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PLC Based Motor Control of Electric Vehicles

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Abstract:

Vehicles that run on gasoline heavily burden the environment by releasing carbon dioxide and other greenhouse gases. Several types of research and published articles have proven the disadvantages of a gasoline engine only vehicle. The solution to this came up with the electric vehicles. In this work, speed control of the electric motor is shown along with some of the controls of the vehicle like lights, horn, power etc. The lights like head light, right indicator and left indicators are controlled from controller as well as the visualization device. Horn is also controlled similarly. The power signal is programmed that can be controlled mechanically and remotely. The main importance of this work is to control the RPM of the motor on the basis of the acceleration and brake applied to the motor. The calculated speed is used to generate the pulse width modulated signal. PWM signal gives the output as average power to the motor. As soon as the motor starts running, the temperature is recorded and at a certain temperature limit, the motor automatically reduces its speed.

Keywords **— EV, PHEV, BLDC, PLC, HMI.**

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I. INTRODUCTION

These days utilization of fueled vehicles is increasing rapidly resulting into very high air pollution. Utilization of EV is a very good option to control the adverse pollution problem. It is suitable for high vehicle density areas to avoid the emission of harmful gases. Thus, it can reduce the atmospheric pollution [1]. With increasing price of petroleum, the electrically charged vehicle seems to be the very good alternative to the traditional vehicle. E-scooters are more suitable for such areas where petrol bunks are not adequate. Electric vehicles have plug-in feature with two or three or four wheels. The electricity is stored within the boarded rechargeable battery, which drives the motor of vehicle [2]. However, in market, the sale of Plug-in Hybrid E-Vehicle (PHEV) will be dependent on various factors lead by the growth of charging infrastructure.

Electric vehicles also serve indirectly by re-generating power. Electric traction allows the use of regenerative braking where the vehicle motors are used as brakes, i.e., stop the vehicle, and become generators that transform the rotational energy of the motor into electricity and can feed it back into the circuit for re-use [3]. This system is particularly advantageous in mountainous regions as vehicles can be used to re-generate power on down-hill side. In EVs, batteries are the fuel tanks and motors are the engine. There are many types of Motors used in EV. The motors that are used in two wheelers are different from those used in four wheelers [4].

The most important thing that electric system does is that it supplies controlled power to the motor which helps in the maintaining the motion of the scooter. The source of this energy in the form of chemical or electric energy which is stored in the battery. Hence in EVs electric or chemical energy is converted into mechanical energy [5]. A proper electric system is important to ensure the safety of driver and vehicle.

II. REVIEW OF PREVIOUS WORK

The living style always keeps on changing in the world with the change in available resources. This is also leading increase in the density of the vehicles all over the world [6]. This increasing vehicle density is leading to very high consumption of sustainable energy resources. And thus, the available of such resources has become a vital factor for automotive industry to maintain the long term existence of the vehicles supply

In general, there are three main types of EVs [7]. The first type of EV category uses electric power that is given directly to it by an external power station. The second type of EV category uses rechargeable batteries to store and provide electric power. The third type of EV category uses rechargeable batteries, but also includes an Internal Combustion Engine (ICE). The third category is called hybrid electric vehicle (HEV). For designing the architecture of the EV, a pattern designed by Volvo was proposed. This pattern is called Complete Vehicle Control (CVC). Its architecture is based on the description as mentioned in [8] and provides a conceptual model for control architecture.

Vehicle Motion Management is very important characteristic of any vehicle. It deals with the dynamic behaviour of the motion of the vehicle as a whole system [9]. Any control failure in this domain can result in significant physical damage or economics losses. At this management level of Vehicle System, no mechanical parts like actuators or sensors are included. This domain includes only software that controls and defines operational points for the actuators. In EVs DC-to-DC converter also plays very important role in power distribution. It is an electronic circuit that converts a source of direct current (DC) from one voltage level to another [10]. It supplies voltage signal to various operational circuits and actuators.

Motion Support Devices is the sub system is the lowest level that interacts directly with the vehicle. At this level of system the motion of the vehicle is actually functioned. This level actually includes devices and facilitates the higher levels of CVC to control motion [11]. This domain can include devices that consist of actuators along with some software.

