Electric Tricycle for Commercial Transportation

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***Abstract*—The paper analyses the design of an electric solar-powered tricycle for use as a commercial means of transportation. The tricycle uses an electric brushless direct current motor connected to the rear wheels of the tricycle using the chain and sprocket mechanism. This motor is powered by direct current from the battery bank. The battery bank is charged via a solar PV system directly installed on the roof of the tricycle. This enables the panel to charge the battery bank while the tricycle is in motion. The tricycle also employs the regenerative braking system which also charges the battery every time the brake is initiated. If effectively deployed, an estimated 32tonnes of CO2 emissions is calculated to be the CO2 savings effected by this energy system annually. Conclusively, this paper addresses the need to provide a sustainable and affordable solution to commercial passenger transportation in developing countries of the world.**

Keywords—solar powered; tricycle; electric tricycle; research paper; direct current motor

I. INTRODUCTION

The electric hybrid tricycle is an electrically powered device that has zero carbon emission that can be used for commerci*al* transportation. The tricycle uses an electric brushless direct current motor connected to the rear wheels of the tricycle using the chain and sprocket mechanism. This motor is powered by direct current from the battery bank. The bank is charged by direct connection to the mains and also by a solar panel that sits on the roof of the tricycle, so even when the tricycle is in motion, the panel charges the battery to replenish some power that has already been used. The tricycle also employs the regenerative braking system which also charges the battery every time the brake is initiated.

Electric vehicles tend to cost more than their gasoline counterparts. This is because gasoline vehicles have benefited from a century of intensive development; electric cars have been virtually ignored for several years. Gasoline vehicles still profit from billions of dollars of research conducted in its favour every year while researches conducted in electric vehicles haven't been beneficiaries of this resources.

II. THE PROBLEM DEFINITION

The alarming reality in our world today is that automobile usage is beginning to grow at a much faster than the human population, with saturation nowhere in sight. If present trends continue, overtime 3 billion vehicles could be in operation by the year 2050, exceeding 20 cars per 100 people. With challenges like fuel scarcity, pipe line vandalism, sabotage etc. This initiates a concern our hearts that vehicles powered by other sources of energy is not a nice to have but absolutely a necessity. Hence a solution is being proffered in the electric hybrid tricycle. Knowing that the gasoline powered tricycle is a major means of transportation in this part of Africa. An efficient replacement such as this will definitely reduce the dependency on automobiles.

III. REVIEW WITH RESPECT TO EXISTING WORKS

The following papers are being studied and are referred for the project. These papers belong to various authors, having various papers related to the research work.

The aim of this project is to add an electric power train and control system to the current hand-powered tricycle to provide tricycle users with improved levels of mobility [1]. The design objectives required a simple and affordable design for the power train and controls, a design that needed to be reliable, sustainable, and functional the design of the Electric Tricycle is adaptable to the current hand-powered tricycles with little modification. The design consists of an electric motor, a drive system, motor and steering controls, and a power supply.

The solar assisted bicycle developed is driven by DC motor fitted in front or rear axle housing & operated by solar energy. The solar panels mounted on the carriage will charge the battery & which in turn drive the hub motor [2]. When the bicycle is idle, the solar panel will charge the battery. This arrangement will replace the petrol engine, the gear box & the fuel tank in case of a two wheeler or a chain sprocket, chain & gear shifting arrangement of a conventional bicycle being used by most common man. As a part of dissertation work, the solar assisted bicycle is fitted with a dc hub motor on front axle of a bicycle with power rating of 250W and with a travelling speed of around 25-30 kmph. It is provided with a pair of lead acid batteries of 35 Ah each, a photovoltaic solar panel with capacity of 20 watt, a voltage regulator of 24v 10 Amp, accelerator and motor controller of 24v 25Amp. There is also a provision for charging of the battery with 220-240V, AC wall outlet supply, in case of poor solar supply due to cloudy weather [3].

