Design, Modelling and Simulation of Advanced Electric Vehicle Using FLC

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Abstract - The objective of this paper is to presents the simulation of an advanced electric vehicle drive system that is used to explore power flow throughout motoring and regeneration mode, considering a DC motor, an ideal controller combined with a Fuzzy Logic controller, a battery and a battery controller. The simulation model is used to appraise the electric drives energy stream and efficiency for specific speed and torque conditions. A stable Simulink model is design to govern the system performance over a given speed and torque conditions. The number of electric vehicles on the roads is growing every year, therefore this paper denotes the cost effective design, robust design, growing efficiency and environment friendly vehicle.

Keywords - Advanced Electric Vehicle [AEV], DC motor, motor controller, battery, battery controller, fuzzy logic controller.

1. INTRODUCTION

Due to the increasing environmental pollution and decrease of fuel sources, automobile industries move on the way to the electric systems. Therefore in automobile industries electric vehicles are come forward than the traditional vehicles. Most electric vehicles including electric cars, electric scooters, electric bicycles, etc. are driven by electricity kept in battery. Later how to use batteries' energy efficiently is an important issue for developing AEV's. [1][2]

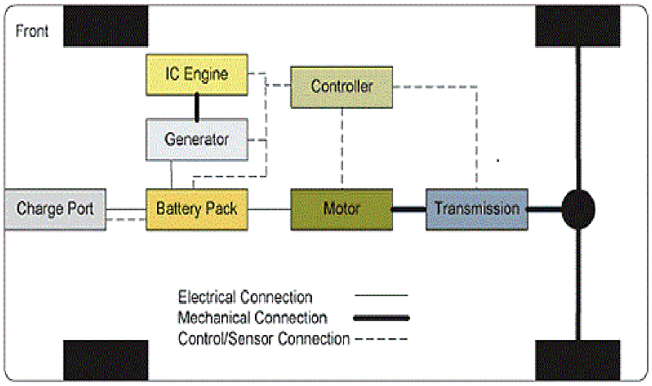


Fig. 1. Schematic of Advanced Electric Vehicle

The AEV's run on Brushless DC Motor, because its benefits like, simple and robust construction, high efficiency, high active response, higher speed range, large starting torque, noiseless operation etc. BLDCM been applied in many fields, because of its most benefits such as compact hardware dimension and mass, high performance of driving system etc. [1]

2. KEY EQUATIONS

Determining the key equations and their equivalent variables and parameters is an essential first step in model expansion. Every block in this simplified model denotes one or more major equations as listed below with the components. The model of the armature winding for the DC motor is expressed as follows. [7]

DC Motor Equations:

$$V_A = RI_a + L\frac{di_a}{dt} + e_a \qquad (1)$$

$$V_B = RI_b + L\frac{di_b}{dt} + e_b \qquad (2)$$

$$V_C = RI_c + L\frac{di_c}{dt} + e_c \qquad (3)$$

Where,

L is the armature self-inductance.[H]

R is the armature resistance.[Ω]

V is the terminal voltage.[V]

e_a, e_b, e_c is the back EMF.[V]

I_a, I_b, I_c is the input current.[A]

In the 3-phase BLDC motor, the back-EMF is related to a function of rotor position and the back-EMF of each phase has 120^0 phase angle difference so equation of each phase should be as follows:

$$e_a = B_e f(\theta_e)\omega \qquad (4)$$

$$e_b = B_e f(\theta_e - \frac{2\pi}{3})\omega \qquad (5)$$

$$e_c = B_e f(\theta_e + \frac{2\pi}{3})\omega \qquad (6)$$

Where,

B_e = back EMF constant of one phase [V/rad.s^{-1}]

θ_e = electrical angle

ω = rotor speed [rad.s^{-1}]

Developed motor torque Equation:

Torque is directly proportional to armature current:

$$T_D \text{ (Nm)} = K_m * I_A \text{ (Amp)} \qquad (7)$$

Developed motor voltage Equation:

Voltage is directly proportional to armature speed:

$$V_D = W_D \text{ (rad/sec)} * K_m \qquad (8)$$

Motor Voltage Equation:

$$V_H \text{ (Volt)} = I_H \text{ (Amp)} * R_A \text{ (Ohm)} + L_H \text{ (Henry)} * di(t)/dt \text{ (A/s)} + V_D \text{ (Volt} \qquad (9)$$

Controller High voltage Equation:

High side voltage is equivalent to K times the low side voltage:

$$V_H=K*V_L \qquad (10)$$

Controller High current Equation:

High side current is equivalent to 1/K times the low side voltage:

$$I_H = (1/K)*V_L \qquad (11)$$

Battery model calculation Equation:

$$V_B = I_A * R_A + E_B \qquad (12)$$

$$V_L = I_L * R_A + E_B . \qquad (13)$$

Assuming: $V_B = V_L$ and $I_A = I_L$

Error Voltage Calculation Equation:

$$BErr=E_B(\text{actual})-E_B(\text{calculated}) \qquad (14)$$

PID Calculation Equation:

$$K=(K_p + (1/s)*K_I +du/dt*K_d)*BErr \qquad (15)$$

3. SIMULATION MODEL 0F AEV

In this section, we will study each section of the model in detail, The AEV system consists of some subsystems, the electric motor and the vehicle stage system; both to be modelled, allowing for all acting forces and parameters, AEV stage to be coupled with the wheel rotational velocity via features of the electric motor and surface, as well as, to derive the terminologies for the acting forces, to calculate required torque and power expressions,[4] that can be used to build the Simulink model, finally, suggest, design couple and examine control systems. The Speed and Torque values were written to the MATLAB Workspace, and the values were then read into the model speed and torque look-up table. The Clock timer input to the look-up tables used the following time base values that were setup in the model parameters table: Tmin = 0 sec, Tstep = 0.01sec, Tstop = 100 secs. The Speed and Torque values are given in table [5]-[9]

Load Speed values and times given in the lookup table.

Svals = [0 1000 2000 3000 5000 2000 1000 2000]

Stime = [0 5 20 30 50 65 85 100]

Load Torque values and times given in the lookup table

T vals = [0 550 550 330 330 160 160 -220 -220 130 130 0 0]

T time = [0 5 10 15 20 30 40 50 55 70 80 85 100]

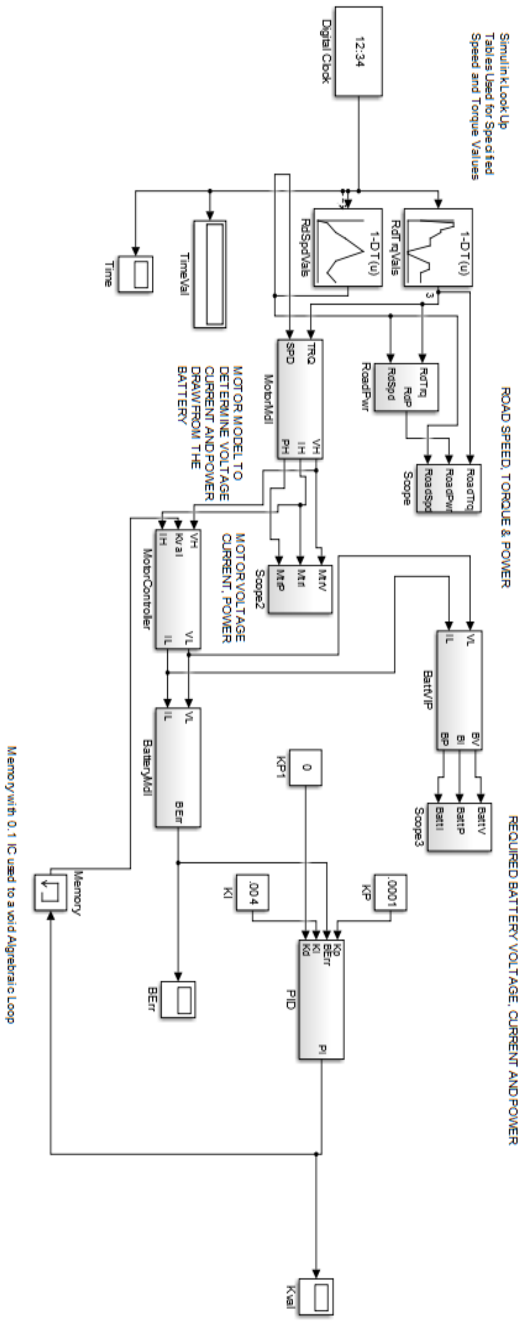


Fig-2 HEV model

4. PREVIOUS WORK

In the previous paper **is** presents the simulation of a basic electric vehicle motor-drive system that is used to study power flow. The simulation assumes a BLDC permanent magnet motor, a motor controller combined with a fuzzy logic with proportional-integral controller, and the advanced electric vehicle battery. The model can be used to estimate the electric drive's energy flow and efficiency for specific speed and torque. Some of the key system parameters are specified and others are modelled as ideal parameters. A stable MATLAB/Simulink model is recognised and valid. It is then used to govern the system performance and energy flow over a given set of motoring and regeneration speed/torque conditions. [7]

