
AC 2011-295: EDUCATIONAL TOOL DEVELOPMENT OF AN ELECTRIC DRIVETRAIN BENCH UNIT

Y. Gene Liao, Wayne State University

Y. Gene Liao received the BSME from National Central University, Taiwan, Mechanical Engineer from Columbia University, and Doctor of Engineering from the University of Michigan, Ann Arbor. He is currently an Associate Professor at Wayne State University. He has over 15 years of industrial practices in the automotive sector prior to becoming a faculty member. Dr. Liao has research and teaching interests in the areas of multi-body dynamics, hybrid vehicle powertrain, and CAE applications in products development and manufacturing.

D Fu, Wayne State University

Educational Tool Development of an Electric Drivetrain Bench Unit

Abstract

The industry consensus is that the vehicle electrification is the currently available technology for increasing propulsion system efficiency and decreasing pollutant emissions. However, the electric drivetrain operates much differently than conventional vehicle powertrain. There is a need for training automotive engineers and educating students in this new and emergent technology of electric drivetrains. This paper presents the educational tool development of an interactive, industrial-component-based bench unit for two different configurations of electric drivetrains: battery-electric and series-hybrid electric. The developed bench unit is capable of demonstrating, illustrating and displaying the multiple energy flows in the electric-drive vehicle based on its configuration and driving conditions. The integrated unit serves as a hands-on experience workstation for multidiscipline students enrolled in the electric-drive vehicle technology courses. The hands-on experience not only enhances the vehicle electrification training and education, but also inspires students' interest in the green movement of transportation.

1. Introduction

World competition and stringent United States fuel economy goals and emission regulations for the 21st Century vehicle have pressured the automotive industry to design and evaluate advanced automobiles at an accelerated rate. The industry consensus is that the vehicle electrification is the currently available technology for increasing propulsion system efficiency and decreasing pollutant emissions [1-4]. The vehicle electrification involves electric drivetrain and electrically powered automotive auxiliary subsystems that are at the heart of Battery Electric Vehicle (BEV), Hybrid Electric Vehicle (HEV), and Plug-in Hybrid Electric Vehicle (PHEV). The electric drivetrain operates much differently than conventional vehicle powertrain. Therefore, existing development, design, maintenance techniques and guidelines created for conventional powertrains do not apply well to electric drivetrains. There is a need for training automotive engineers and educating engineering students in this new and emergent technology of electric drivetrains.

In response to the need of a trained and educated workforce in vehicle electrification, several universities and colleges recently have developed projects, courses, and degree programs for training students and automotive engineers and technicians in electric-drive vehicle technology [5-10]. Developing new education and training for electric-drive vehicles requires careful planning of support laboratory, equipment and facilities. Existing courses in power electronics and electrical machines can be expanded and their laboratory resources leveraged with moderate cost. However, the costs will increase if the instruction includes hands-on experience with electric-drive propulsion components or dynamometer testing equipment. An overview course can be introduced with minimal laboratory impact provided existing electric machinery equipment already exists. Laboratory instruction can include exercises on DC motors, AC

induction or synchronous motors to build a solid foundation of the basic principles of electro-mechanical conversion such as torque, power, and efficiency. Vehicle subsystem tests could involve vehicle chassis dynamometer, electric motor dynamometer, and vehicle electronic control units integration.

Although several curricula, short courses and training programs have been developed and delivered in the emerging technology of vehicle electrification, no integrated electric-drive vehicle laboratory has yet been established for educational purposes. Classroom project-based laboratory activities on instrumentation for electric-drive components were presented by [10-12]. LabVIEW software-based computer simulators for virtual hybrid electric vehicle were reported by [13-14]. The tremendous capital investment, tedious and time-consuming tasks required to establish a full function of vehicle electrification laboratory are convincing evidence that the university/colleges are in need of a low-cost unit with industrial-functionality electric drivetrain laboratory.

The motivation of this project is to develop an interactive, industrial-component-based bench unit for two different configurations of electric drivetrains (battery-electric and series-hybrid). The developed bench unit is capable of demonstrating, illustrating and displaying (on the digital screens) the multiple energy flows in the electric-drive vehicle based on its configuration and operating conditions. The integrated unit serves as a hands-on experience workstation for multidiscipline students enrolled in the electric-drive vehicle technology courses. The learning-by-doing experience not only enhances the vehicle electrification training and education, but also inspires students' interest in the green movement of transportation.

2. Features of Electric-Drive Vehicles

The potential features of HEV include engine idle stop-start, engine-off driving (pure electric vehicle mode), power boost (maximum acceleration), and energy recuperation (regenerative braking). These typical HEV features are shown in Fig. 1 [15]. As previously mentioned, electric drivetrain includes propulsion systems of BEV, HEV and PHEV. In the BEV, the batteries must supply all the energy needs. There is no onboard charging system except for regenerative braking. The batteries provide the power to propel the vehicle and to power all accessories such as air conditioning and power steering. The traction power of the BEV is provided by an electric motor using electrical energy stored in a battery rather than utilizing a heat engine. The range/distance that a vehicle operates on electrical power exclusively is called All Electric Range (AER).

