RESEARCH

2(6), December 1, 2012

ISSN 2278–5469 EISSN 2278–5450

Discovery

A Direct cost savings analysis of a gasoline-electric vehicle

Kwasi-Effah CC[1], Obanor AI[2]

1.Department of Mechanical Engineering, University of Benin, P.M.B 1154, Benin City, Nigeria. collinshicent@yahoo.com
2.Department of Mechanical Engineering, University of Benin, P.M.B 1154, Benin City, Nigeria. aiobanor@yahoo.com

Publication History
Received: 12 October 2012
Accepted: 23 November 2012
Published: 1 December 2012

Citation
Kwasi-Effah CC, Obanor AI. A Direct cost savings analysis of a gasoline-electric vehicle. *Discovery*, 2012, 2(6), 41-45

ABSTRACT
Generally, vehicles ability to reduce emissions is particularly important as they contribute to environmental pollution which threatens public health and welfare. Hybrid vehicles are seen as one of the major solutions in reducing the consumption of gasoline and emissions of greenhouse gases. Besides the reduction of green house gases, hybrid vehicles contribute significantly to the reduction of the operating cost of the user. So far, different approaches have been used to evaluate the cost benefit of hybrid vehicles. In this paper, a direct method involving combined simulated high way fuel economy test (HWFET) and urban dynamometer driving schedule (UDDS) drive cycle data and analysis was used to evaluate the life cycle cost of a series-parallel gasoline-electric vehicle based on the energy consumption of the model. Considering a vehicle life of 15 years and comparing the Net Present Value (NPV) of the gasoline-electric vehicle (GEV) with a conventional vehicle, the net consumer savings of the gasoline-electric vehicle was found to be ₦494, 352 (four hundred and ninety four thousand three fifty two Naira). The hybrid electric vehicle technology has shown great potential of substantially reducing fueling cost and green house gases compared to conventional vehicle.

Key words: Series-parallel, gasoline-electric vehicle, NPV, hybrid, energy, cost analysis, HEV technology.

1. INTRODUCTION
A gasoline electric vehicle (GEV) combines a conventional internal combustion engine (ICE) with an electric motor. GEVs make use of efficiency-improving technologies such as regenerative braking, which converts the vehicle's kinetic energy into electric energy to charge the battery, rather than wasting it as heat energy as conventional brakes do (Kwasi-Effah, 2012). One of the advantages of GEVs is that, at low speed, they reduce emissions of CO_2 by shutting down the ICE and restarting it when needed. However, this indirectly reduces the overall fuel consumption of the vehicle (Babici and Alexandru, 2006). The hybrid-electric vehicle did not become widely available until the release of the Toyota Prius in Japan in 1997, followed by the Honda Insight in 1999 (Matt, 2001).While initially perceived as unnecessary due to the low cost of gasoline, worldwide increases on the price of petroleum caused many automakers to release hybrids in the late 2000s; they are now perceived as a core segment of the automotive market of the future (Elizabeth, 2007). Hybrid cars have been on the market since 1997, but are still limited due to high manufacturing cost. The conventional vehicle is about 20% lower in price than the hybrid counterpart (www.carsales.com, 2012), but the fuel savings of hybrid vehicles are recouped based on mileage and driving conditions (Rob, et al, 2009).Besides the high cost, hybrid vehicle technology will decrease emissions of conventional air pollutants substantially as compared to a standard conventional vehicle on the roads today. Research has shown that, road transportation is responsible for 17-18% of global CO_2 emissions from fossil fuel combustion (Cacciola and Sarva, 2010). Analysis of road transport growth has shown that car ownership will continue to increase exponentially as years pass by (Rob, et al, 2009) hence, the emission rate of CO_2 will increase correspondingly. Purely electric vehicles are seen as a long-term solution to this problem, but existing batteries cannot store enough energy to give a satisfying distance range. The cost effectiveness of energy savings is also a factor of the hybrid system architecture (Babici and Alexandru, 2006). The most

common way of classifying hybrid vehicles is by their drivetrain architecture. Thus, the configurations are Series, Parallel and Series-parallel. However, a series-parallel powertrain brings in more degrees of freedom to vehicle engine operation with added system advantages (Cacciola and Sarva, 2010).

