CHAPTER 5

SIMULATIONS & RESULTS

Simulations of the various models – basic model, two wheeler model and complete main circuit are explained with their respective output in this chapter.

5.1 BASE CIRCUIT:

The Bidirectional converter used is simulated separately without load, as shown in Fig 5.1

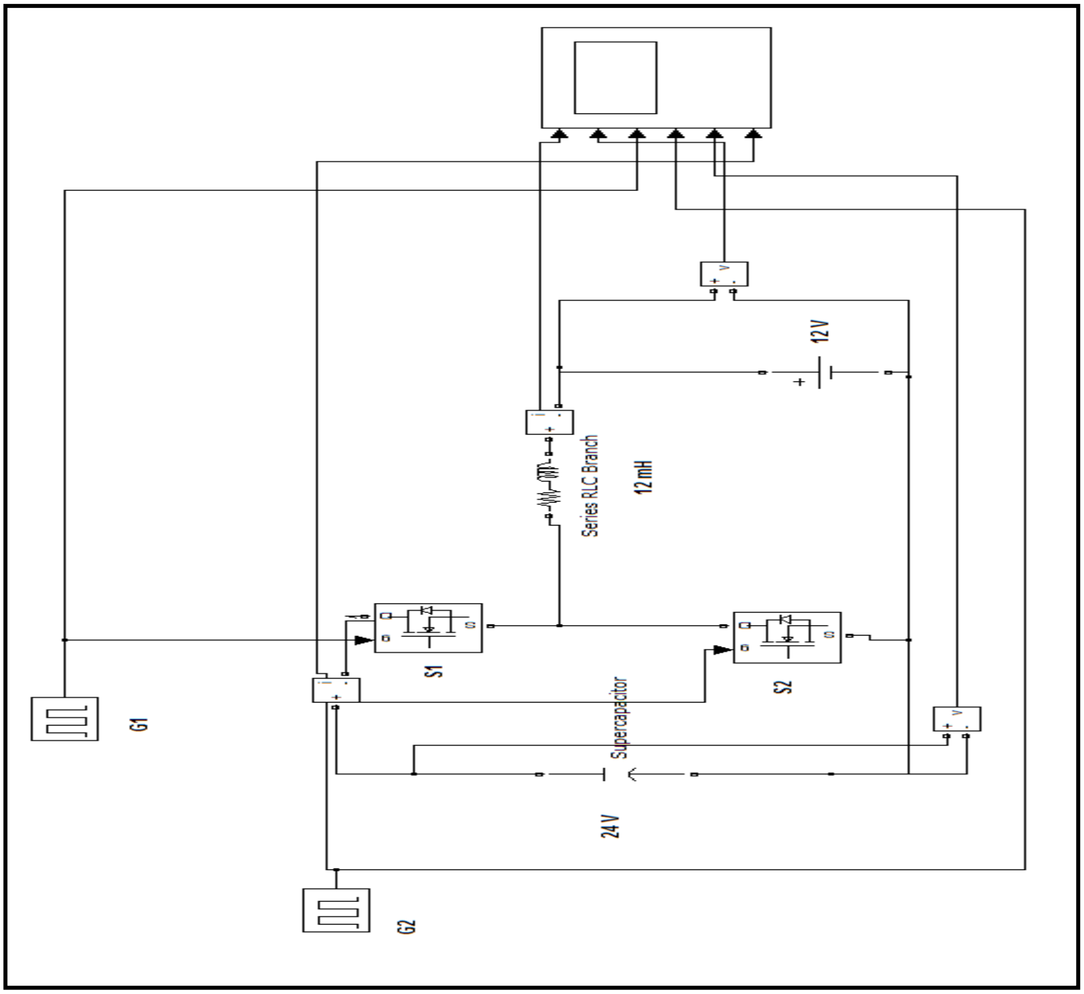

Fig. 5.1 The Brushed Direct Current Setup

Here for simulation purpose at the basic research two cases are considered: For Battery potential 12 Volt and Supercapacitor at 24 Volt, case 1 is studied. The behaviour of branch current, voltage profile and power as well as battery voltage with current exchange between the two sources are understood and displayed. The obtained waveform for the current Ibranch and Isc are as expected and waveform for the $V_{battery}$ and V_{sc} are also of expected results. In this case, power generated can be seen of the order of 36 % of the total power rating.

For battery potential 12 Volt and Supercapacitor at null voltage, case 2 is simulated. Here also the behaviour of branch current, voltage profile and power as well as battery voltage with current exchange between the two sources are understood and displayed. The obtained waveform for the current I_{branch} and I_{sc} are as expected and waveform for the $V_{battery}$ and V_{sc} are also of expected results. In this case, power generated can be seen of the order of 20 % of the total power rating. Fig. 5.2 and Fig. 5.3 represents the out put waveform for case 1 and case 2 respectively, while Fig. 5.1 shows the simulation circuit diagram with G_1 and G_2 are to pulse generators with 50 % duty cycles and later is with 50% of timedelay of the former one.

Fig. 5.4 shows the schematic circuit diagram of the simulation done to increase the life of battery using the logic circuits. The results are represented in Fig. 5.5 to 5.9. The simulations comes out with the result of power charging capacity in case of single pulse conversation, similar to braking is 18.89 Watt, by average speed of 716.2 rpm. Fig. 5.5 shows the output result of Power regenerating, $V_{battery}$ and I_{branch} with repple of less than 1%. on the contrary Fig. 5.8 shows the similar results but when the battery potential is above 9 Volt. It can be visualized that power storage into SC is larger when the battery potential is below 9 Volt. Figure 5.7 and 5.9 shows the voltage reading of SC in case of battery potential is below 9 Volt and above 9 Volt for the respective cases. The potential level 9 Volt is based in 33.33 % of rating of the SC potential as the life of the Battery can be enhanced by doing so. The speed result is almost shame as the motor is independent of the voltage level rather than power and energy requirement.