IV. METHODOLOGY

In actualizing the objectives of this project above, the electric tricycle will be segmented into two (2) stages. These are:

1. The electrical system design stage
2. The mechanical coupling stage

The electrical system design stage would include wiring the battery, solar panel, motor and constructing a speed controlling circuitry to ensure proper travel speed control during the operation of the tricycle.

The mechanical coupling includes the proper welding, creating of frames and arrangements of all these components especially the motor and batteries on the frame work of the tricycle. This would ensure that it retains a steady standing frame and maintain its balance when in motion [4].

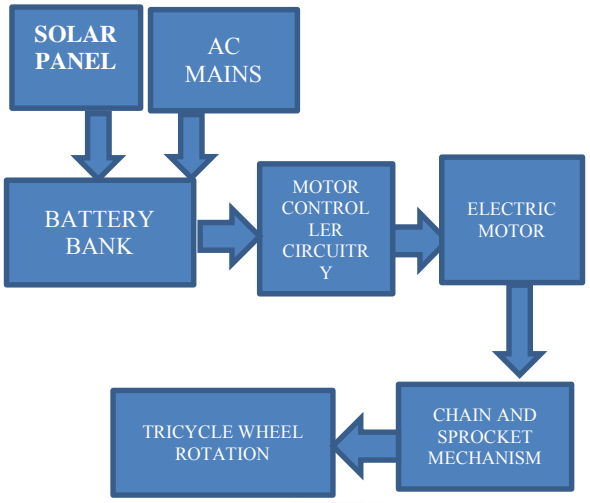


Figure 1: Block Diagram of the System Design

230-V AC from a 13A socket is supplied to the charging circuit which steps down and rectifies the voltage to 24V DC which is then supplied to the 24V 200AH battery bank. The charging circuit contains first the step-down transformer which steps 230V AC to 24V AC then a bridge rectifier diode is used to convert the 24V AC to DC. At this stage a filter capacitor is employed for the filtration of AC ripples to ensure we have a pure direct current output supplied to the motor. The motor with a power rating of 1200watt with an average speed of 20-30kmph is connected to the rear wheels for the movement the tricycle undergoes. [5] That produces pulse width modulation pulses. The solar panel rated at 300watts also feeds the battery bank to ensure that while the tricycle is in motion, the bank is being charged. Other devices include, 24v solar charge controller, Speed Control circuitry etc.

A. The Power Unit

The Power supply is one of the basic requirement for all electronics appliances. Most electronics devices require dc power sources to be able to function. Batteries are one form of dc sources; they are not large are free of ripples. However their voltage output is low, frequent replacements are require due to discharge and they are more expensive than conventional dc power supplies. Most importantly, alternating voltage conversion to dc voltage is possible and very advantageous since ac power supplies is economical to produce.

