Fuzzy Logic Controlled Speed Control of DC Motor in Hybrid Car Application

S. Varsha[1] Surya Prakash[2] Murali[3] Kathiravan[4] Mr. Sudhagar V.[5]
[5]Assistant Professor
[1,2,3,4,5]Department of Electrical & Electronic Engineering
[1,2,3,4,5]Valliammai Engineering College, India

Abstract— The tremendous depletion of natural fuels like petrol, diesel, CNG, etc. & their storage and transportational cost makes us to look forward towards the renewable energy like solar, wind, etc. & therefore our project is dealing with the 'speed control part of the hybrid vehicle application'. Controller is the heart of an electrical vehicle and it is the key for the realization of high performance electric vehicle with an optimal balance of maximum speed, acceleration performance. The controller should be designed to make the system robust and adaptive, improving the system on both dynamic and steady state performance. Fuzzy control is generally used to increase the efficiency and deal with complex operation mode which can be simulated using MATLAB software. Thus it focuses on model based control design and hardware implantation.
Key words: DC Motor Control, Fuzzy-Logic Controller

I. Introduction

The major components of an electric vehicle system are the motor, controller, power supply, charger and drive train. Controller is the heart of an electric vehicle, and it is the key for the realization of a high-performance electric vehicle with an optimal balance of maximum speed, acceleration performance, and traveling range per charge. Control of Electric Vehicle (EV) is not a simple task in that operation of an EV is essentially time-variant (e.g., the operation parameters of EV and the road condition are always varying). Therefore, the controller should be designed to make the system robust and adaptive, improving the system on both dynamic and steady state performances. Another factor making the control of EV unique is that EV's are really "energy-management" machines (Cheng et al., 2006). Currently, the major limiting factor for wide-spread use of EV's is the short running distance per battery charge. Hence, besides controlling the performance of vehicle (e.g., smooth driving for comfortable riding), significant efforts have to be paid to the energy management of the batteries on the vehicle. Due to the complex operation condition of electric vehicle, intelligent or fuzzy control is generally used to increase efficiency and deal with complex operation modes. This chapter will mainly focuses on model-based control design and hardware implementation for Golf Cart EV's and the implementation of the platform for realization of variant control strategies.

A. Existing System

DC motor speed controllers are very useful for controlling the motion of robotic and industrial automation systems. The controller presented here uses the pulse-width modulation (PWM) technique. The PWM wave for speed control is generated using PIC microcontroller. To control the speed of the DC motor. And it consist of battery, PIC Microcontroller, Isolation and amplification circuit, Power circuit, Motor

B. Compound Motors

The DC compound motor is a combination of the series motor and the shunt motor. It has a series field winding that is connected in series with the armature and a shunt field that is in parallel with the armature. The combination of series and shunt winding allows the motor to have the torque characteristics of the series motor and the regulated speed characteristics of the shunt motor. Cumulative compound motor is so called because the shunt field is connected so that its coils are aiding the magnetic fields of the series field and armature. The shunt winding can be wired as a long shunt or as a short shunt. The motor connected as a short shunt where the shunt field is connected in parallel with only the armature. The motor connected as a long shunt where the shunt field is connected in parallel with both the series field, interpoles, and the armature.

The cumulative compound motor is one of the most common DC motors because it provides high starting torque and good speed regulation at high speeds. Since the shunt field is wired with similar polarity in parallel with the magnetic field aiding the series field and armature field, it is called cumulative. When the motor is connected this way, it can start even with a large load and then operate smoothly when the load varies slightly.

C. Isolation & Amplification Circuit

Through microcontroller firing pulse is given and it is operated at a voltage of about 5V.This operating voltage can't be directly used to trigger the power circuit. Inorder to trigger the power circuit, using amplification circuit amplifies 5V to 12V.Isolation circuit blocks high voltage and voltage transients, so that the surge in one part of the system won't affect the other parts.

1) Power Circuit

Here power mosfet IRF1407 is used and 4 mosfets are connected in parallel for surge current minimization. The fast recovery diode RHR30120 is used to block the reverse current.