.5. PROPOSED METHODOLOGY

The main work behind this paper has enclosed of exploring the market for advanced electric vehicles, and to some scope light commercial automobiles, to get nearer to developments, future products. At the same time, a countless event to actively work in a project involving advanced propulsion is offering. This is a distinctive occasion to host discussion with colleagues about the potential and features of advanced cars and its mechanisms. The third most important module in this work is a sequence of simulations to evaluate the energy efficiency and performance of propulsion in personal cars. In this method for improving the Accuracy of the self-motivated programming is presented. This paper is introduce the fuzzy logic controller used in the advanced electric vehicle which improve the performance and efficiency of the vehicle that is used to investigate power flow during both motoring and regeneration modes.

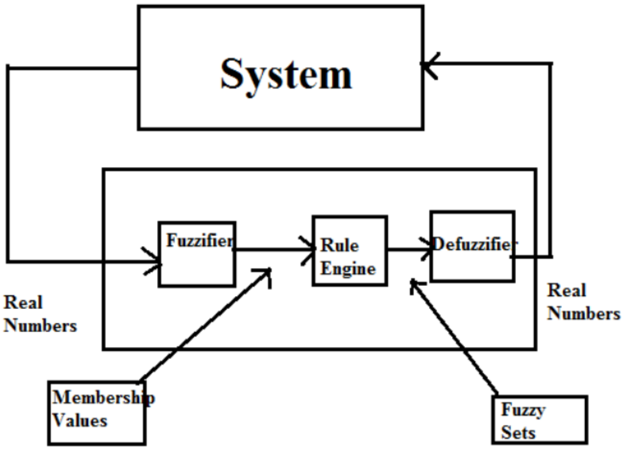


Fig-3 Structure of fuzzy logic controller

Error (E) and change in error (CE) are the inputs for the fuzzy controller whereas the output of the controller is change in duty cycle (ΔDC). The error is defined as the difference between the refereed and actual speed, the change in error is defined as the variance among the present error and previous error and the output, Change in duty cycle ΔDC is which could be either positive or negative is added with the existing duty-cycle to determine the new duty-cycle (DC new) Fig. 3 shows the basic structure of fuzzy logic controller. The fuzzy logic controller is comprises of the following four elements: fuzzification, rule-base, inference engine and defuzzification [4].

