National Conference on Recent Advances in Computer Science and IT (NCRACIT)
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2018 IJSRCSEIT | Volume 4 | Issue 1 | ISSN : 2456-3307

MATLAB Simulink Modelling of Hybrid Electric Vehicles

Faizah Fayaz[1], Saima Yaqub[2], Mohd Irfan Khan[3], Faheem Bashir[4], Farhad Ilahi Bakhsh[5]

[12345]Department of Electrical and Renewable Energy Engineering , School of Engineering and Technology, Baba Ghulam Shah Badshah University, Rajouri, J&K - 185234.
peerzadifaizah@gmail.com[1], bhataseem88@gmail.com[2], irffan.khan24@gmail.com[3], faheemb801@gmail.com[4], farhad@bgsbu.ac.in[5]

ABSTRACT

Energy storage and environmental pollution are two big issues which restrict the development of automobile industry. With this concern, Hybrid electrical vehicle has been developed to achieve energy saving and emission reduction. A conventional vehicle actuated with only internal combustion engine cannot enhance the fuel economy due to wide range operation requirement of power train. Instead of this, a Hybrid electrical vehicle which uses ICE and two motors can effectively improve the efficiency of power train. This type of Hybrid electrical vehicle provides four modes of operation, including Electrical vehicle (EV) mode, range extending (RE) mode, hybrid mode, and engine mode. Despite continuous development in HEV'S: short range, long recharging time and cost still act as barriers for their widespread adoption. Therefore, the increasing interest in the development of HEV's, has break in new designs of HEV'S namely Series Hybrid electrical vehicle, Parallel Hybrid electrical vehicle, Battery electrical vehicle, Plug-in Hybrid electrical vehicle, Range –extending Hybrid electrical vehicle. This paper gives us a simulink imitation of Hybrid Electrical Vehicle and a simulink model is developed for every part of Hybrid Electric Vehicle for individual exertion.

Keywords: MATLAB; Modeling; Hybrid Electric Vehicles (HEVs); SPV; Management.

I. INTRODUCTION

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviors and functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation is also used with scientific modelling of natural systems or human systems to gain insight into their functioning, as in economics. Simulation can be used to show the eventual real effects of alternative conditions and courses of action.

II. GENERAL SIMULINK MODEL

The accelerator generates a signal to control pedal position and car speed. Input command from the driver, ranges from 0 to 1 corresponding to the position of the brake pedal. This value is 0 at rest and 1 when the pedal is completely depressed. The input to the energy management system generates Motor torque* and SPV current*. These two quantities derived from the Energy Management System act as a input to SPV Electrical Sub- System also with the speed measurement From block. The output to this block is Electrical Torque and SPV current and Battery output. The electrical torque is then converted into physical quantity by Simulink-PS Converter block. Finally this physical quantity is converter into mechanical energy which develops a torque to drive the vehicle. The Simulink model of Hybrid Electrical Vehicle is shown in fig 1.

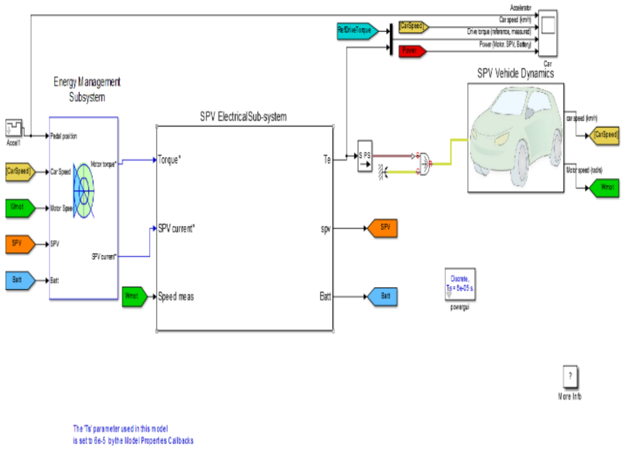

Figure 1. General Simulink Model.

