13 th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

CLOSED LOOP PLC CONTROL OF ELECTRIC VEHICLE

Prof. Dr. Ashraf Salah El Din Zein El Din
Department of Electrical Engineering, Faculty of Engineering, Shebin El Kom, Minoufiya University, Egypt, e-mail: ashrafzeineldin2002@yahoo.com

ABSTRACT
New technologies in electrical engineering refresh repeatedly the interest of researchers and engineers dealing with electric vehicle development. The motorization of a vehicle needs to work at very wide range of speed. The motor axis is connected to the wheel. Rapid developments in automation are increasing flexibility for plant manufacturers in the industry. The Programmable Logic Controller (PLC) is used for controlling the electric vehicle motor speed in both open and closed loop operation. A PLC has the advantages that, designed to operate in noisy industrial environments, no extra filtering required, smaller, faster, acting and more reliable than hard wired systems. This paper represents an experimental and computed study for speed control of electric vehicle motor using ON/OFF control method. The controller is based on continuous adaptation for the dc chopper duty ratio to readjust the motor speed of electric vehicle. Transient and steady state response of electric vehicle motor performance are presented. The proposed control method is simple, effect and useful in electric vehicle application which needs variable speeds with good motor performance.
Keywords: Electric `Vehicle, PLC, ON/OFF Control.

1. INTRODUCTION
Programmable Logic Controllers (PLCs) are by textbook definition "solid-state members of the computer family, using integrated circuits instead of electromechanical devices to implement control functions." More simply put, PLCs are the computers that use programmable logic to control automated machinery whether it is in a manufacturing plant or in an amusement park [1,6]. We are all aware of how important it is to choose the right combination of hardware and software to deliver optimal results in a manufacturing automation application in specific circumstances, even though we may not always apply it [2]. HEV Sabre Tool™ is Sabre Engineering's proprietary software model of hybrid vehicle dynamics (HEV). It embodies years of observation and data from the successful use of Sabre Engineering's first generation of hybrid vehicle controls by analyzing both the vehicle and its hybrid component requirements, this software enables proper HEV system analysis to provide for a dependable and affordable hybrid system design. This all encompassing modeling package analyzes power creation, power stored and power consumed on a dynamic hybrid vehicle. In addition, the software models vehicle motion and use cycles as well as environmental conditions [3,4,5]. This paper presents the design and implementation of a PLC based closed loop speed control for electric vehicle d-c motor. The ON/OFF control method for adopting the motor input voltage to keep its speed within the desired value. Computing and experimental results have shown the effectiveness of the proposed simplified model

2. SYSTEM DESCRIPTION
A schematic diagram for the proposed electric vehicle control is shown in Figure 1. It consists of Comparator, PLC, External Relay, Electric Vehicle model. And DC motor. A voltage comparator compares between the reference speed voltage (Ref.) and electric vehicle motor speed (Tacho.). The output of the comparator (Output) is either positive or negative saturation voltage of the operational amplifier or zero volts. When Ref.> Taco volt., Output = + 0.9*Vcc = 10.8 volt. (at Vcc=12 volt). In other hand when Ref.≤ Tacho volt. Output = - 0.9*Vcc = - 10.8 volt. (at Vcc=12 volt). From the basic operation of the PLC. It operates at an input voltage range between +8 to +30 d-c voltage. So, PLC operates here as a controller for connecting or disconnecting electric dc power to electric vehicle (d-c motor via a Relay). In other words, a feedback motor

speed from a tacho-generator is compared with a desired or reference speed, and the difference between them controls the operation of the PLC. A simple ladder program (only one statement) is used for connecting the output relay contactor of PLC if and only if PLC is in operation mode and hence relay is in active operation and d-c power voltage delivers the dc motor of electric vehicle. Other wise, when PLC is in off mode operation, relay is inactive operation and there is no d-c power passes to d-c motor. A PLC operates as a d-c to d-c chopper control. The chopper fed electric vehicle loaded motor.

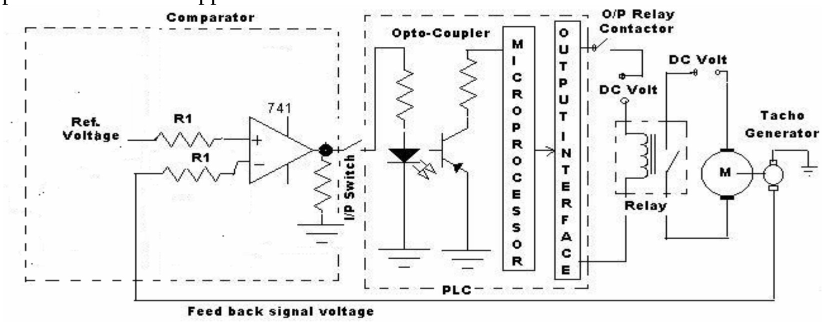


Figure 1. A proposed control system

3. MECHANICAL SYSTEM DESCRIPTION OF ELECTRIC VEHICLE MODEL

We provide research and development work for prototype to full scale production designs of mechanical and electrical systems. As shown in Figures 2,3. Three dimension view, side view, elevation and plane of electric vehicle model.