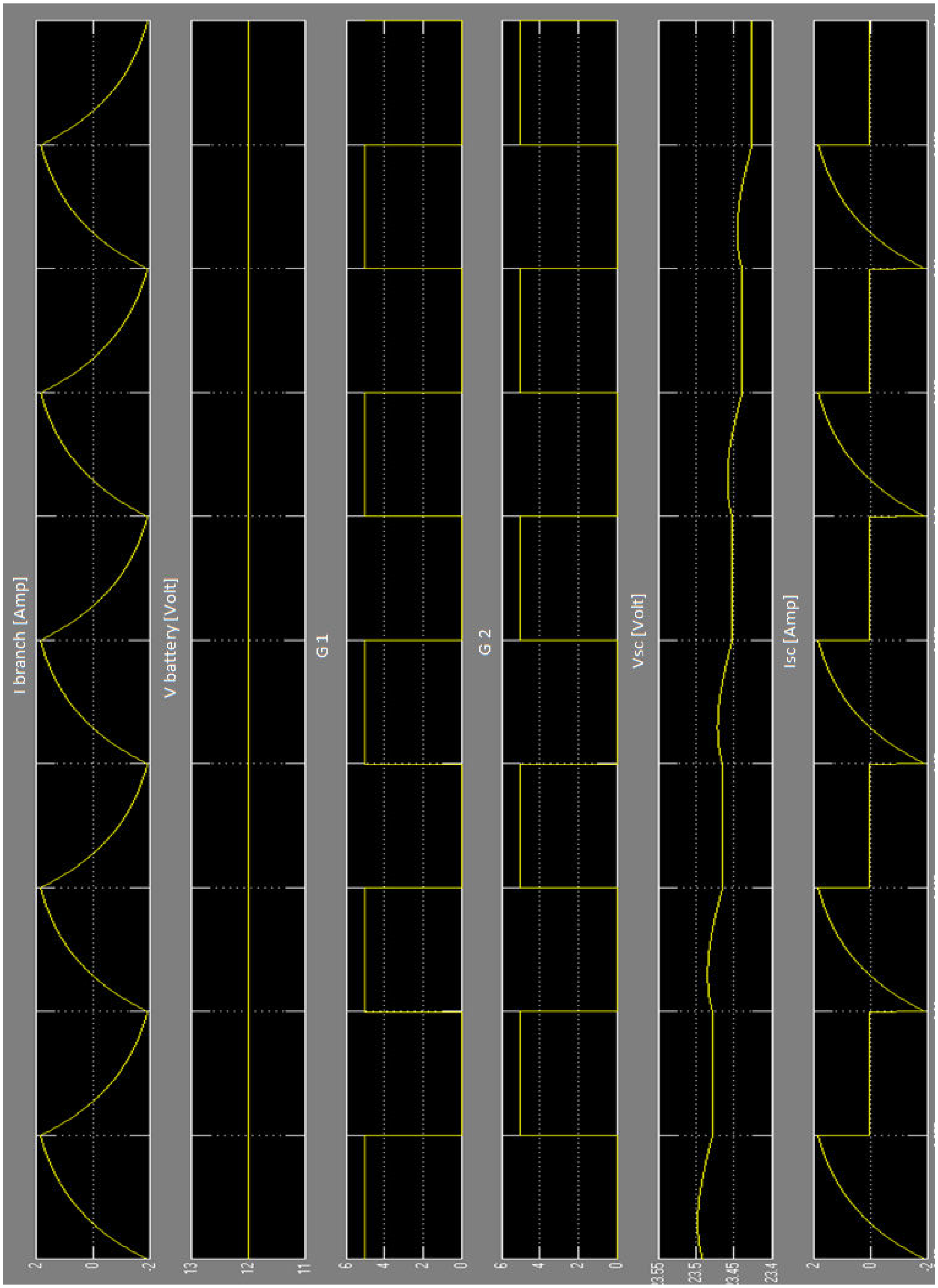

Fig. 5. 2 Brushed DC Output for SC at 24 Volt

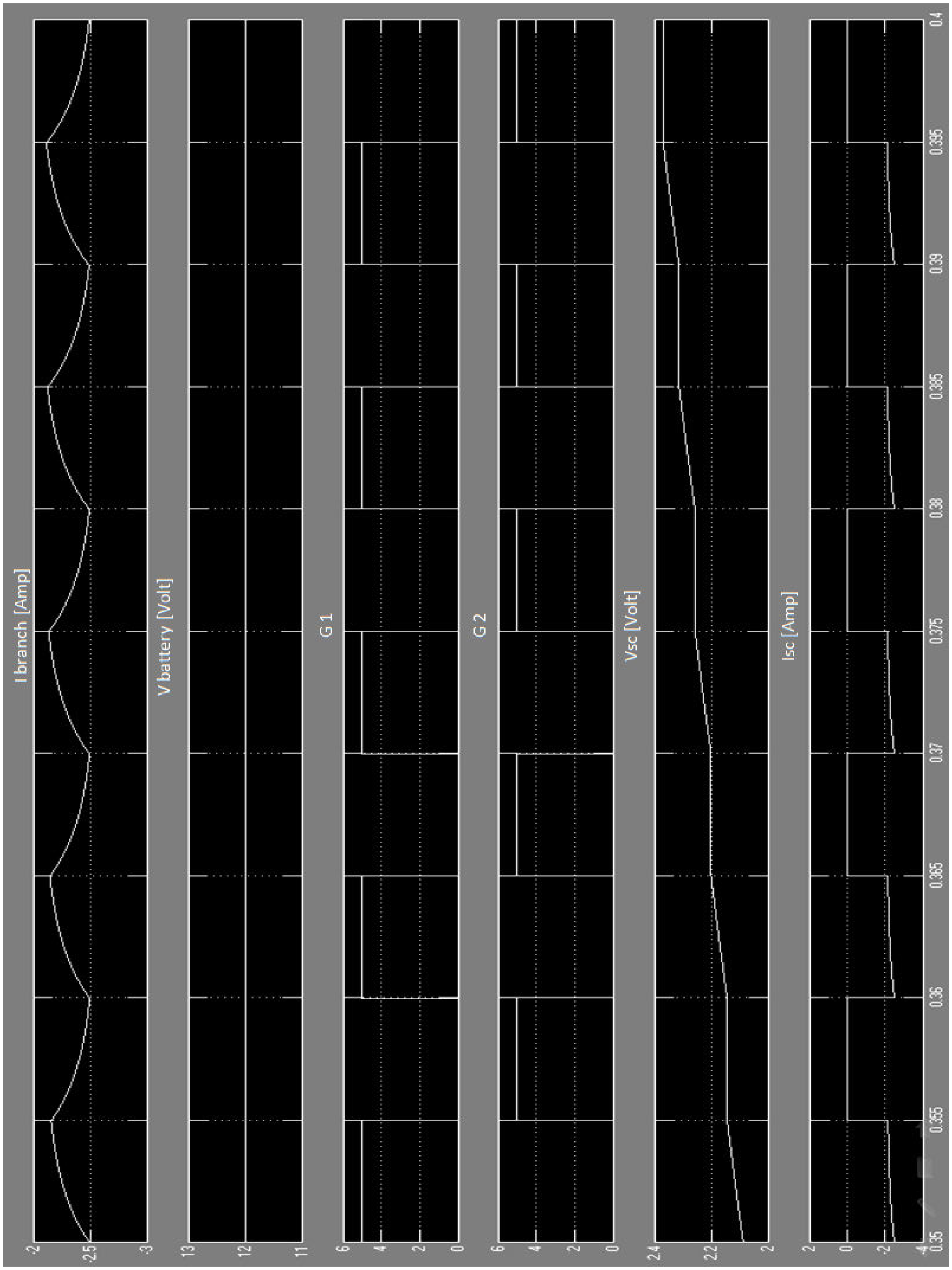

Fig. 5.3 Brushed DC output when SC Voltage is 0 Volt

5.2 FINAL CIRCUIT :

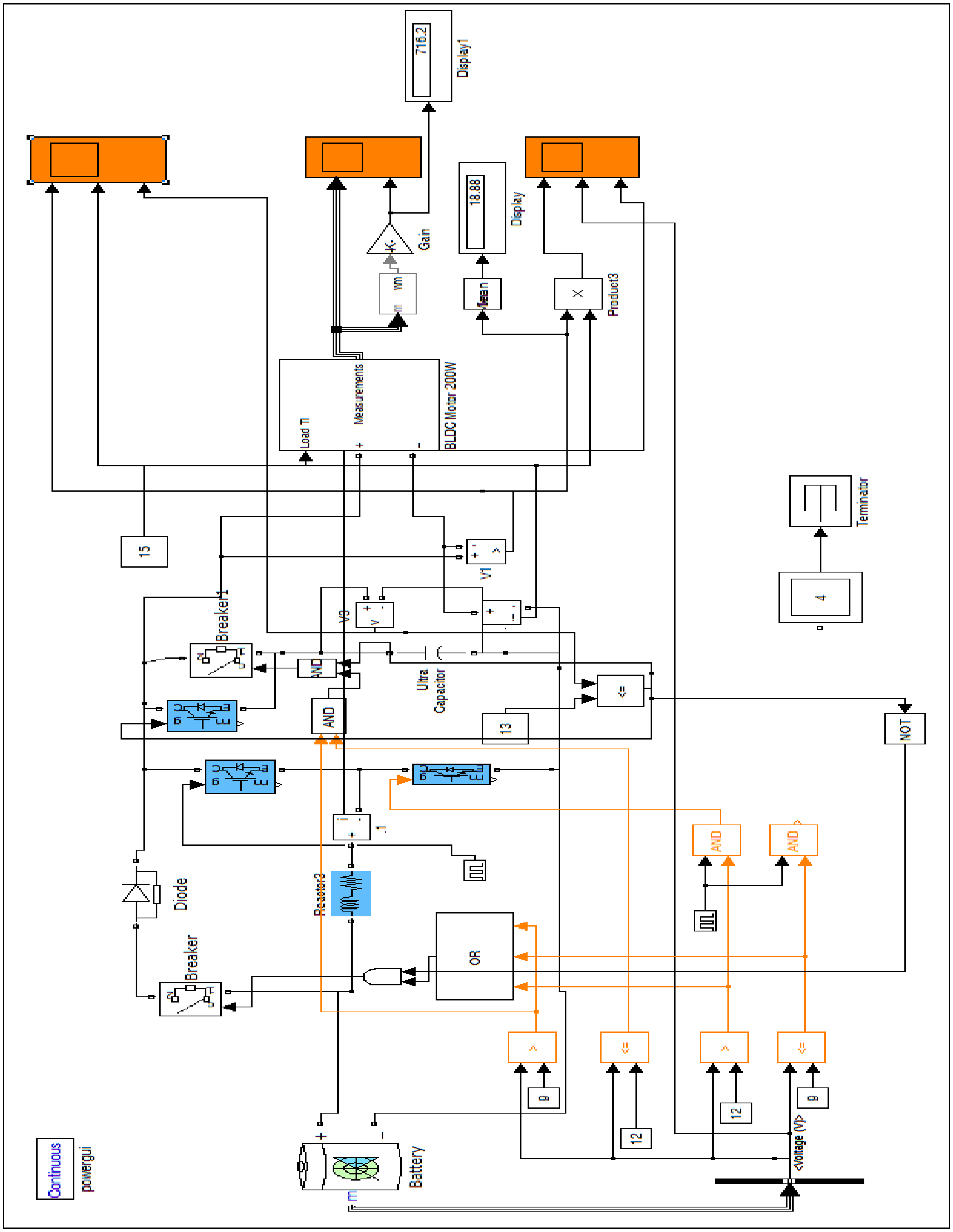

Fig.5. 4 HSS for Battery Life Enhancement (Schematic)