III. ENERGY MANAGEMENT SUB-SYSTEM

The Simulink model of the Energy Management Sub- System is shown in fig. 2. The inputs to the Energy Management sub-system are:

1. Pedal Position.
2. Car Speed.
3. Motor Speed.
4. SPV
5. Battery.

The pedal position rate is limited by using a saturation block, which the after suitable operation gives us required drive torque. This required torque is multiplied by Motor speed in Product block and gives us required drive power as output. The SPV is directly fed to the Power Management system. The Motor torque* and SPV current* are the two outputs of Energy Management sub system.

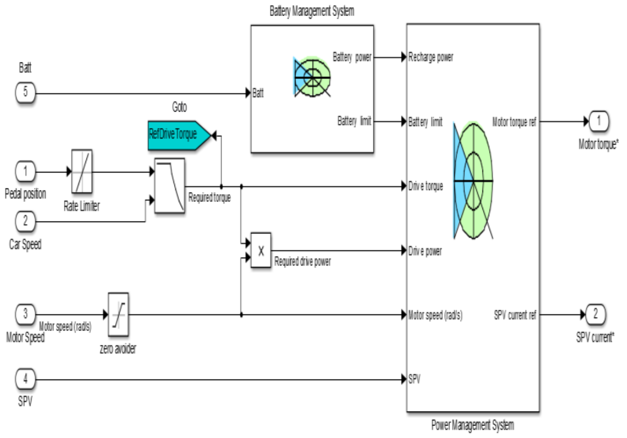

Figure 2. Simulink Model of Energy Management Sub-System.

IV.BATTERY MANAGEMENT SYSTEM

One of the important methods of battery management system is by using non-linear model predictive control of Hybrid electric vehicle [1]. The key technology of HEV is energy management. To investigate the energy management problem of a power-split HEV a model predictive control was used [2]. New charge/discharge control system supported by car navigation information was also developed for HEVs [3]. For energy management, dynamic programming was developed with equivalent consumption minimization strategy of a power HEVs [4]. None of the above explored a relationship between the battery power and future load for energy management. So in this paper, we apply the non-linear model predictive control to the HEV energy management system. The battery state of charge (SOC) is considered the only state of system and battery power as the only control input of the system. Here, a apparent relationship is explored between the battery power and the future road load for significant improvement in fuel economy.

A new battery charger for plug-in HEV using Back to Back converter in a utility connected Micro grid is developed to overcome the drawbacks of battery chargers [5]. High volume, weight, low pressure, long charging time, deleterious harmonic effect, low reliability and flexibility are the drawback that most of battery chargers for PHEV have. The proposed structure in this paper, can run in four different modes: battery charging mode from grid (G2V) or micro-grid (M2V), vehicle to grid mode (V2G), and vehicle to micro-grid mode (V2H). Bi-directional battery chargers are used to operate PHEV as a distributed generation (DG) to supply power to the grid or micro-grids [6-9], this result to increase in flexibility and reliability but the other major drawbacks remain the same. In this paper, integration of PHEV with a main grid or micro grid is implemented by using back-to-back converter in a utility connected micro- grid. This structure involves: an AC micro-grid, in which load is fed from DG source, a battery charger, in which bidirectional DC/DC converter is used, and main grid. Power flow control between utility and micro-grid can be achieved by using back-to-back converters [10], which facilitate desired real and reactive power flow between the utility and micro-grid. The proposed scheme is very flexible and reliable and its excellent performance has been confirmed through extensive simulation on MATLAB/SIMULINK for various operating conditions.

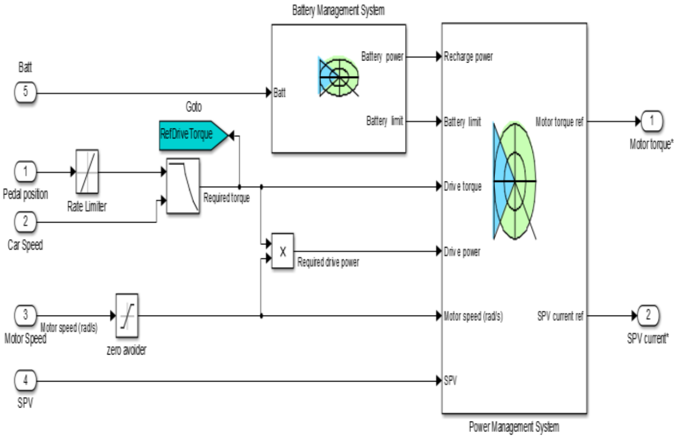

Figure 3. Simulink Model of Battery Management System

The input to the Battery Management System is divided into two forms: one is voltage and the other is state of charge (SOC). The battery voltage is subtracted from nominal battery voltage and is then given a gain according to the dynamic equation and then the output of gain is subtracted from the nominal power. This output power is then given a upper and lower value or we can say Battery discharge range is given to obtain Battery limit as output. The SOC of the battery is compared with the battery charge (<40) and battery discharge (> 80). These two outputs are fed to S-R Flip-Flop, whose output is given a gain to obtain required Battery power as output.

