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Solar Based Plugged-in Hybrid Engine Driven rickshaw (Auto-Rickshaw) & its Feasibility Analysis for Bangladesh

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Abstract

Auto-rickshaws are used thoroughly in Bangladesh, India, and Pakistan etc. countries for transportation of public and goods. The vehicles are small and narrow allowing for easy transportability in busy Asian metropolises. In Bangladesh, auto rickshaws/easy bikes commonly offer their taxi-services, as they are incredibly inexpensive to operate. Concurrently these three-wheelers running on fuel cause severe air-pollution and produce considerable amounts of greenhouse gasses (i.e. carbon dioxide). This paper presents a transportation system based upon auto rickshaws that operate in an eco-friendly way. Existing vehicles are to be substituted by a micro cross type system redesigned in a manner which boosts the efficiency of the vehicle. In addition, a recharging infrastructure is proposed that will allow for the power-packs to be charged using partially alternative energy such as solar power. Thus far, we have appeared at the existing vehicle and the environment, in which it operates and investigated re-charging infrastructure requirements and designs. The goal of the research presented in this paper is to develop a compact, robust and affordable hybrid system as a way to significantly reducing fuel consumption and exhausts of auto-rickshaws.

Keywords: Plug-in hybrid, Hybrid three-wheeler, Hybrid Auto-rickshaw, Solar Hybrid Vehicle.

1. Introduction

With economic development, Bangladesh is industrializing. Megacities of the country are experiencing traffic problems day by day. The main public transports in its megacities (i.e. Dhaka, Chittagong, and Rajshahi) are Buses, Rickshaws and Auto-Rickshaws (Electric or ICE run). [1] The word ‘rickshaw’ was first used in 1887 [2]; originated from Japanese language, and it converts to "a human derived vehicle". In Bangladesh rickshaw commenced as a three-wheeled transport, known as man-pulled rickshaw, generally ripped by one man with one or two voyager. The auto-rickshaw and the relatively modern iteration of the e-rickshaw (electric rickshaw) because of their low travelling cost; becoming more popular than taxis in 21st century. [3] Asian megacities like Mumbai, Dhaka, Kolkata, Chennai, Delhi, Bengaluru and Chittagong this vehicle is mostly used to travel medium distance (1 to 7 km’s). Auto-rickshaws are also used as a public transport in many developing countries in the world [4, 1].Auto-rickshaw is a three wheeler mostly running on fuel (CNG/LPG) or electrical energy. Those running on batteries by means of electricity are often called “Easy Bikes”, locally. This is a very cost effective vehicle. LPG (Liquid Petroleum Gas) and CNG (Compressed Natural Gas) are nonrenewable energy sources. At present in Bangladesh the fuel price is increasing day by day. Burning of fossil fuels produces carbon dioxide, which traps heat to earth’s surface and causes enhanced greenhouse effect. Moreover engine exhaust gases release different types of deadly fluid aerosols and chemicals to the atmosphere which is very harmful for humans and animals. [5, 6] Presently there are many different auto-rickshaw types, designs, and variations. The most common type is characterized by a sheet-metal body or open frame resting on three wheels, a fabric roof with drop-down area curtains, a tiny cabin at the front for the driver with handlebar controls, and a valuables, passenger, or sewing-embroidery space at the rear [7]. The best way to redesign the rickshaw is to make the key power source separated. One way to do this is to use an energy system that can take advantage of several sources of renewable energy - namely, solar energy, bio-fuel and etc. Auto-rickshaws are a great prospect for electrification because of relatively low velocity and a relatively small distance protected in a day. [1, 4, 8, 9] In this paper a mechanism using micro hybrid system to run a car rickshaw is shown and defined. Hybrid systems can reduce fuel consumption and CO_2 emissions by up to 35%, equivalent to more than a 50% increase in fuel economy. [24] Solar energy and thermal energy can be used to drive the auto-rickshaw jointly by means of hybridization. Solar energy is chosen here because Bangladesh gets huge amount of energy from the sun. Here the best sunlight energy received is in Khulna ranging from 2.86 to 9.04 hours and in Barisal with readings varying from 2.65 to 8.75 hours. [10, 26]

