“DESIGN AND IMPLEMENTATION OF DSP BASED DC DRIVE FOR CRANE APPLICATION”

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY
IN
ELECTRICAL ENGINEERING
(Power Apparatus & Systems)

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CERTIFICATE

This is to certify that the Major Project Report entitled **"Design and Implementation of DSP Based DC Drive for Crane Application"** submitted by **Mr. Devendra N. Tandel (07MEE017)** towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Power Apparatus & System of Nirma University of Science and Technology is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other university or institution for award of any degree or diploma.

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ABSTRACT

DC drive has number of applications in the industries for the different functions like load transport, heavy material handling etc. There are many techniques are available for speed control of dc series motor, but they suffer from several disadvantages viz, they are not applicable for speed control, they require external contactors for speed reversal, they have a slow speed response. In this project the novel technique pertaining to DC drive is simulated, designed and successfully implemented to obtain the superior performance compared to conventional techniques. In this report fundamentals of DC series motors are considered and compatibility of DC series motor with crane type application is analyzed. Conventional techniques for speed control of DC series motor are given and comparison of those techniques is given according to the performance and economical consideration. The project work presents the simulation results for proposed technique for different reference speed for forward as well as in the reverse direction. From the simulation results the speed response of the motor in the close-loop operation is observed. The novel technique with the independent armature and field current control is done for hoist and bridge configuration. The novel technique with controller is also implemented and tested with the prototype module using DSP (TMS320F2811). The results confirm the approach presented in this work.

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ABBREVIATION

PWM : Pulse Width Modulation
IGBT : Insulated Gate Bipolar Transistor
A/D : Analog to Digital Converter
PI : Proposnal Integral Controller
RPM : Revolution Per Minute
EEPROM : Erasable Programmable Memory
DSP : Digital Signal Processing
DLL : Dynamic Link Library

NOMENCLETURE

T1 : Output terminal of the first leg of the power topology
T2 : Output terminal of the second leg of the power topology
T3 : Output terminal of the third leg of the power topology
Q1P : Label for the upper IGBT of first leg of the power topology
Q1N : Label for the lower IGBT of first leg of the power topology
Q2P : Label for the upper IGBT of second leg of the power topology
Q2N : Label for the lower IGBT of second leg of the power topology
Q3P : Label for the upper IGBT of third leg of the power topology
Q3N : Label for the lower IGBT of third leg of the power topology
L1(+) : Positive terminal of the DC supply
L2(-) : Negative terminal of the DC supply
I_A : Armature current
I_F : Field current
A1 & A2 : First and second terminal of the armature winding
S1 & S2 : First and second terminal of the field winding
Speed* : Speed reference
Ia* : Armature current reference
If* : Field current reference
Ra : Armature winding resistance
Rf : Field winding resistance
La : Armature winding inductance
Lf : Field winding inductance
KHz : Kilo hertz
Skp : Speed PI controller gain
sTi : Speed PI time constant
Akp : Armature current PI controller gain
aTi : Armature current PI time constant
Fkp : Field current PI controller gain
fTi : Field current PI time constant

CONTENTS

CHAPTER: - 1
INTRODUCTION

1.1General: -

Applications of the transport machines in automated production systems require specific control system, simultaneously development of the control systems of electrical drives, based on DSP and applying power electronic converters, enables to obtain better properties of the transport machines.

DC series motor has a characteristic, which is very suitable for the crane (hoist) applications. In the hoist application it requires high starting torque at very low speed or at zero speed in such application DC series motor is used because at low speed at rated field current it gives higher starting torque. In the series motor field and armature windings are in series so speed control of this motor is difficult. The speed reversal requires either of the field or armature voltage reversal and this task is quite difficult in series motor. In the crane application precise control is require to regulates the speed in the both the direction.

1.2 Project Definition: -

1.2.1 Goals: - It requires smooth speed variation from zero to rated speed in the both direction, and it require individual converter for hoist, trolley and bridge.

1.2.2 Objectives: - To design a dc motor drive for crane application for smooth speed control. The objectives are to design a converter with the following requirements:

- ⇨ Cost efficient DC-DC converter.
- ⇨ Smooth speed control in forward as well as in the reverse direction.
- ⇨ Individual controller for Hoist, Crane and Bridge.
- ⇨ Hoist motor (Two motors) ratings are as follows:
    - o 265 HP
    - o 230V DC
    - o 955A DC
    - o 30Min rating
- ⇨ Trolley motor (One motor) ratings are follows:
    - o 25 HP
    - o 230V DC

  - 129A DC
  - 60Min rating
- ⇨ Bridge motor (Four Motors) ratings are as follows:
  - 50 HP
  - 230V DC
  - 248A DC
  - 60Min rating

1.2.3 Constraints: - Drive should contain individual speed controller for all motors. All controllers can control the speed in both the directions. It should contain dynamic as well as mechanical brake for hoist lowering.

1.3 Basic Block Diagram: -

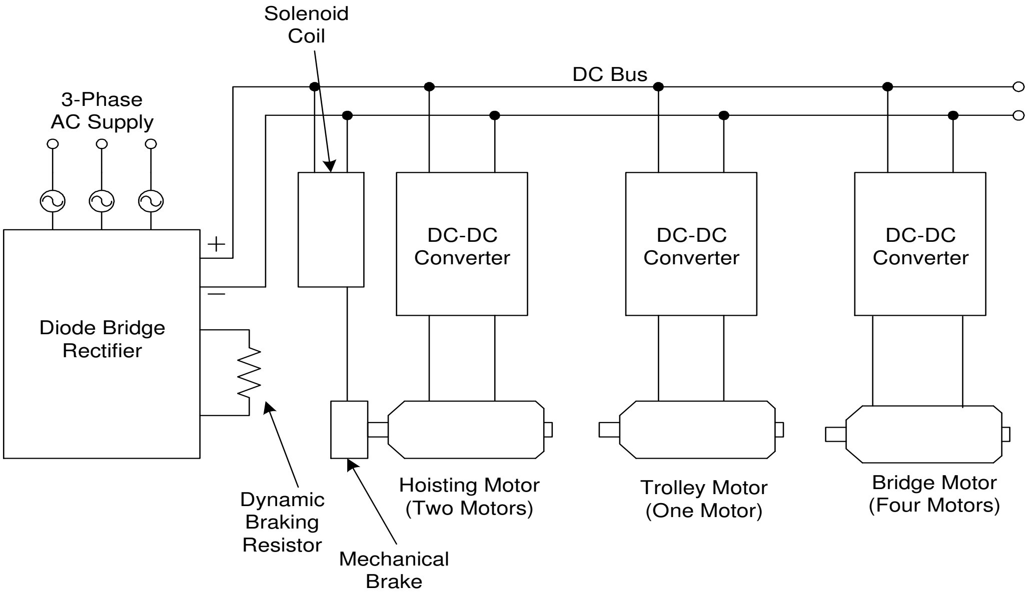


Figure 1.1: Basic Block Diagram of DC Drive for Crane Application

In this scheme the 3-phase uncontrolled diode rectifier converts AC voltage in to the DC. In the crane drive three motors are used for three different tasks one is for hoist mechanism second for trolley and third for bridge mechanism and for all of these motor operation three different controllers is used. In this scheme each motor is controlled by input voltage control using DC-DC converter (chopper). For the speed reversal either armature voltage or the field reversal technique is used. For the braking purpose mechanical brake is used which is inter-locked with the hoist position as well as speed position. This scheme has a combine dynamic braking resistor connected in parallel with the common dc bus and controlled with series connected solid-state switch.

1.4 Literature Survey

Extensive data collection and current market development in the filed of DC drives was studied. There are several books and publications dealing with the issues like basics of DC drive, modeling of DC drive, control topologies, and various techniques to estimated speed and position.

Important information was derived from the major references cited below: -

[1]. Kazimierz Gierlotka

In the paper titled as “**Control of Overhead Crane Drive with Centered Motion and Elimination of the Bevel**” the control strategy for the carne drive is introduced with the elimination bevel. The system described in this work controls the crane speed, compensates its bevel and centers the crane bridge position. The paper contains also the results of numerical experiments, in which the elasticity of the crane and runway slides of the wheels and geometrical imperfections of the system were taken into account.

The work was undertaken as a preliminary stage of designing of the real control system for overhead bridge crane.

[2]. F. Busschots

In the paper titled as “**application of field oriented control in crane drives**” an overview of the crane drive and required characteristics of the motor for different load conditions are described. Design of the crane drive is also described and application of common dc bus is introduced.

[3]. Gerhard L. Fischer

In the paper titled as “**Comparison of DC and AC Container Crane Drive Systems**” behavior of dc motor drive for the crane application is introduced and it is compared with the ac drive. Also the advantages and disadvantages of the dc motor drive for crane application are given.

[4]. Ronald Wayne Hughes

In the paper titled as “**Method and System for DC crane control**” control topology for the speed control of DC series motor is described and also different possibilities for the dissipation of regenerated energy is given. And also other possibility for the power circuit connection is given.

[5]. Anthony J. Davis

In the paper titled as “**Reversible dc motor drive including a dc/dc converter and four quadrant dc/dc converter**” power circuit for the dc motor control is explained and the controller for this circuit is given which controls the armature and field current independently for the speed control from very low speed up to rated or above the base speed.

[6]. Gopal K. Dubey

In the book titled as **"Power Semiconductor Controlled Drives"** explains the different possible control techniques for the close loop speed control of the motors from this book the inner current control close loop speed control of dc motor technique is used for proposed novel technique.

1.5 Thesis Organization

Chapter-2: *"An Overview of Crane Drive"* describes basic characteristics of crane drive for industrial applications. The four quadrant operation of hoist is discussed in brief as an example of elevator. Torque and power requirement for crane application for all empty and loaded conditions and with wind load and without wind load is described with help of torque and power characteristics.

Chapter-3: *"Conventional Techniques for speed control"* describes different conventional techniques those are applicable for speed control with the help of real simulation circuit, the speed response for all technique is given and features and limitations for all techniques are compared with proposed technique.

Chapter-4: *"Proposed Novel Technique Description"* describes the detail theoretical description of proposed novel technique for speed control of dc series motor for both hoist and bridge configuration. The close-loop controller for speed control is discussed with the block diagram presentation.

Chapter-5: *"Simulation of the Proposed Technique"* shows the simulation circuit, which is simulated in the Psim software tool for the close-loop speed control of dc series motor with the help of analog controller. The analog controller circuit includes speed PI controller, armature current controller and field current controller. The speed response for different reference speed is given and the armature voltage at difference reference speed is observed.

Chapter-6:- *"Flowchart for Programming"* describes the algorithm of the flowchart for programming for controller, includes main operation flowchart, PI controller flowchart and flowchart foe PWM generation.

Chapter-7:- *"Simulation of Proposed Technique with DLL Block"* show the simulation results for proposed technique with programming, for that the controller circuit logic is programmed in the visual basic C++ and that is linked with the Psim tool. The speed response for the different reference speed condition is observed.

Chapter-8:- *"Hardware Implementation of DC drive"* this chapter shows the actual experimental results of the proposed technique, the actual experiment was carried out with the dc series motor and those experimental results are compared with the simulation results.

Chapter-9:- *"Comparative Description of all techniques"* this chapter describes the comparison of all techniques according to the control and speed responses and discuss the advantages and disadvantages of all techniques.

Chapter-10:- *"Conclusion & Future Task"* finally the overall work is concluded in this chapter with the comparison of proposed technique and the experimental and simulation results are compared. The future task of the project is described in this chapter.

CHAPTER: - 2
AN OVERVIEW OF CRANE DRIVE

2.1 Four-Quadrant Operation of a Motor Driving a Hoist Load

In industry, a large amount of crane drives is found. The most evident application area of cranes in undoubtedly the harbor where they are found for moving containers and bulk material from ship to store and vice versa and to load and unload trucks and trains. These cranes are mostly installed outdoor, and therefore the influence of the wind on the behavior of the drive may be considerable. Further on, it will be indicated how the wind may influence the layout of the drive.

However, far more cranes are installed in industry, especially in metallurgy. They are used for transporting heavy loads, e.g. coils and slabs. Most applications are indoor. Therefore, the influence of the wind does not exist. However, other considerations as the influence of dust, smoke, water and heat, interfere with the drive design.

The electrical drives used in these cranes were until recently, dc motors with a variable voltage supply. First the rotating Ward-Leonard combination was common, which was then replaced in the sixties by a four-quadrant converter. The four-quadrant operation is essential as braking capacity is required for lowering the load.

The wound rotor induction motor with rotor resistors offered an alternative for the dc motor. First it was only possible in a discontinuous way; contactors were used to short-circuit parts of the resistors. The main disadvantage is that the actual speed depends heavily on the load. More recently, an electronic control system was added to continuously control the rotor resistance value. Also stator voltage regulation may be added.

Speed control is an essential feature in crane drives. It is required for allowing soft starting and stopping of the travel motions, for avoiding swinging of the load and for enabling its correct positioning. The latter one may not be underestimated positioning a 12 m long, 30-ton heavy container with accuracy of *5 cm* or less, is a difficult task. For the hoist motion, the speed control is essential in the low speed range avoiding damage to the load when putting it down and minimizing the stress on the mechanical brakes. Furthermore, the speed control limits the starting currents. This is particularly important for cranes as the electricity is provided via a sliding contact on rails or a cable drum, both leading to relatively high impedances of supply and therefore high voltage drops if no measures are taken for limiting the starting current.

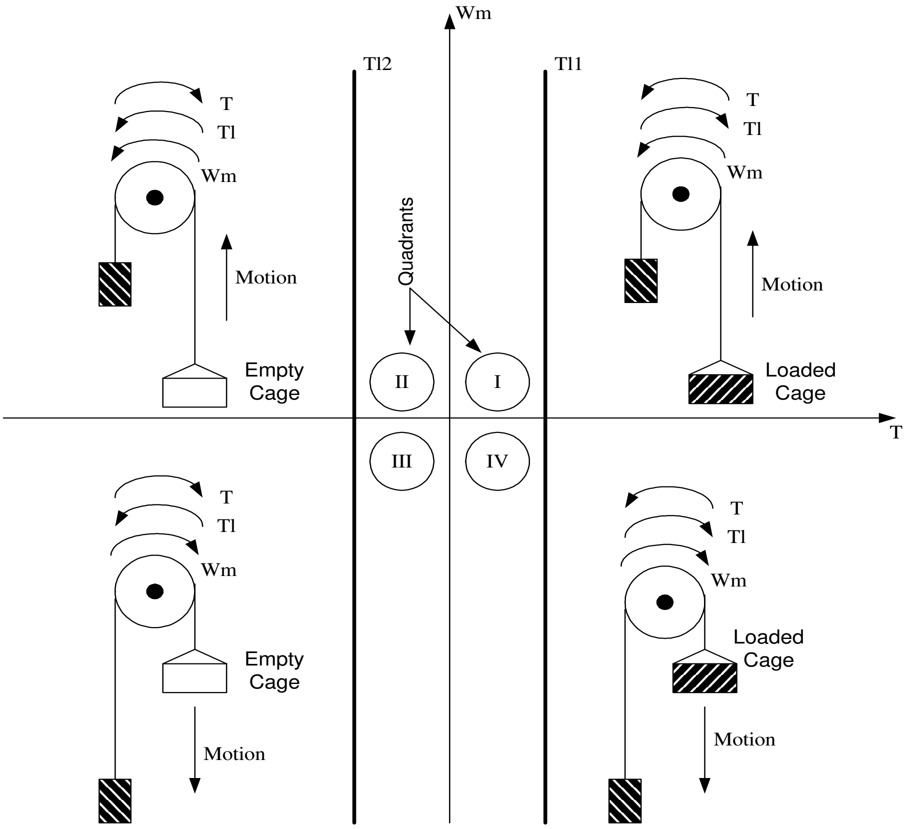


Figure 2.1: Four-Quadrant Operation of a Motor Driving a Hoist Load

A hoist consists of a rope wound on a drum coupled to the motor shaft. One end of the rope is tied to a cage, which is used to transport material from one level to the other level. Other end of the rope has a counter weight.

Forward direction of the motor speed will be one, which gives upward motion of the cage. Speed-torque characteristics of the hoist load are also shown in fig.2.1. Though the positive load torque is opposite in sign to the positive motor torque, it is convenient to plot it on the same axes. Load-torque curve drawn in this manner is in fact, negative of the actual.

Load torque has been shown to be constant and independent of speed. This is nearly true with a low speed hoist where forces due to friction and windage can be considered to be negligible compared to those due to gravity. Gravitational torque does not change its sign even when the direction of the driving motor id\s reversed. Load torque line T_{l1} in quadrant **IV** and **I** represents speed-torque characteristic for the loaded hoist. This torque is the difference of the torques due to the loaded hoist and counter weight. The load-torque line T_{l2} in quadrant **II** and **III** is the speed torque characteristic for an empty hoist. This torque is the difference of torques due to counter weight and the empty hoist. Its sign is negative because the weight of the counter weight is always higher than that of an empty cage.

The quadrant I operation of a hoist requires the movement of the cage upward, which corresponding to the positive motor speed which is anticlockwise direction here. This motion will be obtained if the motor produces positive torque in anticlockwise direction equal magnitude of the load torque T_{l1}. since developed motor power is positive, this is forward motoring operation.

Quadrant **IV** operation is obtained when a loaded cage is lowered. Since the weight of the loaded cage is higher than that of counter weight, it is able to come down due to the gravity itself. In order to limit the speed of the cage within a safe value, motor must produce a positive torque T equal to T_{l2} in anticlockwise direction. As both power and speed are negative, drive is operating in reverse braking.

Operation in quadrant **II** is obtained when an empty cage is moved up. Since a counter weight is heavier than an empty cage, it is able to pull it up. In order to limit the speed within a safe value, motor must produce a braking torque equal to T_{l2} in clockwise (negative) direction. Since speed is positive and developed power negative, it is forward braking operation.

Operation in quadrant **III** is obtained when an empty cage is lowered. Since an empty cage has a lesser weight than a counter weight, the motor should produce a torque in forward direction. Since speed is negative and developed power positive, this is reverse motoring operation.

2.2 Torque and Power Requirements

The torque and power that have to be delivered by the drive may be obtained from the torque versus speed characteristic from the load. If no wind influence has to be taken into account, the load characteristic is given in Fig.2.2. Apart from the zone around zero, the torque is constant. The surplus of torque available is used for accelerating the system.

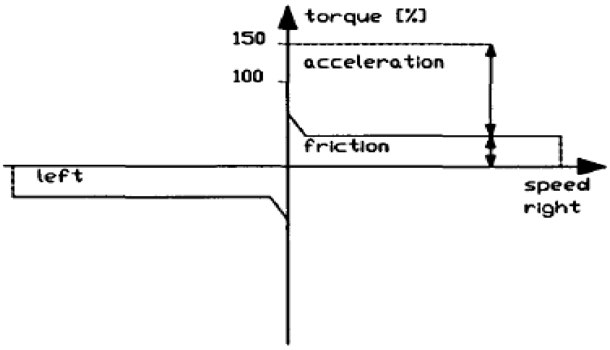


Figure 2.2: Torque Vs speed characteristic of travel motion without wind

The crane drive supplies the speed reference signal. For a travel in a one direction, braking and reversing to the full speed in the other direction, the speed reference signal is given by top curve of fig.2.3. Integration yields the control signal of the inventor (dotted line). The torque reference signal is generated (second curve), lading to the machine actual speed. Multiplying the actual speed and the torque reference yields the actual power (third curve). The peak power found at the end of the acceleration period.

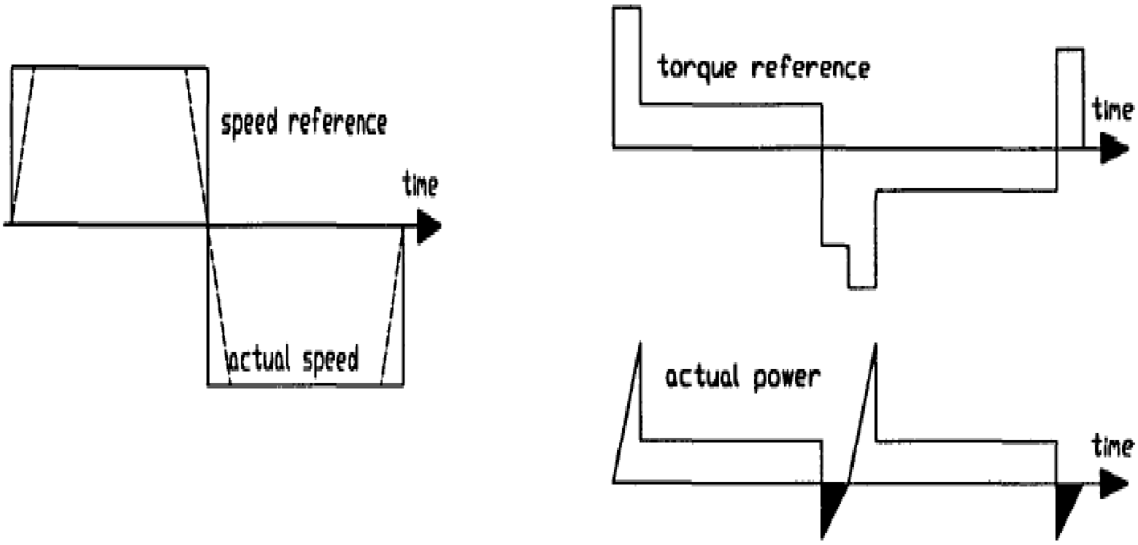


Figure 2.3: Time pattern of the different signals for a travel without wind.

If wind forces are taken into consideration, the torque Vs speed curve is shifted vertically as shown in Fig.2.4. The torque and speed reference remain the same, as well as the actual speed. However, the torque reference and the actual power differ, as shown on Fig.2.5

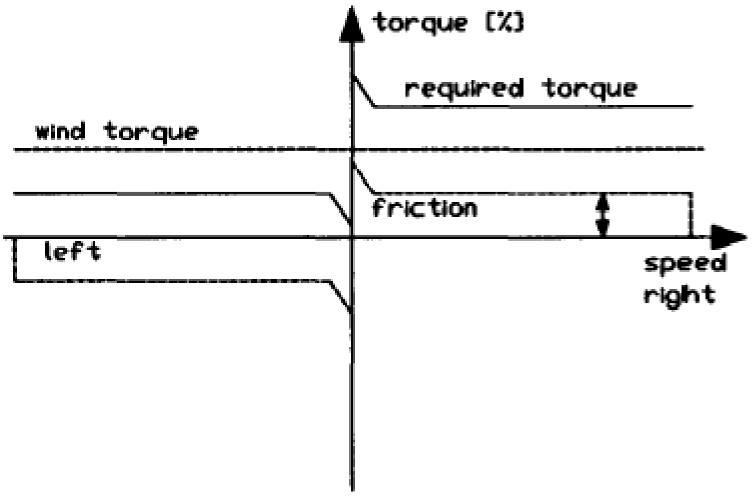


Figure 2.4: Torque speed characteristic of travel motion with wind

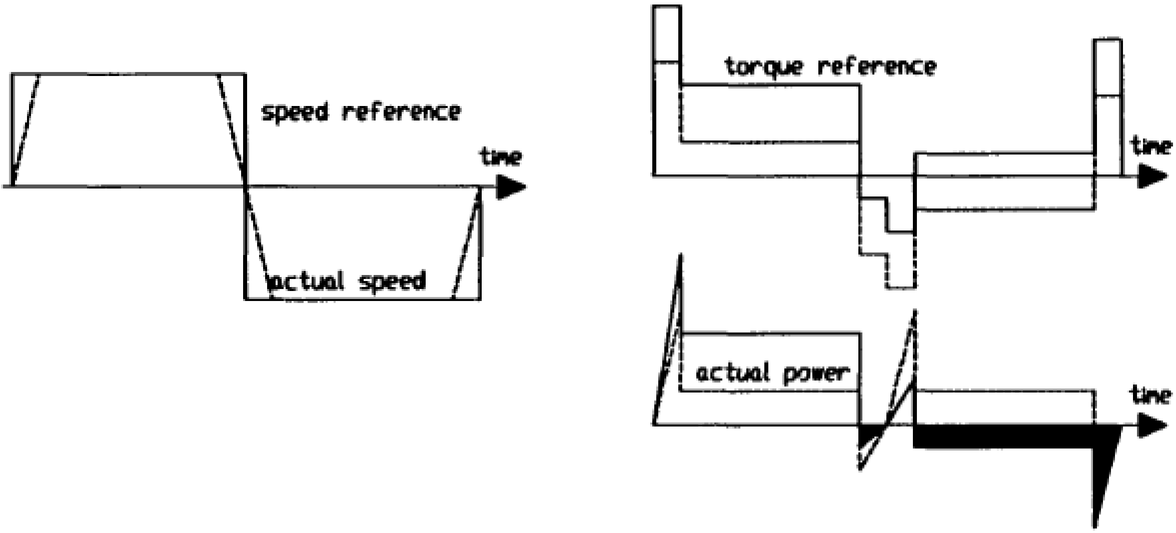
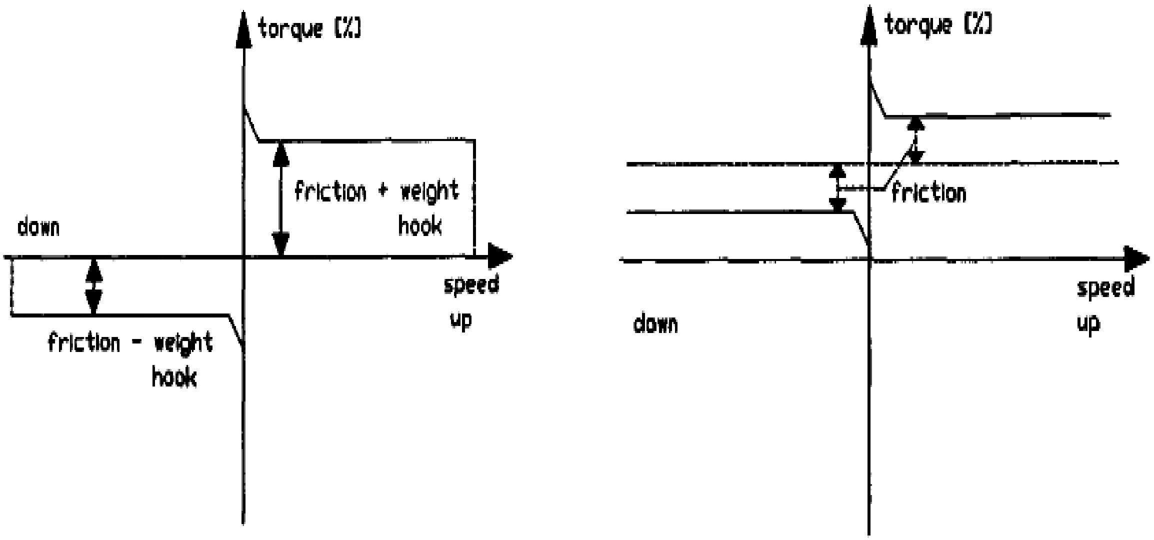


Figure 2.5: Time pattern of the different signals for a travel with wind.

During acceleration, kinetic energy is stored in the system. To stop the crane, this energy must be absorbed by the drive. In the indoor situation, this energy is well known and only present for a short period of time. For outdoor applications, the wind forces may become very important. When traveling in the same direction as the wind, the wind drives the crane and a situation may occur, where a continuous electrical braking is required. The drive must be capable of handling this inverse power direction either by consuming the power in a resistor or preferably by feeding it back to the supply. The latter has consequences for the rectifier layout as will be discussed further on. The shaded area on the power Vs time characteristic indicates the amount of braking power required.

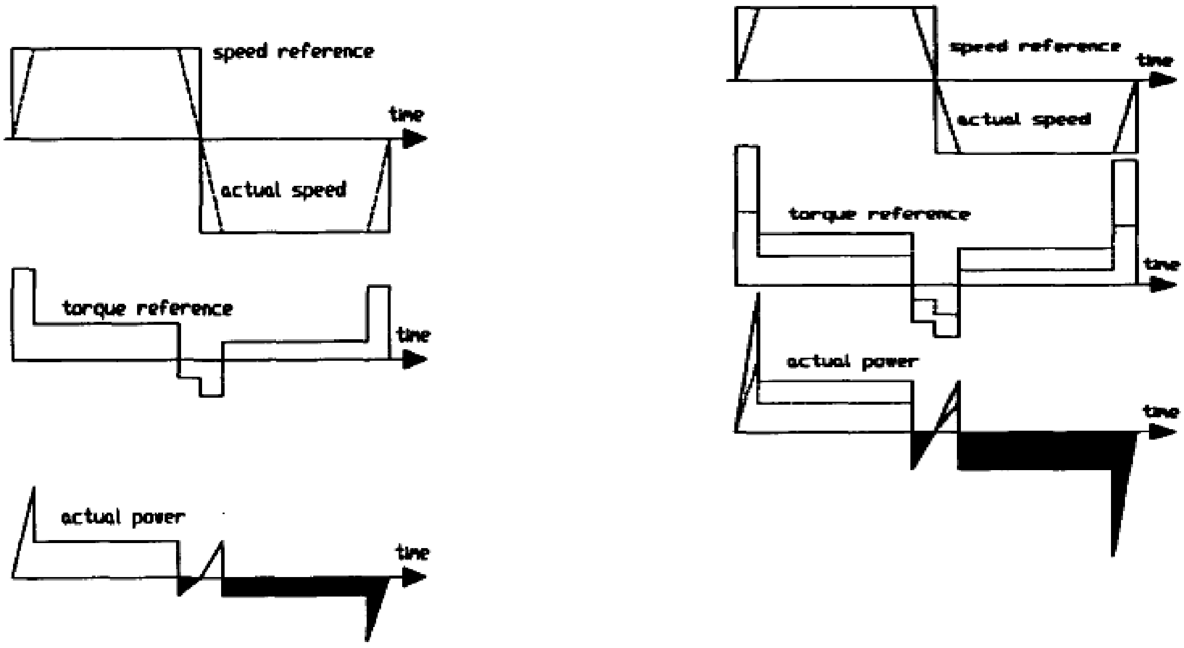
The hoist torque Vs speed characteristic is shown in Fig.2.6 (a) for an unloaded hook. The characteristic resembles the one for the travel motion. However, it is always asymmetric with respect to the horizontal axis; due to the gravitation force loaded (Fig.2.6 (b)). For both unloaded and loaded situation, this asymmetry becomes more pronounced when the hook is for the travel motion. However, it is always asymmetric with speed, torque and power is given in Figs.2.7 (a) and 2.7 (b). Again the amount of braking power is indicated. The worst braking case with a hoist motion is when sinking a loaded hook.

It should be noted that the wait of the hook might be considerable. The hook may be simple or have a several parts to handle the load. In ladle crane drive in foundries, hook, ladle and cable together are a significant portion of the load. For bulk material handling, system components as e.g. the magnet and the grab, do contribute. In container application, the spreader mass may be as high as 12 ton.



(a). Without Load (empty hook) **(b). With load**

Figure 2.6: Torque Vs speed characteristic of the hoist



(a). Without Load (empty hook) **(b). With load**

Figure 2.7: Time pattern of the different signals for a hoist with load.