2) Speed Control

When accelerated, pedal is pressed and then resistance value in potentiometer changes. This fed to controller and microcontroller generates PWM pulse and required operation are performed to control speed and torque.

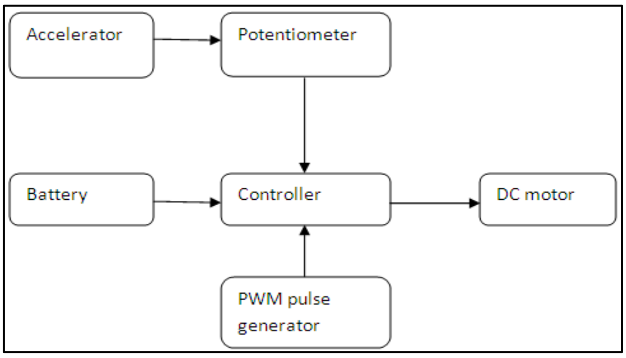

Fig. 1: Block Diagram

II. FUZZY LOGIC CONTROLLER

The fuzzy logic foundation is based on the simulation of people's opinions and perceptions to control any system. One of the methods to simplify complex systems is to tolerate to imprecision, vagueness and uncertainty up to some extent. An expert operator develops flexible control mechanism using words like "suitable, not very suitable, high, little high, much and far too much" that are frequently used words in people's life. Fuzzy logic control is constructed on these logical relationships. Fuzzy Sets Theory is first introduced in 1965 by Zadeh to express and process fuzzy knowledge. There is a strong relationship between fuzzy logic and fuzzy set theory that is similar relationship between Boolean logic and classic.

A. Advantage of using Fuzzy Technique

1) Inherent approximation capability
2) High degree of tolerance
3) Smooth operation

1) The Design Procedure of FLC Contains Three Steps as

a) Defining input and output.
b) Defining membership functions and rules.
c) Adjusting membership functions and rules.

2) Proposed Fuzzy Logic Based Controller Work as Per Following Steps

We need to control the speed of a motor by changing the input voltage. When a set point is defined, if for some reason, the motor runs faster, we need to slow it down by reducing the input voltage. If the motor slows below the set point, the input voltage must be increased so that the motor speed reaches the set point.

3) Let the Input Status Words Be

1) Too slow
2) Just right
3) Too fast

4) Let the Output Action Words Be

4) Less voltage (Slow down)
5) No change
6) More voltage (Speed up)

5) Define the Rule-Base

1) If the motor is running too slow, then more voltage
2) If motor speed is about right, then no change.
3) If motor speed is to fast, then less voltage.

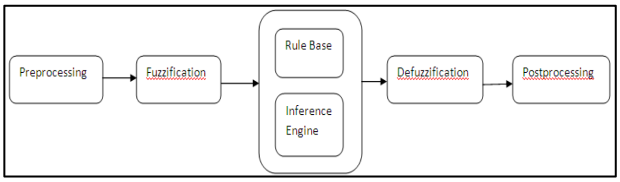

Fig. 2: Basics of Fuzzy Logic Concept & Processing

There are specific components characteristic of a fuzzy controller to support a design procedure. Controller consists of between the pre-processing block and post processing block. The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable.

B. Rule Base

The collection of rules is called a rule base. The rules are in "If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error, d (e). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

C. Preprocessing

The inputs are most often hard or crisp measurement from some measuring equipment rather than linguistic. A preprocessor, the first block in Figure 1 shows the conditions the measurements before enter the controller.

D. Defuzzification

Defuzzification is when all the actions that have been activated are combined and converted into a single non- fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non- linearity's existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the nonlinearity.

E. Post Processing

The post processing block often contains an output gain that can be tuned and also become as an integrator.

1) Fuzzy Membership –Function

The membership function of input, output, fuzzification process & fuzzy rule based in propose MALTAB simulation used in this control of DC motor.

Each rule in general can be represented in the following manner:

If (antecedent) Then (consequence).