V. POWER MANAGEMENT SYSTEM

The traditional combustion vehicles have large amount of fuel consumption and pollution emission [11]. However by the use of HEV, fuel consumption and pollution emissions get reduced [12-14]. Power management policy determines power split between the internal combustion engine (ICE) and electric motor (EM). The power management approaches are based on heuristics, intuition and human expertise [15-16]. The dynamic programming (DP) technique is also being applied to various types of HEVs [17-19]. The drawbacks of DP technique were overcome by a new strategy called Equivalent Consumption Minimization strategy (ECMS). This strategy was proposed in order to reduce the problem of instantaneous optimization and global optimization [20]. This technique (ECMS) mainly depends on equivalence factor (EF). EF is sensitive to driving cycles. EF being suitable for one driving cycle leads to the poor performance of other driving cycle. These challenges were overcome by another strategy called Adaptive-ECMS (A-ECMS).The adaptive power management strategy for a Four-mode Hybrid electric vehicle is an important aspect of PMS [21]. The Four mode HEV consists of an internal combustion engine and two motors. Electric vehicle (EV) mode, range extended (RE) mode, hybrid mode, and engine mode are the four modes of operation of HEV. For maintaining the state of charge for charge sustaining adaptive PMS is designed. For adjusting equivalence factor of electric energy consumption based on SOC deviation and the change of SOC deviation, self-organizing fuzzy controller is employed. Adaptive PMS can effectively improve the fuel economy for different driving cycles. PMS can be classified into three types. The first type is rule based control [22] which is designed based on rules extracted from engineer expertise. The second type is the equivalent fuel consumption minimization strategy [23] which uses static optimization to achieve minimization of an instantaneous cost function. The third type is the global minimization [24] based on dynamic programming. Sun C et.al [25] used an adaptive–ECMS combined with a velocity Model predictive control for temporary driving information for real-time adaptation of equivalence factor (EF).

Yan F et.al [26] employed Model predictive control (MPC) to design power management strategy (PMS). Borhan et al. [27] devised a nonlinear and constrained optimal problem for the PMS design. After simulation of these methods, we find out that in RE mode, both ICE and integrated starter generator (ISG) operating points are operated around the optimal operating curve and for Hybrid and ICE modes, the ICE operating points fall in the low fuel consumption regions. Traction motor (TM) operates below middle velocity for the EV and RE modes. Traction motor provides additional power for the HEV mode when necessary. By using adaptive power management strategy, instantaneous cost function of the fuel consumption of ICE and the equivalent fuel consumption of the battery is minimized to obtain the optimum power distribution of ICE, ISG, and TM. After simulation of the models, results show that adaptive PMS has superior fuel economy improvement than ECMS for different driving cycles. The Simulink block diagram of power management system is shown in Fig. 4.

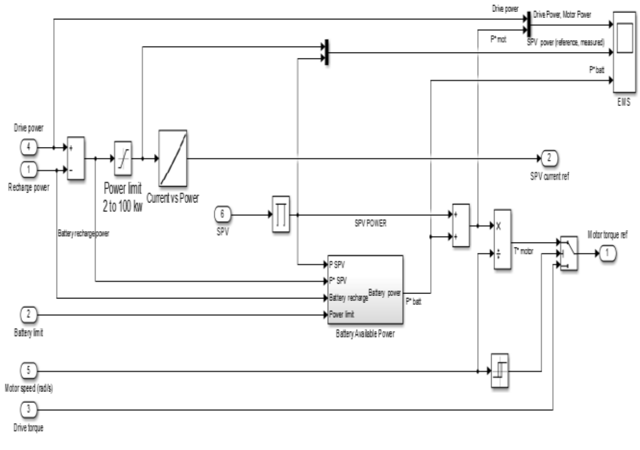

Figure 4. A Power Management System

Power management policy determines power split between the internal combustion engine (ICE) and electric motor (EM). The power management approaches are based on heuristics, intuition and human expertise. The dynamic programming (DP) technique is also being applied to various types of HEVs. By the use of DP technique, fuel consumption during the whole driving cycle gets reduced. But DP technique is not applicable for real-time implementation because it requires a priori knowledge of the driving cycles as well as detailed and accurate HEV modelling.