1.1 Drive Cycle Data

A drive cycle is a series of data points representing the speed of a vehicle versus time. It is a representation of road driving in various locations e.g rural, urban or high way drive. Drive cycles are produced by different countries and organization to assess the performance of vehicles e.g fuel consumption and polluting emissions (www.wikipedia.com, 2012). Drive cycle is crucial not only in assessing the performance of a conventional vehicle but also in simulating and accessing a hybrid electric vehicle so as to ascertain the overall performance over its conventional counterpart. There are standard drive cycles available and are used worldwide e.g UDDS, HWFET e.t.c. As a product of advanced design philosophy and component technology, the maturing and commercialization of GEV technologies demand extensive research and developments. Thus, this paper focuses on the cost savings potential of a series-parallel GEV.

2. METHODOLOGY

Mat lab/Simulink was used to model and simulate a 1325kg Gasoline-Electric Vehicle. The simulated model was based on the Toyota Prius series-parallel hybrid electric vehicle.

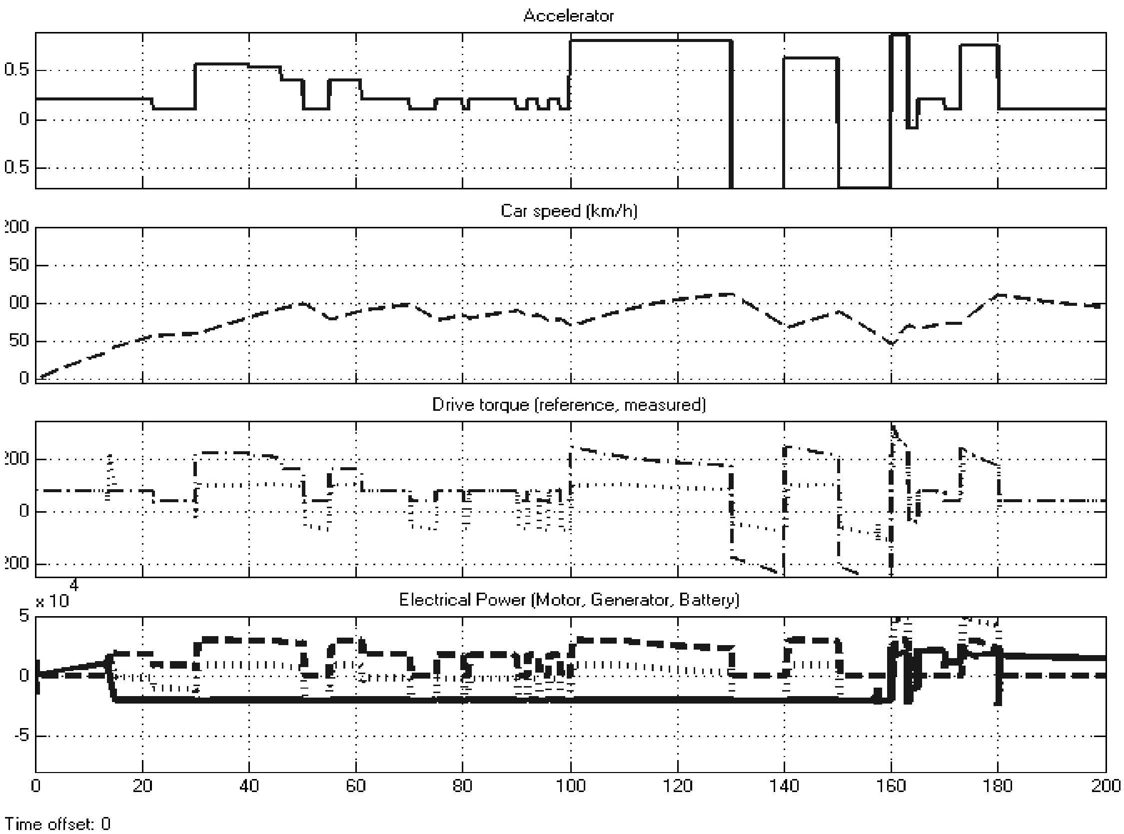


Figure 2.1
HWFET DRIVE

However, a combined simulation and analytical approach enables evaluation of the cost savings based on the energy consumption of the model. Figures 2.1 and 2.2 show the simulated model plot for both HWFET and UDDS drive cycle respectively. It is known that the most fuel efficient conventional car consumes approximately 8.10 liters/100km of fuel for HWFET drive cycle and 11.10 liters/100km of fuel for UDDS drive cycle (www.extension.iastate.edu, 2012).

