HEV Model Control Scheme

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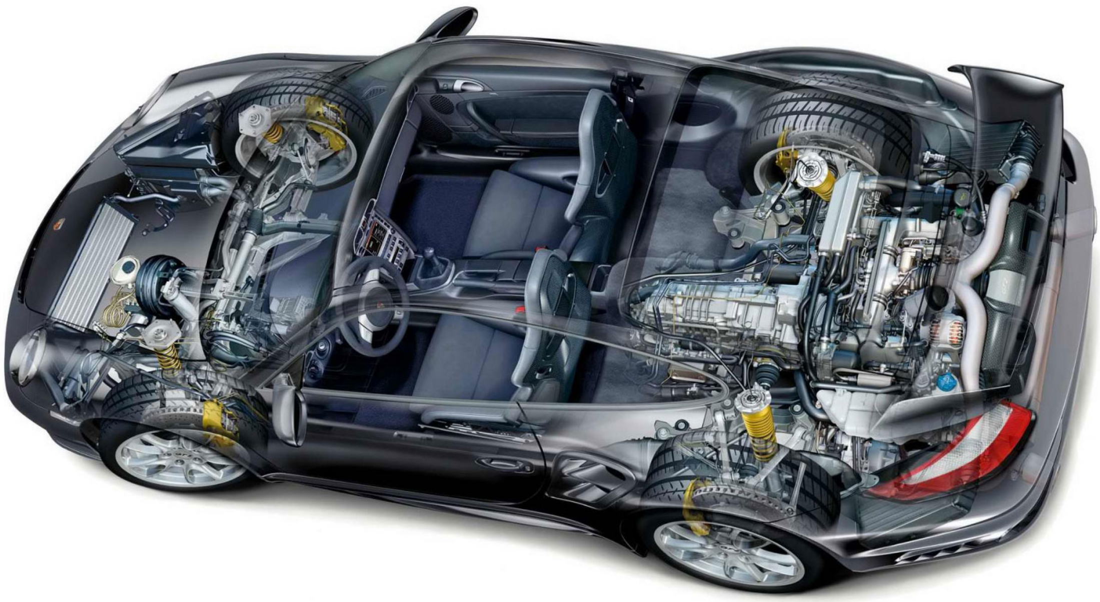

Introduction

This report details the design, implementation, and analysis of a control scheme for a Hybrid Electric Vehicle (HEV). The primary objective was to develop and evaluate a controller using MATLAB/Simulink and analytical transfer function methods. The Simulink model provides a dynamic simulation environment to assess the controller's performance under various operating conditions.

At the same time, the transfer function analysis offers a complementary approach to understanding the system's inherent characteristics and stability. The report presents the derived transfer function model of the HEV system, the designed controller, the Simulink implementation, and a comparative analysis of the resulting time-domain responses, evaluating the efficacy of the implemented control strategy. The results highlight the controller's performance metrics such as transient response, steady-state error, and robustness, demonstrating its suitability for HEV applications.

SIMULINK Implementation

Here is the SIMULINK scheme for the given HEV system to simulate the environment and ensure performance.