A brushless DC motor is most commonly used in EV to actuate motion.. It has few benefits over AC motors. It is a synchronous machine that approximates the behaviour of a brush-type DC motor. In order to stimulate the permanent magnets of the rotor part of the motor, a three phase AC voltage is applied on the armature windings of the stator. Their difference is that power electronics are taking the place of the brushes [12]. Following are the advantages of using BLDC motor in EVs as compared to ICE or AC motor:

- The rotation of a DC motor, as compared to AC motor, can be easily controlled using the supply current.
- Torque can be controlled without using a gear box. Maximum torque of a DC motor is available at less RPM and can be varied easily as required for a wider range compared to what happens to ICE.

III. PROPOSED CONTROL STRATEGY

When using control allocation, the control design is separated in two different steps. At the first step a control law is implemented for regulating the total control effort, which is also called virtual inputs. At the second step, control allocator maps the virtual inputs to set points for the different actuators. Fig. 1 shows basic representation of control system using blocks.

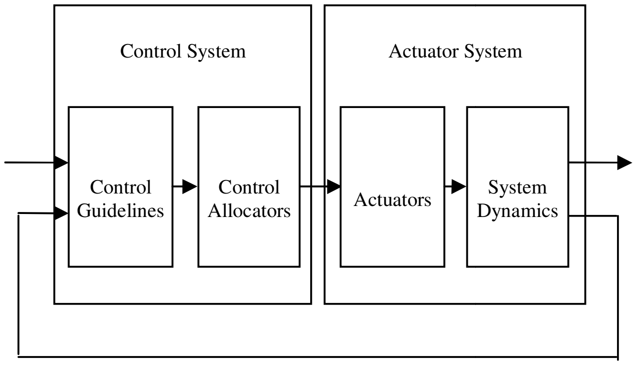

Fig. 1 Control System Architecture

Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation. High power (high speed and/or acceleration) is achieved when the intervals (when the current is turned off) are short. Low power (low speed and/or acceleration) occurs when the intervals are longer. Pulse Width Modulation speed control works by driving the motor with a series of "ON-OFF" pulses and varying the duty cycle, the fraction of time that the output voltage is "ON" compared to when it is "OFF", of the pulses while keeping the frequency constant.

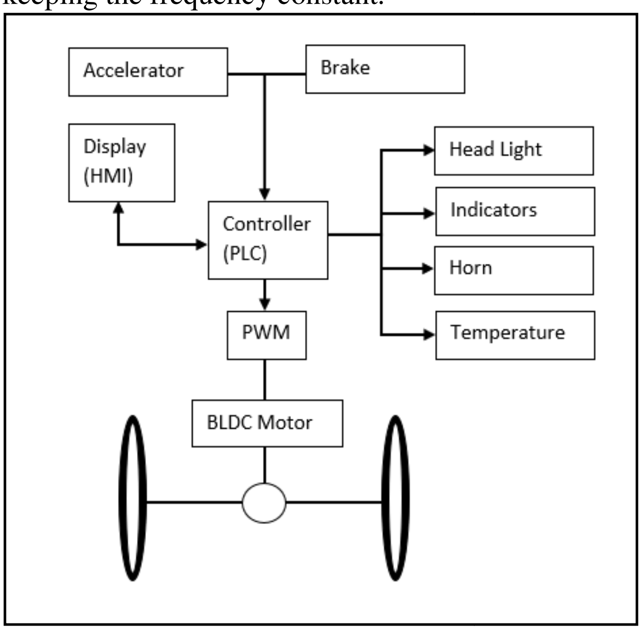

Fig. 2 Block Diagram of Proposed Control Strategy

Fig. 2 represents the block diagram of the proposed control strategy. In this work PWM is used to control the speed of the EV. The power applied to the motor can be controlled by varying the width of these applied pulses and thereby varying the average DC voltage applied to the motor's terminals. By changing or modulating the timing of these pulses the speed of the motor can be controlled, i.e., the longer the pulse is "ON", the faster the motor will rotate and likewise, the shorter the pulse is "ON" the slower the motor will rotate. In other words, the wider the pulse width, the more average voltage applied to the motor terminals, the stronger the magnetic flux inside the armature windings and the faster the motor will rotate.

IV. LOGIC DEVELOPMENT AND SIMULATION

The project is programmed in ladder logic in STEP7. Initially the power status is monitored by providing the active power through PLC as well as HMI. For the HMI inputs, memory is used to store the value in PLC. Fig. 3 shows the ladder logic of ON-OFF control of the power supply of the vehicle.