The inputs to this block are:

1. Recharge power
2. Battery limit
3. Drive torque
4. Drive power
5. Motor speed
6. SPV

The recharge power and battery limit comes from battery management system. Drive torque comes from pedal position and car speed where pedal position is incorporated with rate limiter. The input to the drive power comes from the combination of motor speed and required torque where motor speed is incorporated with zero avoider. SPV comes directly from SPV block.

Now recharge power is subtracted from drive power which goes to power limit block which is limited upto 2 to 100 kw. To every value of power there is a corresponding value of current which will give us a SPV current ref. Battery limit is connected to battery available power block. Motor speed through a relay and drive torque act as an input to switch which gives Motor torque reference. The voltage and current of SPV gives us SPV power which is then added to P*batt and gives P*mot. Drive power, SPV power and P*batt are shown in electrical measurement system.

VI. SPV ELECTRICAL SUBSYSTEM

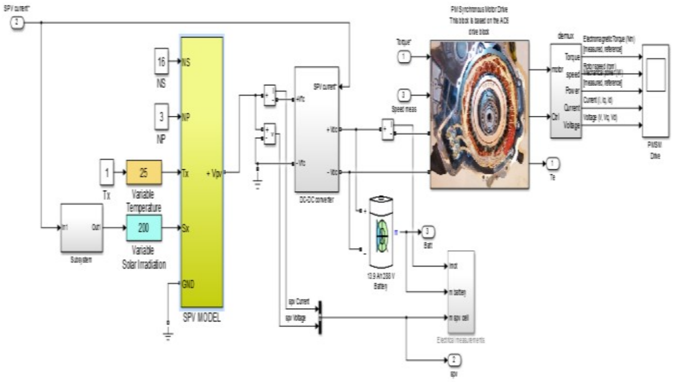

Figure 5. The General Layout of SPV Electrical Subsystem.

The output signal generated from the energy management subsystem i.e. the SPV current is fed to the DC-DC converter and is also supplied with solar irradiation and is connected to the SPV model. The SPV model consists of SPV panels connected in series and parallel. On connecting the panels in series the voltage increases but the current remains same however if the panels are connected in parallel the current increases but the voltage remains same. However in this case 16 panels are connected in series and 3 panels are connected in parallel. And each panel consists of 36 cells each cells produces 0.5V thus a panel produces 18V. The constant block is provided with variable solar irradiation and is given to the SPV model.

The output of the SPV model produces voltage and current. Both the voltages and current are given to the DC-DC converter and for electrical measurements both the voltages and current are supplied through bus creator for measurements.

The output of the DC-DC converter is given to the battery and is also supplied for the electrical measurements and is noted as 'm battery' and the output current from the converter is given to the motor as the motor current and is measured in electrical measurements as I_{motor}.

The output of the energy management subsystem which is the torque also the speed which is input to the SPV electrical subsystem are given to the permanent magnet synchronous motor which is the AC motor.

The output of the motor is measured and by using the 'demux' the graphs of the torque, speed, power, current, voltage is checked in the scope.

VII. DC – DC CONVERTER

Upon examination of the general configurations of HEVs, it can be seen that there are two major power electronic units. Usually AC motors are used in HEVs for traction and they are fed by inverter and this inverter is fed by DC-DC converter.

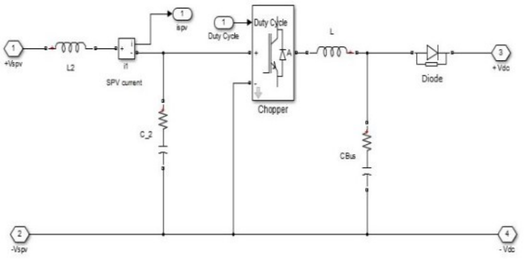

Figure 6. DC-DC converter.