CHAPTER: - 3
CONVENTIONAL TECHNIQUIES FOR SPEED CONTROL

3.1:- 3-Phase controlled rectifier

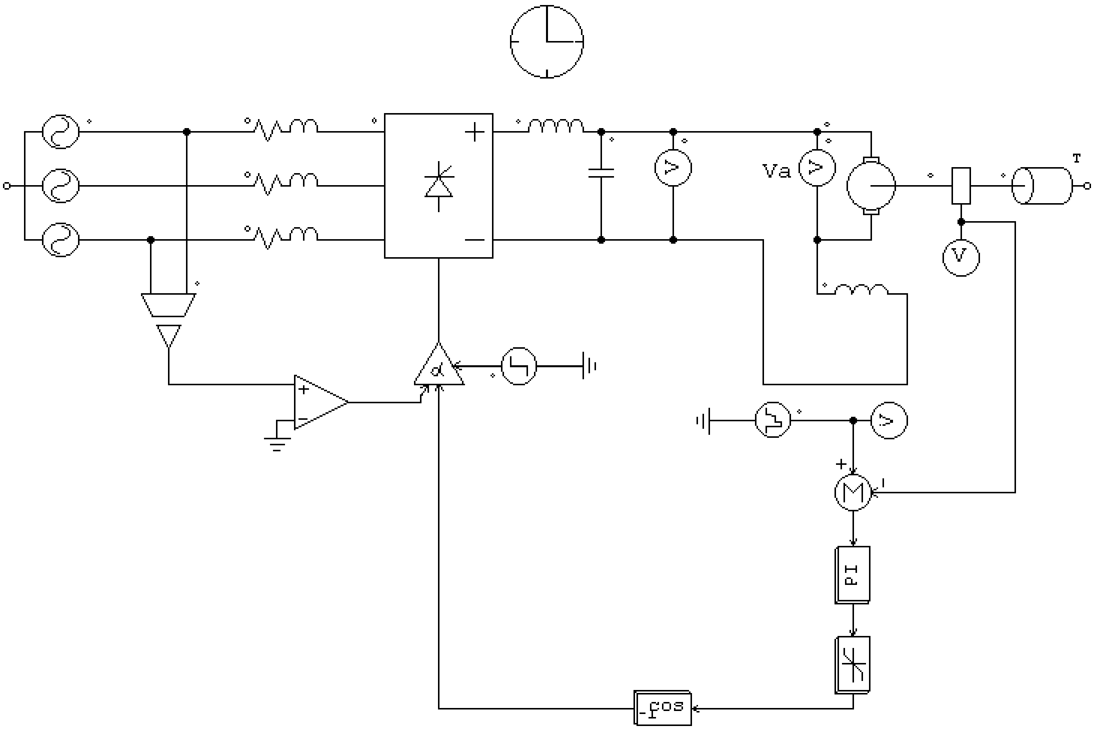


Figure 3.1: Three-phase controlled rectifier for speed control of dc series motor

Fig.3.1 shows the power schematic with control circuit of three-phase full controlled rectifier for the close loop speed control of dc series motor. In this scheme for the speed control the firing angle of the SCR is controlled. As shown in fig.3.2 for the different speed position different reference signals are generated. The generated reference signal is then compared with the actual signal and speed error is generated, this error signal is processed with the PI controller and output of the PI is then given to the alpha controller the generate the triggering pulse for SRCs.

The major advantage of this scheme is that in this scheme the speed control is achieved directly using control rectifier means it does not required any uncontrolled rectifier and then extra chopper for the speed control, so the system becomes economical

But the disadvantage of this system is that the time response for the controller is very low in the rectifier circuit as it requires at least one cycle for the stabilization and in the crane drive application the control must be as fast as possible because in such application the consecutive forward and reverse operation at different speed position is required so for this crane application this scheme gives poor performance.

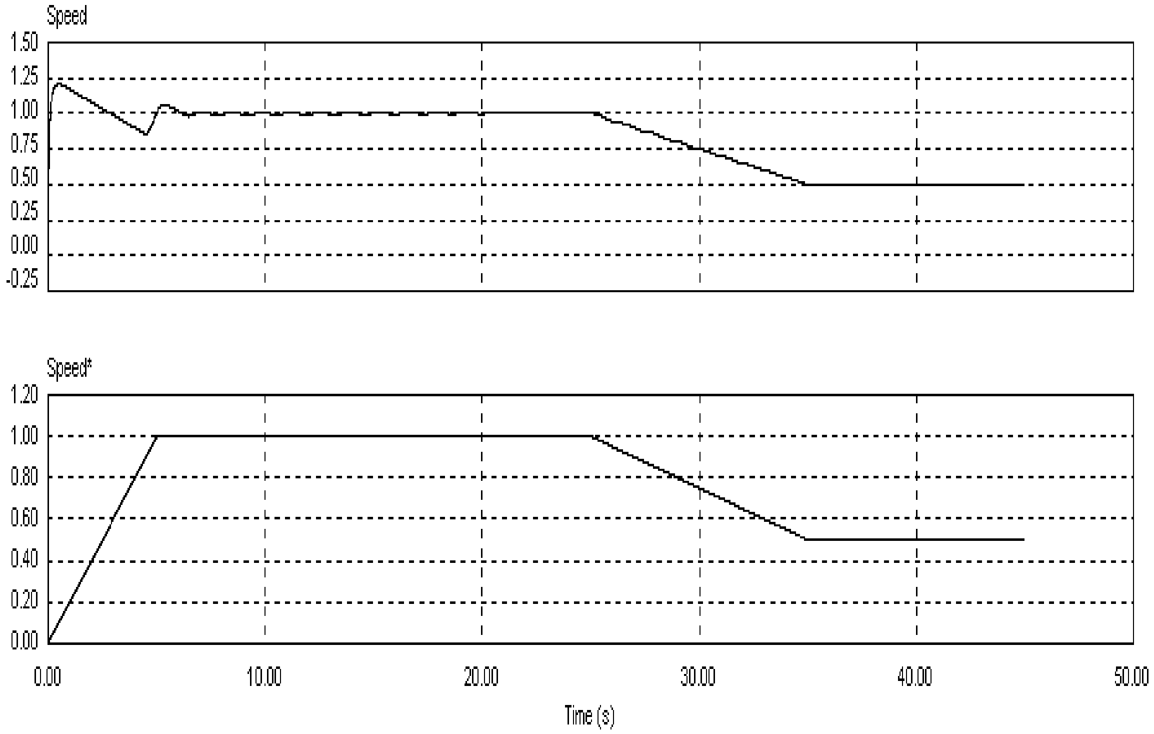


Figure 3.2: Actual and reference speed wave-forms For Scheme-1

Fig.3.2 shows the speed output wave-forms which is simulated in the Psim software tool the fig shows that at starting the actual speed is not completely follows the reference speed and time for the stable speed is round about 5sec which is very slow.

3.2 Buck chopper

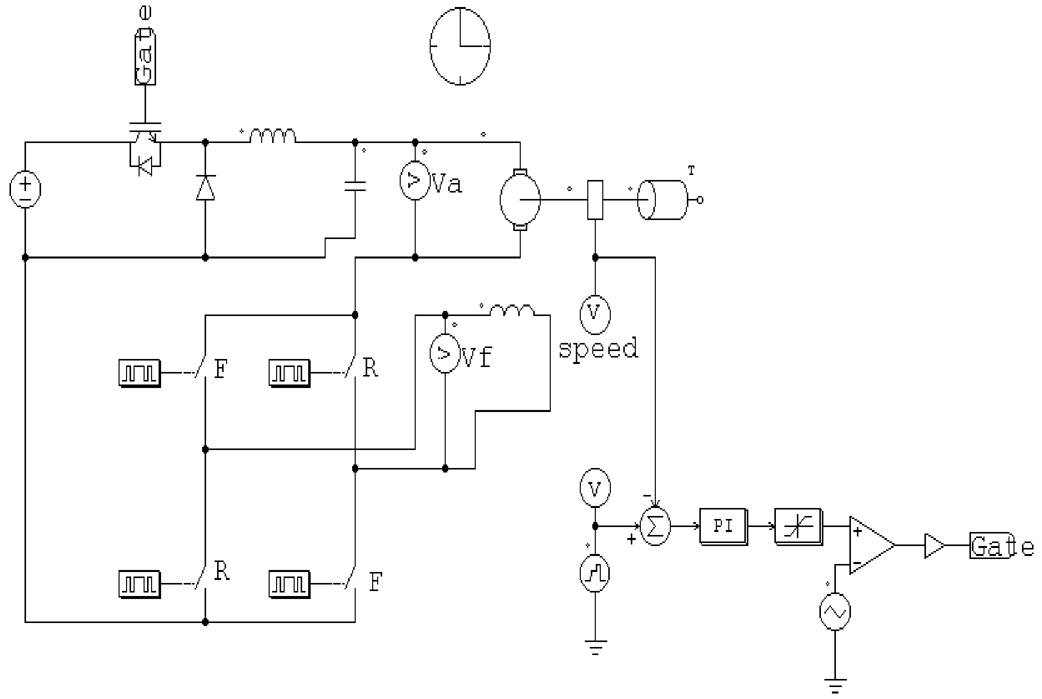


Figure 3.3: Buck chopper for the speed control of DC series motor

Fig.3.3 shows the one of the possible schematic for the close loop speed control of the DC series motor. In this scheme buck type chopper is used for voltage control. The generated reference speed is compared with the actual speed and generated error is processed by the PI controller and that PI out-put is given to the comparator as a reference which is compared with the triangular carrier signal and with this comparison PWM signal is generated for the switch of the chopper. In this type of speed control method for the speed reversal contactors are used in the field (or in the armature) as shown in fig.3.3.

This scheme gives a very fast response for the speed control in the either direction and due to the PWM modulation the controller gives very smooth speed control. But this scheme has a major disadvantage as it is used only for the speed control up to base speed because of buck chopper. Other disadvantage of the system is it requires additional contactors for the speed reversal which reduces the reliability of the system and because of the series motor armature and field winding caries same current so, it requires higher ratings of contactors which increases the cost of the system.

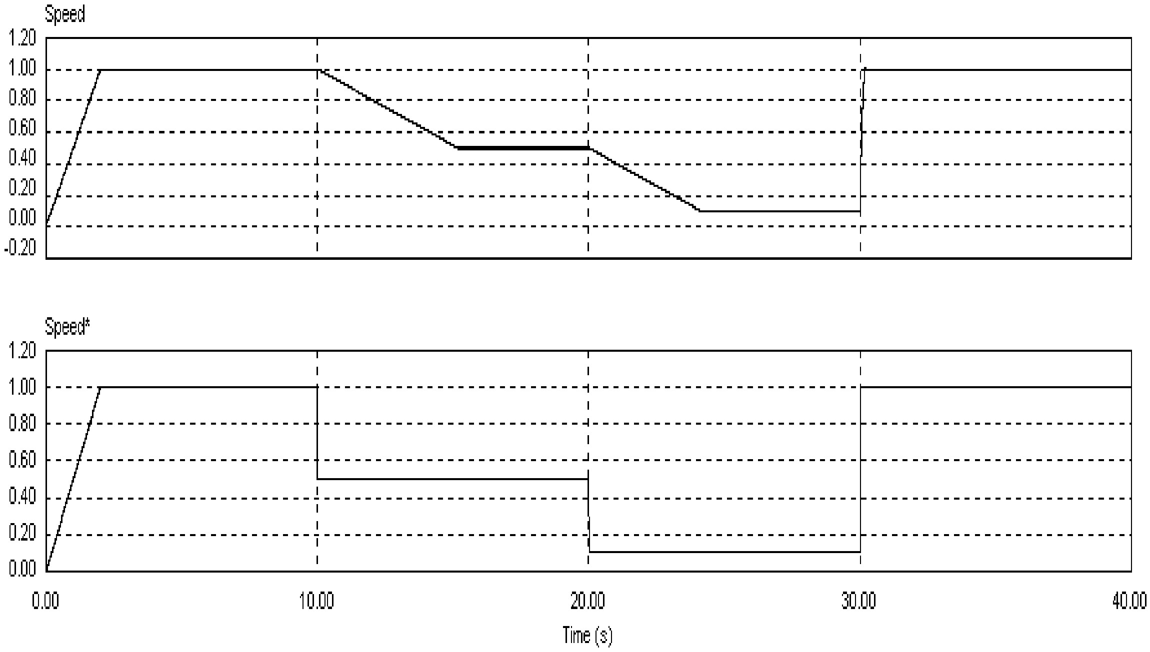


Figure 3.4: Actual and reference speed waveforms for scheme-2

Fig. 3.4 shows the speed waveforms for the different reference input command. It shows that with this scheme we can get very fast response for the speed control. As shown in fig with this scheme we can four speed steps only within 40 seconds and we can also reduce it up to 30 sec.

3.3:- H-Bridge type chopper

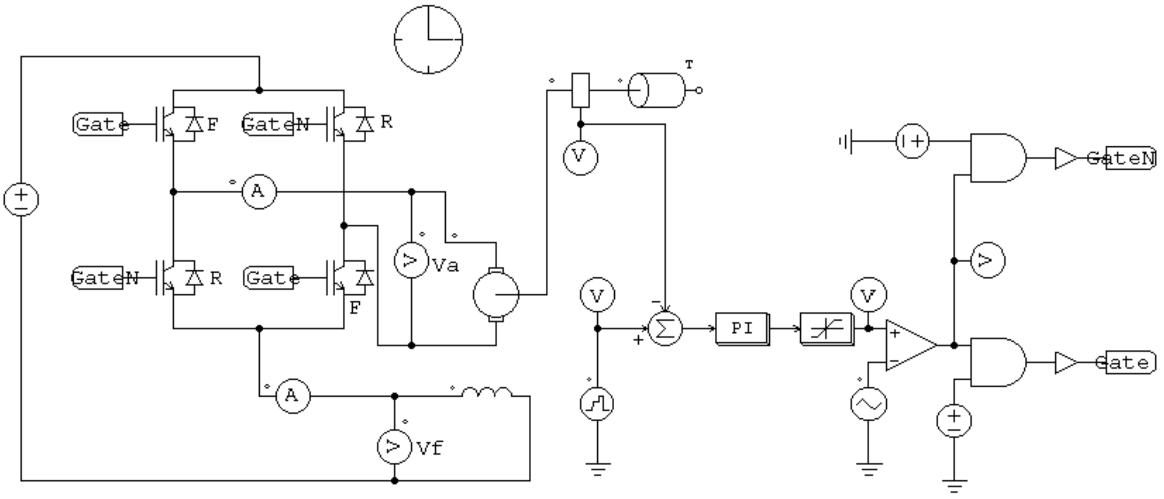


Figure 3.5: H-bridge type chopper for the speed control of DC series motor

Fig.3.5 shows the H-bridge chopper configuration for the speed control of the dc series motor. In this scheme for the speed control four IGBTs are used for feeding the supply to the armature of the motor and field is connected in series with the armature circuit. For the speed control in the forward direction two switches (named as F in the fig) are modulated with PWM control technique using close loop PI controller.

For any speed position required reference speed command is given to the controller this reference speed is compared with the actual speed, which generates speed error command, then this generated error is processed with the PI controller and that PI out-put is given to the comparator as a reference which is compared with the triangular carrier signal and with this comparison PWM signal is generated for the **F** switches of the chopper.

The major advantage of this scheme is that it does not require any external contactors for the speed reversal, four switches used for the modulation can same uses for the speed reversal.

This scheme also gives very fast speed control response but for the hoist application at the starting the load torque is very high at low speed. In the dc series motor at starting if we start motor with rated field current than we can get the higher torque with very low speed, but for this application we required two different controllers for the field and armature current control and we required switches in the field circuit also so for this application different scheme is required.

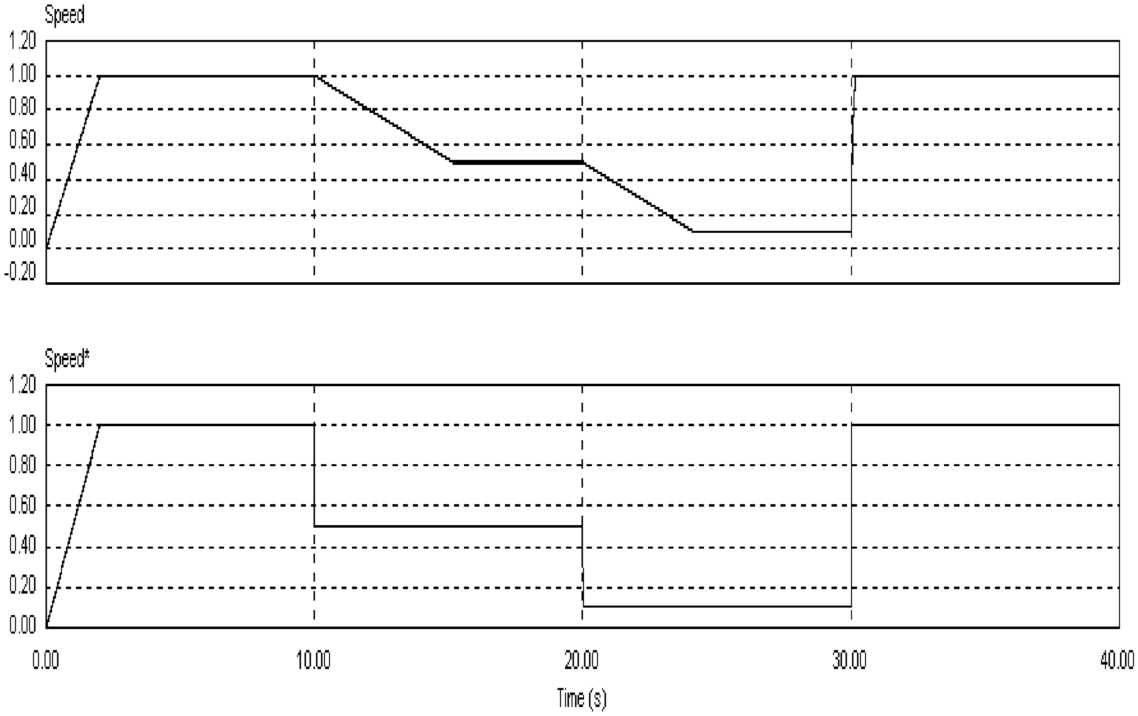


Figure 3.6: Actual and reference speed waveforms for scheme-3

Fig.3.6 shows the speed output waveforms for the different speed references, which is simulated on the Psim software tool. Speed response of this scheme is same as in the scheme1.

CHAPTER: - 4
PROPOSED NOVEL TECHNIQUE DESCRIPTION

4.1 Power Circuit for Hoist

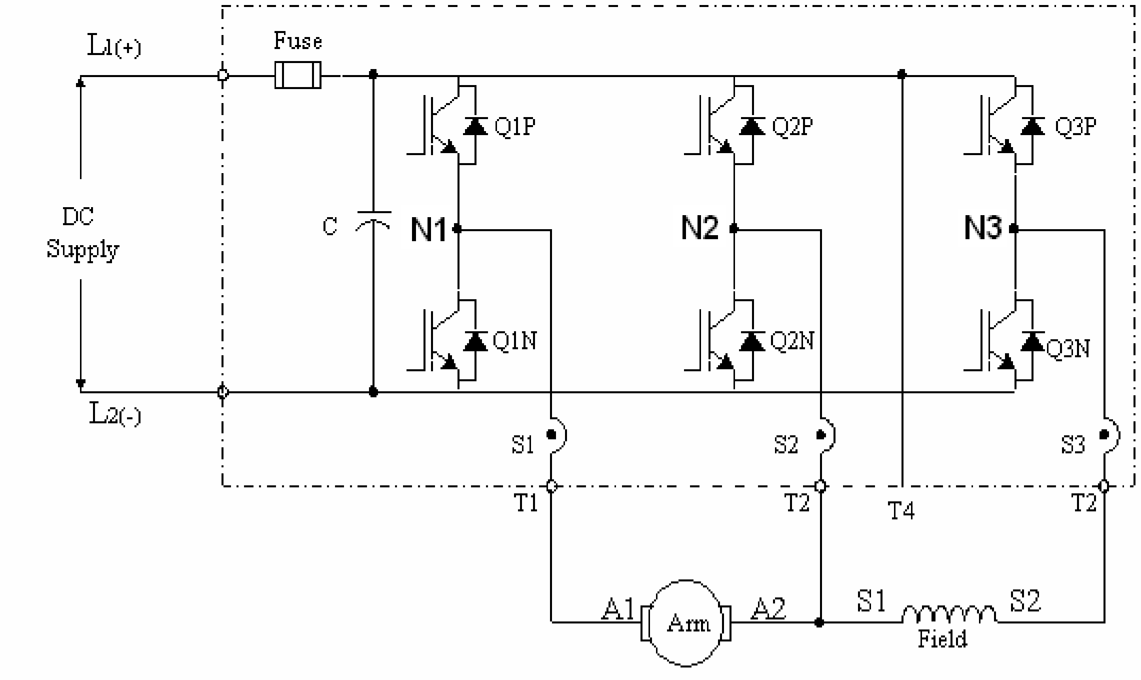


Figure 4.1: Proposed novel technique power circuit for hoist

Fig.4.1 shows the power schematic for the reversible DC series motor drive, which supplies the motor current through terminals T_1, T_2 and T_3 only. This allows some or the entire armature current to pass directly to the field current winding when the torque is in the usual direction for balancing the load on the hoist. This substantially reduces the heating in the semiconductor device that controls T_2. This scheme gives four-quadrant operation. This means that it can produce either positive or negative torque irrespective of whether the motor is running in the forward direction or the reverse. The controller is therefore able to absorb energy from the motor when it is providing torque such a direction as to decelerate a high inertia or when it is providing a braking torque during lowering of a heavy load. The efficiency of the controller is sufficiently high to allow it to recover some energy from the load and return it to the DC supply. For the speed control of motor Pulse Width Modulation (PWM) is used to produce an output voltage on each terminal that is a proportion of the DC supply voltage by controlling the duty cycle of the top and bottom IGBTs of each half bridge. In fig.4.1, the voltage that appears across the motor winding is the difference between that of two terminals and may be made positive or negative as desired. The pulse frequency, typically 1 KHz, is high enough for the inductance of the motor windings to act as a very effective smoothing choke. The current that flow have a small amount of high frequency ripple but are substantially the same as if they had been derived from a smooth DC source.

As shown in fig.4.1, IGBTs Q2P and Q2N are employed to control the voltage at second output terminal by switching it to either the positive or negative side of the DC supply voltage. IGBT Q3N controls the voltage at a third output terminal. A diode that across the Q3N provides a free wheel path for current entering terminal when Q3N is not conducting.

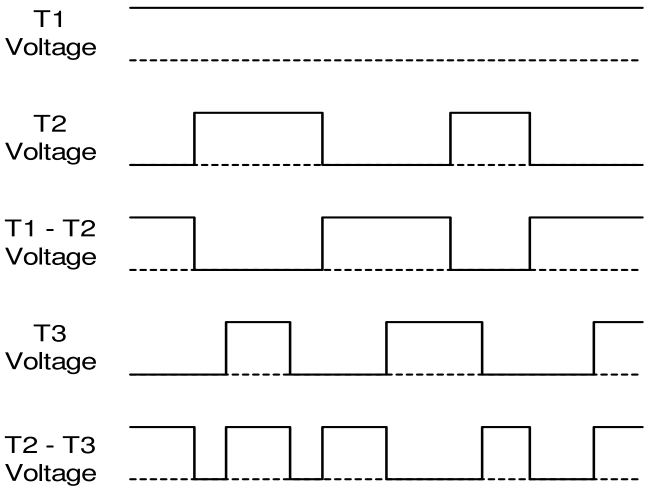


Figure 4.2: Pulse Width Modulation waveforms for hoist

Referring to the fig.4.2, node N1, nodeN2 and node N3 are at the junction of IGBTs pair Q1P/Q1N, Q2P/Q2N and Q3P/Q3N, respectively of the DC/DC converter. When a hoisting operation is about to commence, with the load resting on the floor, the DC/DC controller modulates these three nodes at 50%in order that they are all at the same average DC voltage level, namely 50% of the DC supply voltage. Consequently, there is no current in either the armature or the field of the DC series hoist motor.

To initiate hoisting, the operator moves a master switch of the operator's control panel away from the "OFF" potion to the "RAISE" direction. In response, the DC/DC controller modulates the DC/DC converter to initiate current flow in the direction from node N1, to terminal T1, to point A1, to the armature, and to the point A2 by increasing the voltage at node N1 above 50%V. With node N2 remaining at 50% V and node N3 at less than 50%V, current will then flow in two paths (1) in to terminal T2 to node N2 and (2) into point S1, to field winding, to point S2 and in to terminal T3 to node N3.

The operator than moves a master switch of the operator's control panel to desired speed reference position. In response, the DC/DC converter to cause the DC voltages at all three nodes vary in order to maintain the appropriate armature and field currents corresponding to "series motor" mode operation during which such armature and field currents are equal or by alternate setup to a customized speed-torque profile. At the maximum hoist speed and load, typical node voltages are 100%V, 5%V, and 0%V at nodes N1, N2, and N3, respectively, corresponding to 95% input voltage across the armature and 5% input voltage across the field winding, with the armature and field currents being equal.

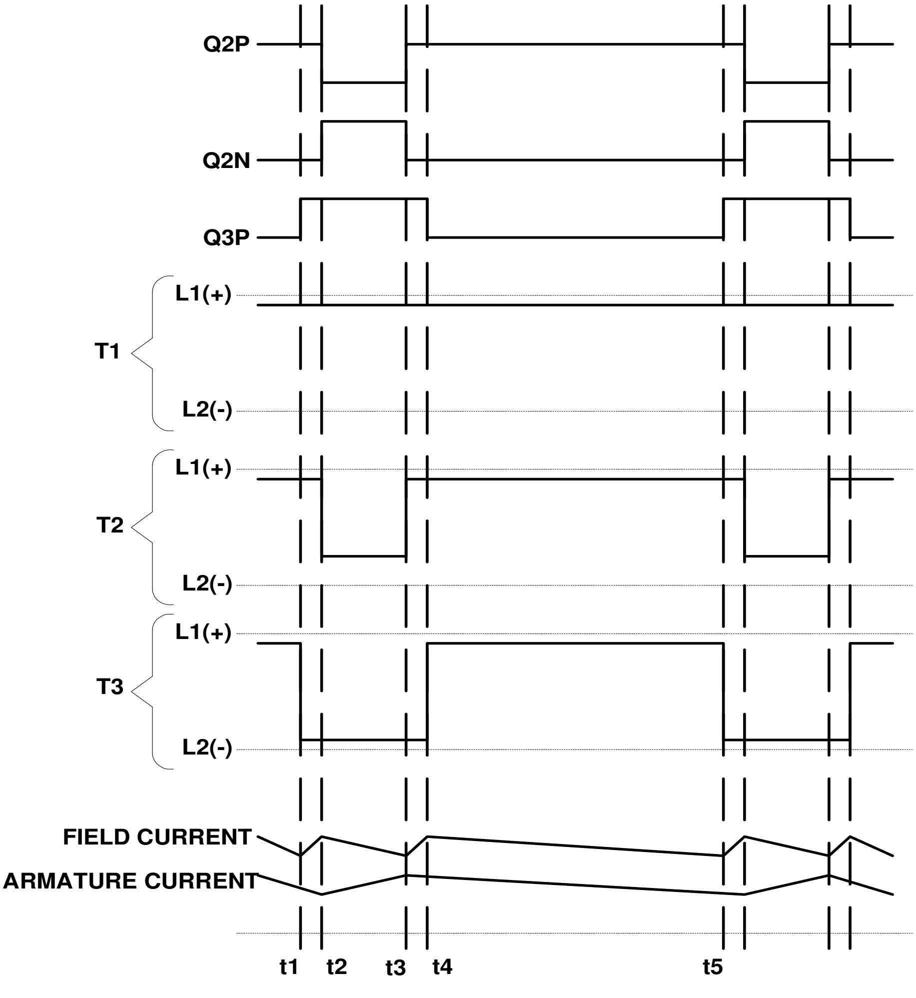


Figure 4.3: Mode of operation for the hoisting motion

Fig.4.3 shows one of the mode for the operation of DC/DC converter of fig. 4.2. This mode allows speed under light load to be limited. In this mode the field current I_F is controlled independently and may be maintain at a higher value or a lower value than the armature current I_A when the need arises. When forward motion is requests IGBT Q1P is ON. IGBT devices Q2P and Q2N are driven by Q2P and Q2N signals respectively of fig.13. IGBT device Q3N is modulated with a suitable duty cycle on Q3N signal of fig.5.1. Node N1 is set to 100%V during this operating mode, thereby, in effect, connecting output terminal T1 to positive DC supply voltage. IGBTs Q2P and Q2N are electronically interlocked through the microprocessor in order that when Q2P is ON Q2N is OFF and vice versa.

This sequence of states permits the mean voltage across the armature to be controlled independently of the mean voltage across the field with the restriction that the sum of the two voltages cannot exceed the positive DC supply voltage. The voltage across the field is not more than a few percent of the positive DC supply voltage. Using this mode of operation, it is possible to achieve hoisting speeds that are less dependent on the load being lifted.

Continuing to refer to fig.4.3, the field current may also be held constant if necessary. This is most advantageous for light load where the difficulty of controlling the speed of a simple series field motor is most pronounced. By maintaining the minimum level of field current, a natural speed limit is reached when the armature voltage V_A approaches to positive DC supply voltage. In other words, the motor cannot over-speed since there always exists a finite and significant field flux even when armature current is very low [4]. When maximum hoisting effort is required, the field current is increased in line with the armature current, but may still be independent controlled so as to modify the torque/speed characteristic of the motor if desire.

Referring to fig.4.4, when a request for the movement in the lowering direction, IGBT Q1N is ON. Terminal T1 is set to 0%V, thereby effectively connecting point A1 to the negative terminal. During power lowering, current flows from output terminalT2 and divides to become partly field current into point S1 and partly armature current in to point A2. IGBT Q2P and diode of that IGBT supply the sum of these two currents. The overall torque capability in this mode is, hence limited by the rating of this two devises, but fortunately, the torque requirement for power lowering is merely that necessary to overcome friction losses which are relatively small. It is, therefore, readily possible to provide sufficient torque for this mode without excessive current in to two devises.

