing or decreasing the voltage. Normal friction type braking system (as used in bicycle) is used in front as well as in rear-left wheel of this solar three-wheeler for better safety. The hand liver attached with handle/steering is used to actuate the brake. One headlight, indicator lights and backlights are attached to the solar three-wheeler, which get power from the battery. High-grade wires are used to make necessary circuits/wirings for electrical system of the solar three-wheeler.

4.6 Desired Speed And Power Requirement

In considering the physical condition of a disabled person, over all terrain condition, safety etc., the speed of the solar three-wheeler is set to 6 km/hr or 100 m/min. This speed will ensure better stability as well as comfort for the user. Practically it is experienced and measured that the total force (F_p) required for moving the loaded solar three-wheeler on smooth road is almost 6kg. Here rear wheel diameter is 0.4 m; speed of the three-wheeler is 6 km/hr or 100 m/min. So, wheel rpm and torque will be 80 rev./min and 12 N-m respectively. Finally required power is 134W. If power loss due to chain drive is 10% then desired power requirement for driving the solar three-wheeler will be around 149 W.

4.7 Motor

The prime mover to be used in this solar three-wheeler is a permanent magnet D.C. motor. The main reason for using this motor is that it is highly efficient and the flux density does not decrease with time. It's performance characteristics suite very well to the requirement of our solar three-wheeler. At standard load condition, the motor needs 149Watts. This power will cover the required power needed to run the solar three-wheeler at a speed of 6 km/hr. If the load increases or the three-wheeler climbs up-ward slope, then the current will also increase and power output of the motor will also increase. However, considering standard power requirement and the safety, the designed motor power capacity is set to 200 W.

4.8 THE SOLAR POWER SYSTEM

The solar power system of the solar three-wheeler consists of solar panel (100W), MPPT solar charge controller, Lead-acid battery (12V-80Ahr.) etc. The typical solar power system is shown in Figure 5.

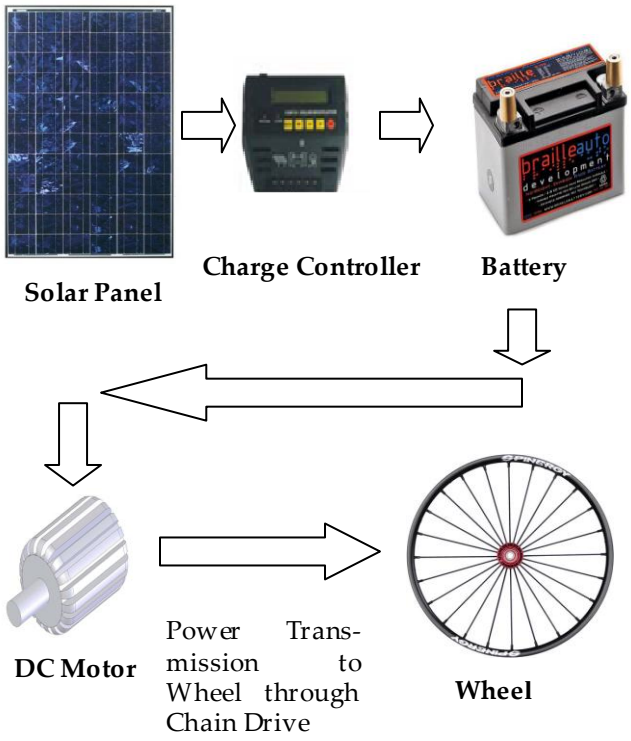

Figure 5: Diagram of solar power system

4.8.1 BATTERY

A solar three-wheeler is the stand-alone system**.** To make practical use of the solar energy generated from solar panels, batteries are used to store the energy to meet up motor power requirement as needed at any time either in day or night. A 12-volt, 80 A-hr lead-acid battery is preferred and used here in solar three-wheeler power system as used in most of the PV systems. Main reason of using such lead acid battery is, it's availability and comparatively cheaper cost.

4.8.2 ENERGY/POWER AVAILABLE FROM A LEAD-ACID BATTERY

An average 12 volts 80 A-hr capacity Lead-acid battery (car battery) should supply about 960Wh, provided that the energy withdrawal is at low level current. For the speed of 6 km/hr, the solar three-wheeler requires 149 watts in full load condition. Thus a 12 volt battery has to supply amps approximately 12.2 amps, which is a very reasonable rate of withdrawal from a lead-acid battery of intermediate range for meeting normal playing load. The solar three-wheeler requires 149 W for running a distance of 6 km. Therefore, with a single lead-acid battery (12 V, 80 A-hr.), it can cover a distance of 39 km in full charge. It is experienced from the survey report that a disabled person normally travels maximum 15~20 km per day. So a 12 volt 80 A-hr lead-acid battery once fully charged can run for 2 days easily.

4.8.3 SOLAR CHARGE CONTROLLER (MPPT TYPE)

A MPPT solar charge controller is chosen for the solar power system of the solar three-wheeler to extract maximum power from solar panel throughout the day. This is operated by microprocessors for sensing and recording the panel voltage and current at frequent intervals for computing and adjusting the power output. This solar charge controller takes the uncertain voltage from the solar panel and conditions it to charge the lead-acid battery safely. It cuts out the batteries from the load when the lead acid batteries are depleted to prevent damage to the battery and also protect the panels from the batteries after the sun goes down. Here, it collects charges from solar panels and charges the 12 volt lead-acid battery. It has LED bar readout to show the status of the solar charging system and batteries. With the help of this MPPT solar charge controller about 20 to 30% more energy can be generated than that of a common type charge controller.

