Development of a Robust Hybrid Vehicle Power Management Control System

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***Abstract*—Hybrid vehicles (HVs) have the advantages of both internal combustion (IC) engine vehicles and electric vehicles (EVs) and overcome their disadvantages. In order to enhance the performance of hybrid vehicle, "Arduino" based control system is utilized to design power management strategies for parallel HVs .The models of hybrid vehicle are developed by electric vehicle simulation software ADVISOR which uses a hybrid backward/forward approach. The results demonstrate that the proposed control system provide a good approach for the advanced power management system of robust hybrid vehicle.**

Keywords—Robust hybrid vehicles; control systen; power mangment system; parallel hybrid vehicle; Ardueno; stateflow; simscape; matlab simulink; ADVISOR.

I. INTRODUCTION

The development of internal combustion engine automobiles is one of the greatest achievements of modern technology. However, the deteriorating air quality, global warming issues, and depleting petroleum resources are becoming serious threats to modern life. Progressively more rigorous emissions and fuel efficiency standards are stimulating the aggressive development of safer, cleaner, and more efficient vehicles. It is now well recognized that electric, hybrid electric drive train technologies are the most promising vehicle solutions for the foreseeable future. The disadvantages of ICE vehicles include low energy efficiency, excessive harmful chemical emissions, high noise level and heavy dependence on a single fuel source. Hybrid vehicles are one of the solutions proposed to tackle the perceived problems associated with the energy crisis and global warming. Hybrid vehicles are vehicles that use two or more power sources into one drive system [10 and 11]. In recent years, a variety of control strategies for energy management have been used to hybrid vehicle. Schiffer et al. [2] had reported a state control strategy for FC + UC hybrid vehicle based on different driving phases to minimize the hydrogen consumption and to assure power availability at any time Kim et al. [5] had proposed a fuzzy controller to optimally distribute the relative power between the fuel cell and the battery. Paladini et al. [6] had presented an optimal control strategy to power a vehicle with both fuel cell and battery to reduce fuel consumption. Thounthong et al. [9] had used an innovative control law based on flatness properties for fuel cell/super-capacitor hybrid power source. However, in these works the proposed control strategies had not adequately considered the balance between fuel economy and dynamic property of hybrid vehicle [1-9].

II. CLASSIFICATION OF HYBRID VEHICLE

Traditionally, Hybrid vehicle are classified into two basic types: series and parallel. It is interesting to note that, in 2000, some newly introduced HEVs could not be classified into these kinds. Hence, HEVs are presently classified into four kinds: series hybrid, parallel hybrid, series–parallel hybrid, and complex hybrid—that are functionally shown in fig. 1[8].