There are two basic HEV configurations, series and parallel. The main difference between them is how the propulsion power from heat engine and electric machine are distributed. In a series HEV, a small heat engine directly drives a generator to generate electricity. The electricity is then distributed through the power bus, partially for drive the electric motor and partially stored in the battery pack. The engine turns on and begins to recharge the battery pack when it is drained to a certain level. The engine can be operated within a narrower and more efficient range of speeds because it is not directly connected to the drive wheels. However the peak power required for acceleration and high speed cruising is limited by the capability of electric motor. A parallel HEV is configured with two power sources, so that either the heat engine or the electric propulsion system, or both, can be used to produce the motive power to the drive wheels. Since

the power from the heat engine and electric motor can simultaneously propel the vehicle, a higher peak power will be achieved comparing to the series configuration. A mechanical coupler, such as the planetary gear set, for torque and speed summation is needed which increases the complexity of packaging and control. Figure 2 show the typical layouts of BEV, series HEV and parallel HEV [16].



Figure 1. Energy sources in a typical HEV subject to driving conditions [15]

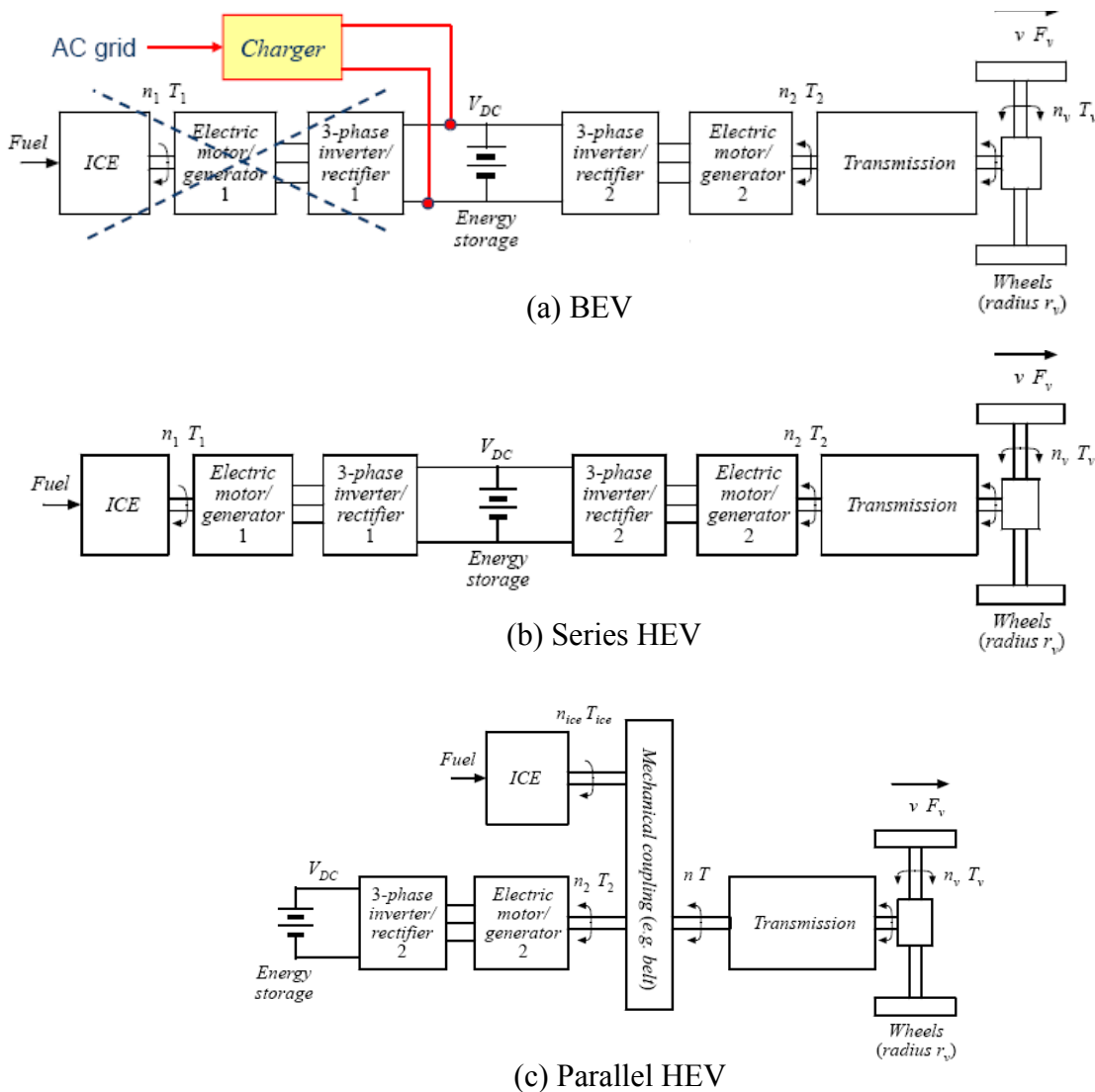


Figure 2. Typical layouts of electric-drive vehicles [16]

The developed bench unit is capable of demonstrating the features of electric propulsion systems of BEV and series HEV. This includes charge-depleting mode of BEV that vehicle is moved on electric power alone until its battery State Of Charge (SOC) is depleted to a predetermined level. The charge-sustaining mode is also demonstrated in the bench unit for series HEV. A series-HEV combines the operation of the two energy sources in such a manner that the vehicle is operating as efficiently as possible and maintaining the battery SOC within predetermined band.