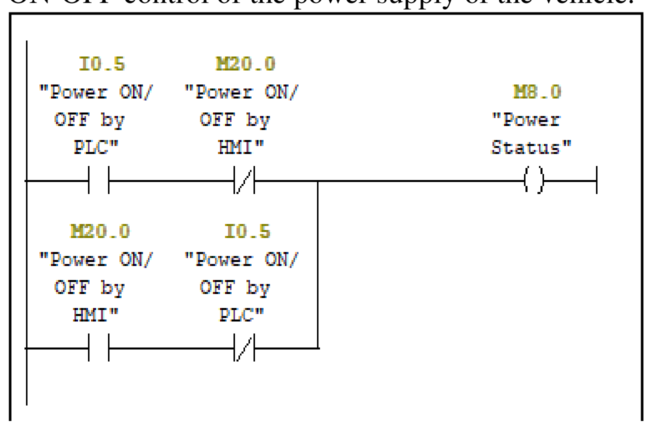

Fig. 3 Ladder Network of Power ON/OFF control

The logic network in Fig. 4 shows control of head-light of the electric vehicle. Power status is used initially. The inputs from HMI and PLC are taken for head light lamp. The XOR logic is implemented.

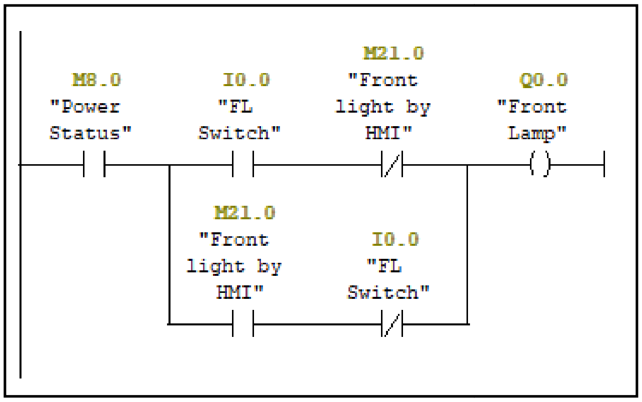

Fig. 4 Ladder Network of Head-light control

The logic network in Fig. 5 represents the right indicator control of the vehicle. XOR logic is used in taking inputs from both PLC and HMI.

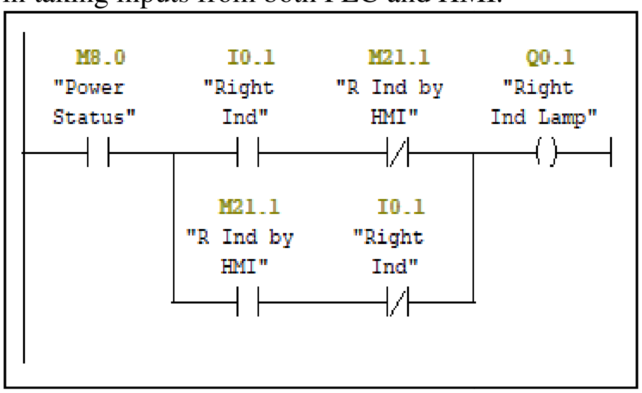

Fig. 5 Ladder Network of Right Indicator Control

As shown next in Fig. 6, horn output is controlled using ladder logic. It can be operated from both the HMI panel and the PLC Simulator.

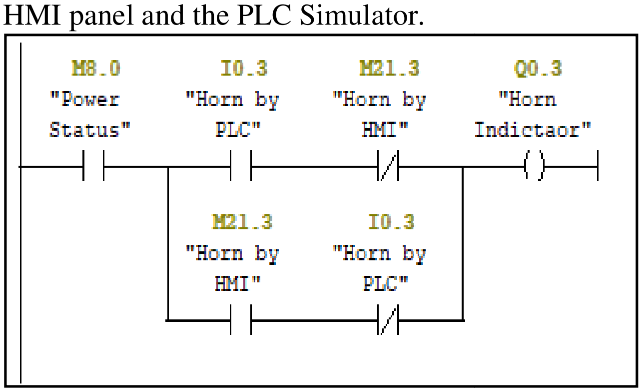

Fig. 6 Ladder Network of Horn Control

As the motor's temperature increases from a specific value (110 degree centigrade used in this work), the motor automatically decreases the speed and comes at rest. The control logic is shown in Fig. 7.