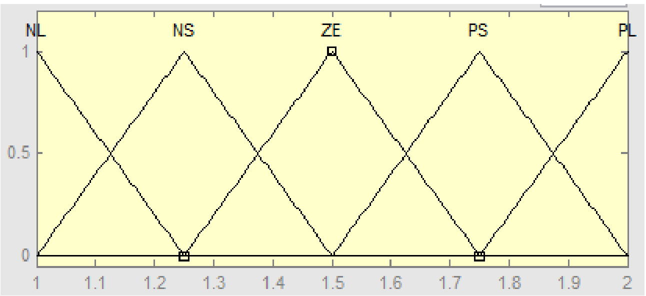


Fig-4 input membership function error

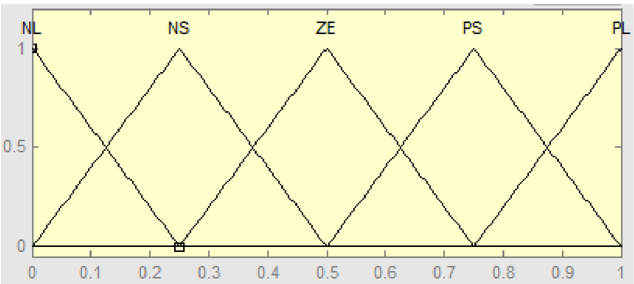
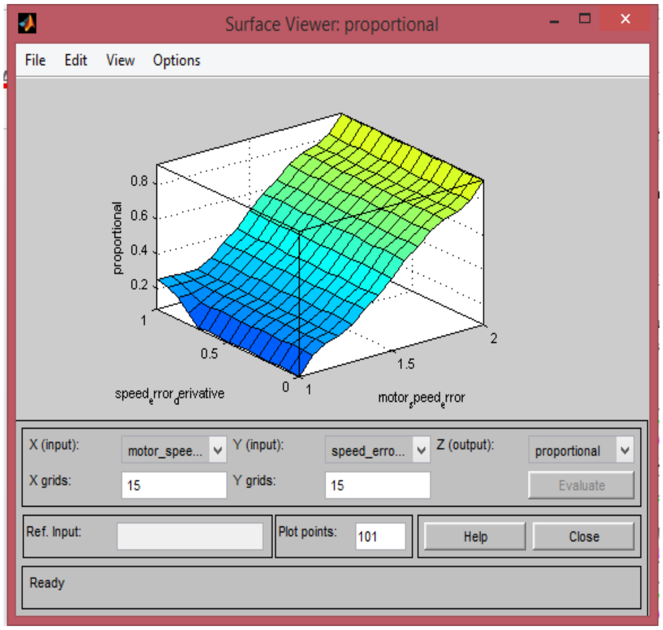


Fig-5 input membership function change in error



X (input): motor_spee...
Y (input): speed_erro...
Z (output): proportional
X grids: 15
Y grids: 15
Ref. Input:
Plot points: 101
Ready

Fig-6 surface viewer

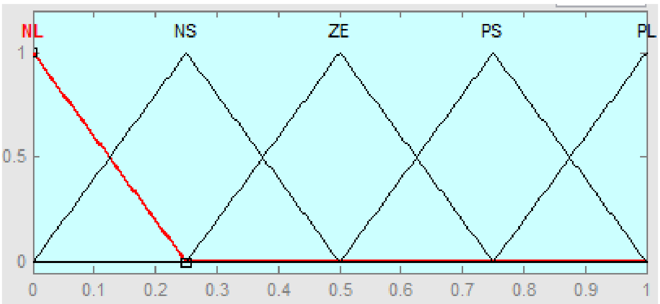


Fig-4 output membership function

6. SIMULATION RESULTS

In the simulation result section the various scopes shows the results of various values. An advanced electric vehicle control system is simulated using fuzzy logic controller and the related simulation results are presented and discussed. /Simulink model block diagram of this system is shown in figure 2 .The system response with FLC is shown .below the performance of the controller. The execution of simulation was done using the MATLAB Simulink tool box.