3. Establishment of an Electric Drivetrain Bench Unit

Figure 3 shows the schematic diagram of a teaching tool for the electric-drive powertrain bench unit. It is a state-of-the-art combination of battery-electric and series-hybrid electric drive demonstration unit. The major components include engine, alternator, system controller, battery, electric motor, voltmeter, current meter, switch, motor speed controller, and real vehicle acceleration pedal. A three-phase AC alternator is operated by an engine in the system. A battery controller (or a battery management system) is applied to manage the charging and discharging process of the battery pack. A DC motor controller drives the motor to achieve the desired torque-speed characteristic curve. The motor shaft connects to a tire contacting with a rotating drum. The load applied to the tire from the drum simulates the road load.

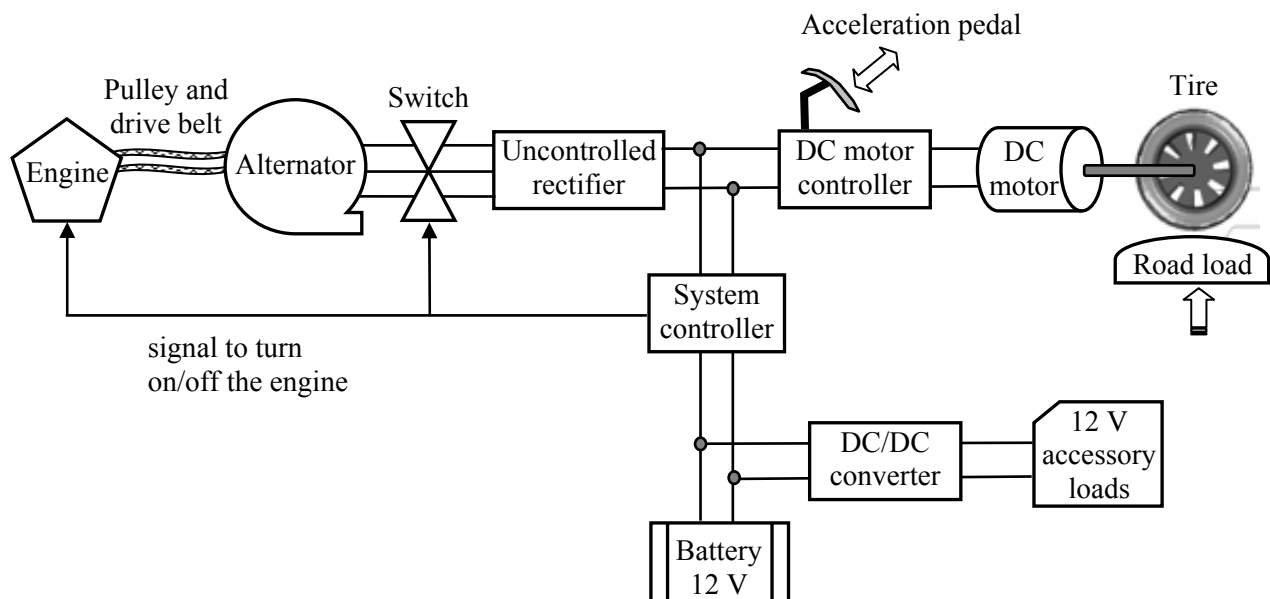


Figure 3. Schematic diagram of the electric-drive bench unit

3.1 Hardware of the bench unit

The major components of the bench units are listed in Table 1. Figure 4 illustrates the major components and their connections in the developed bench. There are four main functional blocks in the bench as illustrated in Fig. 4: battery and battery management, motor drive and brake system, internal combustion engine and alternator, and system controller.

(1) Battery and battery management

By measuring the current flow and voltage at the battery terminal, the battery SOC meter will calculate and keep track of the remaining capacity of the energy in the battery. The output of

the SOC meter is connected to the system controller to initiate the action of starting engine and generating charging current to the battery.

(2) Motor drive and brake system

The motor drive and brake system is to simulate the road load of the vehicle. Like normal vehicles, the accelerator pedal is used to command the speed controller to drive the motor. The brake system is adding the load to motor to consume the energy from the battery.

(3) Internal combustion engine and alternator

In the series HEV architecture, there is no mechanical connection from internal combustion engine to the traction motor. The only device attached to the engine from the belt drive is the generator. For this demonstration bench, a vehicle alternator is used to couple with the engine to generate electricity and charge the battery. The pulley ratios on both the engine and alternator shafts are carefully selected so it will keep a minimum speed on the alternator to effectively generate power.

(4) System controller

System controller is the brain of the bench. It monitors the SOC of the battery from Battery SOC meter and decides the action of the engine and alternator. It will also control the current from alternator and braking power of the brake.

