

Hybrid Energy Modeling for Auto Vehicles

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Abstract

Hybrid electric technology has become the latest milestone in the automotive industry. This paper presents an auto rickshaw based hybrid energy storage system that operates in an environmentally friendly way. The proposed auto rickshaw consists of a Solar panel, a Plug in Battery charger, a Maximum Power Point Tracking (M.P.P.T) circuit, battery module, Power controller, Control circuitry, Instrumentation system and a DC series excitation motor. The battery is fully charged by battery charger and the PV panel is trying to keep the state of full charged battery by continuous trickle charging. The charge sustaining capability enables the vehicle to accelerate faster, enhance the cruising capability, driving range, the battery life-span, and reduce road accident. The proposed vehicle model is analyzed by the Advanced Vehicle Simulator (ADVISOR) software. Finally, the use of hybrid energy can effectively improve the vehicle performance and efficiency.

Keywords: Hybrid energy, solar panel, MPPT, auto vehicle, ADVISOR.

1. Introduction

The first ever HEV was built in 1898, and there were several automotive companies who were selling HEV s in the early 1900s [1]. But the production of HEVs did not proceed due to the requirement for a smooth coordination between the engine and the motor, which was not possible due to the use of only mechanical controls and the poor efficiency compare to the combustion engine vehicle. Motorization was increasing day by day with the development of industrialization and urbanization.

The oil crisis of the 70s and the growing threat of global warming, excessive fossil fuel dependence, and increasing the fuel prices which have accelerated the development of Hybrid Electric Vehicles (HEV) into the political spotlight. Hybrids have been looked at as a possible solution to resolve consumption and pollution problems without having to reduce performance or range compared to a normal car. Therefore, serious research on hybrid cars began in the late 70s [2]. Electric drives are becoming very popular in the control of hybrid vehicles. The revolution in the design of automobile's electrical system creates a very large and diverse market for a practical 48V electrical system, new electrical functions, alternative electrical sources and necessity of power electronic controls and interfaces [3],[4]. Many automobile industries developed hybrid vehicles namely Honda Insight, Honda Civic, Toyota Prius, Volkswagen, Venturi Astrolab, Chevrolet Volt etc. The hybrid vehicles still have the disadvantage of a too high price. Also this type of hybrid vehicles (a four seated middle class car) does not really fulfill the needs of the Bangladeshi society and does not meet the requirements of a typical Bangladeshi city either. Conventional auto rickshaws are suited to the Bangladeshi environment. They are small and narrow, allowing maneuverability on congested roads. So, conventional auto rickshaw was converted to the hybrid energy storage system and it will be suitable in the development country.

Bangladesh is situated between 20^o34' and 26^o38' North Latitude and 88^o01' and 92^o41' East Longitude and the climate is tropical [5]. It gets abundant sunlight year round. The monthly average solar insolation at different Locations of Bangladesh is given in Table 1[6]. The Table 1 showed that the monthly average solar insolation is the highest in Rajshahi and the lowest in Sylhet. The daily average of bright sunshine hours at Dhaka city is given in Table 2 and showed that the daily sunlight hours in Bangladesh to range from 10 to 7 hours [7]. Maximum amount of radiation is available on the month of March-April and minimum on December-January [6].

The total solar energy reaching in Bangladesh is 180×10⁹ Mwhr/year which is 105 times the energy generated as electricity [5]. So, the solar resource in Bangladesh is rich and suitable form of renewable energy for urban region because of availability of plenty of sunshine. In effective operation, keeping the produced energy by this green source and the designed stand-alone system can operate economically. The vehicle is emission, noise and maintenance free. The oil prices all over the world are increasing day by day. In this system, our country does

not depend on foreign oil. At night time charging of EVs will help to balance the load and improve the power plant efficiency.

Table 1. Monthly Average Solar Insolation (KWh/m²) at Different Locations of Bangladesh

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barisal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source: Mondal, M. A. H., 2005, p.29

Table 2: Daily Average of Bright Sunshine Hours at Dhaka City

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Source: Bashar, REEIN, 2010a

With the factors of pollution, increased traffic in mind, drive range, charging cost, battery life and power crisis the best way to revamp the auto rickshaw is to develop a more efficient design that will be powered by a nonpolluting hybrid energy source, which can be achieved with an electric drive train since there are zero pollutants at the tailpipe. A hybrid energy source would make it a better solution compared to the current alternative-fuel-powered rickshaws and auto rickshaw.

