Designing, Modelling and Simulation of Hybrid Electric Vehicle using Self-Adaptive PID Controller with MATLAB

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Abstract—*The objective of this paper is to presents the simulation of a advanced electric vehicle drive system that is used to explore power flow during motoring and regeneration, considering a DC motor, an ideal motor controller joint with a proportional-integral-derivative controller, and the battery. The simulation model is used to evaluate the electric drive's energy stream and efficiency for specific speed and torque conditions. A stable Simulink model is drawn to determine the system performance over a given speed/torque conditions. The number of electric vehicles on the roads is increasing every year, therefore this paper represents the low cost and environment friendly vehicle.*

Keywords*: HEV, motor, motor controller, battery, battery controller, PID 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 stored in battery. Hence how to use batteries' energy efficiently is an important issue for developing HEV's. [1]The HEV's run on Brushless DC Motor, due to benefits like, simple and robust construction, high efficiency, high active response, higher speed range, large starting torque, noiseless operation etc.
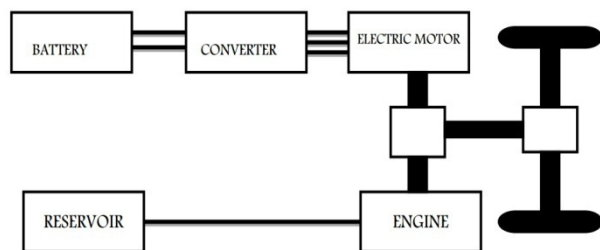

Fig. 1: Schematic of Advanced Electric Vehicle

BLDCM been applied in many fields, because of its most advantages such as reduced hardware size and weight, no reduction gear, high efficiency of driving system etc.[1]

2. KEY EQUATIONS

Determining the key equations and their equivalent variables and parameters is a essential first step in model development. Each block in this simplified model represents 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

2.1 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 120o 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}]

2.2 Developed motor torque Equation:

Developed Torque is proportional to armature current:

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

2.3 Developed motor voltage Equation:

Developed Voltage is proportional to armature speed:

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

2.4 Motor Voltage Equation:

V_H (Volt) = I_H (Amp) * R_A (Ohm) + L_H (Henry)

$$* \, di(t)/dt \text{ (A/s)} + V_D \text{ (Volt} \qquad (9)$$

2.5 Controller High Side voltage Equation:

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

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

2.6 Controller High Side current Equation:

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

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

2.7 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 $I_A = I_L$

2.8 Error Voltage Calculation Equation:

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

2.9 PID Calculation Equation:

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

3. SIMULATION MODEL OF MOTOR DRIVE IN HEV

In this section, we will study each component of the model in detail, The HEV system consists of some subsystems, the electric motor and the vehicle platform system; both to be modelled, considering all acting forces and parameters, HEV platform to be coupled with the wheel rotational velocity via characteristics of the electric motor and surface, as well as, to derive the expressions for the acting forces, to calculate required torque and power expressions, that can be used to build the Simulink model, finally, suggest, design couple and test control systems [7].
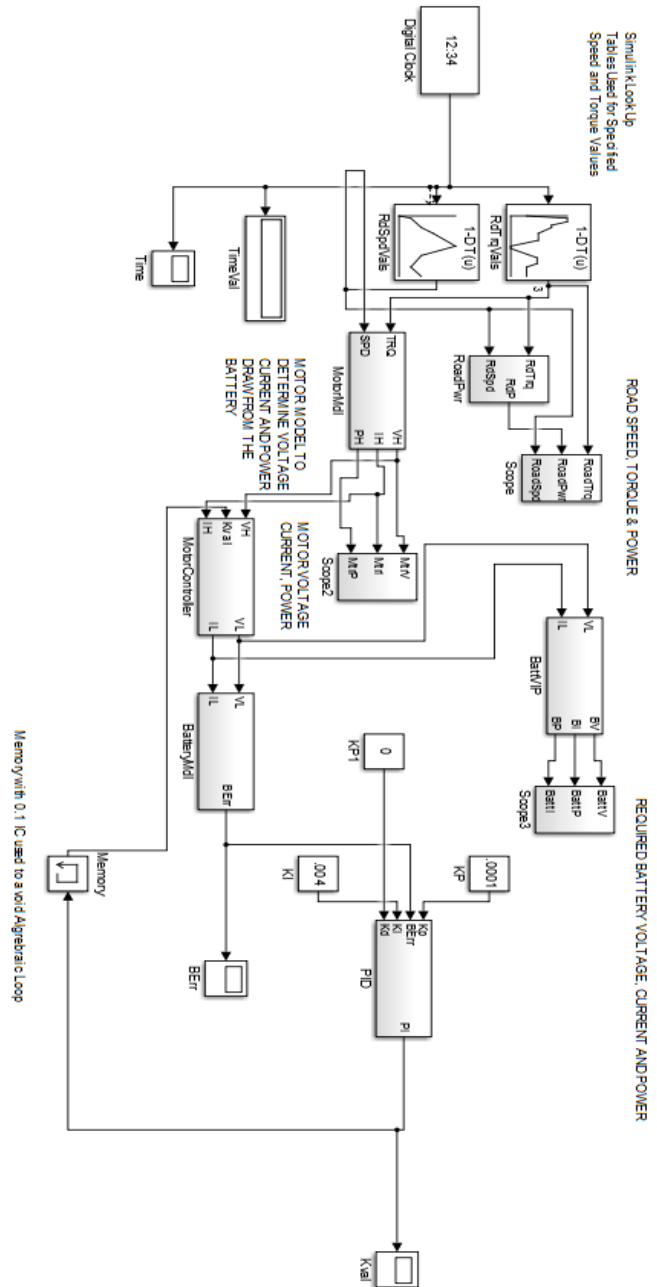