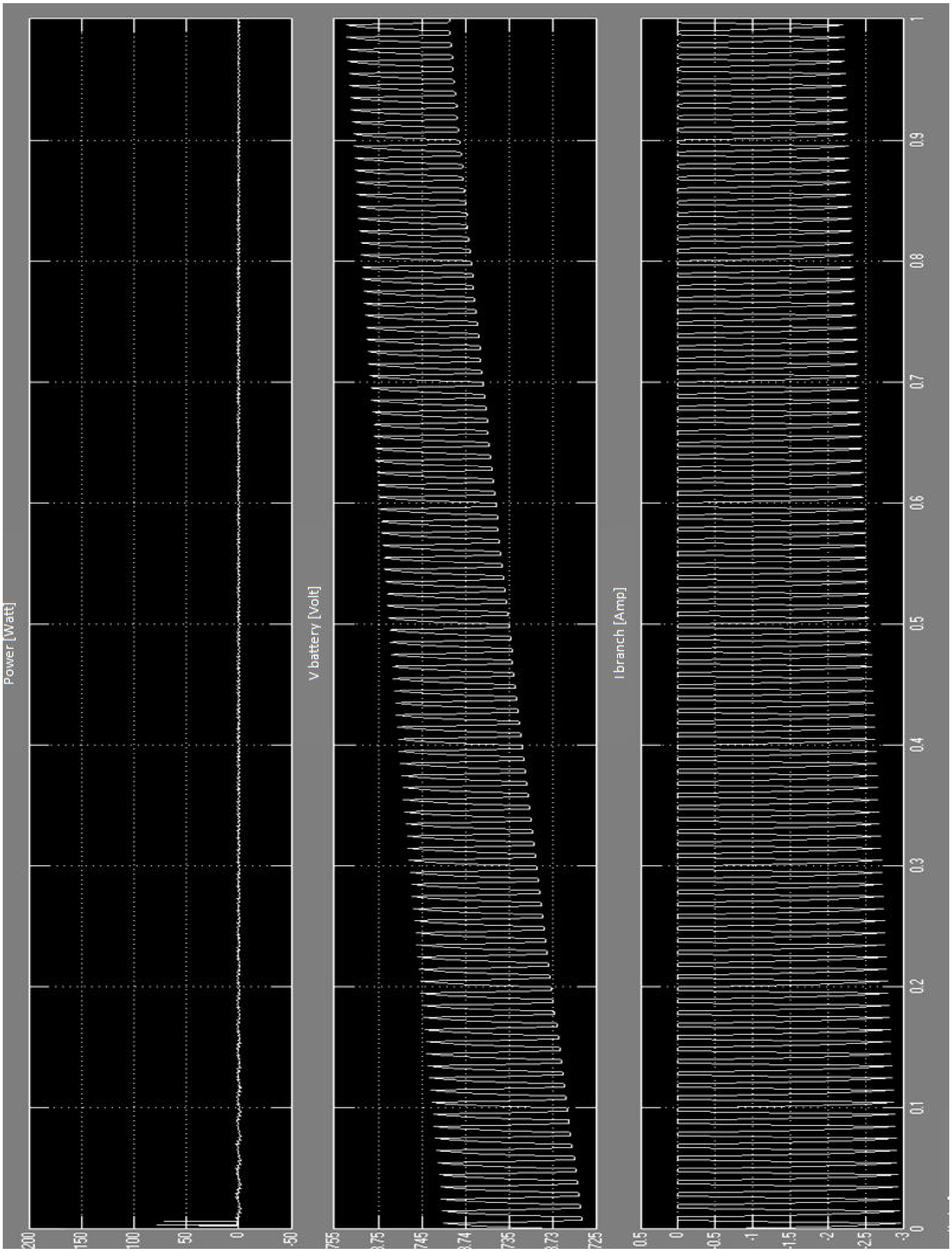

Fig.5. 5 Output When Battery Voltage is Below 9 Volt.