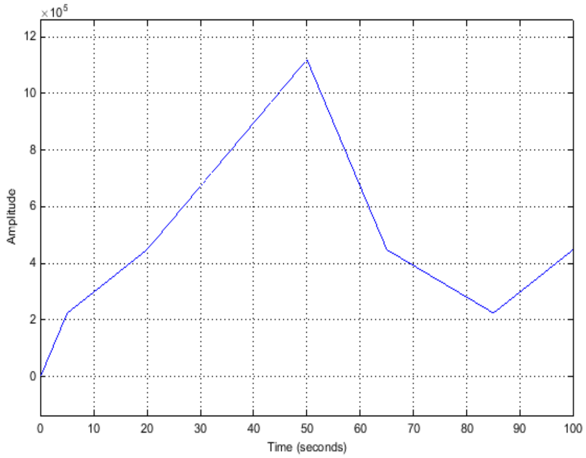


Fig-7 motor voltage

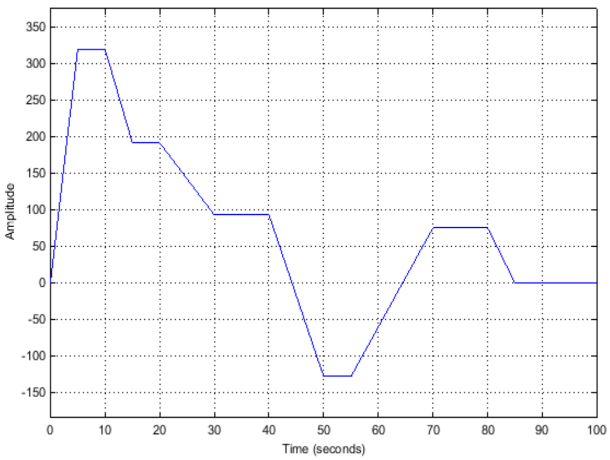


Fig-8 motor current

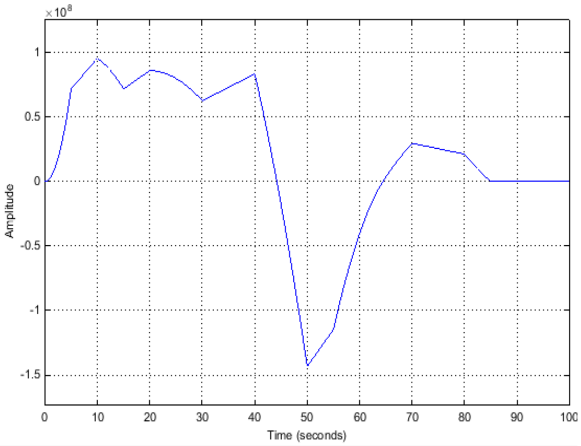


Fig-9 motor power

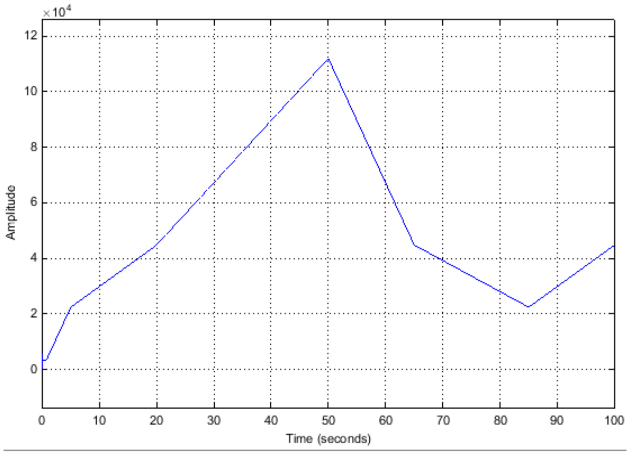


Fig-10 battery voltage

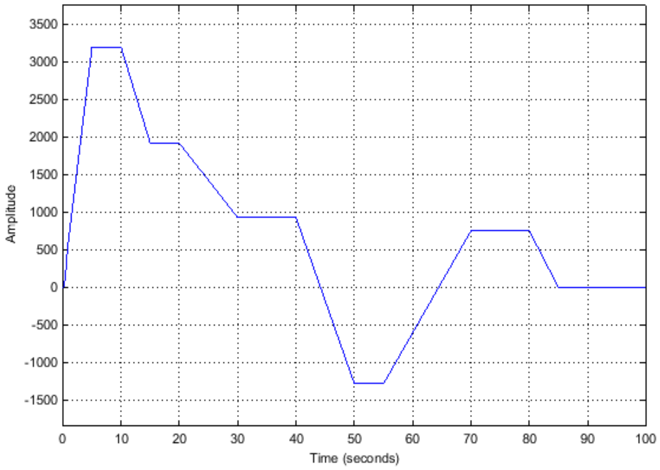


Fig-11 battery current

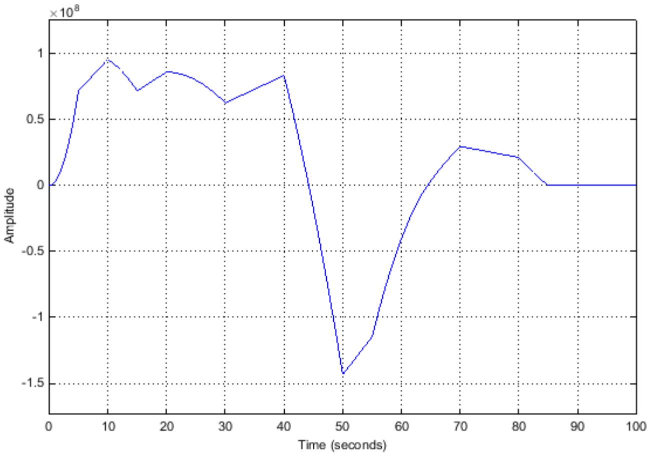


Fig-12 battery power

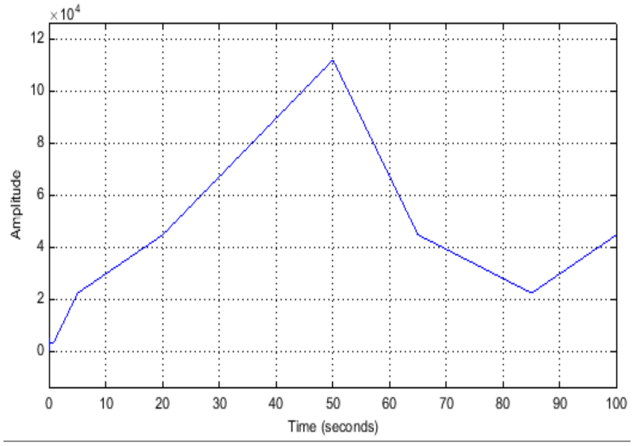


Fig-13 battery error

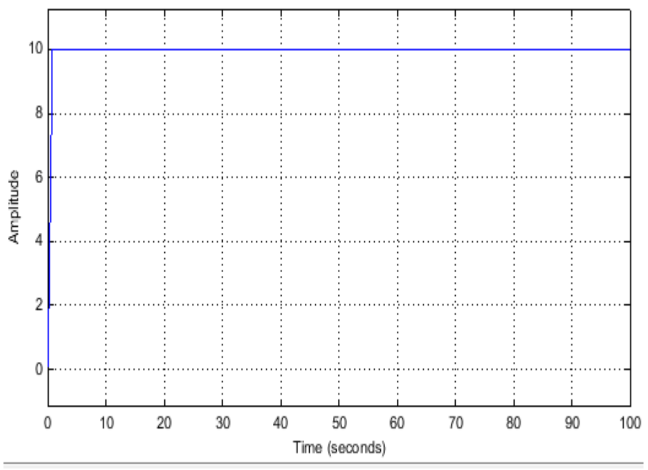


Fig-14 K gain value

Table-1: Summary of performance characteristics

Values	Rise Time	Settling Time	Overshoot %
K gain value	0.517 sec	0.0 sec	0.532
Battery error	4.001 sec	2.00 sec	1.903
Battery voltage	15.740 sec	18.244 sec	1.750
Battery current	0.989 sec	3.404 sec	1.988
Battery power	9.414 sec	4.47 sec	1.980
Motor voltage	15.75 sec	18.25 sec	1.740
Motor current	1.176 sec	3.404 sec	1.990
Motor power	9.474 sec	4.414 sec	1.980

The motor draws power from the battery as shown in figure, Motor Voltage, Current, and Power are plotted. As can be seen by comparing Figure 8 and Figure 11, and the voltage curves generally follow each other, and from Figure 7 and Figure 10 the current curves also generally follow both. The energy dissipated in motoring and regeneration is resolute by performing numerical integration of the power curves. Figure 9 and figure 12: Battery Voltage, Current and Power is to the variation of Energy with Time (Seconds). Therefore the integral of the power curve is equal to energy in Watt*Seconds. The numerical integration is performed in MATLAB using the trapezoidal rule function, trapezoidal. The simulation model adjusts the controller gain (K) to meet drive torque and regeneration. The simulation compared the nominal battery internal voltage, VB =220 volts or $V_{Battery}$ (actual), with