4.8.4 SOLAR PANELS (MODULES)

Solar PV panels are designed to generate/collect desired energy required by the solar three-wheeler. Power needed to run the solar three-wheeler is indirectly supplied from solar panel. Basically this solar panel when exposed to the sunlight produces DC current (solar electricity) which is stored in a battery and used by motor as per the requirement, as and when required basis. Now, it is important to design the solar panel size and it's power output in working condition. The solar panel consists of solar cells. The amount of power output of a solar cell depends on solar cell efficiency and solar cell area. Usually 30~36 solar cells connected in series are laminated together to make a so-called solar PV module. Commercially available single solar cell normally having the dimensions of (3"× 6"), (10 cm ×10 cm) etc. A (10 cm ×10 cm) solar cell's electricity output is likely rated at 0.50 to 0.55 volts with 3 to 3.3 amps. Here, in the module, 36 cells are connected (in series) together so that in all operating conditions a PV module gives well above 12 volts, which is the required to charge a 12 V battery. As we

know, Watts equals to Volts multiplied by amps and a (10 cm ×10 cm) solar cell's output is 0.5 volts and 3 amps in general. So, a single module (consists of 36 cells) will have 18 volt rated output and 54W rated power. If operating factor considered as 0.9, then the actual (practical) output voltage and power will be 16.2 V and 48.6W. However, this 16.2V output in practical field matches and good enough to meet up the requirements of charging 12V lead-acid batteries. Thus two 50W solar panels in parallel connection will give us 100 watts with 16.2 volts and 6 amps.

Now, The size of the single panel = (36×0.1×0.1) sq-m. = 0.36 sq-m in general. So, total area needed for 2 panels = (0.36 ×2) sq-m = 0.72 sq-m, which fits well in the space available at the roof of the solar three-wheeler.

4.8.5 Battery Charging Voltages And Currents

To charge a battery, the charging voltage must be higher than the battery voltage or at least equal. As per the motor power requirement, a 12 V- 80 A-hr. lead acid battery is very much feasible for the solar three-wheeler. "Trickle charging" (charging in low amps, 2 to 10 amps) is always better for any battery charging; it increases battery life and decreases electricity pilferage. Here, the charge controller will charge the battery at around 16.2 volts and 6 amps. A full day of sunlight (6 hours) will charge it fully if it's not fully discharged when hooked up.

4.8.6 Impotant Features And Major Specifications

The main features of the solar three-wheeler are: a) Automatic (solar powered) and environment friendly. b) A Standalone system- can be used at remote places where there is no electricity. c) Biomechanics- comfortable and suitable for the health of the disabled. d) Having better safety, stability, maneuverability and modularity in design. e) Suitable for Bangladeshi-terrain and having protection from sunshine, rain etc. and f) Economic as no power cost and easy maintenance. The major specifications are summarized in Table 2.

Table 2. Major specifications of the proposed solar three-wheeler

General specifications	
Size: 132x86x137 cm	Steering/Drive system: Handle Bar
Height: 137cm	Speed control: Continuous (Voltage Regulation)
Weight with battery: 85 kg	Seat: Cushioned and Water proof.
Speed: 6 km per hour	Braking system: Friction Type
Distance per charge: 39km	Shock absorber: leaf spring at rear.
Maximum load/weight capacity: 70 kg	Tool kit: Standard
Tire size: (40 x 5) cm	Career: Attached at the back.
Power specifications	
Solar Panel: 100Watts(16.2 V, 6 amps)	Batteries: lead acid battery, 12 V- 80 A-hr.
Motor: 200 W (DC)	Charge controller: Solar based (MPPT type).

5 Conclusion

Development of the solar three-wheeler is a blessing for the disabled people and will have significant change in their mobility as well as life style. The overall designing of the solar three-wheeler is done with a view to provide maximum possible facilities to it's user - the disabled people. Automation by solar power, biomechanics, comforts and safety get maximum priority in designing. Other attractions of this solar three-wheeler are flexible and modular designing. Because of flexibility and modularity in design, desired modification (change of wheels, seat, height of the chassis etc.) if needed, can easily be done to meet up any individual requirement. Though it is solar operated but it can also be charged with grid electricity if desired. Long distance (over 35 km/day) travelling is not possible by this solar three-wheeler due to limited energy storage and it may not perform well during consecutive cloudy/rainy days. Again, the volume/size of the solar panel cannot be increased for increased energy demand due to limited space over head (roof). However, more efficient solar panel or solar power tracker can be used to extract more (maximum possible) energy from the sun to meet up increased energy demand. Nickel-cadmium batteries though expensive are ideally more suited to PV system than the lead-acid battery and can be used for better performance; it also has less of weight and no damage if the battery remains fully discharged for long periods. As a "stand alone system"- all the disabled people at any corner of the country can enjoy the benefits or advantages of this solar three-wheeler for their daily use. Though the solar three-wheeler has been designed and developed in consideration of the disabled people of Bangladesh but disabled people at different corners of the world can use it provided that there is sufficient amount of solar radiation. Finally it is important to mention that the solar three-wheeler is not only environment friendly transport for disabled people but also prevent the secondary disability as auto power transport. So, it is a complete solution for mobility of the disabled people of the society.

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