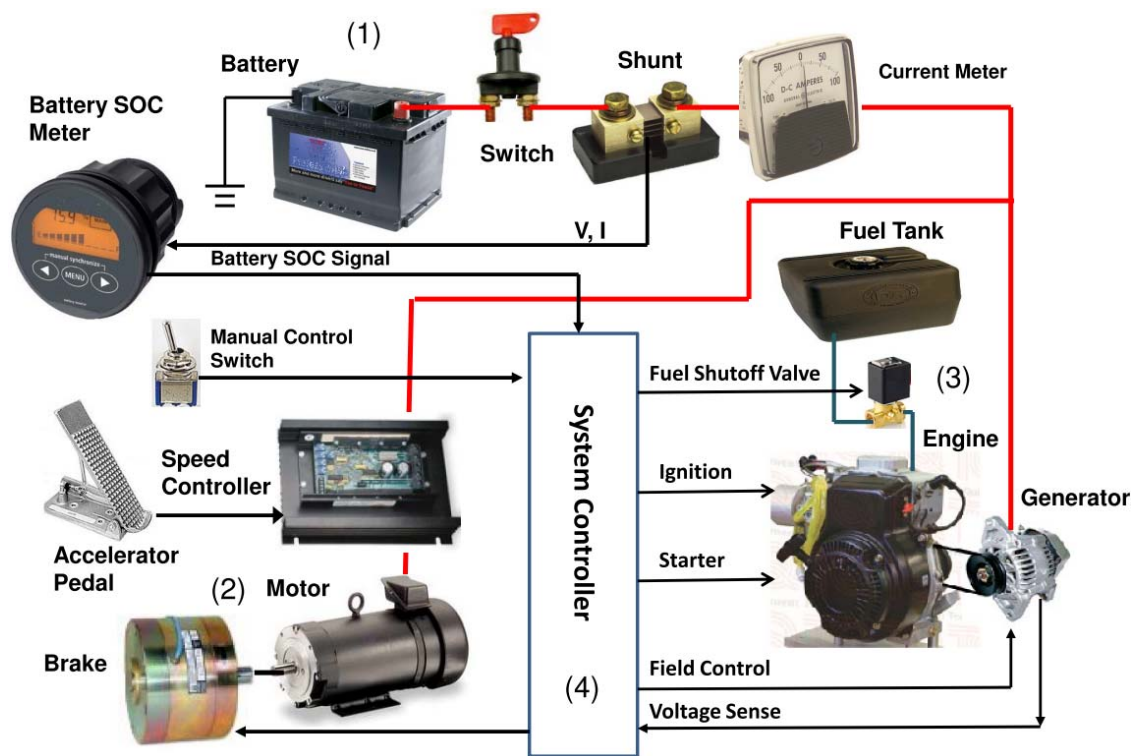


Figure 4. The connections of the hardware in the bench unit

3.2 Integration of the bench unit

System controller, as shown in Fig. 5, is a microprocessor-based device including five functions:

- (1) Input filtering stage removes voltage spikes and noise to protect sensitive electronic components.
- (2) The power supply will step-down the +12V from battery to +5V for the microprocessor.

- (3) The input signal conditioning stage adjusts the input voltage level and filters noise from the wire harness.
- (4) Microprocessor executes the software commands.
- (5) The output driver stage will increase current capability to drive external devices (solenoid).

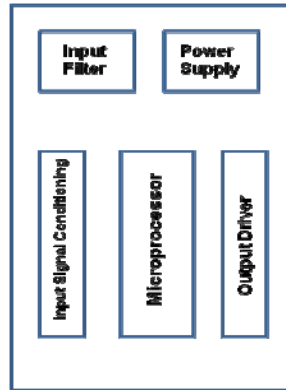


Figure 5. Microprocessor-based system controller

Table 1. Major components of the bench unit

| | |
|-------------------|---|
| Engine | Generac, 250 c.c., 7.8 hp, OHV, electric and recoil start, horizontal mounting. |
| Alternator | Remy, automotive generator. |
| Battery | YTZ7S AGM maintenance free battery |
| Electric motor | Dayton, permanent magnet DC, 1 hp, 1800 rpm, armature 12 VDC. |
| Motor controller | Dart, 65E60-12, variable DC speed control, output voltage 12 VDC, power rating 1/8 – 1 hp, speed range 30:1, maximum current 60 amps. |
| Microprocessor | BasicATOM, Pro 28-M |
| Voltmeter | Blue Sea, 8028 DC analog micro voltmeter. |
| Battery SOC meter | Xantrex, LinkPro/LinkLite battery monitor. |
| Main switch | Motormite 85988, battery isolator switch. |
| Fuse blocks | Littelfuse, MEGA, 298 series, 100A and 250A, 32V. |

The detail connection of the system controller is illustrated in Fig. 6. The engine is connected directly to the alternator via pulley and drive belt. The engine has an electric starter which is connected to system controller with two connections:

- (1) The positive terminal of the starter is connected with the solenoid which is connected to the starting relay in the system controller. The solenoid is also connected to the positive terminal of the battery. The negative terminal of the battery is directly connected to the negative terminal of the electric motor.
- (2) The wire coming out from the engine ignition coil to the manual ON/OFF switch is extended out and connected to the stopping relay in the system controller. The stopping relay replaces the original manual ON/OFF switch in the engine. The other end of the wire is connected to the spark plug. Thus the stopping relay is the connection between the spark plug and the ignition coil and this connection is the secondary ignition circuit. The secondary ignition circuit always needs to be connected to avoid the primary ignition circuit getting activated.

The secondary ignition circuit is used and active until it is connected and complete so that primary circuit will not be activated. The reason to avoid the use of primary circuit is that we do not have any control to stop the engine and the engine will keep on running until it runs out of fuel or is stopped by the tempering the throttle and fuel ratio which is advised to be done only by a technically qualified person.