2.1 Analysis of HWFET Drive Cycle

From the simulated HWFET plot, Car average speed = 67.6km/hr

Distance covered = 67.6km/hr x 200/3600 hr

= 3.756km

The higher heating value (HHV) of gasoline is 34.8MJ per litre (www.extension.iastate.edu)

From the simulated HWFET (Appendix A), Approximated total fuel energy input = 5,500KJ (3.756Km)

Hence fuel consumption = $5{,}500e^3 / 34.8e^6$

=0.14litre per 3.756km

Assuming driving pattern remains steady over a 100km thus, the fuel consumption per 100km = 0.16 x 100/3.756

=4.260litre per 100km

2.2 Life Cycle Cost

Assuming 15 years of vehicle life and it runs for 300 days a year with an average distance of 54km per day. The distance travelled by the vehicle in 15 years=243,000km.

The conventional vehicle is about 20% lower in price than the hybrid counterpart,

The purchase price of GEV = N3, 550, 000 (Nigerian Naira) (September 2012)

And purchase price of conventional vehicle=N3, 200, 000

1 liter of gasoline = N97 (September 2012)

For the GEV,

Comparing the fuel consumption, savings in fuel per 100km = 8.10-4.260 litres

= 3.840litres x 97 =N372.480

Savings in fuel per day = N201.139 (54km)

Therefore,
Savings in fuel per annum = N60, 341.76
Since GEV fuel consumption is 4.260 liter /100km thus,
Fuel consumption cost per annum = N66, 941.64
Hence cash flow per annum = 20, 000+66, 941.64

=N86, 941.640
(Where N30, 000 is other maintenance expenses and Tax)
Net Present Value (NPV) =cash inflow – cash outflow
Also, assuming rate of return is 7%.
NPV for 15 years of vehicle life:

NPV=$\sum \frac{CF}{(1+R)t}$ - ∩

Where CF= future value
R= rate of return
t=period
∩= cash outflow

NPV= -773,394 - 3, 550, 000
=-N4, 323, 394.240
For Conventional vehicle since there is no savings in fuel consumption
Cash outflow =N785.7/100km
Thus, future value per annum = N127, 283.4 + N20, 000