2. Theoretical Approach

In this proposed vehicle, electrical and thermal energy sources are combined via plug-in hybrid system. As energy sources ICE and Batteries are being used. These two power sources are hybridized. The battery is charged my means of national grid and solar energy. There are several hybridization methods available like Series, parallel, series-parallel and complex; parallel hybridization is implemented here. If Plug-in hybrid vehicles run totally on battery power then it would be zero fuel consuming [11]. The power train of the hybrid system is shown in figure 1 below.

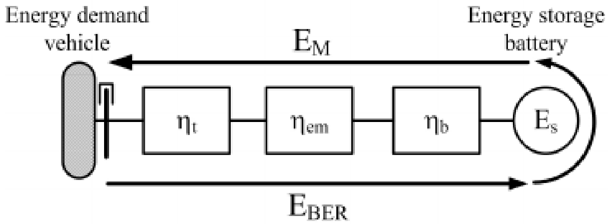

Fig. 1: Schematic diagram of power train [9]

The PHEV with an arrangement powertrain topology is investigated in this paper, as appeared in figure 2.The vehicle is pushed by an electric motor (EM) with an automatic mechanical transmission (AMT). Engine generator set (EGS) and Lithium-ion battery pack are utilized to supply electric energy to the engine. The battery pack is fundamentally in charge of energy supply to the EM amid the underlying time of a driving course. Be that as it may, when the condition of charge (CoC) of battery is relatively low, EGS will begin to work keeping in mind the end goal to accomplish a prolonged travel range [4, 22].

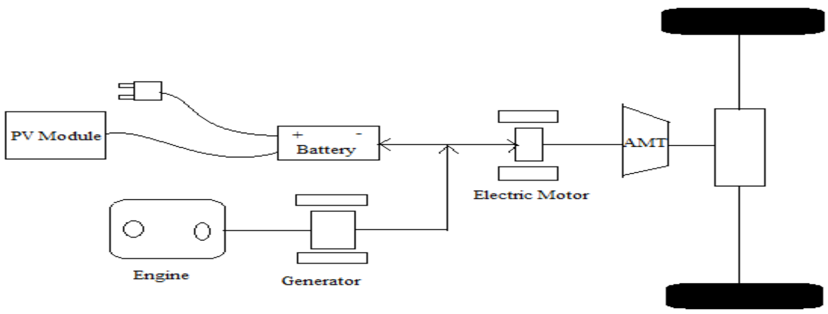

Fig. 2: Schematic diagram for power train system of plug-in hybrid electric vehicle (PHEV).

3. Analysis of Power

This paper focuses on plug-in hybridization of three-wheeler auto-rickshaw. A vehicle can be hybridized in many different methods. Plug-in hybridization is the basic type. Here the proposed vehicle is being designed and the power calculations along with fuel consumption economy has been done under typical conditions and the parameters (with dimensioning) of the machine elements are given as per local market specifications available in Bangladesh.

3.1. Engine Specifications and Testing

The specifications of the experimental engine are given below in Table-I: [12, 13]

Table-1: Experimental Engine Specifications [14]

Parameters	Dimension (SI unit)
Piston Diameter	.050228 × 10^{-3}m
Bore Radius	0.025114 × 10^{-3}m

Length of the Bore	0.046 m
Length of Stroke	0.042 m
Cubic Capacity	69.9×10^{-6} m^3
Type of Engine	2 Strokes
Number of Cylinders	01 pcs
Torque	12.531 N-m
Engine Efficiency	25%
Fuel	Petrol/Octane
Volume of Engine Cylinder	19 m^3 (Approximate)
Brake Power	2.61kW @ 5000 rpm

3.1.1. Power calculation for experimental ICE:

Power calculations of engine are shown in Table-II.