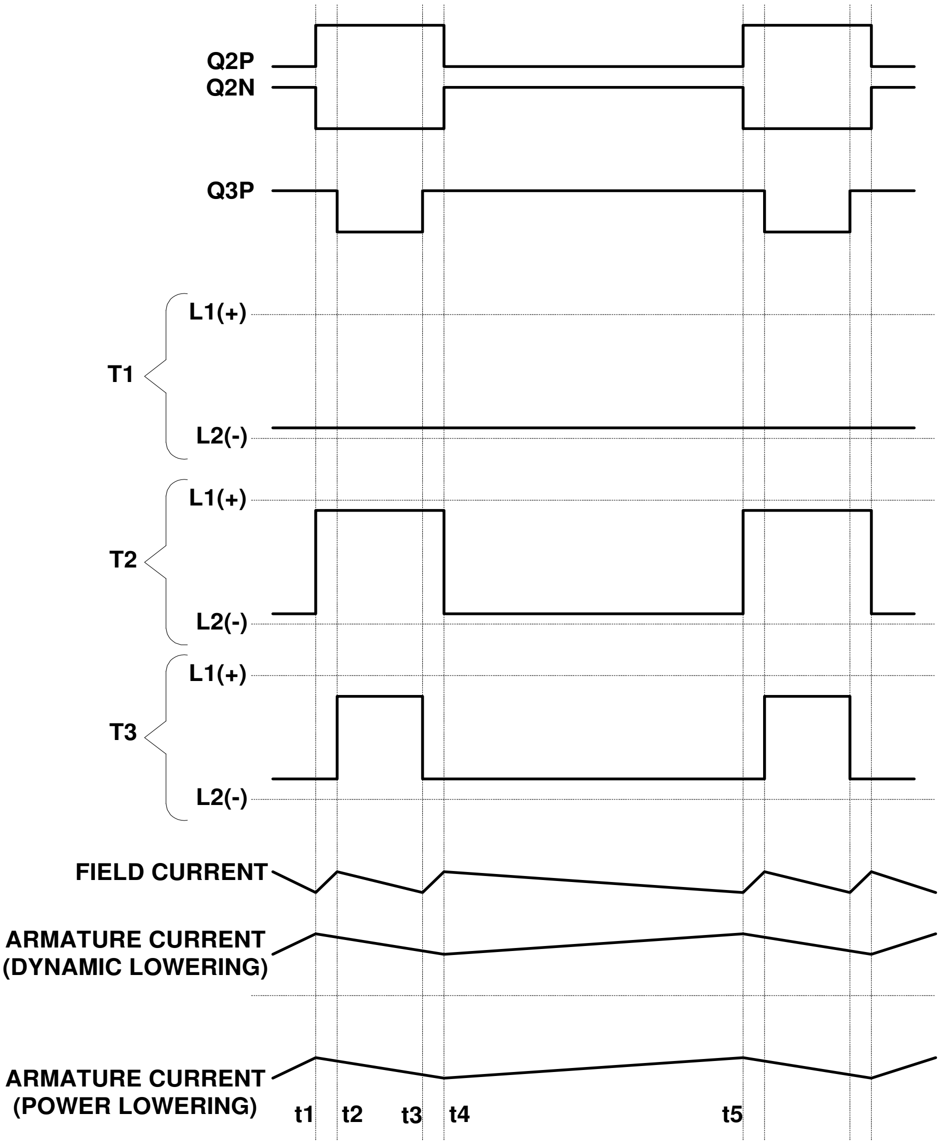


Figure 4.4: Mode of operation for the lowering motion

4.2 Power Circuit for Bridge and Trolley

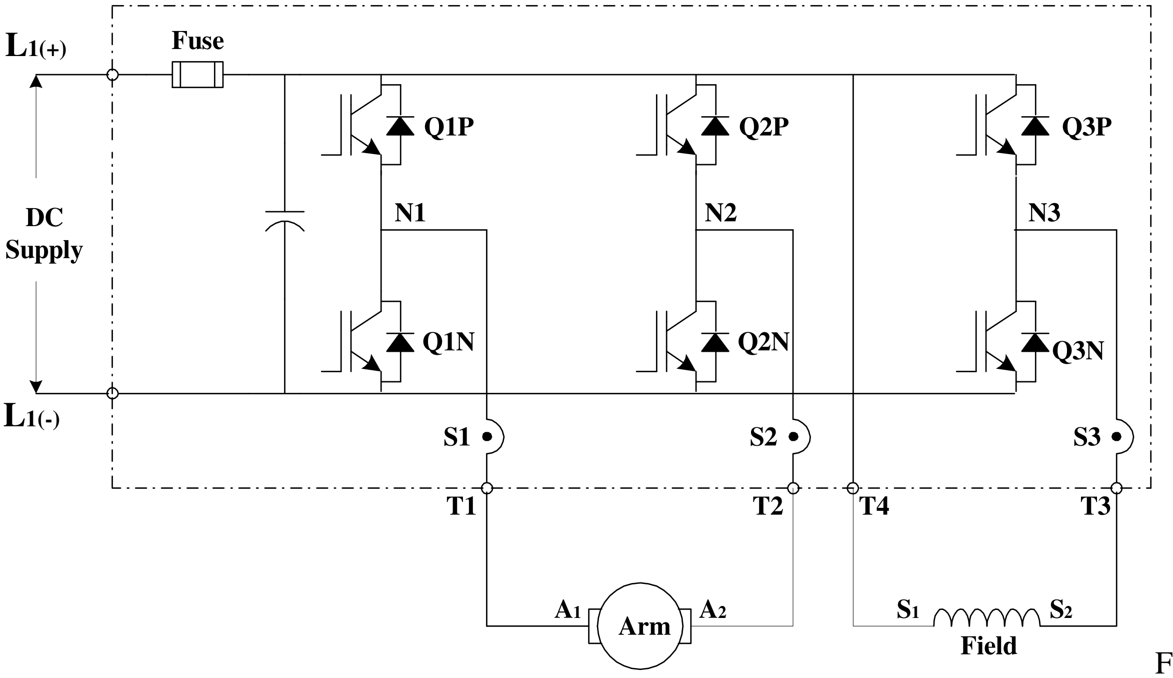


Figure 4.5: Proposed novel technique power circuit for bridge and trolley

Fig.4.5 shows the power topology for the speed control of dc shunt motor for bridge and trolley configuration. By comparing the fig.4.1 with the fig.4.5, in the topology for the hoist configuration the motor shunt field winding is supplied by the T3 and T4 terminal. The motor armature voltage is the difference between the T1 and T2 terminal voltage and motor shunt field voltage is the difference between the T4 and T3 terminal voltage. The close-loop speed controller is same as for the hoist configuration.

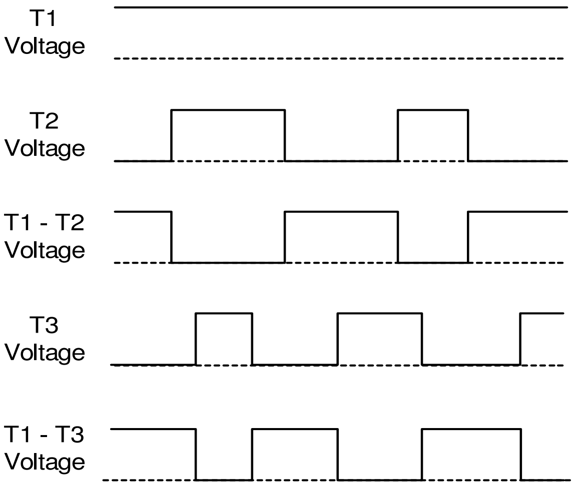


Figure 4.6: Pulse Width Modulation waveforms for bridge and trolley

Fig.4.6 shows the required voltage pattern for the bridge configuration, as shown in fig the voltage across the motor armature is the difference between the T1 terminal voltage and T2 terminal voltage (Va = T1 – T2), and voltage across the motor shunt field winding is the difference between the T4 terminal voltage and T3 terminal voltage (V_f = T4 – T3).

4.3 Close-Loop Controller for the Speed Control

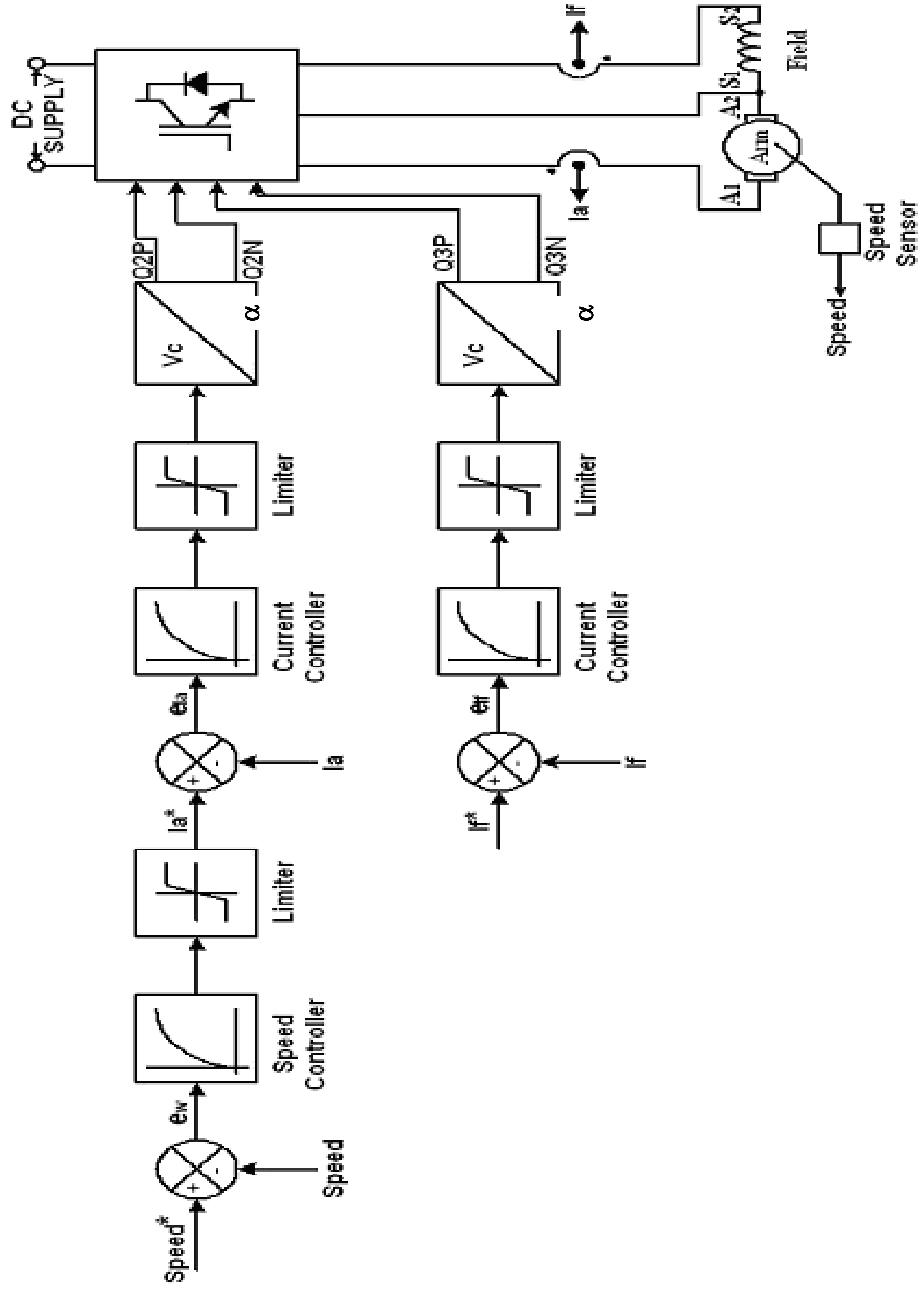


Figure 4.7: Control strategy for the close-loop speed control

This controller includes a nested loop structure including an outer controlling loop for the speed of the dc series motor and two separately controllable inner control loops for the armature and field current of the dc series motor. The operator, through the A/D converter from the continuously variable analog speed response, inputs a suitable speed response. Alternatively, any suitable signal may be input such as, for example, a current signal, a 5-step voltage signal corresponding to 5-steps on the operator's master switch on the operator's control panel. A speed reference signal is input by an acceleration/deceleration control block, the output of which is applied to the positive input of the summing junction. The negative input of summing junction receives an actual speed feedback signal coming from the speed sensor. The output of the summing junction is input by the speed loop (P+I) regulator, which produces the armature current reference Ia*. The current reference signal is applied to the positive input of the summing junction. The negative input of the summing junction receives the armature current value Ia sensed by the current sensor. The output of the summing junction is input by the armature current (P+I) regulator.

For the field current regulation external field current reference current is input to the positive input of the summing junction. The negative input of the summing junction receives the field current value sensed by the current sensor. In turn, the output of the summing junction is input by the field current (P+I) regulator.

The output of armature current (P+I) regulator is applied to the PWM generator and IGBT logic block, which, in turn, drives the IGBT driver block in order to continuously, adjust the appropriate IGBTs to provide suitable armature current to satisfy the required operating conditions.

Similarly, the output of the field current (P+I) regulator is applied to the PWM generator and IGBT logic block, which, in turn drives the IGBT driver block in order to continuously, adjust the appropriate IGBTs to provide suitable field current to satisfy the required operating conditions.

In response to the applied sped reference signal provided by the operator, the controller responds by continuously adjusting the duty cycles of the IGBTs Q2P, Q2N, Q3P, Q3N in order to operate the motor at the speed desired within the constrains of the maximum capability of the system. A nested loop structure is employed including the outer speed loop.

CHAPTER: - 5

SIMULATION OF THE PROPOSED TECHNIQUE

5.1 Simulation for Hoist Configuration

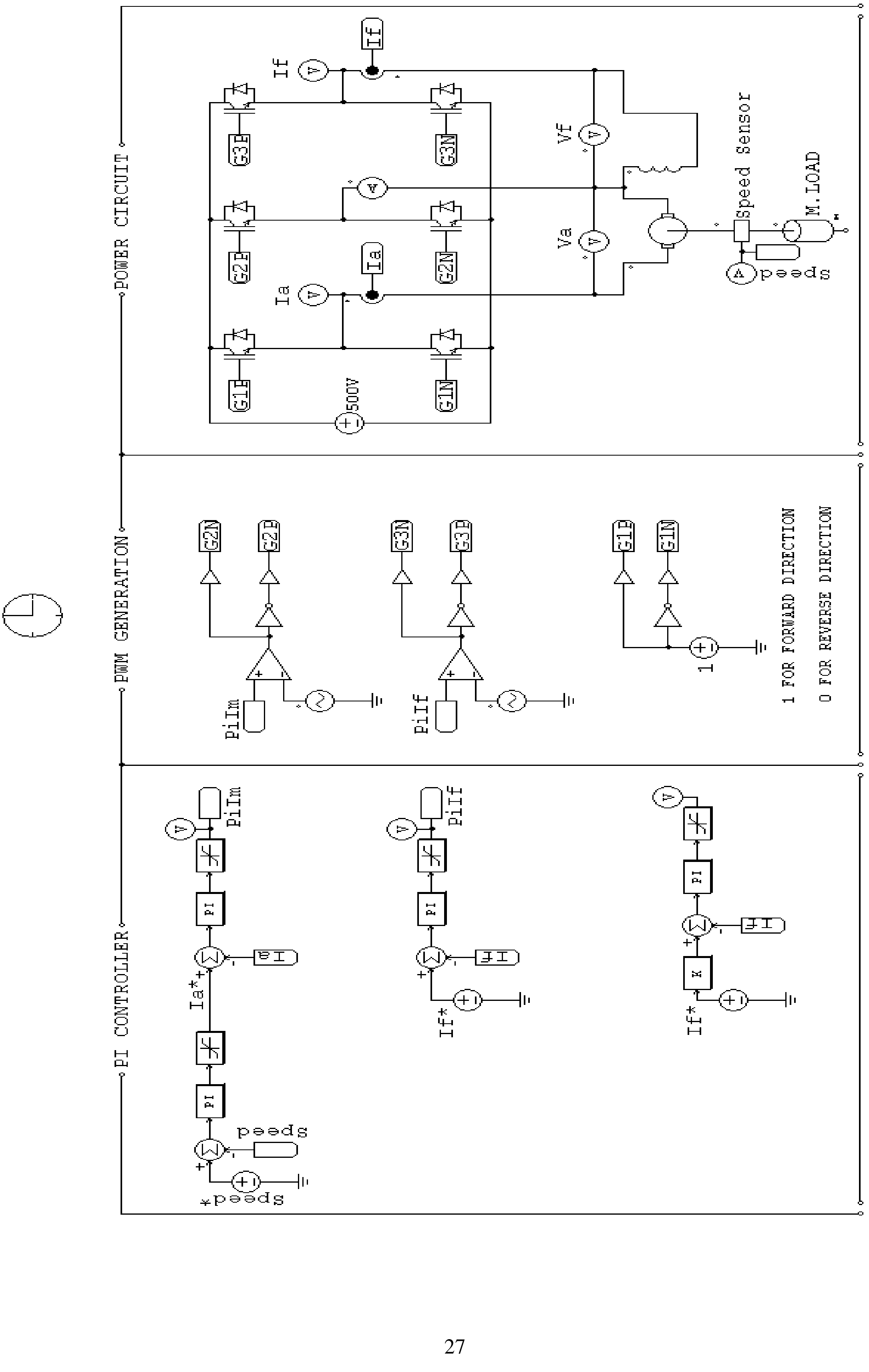


Figure 5.1: Simulation circuit for hoist configuration

Fig.5.1 shows the power schematic for the close-loop speed control of the dc series motor with the PWM generation logic and the PI controller. This power schematic is simulated on the Psim software tool with DC series motor with the rated voltage of 500Vdc, current of 10Adc, and speed of 1200rpm. The value of the armature resistance Ra = 0.5Ω, Rf = 1Ω, La = 2mH, and Lf = 2mH. For the power topology IGBTs are used as switching devices with the switching frequency of 1KHz. PWM technique is used for the switching of IGBTs. The control circuit for the power topology, this includes the speed loop PI controller, armature current control PI controller and field current PI controller to regulate the speed at the reference speed.

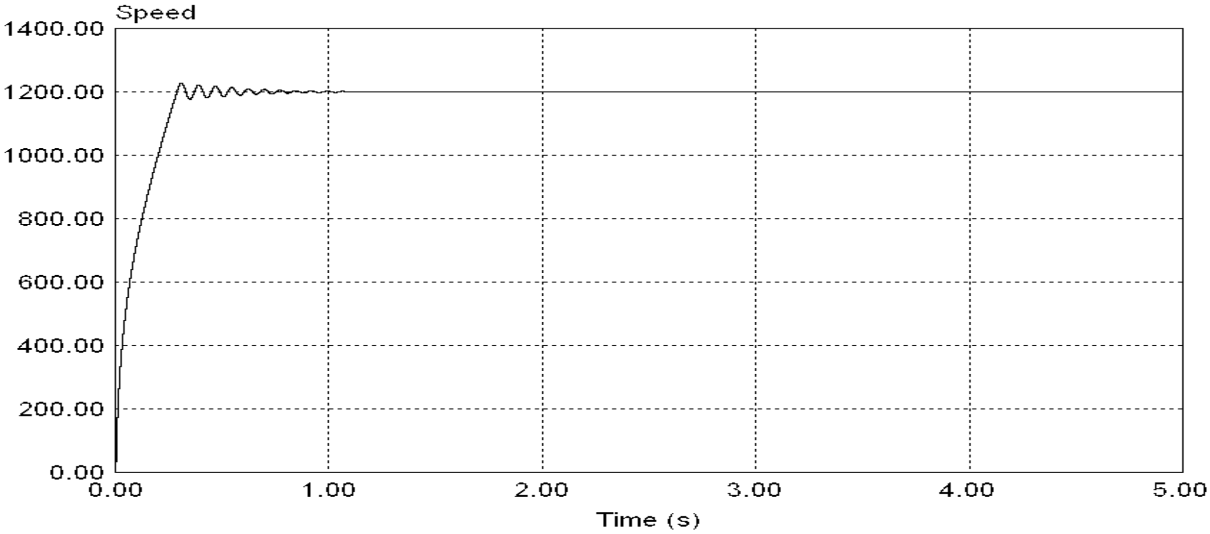
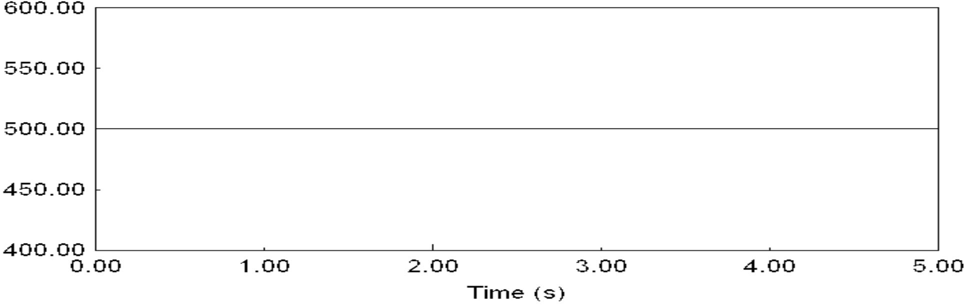


Figure 5.2: Speed of the motor with 1200-rpm reference

Scale: X-axis 1block = 1Sec.

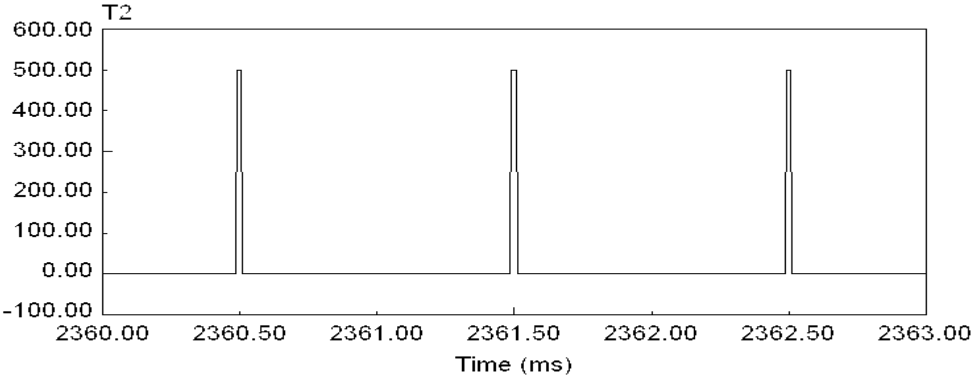
Y-axis 1block = 200rpm

Fig. 5.2 shows the speed of the motor in rpm at the no load when the reference speed is set to 1200rpm, as shown in fig. 8 motor speed sets at the reference speed very fast which proves the fast dynamic response of the motor during the hoisting motion.



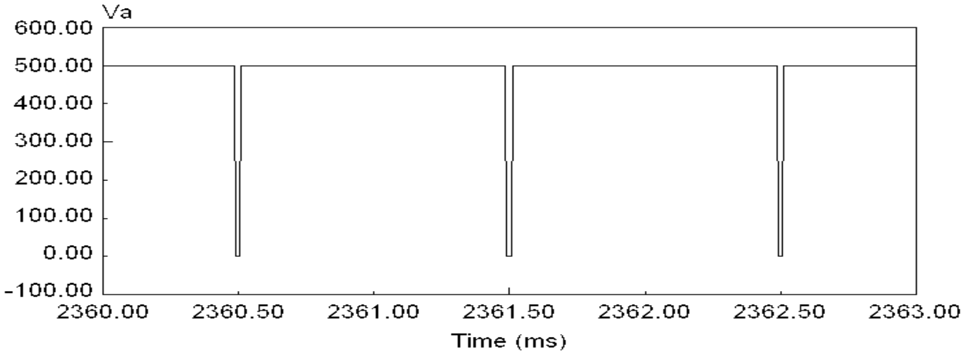
(a). T1 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = 50V



(b). T2 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

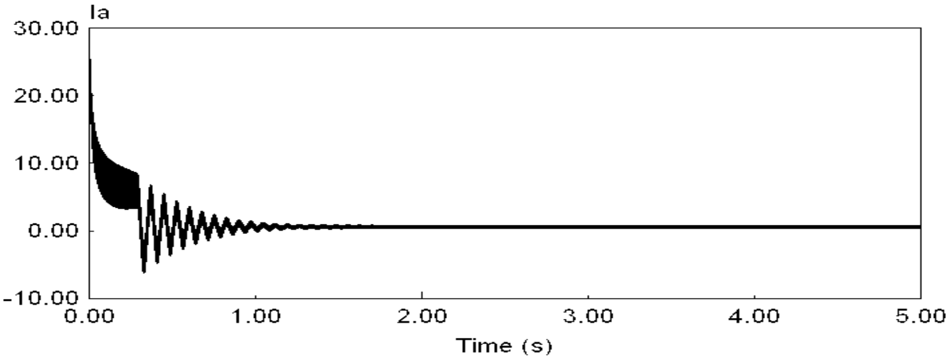


(c). Voltage across armature

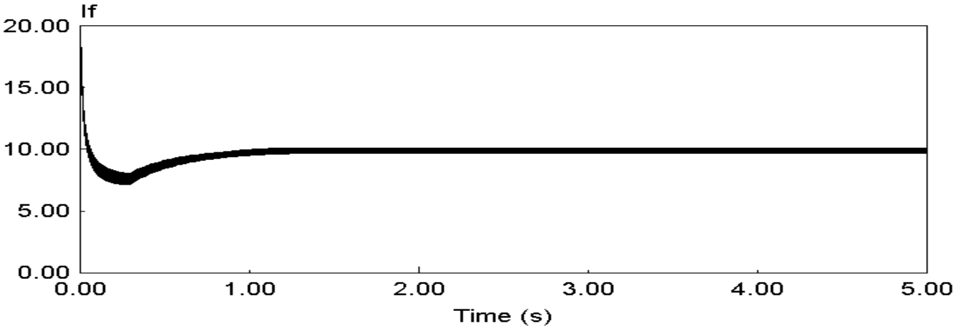
Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

Figure 5.3: Armature voltage waveform for 1200rpm

Fig.5.3 shows the voltage pattern for the maximum speed and it also shows the voltage across the armature (c) is the difference between the (a) T1 terminal voltage and (b) T2 terminal voltage. And at the maximum speed, maximum voltage is available across the armature of the series motor. Because during this reference speed maximum modulation of the switches occurs.



(a). Armature current
Scale: X-axis 1block = 1Sec, Y-axis 1block = 10A

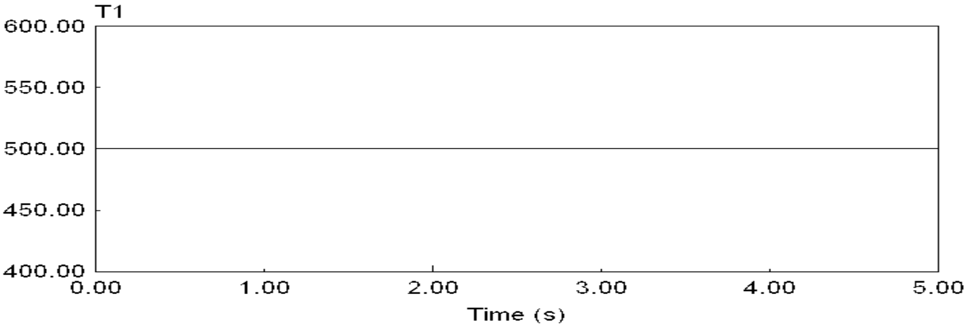


(b). Field current

Scale: X-axis 1block = 1Sec, Y-axis 1block = 5A

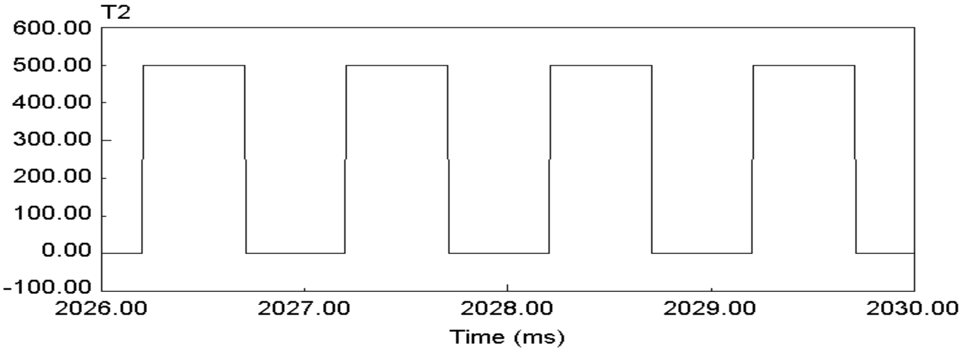
Figure 5.4: Armature and Field current waveforms for 1200RPM

Fig.5.4 shows the armature (a) and field (b) current at the maximum speed and it shows that both the currents are independent with each other, so both the current can control independently. In the fig armature current shows very low because motor operates on no-load and as load increases armature current will increases.



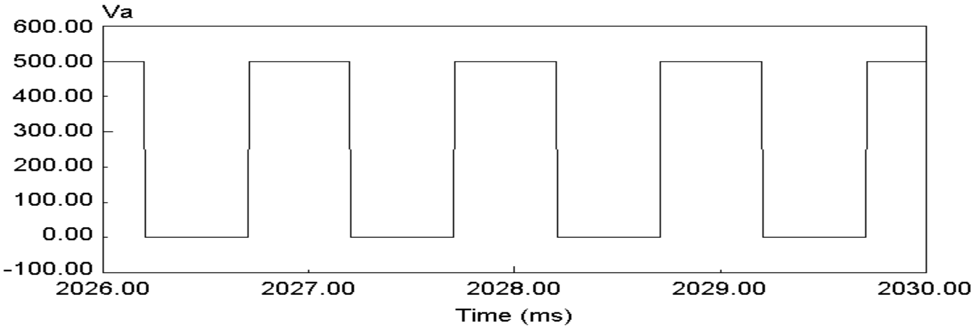
(a). T1 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = 50V



(b). T2 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

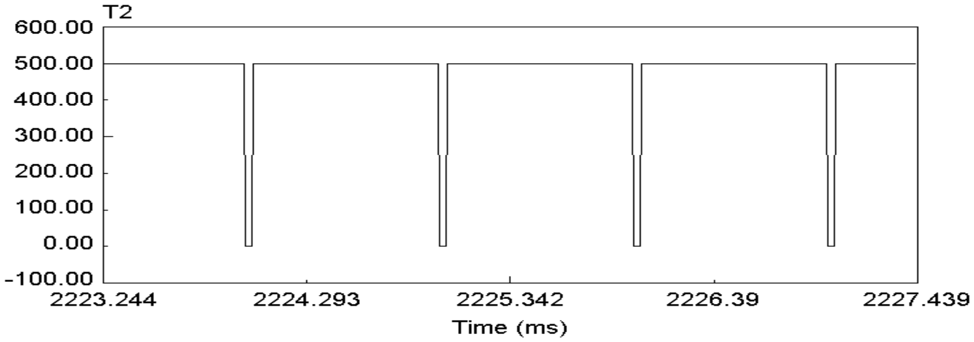


(c). Voltage across armature

Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

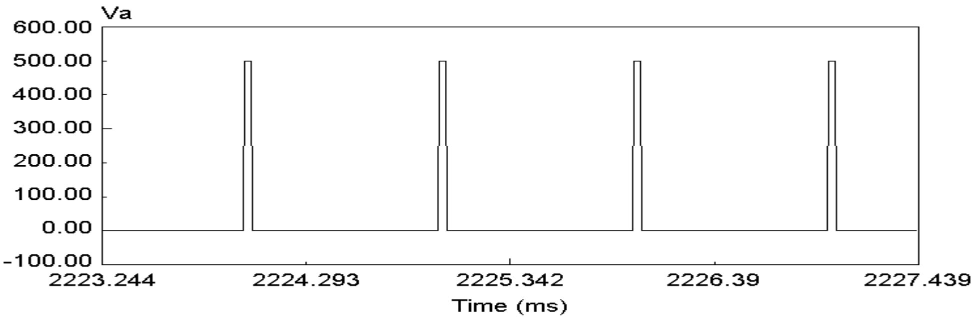
Figure 5.5: Armature voltage waveform for 600rpm

Fig. 5.5 shows the voltage pattern for the half speed reference, it shows that as reference speed decreases width of the T2 terminal voltage (a) waveform increases and the difference between the T1 and T2 terminal voltage decreases and as a result voltage across the armature (c) decreases, this shows that this follows the same pattern as discussed in the fig.4.2. At this speed also the field current is same as the maximum range and armature current is reduced.