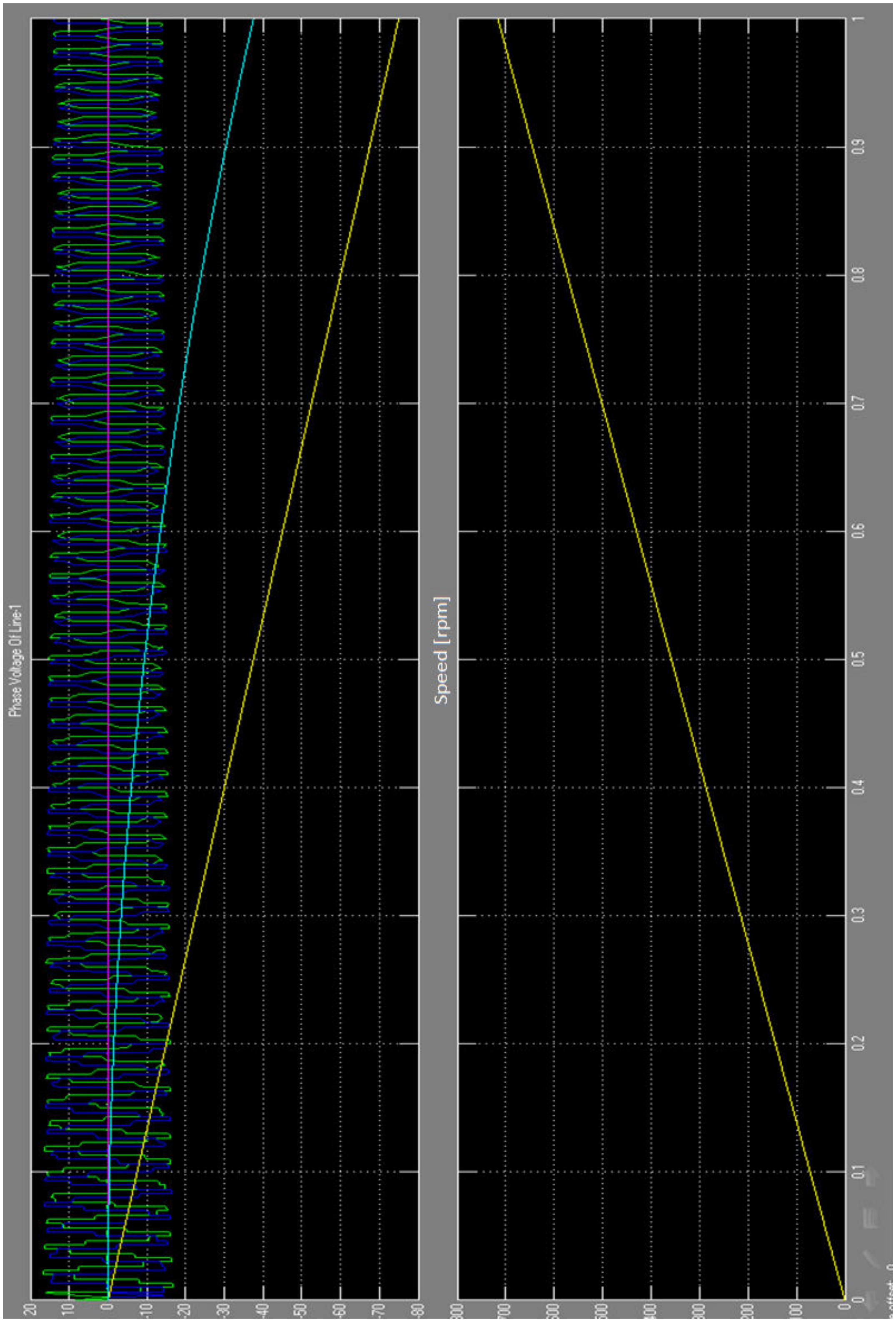

Fig.5. 6 The Speed Result of Motor

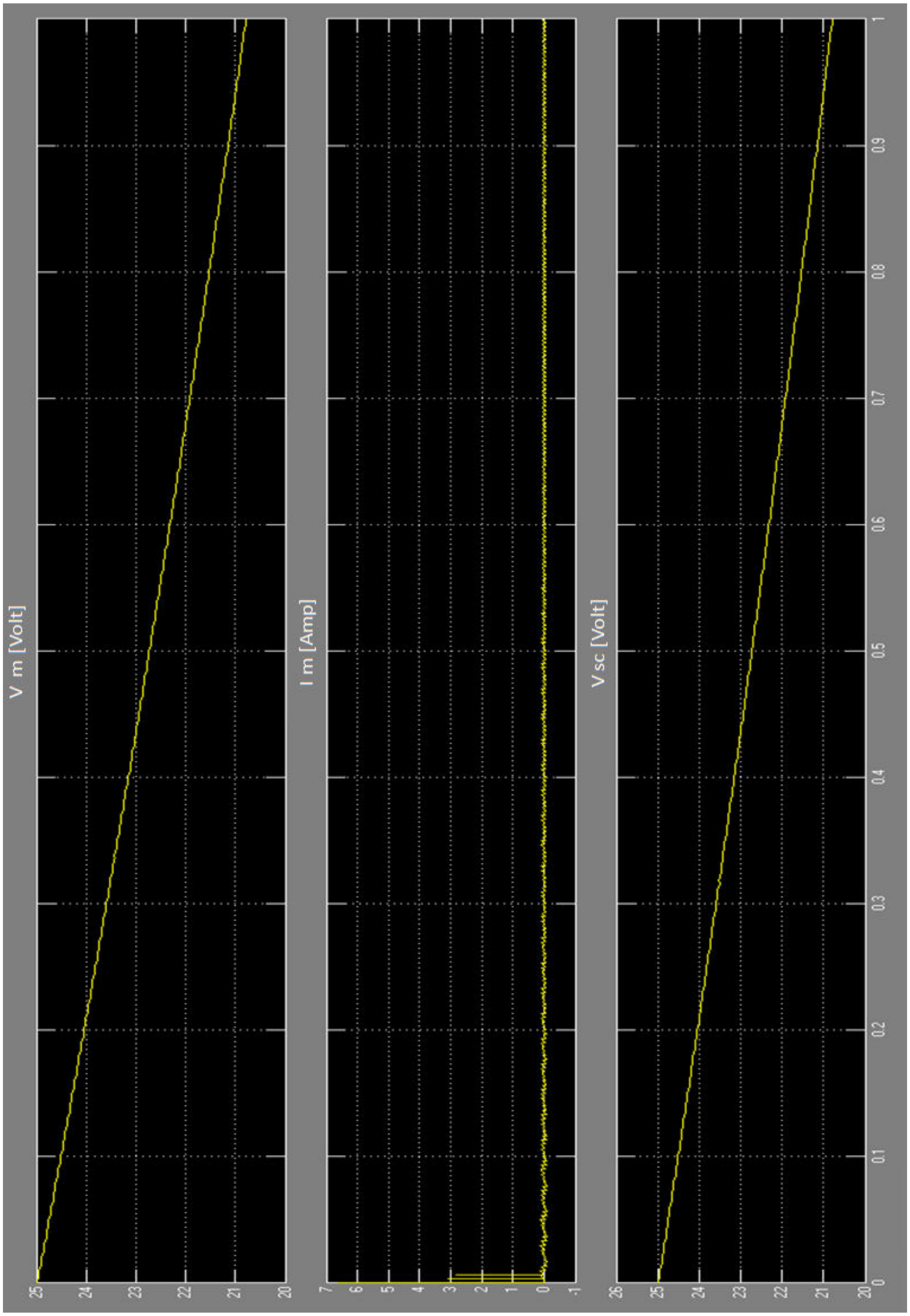

Fig.5. 7 Voltage Reading for SC When Battery is Below 9 Volt.