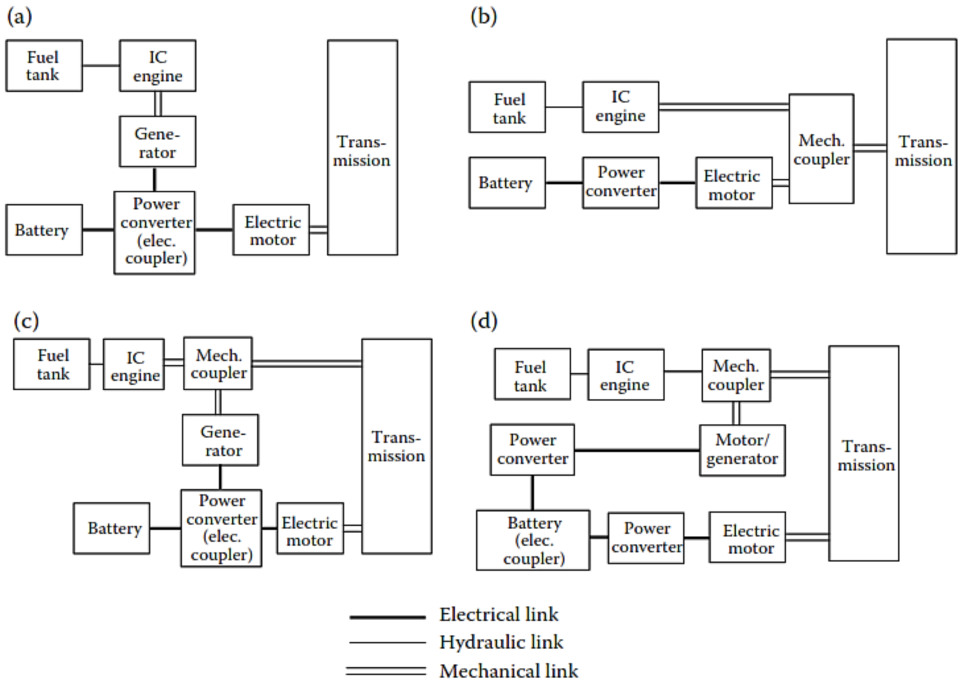

Fig.1. Classifications of HVs. (a) Series (electrically coupling), (b) parallel (mechanical coupling), (c) series–parallel (mechanical and electrical coupling), and (d) complex (mechanical and electrical coupling) [8].

Fig. 1-a functionally shows the architecture that is traditionally called a series hybrid drive train. The key feature of this configuration is that two electrical powers are added together in the power converter, which functions as an electric power coupler to control the power flows from the batteries and generator to the electric motor, or in the reverse direction, from the electric motor to the batteries. The fuel tank, the IC engine, and the generator constitute the primary energy supply and the batteries function as the energy bumper. Fig. 1-b is the configuration that is traditionally called a parallel hybrid drive train. The key of this configuration is that two mechanical powers are added together in a mechanical coupler. The IC engine is the primary power plant, and the batteries and electric motor drive constitute the energy bumper as shown in fig. 2. The power flows can be controlled only by the power plants—the engine and electric motor. Fig. 1-c shows the configuration that is traditionally called a series–parallel hybrid drive train. The distinguished feature of this configuration is the employment of two power couplers—mechanical and electrical. Actually, this configuration is the combination of series and parallel structures, possessing the major features of both and more plentiful operation modes than those of the series or parallel structure alone. On the other hand, it is relatively more complicated and may be of higher cost. Fig.1-d shows a configuration of the so-called complex hybrid, which has a similar structure to the series–parallel one. The only difference is that the electric coupling function is moved from the power converter to the batteries and one more power converter is added between the motor/generator and the batteries. This paper concentrate more on the parallel configurations.

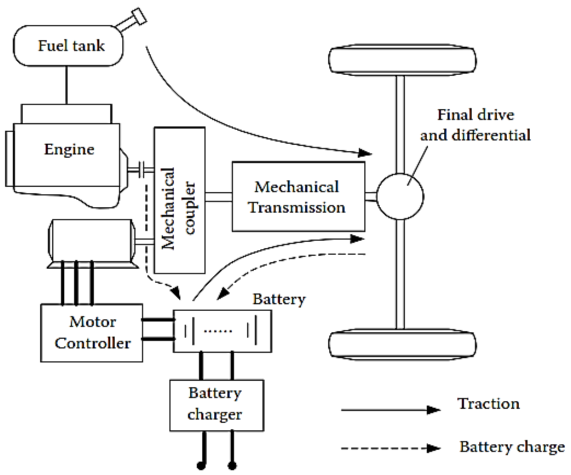

Fig. 2. Configuration of a parallel hybrid electric drive train [8].

III.CONTROL SYSTEM

As the hybrid vehicle is nonlinear and multivariable, "Arduino" based controller (ABC) is more suitable for the energy management. The controller relates its output to inputs using a list of IF-THEN rules. The IF part of a rule, specifies the condition for which a rule holds. The THEN part of a rule refers to values of the output variable to obtain the output of the controller.

A degree of membership is assigned to the variables according to the membership functions definition. The membership degree of the IF part of all rules are evaluated and all rules of the THEN part are averaged and weighted by these membership degrees.