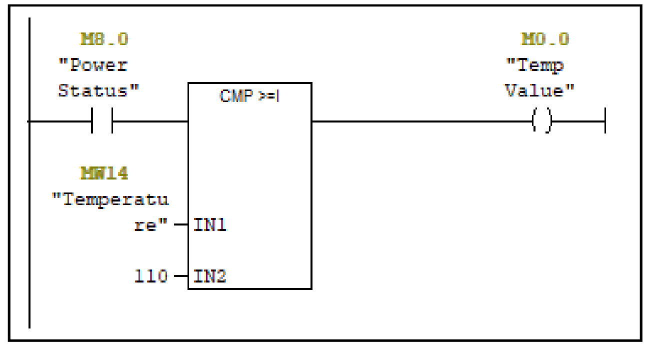

Fig. 7 Ladder Network of Over-heating Control

The logic in Fig. 8 represents the acceleration and deceleration of the speed of the electric vehicle. The values are taken from both PLC and HMI panel. It is prioritized according to the mode of the system. The mode is selected as PLC or HMI mode.

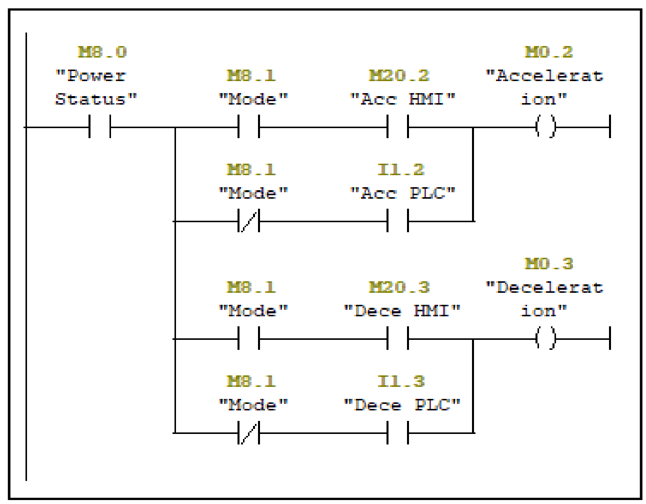

Fig. 8 Ladder Network of Accelerator control

The logic in Fig. 9 represents the increase and decrease of the brake value of the electric vehicle. The values are taken from both PLC and HMI panel. It is prioritized according to the mode of the system. The mode is selected as PLC or HMI mode.

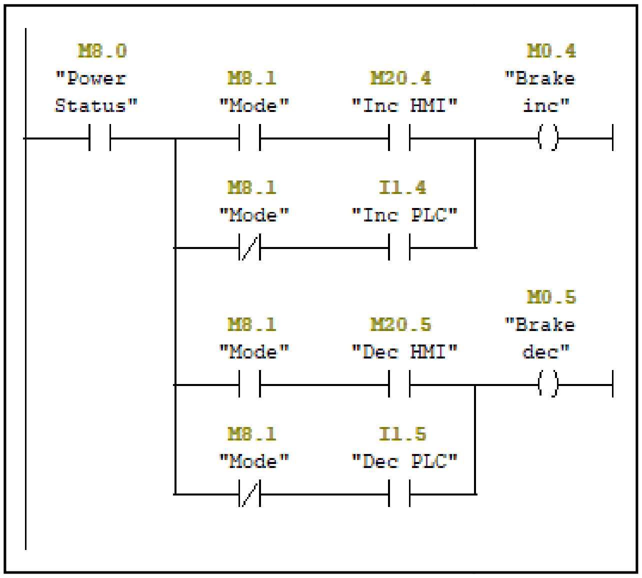

Fig. 9 Ladder Network of Brake control

Further, the accelerator value and brake values are subtracted to find the exact value of the volts provided to the motor for the speed. This logic is shown in Fig. 10.

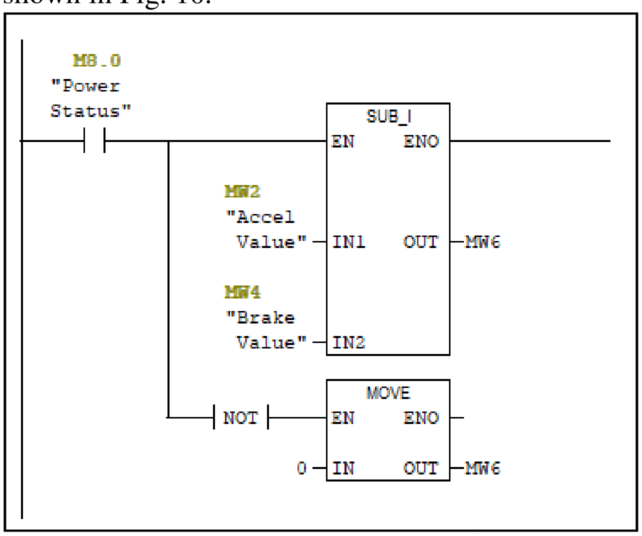

Fig. 10 Ladder Network Speed/RPM value calculation

The value of the pulse generated is compared to the required speed value. According to the value the pulse width modulated signal is produced. Further, PWM signal is given to the electric motor for the proper torque production. This is shown in Fig. 11.