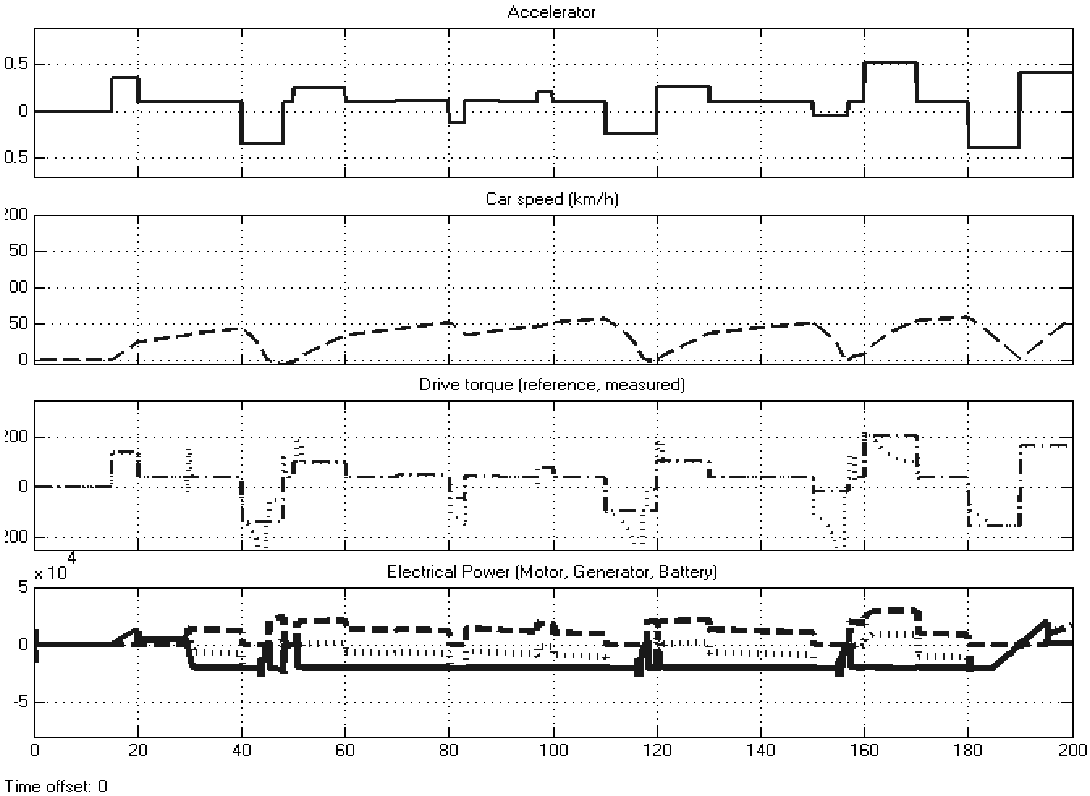


Figure 2.2
UDDC DRIVE

=N147, 283.400
(Where N20, 000 is other maintenance expenses and Tax)

$\sum \frac{CF}{(1+R)t}$ = -1,341,445

Thus,
NPV= -1,341,445-3,200,000
= N4, 541, 445 (out flow)

2.3 Analysis of UDDS Drive Cycle

Car average speed = 32.2km/hr
Distance covered = 32.2km/hr x 200/3600 hr
= 1.789km
From appendix B, Approximated total fuel energy input = 1,938kJ
Hence fuel consumption = 1,938e^3 /34.8e^6
=0.056litre per 1.789km
Since it is assumed that the driving pattern is steady over a 100km thus,
Fuel consumption per 100Km = 0.056 x 100/1.789
=3.130 litres

2.4 Life Cycle Cost

Savings in fuel per 100km = (70.5litrex97) =N759.12
Savings in fuel per day = N409.9 (54km)
Therefore,
Savings in fuel per annum = N122, 977.76
Fuel consumption of GEV = 3.130liter per 100km
Thus, Fuel cost per annum = N49, 184.820
Hence future cash flow per annum = N49, 184.82+N20, 000-
=N69, 184.820
(Where N20, 000 is other maintenance expenses and Tax)
Net Present Value (NPV) =cash inflow – initial investment
Where initial investment is N3, 550, 000
Also, assuming rate of return is 7%.
NPV for 15 years of vehicle life:
NPV= -650166.62 - 3, 550, 000
=-N4200, 166.62

For Conventional vehicle since there is no savings in fuel consumption
Cash outflow =N1076.700 per 100km
Thus, Cash outflow per annum = N174, 425.4 + N20, 000
=N194, 425.4
(Where N20, 000 is other maintenance expenses and Tax)

$$\sum\frac{CF}{(1+R)t} = 1770809.82$$

NPV=-1,770, 809.82 - 3, 200, 000
= - N4, 970, 809.82
Hence taking the average of both drive cycle,
For GEV,
NPV = (-4323, 394.24 – 4200,1 66.62)/2
=-N4261, 780.43
Also for conventional car
NPV_A= (-4541455 – 4970809.82)/2
=-N4756, 132.41