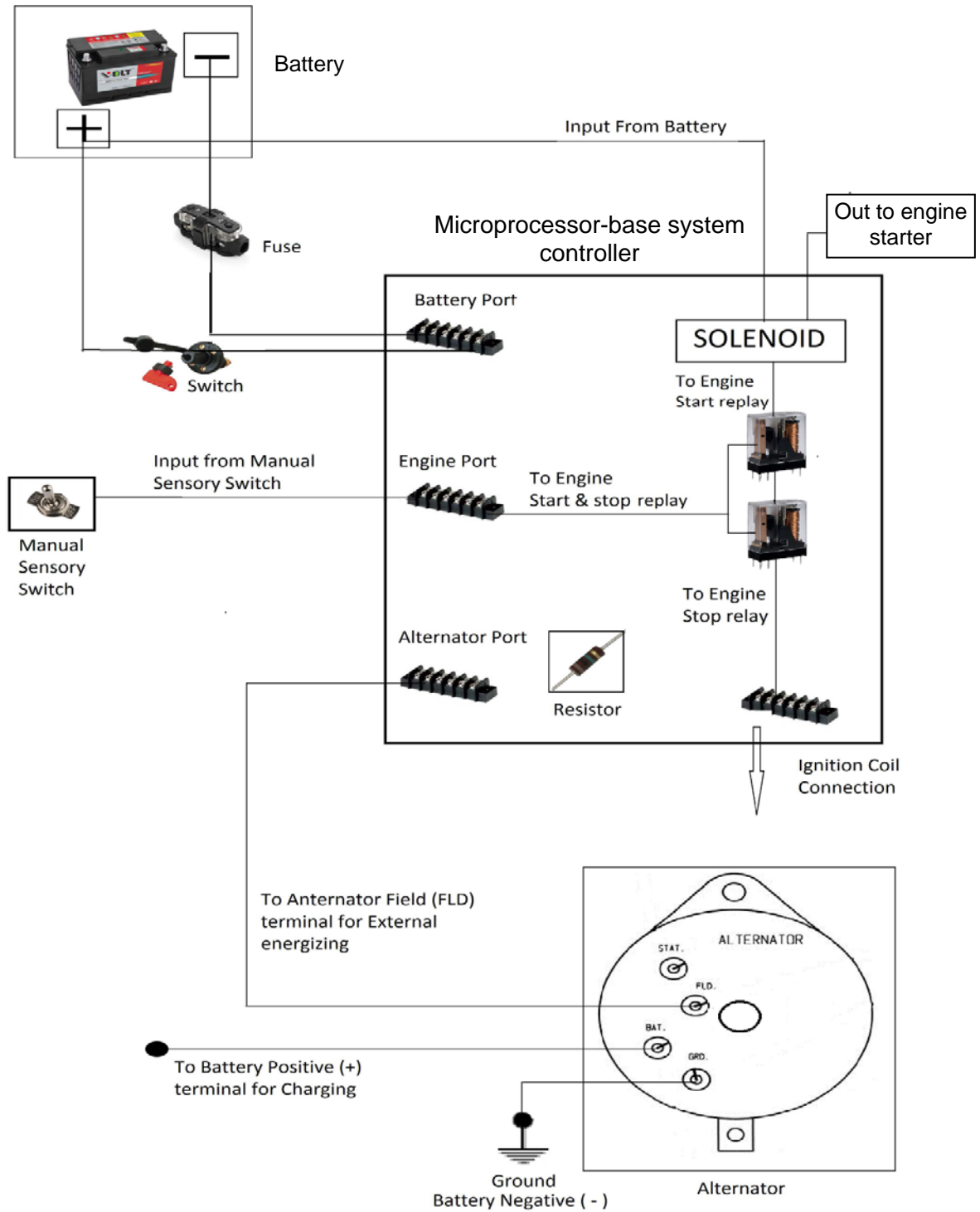


Figure 6. The connections of system controller

Four control signals are used to control the engine/alternator system. The fuel shutoff valve is the first signal needs to be turn-on before initiate the engine cranking sequence. Ignition and starter are two signals from the system controller to start the engine. Alternator field control is the signal to control how much current output from the alternator. The engine cranking sequence will be automatically repeated in the event of engine no-start that is detected by sensing the voltage produced from the alternator.

The alternator is connected to the battery and the system controller. The positive terminal of the alternator, denoted “BAT” notation on the alternator, is connected with the positive terminal of the battery. The negative terminal of the alternator, denoted “GND” on the alternator, is connected with the negative terminal of the battery. The direct connection between the alternator and the battery terminals is to ensure the active connection even though the main switch is turned off. The purpose of making these direct connections is that in case the main switch is turned off out of a sudden, then still the alternator has a buffer (battery) connected to it to store its instant generated electric energy. If a switch disconnects the battery from the alternator, the alternator will have no buffer to store its suddenly generated power as soon as the switch is turned off. When the sudden power generated by the alternator runs into the entire system, it will result in the burning of the microprocessor in the system controller and other electric devices in the system (voltmeter and current meter).

In the system controller, a resistor with 15Ω resistance is connected with the alternator field terminal denoted by symbol “F” on the alternator. The alternator selected in this bench unit is an automotive alternator which does not directly generate electricity as soon as it starts. The current passing through the 15Ω resistance to the field terminal on the alternator provides an external energizing to the field windings of the alternator. As the field windings get energized, the alternator produces the electricity which then is used to charge the battery. The resistance size is inversely proportional to the electricity output from the alternator. As the resistance is increased, the electricity output from the alternator is reduced and vice versa. The resistance size of the resistor was determined by several experiments. The 15Ω resistance is selected for generating appropriate charging current to the battery in the system.