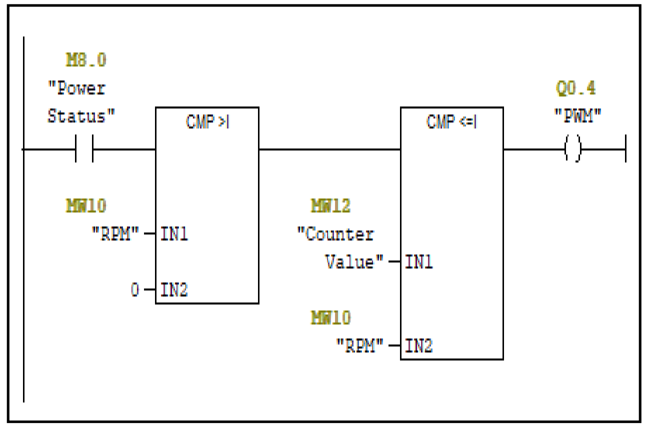

Fig. 11 Ladder Network of PWM signal generation

The developed logic is simulated using PLCSIM Tool. The simulation of the various conditions is tested. The simulation of Head-light control and Accelerator control are shown in Fig. 12 and Fig. 13 respectively

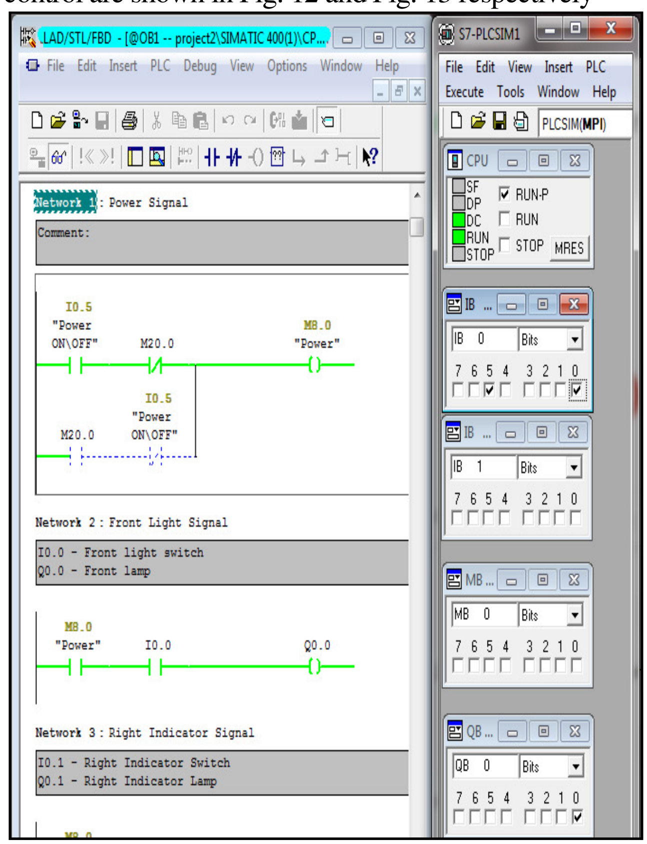

Fig. 12 Simulation of Head-light control

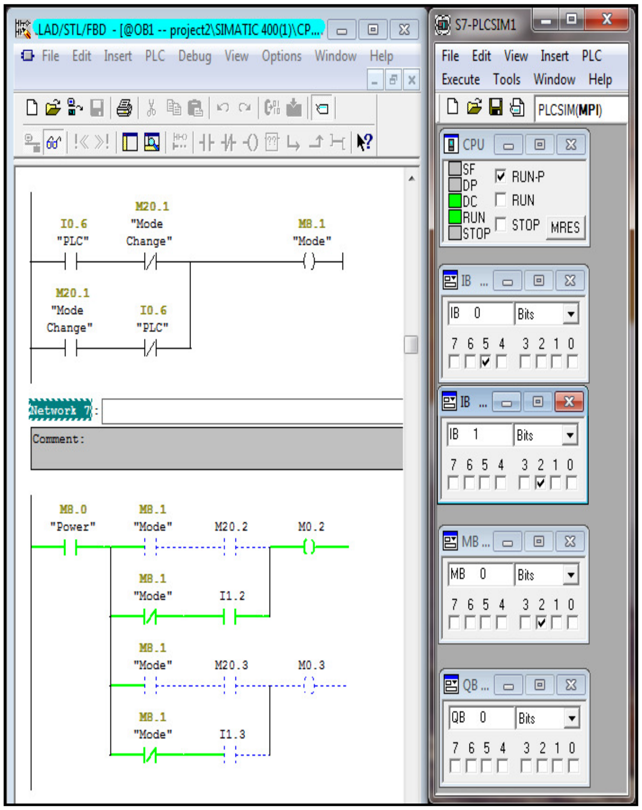

Fig. 13 Simulation of Accelerator control

V. CONCLUSIONS

In order to validate that the designed control system had the desired behaviour, different test cases were simulated. Although the test cases were chosen arbitrary, their purpose was to cover various different driving commands. Two groups of tests cases were done. The test was for validating the driver wished control. The simulation tests were independent of the vehicle model.

There is always scope of future work with every activity. By testing the different systems alone and working all together, the modularity of the control system is validated. This is an advantage because parts of this thesis can be used in other projects as well. It would be interesting to explore the possibility of using a more advanced controller, as for example a model predictive controller, although this would increase the execution time of the control system. Moreover, for complexity reasons, no disturbances were used in the simulations. If disturbances, like wind speed or noise in sensors, are included in the modelling, more useful observations might be extracted from the simulation tests.

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REFERENCES

[1] K.W.E Cheng, “Recent Development on Electric Vehicles”, Department of Electrical Engineering, The Hong Kong Polytechnic University, Hong Kong. June 2009

[2] Ji-Young Byung-Chul Woo, Jong-Moo Kim and Hong Seok Oh “In-wheel Motor Design for an Electric Scooter” J Electr Eng Technol. Nov.2017

[3] Zhai Haizhou Heze University, Heze, China “Modeling of Lithium-ion Battery for Charging/Discharging Characteristics Based on Circuit Model” Article submitted 05 March 2017. Published as resubmitted by the author 17 April 2017