3. DISCUSSION

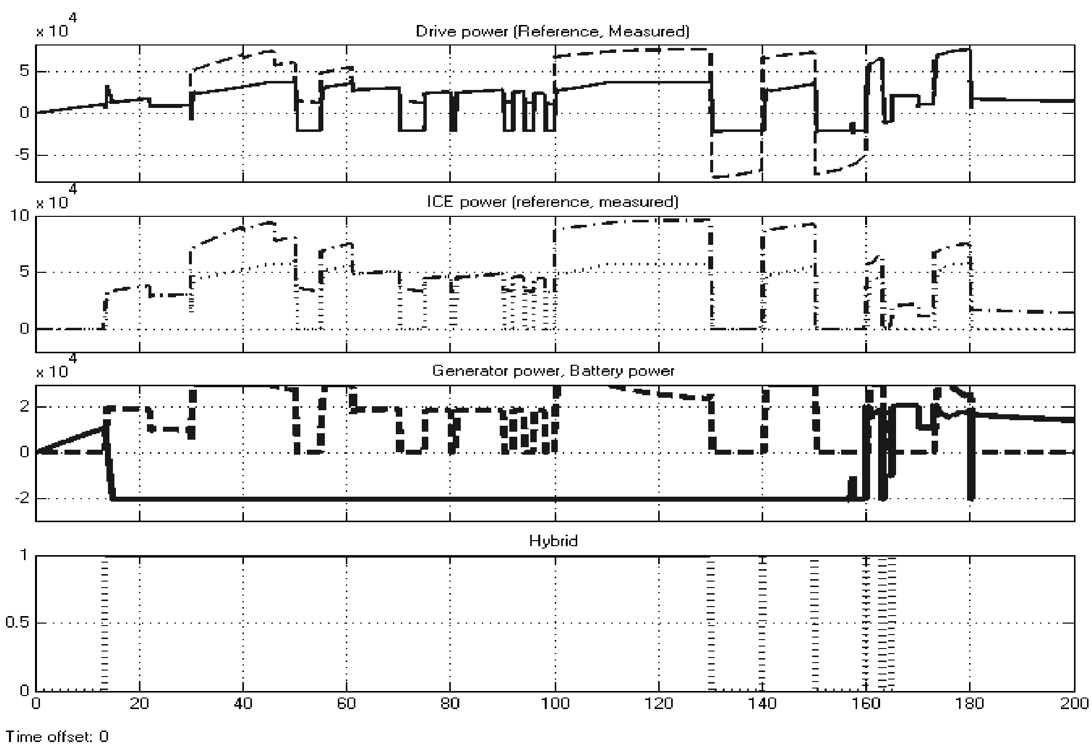
Technical and cost considerations are driving hybrid vehicle architectures to be improved day by day. However, managing a car for private use is generally considered as a liability asset, since the rate of return is always very small compared to the cash outflow (i.e cost of maintenance and operating). Thus, the less negative NPV is considered as more advantageous than the most negative. From the analysis, after considering a maximum distance of 243,000km which is equivalent to 15 years of vehicles life and comparing the net present value of the gasoline electric vehicle and the conventional vehicle counterpart, the net consumer savings of the gasoline electric vehicle was found to be N494, 351.98 more significant than the conventional vehicle. This is achieved as a result of the savings in fuel consumption and energy recovery of the regenerative braking system during the life of the vehicle. Though, the initial cost of the gasoline electric vehicle is high, the net operating cost is lower than the conventional vehicle. Hybrid electric vehicles are expected to be introduced on an increasing scale in the next 5 to 10 years beginning from 2012 through enabling policies governing the transport sector(i.e. policies in line with environmental and energy factors). While this hybrid technology is still maturing, a number of HEVs on the road can start making a significant change in transport energy usage today, and can help countries meet fuel efficiency targets by 2050.

4. CONCLUSION

A direct approach has been used to evaluate the cost benefit of gasoline-electric vehicle. Having run the car on the UDDS and HWFET cycles, the NPV of the GEV seems higher than the conventional car by at least N494, 351.980. This is as a result of the savings in fuel consumption during 15 years of the vehicle's life. Thus, analysis has shown that the gasoline-electric vehicle is not only an alternative for reducing the green houses gas emissions, but also a cost effective alternative for transportation.