Table-2: Power calculation for IC engine

Particulates	***Equation***	***Value***
Displacement of engine	$\pi . S^2 . B . n$	69.79×10^{-6} Cubic Meters
Stroke	$\frac{4D}{\pi B^{2n}}$	0.042 Meters
Bore	$\frac{4D}{\pi S n}$	0.046 Meters
BMEP	$\frac{2\pi \times Torque}{Displacement\ of\ Engine}$	1129773.75 Pa
Fuel Consumption (specific)		10 kg/hr (Assumed) = 0.014 m^3/h (As 1kg/sec = 5 m^3/hr)
Mass Flow Rate	$\frac{Volume\ of\ Engine\ Cylinder \times Sp.Gravity\ of\ Fuel}{Time \times 1000}$	0.014 m^3/hr = .0028 kg/sec
Angular Velocity	$\frac{2\pi N}{60}$	521.5 rad/sec (N = Engine Speed in rpm)
S.P. Fuel Consumption	$\frac{Wt.of\ Fuel}{Brake\ Power}$	0.036 kg/kW (Approximately)

3.1.2. Solar PV Module specifications and Calculations

The battery used as electrical energy source will be charged in two ways, from National Grid and Solar PV module respectively. A perfect designed PV module is needed to charge the batteries. The specifications of the PV module are given in Table-III below.

Table-III: Experimental PV module Specifications [15, 25]

Parameters	***Dimension (SI units)***
Solar Panels	2 pcs
Rated Output	12V-180 W (Total)
Dimensions	1.5 × 0.8 × 0.05 meters
No. of Cells per Panel	N/A (variable)
Efficiency	18% (Approximately)
Battery	24 Volts, 4 pcs
No. of Solar Cells	60 mono crystalline cells

Power Consumption for PV module:

Let, The total weight of the vehicle (with passengers) = 500 kg,Average velocity of vehicle = 35 kmph

Total Power = $Total\ weight\ of\ vehicle \times g \times speed \times gradient\ of\ velocity$ = $500 \times 9.8 \times 35kmph \times .03$ Watts =$500 \times 9.8 \times 9.7mps \times .03$ Watts =1426 Watts, Here, the induction motor used is of 12V-1kW rated, Current Flow = $\frac{P}{V} = \frac{1500}{36}$ $\approx$ 42 Amp. Load Current per Day = $Current\ Flow \times Running\ Time\ per\ Day \times 1.2$ =42 × 5 hrs × 1.2 $\approx$ 250 Amp.hrs/Day, Capacity of the Battery = Load Current per Day × 1.2 = 300 amp.hrs/Day (overall 25% losses), Power required to run the motor = Capacity of Battery × Voltage Difference =250 × 36 = 9000 W.hrs/Day No. of Batteries to be used = $\frac{1430}{378}$=4 pcs, Now, here The Capacity of Solar Panel is 12V-180W, Current Flow = (180/12)/4 = 3.75 Amp to each Battery, Charging Time = 250/3.75 = 66.67 hrs, if one Solar Panel is used then in 8 hrs of daylight the system will be charged $\frac{100 \times 8}{73.8}$ or 12%. But if the numbers of solar panels are increased then this charging would be more efficient. This percentage of charging can be increased by increasing the number of solar panels. If two solar panels are used, then the system will be charged 24% using PV module.

4. Feasibility testing

Feasibility of this proposed system is analyzed by means of system installation cost and it's impact on environment.

4.1. Cost Analysis

Total power calculated to run the system = 1426 watts, Power required to run the motor 9 kwatts.hr/day=9 unit

In Bangladesh commercial electric line cost 25 BDT/unit, Requires =9000/ 5*36*4=12.5 hours to charge the full battery. Cost to charge the battery= 12.5*25=312.5 BDT/day

Case-1: When 1 pcs of Solar Panel is used, PV module will supply 12% of total power, So PV module will supply=9000*.12=1080 watts/day, So, Cost reduction= (1.08kw.hr*25) =27 BDT/day,Typical 180 W PV module costs approximately 40,000-45,000 BDT, For one 40,000 BDT; payback time=40000/27=1482 days=4.05 years (approx. ,For one 45,000 BDT; payback time = 45000/27=1667 days=4.57 years (approx.).