The most commonly DC-DC converters are:

(a)Unidirectional Converters: They cater to various onboard loads such as sensors, controls, entertainment, utility and safety equipments.

(b) Bidirectional Converters: They are used in places where battery charging and regenerative braking is required. The power flow in a bi-directional converter is usually from a low voltage end such as battery to a high voltage side and is referred to as boost operation. During regenerative braking, the power flows back to the low voltage bus to recharge the batteries know as buck mode operation. the bi-directional DC-DC converters are preferred to be isolated to provide safety for the lading devices. In this view, the DC-DC converters used in this HEV is bi-directional DC-DC Converter.

Classification of Converters; the converters are classified as

(a) Buck Converter: The buck converter is step down converter and produces a lower average output voltage than the dc input voltage.

(b) Boost converter: In this converter the output voltage is always greater than the input voltage.

(c) Buck-Boost converter: In this converter the output voltage can be either higher or lower than the input voltage. The buck boost converter is a type of DC-DC converter .Like the buck and boost converters, the operation of the buck-boost is best understood in terms of the inductor's "reluctance" to allow rapid change in current. From the initial state in which nothing is charged and the switch is open, the current through the inductor is zero. When the switch is first closed, the blocking diode prevents current from flowing into the right hand side of the circuit, so it must all flow through the inductor. However, since the inductor does not like rapid current change, it will initially keep the current low by dropping most of the voltage provided by the source. Over time, the inductor will allow the current to slowly increase by decreasing its voltage drop. Also during this time, the inductor will store energy in the form of a magnetic field. In this simulation model of HEV the Buck-Boost converter is used.

VIII. PERMANENT MAGNET SYNCHRONOUS MOTOR DRIVE

The output from the DC-DC converter is given to the motor since the motor is an AC motor and output from converter is DC in order to make it AC we use 3-phase inverter which converts DC into AC. The three phase output from inverter is measured and the measured output is given to the permanent magnet synchronous motor. The output of the PMS motor is given to the SPV vehicle dynamics and is given to the bus creator which gives rotor speed and rotor angle. The rotor speed is given to the speed controller which controls the speed. The output of the speed controller produces normal flux and torque and is given to the vector controller and the vector controller controls these quantities. The output of the vector controller is given to the mux and the controlled signal is given to 3-phase inverter.

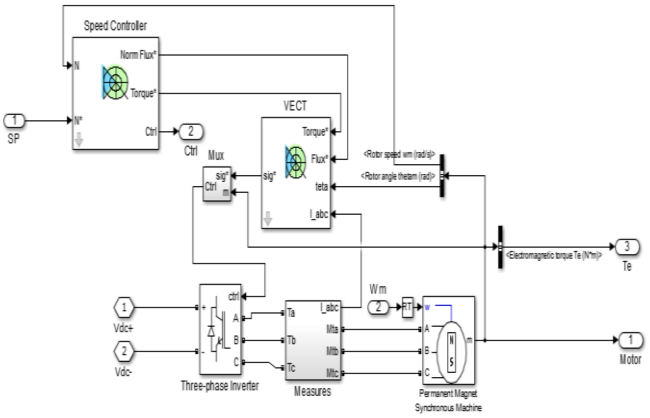

Figure 7. Permanent Magnet Synchronous Motor Drive

The output of the electrical subsystem produces electromagnetic torque. From fig 1. The drive torque (measured torque) along with reference torque is given to scope to check the graph. Accelerator, car speed and power signal are given to the scope to check the graph.

IX.SPV VEHICLE DYNAMICS

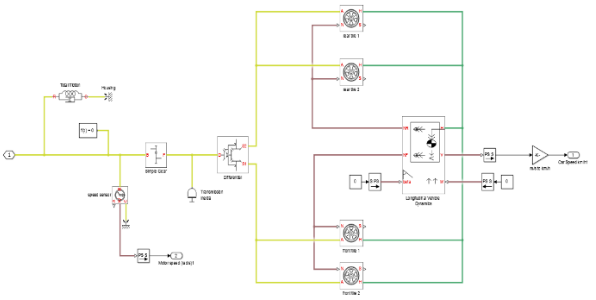

Figure 8. SPV Vehicle Dynamics.