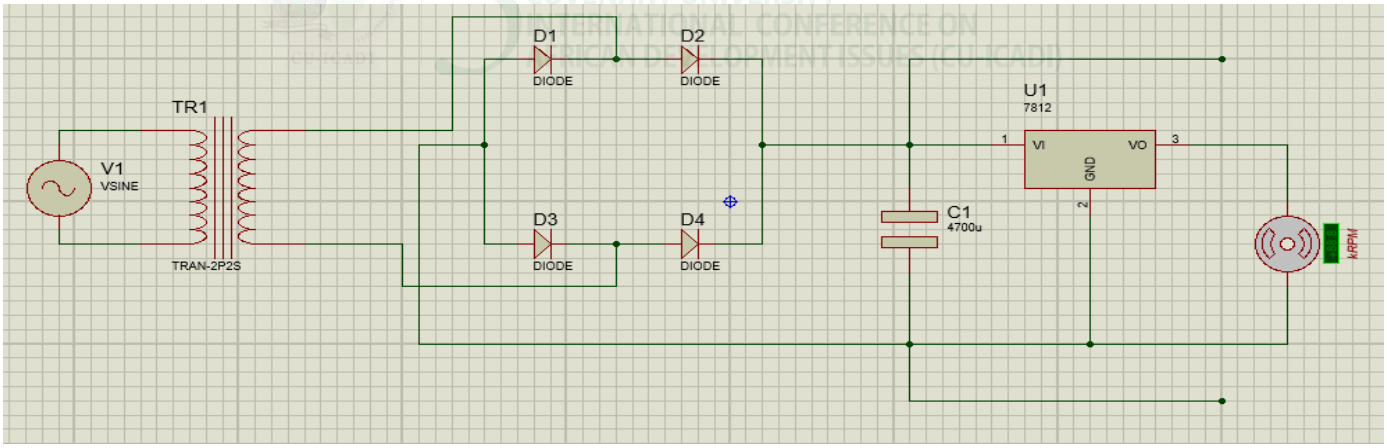


Figure 2: Charging Circuit

For the execution of this project a 230V AC supple from the mains was utilized to provide a 25V DC output. The 25-V DC output was regulated to 24V by current limiting resistors, this was in turn used to power the control circuit which required only 5V as its inputs to control the electric motor rated at 1.5hp.

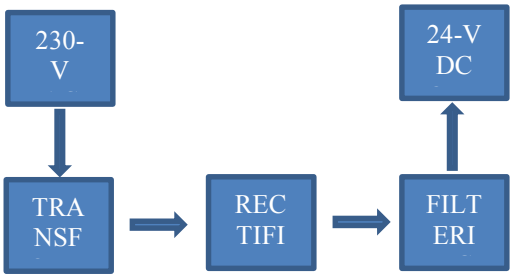


Figure 3: Block diagram of the power supply unit

1. Transformation

A transformer is a device that transfers electrical energy from one circuit to another by the use of electromagnetic induction. It is a static (or stationary) electro-magnetic passive electrical device that works on the principle of "Faradays law of electromagnetic induction" by converting electrical energy from one form to another. Transformers are capable of either increasing or decreasing the voltage and current levels of their supply without modifying its frequency, or the amount of electrical power being transferred from one winding to another via the magnetic circuit.

There are two types of transformers namely:

- Step-Up Transformer: provides an output voltage that is higher than the input voltage
- Step-Down Transformer: Provides an output voltage that is lower than the input voltage.

For the execution of this project a step down transformer was used to step down a 230V to a 28V supply which is unregulated and is alternating voltage.

2. Rectification

Rectification is the process of converting an alternating ac voltage to a pulsating dc voltage. In this application of rectification a full wave bridge of four diodes incorporated into a single electronic was used. During the positive half cycle of the input voltage, D1 and D4 are forward biased; D3 and D4 are reverse biased. During the negative half cycle; D2 and D3 are reverse biased.

In the full wave rectifier, there is a voltage drop of 1.4V which is as a result of the 2 diodes which are always present in the conduction path of each cycle. When a voltage greater than 1.4V is across the rectifier cuirtcui.t D1 and D4 are forward biased and current starts to flow through D1 to the load and to the ground, then up from the ground through D4 to the lower part of the transformer.

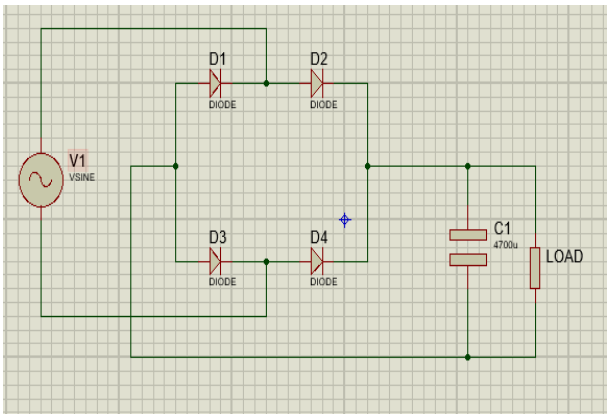


Figure 4: Full wave bridge rectifier

At this stage, D2 and D3 are reverse biased and thus only negligible leakage current will flow through. This implies D2 and D3 do not allow current to pass through in the opposite direction and thus the diodes behave like a switch

At the opposite half cycle D2 and D4 are now forward biased, thus current flows out of the lower part of the transformer through D2 to the load and then to the ground and also up from the ground to the upper part of the transformer through D4 and D1 and D3 are now reverse biased.