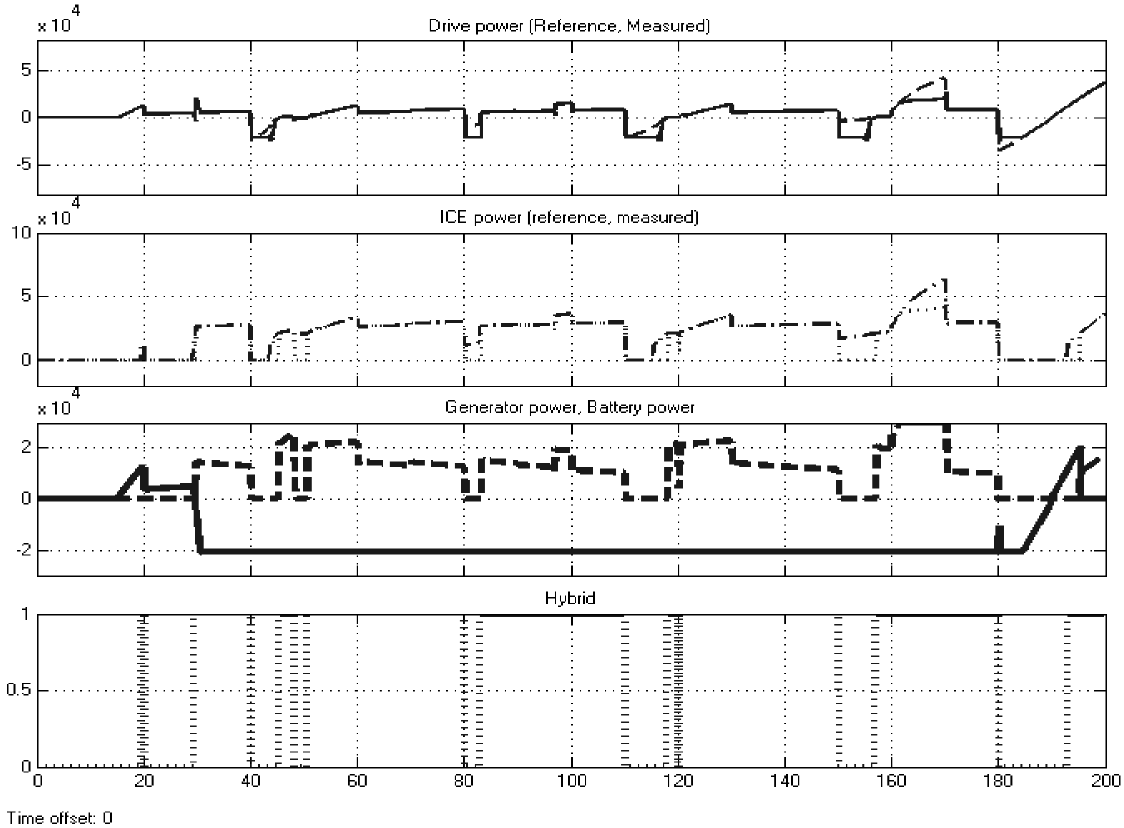
APPENDIX A

HWFET (ICE, TORQUE AND GENERATOR)



APPENDIX B

UDDS (ICE, TORQUE AND GENERATOR)



REFERENCE

1. Babici C. and Alexandru O. (2006): A Brief Study of Reducing Fuel Consumption in Hybrid Electric Vehicles . Technical report, Automatic Control and Applied Informatics Department, "Gheorghe Asachi" Technical University of Iasi.
2. Cacciola, R.R. and Sarva M.(2002): *Adverse respiratory effects and allergic sysceptibility in relation to particulate air pollution: flirting with disaster allergy report.*
3. Elizabeth L. (2007): Energy diversity as a busness imperative. Future society vol. 41.
4. Kwasi-Effah C. C (2012): Performance appraisal of a gasoline-electric vehicle. Technical report, Department of mechanical engineering, University of Benin.
5. Matt L. (2001): How it works; A Tale of 2 Engines: How Hybrid Cars Tame Emissions .nytimes technology.
6. Rob d. J, Max A, and Elisa D (2009): overview of current technology and its application in developing and transitional countries. United Nations Environmental Programme (UNEP).
7. www.carsales.com/pdf. (2012)
8. www.wikipedia.com/emissions(2012)
9. www.extension.iastate.edu (2012)