(a). T2 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

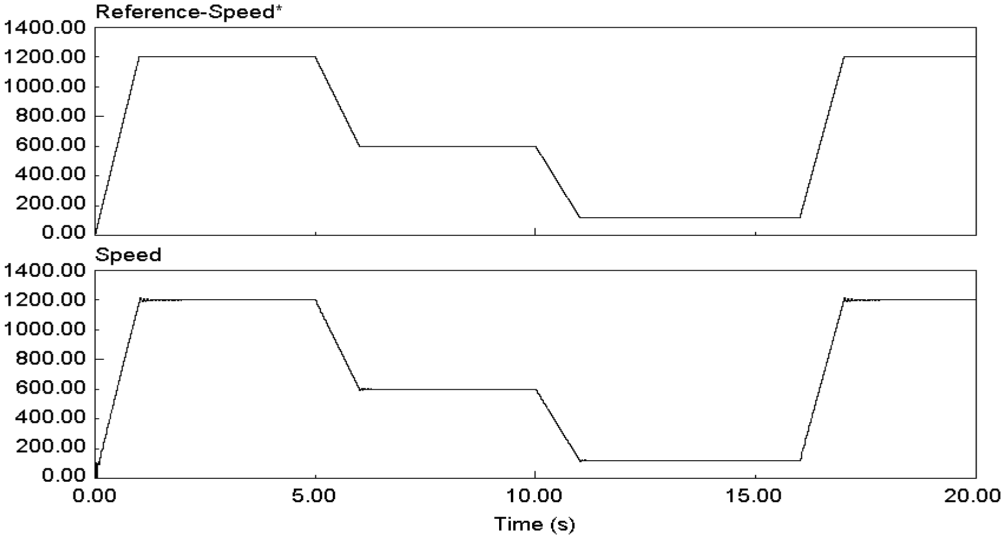


(b). Voltage across armature

Scale: X-axis 1block = 1Sec, Y-axis 1block = 100V

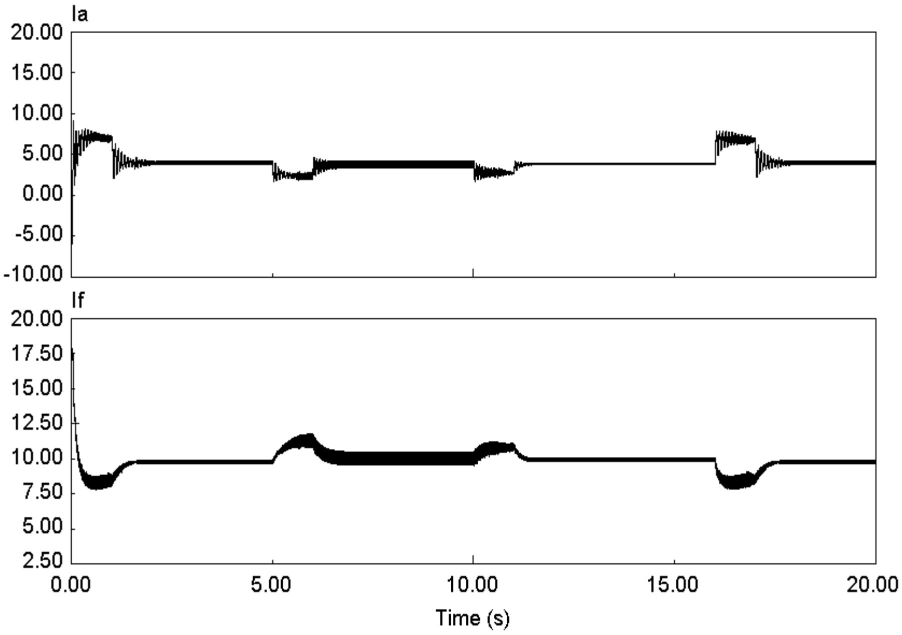
Figure 5.6: Armature voltage waveform for 50rpm

Fig.5.6 shows the armature voltage waveforms for the 50rpm speed condition and it shows that at this speed very low voltage is available across the armature (b) and maximum modulation is there for the T2 terminal voltage (a).



(a). Actual motor speed at different reference speed

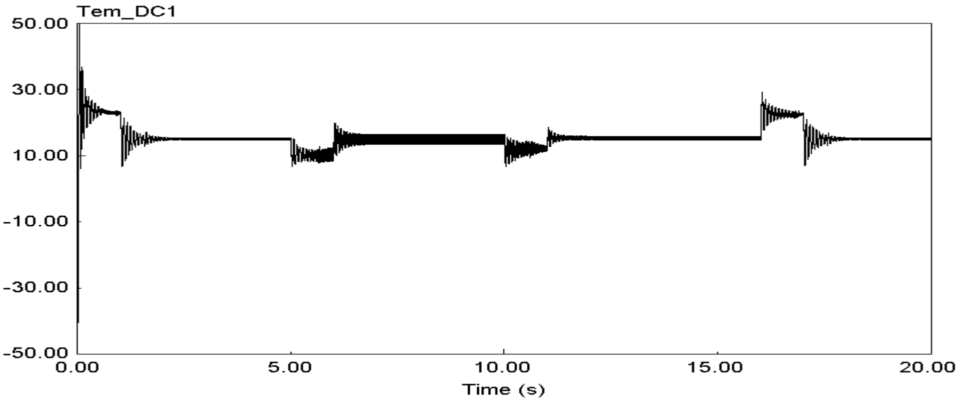
Scale: X-axis 1block = 1Sec, Y-axis 1block = 200rpm



(b). Armature and Field current at different ref. Speed

Scale for Ia: X-axis 1block = 1Sec, Y-axis 1block = 5A

Scale for If: X-axis 1block = 1Sec, Y-axis 1block = 2.5A



(c). Generated motor torque at 15N-m load torque

Scale: X-axis 1block = 1Sec, Y-axis 1block = 20N-m

Figure 5.7: Motor Response at 15N-m load with different Reference Speed

Fig. 5.7 shows the motor response for the different reference speed condition with the constant 15 N-m load torque and it shows in fig.5.7 (c) that motor can generate the same motor torque at any speed position and is also shows that motor armature current increases as the load torque increases and field current remains constant for the entire speed range. Fig. 5.7 (a) shows the actual speed of the motor which follows the reference speed signal as in fig. 5.7 (b); it shows the dynamic response of the motor which is very fast for the minimum to the maximum speed.

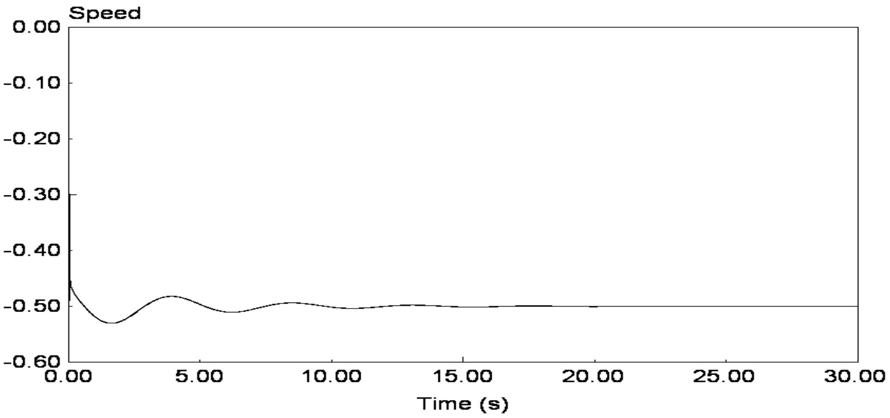
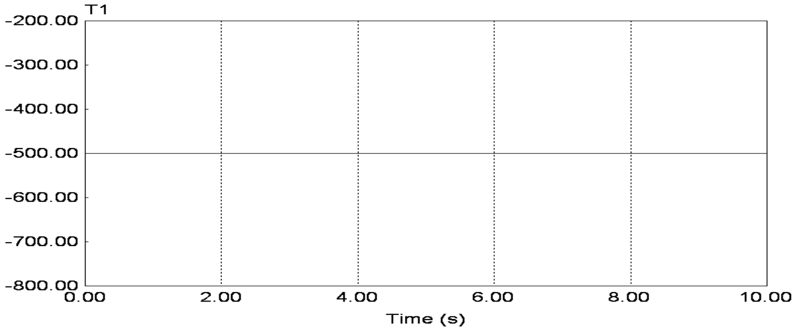


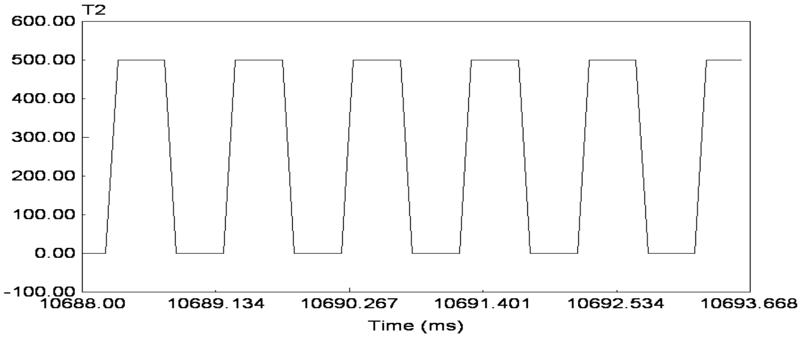
Figure 5.8: Speed of the motor with -600RPM reference
(For the Reverse Direction)

Fig.5.8 shows the speed of the motor in the reverse direction for that -600rpm is given as a reference speed here in the fig.14 shows the speed as -0.5 means the gain of the speed sensor is set the [1/1200] so the actual speed of the motor is [-0.52*1200]. Fig shows that, proposed topology also works with the same response in the reverse direction. This speed response is shown for the no-load condition.



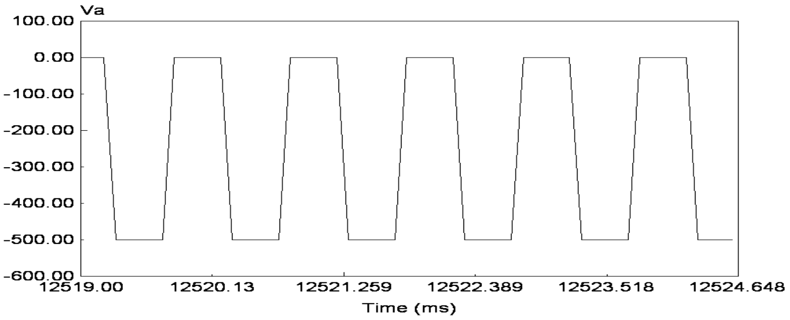
(a). T1 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = -100V



(b). T2 Terminal voltage

Scale: X-axis 1block = 1Sec, Y-axis 1block = -100V



(c). Voltage across Armature

Scale: X-axis 1block = 1Sec, Y-axis 1block = -100V

Figure 5.9: Armature voltage waveform for -600rpm

Fig. 5.9 shows the voltage pattern for the -600rpm reference speed and it also shows the voltage across the armature (c) is the difference between the (a) T1 terminal voltage and (b) T2 terminal voltage. In this mode of operation the switch Q1N is turn on so -500V is available at the terminal T1 as in the fig.5.9 (a).

5.2 Simulation for Bridge & Trolley Configuration

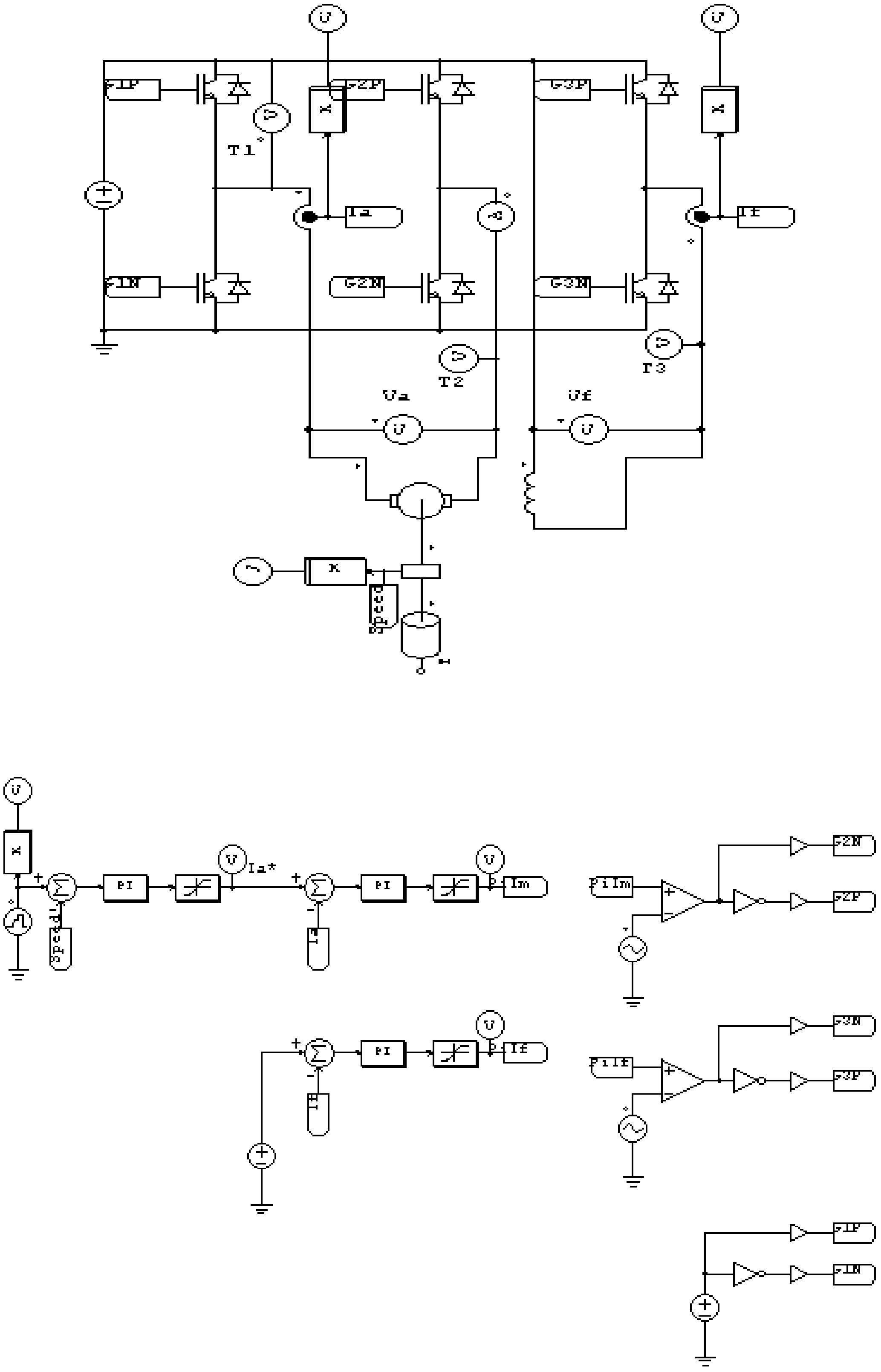


Figure 5.10: Simulation circuit for bridge and trolley configuration

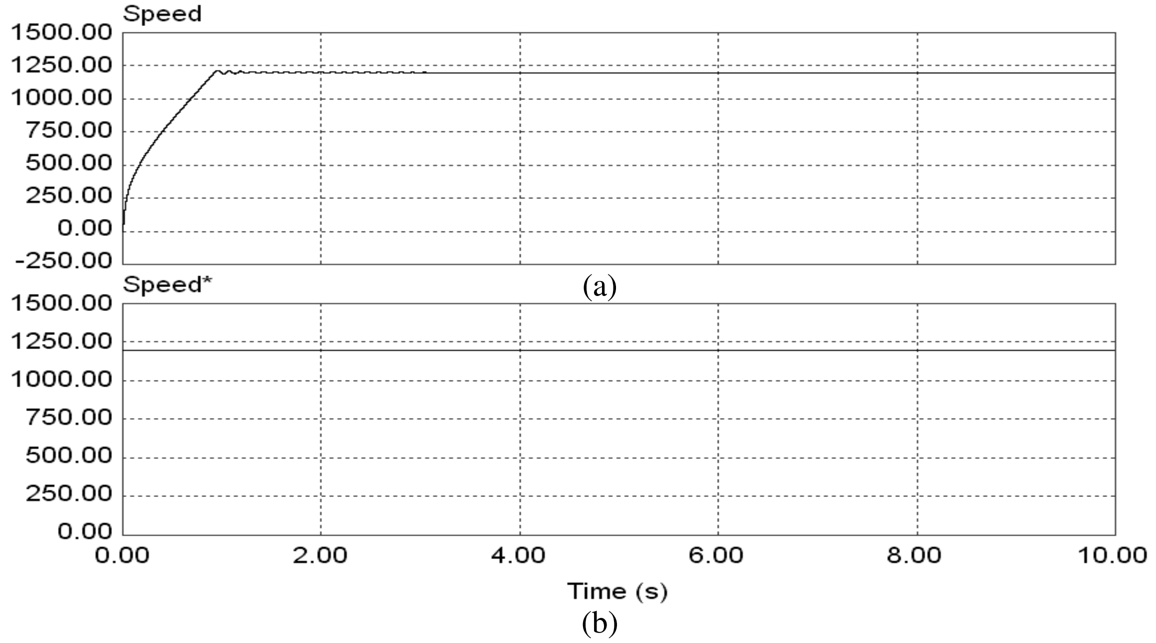


Figure 5.11: (a) Actual motor speed (b) 1200RPM reference speed

Fig. 5.11 shows the speed of the motor in rpm at the no load when the reference speed is set to 1200rpm.

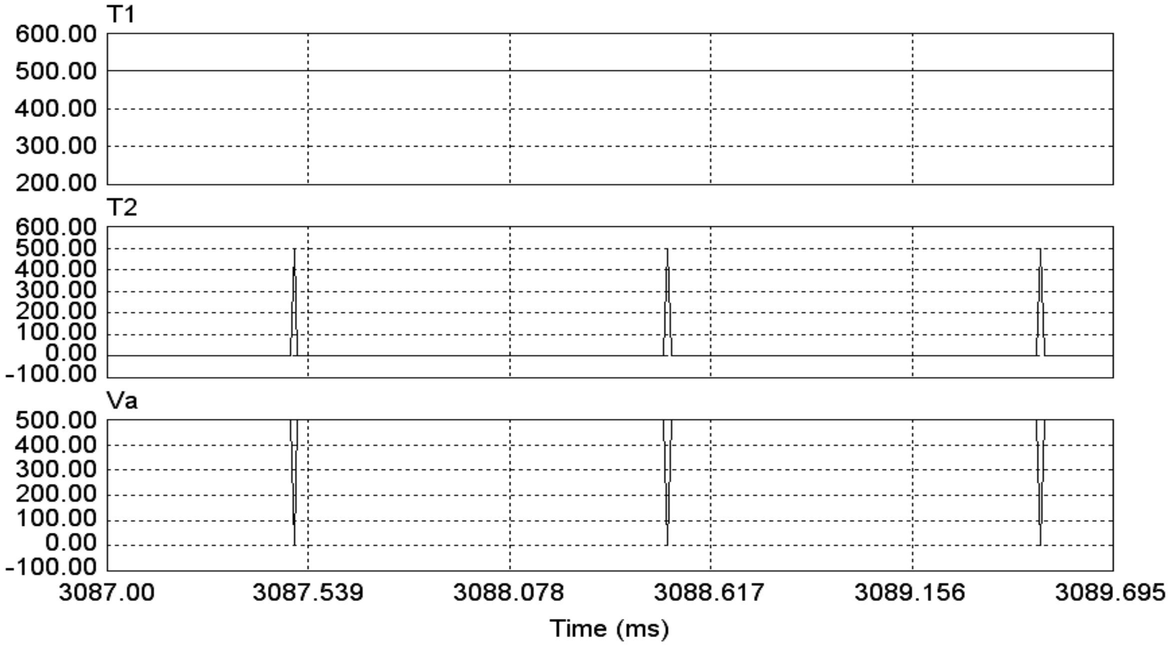


Figure 5.12: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

Fig. 5.12 shows the voltage pattern generated using the given power topology for the 1200rpm reference speed. As discussed in the basic concept of the topology the Voltage across the armature (c) is the difference between the T1 terminal voltage and the T2 terminal voltage.

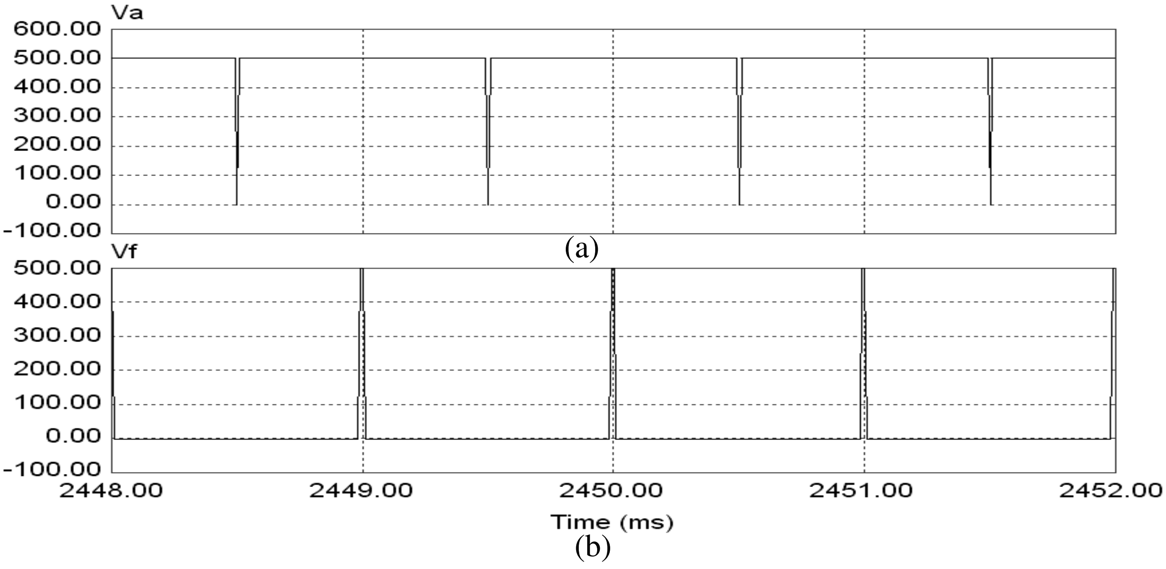


Figure 5.13: (a) Armature voltage (b) Field voltage

Fig. 5.13 shows the armature and field voltage waveforms for the 1200rpm reference speed as in stated in the concept of the topology for the fixed field current reference only 2 to 4 % of the armature current and as in the fig. the average value of the armature current is 480V and the field voltage is 10V, which is the 2.08% of the armature voltage.

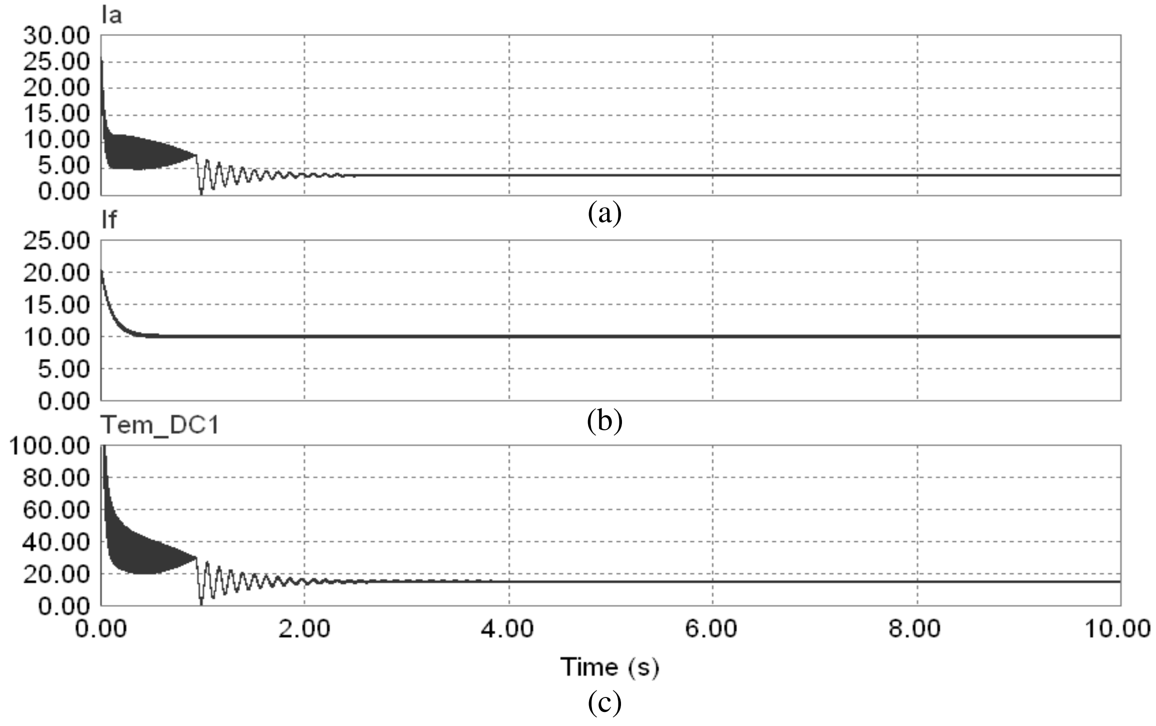


Figure 5.14: (a) Armature current (b) Field current (c) Generated motor torque

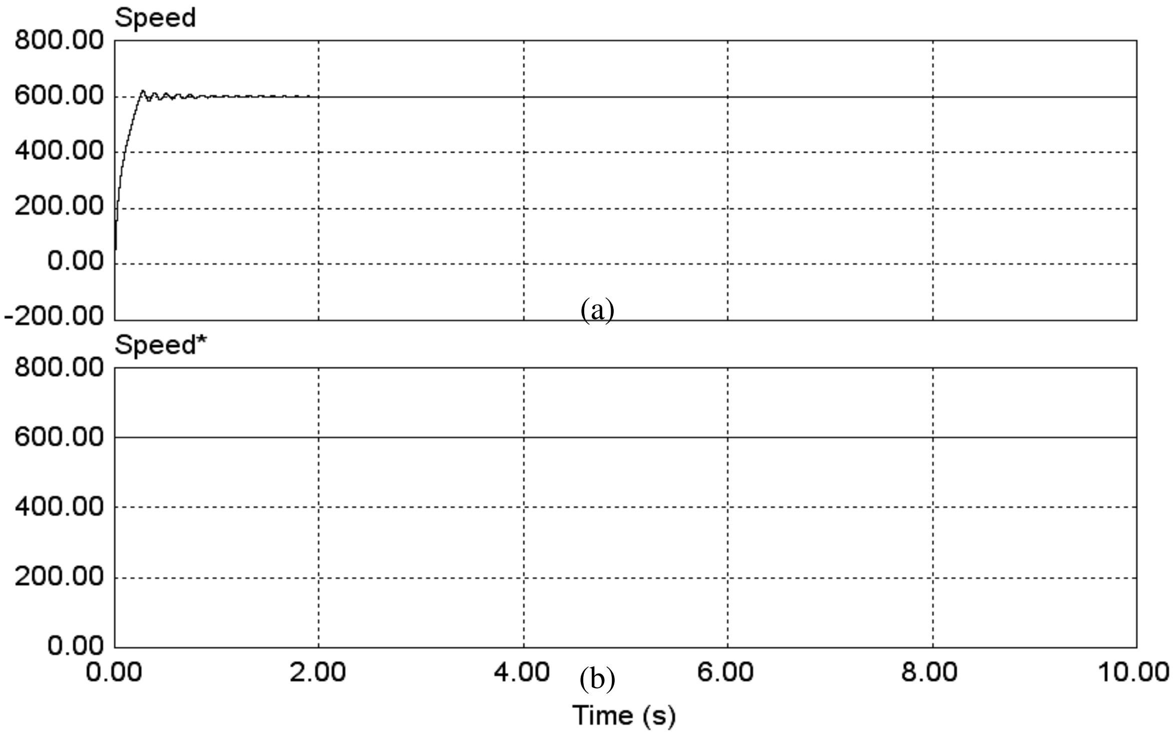


Figure 5.15: (a) Actual motor speed (b) 600RPM reference speed

Fig. 5.15 shows the speed of the motor in rpm at the no load when the reference speed is set to 600rpm.

Figure 5.16: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

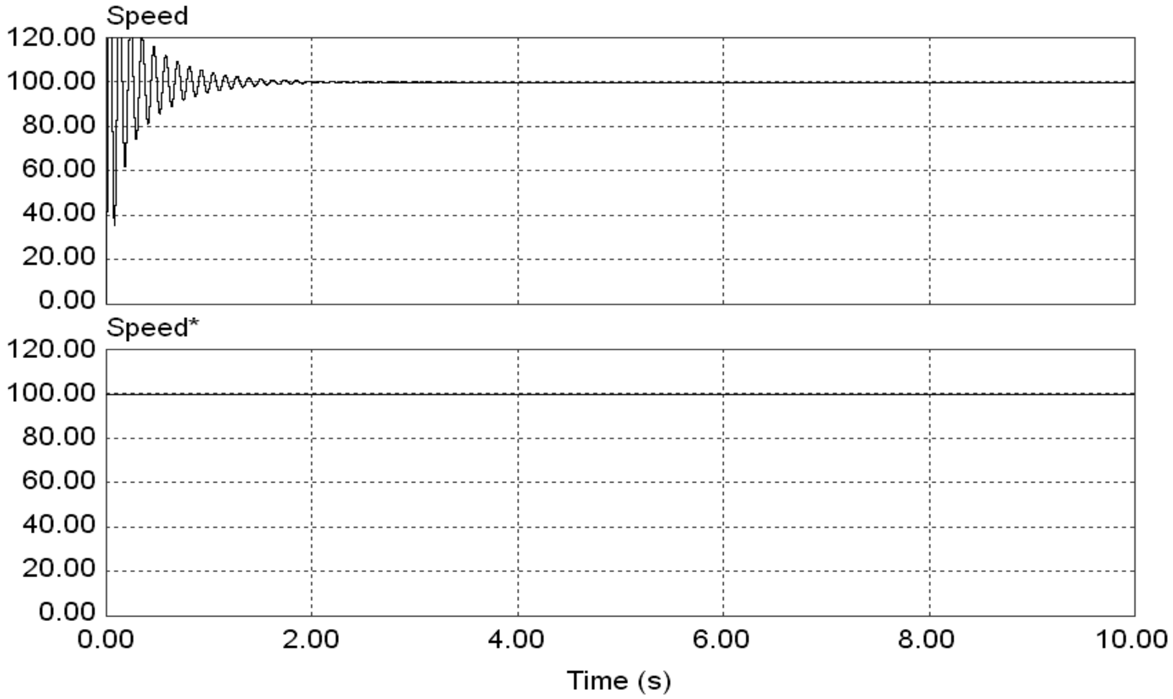


Figure 5.17: (a) Actual motor speed (b) 100RPM reference speed

Fig. 5.17 shows the speed of the motor in rpm at the no load when the reference speed is set to 100rpm.