3. Filtering

This is also known as smoothening and can be defined as the removal of pulsations found in the output voltage. Smoothening is performed by an electrolytic capacitor which has a larger value connected across the supply to act as a reservoir, sending current to the output when changing DC (dotted line) and the smoothed Dc (Solid line). The capacitors charges rapidly near the peak of the changing of the changing DC and then discharges as it supplies current to the output.

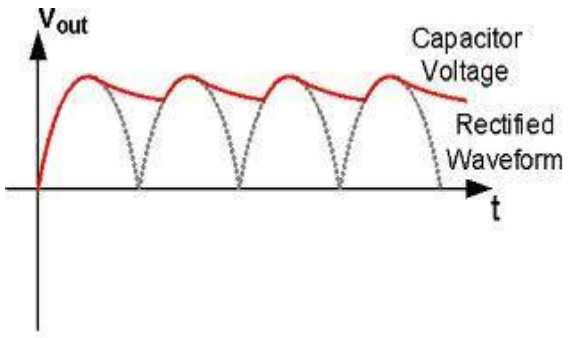


Figure 5: Rectified Waveform

4. Smoothening Process

Filtering increases extensively the average value of Dc voltage to almost the peak value (1.4 x RMS value). Smoothening is not perfect due to the capacitor voltage reducing a little as it discharges, providing a small ripple voltage.

5. Voltage Regulation

A voltage regulator is designed to automatically maintain a constant voltage level. It provides the function of

pass element. Voltage reference and protection from over current in one package. It may use an electromechanical mechanism or electronic components, depending on the design; it may be used to regulate one or more AC or DC voltages. The voltage regulator has the primary function of keeping the terminal voltage of the Dc supply constant when the ac input voltage to the transformer changes or the load varies.

B. Battery Unit

A battery is a device that converts chemical energy directly into electrical energy. It consists of a number of voltaic cells; each voltaic cell consists of two half-cells connected in series by a conductive electrolyte containing cations and anions.

Figure 6: Battery Compartment

Two 12 V rechargeable batteries were selected for the actualization of this project due to its following advantages.

- Improved energy density (up to 40% greater than nickel-cadmium cells) which can be translated into either longer run times from existing batteries or reductions in the space necessary for the battery.
- Elimination of the constrains on cell manufacture, usage and disposal imposed because of concerns over cadmium toxicity
- Simplified incorporation into products currently using nickel cadmium cells because of the many design similarities between the two chemistry.

C. Solar Panel

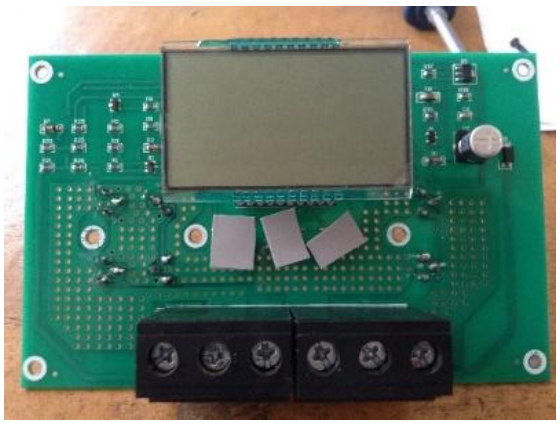
Solar or Photo Voltaic (PV), cells are electronic devices that essentially convert the solar, energy of sunlight into electric energy or electricity. The physics of solar cells is based on the same semiconductors principles are diodes and transistors, which form the building blocks of the entire world of electronics. Solar cells convert energy as long as there is sunlight. In the evenings and during cloudy condition, the conversion process diminishes. It stops completely at dusk and resumes at dawn. Solar cells do not store electricity but batteries can be used to store the energy. One of the most fascinating aspects of the solar cells is their ability to convert the most abundant and free form of energy into electricity, without moving parts or components and without producing any adverse forms of pollution that affect the ecology as is associated with most known forms of non-renewable energy production methods, such as fossil fuel, hydroelectric or nuclear energy plants. [6]