Fig. 2: HEV model

4. SIMULATION TORQUE AND SPEED

The first application of the model focused on processing a given set of Speed and Torque data to determine evaluate the drive system's performance and efficiency. The key Speed and Torque data was entered into the MATLAB Workspace using the section of MATLAB code shown below in Figure 8: Road Speed and Torque Data. The data represents Speed-Time and Torque-Time values which correspond to transition times of their corresponding Speed and Torque curves. This data was then processed by the Simulink Speed Look-Up Table and

Torque Look-Up Table. The key Speed and Torque values are loaded into the MATLAB Workspace % for use by the Simulink Model.

Load Speed vals and times into the lookup table

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

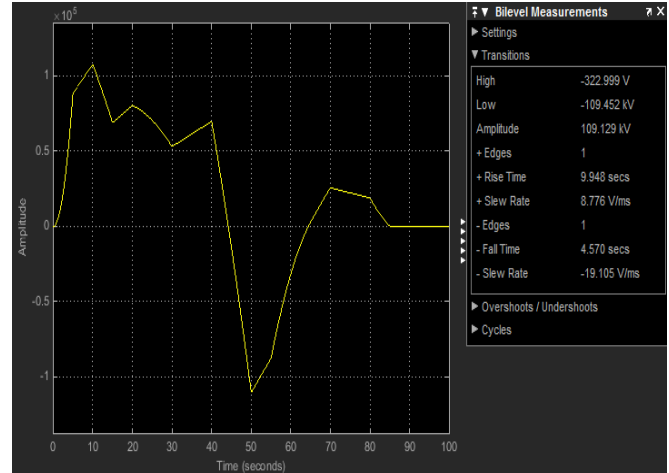**Stime = [0 5 20 30 50 65 85 100]**

Load Torque vals and times into the lookup table

Tvals = [0 550 550 330 330 160 160 -220 -220 130 130 0 0]

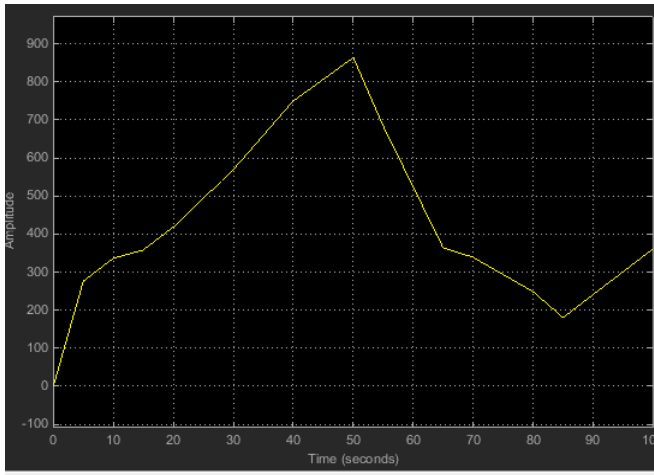**Ttime = [0 5 10 15 20 30 40 50 55 70 80 85 100]**

5. SIMULATION RESULTS

In this part the scopes shows the motor voltage, current and motor power.