In this paper, hybrid energy for auto vehicles is presented and comparison between electric vehicle and hybrid energy auto vehicles was done using a realistic driving cycle. The main purpose of this study is to evaluate the solar energy based auto vehicles for zero environmental pollution and to propose an efficient model for increasing the driving range, driving speed, minimize the charging time, enhance battery life and reduce the charging cost. The proposed vehicle model is analyzed by the Advanced Vehicle Simulator (ADVISOR) software. For designing and parameters analysis the data are collected from local markets and international markets through internet and the solar panel estimation data is calculated with respect to Dhaka city.

2. Conventional Auto Rickshaw

Auto rickshaws are three-wheeled vehicles that are widely used in many Asian countries as taxis or Easy bike for people. The existing electric three-wheelers are popularly known as Borak, E-Bike, Easy Bike, City Bike, etc. are now being used in 17 districts in Bangladesh. It has only battery powered electric vehicle. The battery is fully discharged in the evening. At night, the battery is charging 9 to 10 hours. At new condition, it covered 110km to 140km per day in a single charge with the top speed approximates 40 to 45 km/ph. The vehicle speed depends on the battery charge. The slope and bad road condition discharge the battery charge rapidly and

Components	Value
Outline dimension(L*W*H)	2650*1000*1650 mm
DC series excitation Motor	60V--1000W
Top speed	40~50km/h
Front wheel	4.00-12
Back wheel	4.00-12
Break distance	25km/h less than 4m
Storage battery	12V, 120AH(5 set)
Solar panel	260W, 44.6V
Solar panel size	1955*982mm
Daily distance covered	160km ~ 180km
Vehicle weight	300~400 Kg
Loading Capacity	450~500 Kg

4. Energy Storage System

In order to improve the vehicle efficiency, a hybrid energy storage scheme has been proposed. The battery module is charging by the home charge, solar charge and regenerative charge in a convenient way. The hybrid energy storage system block diagram is shown in figure 2.

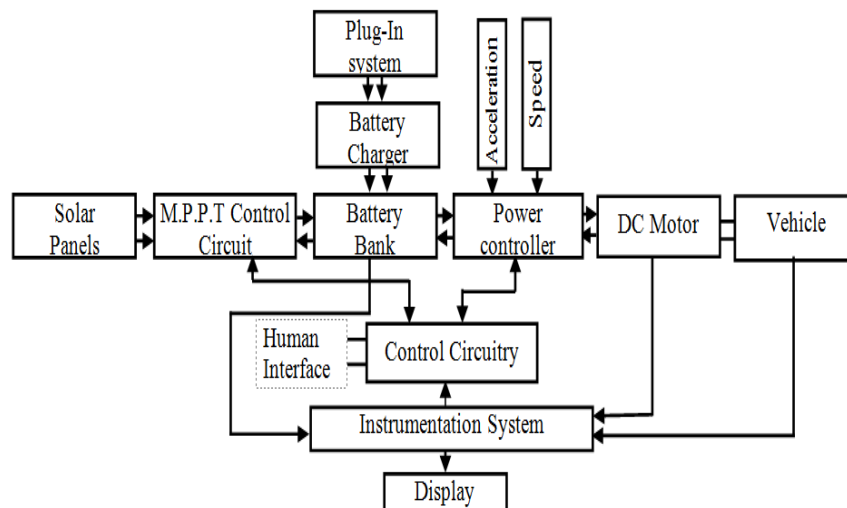


Fig. 2. Hybrid Energy Storage System

4.1 Home Charge

When the auto vehicle is parked at home at night, the vehicle on-board-charger can be connected to a single phase AC plug for slow night time charging. The battery is recharged at the correct charge rates and the current is automatically switched off when the charge is completed. In Figure 2 shows block diagram of a typical controlled on-board-charger. Depending on the battery capacity and depth of discharge, the charging time takes about 6-8 hrs and charging current is usually limited to 12A to 15A. This on-board-charger should be light & inexpensive. As the electricity demand is relatively low at night, this home charging scheme can facilitate the low level control of power utilization.