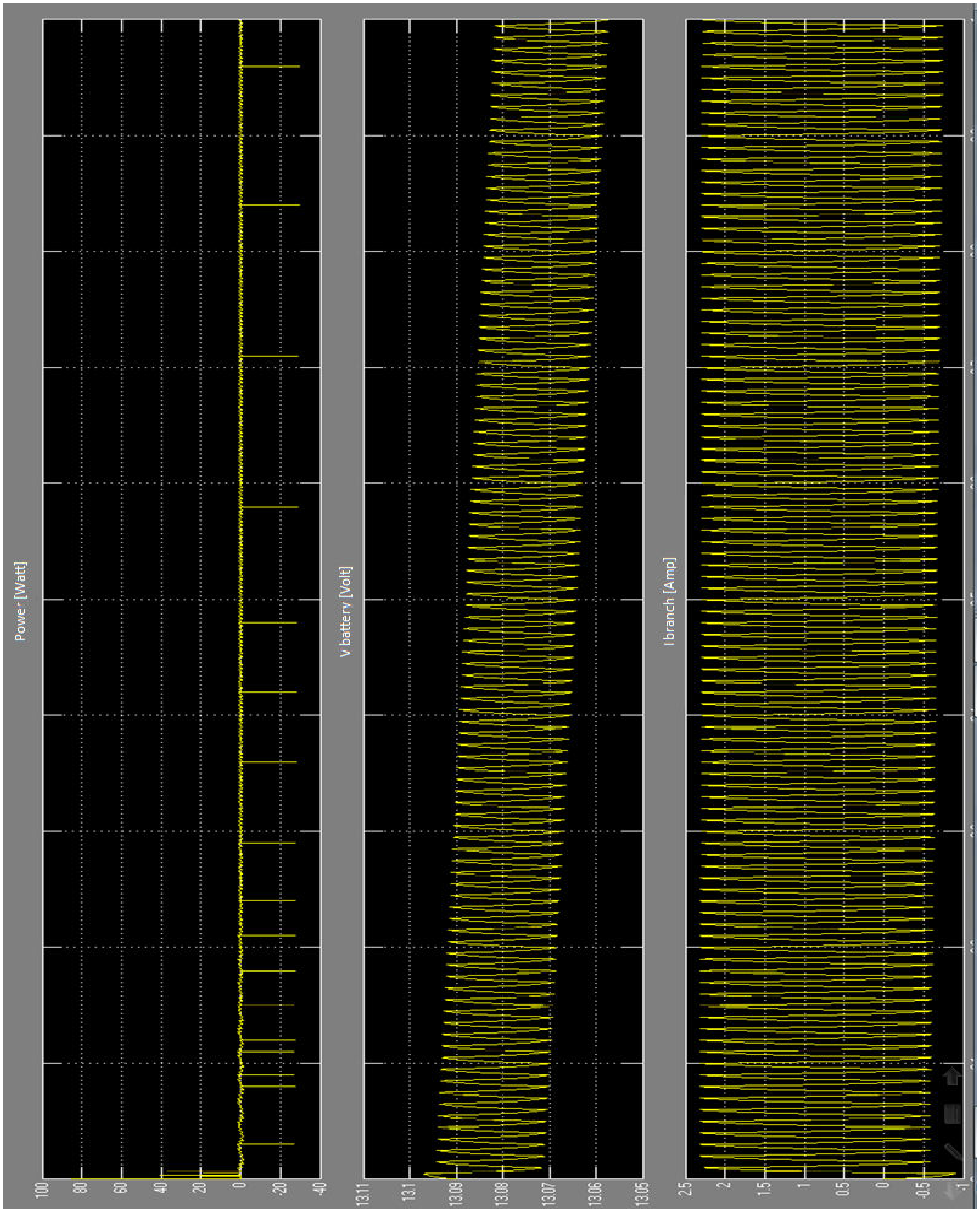

Fig.5. 8 Output When Battery Above 9 Volt

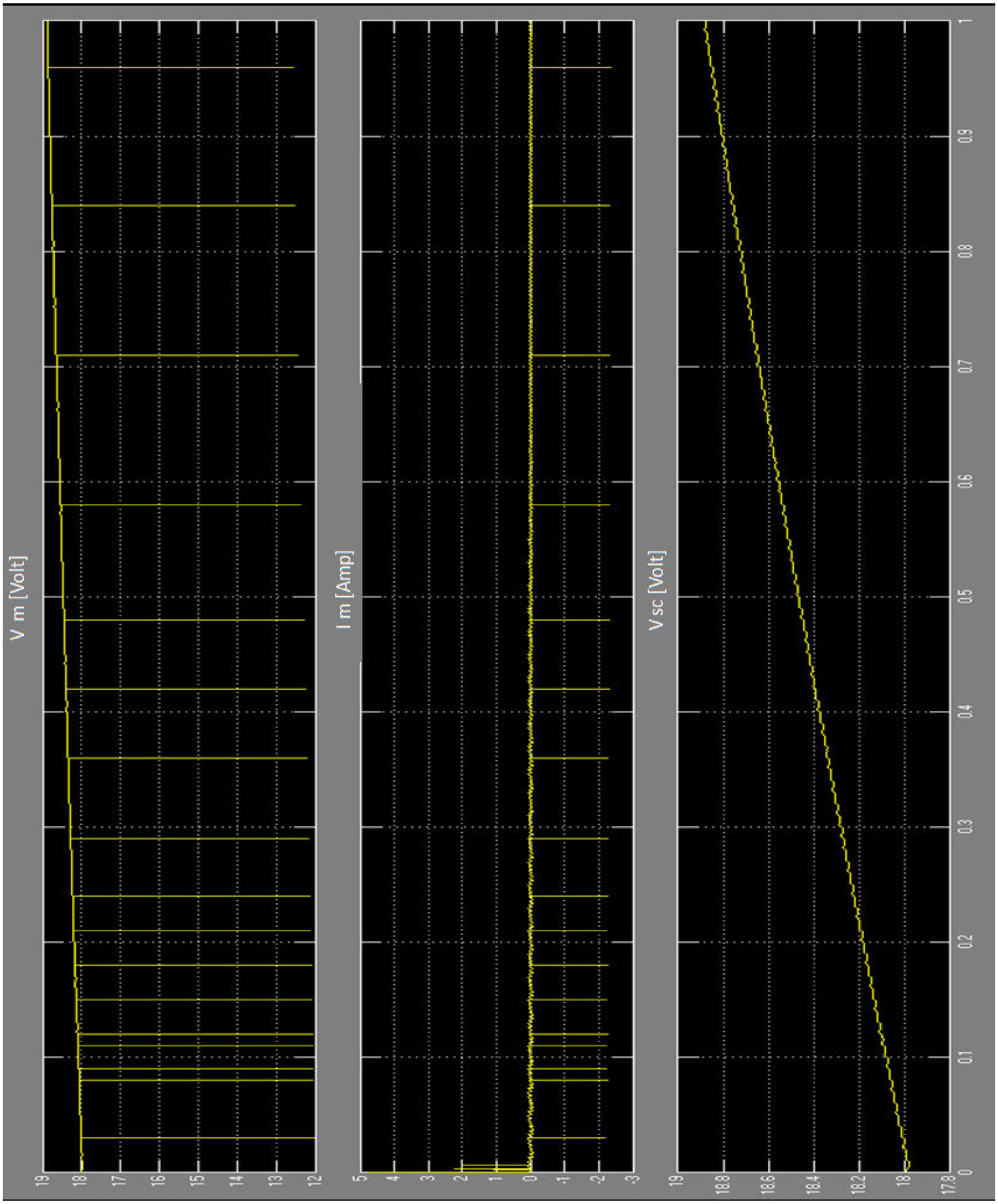

Fig.5. 9 The Charging of SC When Battery Above 9 Volt.

5.3 CIRCUIT DESCRIPTION:

This circuit shows (Fig. 5.10) a multi-domain simulation of a HYBRID ENERGY STORAGE based vehicle power train. The hybrid power train is of the parallel type & the vehicle is propelled by one electric motor powered by a supercapacitor and a battery. There are three subsystems in the main circuit.

1. The Hybrid Storage System + BLDC

2. Control Circuit

3. Dynamic Vehicle Drive

Reference signals are generated according to the accelerator position and speed of the car. Diverse feedback signals are given to the control circuit according to which the reference signals are generated and according to that signals the power from the battery and supercapacitor drawn simultaneously.

The hybrid storage system is consisted of the battery and supercapacitor. During peak power demand the supercapacitor supplies the part of the power and during continuous power demand the battery module supplies the power. Thus the load profile for the battery module becomes smoother. The permanent magnet synchronous motor is used as the traction motor which drives the car.

A dynamic vehicle drive is connected to The BLDC, which act as a car. Diverse types of losses are included in the dynamic vehicle drive. Details of all three subsystem and their respective circuits are given below:

The **HYBRID STORAGE SYSTEM + BLDC (Fig 5.11)** is composed of four parts:

The permanent magnet synchronous motor, the battery, the supercapacitor and the DC/DC converter.

• The electrical motor is a 48 V, 1 kW interior Permanent Magnet Synchronous Machine (BLDC) with the associated drive (based on AC6 blocks of the Sim PowerSystems Electric Drives library).

This motor has 8 pole and the magnets are buried (salient rotor's type). A flux weakening vector control is used to achieve a maximum motor speed of 12500 rpm.

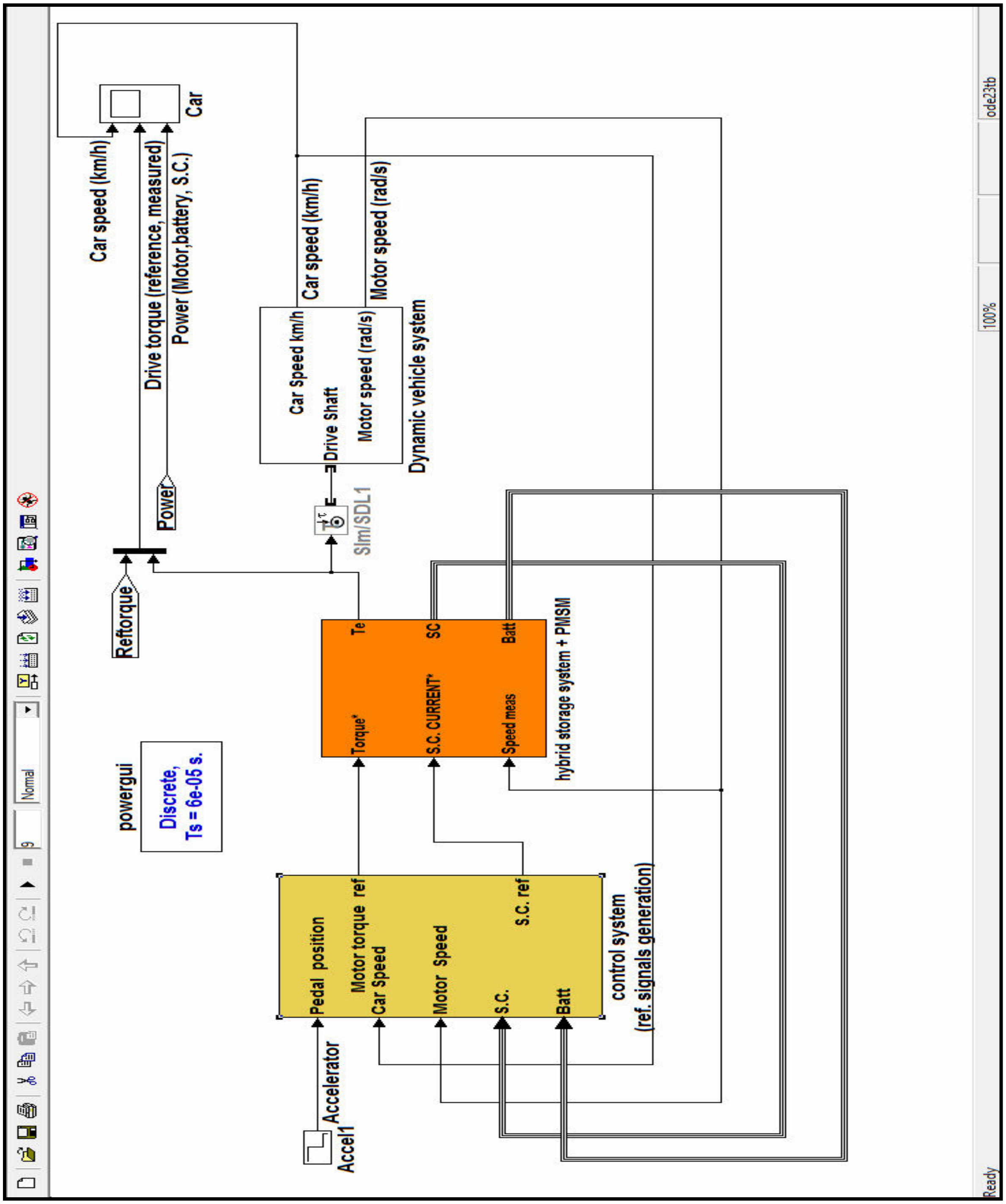

Fig.5. 10 Main Simulation Circuit

- The battery module is a 13.9 Ah, 48 V of Lithium-Ion batteries. The continuous average power demand is supplied by battery, so the parameters of the batteries are adjusted according to the 1000W BLDC.

- The supercapacitor module is a 270 F, 48 V. Peak Power Demand will be supplied by the Supercapacitor module of storage system as well as regenerative braking loss is incurred by SC module.

- The DC/DC converter (buck type) is current-regulated.

The **Control System (Fig. 5.12)** provides the idea about the reference signals for the electric motor drives, the HSS and the DC/DC converter in order to supply perfectly the power from the two electrical sources. These signals are calculated using mainly the level of the accelerator, which is between -100% and 100%, and also the car speed. Negative acceleration means braking is positive.

- The Battery management system maintains the State-Of-Charge (SOC) between 40 and 80%. Also, it prevents against voltage collapse (33.33% or lower) by controlling the power required from the battery.