Figure 7: Solar Panel

D. Solar Charge Controller

A solar regulator (also known as a charge controller) is used in conjunction with a standalone (off grid) system, or a grid connect solar power system that incorporates a backup battery bank. For a grid connect solar power system that doesn't use batteries, a solar regulator is not needed [7].

Figure 8: Solar Charge Controller



A solar regulator is a small box consisting of solid state circuitry that is placed between a solar panel and a

battery. Its function is to regulate the amount of charge coming from the panel that flows into the deep cycle battery bank in order to avoid the batteries being overcharged. A regulator can also provide a direct connection to appliances, while continuing to recharge the battery; i.e. you can run appliances directly from it, bypassing the battery bank; but the batteries will continue to be charged. Modern solar regulators are very efficient.

a. Resistors

Resistors is a two terminal electronic component that produces a voltage across its terminals that is proportional to the electric current passing through it in accordance with ohms law.

$V = I\,x\,R$ (1)

The formula for calculating resistance is given by.

$R = V/I$ (2)

The function of the resistor in both the charging and control / switching circuits is for current limiting.

b. Capacitors

A capacitor, which is a passive electronic component, consist of a pair of conductors which are separated by a di-electric. A capacitor has good similarities with a battery but charges and discharges more efficiently. An ideal capacity is characterized by a constant capacitance C, defined as the ratio of charge +/- Q on each conductor to the voltage V between then i.e. $C = Q/V$

Large capacitors are used in the battery charging unit for filtering and elimination of pulses while they are used in the micro-controller unit for the oscillator.

E. DC Cooling Fan

Cooling fans provide cooling solutions to your system thermal problems. The need for forced-air cooling by using an AC or DC axial fan or blower should be determined at an early stage in the system design. It is important that the design plans for good airflow to heat-generating components and allows adequate space and power for the cooling fan or blower. [8] Cooling fans and blowers are essential to systems that produce a significant amount of heat like computers and other electronic components. Different systems are engineered to work with specific types of fans. Cooling fans come in all shapes and sizes as well as voltage, airflow and case size, some are even weather resistant and can stand up against the elements. It's important to know the specific type of fan your electronic component requires as fans are not universal. (NMBTC, 2016).

F. Gear

A gear is a rotating machine part having cut teeth or cogs which mesh with another toothed part to transmit torque, in most cases with teeth on the one gear being of identical shape and often also with that shape on the other gear. When two gears mesh, and one gear is bigger than the other (even though the size of the teeth must match), a mechanical advantage is produced, with the rotational speeds and the torques of the two gears differing in an inverse relationship, when two gears mesh, the smaller gear usually rotates faster than the larger gear though the larger torques gear is still proportionally greater [9]

In transmissions with multiple gear ratios such as bicycles, motorcycles and cars, the term gear refers to a gear ration rather than an actual physical gear.

a. Gear Ratio

The gear ratio of a gear train, also known as its speed ration is the ratio of the angular velocity of the input gear to the angular velocity of the output gear. The gear ration can be calculated directly from the numbers of teeth on the gears in the gear train. The torque ration of the gear train, also known as its mechanical advantage, is determined by the gear ratio. [10] The speed ratio and mechanical advantage are defined so they yield the same number in an ideal linkage.

b. Gear Trains with Two Gears

The simple's example of a gear train has two gears and that is type used for the implementation of this project. The input gear (also known as drive gear) transmits power the output gear (also known as the driven gear). The input gear will typically be connected to a power source such as a motor or engine. In such an example, the power output of the output gear (driven gear) depends on the ratio of the dimension of the two gears.