4.2 Solar Energy

In order to further enhance the vehicle drive time, batteries can also be charged by the solar panel embedded in the vehicle roof. The rickshaw has about 2.65 m² of space available on the roof alone to put solar panels. The output characteristic of PV cells could be expressed by volt-ampere (I-V) characteristic. The I-V characteristic is changed with the solar radiation intensity(S) and temperature (T). MPPT systems can be designed in such a way to achieve great output even under changing atmospheric conditions, shading, or irradiance conditions, such as those that would inevitably occur on the roof of a vehicle and in addition, to prolong the life-span of battery, a three-stage charging method is controlled the battery charge [8, 9]. A fully charged battery needs only trickle charge. The equivalent circuit of a PV cell is shown in Figure 3. [10, 11]

$$I = A_T J_o \left\{ \exp \left[\frac{q(U - IR_s)}{akT} \right] - 1 \right\} + \frac{U - IR_s}{R_{sh}} - A_E J_L \quad (1)$$

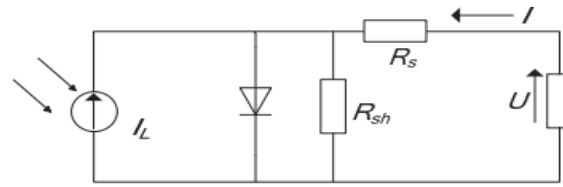
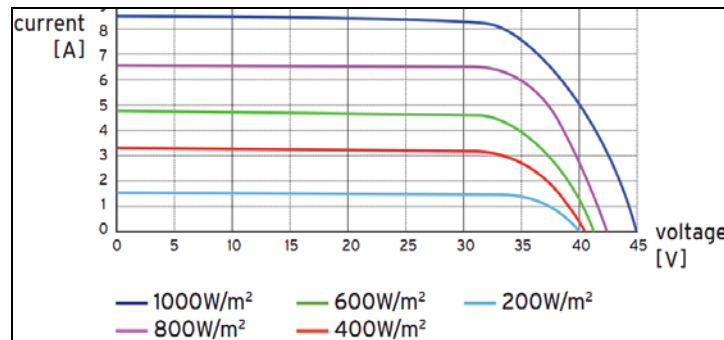


Fig. 3. PV cell model Electrical equations of the model is [12]

Where, A_T = total light area, A_E = effective light area, J_0 = saturation current intensity of diode, J_L = light current intensity, q = electronic charge, K = Boltzmann's constant, T = temperature.

The Solar panel used in the proposed system is 260Wp. In Bangladesh, the monthly average solar radiation is around 4.5 to 5 kWh /m²/day and the MPPT system track the maximum power from the panel. Considering only being able to capture about 5–10% of that energy due to inefficiencies of the panel, converters, dust, shadow and less-than-ideal tracking conditions, the actual energy recoverable per day is more than 1.8–1.9 kWh when using the entire surface. The I-V characteristic of a PV panel was given under factory laboratory conditions, just as shown in figure 4 and panel specification is shown in Table 4.



(Source: YINGLI SOLAR)

Fig. 4. I-V Curves of a Solar Panel

Table 4. 260W Solar Panel Specification

Parameter	Value
Power Output	260W
Module Efficiency	13.3%
Voltage at P_{max} , V_{mpp}	35V
Current at P_{max} , I_{mpp}	7.43A
Open circuit voltage, V_{oc}	44.6V
Short circuit current, I_{sc}	8.04A

(Source: YINGLI SOLAR)

4.3 Regenerative Charge

For recapturing the wasted energy to the battery pack regenerative braking system is used in driving schedules which involves in the vehicle frequently starts and stops. This method can increase the vehicle driving range by 8-25%. [13], [14]. Energy can be saved about 20% in a low speed urban based schedule with stops at about one km intervals and a cruise speed of 10 m/s and, vehicle range can be expected to increase proportionately [15]. However, high speed suburban cycles with relatively long steady state cruise modes of about 15 km and a cruise speed of 30 m/s save only about 6% energy for a modest extension of range. Fig. 2 shows the regenerative braking system block diagram.