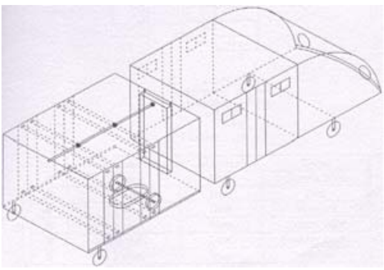


Figure 2. Three dimension view of Electric vehicle prototype.

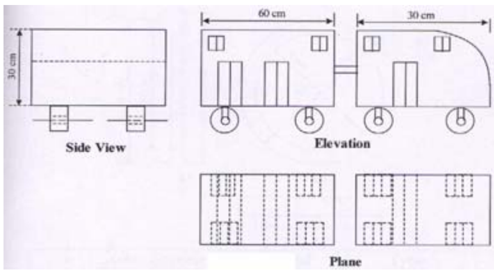


Figure 3. Side View, Elevation and Plane of Electric vehicle prototype

4. D-C MOTOR MATHEMATICAL MODEL

A d-c motor is used for moving wheels of electric vehicle. The performance equations for the d-c motor are expressed in the following form:

$$V=(L_f+L_a)\frac{di_a}{dt}+(R_f+R_a)i_a+E_b \qquad (1)$$

$$E_b= -k_1\,\omega_m\,i_a \qquad (2)$$

$$T_e = T_L + J \quad + K_2 \qquad (3)$$

$$T_e = - K_1\, i_a^2 \qquad (4)$$

5. A LADDER PROGRAM

Only one statement is used as a program written in ladder diagram for a PLC to control the electric vehicle motion. In other words, connect or disconnect d-c power supply to electric vehicle motor via an external relay interfaced to PLC.

Figure 4. A ladder diagram program

01 is an input address to emergency switch (start/stop switch), and 011 is an output relay contactor address. So, if switch 01 is switched on and address 011 is active, this means that connect d-c power to electric vehicle motor via an external relay interfaced to PLC. On the other hand, if switch 01 is switched off or output relay address 011 is inactive, disconnect d-c power to electric vehicle motor.

6. A PROTO-TYPE OF A SYSTEM

It is shown in Figure 5, a photo of the proto-type of the experimental system. Allen Bradelley SLC 150 is used (Model of PLC), electric vehicle model and d-c power.

Table 1. Motor parameters

Motor parameter	Value
Input voltage	12 volt.
Rated current	2.5 Amp.
Rated power	0.5 HP
Ra	3 ohm
La	30 m.h.
K1	0.03 ohm.sec./rad.
K2	2E-04 Kg m^2/sec
J	2.4E-5 Kg m/sec
No of pair poles	1

Figure 5. A Photo of the Prototype of the system

7. SIMULATION AND EXPERIMENTAL RESULTS

A computer programming is written to simulate the electric vehicle motor performance in case of open loop and closed loop operation of electric vehicle prototype motor. It is based on the performance Equations 1-5, 4^{th} order Runge-Kutta method is used for solving the equations. The electric vehicle motor parameters are listed in table 1. The electric vehicle system is subjected to a sudden up change in reference speed by 40% of its initial value and maintained for 0.5 sec., the experimental and simulation results are shown in Figures 6&7. The ripples shown in speed at steady state are due to the controller and the fluctuation of speed is accepted. Also, the motor current is discontinuous (interrupted). So, by decreasing the reference speed you can obtain uninterrupted motor current. In other hand, Figures 8&9 show the performance of electric vehicle motor under sudden down change in reference speed by 40% of its initial value and maintained for 0.5 sec experimentally and computed. It is clear that, motor speed follows the reference speed. This means that the controller is accurate, fast and effective. Another experiment is done to the electric vehicle load either increase with 50% of its initial value at fixed reference speed and maintained for 0.5 sec. Figures 10&11show experimentally and computed results. It can observed that the speed is decreased during the period of increasing load torque then return back to its initial value after the load torque is sustained to its initial value.

8. CONCLUSION

The proposed method of speed control (ON/OFF control) has the advantages of robustness and modularity. An experimental proto-type of electric vehicle is controlled via a programmable logic controller has been implemented to verify the proposed control scheme. Experimentally, Only one statement is used in a program written in ladder diagram for connecting/disconnecting d-c power supply via an external relay interfaced to motor of electric vehicle. This is simple, effective and faster. The control program is able to greatly simplify maintenance of the electric vehicle by implementing the simple and effective On/Off control concept. A successful design and performance analysis of high efficiency novel PLC control electric vehicle via a simple analog comparator. Simulation (Computed) analysis of the proposed system has been carried-out and performed using Fortran Programming Languages to obtain transient and steady state performance of electric vehicle motor at different operating cases. Experimental results validate the effectiveness and simplicity of the proposed control scheme.