A. Tools used for modeling and simulation

The control complexity of parallel HVs increases significantly, because power flow has to be regulated and blended from two parallel sources. So several tools is required to model and simulate the control system, the tools utilized in this paper are:

- **Arduino** software is an integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the processing programming language and the wiring projects. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a sketch. Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original wiring project, which makes many common input/output operations much easier.
- **Simulink** is a block diagram environment for multi-domain simulation and Model-Based Design. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems.
- **Stateflow** is an environment for modeling and simulating combinatorial and sequential decision logic based on state machines and flow charts. Stateflow lets you combine graphical and tabular representations, including state transition diagrams, flow charts, state transition tables, and truth tables, to model how a system reacts to events, time-based conditions, and external input signals. Stateflow can be uses to design logic for supervisory control, task scheduling, and fault management applications. Stateflow includes state diagram animation, static and run-time checks for testing design consistency and completeness before implementation.
- **Simscape** provides an environment for modeling and simulating physical systems spanning mechanical, electrical, hydraulic, and other physical domains. It provides fundamental building blocks from these domains that can be assembled into models of physical components.

B. Arduino based controller (ABC)

Arduino based controller utilize Arduino board (Arduino Mega 2560 R3), which is a microcontroller board that has 54 digital input/output pins [of which 15 can be used as pulse width modulation (PWM) outputs], 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Arduino Mega can be programmed with the Arduino software. The specifications of the Arduino board are represented in table I.

TABLE I. THE SPECIFICATIONS OF THE ARDUINO BOARD

Name	Specification
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

C. Energy management strategy

The developing process aimed to reduce the time and cost requirements of the model by dividing the system into individual subsystems. A driver model was developed using a state flow chart that decides the required state either to accelerate or decelerate to achieve a required speed input from a driving cycle, the difference between the current speed and the required speed is sent to the accelerator and brake pedals to develop the required signal. Simscape Generic engine is used to simulate spark ignition engine. There are two physical rotational port representing the engine block and engine crankshaft. The throttle input signal lies between zero and one and specifies the torque demanded from the engine as a fraction of the maximum possible torque. Battery block from the sim-power-systems library was used to model the battery output voltage, current and the state of charge. MOSFET blocks were used to build the D.C. motor driver. Torque coupling was done using a sprocket and chain drive between the gearbox output shaft and the D.C. motor shaft. The driver controllers were tuned by using Simulink control design to achieve a balance between response time and stability, then the controller and the model were tested. Then accelerator and brake pedals, throttle position and vehicle speed is translated to the Arduino based controller as liner variable resistance, variable resistance, and frequency to voltage converter respectively. While, for battery charging four relays are used representing 25%, 50%, 75% and 100% charge level of the battery and a D.C. motor is used to simulate the vehicle electric motor .

Then Arduino based controller, selects the most efficient operation mode to achieve the driver demand as follows:

1. Pure electric traction mode: The engine is turned off and the vehicle is propelled only from the batteries.
2. Pure engine traction mode: The vehicle traction power comes only from the engine, while the batteries neither supply nor accept any power from the drive train

3. Hybrid traction mode: The traction powers are drawn from both the engine and the motor, merging together in the torque coupler.
4. Engine traction with battery charging mode: The engine supplies power to charge the batteries and to propel the vehicle simultaneously.
5. Regenerative braking mode: The engine is turned off and the traction motor is operated as a generator powered by the vehicle kinetic or potential energy. The power generated is charged to the batteries and reused in later propelling.

IV. RESULTS AND DISCUSSIONS

The proposed power mangment strategies are contrasted with the power following control strategy which is wide adopted in ADVISOR. Fig. 3 shows the vehicle parameters in addition to the consequent variation of torque with vehicle speed. The simulation parameters is showed in fig. 4, with the variation of vehicle speed with time. In fig. 5 the effect of proposed control system on vehicle response is showed. As indicated the Arduino based control system provides smooth operation from zero speed to maximum speed. Fig. 6 shows that the vehicle speed with and without the control system is congruence, which indicate that the proposed system provides smooth vehicle operation without effecting the vehicle speed.