- The Power management system controls the reference power of the electrical motor.

The **Dynamic Vehicle Drive** Subsystem models all the mechanical parts of the vehicle:

- The single reduction gear reduces the motor's speed to increase the torque.

- The differential splits the input torque into two equal torques.

- The tires dynamics represent the force applied to the ground.

- The vehicle dynamics represent the motion influence on the overall system.

- The viscous friction models all the losses of the mechanical system.

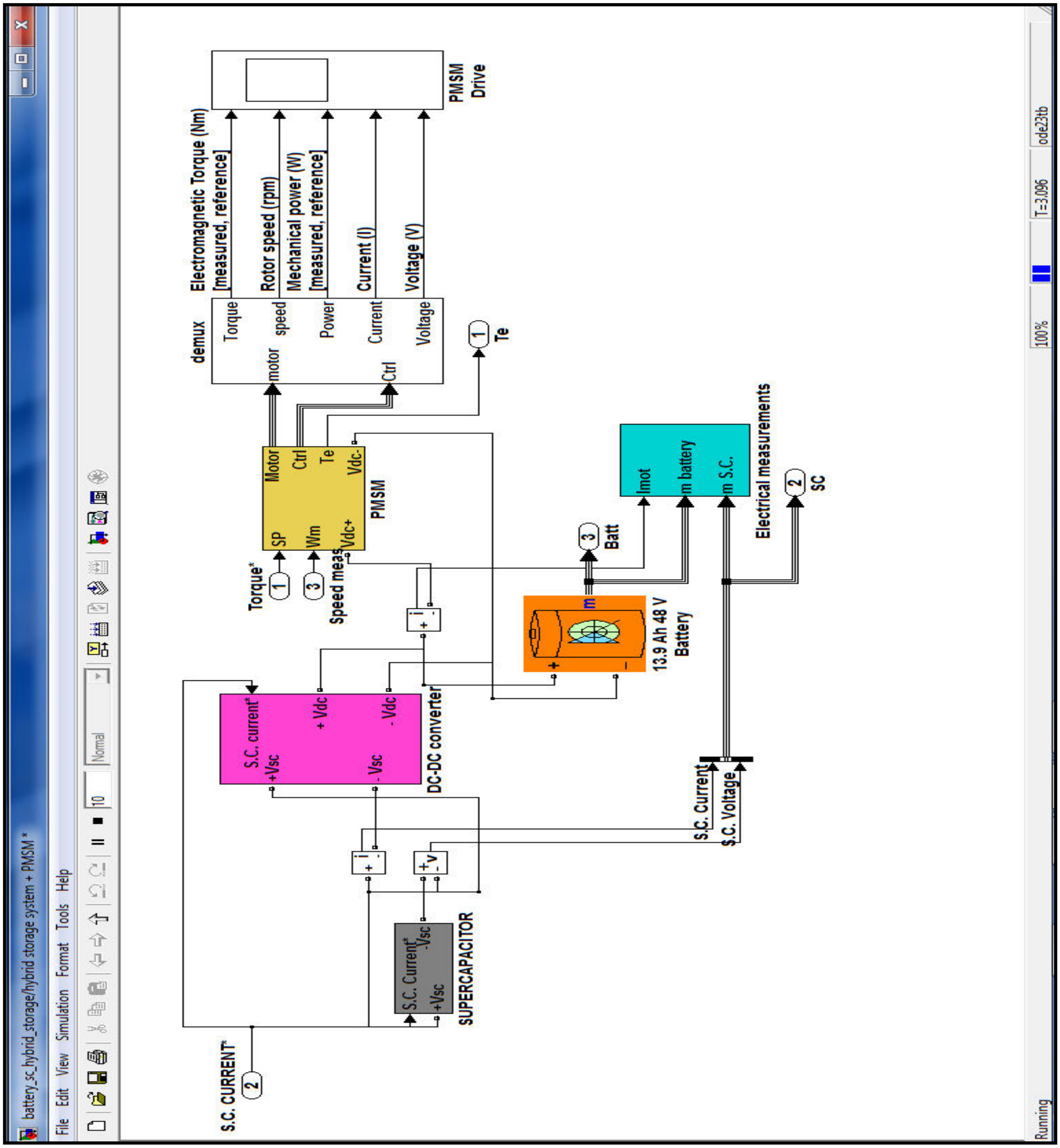

Fig.5. 11 The Hybrid Storage System + BLDC

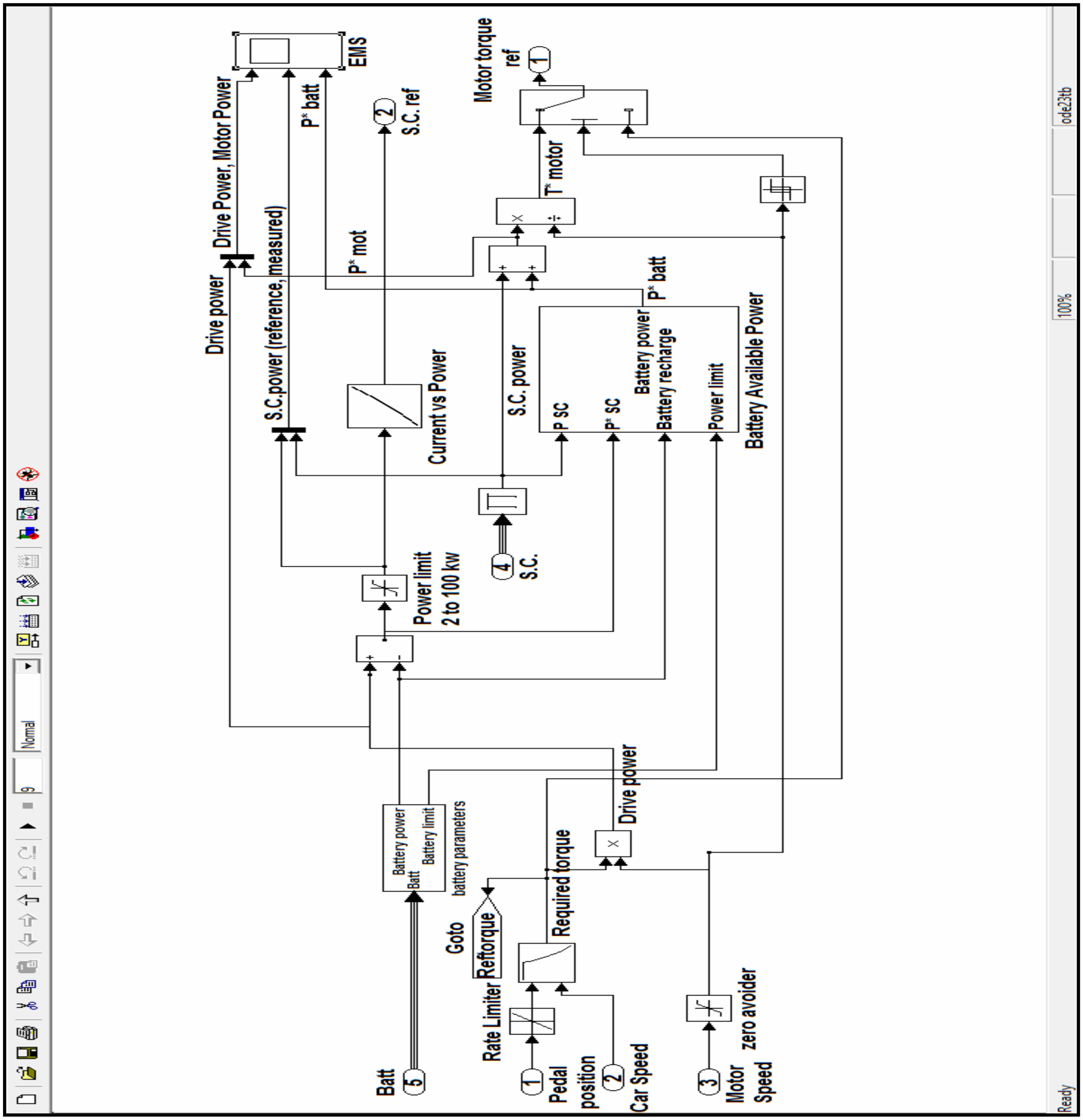

Fig.5. 12 Control Circuit for HSS

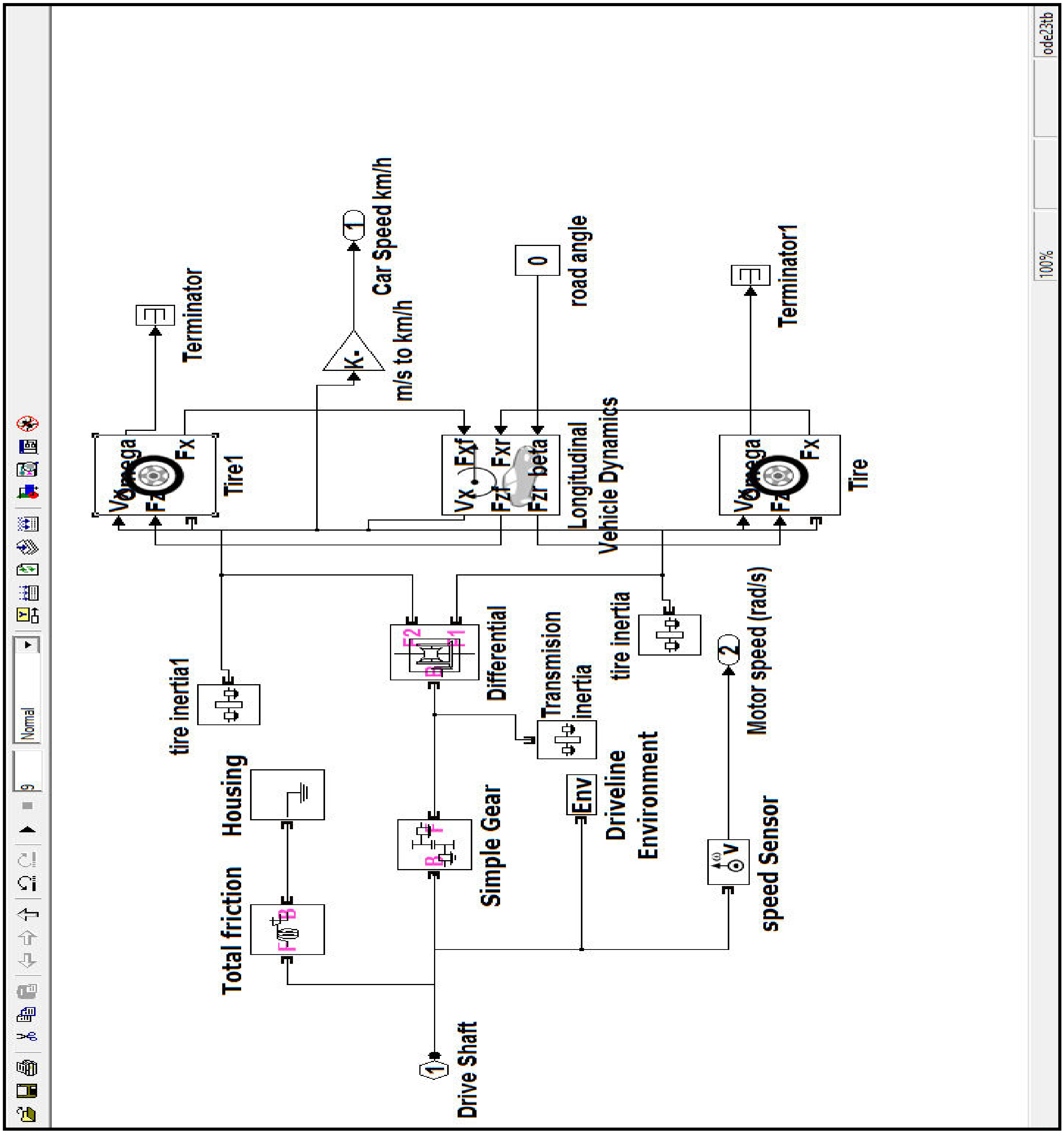

Fig.5. 13 Dynamic Vehicle Drive System

5.4 RESULTS:

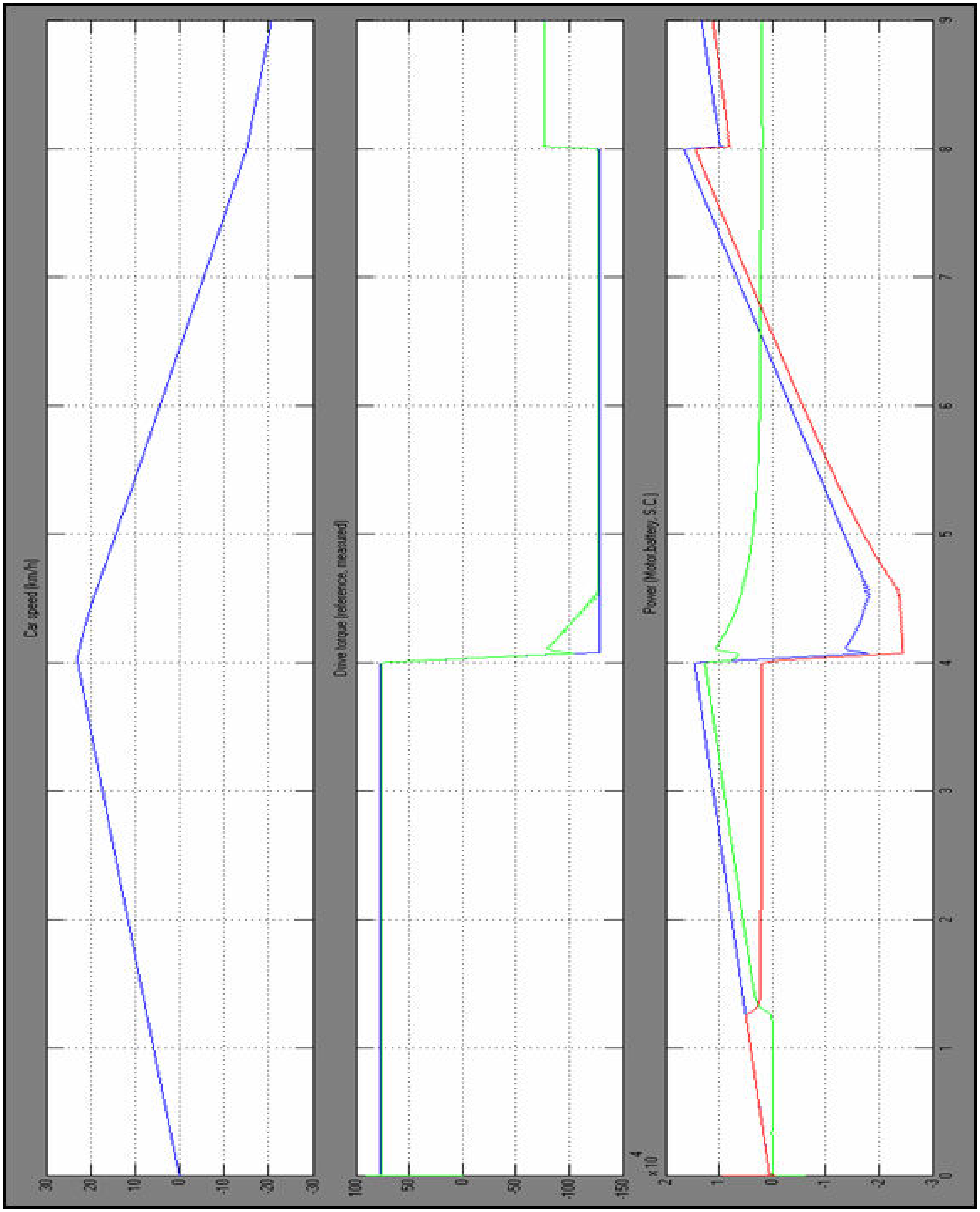

Fig.5. 14 Scope in Main Simulation Circuit

1. **First Quadrant Working:**

- When (at t = 0 sec) we accelerate the motor up to motor up to 30% of the total acceleration, the car will run in forward direction and at the instant of acceleration initially the power will be supplied by the battery and gradually the load will be transferred to the battery. During this time period the torque and speed of the motor and car will be positive (Fig. 5.14) and The BLDC will operate in first quadrant.

2. Fourth Quadrant Working:

- At t= 4 sec we apply the negative torque (-50% of total acceleration) to the motor by accelerator, so the power will be generated due to braking and will be stored in supercapacitor and battery. During this time the torque will be negative and but the speed of the car and motor will be positive (Fig. 5.14) and The BLDC will operate in fourth quadrant (Forward Braking Mode).

3. Second Quadrant Working:

- During t = 4sec to t= 8 sec, the negative torque (-50% of total acceleration) supplied, so car will now run in the reverse direction and most of the load will be fed by battery. During this period the speed of the motor and car will be negative but the applied torque will also be negative (Fig. 5.14) and The BLDC will operate in second quadrant.

5. Third Quadrant Working:

- At t = 8sec. we apply -30% of total acceleration, so the car speed will reduce in reverse direction and power will be generated due to reverse braking mode which will be stored in supercapacitor and battery. During this mode the speed of the motor and car will be negative but the applied torque will be comparatively positive (Fig. 5.14) and The BLDC will run in third quadrant (Reverse Braking Mode).