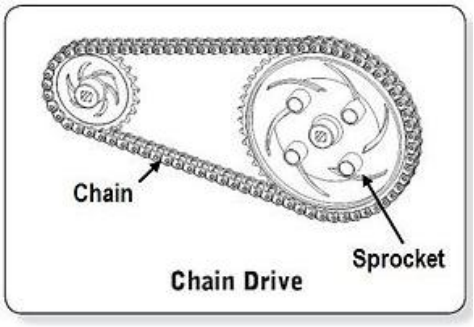


Figure 9: Chain and Sprocket Mechanism

Mathematically if the input gear Ga has the radius Ra and angular velocity Wa and meshes with the output gear GB or radius Rb and angular velocity Wb then,

$$v = r_A w_A = r_B w_B \quad (3)$$

$$\frac{wA}{wB} = \frac{rB}{rA} = \frac{NB}{NA} \quad (4)$$

This shows that a simple gear train with two gears has the ratio R given by

The number of teeth on a gear is proportional to the radius of its pitch circle, which means that the ratios of the gears' angular velocities, radii, and number of teeth are equal. *NA* is the number of teeth on the input gear and *NB* is the number of teeth on the output gear. The following equation is formed:

$$R = \frac{wA}{wB} = \frac{NB}{NA} \quad (5)$$

This equation shows that if the number of teeth on the output gear GB, is larger than the number teeth on the input gear GA, then the input gear GA must rotate faster than the output gear GB.

For the implementation of this project, a 38 teeth gear was used as the drive and a 14 teeth gear as the driven; hence the ratio would be
1:2.7, therefore from equation (5) above, we have

$$Ratio = \frac{38}{14} = 2.714$$

V. Cost Analysis

After a survey carried out on commercial tricycle transporters that ply (Bells Bus Stoptop – Tollgate axis) in Ota, Ogun state Nigeria, it was discovered that a full fuel tank would give two trips to and fro the axis. On a Regular days' work, they refill their tank three to four times. The Comparison between the Gasoline and Electric Tricycle in the aspect of cost in naira implication is as follows:

	INITIAL PURCHASE	RUNNING COST/DAILY	RUNNING COST/YEARLY	INITIAL +RUNNING COST
GASOLINE TRICYCLE	505,000	1800	657,000	1,162,000
ELECTRIC TRICYCLE	337,500	1307.136	477104.64	814604.64

Benefits

The electric tricycle would not use fuel but it would require electricity to recharge the bank @ a rate of #17.02 per Kwh. The bank charges for 8 hours to be full.

a. Job Creation
b. Lower running cost for commercial transportation
c. More accessible commercial transportation
d. Better customer satisfaction
e. Reduced noise pollution.

VI. Export Viabiity/History of Commercial Exports in Nigeria

The opportunities and benefits are endless commercializing this product. This would give to the rise to job opportunities that will come to the forbear when we have the right investment in the tricycle [11].

VII. Conclusion

The electric tricycle as compared the conventional petrol powered tricycles gives you a cost savings of over three hundred thousand naira on running cost as against the petrol powered which is almost enough to purchase another electric tricycle which means good business for the entrepreneur. It also has a carbon savings of 32 tonnes against the conventional tricycle which makes it absolutely a better option if intelligent steps are to be taken to combat global warming.

Safety in automobiles is a very integral part, so the Design was done in such a way the driver does not speed beyond the set limits of 30Km/hr and this helps minimize the hazards that accompany over speeding and it's also helps the brake to be fully initiated at any instance in time.

In conclusion, this project seeks to provide an alternative source of power for vehicles; [12] thereby ensuring that regardless of the various challenges that may affect the petroleum sector in Nigeria, commercial transportation will still be a vibrant sector in the country as total dependence on petrol or diesel will be avoided.

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