[4] Md. Rifat Hazari, Effat Jahan, “Design of a Brushless DC (BLDC) Motor Controller”, Department of Electrical and Electronic Engineering American International University-Bangladesh (AIUB) Dhaka, Bangladesh. Oct 2014

[5] Mahesh S. Khande, Mr. Akshay S. Patil, Mr. Gaurav C. Andhale and Mr. Rohan S. Shirsat, “Design and Development of Electric scooter”, International Research Journal of Engineering and Technology (IRJET) Volume-7 Issue-5, May 2020.

[6] Andreas Schafer and David G. Victor. The future mobility of the world population Transportation Research Part A: Policy and Practice, 34(3):171-205, April 2000.

[7] A. Faiz, C.S. Weaver, and M.P. Walsh, “Air Pollutation from Motor Vehicles: Standards and Technologies for Controlling Emissions. Other World Bank Bks. The World bank, 1996. ISBN 9780821334447. URL http://books.google.se/books?id=Hqsyv_KD0lgC.

[8] James Albus, HM Huang, E Messina, K Murphy, MJuberts, A Lacaze, S Balakirsky, MO Shneier, T Hong, H Scott, et al. 4D/RCS Version 2.0: A reference model architecture for unmanned vehicle systems, volume 6912. 2002.

[9] SAE. Surface vehicle recommended practice, vehicle dynamics terminology. J670E, 1976.

[10] Brahim Gasbaoui, Abdelfatah Nasri and Othmane Abdelkhalek, “An Efficiency PI Speed Controller for Future Electric Vehicle in Severa Topology”, 9th International Conference Interdisciplinarity in Engineering, 2015, www.sciencedirect.com

[11] Gerard Francesco Apolinario, Chrisean Adolfo, Christine Joy Arce and Zyra May dela Rosa, “Design and Implementation of Electric Motor Controller for Two Wheeler Hybrid Vehicle”, 978-1-7281-3044-6/19/IEEE Xplore

[12] L. Guzzella and A. Sciarretta. Vehicle Propulsion Systems. Springer-Verlag Berlin Heidelberg, 2007. ISBN 9783540746928. URL http://books.google.se/books? id=y3xN7jZTesUC.

[13] Ola Harkegard. Backstepping and control allocation with applications to flight control [Elektronisk resurs]. Linkopings universitet, Linkoping, 2003. ISBN 91-7373-647-3(pr t).