5. Simulation Result and Discussion

The battery module is fully charged by the on-board battery charger and the module capacity is 540Ah. The battery is also charged by the PV panel and increase in power due to MPPT system. Theoretically Max. Energy available from solar panel = 260W*7.55h= 1963Wh and Energy extracted by MPPT system=1805.96Wh. In this system, assume only 2% energy is recaptured by the regenerative braking system and it is approx. 150Wh. The proposed system the vehicle is running more than one and half an hour and it increased the driving range from 35Km to 40Km compare to the existing vehicle. The Solar system also acts as a pulse charging, and it reduces the battery charge-discharge current and prolongs the battery life span [16]. The auto vehicle is designed and

simulated by the ADVISOR software. ADVISOR is written in the MATLAB/Simulink and developed by the National Renewable Energy Laboratory. It is used to analyze performance, fuel economy, and emissions of conventional, electric, hybrid electric, and fuel-cell vehicles [17]. The first two ADVISOR input screens provide the interface to change the vehicle parameters and test the vehicle. By clicking “View Block Diagram,” it may look at and change the Simulink blocks of the overall vehicle model. In this way, the solar panel model was chosen by subtracting a constant value from the required power of the power bus and also adding a corresponding weight to the vehicle, which can be done at the first input screen. The constant value is based on research for the power ratings of the feasible panel. This method will not show dynamics but will give the general results for the extended range of the vehicle and the effects on vehicle efficiency. To develop the standard driving cycle, some approaches were considered and some are similar to the Indian urban driving cycle [18]. From the ADVISOR software the vehicle Torque vs. speed curve, driving cycle speed vs. time curve, battery energy discharging efficiency curve is shown in Figure 5, 6 and 7.

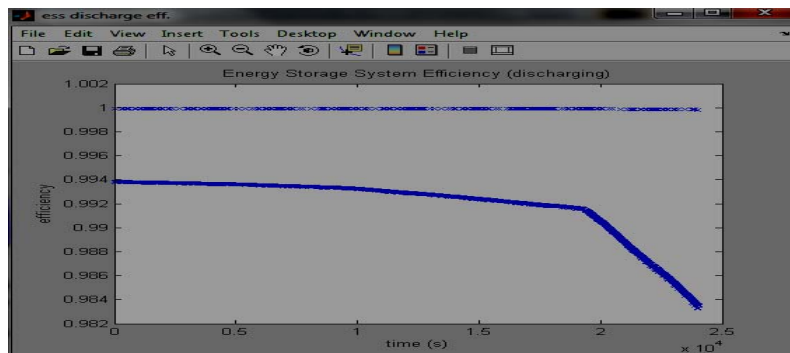
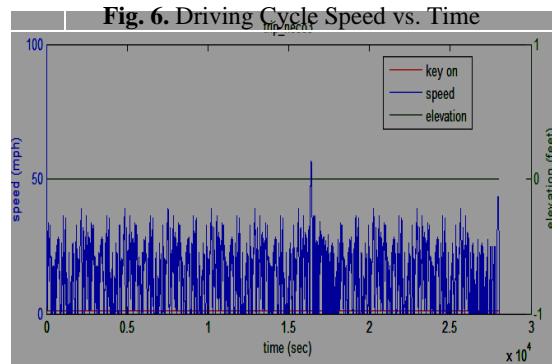
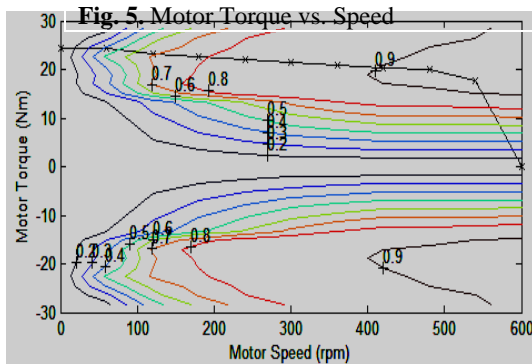


Fig. 7. Battery Energy Storage System Efficiency

The simulator results showed that the vehicle covered 179.26 Km at an average speed 14.3 mph and maximum speed 56.7 mph. The hybrid energy storage system increases the vehicle performance and efficiency. The vehicle does not need to charge at day time and it minimizes the charging cost.

6. Conclusion

The auto vehicles play a fundamental role in the world. Moreover, this vehicle is very popular day by day for the developing country due to the low transportation cost. Research showed that there are adequate renewable energies to support the infrastructure development of the auto vehicle. Thus, simulations have been performed on the electric vehicle supporting infrastructure and built a prototype system. The results showed that the vehicle can be achieved around 179 Km during a single charge with zero environmental pollution. The system facilitate with such feature that reduces the energy dependency, eliminate the additional pressure of the grid in day time, the drivers will not be worried about the battery charge, driving smoothly and avoid the prolong road accident in night. The driving range is increased more than the conventional vehicle. In Future research, the vehicle will be practically developed and analysis the result. To further increase the drive range more efficient motor controller, solar system and mechanical losses will be explored.

7. References

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