9. REFERENCES

[1] Mark T. Hoske, "Control Logic Strategies With so many options for discrete applications, system integrators explain how to make the right choice for your control strategy", Control Engineering, May 1, 2004

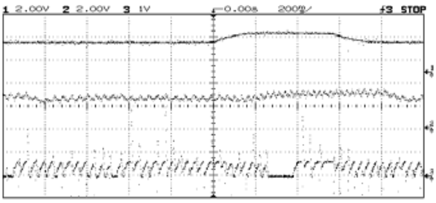
[2] Dan Sussman, "Dedicated I/O Delivers Faster Communication Metro Weighing and Automation switched from PLCs to I/O for its packaging system products, Control Engineering April 1, 2004

[3] Internet network web site www.sabre-engineering.com

[4] D. Lemoine**,** "Improvement of AECV motorization with double rotor electrical motors", %the International Conference AECV2003, 2-5 June 2003, Angers,France

[5] Internet network web site www.gefanuc.com

[6] LJ Technical Systems, "An introduction to Industrial Programmable Controllers", PC06 Curriculum Manual, 1998



ch.1 Reference speed ch.2 Motor speed
ch.3 Motor current

Figure.6 Electric vehicle motor performance if reference speed is stepped-up (Experimental results.)

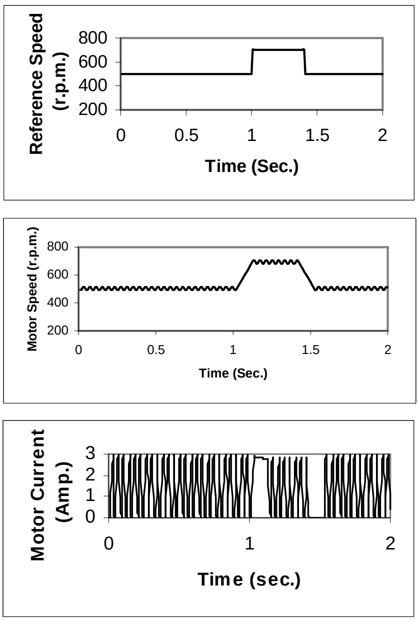


Figure7 Electric vehicle motor performance if reference speed is stepped-up (Simulation results.)

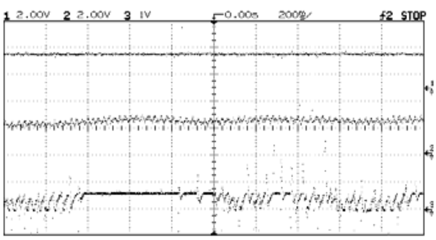
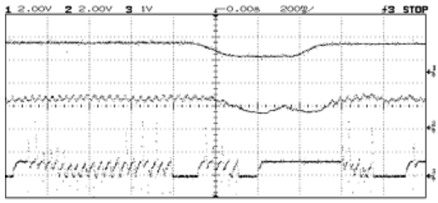


Fig.10 Transient response of electric vehicle speed at load torque is varied

Ch.1 Reference Speed is constant = 500 r.p.m.
Ch.2 Motor Speed
Ch.3 Motor Current.
(Experimental Results)



ch.1 Reference speed ch.2 Motor speed
ch.3 Motor current

Figure 8 Electric vehicle performance if reference speed is stepped down up (Experimental results.)

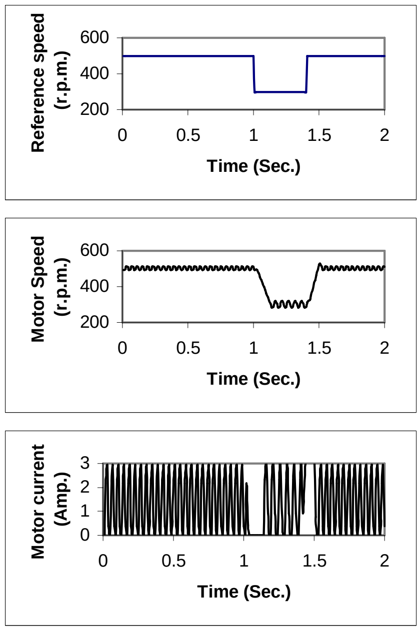


Figure9 Electric vehicle motor performance if reference Speed is stepped down (Simulation Results)

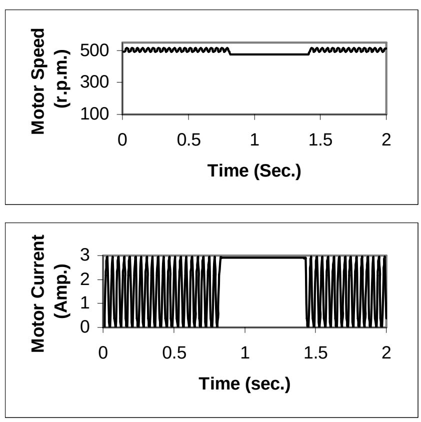


Fig.11 Transient response of electric vehicle speed at load torque is varied (Simulation Results).