The vehicle dynamic model in this instance includes four wheel longitudinal vehicle dynamics for a front wheel drive vehicle. The inputs to the vehicle drivetrain are the motor torque or output from a gearbox (transmission) with motor torque as gearbox input. In addition, the vehicle drivetrain receives braking torque a. Rotational dynamics for each wheel, and half shafts, and a representation of the forces acting on the vehicle, are modelled. Rotational wheel dynamics include wheel slip (skid), tire road surface adhesion coefficient, wheel tractive force as a function of dynamic weight transfer, road load torque for each wheel, and rotational wheel speed. Wheel slip (skid) is used to determine the tire road surface ad- hesion coefficient with a nonlinear analytic tire road surface inter- face model. The tire model used for this study assumed a high road surface adhesion coefficient for dry pavement, because these are conventional driving conditions. The wheel tractive force as a function of dynamic weight transfer is the product of the road surface adhesion coefficient and the normal force acting on the wheel.

X. CONCLUSON

We conclude that hybrid electric vehicles have become research hotspot due to depletion and rising price of fossil fuels, environmental issues etc. The invention of new technology is obviously of the fact from needs and necessity of present world. The hybrid electric vehicle being eco-friendly also contains two power sources either any one of them or both can be used simultaneously. Developed countries are keener towards the advancement of HEVs. Not only a single method can improve the efficiency of HEVs but assimilation of more than one is needed to compensate for each other's deficiencies. Here, topics like Energy Management, Battery Management, Power Management, Component Sizing, Modelling, Simulation, Braking, Performance and Efficiency are discussed. Descriptive view of overall HEV is done to advance HEV technology and creativity. These are the different eras one can work in the field of HEV.

The continuous development in the field of technology for HEV will lead to, use of HEV for future transportation. So we can conclude that HEV is better choice than other vehicles for present and future use as well.

XI.REFERENCES

[1] Kaijiang Yu, Masakazu Mukai, Taketoshi kawabe, "A Battery Management System Using Nonlinear Model Predictive Control for a Hybrid Electric Vehicle", proceeding of International Federation of Automatic control, pg. 301-306, 2013.

[2] H. Borhan, A. Vahidi, A.M. Phillips, M.L. Kuang, I.V. Kolmanovsky, and S.D. Cairano, " MPC-based energy management of a power-split hybrid electric vehicle", IEEE Trans. Control Syst. Technol, pg. 593–603, 2012.

[3] Y. Deguchi and T. Kawabe, "HEV charge/discharge control system based on navigation information", SAE Technical Paper, No. 2004-21-0028, 2004.

[4] J. Liu and H. Peng, "Modelling and control of a power-split hybrid vehicle", IEEE Trans. Control Syst. Technol, pg. 1242–1251, 2008.

[5] Reza Razi, Behzad Asaei, and Mohammad Reza Nikzad, " A New Battery Charger for Plug-in Hybrid Electrical Vehicle Application using Back to Back Converter in a Utility Connected Micro-grid", proceeding of 8th Power Electronics, Drive Systems and Technologies conference, Ferdowsi University of Mashhad, Iran, pg. 13-18, 2017.

[6] Y. J. Lee, A. Khaligh, and A. Emadi, "Advanced Integrated Bidirectional AC/DC and DC/DC converter for Plug-in Hybrid Electric Vehicle", IEEE Trans veh. Technol., pg. 3970-3980, October 2009.

[7] S.S.Williamson, A.K.Rathore, and F.musavi, "Industrial Electronics for Electric Transportation: Current State-of-the-Art and Future challenges", IEEE Trans. Ind. Electron, pg. 3021-3032, May 2015.

[8] Y. Du, S.Lukie, B.Jacobson, and A.Huang, "Review of high power isolated bi-directional DC-DC converter for PHEV/EV DC charging infrastructure", in proc. IEEE Energy Conservation congr. Expo, pg. 553-560, Sep 2011.