For example: If the speed of the car is high, then apply less force to the accelerator. If pressure is high, then volume is small

A fuzzy logic controller has four main components. In order to define fuzzy membership function, designers choose many different shapes based on their preference and experience. There are generally four types of membership functions used are Trapezoidal MF, Triangular MF, Gaussian MF, . Generalized bell MF

2) Implementation of an FLC Requires the Choice of Four Key Factors

1) Number of fuzzy sets that constitute linguistic variables.
2) Mapping of the measurements onto the support sets.
3) Control protocol that determines the controller behavior.
4) Shape of membership functions.

3) The General Considerations in the Design of the Controller are

If both e and ce are zero, then maintain the present control setting i.e. du=0. If e is not zero but is approaching this value at a satisfactory rate, then maintain the present control setting. If e is growing then change the control signal du depending on the magnitude and sign of e and ce to force e towards zero

There are three linguistic variables: Error(e)
Change in Error(ce)
Output(du)

III. CALCULATIONS AERODYNAMICS CALCULATION

1) Design of hybrid car
2) Steps involved in power design:
3) The various steps involved in power design are:
4) Assuming the segment and class of the car and weight of the car, frontal projected area, maximum speed at level road and gradient.
5) Calculation of aerodynamic resistance, rolling resistance, gradient resistance, tractive resistance, power requirement.
6) Calculation of torque

– Assumption Made From Model

Unladen weight = 110 Kgs
Laden weight = 240 Kgs
Gross weight = 350 Kgs (3 Axle trailer truck)
Maximum speed = 40 Kmph = 11.12 m/s
Economy speed range = 25-30 Kmph
Maximum speed on gradient = 35 Kmph (In full load condition)
Coefficient of drag = 0.8
Frontal area = 1.5m^2

– Calculation of Tractive Force & Power Requirement
– On Level Road Condition:

Total tractive resistance = Aerodynamic resistance + Rolling resistance

A. Calculation of Aerodynamic Resistance

Aerodynamic resistance of the car is given by the formula,

$$\text{Aerodynamic resistance, } A_R = (1/2)\, \rho\, A_F V^2 C_d \qquad (1)$$

$$\text{Density of air,} \rho = 1.225 \text{ Kg/m}^3 \qquad (2)$$

$$\text{Maximum velocity, } V = 11.12 \text{ m/s} \qquad (3)$$

$$\text{Aerodynamic resistance, } A_R = (1/2)\, \rho\, A_F V_R^2 C_d. \qquad (4)$$

A_R = (1/2) X 1.225 X 1.5 X 11.12^2 X 0.80

$$\text{Aerodynamic resistance, } A_R = 90.88 \text{ N} \qquad (5)$$

B. Calculation of Rolling Resistance

Coefficient of rolling resistance, μ = 0.01 (For car, standard value)

Weight of the car, W = M X g

$$W = 350 \text{ X } 9.81 = 3433.5\text{N} \qquad (6)$$

Rolling resistance, R_R = μ X W = μ X M X g= 0.01 x 3433.5 (7)

Rolling resistance, R_R = 34.335 N

C. Total Tractive Resistance

Total tractive resistance is the summation of aerodynamic resistance and rolling resistance. Here gradient resistance is not considered as the car travels on level road.

Total tractive resistance, $T_R = A_R + R_R$

$$T_R = 90.88+34.335 \qquad (8)$$

Total tractive resistance, T_R = 125.215 N

D. Power Required to Propel the Car in Top Speed

For calculating the power required to propel the car, the maximum speed of 25 m/s is considered.