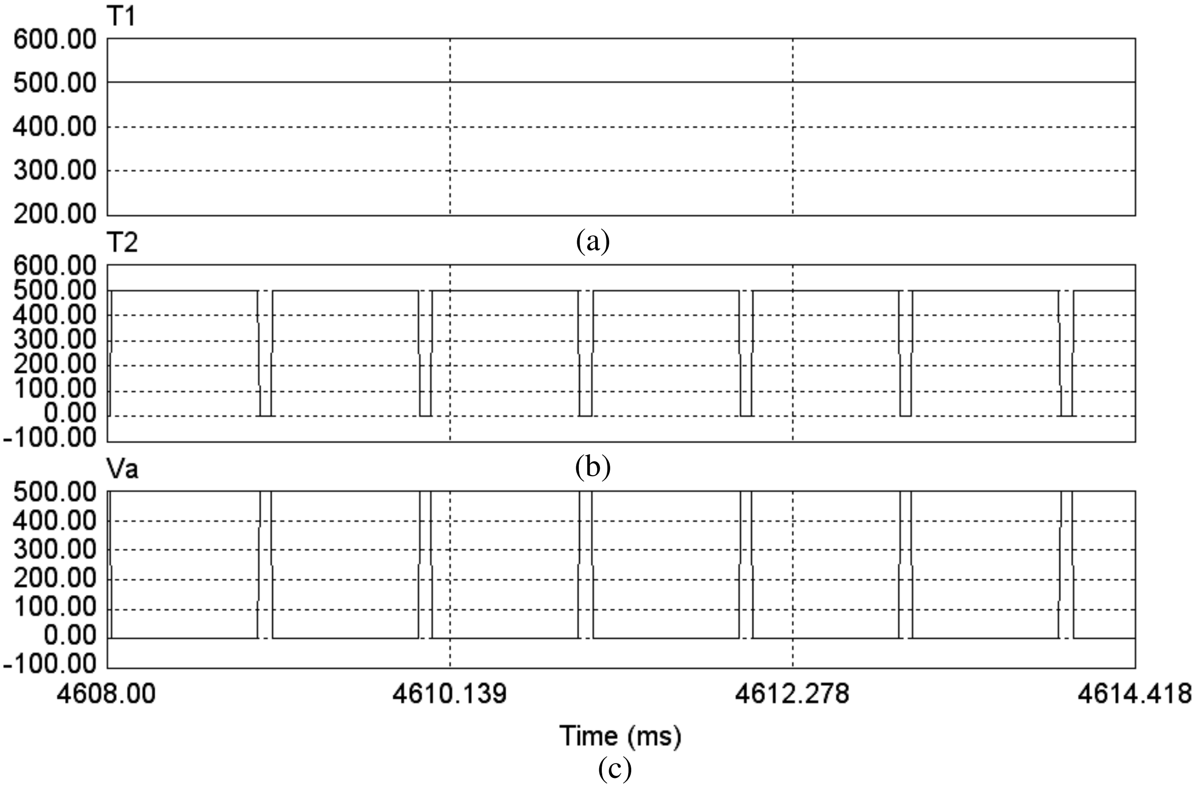


Figure 5.18: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

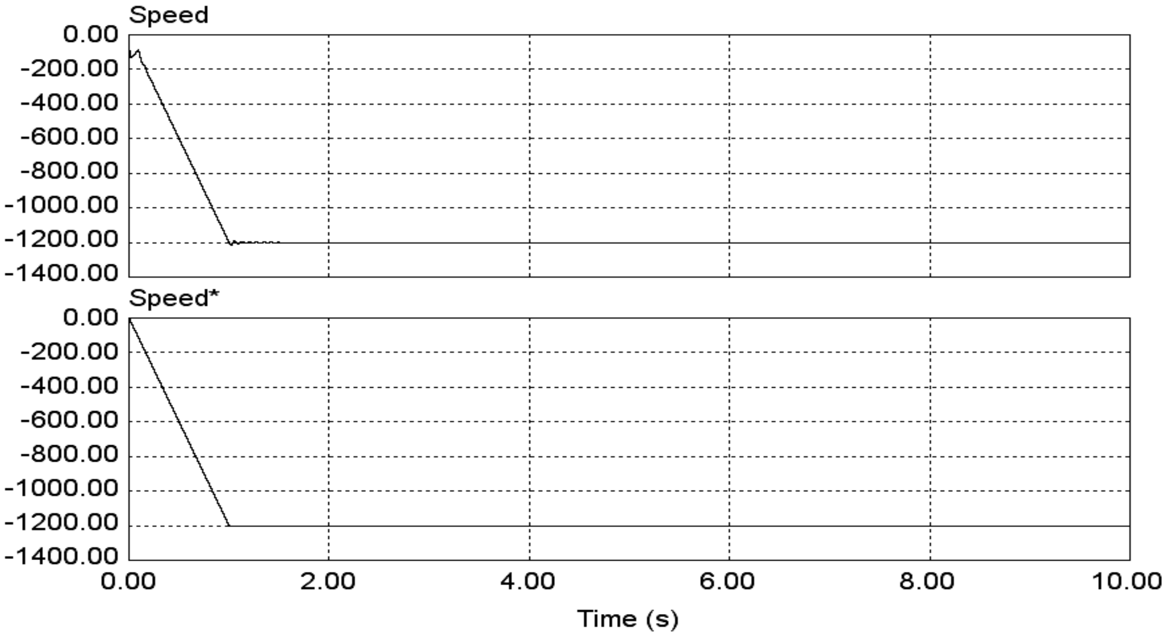


Figure 5.19: (a) Actual motor speed (b) -1200RPM reference speed

Fig. 5.19 shows the speed of the motor in rpm at the no load when the reference speed is set to -1200rpm.

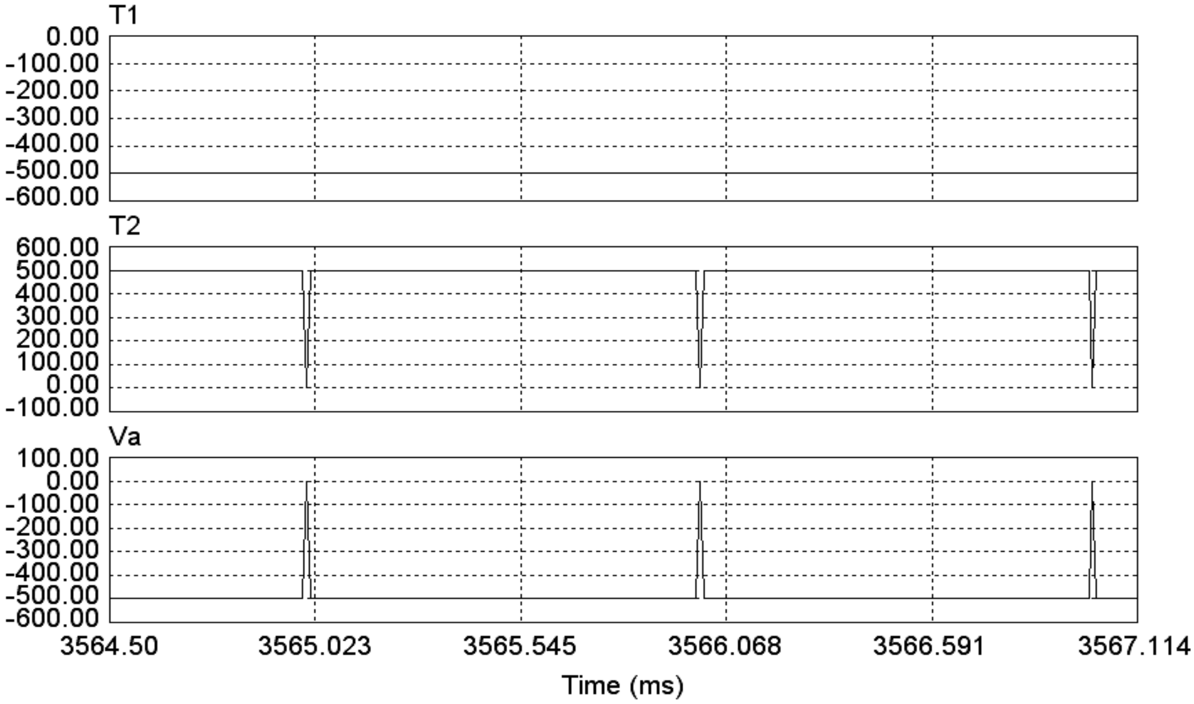
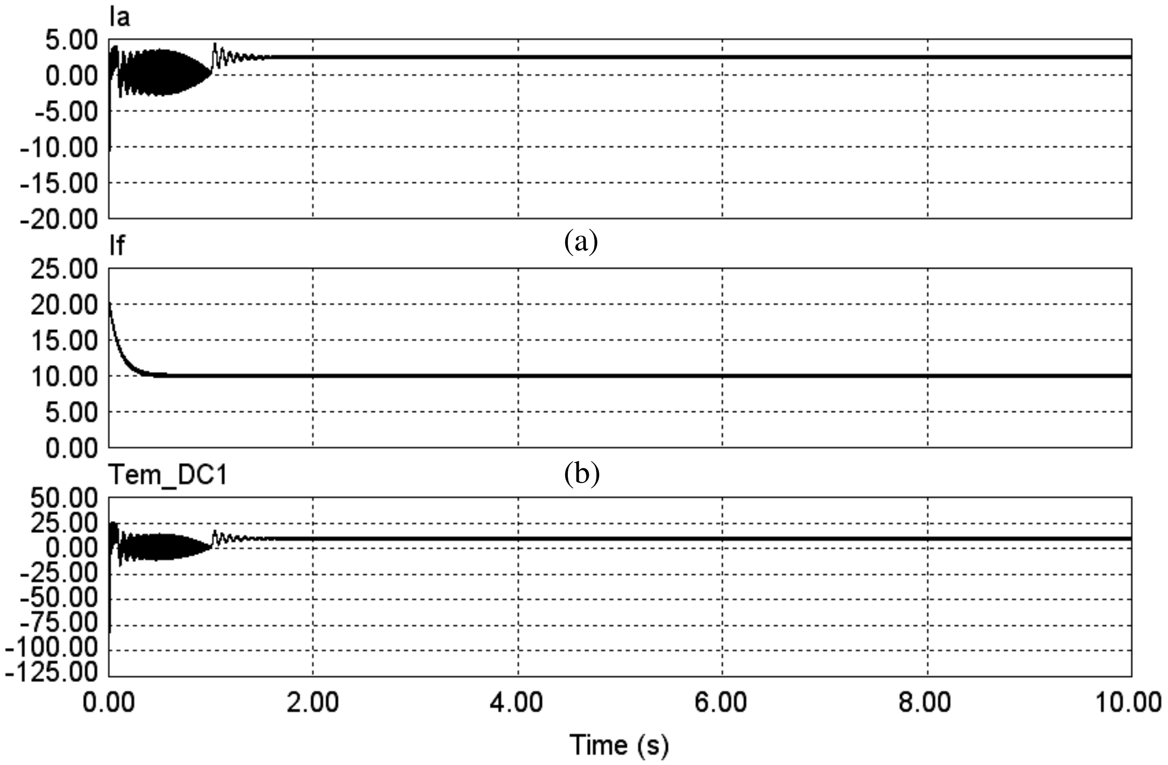


Figure 5.20: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

In this mode of operation for the speed reversal voltage across the armature must be reverse so for that the T1 terminal voltage is made at –500V and the T2 terminal voltage in modulated as same in the forward direction, so the difference between the T1 terminal voltage and T2 terminal voltage becomes –ve, that voltage is applied across the motor armature for the reverse speed. As shown in fig. 5.20 for the 1200rpm reference speed the voltage across the armature in the maximum in the reverse direction.



(a)

(b)

(c)

Figure 5.21: (a) Armature current (b) Field current (c) Generated motor torque

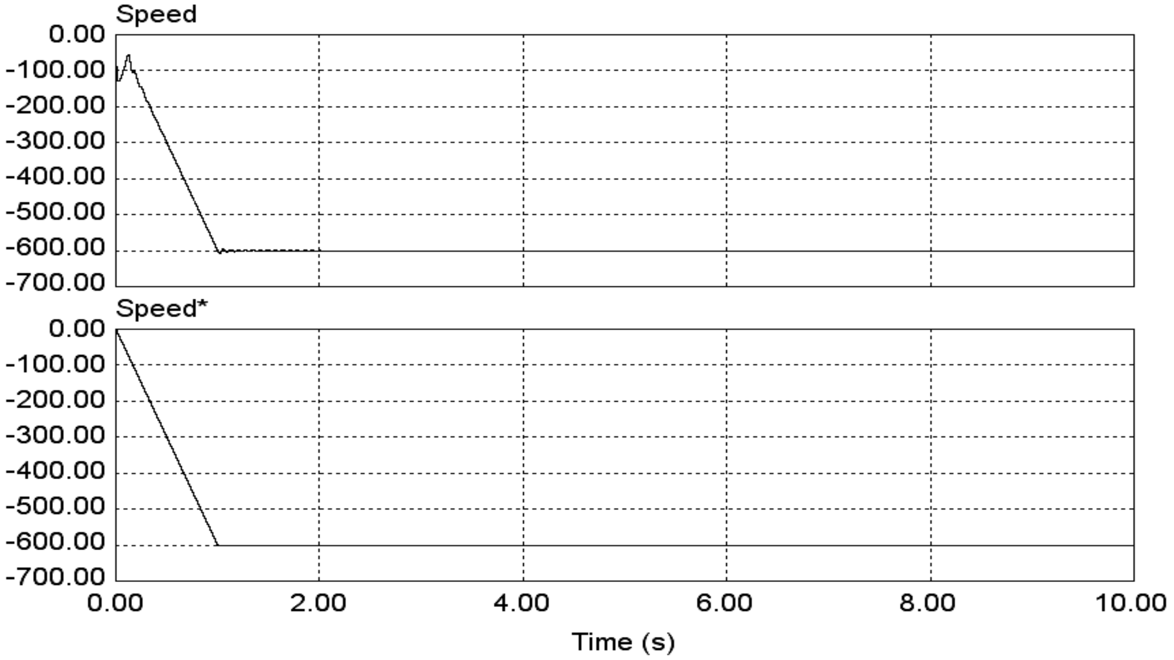


Figure 5.22: (a) Actual motor speed (b) -600RPM reference speed

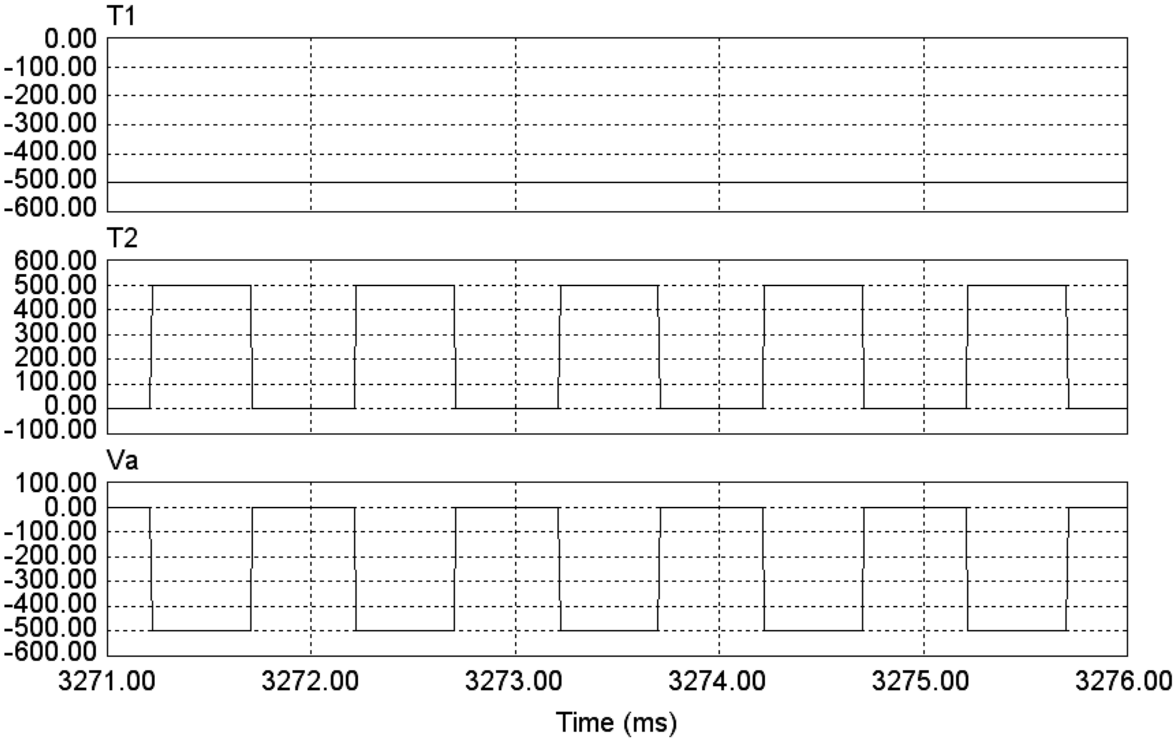
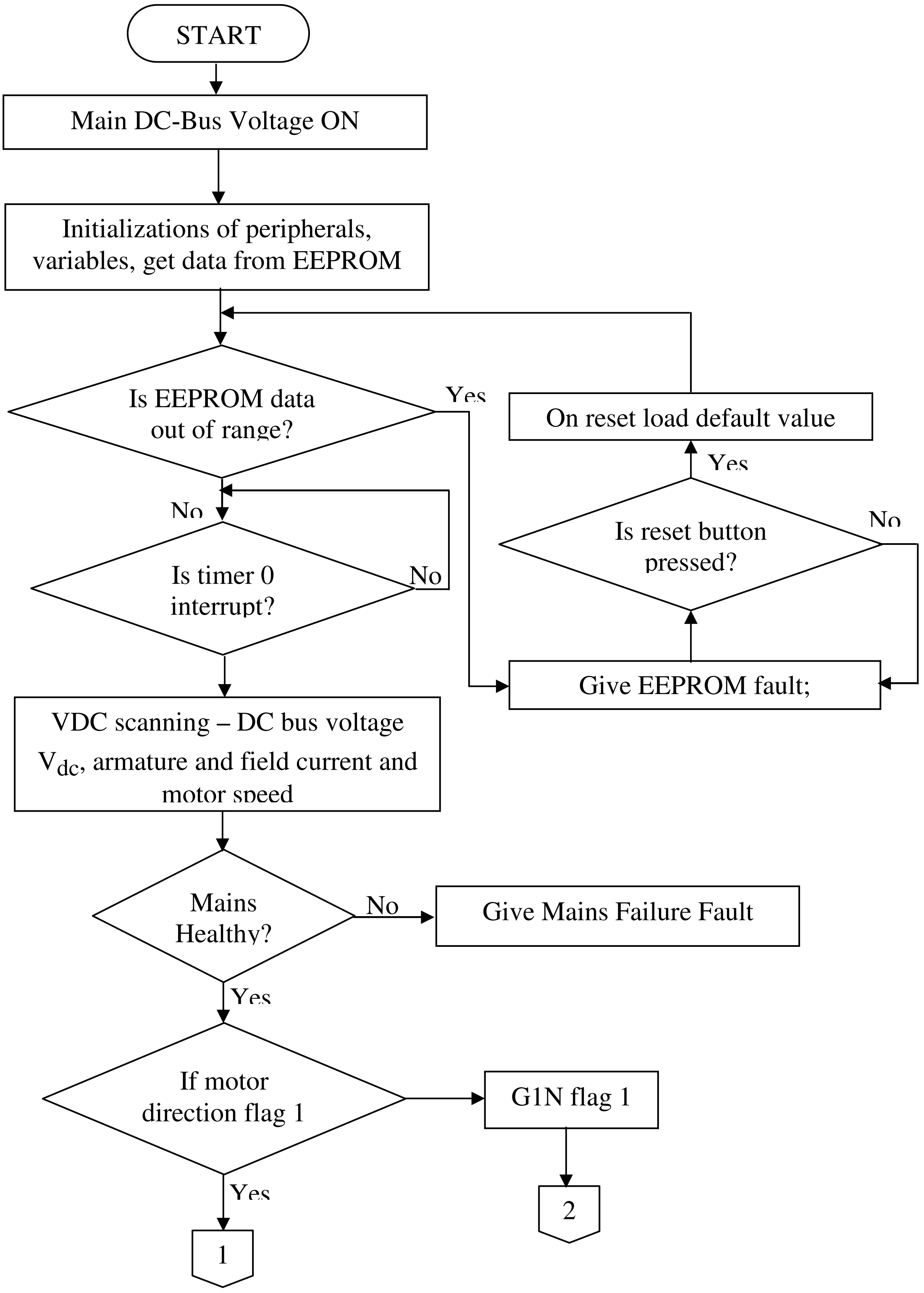


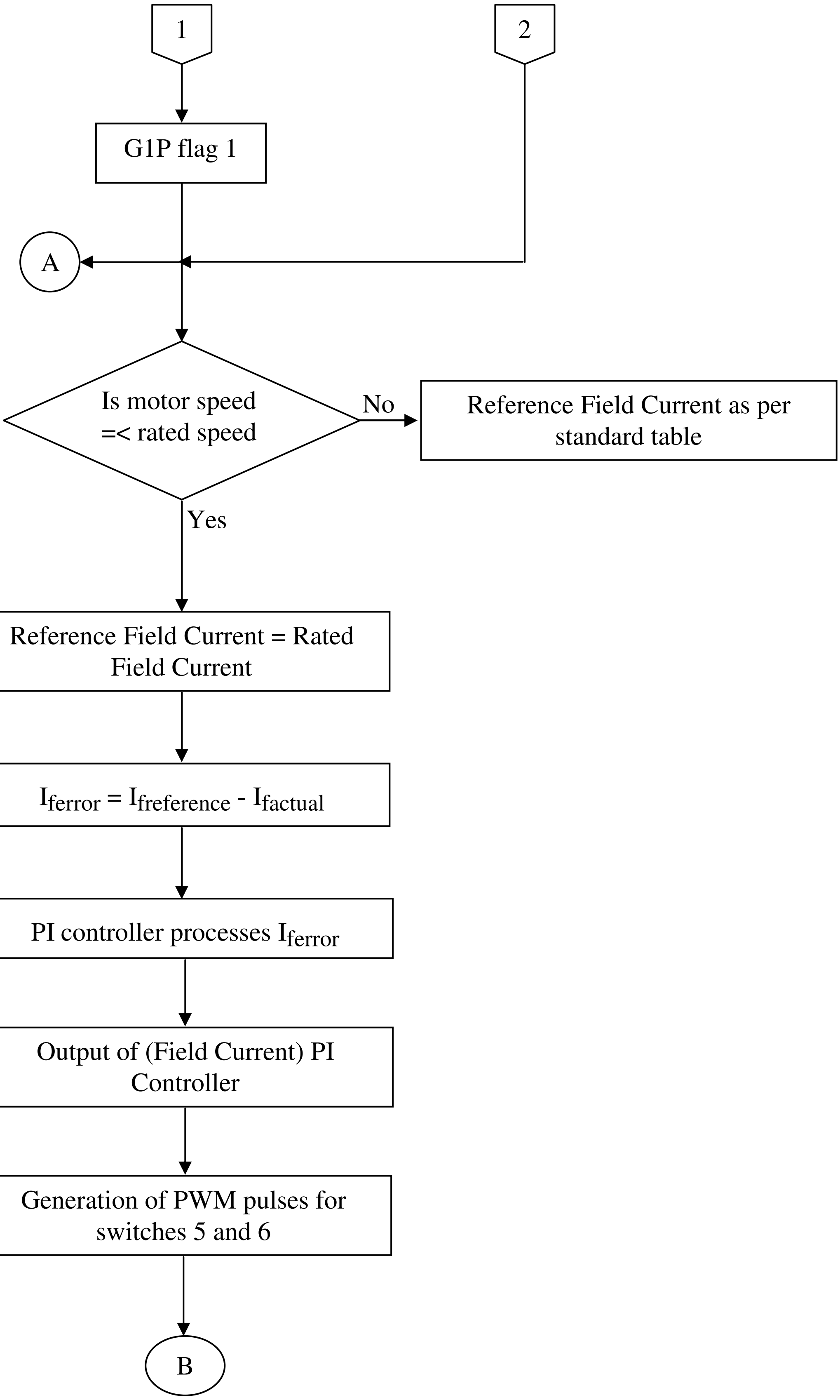
Figure 5.23: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

CHAPTER: - 6

FLOW CHART FOR PROGRAMMING

6.1 Flow Chart for the main program




1
2
G1P flag 1
A
Is motor speed =< rated speed
No
Reference Field Current as per standard table
Yes
Reference Field Current = Rated Field Current
$I_{ferror} = I_{freference} - I_{factual}$
PI controller processes I_{ferror}
Output of (Field Current) PI Controller
Generation of PWM pulses for switches 5 and 6
B

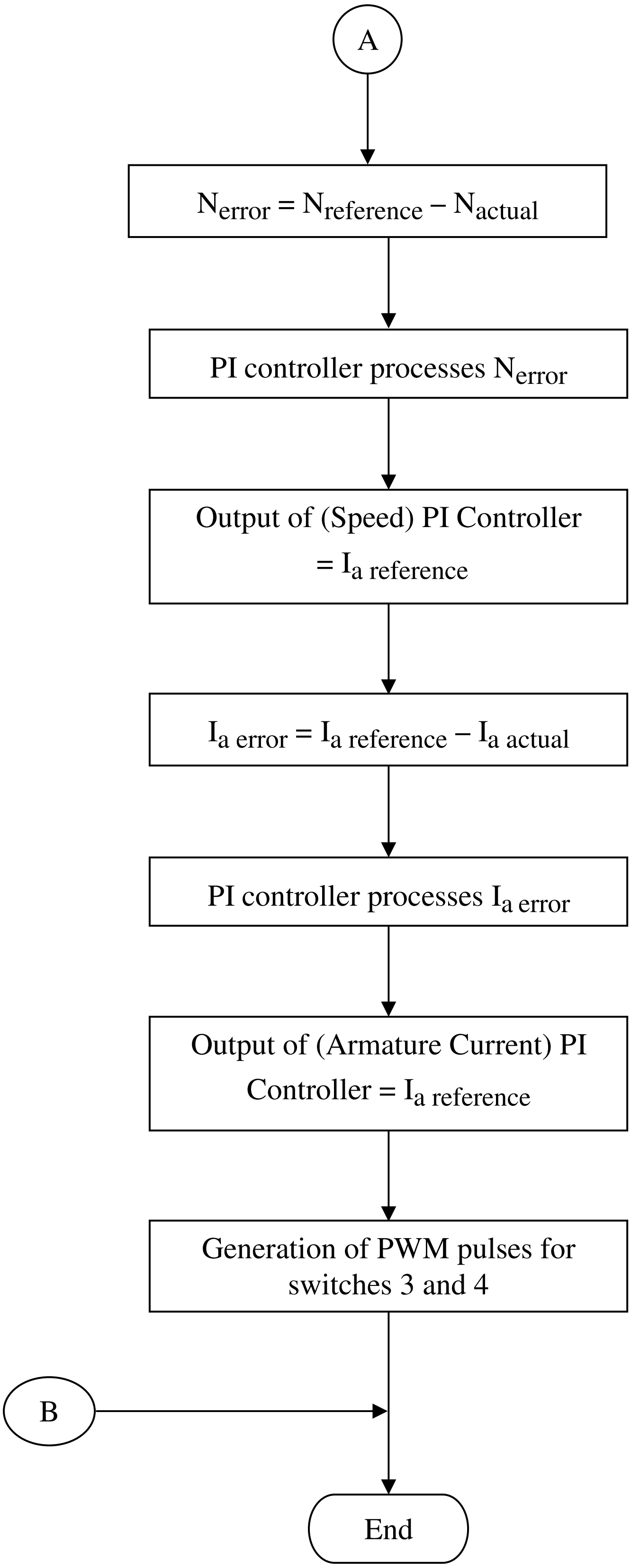
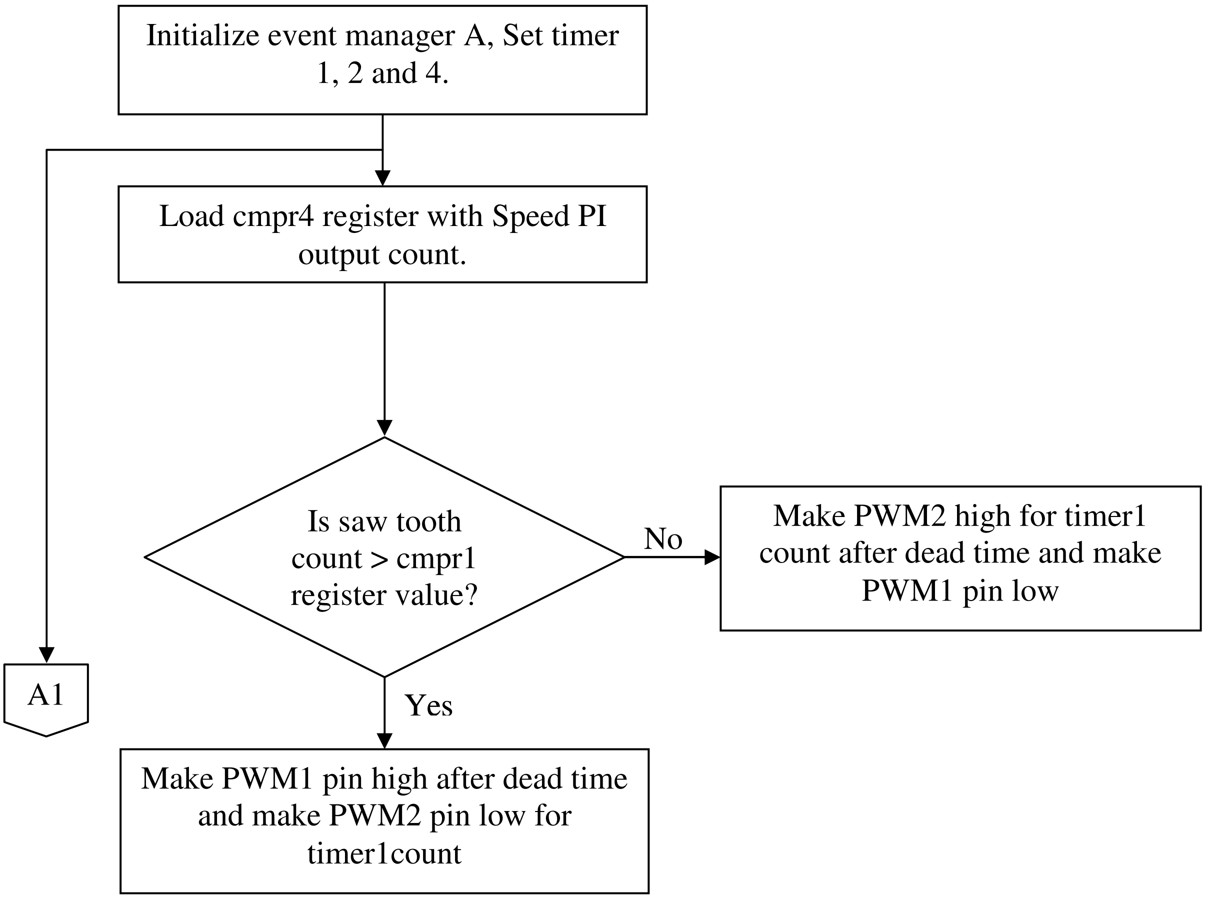


Figure 6.1: Algorithm of the control circuit operation

6.2 Generation of PWM Pulses

For generation event manager-A of the DSP is used. In event manager-A maximum six PWM can be generated. Timer1 is used to generate saw-tooth reference. PWM for leg one is generated automatically. One compare register is loaded with half count. It will generate the pulses with dead time automatically at PWM5 and PWM6 pins of DSP. For generation of PWM for second leg interrupt is used. Here output of PI controller is compared to saw-tooth count. When PI count crosses the value of saw-tooth count, value of PI count is loaded into timer4. When timer4 count is zero, it generates an interrupt, which will generate a fix value pulse including dead time. This pulse is available at PWM4 pin of DSP. Similarly other pulse of second leg is also generated in same manner but here timer 2 is used for the same and reference is taken from the starting of saw-tooth waveform count. These PWM pulses are available at PWM4 and PWM3 pins of event manager A.