a calculated battery voltage based on the motor voltage and current values to become V_{Batery} (calculated). The difference, V_{Berror} , was used as an error signal input to the fuzzy logic with Proportional Integral Controller. This V_{Berror} signal was plotted over the range of the simulation action. This plot is shown in fig-13

6.1 Controller Gain

The Gain (K) of the Motor Controller is determined by the output of the Fuzzy logic PI Controller model. A plot of the value of the Controller Gain (K gain) concluded the simulation is shown below in Figure 13: Controller Gain K Value. The controller gain rises during the time when the motor speed is rises, and drops when the motor speed is drops.

7. CONCLUSION

The Study of Motor Drive Components and Complete model of Advanced Electric Vehicle empowered us in accepting the process of Flow of Energy in the Model, i.e. in the Motoring and Regeneration Region. Voltage, Current and Power at each instant of time in this 100 sec simulation can be used to analyze the model at micro level. The drive cycle study through this MATLAB / SIMULINK model not only prevent us from costly On – Road test but also saves lot of time and manpower of the analysis with the help of this model, one can estimate all significant parameters regarding the AEV with more alertness of road speed.

8. FUTURE SCOPES

The Future Scope of this paper are many, like the study of model with considerations of time lags and power loss due to friction and other rotational losses of hysteresis, eddy current losses may be measured, and windage can be prepared, the inertia effect and also use the various power electronics controller and various techniques like neuro fuzzy, genetic algorithm etc. to improve the performance of AEV.

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