Fig. 3: Motor voltage

Fig. 4 motor current

Fig. 5: Motor power

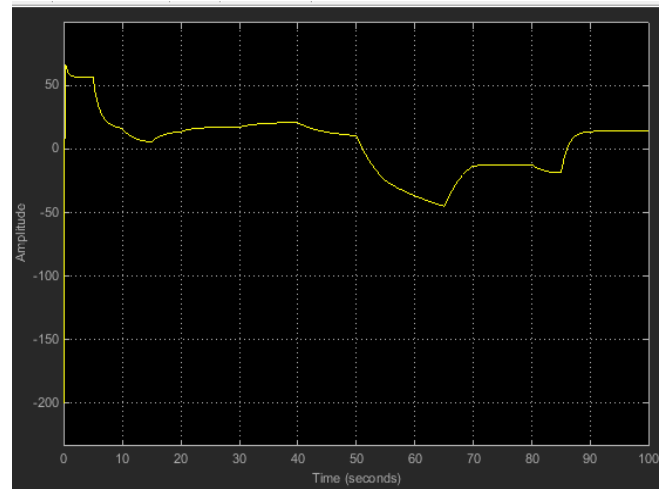### 5.1 Battery Voltage Error (Berr)

The simulation model adjusts the controller gain (K) to meet drive torque and regeneration requirements. The simulation compared the nominal battery internal voltage, VB =200 volts or VBatt(actual), with a calculated battery voltage based on the motor voltage and current values to get VBatt(calculated). The difference, VBerr, was used as an error signal input to the Proportional Integral (PI) Controller. This VBerr signal was plotted over the range of the simulation operation. This plot is shown below
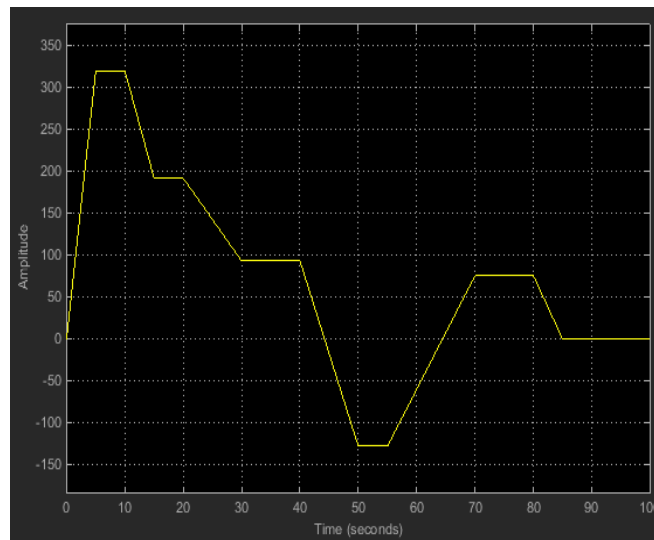
Fig. 6: Battery error

5.2 Controller Gain

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

The gain has an initial starting value of 0.1. This was preset within the controller in the 1/s integration block. This value is set in the simulation by opening up the 1/s block. The addition of the Initial Condition on the integration block helps to minimize the possibility of a Simulink simulation error due to an algebraic loop. An algebraic loop is basically a divide by zero operation when the simulation is trying to solve the set of linear equations.
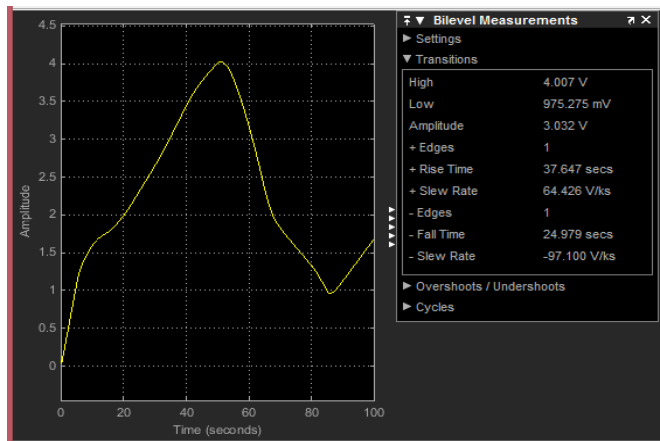

Fig. 7: Controller gain k value

6. CONCLUSION

The Study of Motor Drive Components and Complete model of Advanced Electric Vehicle enabled us in understanding the process of Flow of Energy in the Model, i.e. in the Motoring and Regeneration Region. Knowledge of 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 labour of the analyst. With the help of this model, one can calculate all important parameters regarding the HEV with mere knowledge of Road Speed only.

7. FUTURE SCOPE

The Future Scope of this project 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 considered, and windage can be made, the inertia effect.

8. ACKNOWLEDGEMENT

I would like to thanks my guide Prof, Rameshwar Singh and my co-author Er. Akansha Kaushal for their help and encouragement. It was their cheerful and sincere cooperation, autonomy, regular encouragement and infinite assistance of every kind which made this journey a fruitful, pleasant and experience. I would like to express my gratitude to Mr. MC Donald his valuable ideas and expertise and to introduce me.

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