6.2.1 Flowchart for generation of PWM pulses



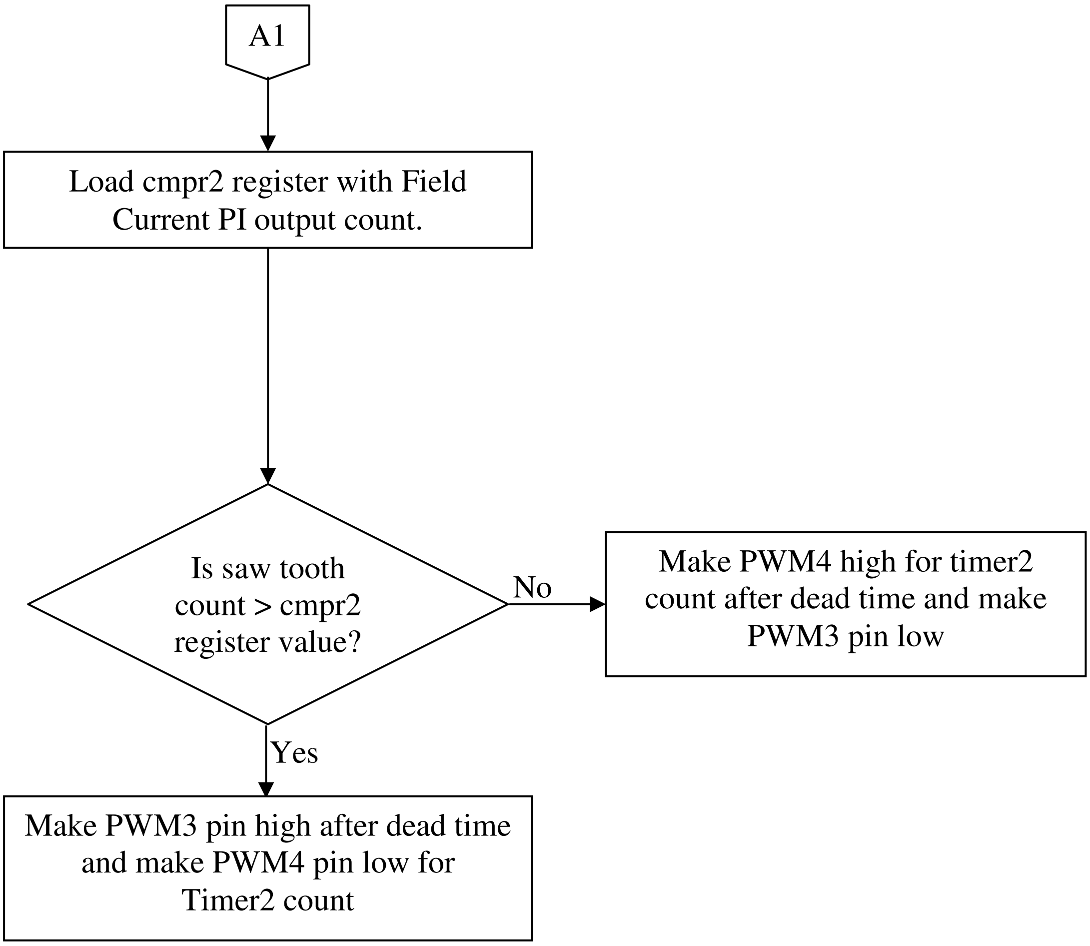


Figure 6.2: Algorithm for the PWM generation

CHAPTER: - 7

SIMULATION OF THE PROPOSED TECHNIQUE USING DLL BLOCK

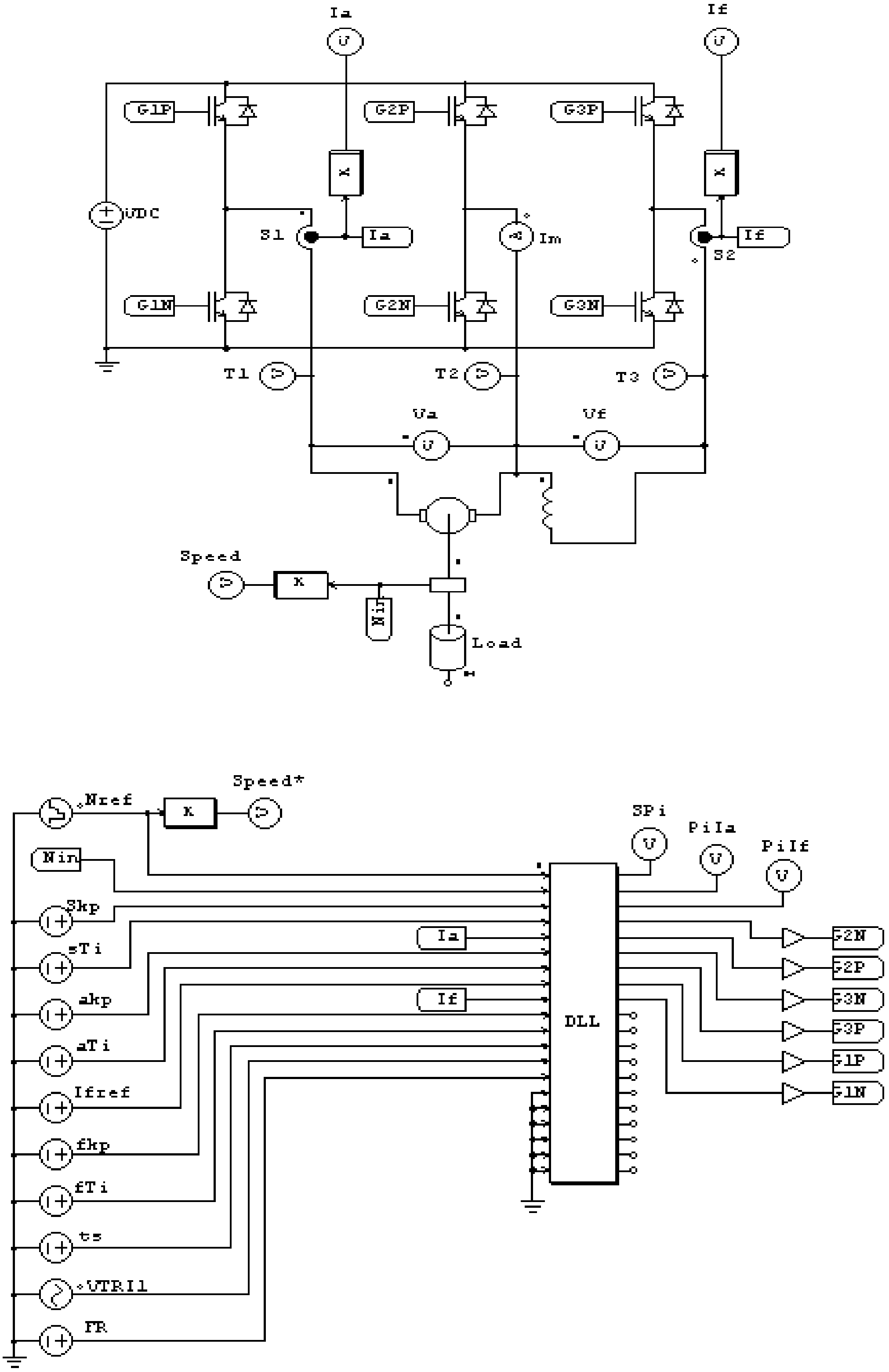
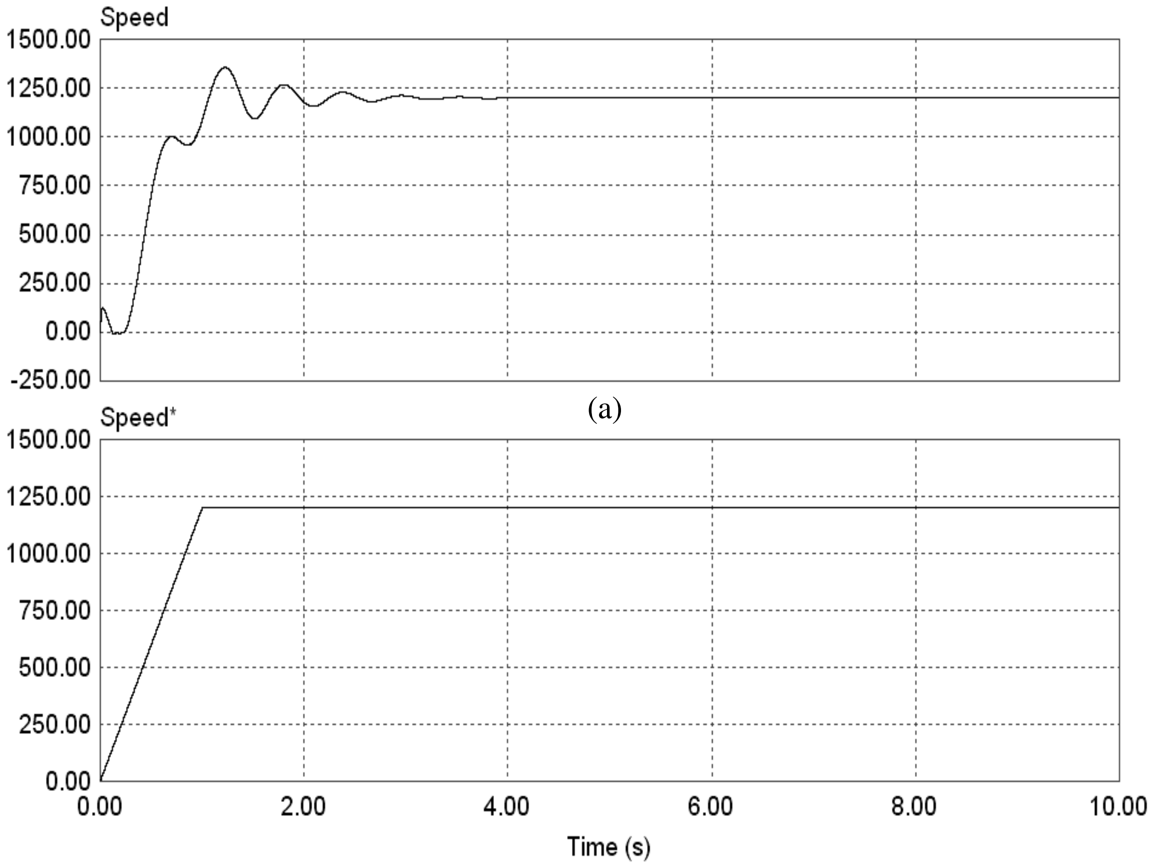


Figure 7.1: Simulation circuit using DLL block

Fig.7.1 shows the power schematic for the close-loop speed control of the dc series motor with using DLL block. This power schematic is simulated on the Psim software tool with DC series motor with the rated voltage of 500Vdc, current of 10Adc, and speed of 1200rpm. The value of the armature resistance Ra = 0.5Ω, Rf = 1Ω, La = 2mH, and Lf = 2mH. For the power topology IGBTs are used as switching devices with the switching frequency of 1KHz. PWM technique is used for the switching of IGBTs. The program does the control circuit for the power topology and PWM logic. This program is written in the '.C' file and the file is link with the DLL block in the circuit The PI parameters are given from the external source.

In the fig.7.1 the 'skp' and the 'sTi' are the gain and the time constant for the speed control PI simultaneously. The 'akp' and the 'aTi' are the gain and the time constant for the armature current control PI simultaneously. And the 'fkp' and the 'fTi' are the gain and the time constant for the field control PI simultaneously.



(a)

(b)

Figure 7.2: (a) Actual motor speed (b) 1200RPM reference speed

Fig. 7.2 shows the speed of the motor in rpm at the no load when the reference speed is set to 1200rpm, as shown in fig. 7.2 the motor speed sets at the reference speed same as using the analog circuit and the response of the controller is very fast which proves the fast dynamic response of the motor during the hoisting motion.

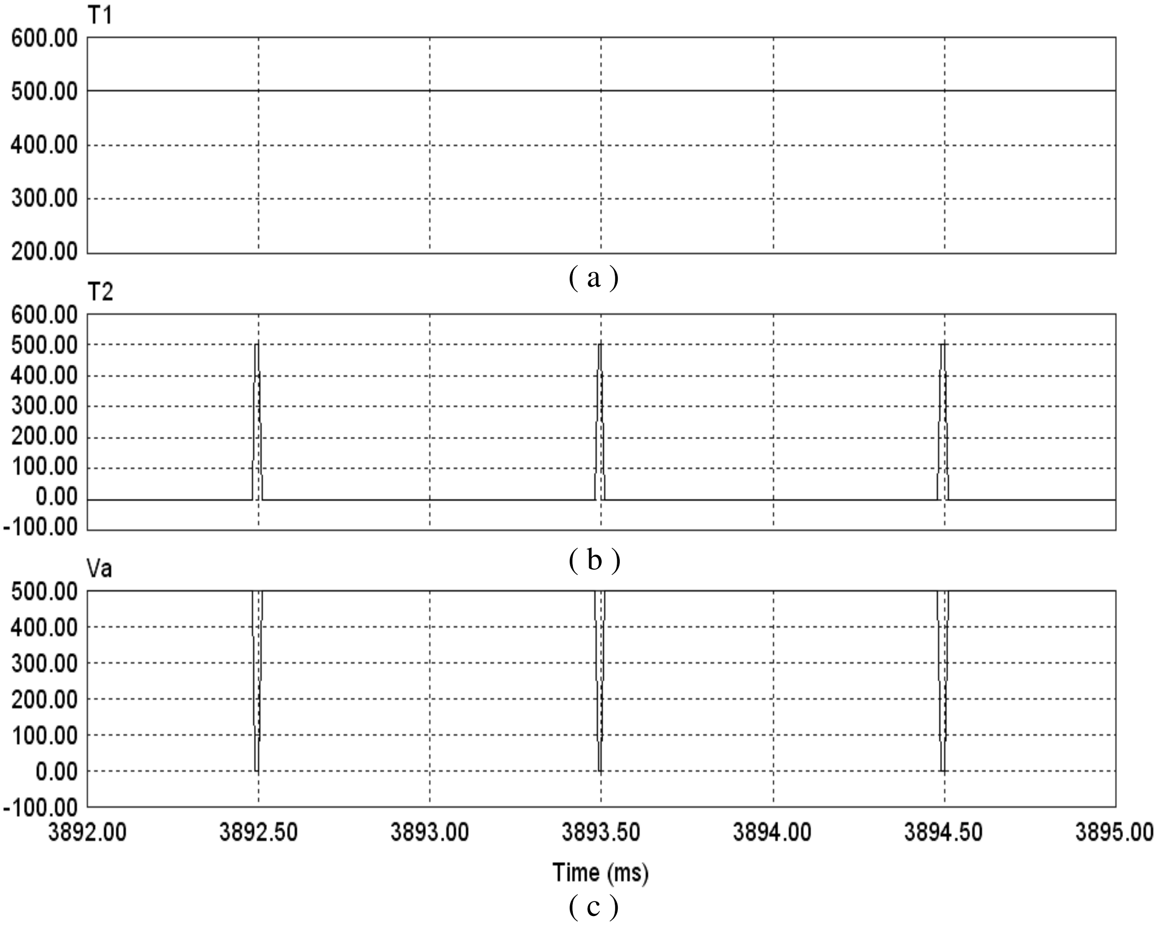
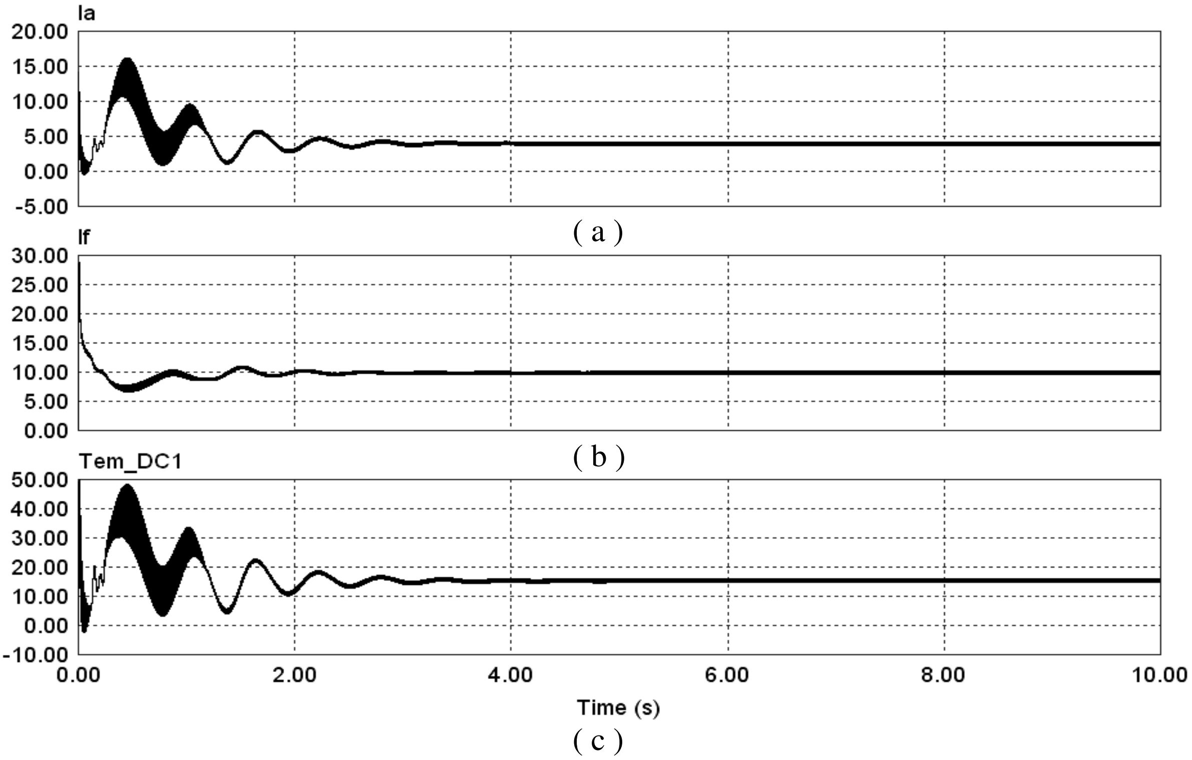


Figure 7.3: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

Fig.7.3 shows the voltage pattern generated using the given power topology for the 1200rpm reference speed. As discussed in the basic concept of the topology the Voltage across the armature (c) is the difference between the T1 terminal voltage and the T2 terminal voltage. At this reference speed the maximum voltage is required at the armature voltage and as the voltage across the armature is the difference between the T1 terminal voltage and the T2 terminal voltage, for the fixed T1 terminal voltage the minimum modulation of the T2 terminal is occurred that can be seen in the fig.7.3

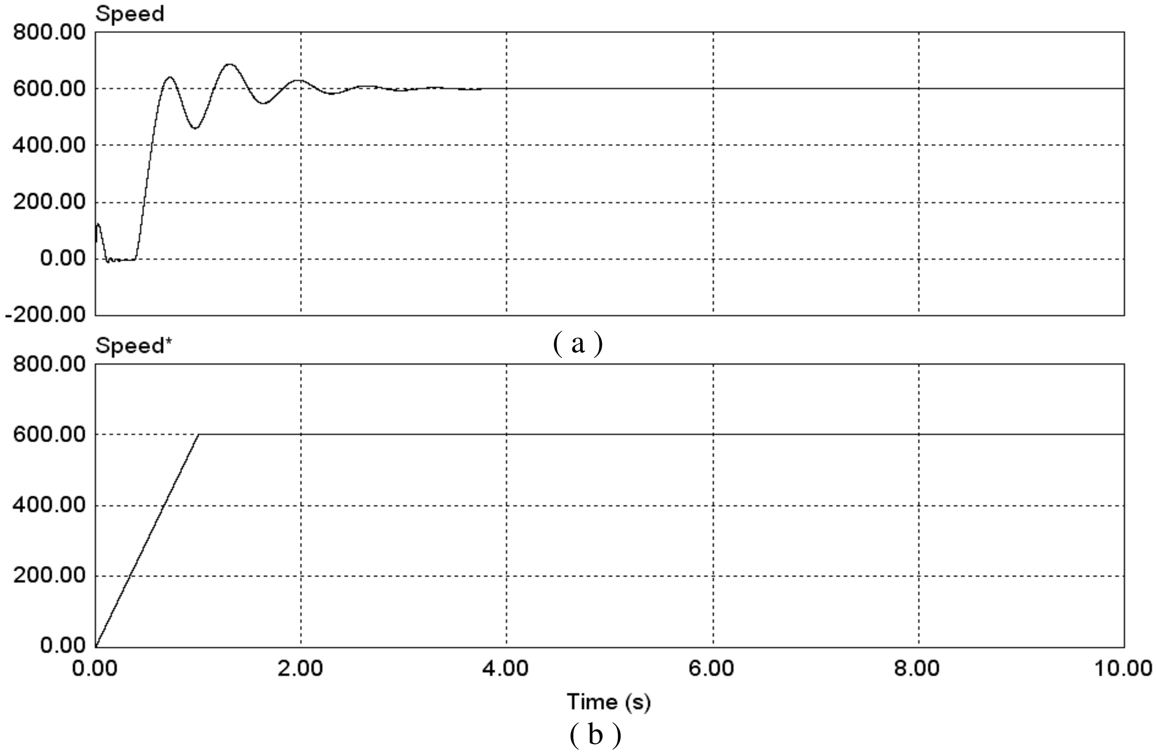


(a)

(b)

(c)

Figure 7.4: (a) Armature current (b) Field current (c) Generated motor torque



(a)

(b)

Figure 7.5: (a) Actual motor speed (b) 600RPM reference speed

Fig. 7.5 shows the speed of the motor in rpm at the no load when the reference speed is set to 600rpm.

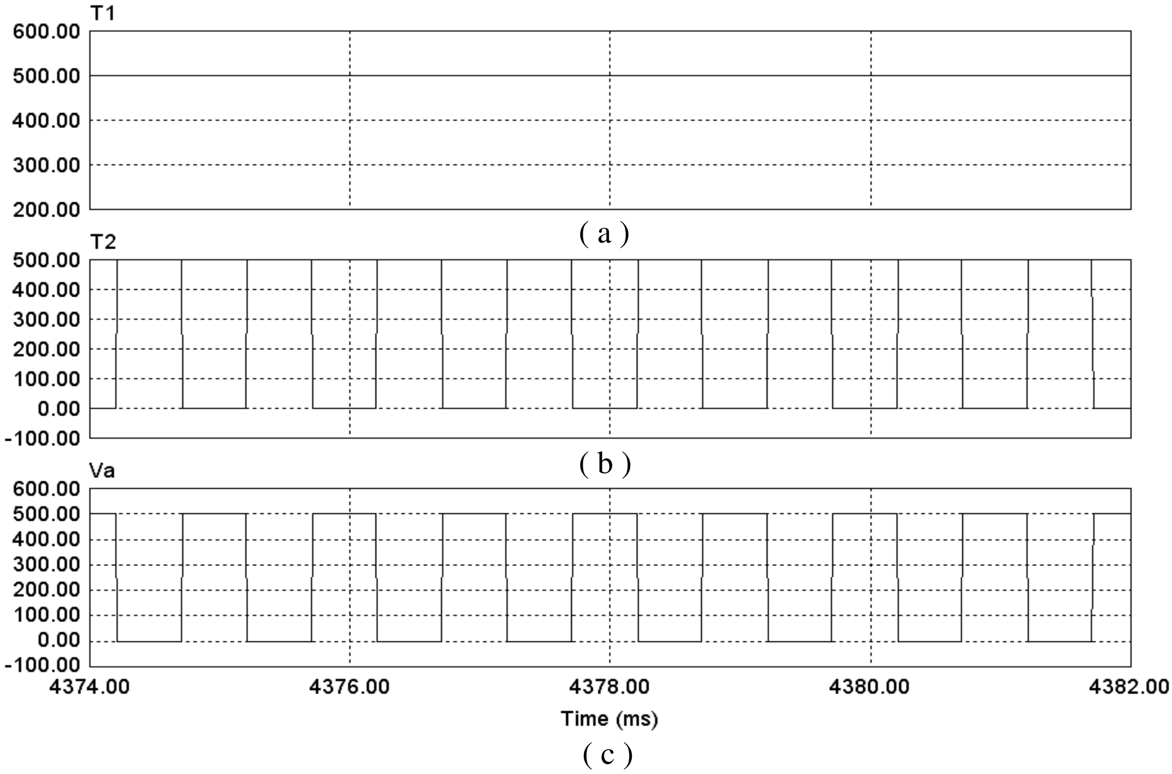


Figure 7.6: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

Fig. 7.6 shows the voltage pattern generated using the given power topology for the 1200rpm reference speed. As discussed in the basic concept of the topology the Voltage across the armature (c) is the difference between the T1 terminal voltage and the T2 terminal voltage.

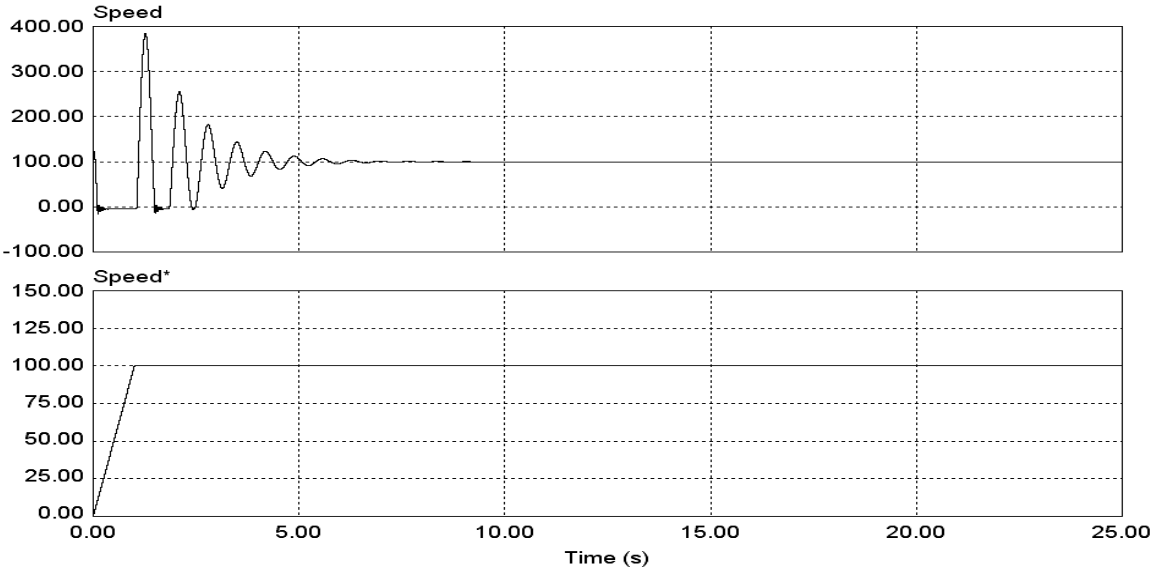


Figure 7.7: (a) Actual motor speed (b) 100RPM reference speed

Fig. 7.7 shows the speed of the motor in rpm at the no load when the reference speed is set to 100rpm.

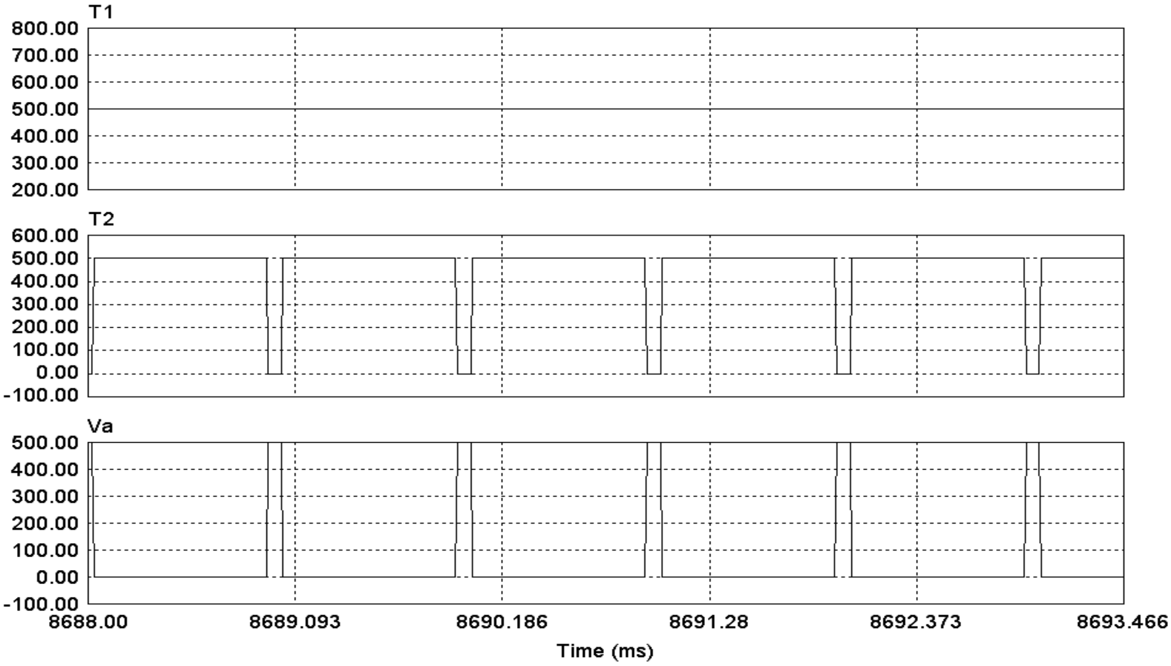


Figure 7.8: (a) T1 Terminal voltage (b) T2 Terminal voltage (c) Armature across voltage

Fig. 7.8 shows the voltage pattern generated using the given power topology for the 100rpm reference speed. As discussed in the basic concept of the topology the Voltage across the armature (c) is the difference between the T1 terminal voltage and the T2 terminal voltage. At this reference speed the lower voltage is required at the armature voltage and as the voltage across the armature is the difference between the T1 terminal voltage and the T2 terminal voltage, for the fixed T1 terminal voltage the maximum modulation of the T2 terminal is occurred that can be seen in the fig.7.8

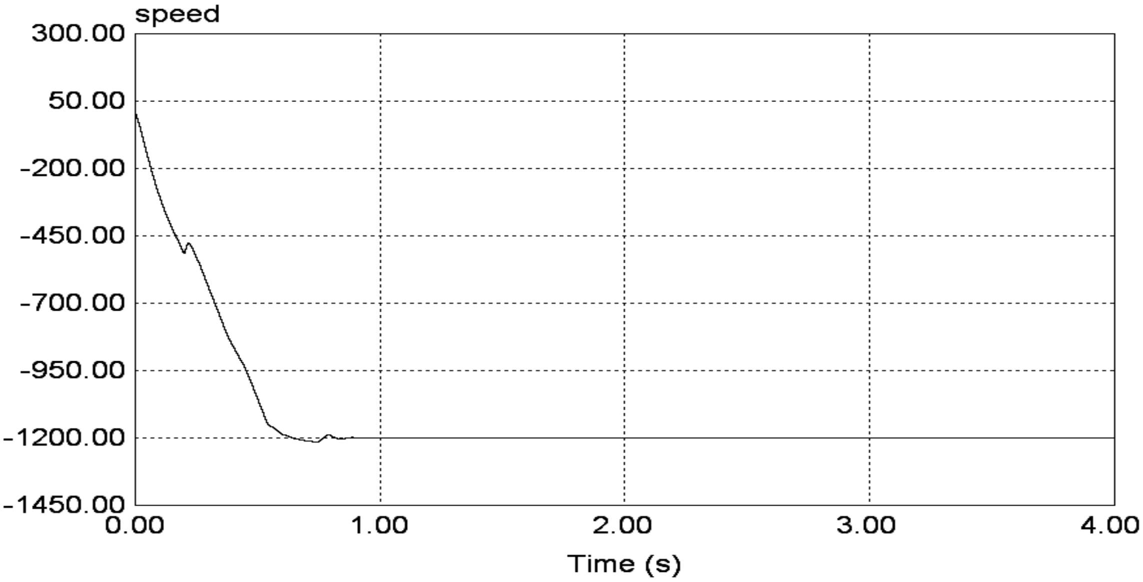
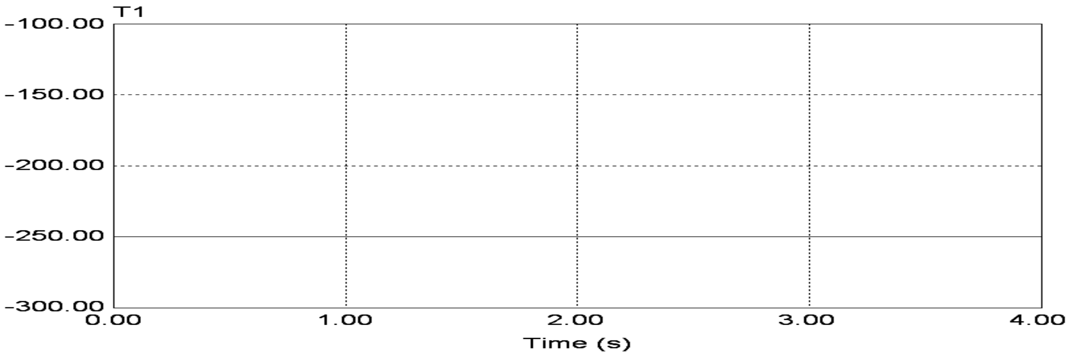
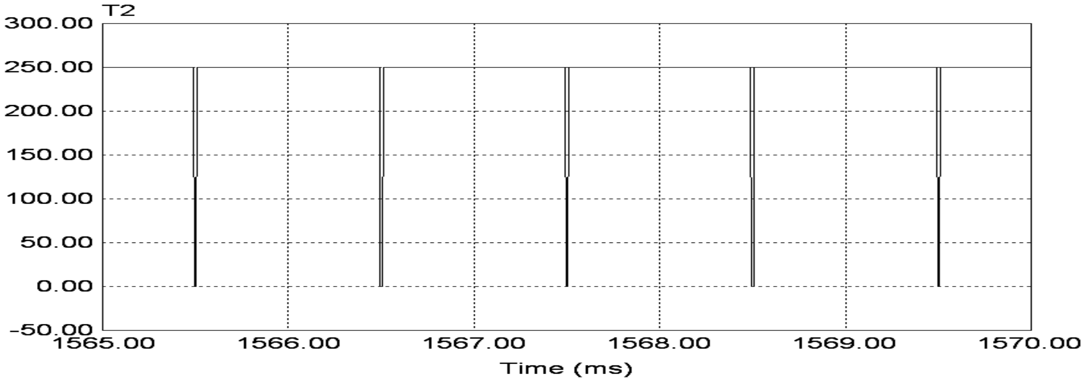


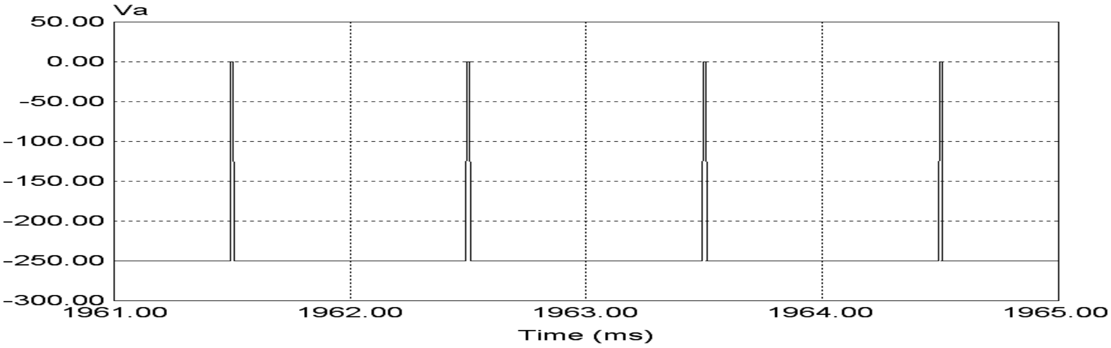
Figure 7.9: Actual speed of the motor at -1200RPM reference speed



(a) T1 Terminal voltage



(b) T2 Terminal voltage



(c) Voltage across the armature

Figure 7.10: Voltage across the armature for -1200RPM reference speed

Fig. 7.10 shows the voltage across the armature for 1200RPM reference in the reverse direction. As shown in (a) T1 terminal voltage in the reverse direction –ve Vdc voltage will appear at this terminal and the voltage across the armature is the difference between the T1 terminal voltage and T2 terminal voltage. As the reference speed increases the voltage across the armature increases in the reverse direction and the T2 terminal voltage decreases in the reverse direction. But in the reverse operation only the armature current direction is reverse to get the reverse flux.