[9] A.M. Bozorgi, M. Sanatkar Chayjani, R.Mohammad Nejad, and M.Monfared, "Improved grid voltage sensor less control strategy for railway power conditioners", IET Power Electron, pg. 2454-2461, 2015.

[10] R.Majumder, A. Ghosh, G. Ledwich and F.Zare, "Power Management and Power Flow control with Back-to-Back converters in a utility connected Micro-grid", IEEE Trans Power Electron, pg. 821-834, May 2010.

[11] Xue Lin, Yanzhi Wang, Paul Bodgan, Naehyuck chang and Massoud Pedram "Reinforcement Learning Based Power Management for Hybrid Electric Vehicle", IEEE, Pg. 1-7, 2014.

[12] C. C. Chan, “The state of the art of electric, hybrid, and fuel cell vehicles,” Proceedings of the IEEE, vol. 95, pp. 704-718, Apr. 2007.

[13] F. R. Salmasi, “Control strategies for hybrid electric vehicles: evolution, classification, comparison, and future trends,” IEEE Trans. Vehicular Technology, vol. 56, pp. 2393-2404, Sep. 2007.

[14] M. Ehsani, Y. Gao, and A. Emadi, Modern electric, hybrid electric, and fuel cell vehicles: fundamentals, theory, and design, CRC press,2009.

[15] H. D. Lee, E. S. Koo, S. K. Sul, and J. S. Kim, “Torque control strategy for a parallel-hybrid vehicle using fuzzy logic,” IEEE Industry Applications Magazine, vol. 6, pp. 33-38, Nov. 2000.

[16] N. J. Schouten, M. A. Salman, and N. A. Kheir, “Fuzzy logic control for parallel hybrid vehicles,” IEEE Trans. Control Systems Technology, vol. 10, pp. 460-468, May 2002.

[17] A. Brahma, Y. Guezennec, and G. Rizzoni, “Optimal energy management in series hybrid electric vehicles,” in Proc. American Control Conf., 2000, pp. 60-64.

[18] C. C. Lin, H. Peng, J. W. Grizzle, and J. M. Kang, “Power management strategy for a parallel hybrid electric truck,” IEEE Trans. Control Systems Technology, vol. 11, pp. 839-849, Nov.2003.

[19] L. V. Perez, G. R. Bossio, D. Moitre, and G. O. Garcia, “Optimization of power management in a hybrid electric vehicle Using dynamic programming,” Mathematics and Computers in Simulation, vol. 73, pp. 244-254, Nov. 2006.

[20] G. Paganelli, M. Tateno, A. Brahma, G. Rizzoni, and Y. Guezennec, “Control development for a hybrid-electric sport-utility vehicle: strategy, implementation and field test results,” in Proc. American Control Conf., 2001, pp. 5064-5069.

[21] Jen-Chiun Gaun, Bo-Chiuan Chen, “Adaptive Power Management Strategy for a Four-Mode Hybrid Electric Vehicle”, published by Energy Procedia 105 (ELSEVIER), Pg. 2403-2408, 2017.

[22] Wirasingha SG, Emadi A, “Classification and Review of Control Strategies for Plug-in Hybrid Electric Vehicles”, Vehicular Technology, IEEE Transactions, Pg. 111–122, 2011.

[23] Kim N, Cha S, Peng H, “ Optimal Control of Hybrid Electric Vehicles Based on Pontryagin’s Minimum Principle”, Control Systems Technology, IEEE Transactions, Pg. 1279-1287, 2011.

[24] Wang R, Lukic SM, “Dynamic Programming Technique in Hybrid Electric Vehicle Optimization”, IEEE International Electric Vehicle Conference, 2012.

[25] Sun C, Sun FC, He HW, “Investigating adaptive-ECMS with velocity forecast ability for hybrid electric vehicles”, Applied Energy 2016.

[26] Yan F, Wang J, Huang K, “ Hybrid electric vehicle model predictive control torque-split strategy incorporating engine transient characteristic”, Vehicular Technology, IEEE Transactions, Pg. 2458–2467, 2012.

[27] Borhan H, Vahidi A, Phillips AM, Kuang ML, Kolmanovsky IV, Cairano SD, “MPC-Based Energy Management of a Power Split Hybrid Electric Vehicle”, Control Systems Technology, IEEE Transactions, Pg. 593-603, 2012.