Case-2: When 2 pcs of Solar Panel is used, PV module will supply 24% of total power.

So PV module will supply=9000*.24=2160 Watts/day, So, Cost reduction= (2.16kw.hr*25) =54 BDT/day

Typical 180 W PV module costs approximately 40,000-45,000 BDT, For two 40,000; BDT payback time=80000/54=1482 days=4.05 years (approx.), For two 45,000; BDT payback time = 90000/54=1667 days=4.57 years (approx.)

Thus, Case-2 is more favorable.

Figure-3 shows a graphical representation of the cost analysis of the system installation.

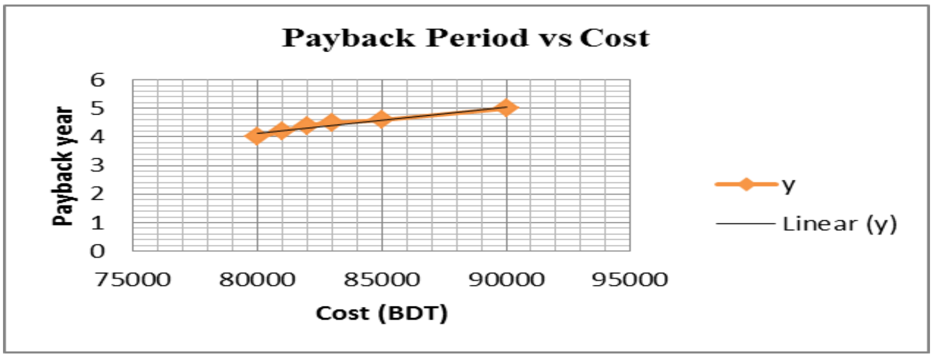

Fig. 3: Graph representing cost analysis of proposed system installation.

So, the payback time of this proposed system is between 4-4.5 years (approximately). A typical auto-rickshaw running age is between 18-20 years without much fluctuations in it's performance. [16] Figure-4 shows the relation between the running age and performance of a typical auto-rickshaw of Bangladesh.

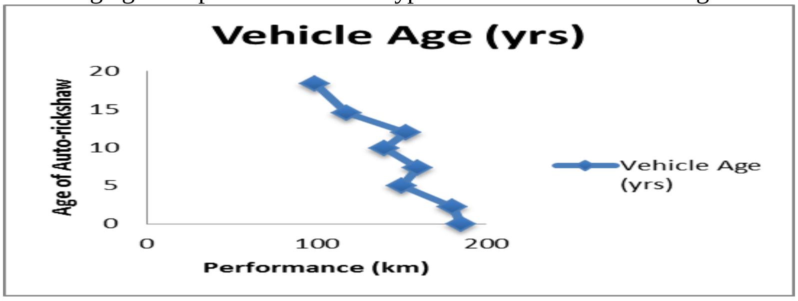

Fig. 4: Graphical relation between running age and performance of a typical auto-rickshaw.

This proposed system needs 4-4.5 years to gain the installation cost, this payback time is only about 22.5-25% or ¼ th of the total running lifetime of an auto-rickshaw.

4.2. Environmental Impact Analysis:

This research is mainly focused on lessen the conventional energy consumption via using renewable energy in Bangladesh. In Bangladesh, electricity is mainly produced by using thermal power plants. Those thermal power plants are a key source of CO_2 gas emission resulting in enhanced greenhouse effect. [5] A 500MW thermal power plant can produce up to 1 kg/kWhr production of electricity. [17] Table-4 gives a complete knowledge about CO_2 emission from the power plants of Bangladesh.

All these properties are approximate and some are estimated. Figure-05 shows a graphical presentation of CO_2 emissions from different power plants in Bangladesh.