Power required is given by the formula,

Power = Total tractive resistance X Maximum velocity

$$\text{Power} = 125.215 \text{ X } 11.12 \qquad (9)$$

Power = 1.39239 KW or 1.87743 bhp

Power of 1.39239 KW is required to move the car in top speed on a level road condition. Rolling resistance contributes more to the total tractive resistance due to high weight of the car.

$$\text{Motorpower}=1.39239/\text{gear box efficiency } (97\%) \qquad (10)$$

Motor power = 1.935 KW

Torque calculation:

On level road:

P = 2ΠNT

$$T = P/2\Pi N \qquad (11)$$

T = (1.435*10^3)/(2*11.12*π)

$$T = 20.5449 \text{ N\_m} \qquad (12)$$

E. Calculation to Find Whether we have to use Heat Sink

IRF1407

– Maximum Power Dissipation Without Heat Sink Calculation

Thermal resistance junction=62 degree Celsius/watt
Tj=175 degree Celsius
Power dissipated = (max(Tj)-Ta)/thermal resistance junction
= (175-25)/62
= 2.4watts (13)
Power loss = I^2R
= (60)*(60)*0.0078
=28. 08 (14)
28.08W > 2.4W
Power loss > maximum power dissipation
Therefore heat sink is used.

IV. SIMULATION

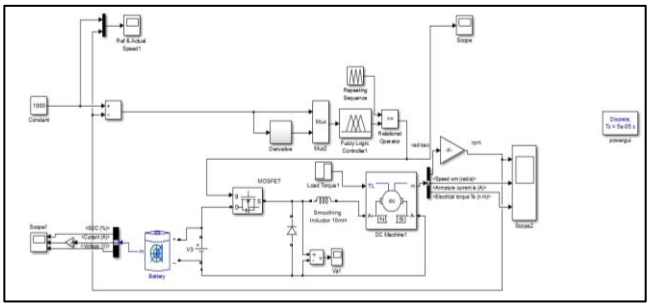

Fig. 3: Simulation

SOC, voltage, current is set up with a value inorder to give as an input to the battery. Battery is connected to Mosfet.

Smoothening inductor is used to filter the noise. Freewheeling diode is used to block the reverse current. And then it is connected to motor and load torque waveform is generated. And to apply fuzzy logic, fuzy logic controller block is included for the smooth waveform.

A. Actual Speed vs Reference Speed

Actual speed is plotted as x-axis and reference speed is plotted as y-axis. Actual speed is plotted against reference speed as shown in figure. 4

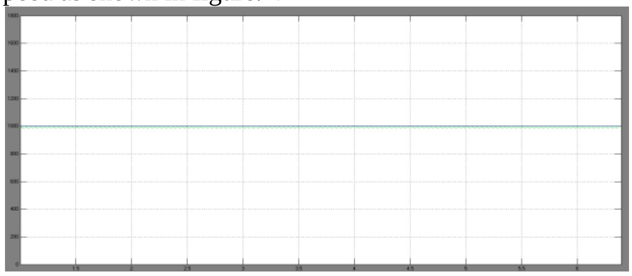

Fig. 4: Actual Speed vs Reference Speed Curve

Motor Speed, Torque, Current

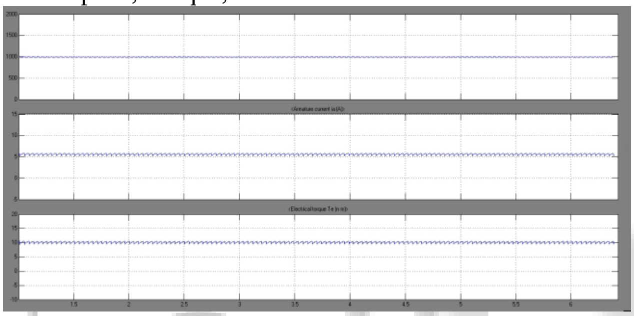

Fig. 5: Speed ,Current, Torque Curve

The first waveform gives the information about motor speed ,second one gives information about armature current,third waveform is about electrical torque.Speed, current and torque is plotted in y-axis and time in seconds as x-axis.

V. CONCLUSION

Hence, a fuzzy based DC motor speed control system was designed the simulation model is implemented in MATLAB/simulink environment. From the output speed wave form, we can see that the proposed fuzzy logic controller is able to sense that the method gives a smooth speed control with less overshoot and no oscillations variation of the reference speed attention, and applied practically in hybrid car application also and greatest advantages are obtained out of it.

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