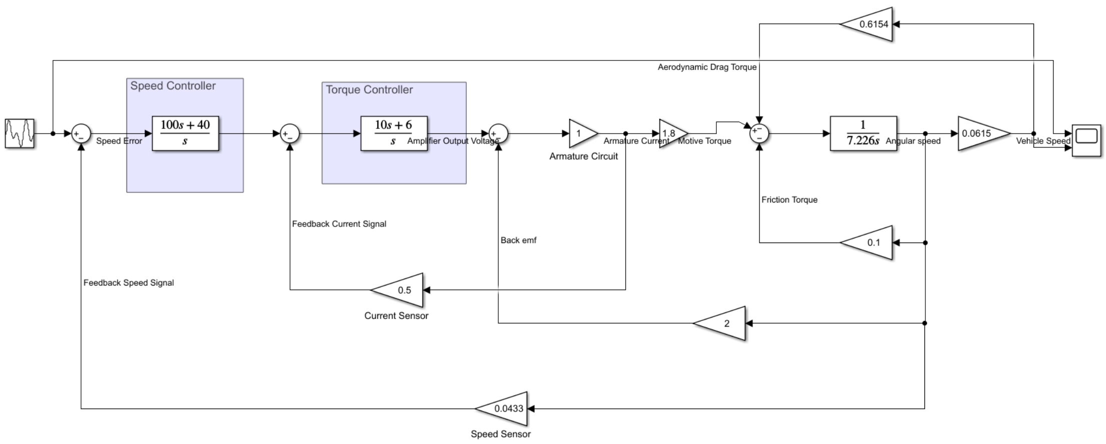

Figure 1: HEV Control System Scheme

Having our square wave (Amplitude = 1, Frequency = 10, and Duty Cycle = 50) as an input for our system according to my student ID. Here is the plot for Vehicle speed vs. Input and Armature Current vs. Input:

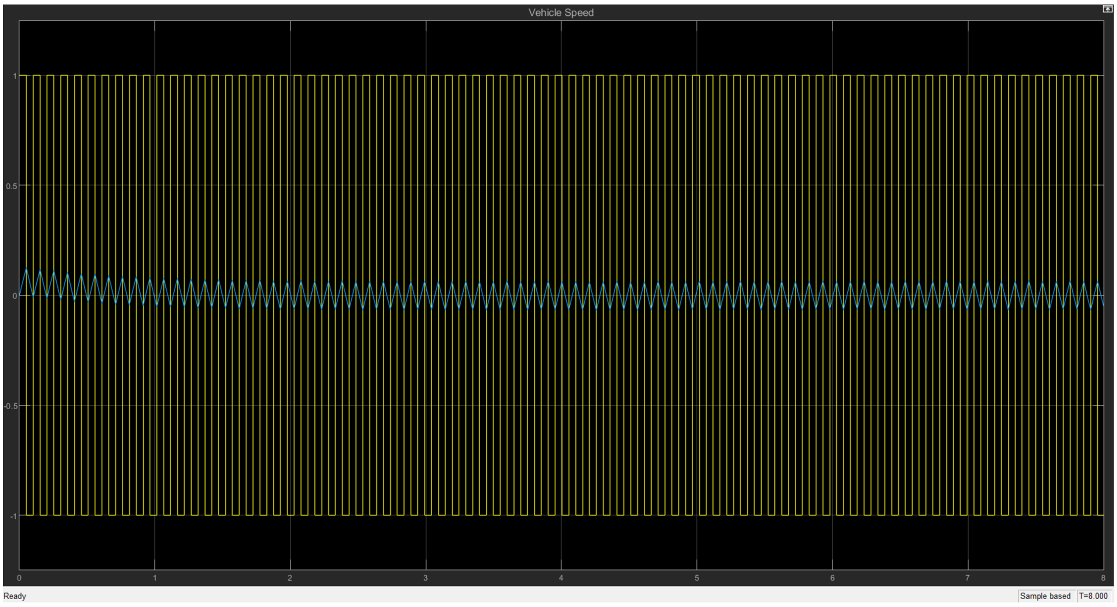

Figure 2: Vehicle Speed Response with time

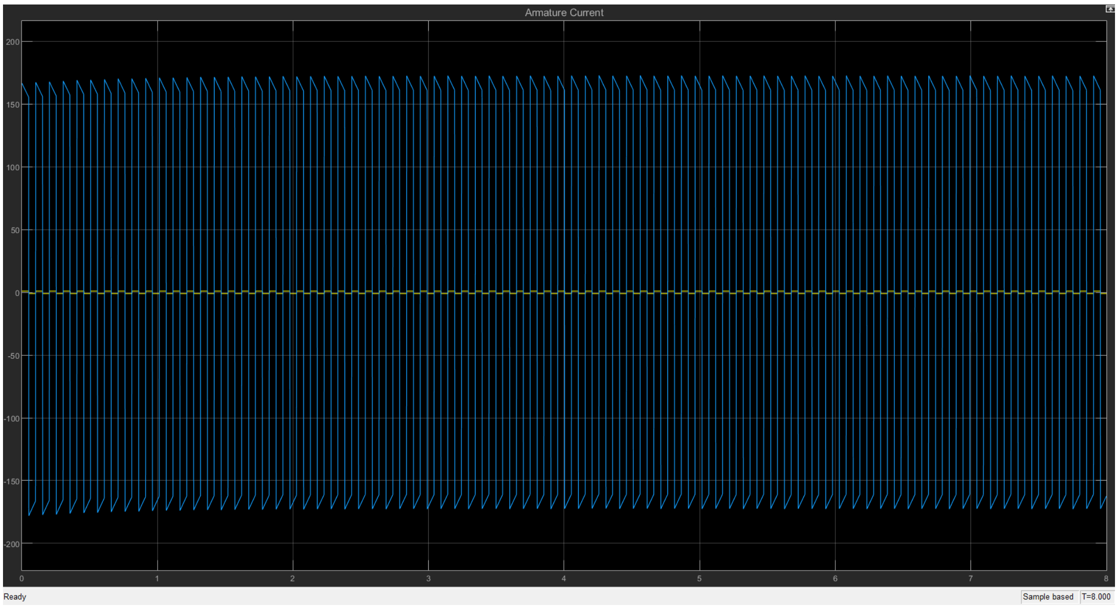

Figure 3: Armature Current Response with time

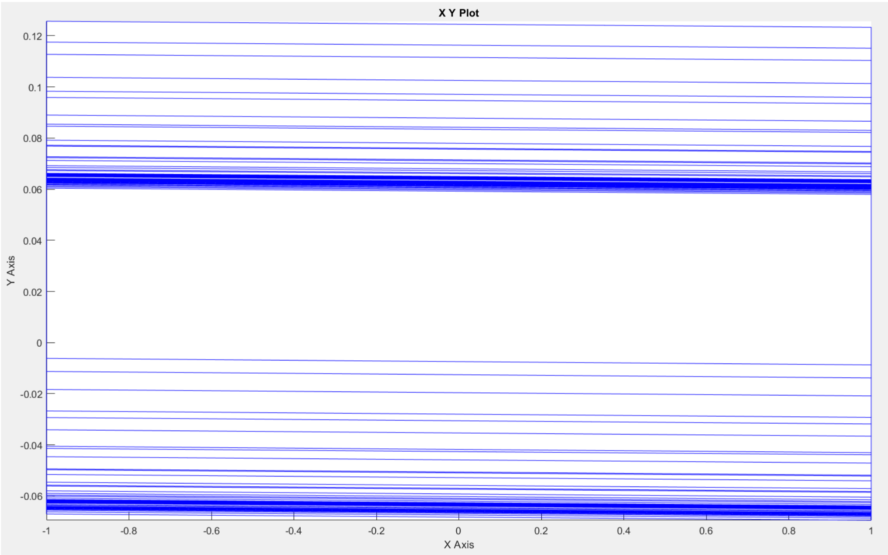

Figure 4: XY Plot Input with Speed

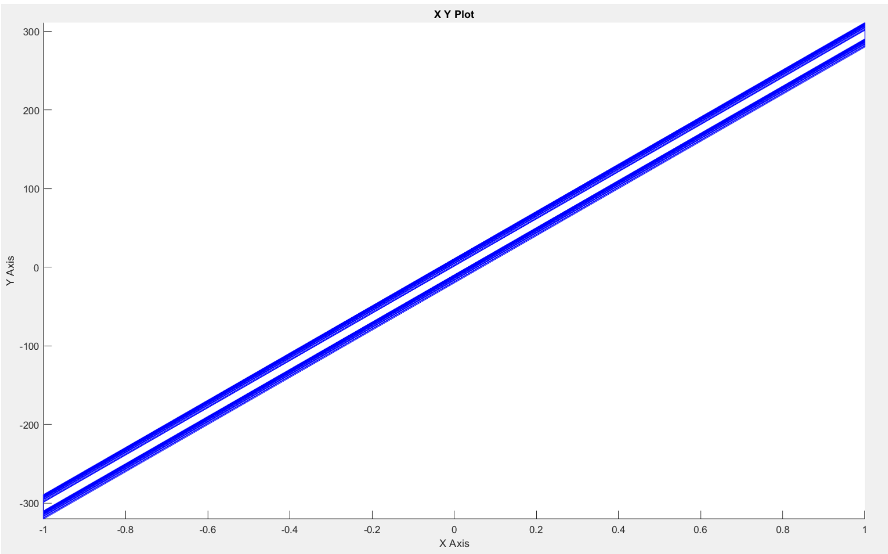

Figure 5: XY Plot Input with Current

After simulating the whole system, we have got the total transfer function for the system using the Model Analyzer application in SIMULINK. Here is our transfer function:

```
>> tf(linsys1)

ans =

  From input "Waveform Generator" to output "Vehicle Speed":
    2.553 s^2 + 2.553 s + 0.6128
  --------------------------------
  s^3 + 2.4 s^2 + 1.807 s + 0.4314

Name: Linearization at model initial condition
Continuous-time transfer function.
```

Figure 6: SIMULINK Transfer Function

MATLAB Implementation

Working on both SIMULINK and MATLAB to maximize our knowledge using both to get the system response. MATLAB's perspective was to reduce the system using the reduction methods. Here is the MATLAB code:

- **Block Definitions:** The variables n1 to n11 represent the numerators and d1 to d11 the denominators of 11 transfer functions (blocks) in the system. Some are simple gains (n3, n4, n6, n7, n8, n9, n10, n11), while others are more complex (n1, n2, n5).
- **Connection Matrix (q):** The matrix q is a crucial part. It describes the connections between the blocks. Each row represents a block, and the columns likely represent:
  - Column 1: Block number.
  - Column 2: Input block number.
  - Columns 3 and 4: Representing multiple inputs to a block, or a feedback path.

HEV_control_scheme_lab1.m

```
n1 = [100 40]; d1 = [1 0];
n2 = [10 6]; d2 = [1 0];
n3 = 1; d3 = 1;
n4 = 1.8; d4 = 1;
n5 = 1; d5 = [7.226 0];