The battery is the power source for the system controller, electric motor and the motor controller. The battery is connected to all these three through the main switch. The electric motor is the driving unit of the wheel and hence its speed must be controlled. A motor controller is attached to the electric motor for speed control. This controller is operated by a real vehicle acceleration pedal, or the throttle pedal. The acceleration pedal and motor controller were calibrated to make the real feeling of the driving. The motor is stalled (no rotation speed) when the acceleration pedal is fully released. The motor speed is increased gradually according to how much and how fast the acceleration pedal is depressed.

3.3 Developed Bench Unit

The development of electric-drive bench unit teaching tool was a team effort lead by a faculty member and group of undergraduate and graduate students, as shown in Fig. 7. The team consisted of students with multidiscipline background including mechanical engineering, electrical engineering, and computer science. The task of development, design, layout, fabrication, and assembly of the bench unit was done in the campus laboratory. The team also

performed the bench unit function testing, modification of components, programming, and system validation. The developed electric-drive bench unit is shown in Fig. 8. The entire bench unit was installed in a movable cart. The cart can be moved to any classroom, laboratory, training room, or demonstration and display areas.

It can be described that the battery and series-hybrid electric drivetrains are respectively installed in the upper and lower portion of the cart. All the battery electric-drive components that consist of drive shaft, wheel, electric motor, motor controller, battery, system controller, and acceleration pedal were installed on the top of the table. The engine, alternator, and gasoline take were mounted in the lower portion of the cart. The gasoline tank was installed in the special design of the drawer which provides safety and convenience of filling gasoline. A transparent plastic plate was installed over the top of the battery electric-drive unit to prevent any foreign object dropped into electronic devices that might cause short circuit and damage the system controller. To ensure no external object interfering with the rotating parts of the engine shaft/pulley, alternator shaft/pulley and belt, the surrounding areas on the lower portion of the cart were covered with metal screen net for safety. The engine exhaust gases can still easily outlets from the screen net.

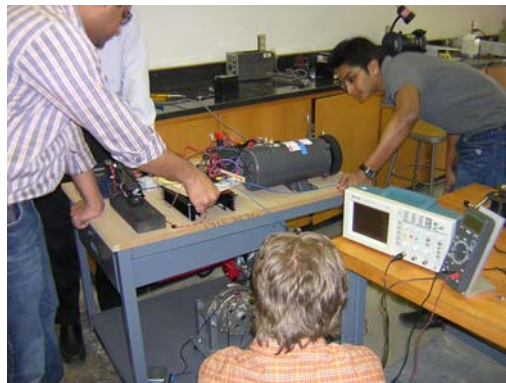
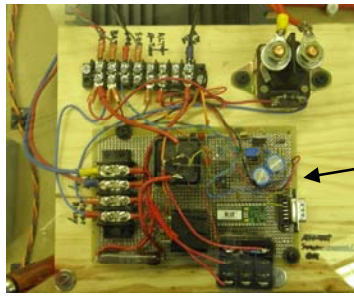


Figure 7. Students were working on the unit

The establishment of a functional electric-drive laboratory needs tremendous capital investment and time. The natural thought might be purchasing a production electric vehicle or hybrid electric vehicle for the laboratory, but the manufacturer warranty and safety will be the issues when students tear-down the vehicle and test the electric-drive components in the campus laboratory. Only a few commercial units for electric-drive training or education are available in the current market [17]. Some production-type electric powertrains can be modified for educational purpose; however it is difficult to keep the full function of the drivetrain in the campus laboratory environment.

4. Operations of the Electric Drivetrain Bench Unit

The electric motor draws energy from the battery and is the driving unit for the vehicle. The motor controller is used to control the speed of the motor and it is operated by a real car acceleration pedal. The battery SOC or voltage can be checked by monitoring the voltmeter attached to the battery. Also the operating status of the battery, charging or discharging, can be visualized by monitoring the current meter attached to the battery.