Table- 4: CO_2 emission rate (estimated) from some power plants of Bangladesh. [18, 19, 20, 21, 25 and 26]

Installation Name	***Capacity (KW)***	***CO_2 emission (tons/day)***	***Nature of Combustion***
Ghorashal	955	12.926	Oil Ignited
Barapukuria	250	5.685	Coal Fired
Ashuganj	660	4.1096	Oil Ignited
Khulna	225	2.5699	Dual Fuel
Haripur AES	360	1.789	Gas
Katakhali	50	0.72399	Oil Ignited

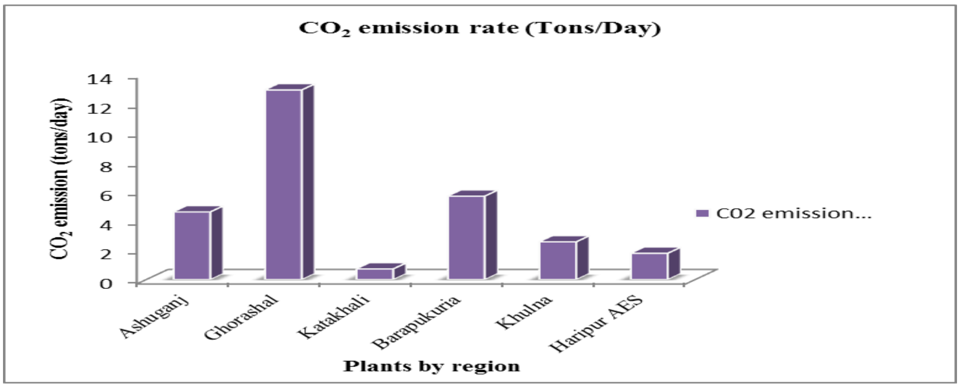

Fig. 5: CO_2 emission rates of various power plants in Bangladesh.

Our proposed vehicle system offers about 24% less power consumption from National Grid. So, a big number of these proposed vehicles will save more electrical energy resulting less emission of CO_2 from the fuel fired power plants. Here, Katakhali Power Plant (Rajshahi) of 50MW capacity will be kept under consideration for calculation. Assuming the plant as a 24 hrs/day working system, Maximum electricity supplied by the plant = 5000 kWhr The daily CO_2 emission from Katakhali = 0.72399 tonsDaily emission of CO_2 per kWh energy = $\frac{Daily\ CO_2\ emission}{Capacity\ of\ the\ Plant\ per\ Day\ in\ kWhr}$ = 1.44798×10^{-4} tons. [26] Now, if this proposed vehicle system is implemented on Rajshahi City then, Let, The numbers of proposed auto-rickshaws = 2000 (estimated) Energy savings per day per vehicle = 2.16 kWh [From previous feasibility calculation] Total energy savings per day = (2000*2.16) kWh = 4320 kWh CO_2 emission to produce 4320 kWh supply is $=(4320 \times 1.44798 \times 10^{-4})$tons = 0.62553 tons (w.r.t. Katakhali Plant) Lessen of CO_2 emission from Katakhali via using this system = $\frac{0.62553}{0.72399} \times 100$ = 86.4%. From the above analysis it can be surely said that the proposed vehicle system if implemented in Rajshahi City, then per day CO_2 emission can be reduced upto 86.4% and power can be saved upto 4320 kWhr per day. This analysis was performed considering no system loss; there remains a 25% system loss in thermal power plants. If the system loss is considered then actual percentage of CO_2 emission lessens from Katakhali Plant will be about 76-82%.

This feasibility analysis shows this system not only a cost effective but also an environment friendly one. This analysis mathematically proofs that vehicle system to be an effective one.

5. Conclusion

In the above described hybrid system A whole system combined with an ICE and electrical power source (rechargeable battery can be charged by solar power and national grid) was used which is not so familiar from the perspective of Bangladesh. Some of the data were collected from different auto rickshaw driver. Some data were neglected which were far away from the majority. Quite similar mechanism can be seen in different automobiles but here the system is applied to a three wheeler.

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