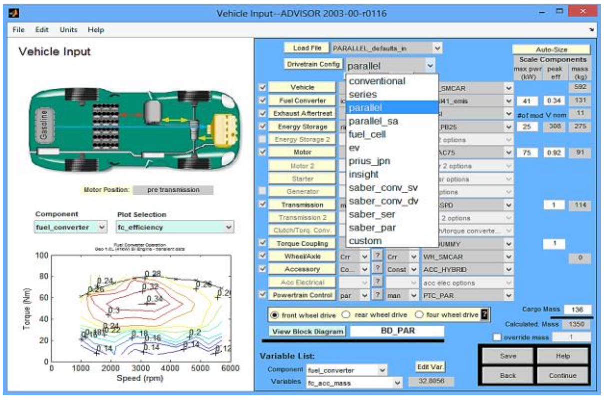

Fig. 3. ADVISOR vehicle input screen.

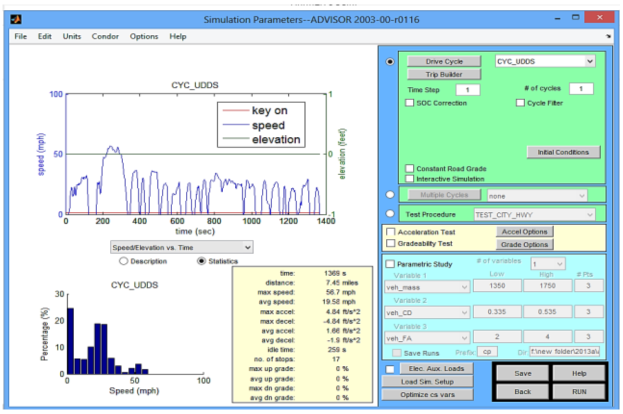

Fig. 4. ADVISOR simulation parameter screen.

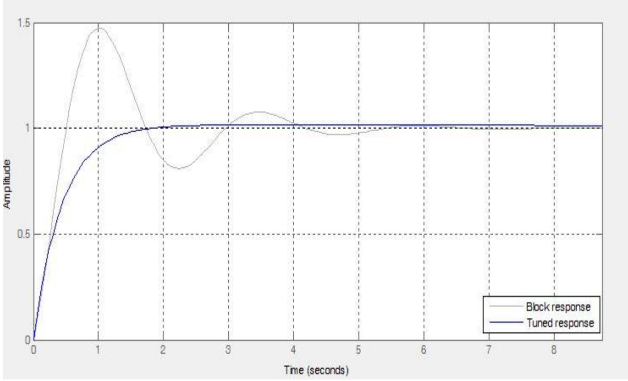

Fig. 5. Unit step response of the driver accelerator.

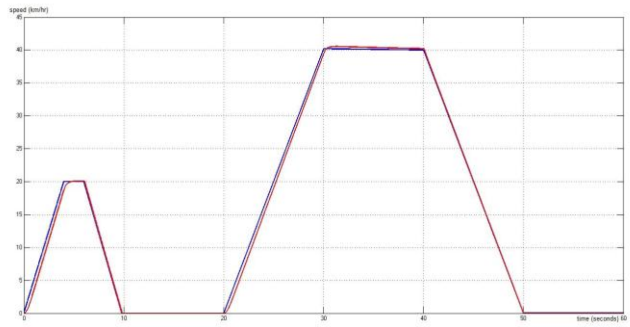

Fig. 6. Target vehicle speed.

V. CONCLUSION

In this paper, an Arduino based control system which utilize ADVISOR environment is used to design relevant power management strategies for parallel hybrid vehicle to manage power sharing between various components and to guarantee the power sources performance. The results showed that the proposed control system provides better performance in terms of fuel economy and power distribution. Hence, the proposed control system will give a good approach for the advanced power management system of hybrid vehicle.

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