Enlarged view of system controller

Microprocessor board

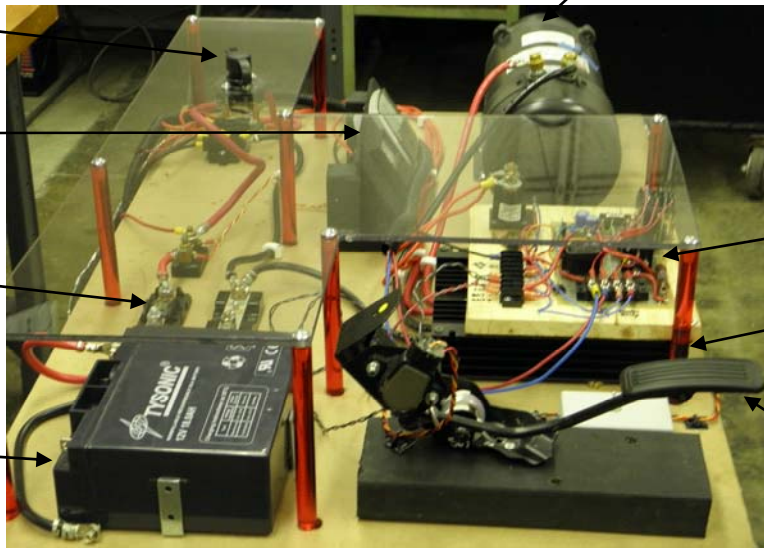
Electric motor

System main switch

Meters

Fusels

Battery

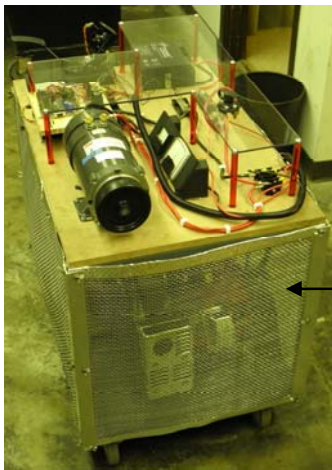


System controller

Motor controller

Real vehicle acceleration pedal

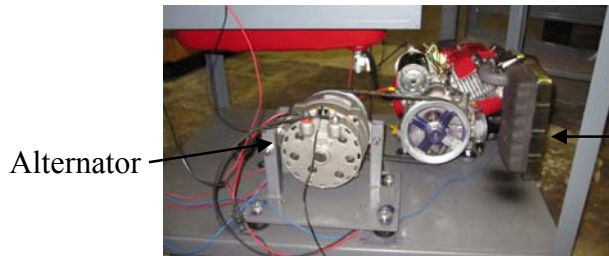
Battery electric-drive portion on the top of cart



metal screen



Series electric-drive portion on the bottom of the cart



Alternator

Engine

Figure 8. A developed electric-drive bench unit

Once the main switch of the system is turned on, the battery gets connected to the system controller and the power supply starts flowing into the microprocessor. The operation stages are classified into BEV and series-HEV demonstrations:

BEV demonstration

- (1) The system is completely in working stage once the main switch of the system is turned on. The acceleration pedal can be depressed or released to any angles within the pedal travel range. The position of the acceleration pedal determines the wheel speed.
- (2) The engine and alternator are always off. The battery SOC/voltage keeps depleting when the acceleration pedal is depressed.

Series-HEV demonstration

- (1) Main switch of the system is turned on.
- (2) As soon as the manual sensory switch is triggered, it gives signal to the system controller to trigger the solenoid switch through the starting relay.
- (3) When the solenoid gets triggered, the current is sent to the starting motor which starts the engine.
- (4) Now the starting motor is getting current through solenoid which is triggered by the opening of the starting relay. This starting relay is programmed to stay open only for 5 seconds after it gets triggered. This means that the current supply to the starting motor stops after 5 seconds which allows sufficient time to start the engine.
- (5) The engine is connected to the alternator with pulley and drive belt. Thus the generator gets running with the engine itself.
- (6) The alternator is directly connected to the battery from its output so the electricity generated by it can be directly stored in the battery.
- (7) The entire circuit remains completed and active as long as the manual sensory switch is kept held. The manual sensory switch can be kept triggered if needed. Once the switch is released, the trigger is off.
- (8) The microprocessor is programmed in such a way to control the engine on and off conditions. As soon as the battery voltage/SOC reaches a pre-defined value, the stopping relay in the ignition is off and circuit opens up. The open circuit breaks the supply of the current to the spark plug for sparking the engine, thus stopping the engine.
- (9) The entire circuit stops once the engine stops. The system becomes a BEV mode.
- (10) The engine will be started again only when the battery voltage/SOC depletes to a pre-defined value.

5. Integration of the Electric Drivetrain Bench with the Curriculum

The University has two degree programs and one graduate certificate program related to hybrid and electric vehicles: M.S. degree program in Electric-drive Vehicle Engineering (EVE), B.S. degree program in Electric Transportation Technology (ETT), and Graduate Certificate in EVE. Three courses have used this developed electric drivetrain bench unit as part of the laboratory experiments for students. This bench unit provides students with practical, hands-on experiences that favor their typical learning styles, encouraging students to ‘learn by doing’. The short description of each course is listed below.

EVE 5110 Fundamentals of Electric-drive Vehicle Engineering, four credit hours.

This course provides an introduction to electric, hybrid, and fuel cell hybrid vehicles explaining the advantages and disadvantages of electric drive vehicles in comparison to conventional internal combustion engine vehicles. The fundamentals of electric machines, power electronics, and energy storage devices for electric drive are provided and demonstrated in lab exercises. The application of electric drive in hybrid and electric vehicles utilizing a variety of powertrain architectures is presented. Elementary analyses of electric drive vehicle performance and fuel economy are included.

EVE5310 Electric-drive Vehicle Modeling and Simulation, four credit hours.

This course focuses on the overall energy conversion, storage, utilization and optimization of complete ground vehicle systems for conventional, hybrid and electric vehicles. A methodology for constructing general models of internal combustion engine, electric machine, energy storage, and power flow processes in hybrid and electric vehicles is developed and implemented using Matlab/Simulink, GT-Drive, or AVL/Cruise.

ETT4150 Fundamentals of Hybrid and Electric Vehicles, three credit hours.

General backgrounds of HEV related technologies, including technical concepts, design factors, energy analysis, and unified modeling approach. Discussion of hybridization, hybrid powertrain architectures, internal combustion engines for hybrid electric vehicles, associated types of transmissions used, PHEVs, fuel cell vehicles, and on-board energy storages.