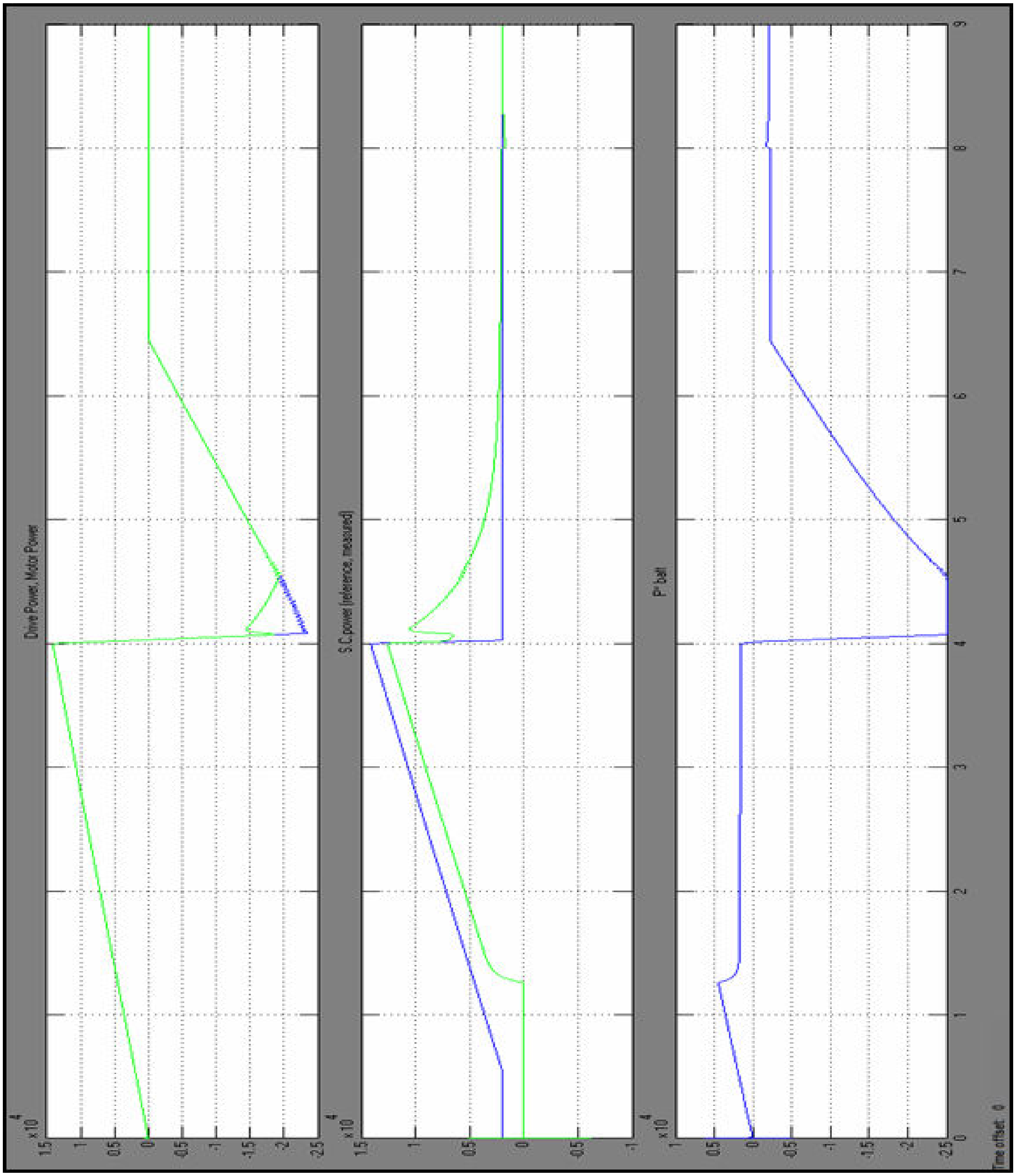

Fig. 5.15 Scope in the Control Circuit

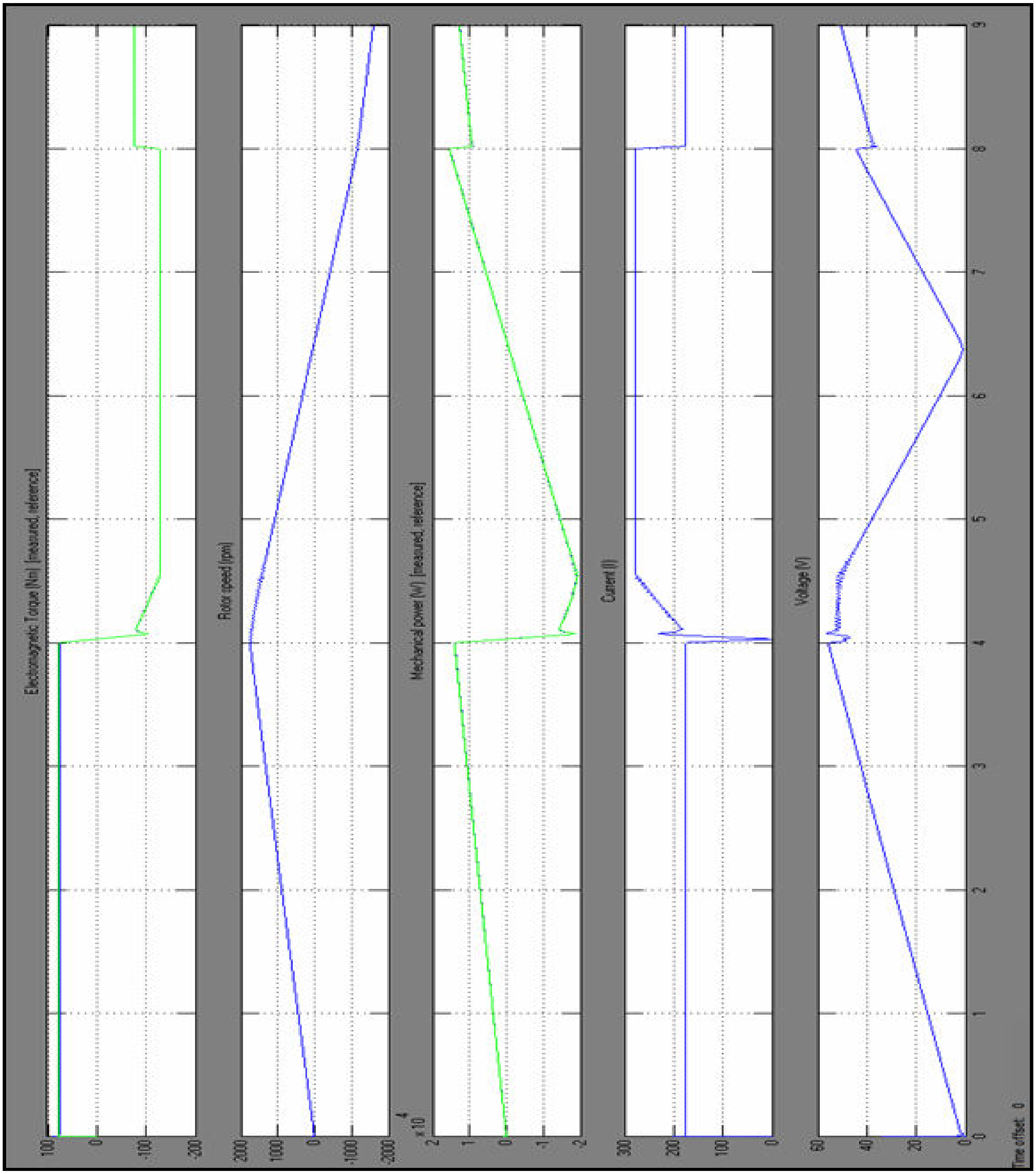

Fig.5. 16 HSS + BLDC Circuit Scope

In the above Scopes the wave forms from the control circuit (Fig. 5.15) and the wave forms (Fig. 5.16) for The BLDC drive is shown. According to the reference signals the power from the batteries and supercapacitors are drawn by the permanent magnet synchronous motor. Diverse parameters of The BLDC are shown in the scope i.e. rotor speed, torque, mechanical power, stator current and stator voltage.

The reference signals in the control circuit are generated according to the positions of acceleration and the speed of the car. Diverse feed backs are given to the control circuit from The BLDC drives. We can see that at the instants of the change of the accelerations the power output from the battery and supercapacitors are changed.

At the instants of negative accelerations the power is regenerated from The BLDC and this power is stored in the supercapacitor module and the battery module. The negative power shows the regeneration of the power while braking and cruising.