n6 = 0.0615; d6 = 1;
n7 = 0.6154; d7 = 1;
n8 = 0.1; d8 = 1;
n9 = 2; d9 = 1;
n10 = 0.5; d10 = 1;
n11 = 0.0433; d11 = 1;

nblocks = 11;

blkbuild
q = [ 1 -11  0   0
      2  1  -10  0
      3  2  -9   0
      4  3   0   0
      5  4  -8  -9
      6  5   0   0
      7  6   0   0
      8  5   0   0
      9  5   0   0
      10 3   0   0
      11 5   0   0 ]

input = 1;
output = 6;
[aa, bb, cc, dd] = connect(a, b, c, d, q, input, output);
[num, den] = ss2tf(aa, bb, cc, dd);
printsys(num, den)
```

Figure 7: SIMULINK Transfer Function

Example: Row 5 (5 4 -8 -9) indicates that block 5 receives input from block 4, and has feedback from blocks 8 and 9 (negative signs usually indicate feedback loops).

- **connect function:** The function connect is central to the process. It takes the block numerators/denominators (a, b, c, d), the connection matrix (q), and the input/output block numbers to construct a state-space representation (aa, bb, cc, dd).
- **ss2tf function:** Finally, ss2tf converts the state-space representation (aa, bb, cc, dd) to a transfer function representation (num, den).

Here is the resulting transfer function, as we see it is the same as we have got from SIMUKINK.

```
>> HEV_control_scheme_lab1
State model [a,b,c,d] of the block diagram has 11 inputs and 11 outputs.

q =

     1   -11     0     0
     2     1   -10     0
     3     2    -9     0
     4     3     0     0
     5     4    -8    -9
     6     5     0     0
     7     6     0     0
     8     5     0     0
     9     5     0     0
    10     3     0     0
    11     5     0     0


num/den =

     2.5533 s^2 + 2.5533 s + 0.61279
   ------------------------------------
   s^3 + 2.6713 s^2 + 1.943 s + 0.43144
```

Figure 8: SIMULINK Transfer Function