The EVE5110 course was offered in Fall term 2010 and had 21 students. The EVE5310 and ETT4150 are offered in Winter term 2011 respectively with 22 and 18 students enrolled. The students have several stand-alone laboratory experiments in each course, such as electric machines, power electronics, electric energy storage, and control. Computer simulation software is also utilized in these courses for vehicle system and sub-systems modeling and simulation. The developed electric drivetrain bench is an integrated unit which consists of all the major components in HEV/BEV and it is capable of demonstrating, illustrating and displaying the multiple energy flows in the electric-drive vehicle based on its configuration and driving conditions. This integrated laboratory experiment provides the students with the in-depth knowledge and hands-on experience on the interface and control of each component in the electric-drive propulsion systems.

Conclusion

Given heightened concerns over the environmental and limited fossil fuels, a clear trend toward electric and hybrid vehicles is emerging. There is a clear need for systematic training and educational programs on electric drivetrains. This paper presents the educational tool development of an interactive, industrial-component-based bench unit for two different configurations of electric drivetrains: battery-electric and series-hybrid electric. The developed bench unit is capable of simulating, illustrating and displaying the multiple energy flows in the electric-drive vehicle based on its configuration and driving conditions. The integrated unit provides students with practical, hands-on experiences that favor their typical learning styles, encouraging students to 'learn by doing.'

The implementation of the electric drivetrain bench unit is a resounding success and initial student reaction has been quite enthusiastic. The hands-on experience not only enhances the vehicle electrification training and education, but also inspires multidiscipline students' interest in the green movement of transportation. For safety concern, the current bench is powered by a low voltage 12V lead acid automobile battery. It will be upgraded to other type of battery chemistries, i.e. NiMH or Li-Ion battery in the future. The development of the second bench unit is ongoing.

Bibliography

1. Ronning, J. and Grant, G., "Global hybrid electric vehicle markets and missions," *Society of Automotive Engineers (SAE) paper* 1999-01-2946, 1999.
2. Hirose, K., Abe, S. and Killmann, G. "Overview of current and future hybrid technology," *SAE paper* 2002-33-0016, 2002.
3. Liao, G., Weber, T. and Pfaff, D. "Modelling and analysis of powertrain hybridization on all-wheel-drive sport utility vehicles," *Proc. IMechE, Part D: J. Automobile Engineering*, 218(10), 2004, 1125-1134, 2004.
4. Hisamitsu, Y., Abe, T., Kinoshita, T. et al., "Research and Development Work on High-Performance Lithium-Ion Batteries for EV Application," *SAE Paper* 2008-01-1332, 2008.
5. McDonald, D., "Engineering and technology education for electric vehicle development," *Proceedings of ASEE AC2010-772*, 2010.
6. Faulkenberry, L. and Shireen, W., "Undergraduate and graduate research project on plug-in hybrid electric vehicles (PHEVS) supported by Centerpoint Energy," *Proceedings of ASEE AC2010-972*, 2010.
7. Liao, Y., Yeh, C.P. and Sawyer, J., "Implementing an integrated learning system for hybrid vehicle technology: supporting the green transportation," W. Aung, et al. (eds.), *Innovations 2009: World Innovations in Engineering Education and Research*, iNEER, Vol. 10, 309-325, 2009.
8. Chapman, E., Ferralis, N., Tallon, R., et al., "Closing the assessment feedback loop: the use of a qualitative evaluation process from the joint hybrid-electric vehicle/NSF-Penn State science education project," *Proceedings of ASEE AC2005-1410*, 2005.
9. D. Tallon, R. Streit, C.Y. Wang, C. Bakis, C. Randall, M. Lanagan, et al., "Graduate Automotive Technology Education in energy storage systems - GATE Penn State," *International Journal of Continuing Engineering Education and Lifelong Learning*, Vol. 11, No. 4/5/6, 534-541, 2001.
10. Rizkalla, M., Yokomoto, C., Pfile, R., et al., "Using senior research, design and development projects in the development of a course in electric vehicle technology," *Proceedings of ASEE AC2000-3432*, 2000.
11. Rizkalla, M., Yokomoto, C., Pfile, R., et al., "Applications of computer-based power electronics to electric vehicle technology, an interdisciplinary senior course," *Proceedings of ASEE AC2000-3432*, 2000.
12. Rizkalla, M., Pfile, R., El-Antably, et al., "Development of a senior selective for EE and EET majors in the design of electronic instrumentation for electric vehicles," *Proceedings of ASEE AC1998-2502 TS/2*, 1998.
13. Liao, G., Yeh, C.P. and Sawyer, J., "Design and Implementation of a Virtual Hybrid Electric Vehicle Simulator for Educational Purpose", *Proceedings of ASEE AC2008-2962*, 2008.
14. Winstead, V., "Applied engineering with LabVIEW: experiences from a plug-in hybrid project," *Proceedings of ASEE AC2008-2707*, 2008.
15. <http://www.honda.com/>. Accessed December 27, 2010.
16. http://ecce.colorado.edu/~ecen2060/materials/lecture_notes/HEV_architectures.pdf/. Accessed January 17, 2011.
17. Automotive Hybrid Training Simulator, Automotive Autotronics, Delorenzo DL AM20 hybrid system, http://delorenzoglob.com/index.php?option=com_content&view=article&id=790%3Adl-am20&catid=130&Itemid=100068&lang=en/. Accessed January 17, 2011.