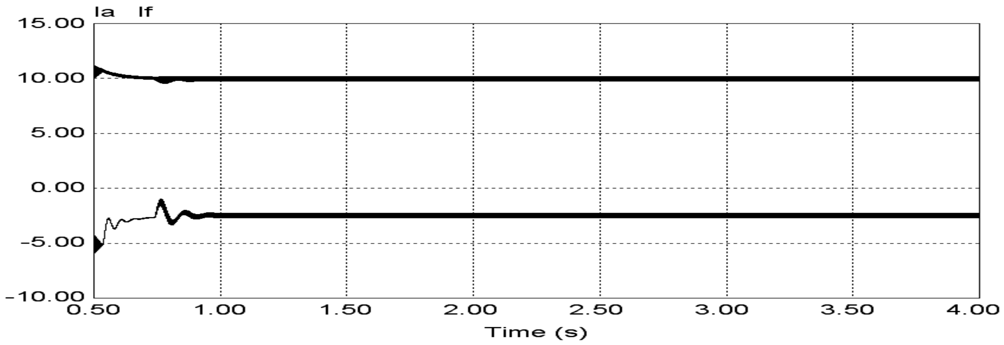


Figure 7.11 Armature and Field current waveform for -1200RPM reference

Fig. 7.11 shows the armature and field current waveform for -1200RPM reference speed. As in the case of dc motors for speed reversal it is required to change the direction of the current either the armature current or the field current. That is shown in fig the armature current is in the reverse direction and the field current is flows in the same direction.

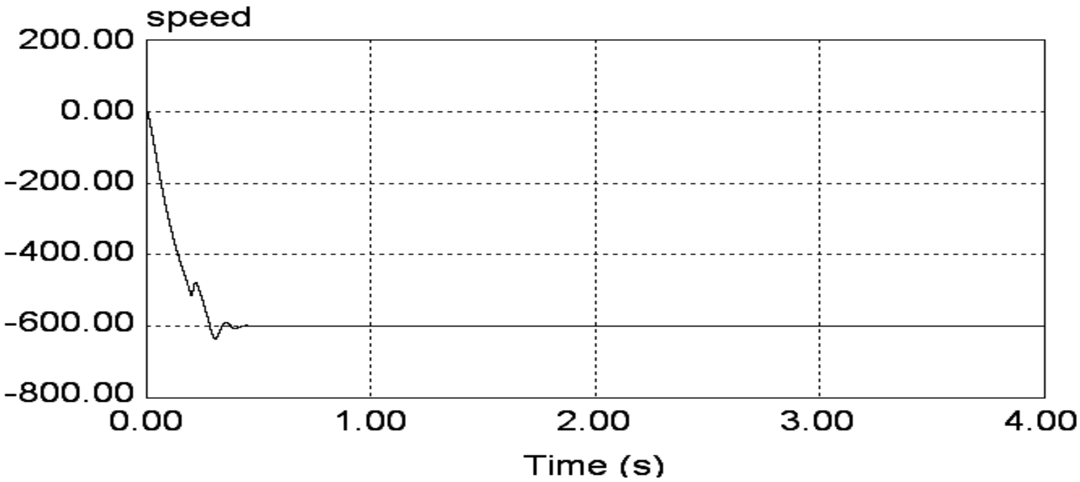
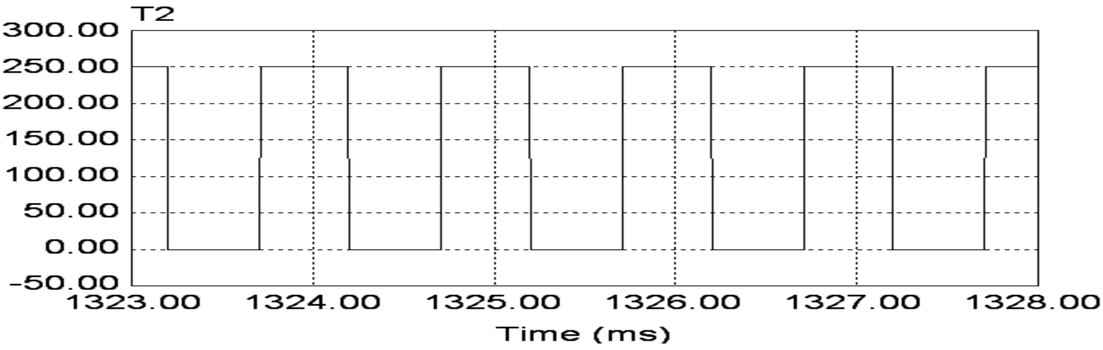
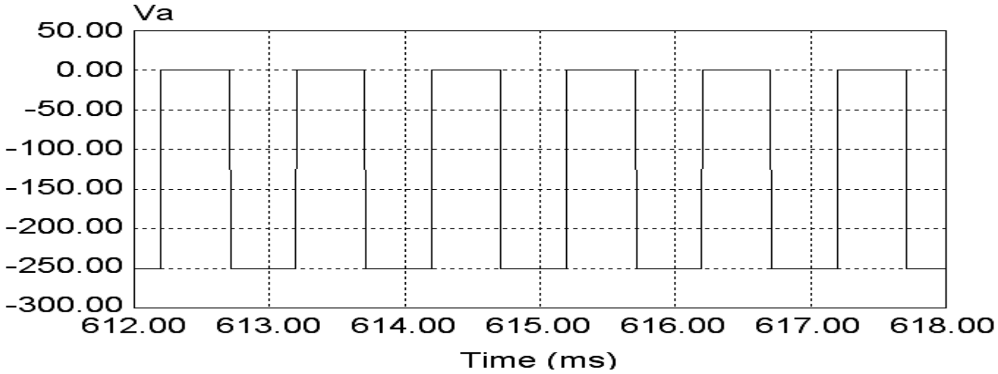


Figure 7.12: Actual speed of the motor at -600RPM reference speed

Fig. 7.12 shows the actual speed of the motor for -600RPM reference speed for the half reference speed in the half modulation is occurred for t2 terminal voltage and half the Vdc voltage will appear across the armature.



(a) T1 Terminal voltage



(b) Voltage across the armature

Figure 7.13 Voltage across the armature for -600RPM reference

CHAPTER: - 8
HARDWARE IMPLEMENTATION OF DC DRIVE

8.1 Hardware Setup for DC Drive

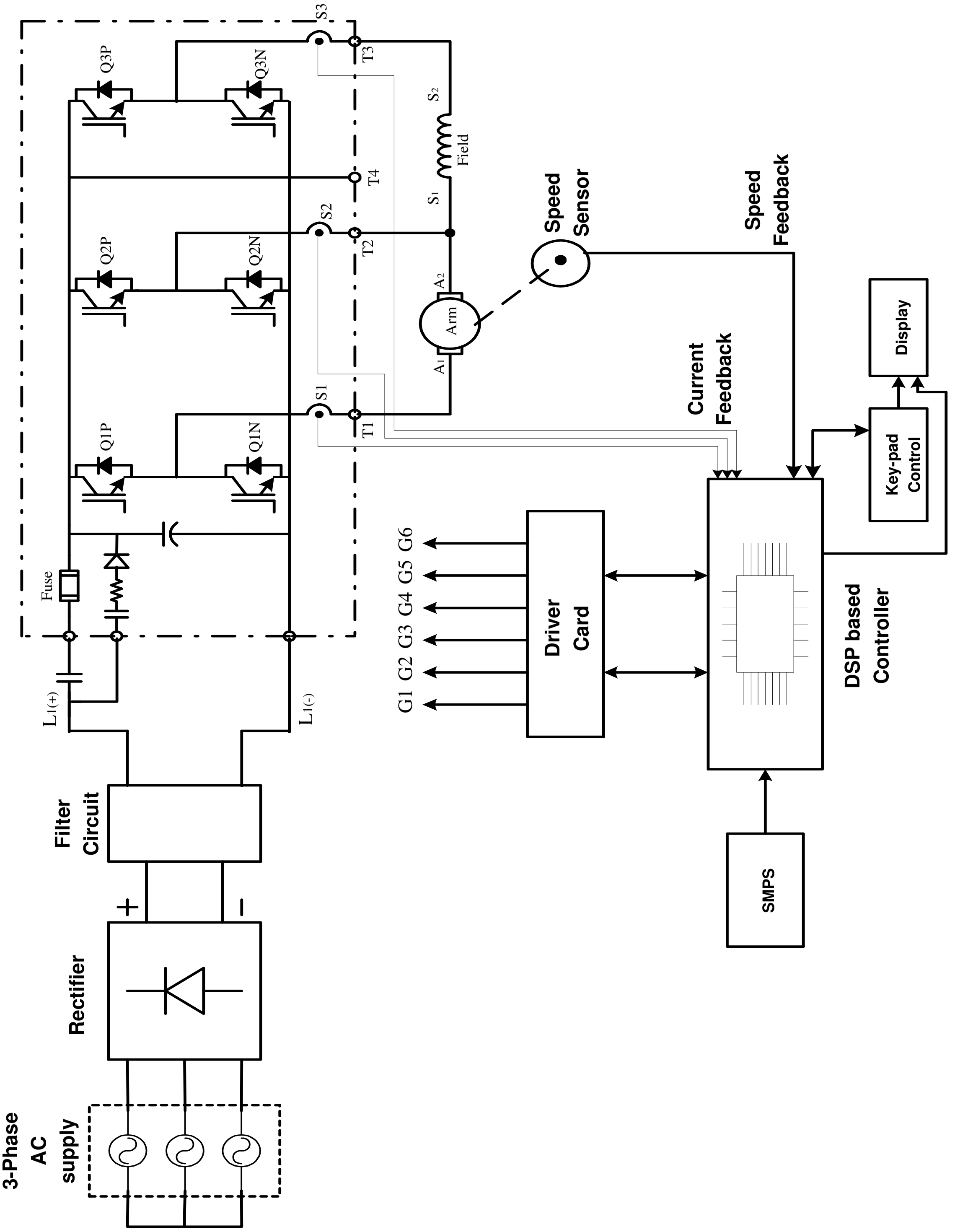


Figure 8.1: Overall block diagram of DC drive using DSP TMS320F2811

Fig.: - 8.1 shows the overall block diagram for the DC drive, which including DSP control card TMS320F2811, IGBT driver card, SMPS, sensors, Display, Keypad. This block diagram can be divided in some parts like,

1. **Supply unit: -** This block supplies the ac supply voltage to the drive, has a rating of 3-phase, 440V, 50Hz.
2. **Rectifier unit:** - This unit is used for ac-dc conversion, this is the full wave uncontrolled rectifier.
3. **Filter unit:** - This unit is used for filter the pulsation at the DC side to get the better motor operation it is necessary to make the smooth DC power.
4. **Main power circuit:** - This power circuit is used to feed the controlled DC supply to the DC series motor. To control the voltage at the motor armature voltage the modulation of the switches are done at required level.
5. **Speed sensor:** - Speed sensor is used to sense the present motor rpm, which is given to the DSP control card as a feedback for the close loop control.
6. **Current and Voltage sensors:** - To sense the motor armature and field current and armature and field voltage these sensors are used, for this application hall sensors are used.
7. **Driver card: -** This card is used to feed the gate pulse to the IGBTs. The required PWM signals that are generated from the control card are given to this driver card.
8. **Keypad & Display: -** Keypad is used for set the different parameters of the controller like PI parameters, over/under voltage limit, over/under current limit, etc. and display is used to display the current parameters of the motor.
9. **SMPS: -** This is the switch mode power supply is used to feed the supply to the control card, this control card needs different dc voltage level, those are generated using this smps.
10. **Control card: -** This control card includes the DSP chip(TMS320F2811), sensing circuit, buffer circuit for the PWM, serial communication circuit, analog and digital output circuits etc. the over all circuit diagram of the control card.

8.2 Hardware Parameters

To verify the proposed technique the actual experimental test is carried out on DC series, motor. The experiment is carried out with the help of 45KW rating prototype module. IGBT have a voltage rating of 1200V and current rating of 200A. For the close loop control the speed feedback is taken with the help of encoder, which gives 2500 counts per RPM. Dual current sensors having a current rating of 50A take armature and field current feedbacks. DSP (TMS320F2811) based control card is used as a controller.

DC series motor specifications:

Rated voltage = 230V dc

Rated speed = 1500rpm

Rated current = 11.8A

Armature winding resistance = 2.3ohm

Field winding resistance = 2.9ohm

Obtained PI parameters are as following:

Speed PI:

Speed gain kp = 2

Speed time Ti = 9.2msec

Armature current PI:

Armature current gain kp = 1.5

Armature current time Ti = 16.5msec

Field current PI:

Field current gain kp = 1.975

Field current time Ti = 10.18msec

8.3 Gate pulses at the output of the gate driver card using DSP

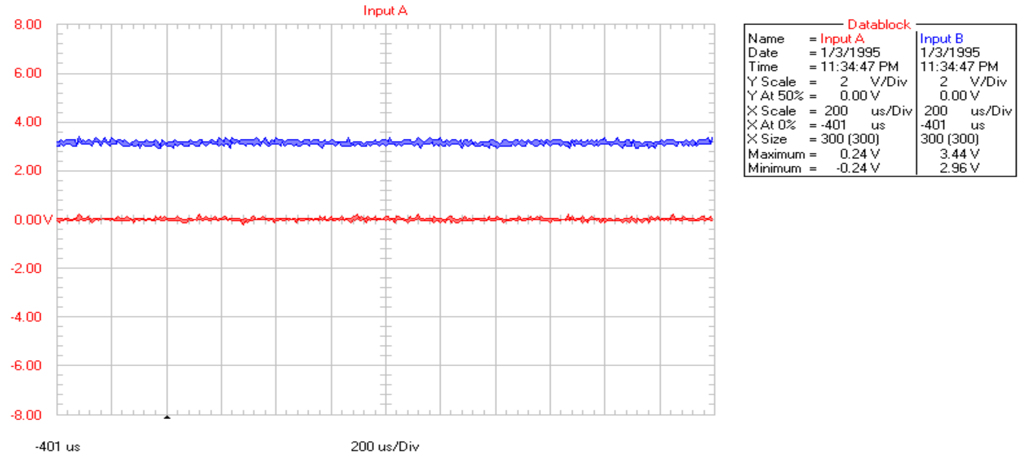


Figure 8.2: Gate pulses for the IGBTs Q1P & Q1N

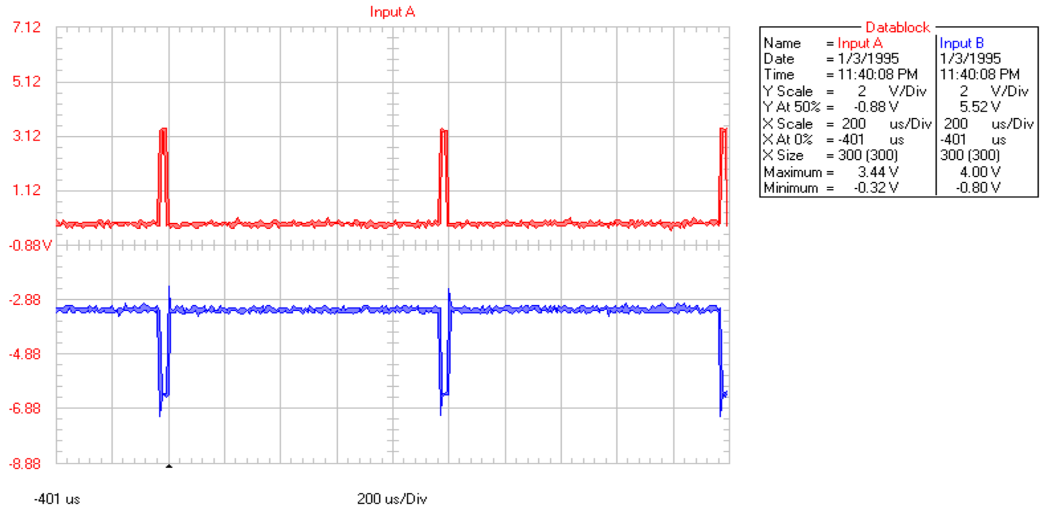


Figure 8.3: Gate pulses for the IGBT Q2P & Q2N for 1200 rpm reference

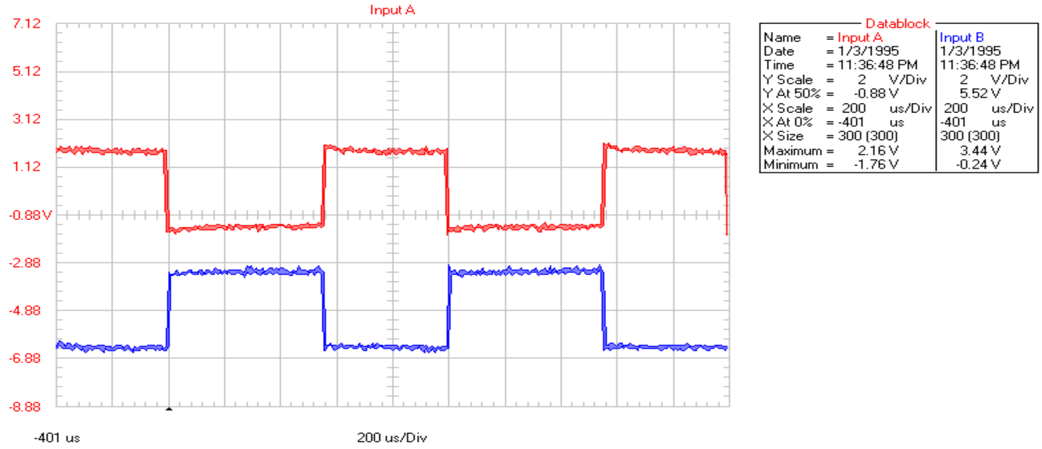


Figure 8.4: Gate pulses for the IGBT Q2P & Q2N for 600 rpm reference

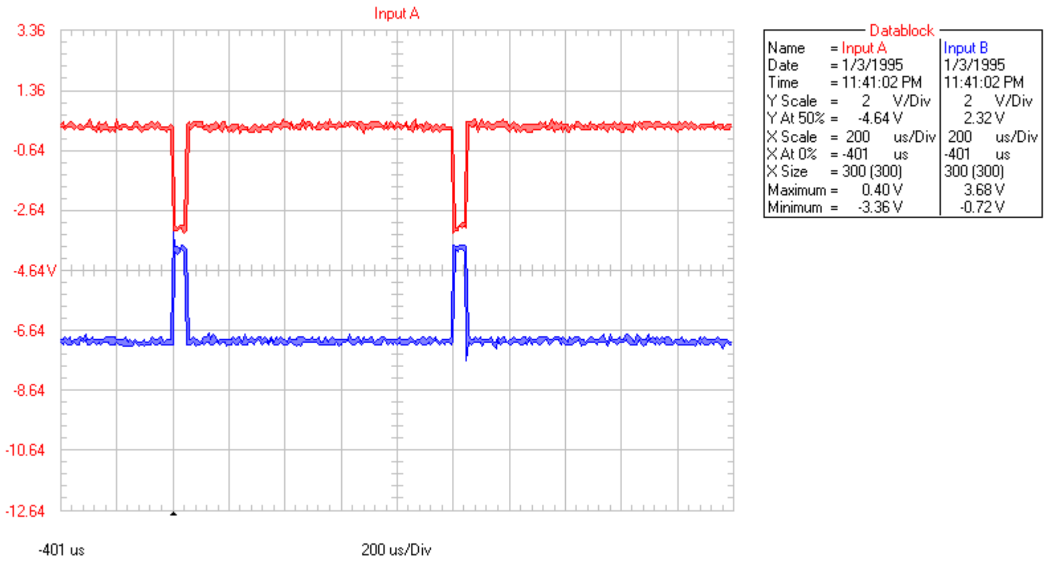


Figure 8.5: Gate pulses for the IGBT Q2P & Q2N for 50 rpm reference

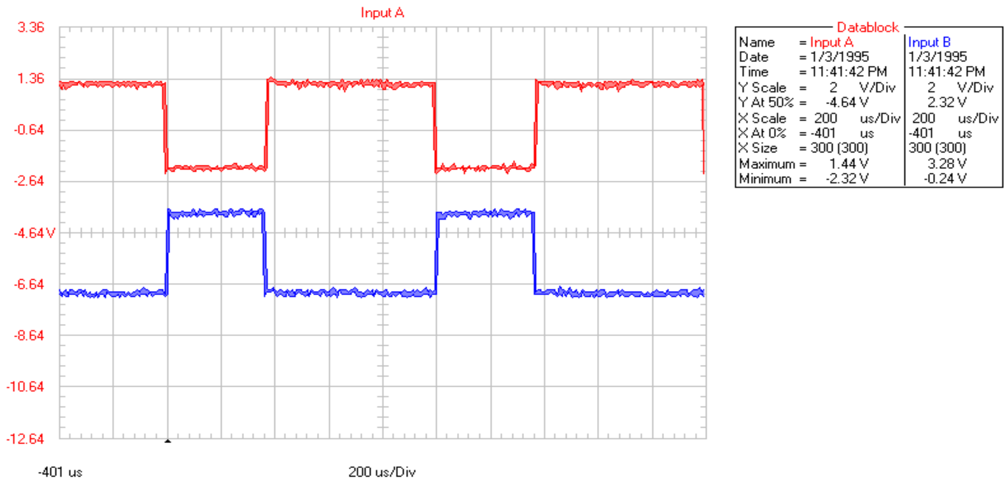


Figure 8.6: Gate pulses for the IGBT Q3P & Q3N

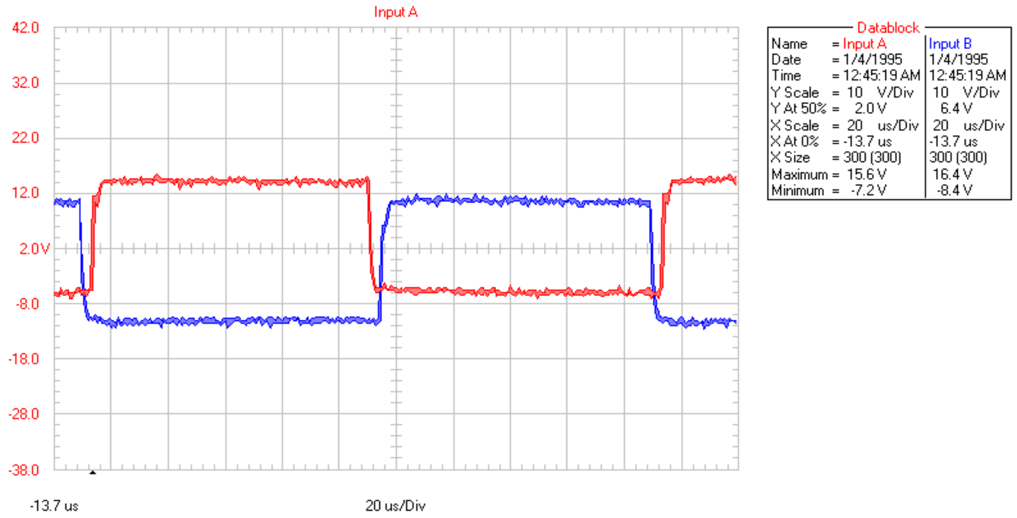


Figure 8.7: Dead time between IGBTs on same leg

8.4 Experimental Results for Different Reference Speed

[1]. Experimental results for the **250RPM** reference speed

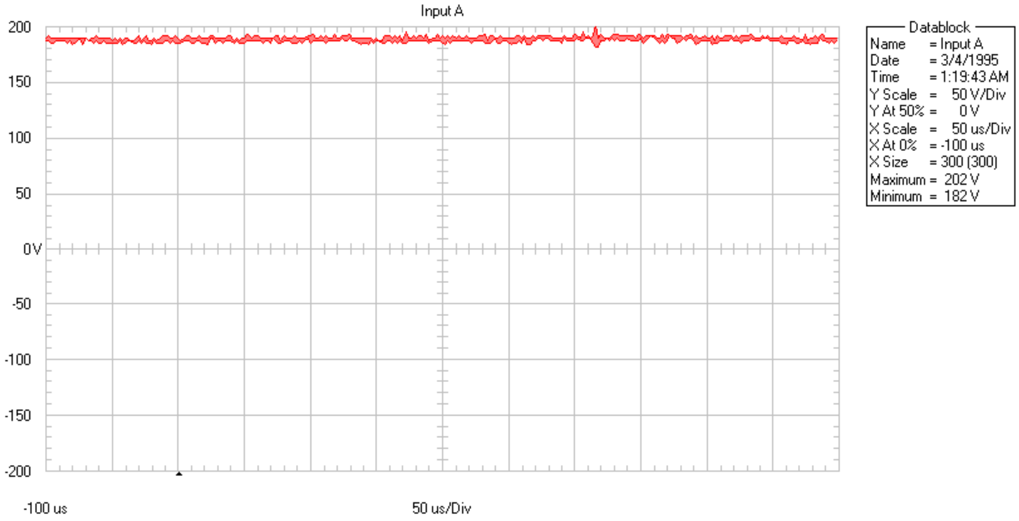


Figure 8.8: T1 Terminal voltage

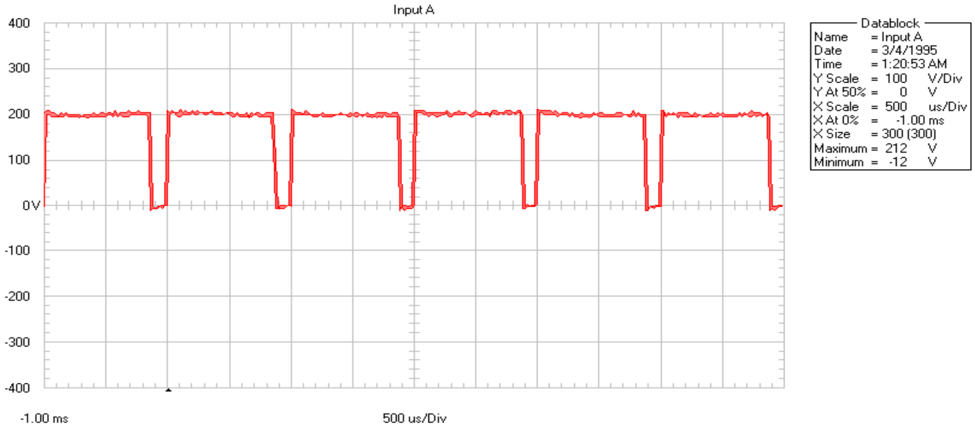


Figure 8.9: T2 Terminal voltage

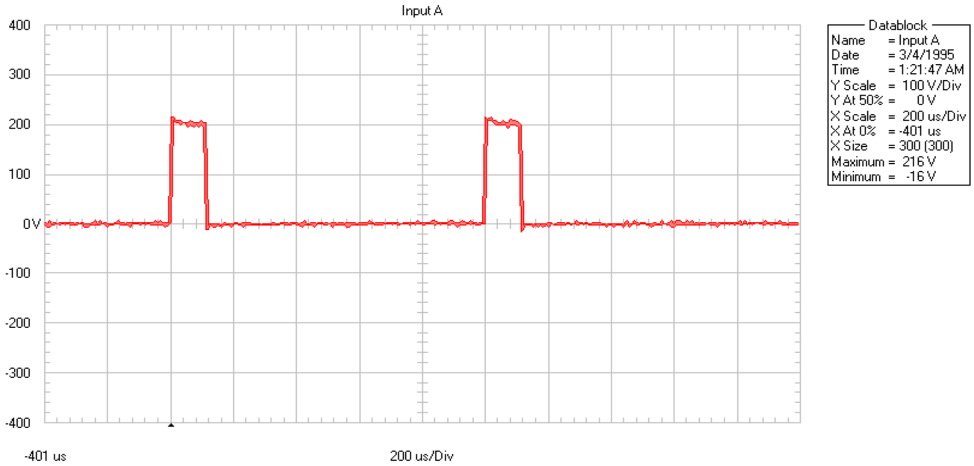


Figure 8.10: Voltage across armature

[2]. Experimental results for **500RPM** reference speed

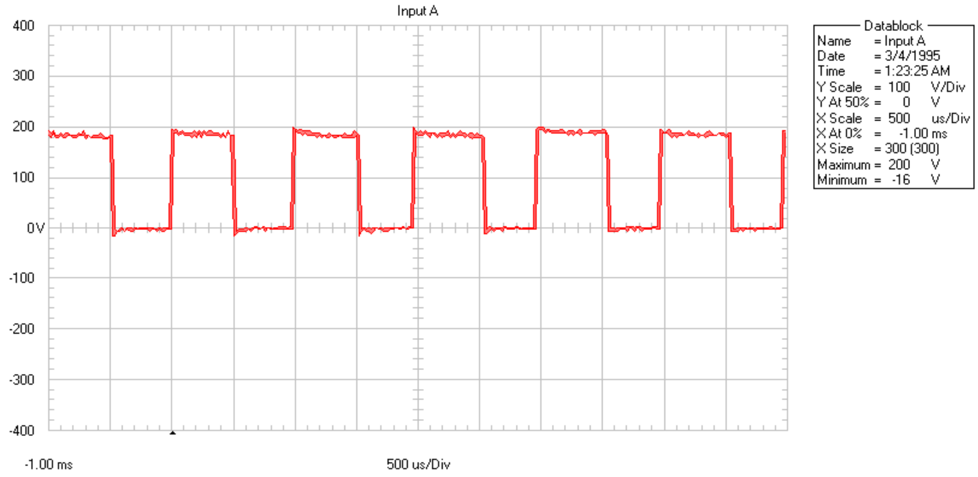


Figure 8.11: T2 Terminal voltage

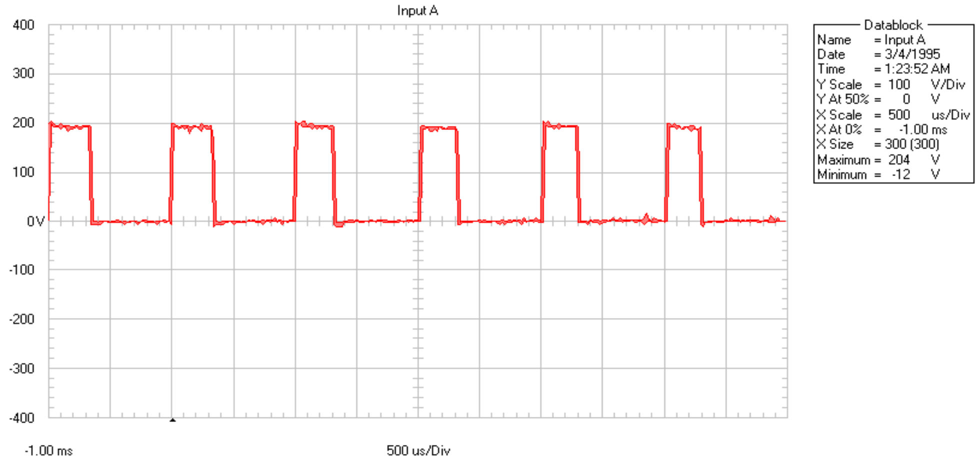


Figure 8.12: Voltage across armature

[3]. Experimental results for **750RPM** reference speed

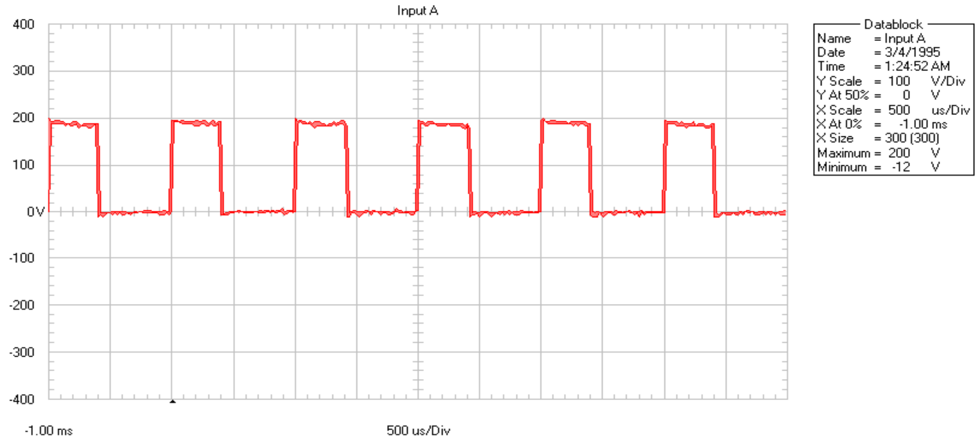


Figure 8.13: T2 Terminal voltage

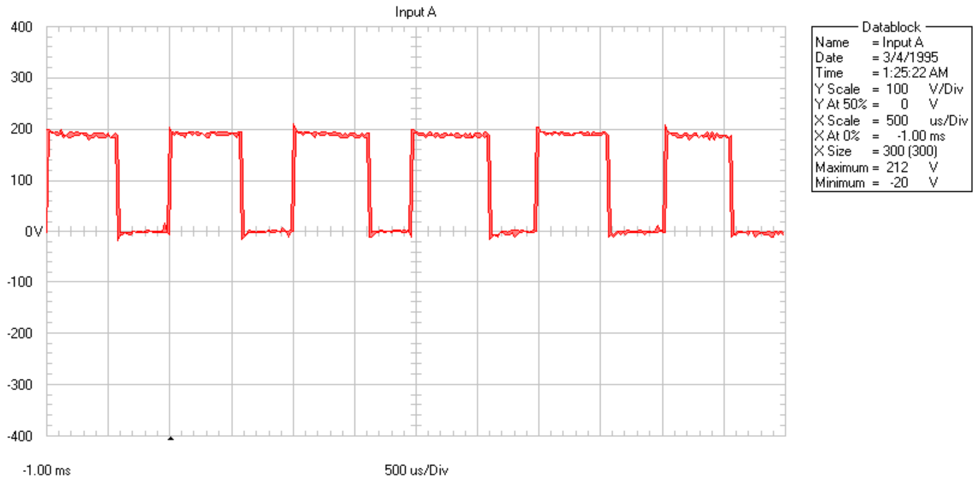


Figure 8.14: Voltage across armature

[4]. Experimental results for **1000RPM** reference speed

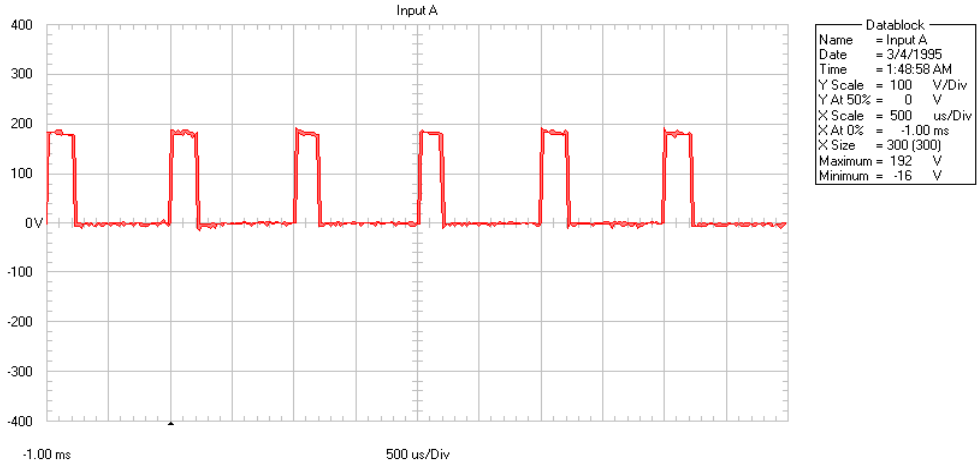


Figure 8.15: T2 Terminal voltage

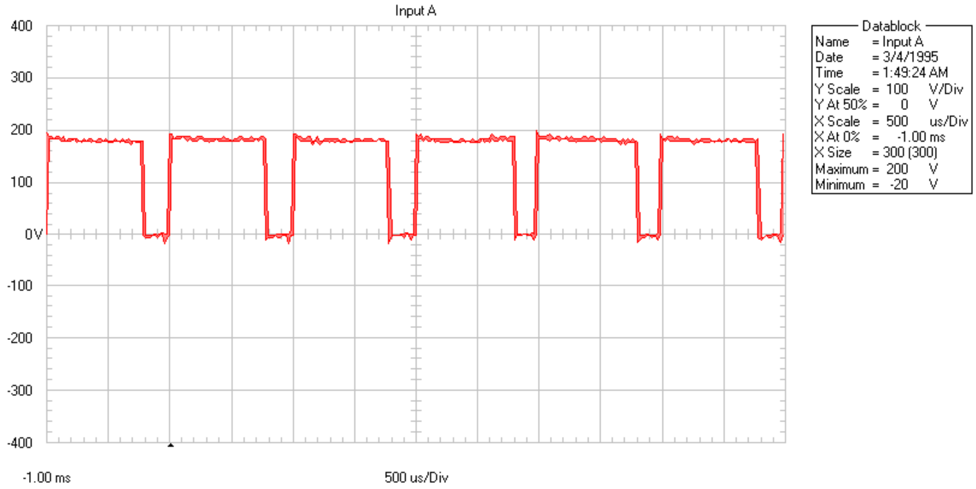


Figure 8.16: Voltage across armature

[5]. Experimental results for **1250RPM** reference speed

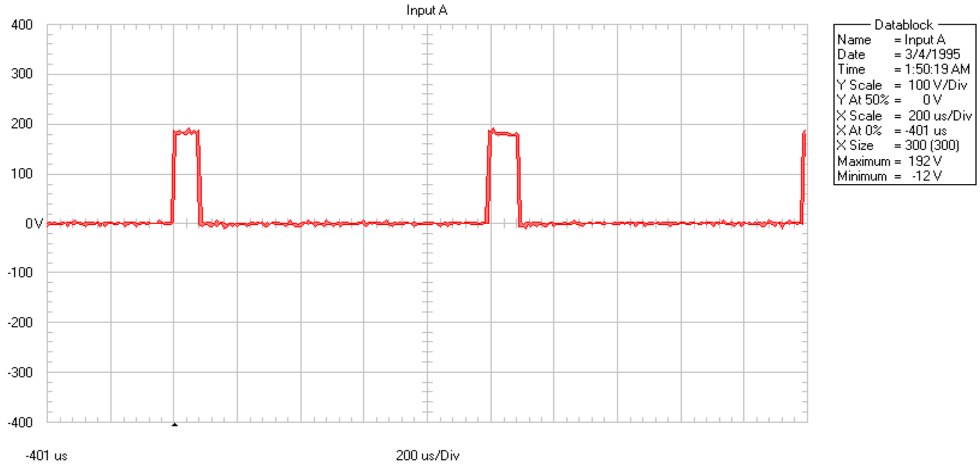


Figure 8.17: T2 Terminal voltage

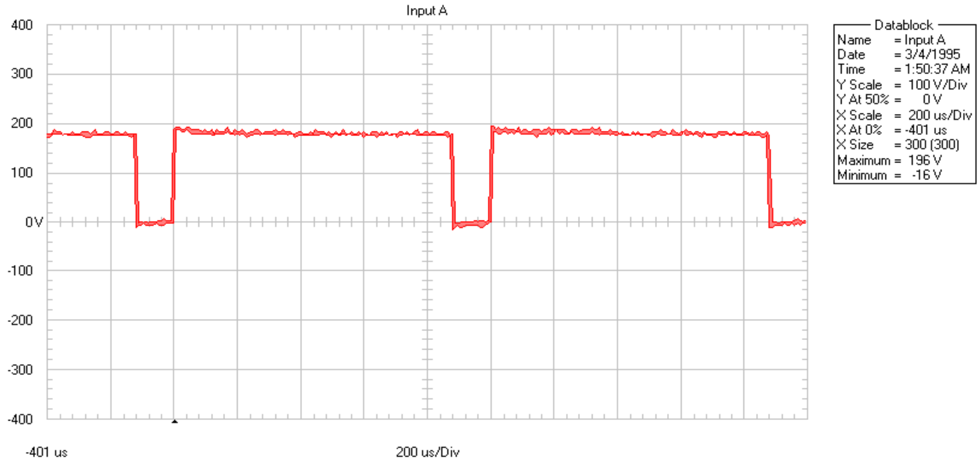


Figure 8.18: Voltage across armature

[6]. Experimental results for **1500RPM** reference speed

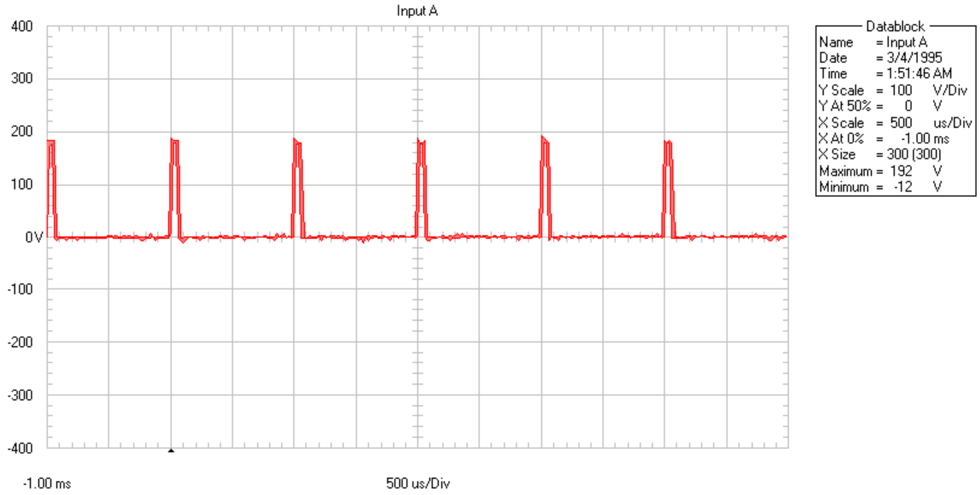


Figure 8.19: T2 Terminal voltage

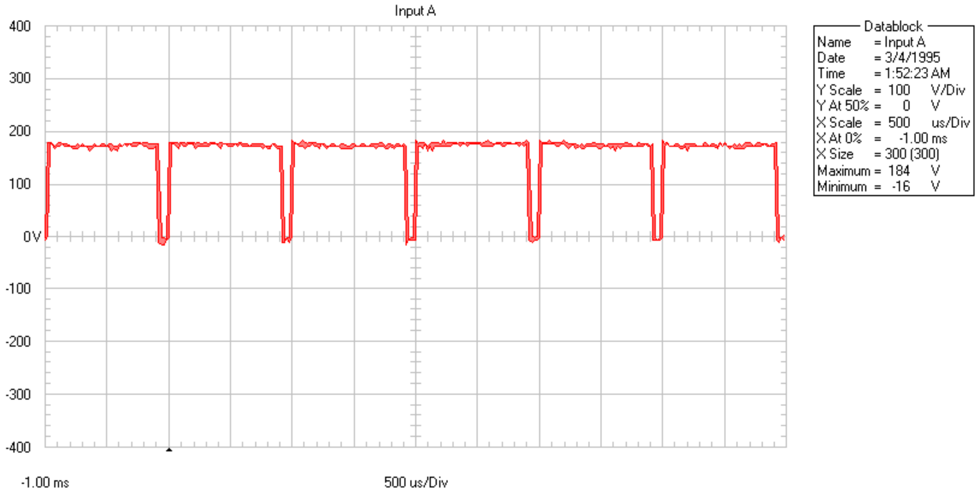


Figure 8.20: Voltage across armature

[7]. Experimental results for **1750RPM** reference speed

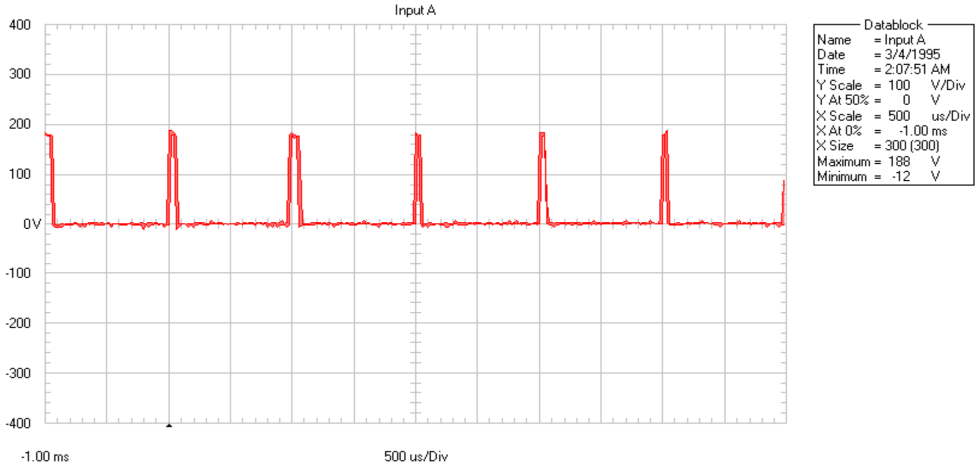


Figure 8.21: T2 Terminal voltage

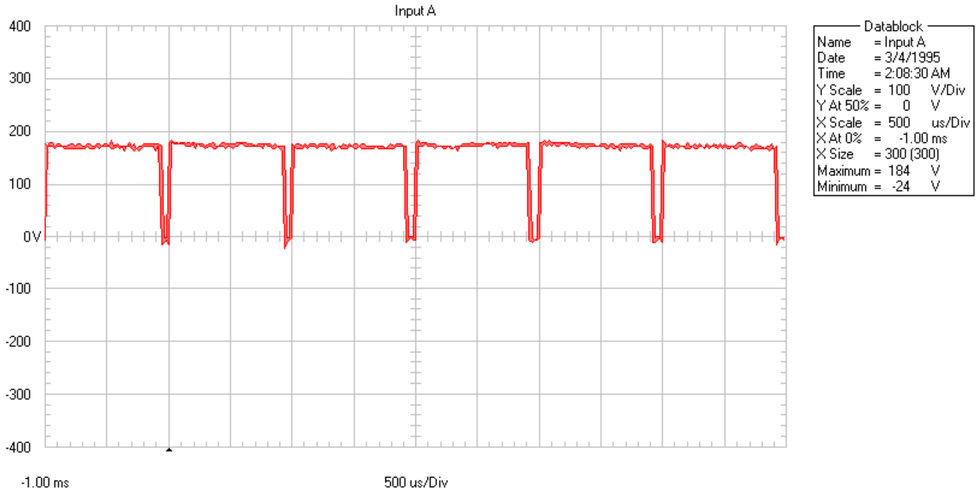


Figure 8.22: Voltage across armature

8.5 Result Table for different reference speed

Reference Speed (RPM)	T1 Voltage (V)	T2 Voltage (V)	Armature Voltage (V)
250	190	167	23
500	190	136	54
750	190	110	80
1000	190	84	106
1250	190	50	140
1500	190	30	160
1750	190	30	160

Table 8.1 Armature voltages for different reference speed

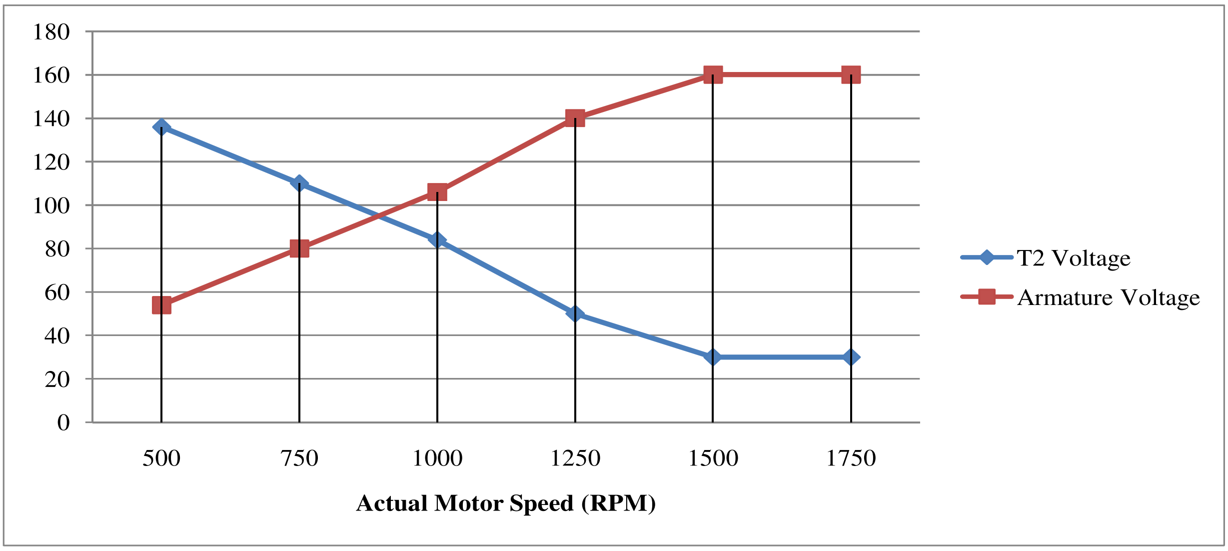


Figure 8.23: Graph of T2 terminal voltage and Armature voltage for diff. Ref. Speed

Table.8.1 shows the armature voltage for different reference speed and it shows that as the reference speed increases the voltage across the armature increases and the voltage at the T2 Terminal decreases and the difference between the T1 terminal voltage and T2 terminal voltage is appeared across the armature.

Reference Speed	Actual Speed (50% Load)	Actual Speed (75% Load)	Actual Speed (100% Load)
100	100	100	97
200	200	100	197
300	300	299	298
400	400	400	398
500	500	499	500
600	600	600	600
700	700	700	700
800	800	800	800

900	900	900	900
1000	1000	1000	1000
1100	1101	1100	1099
1200	1201	1199	1200
1300	1301	1300	1300
1400	1401	1400	1397
1500	1501	1500	1500
1600	1601	1598	1600
1700	1701	1700	1700
1800	1801	1800	1800

Table. 8.2 Comparision of actual and reference speed

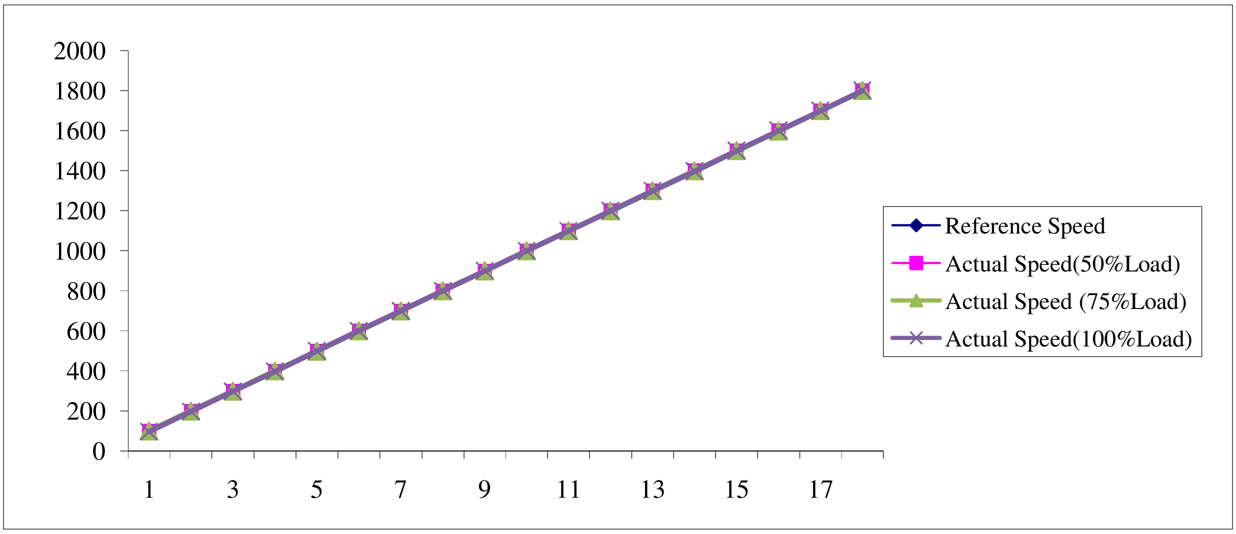


Figure 8.24: Graph for the actual and reference speed relation

CHAPTER: - 9
COMPARATIVE DESCRIPTION OF ALL TECHNIQUES

As all above discussions are shows that with the application of the three-phase controlled rectifier, the time response of the system reduces because of the controlled rectifier as it uses SRCs, and the other disadvantage of such topology is that it requires contactors for the speed reversal across it which reduces the reliability of the system and increases the maintenance of the overall system.

With buck-chopper it shows that it gives fast response for the speed control but it also need contactors for the speed reversal across the armature or field winding, further the rating of such converter is limited due to the buck configuration.

Now, in the H-bridge type chopper; it uses same semiconductor devices for the speed control as well as for the speed reversal so it is consider as the most reliable system for the speed control of the dc motor but for the particular crane application as discussed above it requires independent current control which is not possible in this technique.

COMPARISION OF DIFFERENT TECHNIQUES

Sr. No.		3-Phase Controlled Rectifier	Buck-Chopper	H-Bridge type Chopper	Proposed Technique
1.	Switching Loss	Low	Low	Medium	Medium
2.	Response	Fast	Low	Fast	Very Fast
3.	4-Q Operation	Not - Possible	Not - Possible	Possible	Possible
4.	Maintenance	Low	High	Low	Very Low
5.	Independent Current Control	Not - Possible	Not - Possible	Not - Possible	Possible

Table 1: Comparison of different technique

CHAPTER: - 10
CONCLUSION AND FUTURE SCOPE

10.1 Conclusion

After discussing all the basic required features of the crane drive it shows that for the particular crane application it requires fast dynamic response in the forward as well as in the reverse direction, for dc motor it gives good dynamic response when it is control with independent speed and torque control. So it requires independent armature and field current controller.

For that all requirements the proposed novel technique is suitable and it also proves the simulation of the proposed technique can work for the independent armature current and field current control. And this control we can see in the simulation output waveforms. And it proves that such technique can be used for the required crane application.

The proposed novel technique is also verified with the programming and simulated in the Psim using DLL block, which gives the same response as in the analog control circuit.

For the proposed technique the control algorithm is also programmed in the DSP TMS320F2811 and successfully implemented and tested with the dc series motor and experimental results also shows it matches with the simulation results and the comparison of the actual and reference speed also shows that the actual speed matches with the reference speed for all load conditions.

The other major advantage of the proposed technique is that the future application. If one wants to replace the dc motor with 3-phase induction motor same power topology can be use for speed control of 3-AC motor, only need to change in the program in the processor for the controller.

10.2 Future Scope

- The same technique can implement for the regenerative mode of operation in which during the lowering operation of the hoist motor the generated energy from the hoist motor can feed back to the bridge and trolley motor.
- This project work can extend for the AC as well as DC motor speed control by implementing the program for the both motor controller in the DSP, as the chopper circuit for the DC motor is same as the inverter circuit for the AC motor.

REFERENCES

[1]. Gerhard L. Fischer “Comparison of DC and AC Container Crane Drive Systems” IEEE Conference on power electronics and drive system, PEDS’99, Hong-Kong, p.p.297-302, July-1999.

[2]. F. Busschots “application of field oriented control in crane drives” on Industry Applications Society Annual Meeting, 1991., Conference Record of the 1991 IEEE Publication, pp. 347-353, 28 Sep - 4 Oct 1991

[3]. Kazimierz Gierlotka, Boguslaw Crzesik, Andrzej Nowak and Jozef' Wojnarowski “Control of Overhead Crane Drive with Centered Motion and Elimination of the Bevel” on Industrial Electronics, 1996. ISIE '96., Proceedings of the IEEE International Symposium on Publication, Volume: 2, pp. 1061-1065, 17-20 Jun 1996.

[4]. Ronald Wayne Hughes, Michael Owen Lucas “Method And System For Solid State DC Crane Control” publication at United State Patent Application Patent on Dec. 4. 2003 No. US20030223738A1, p.p. 1-8.

[5]. Omnipulse DDC, DC to DC Crane Control Instruction Manual, MAGNETEK Material Handling Pvt. Ltd. USA.

[6]. Gopal K. Dubey, “Power Semiconductor Controlled Drives”, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey.

[7]. Tamer H. Abdelhamid “Performance of Single-phase DC Drive System Controlled by Uniform P WM Full Bridge DC-DC Converter” 10th IEEE conference on Meditwranean Electrotechnical, Vol-III, pp. 974-977

[8]. Jun-Keun Ji, Seung-Ki Sul “DSP-Based Self-Tuning IP Speed Controller for Rolling Mill DC Drive” IEEE Transaction on Industrial Electronics, Vol. 3, pp. 2276-2281, Nov. 1993

[9]. Ramachandran Balasubramanian and Kong Hung Wong, “A Microcomputer-Based Self Tuning IP Controller for DC Machines” , IEEE Trans., on Ind. App., Vol. IA-22, No. 6, pp. 984-999, Nov/Dec, 1986

[10]. Louis A. Dessiant, Bernard J. Hebert, HOU Le- Huy and Gianni Cavuoti ," A DSP-Based Adaptive Controller for a smooth positioning System ," IEEE Trans., on Ind. Elec., Vol. IE-37, No.5, pp. 372-377, Oct, 1990

[11]. L. Sicot, S. Siala, C. Bergmann, " Sensorless control of DC motors with current and voltage limitation", EPE Symposium on Electric Drive Design and Applications, to be presented at Nancy, France, 1996.

[12]. Chevrel P, Sicot L, Siale S, "Switched LQ Controllers for dc Motor Speed and Current Control: a Comparison with Cascade Control." 27th IEEE Conference on power electronics specialist, Vol. 1, Jun. 1996, pp. 906-912.

[13]. G. Joos, P. Sicard, E.D. Goodman, "A comparison of Microcomputer-Based Implementations of Cascaded and Parallel Speed and Current Loops in dc Motor Drives", IEEE Trans. on Ind. Appl., Vol-28, no. 1992.

[14]. S. P. Chowdhury, Dr. S. K. Basu, R. Mondal, "A Laboratory Model of Microcomputer Based Speed Control Of A D.C. Motor" IEEE Transaction on power system., Vol. 7., No. 1., pp. 403-409 Feb, 1992.

[15]. Sadeq A. Hamed, "Performance Evaluation of three-phase variable speed dc drive system with uniform" IEEE transactions on power electronics, vol. 12, no. 2, pp. 218-242, march1997.

[16]. D. R. Tutakne, H. M. Suryawanshi, S. G. Tarnekar "Universal Input Zero Current Switched High Power Factor Variable Speed DC Drive" IEEE International conference on Industrial technology, Mumbai, pp. 1618-1623, Dec. 2006.

[17]. Pradeep K. Nandam, Paresh C. Sen, "Analog and Digital Speed Control of DC Drives Using Proportional-Integral and Integral-Proportional Control Techniques" IEEE Transactions On Industrial Electronics, Vol. Ie-34, No. 2. May 1987

[18]. Mehta, S. Chiasson J., "Nonlinear control of a series DC motor: theory and experiment", IEEE Transactions on Industrial Electronics, Volume 45, Issue 1, pp. 134 – 141, Feb 1998

[19]. Saffet Ayasun, Gultekin Karbeyaz, "DC Motor Speed Control Methods Using MATLAB/ Simulink and Their Integration into Undergraduate Electric Machinery Courses" Department of Electrical and Electronics Engineering, Nigde University, Nigde 51100, Turkey, 12 March 2007

[20]. S. R. Doradla, Paresh C. Sen, "Solid State Series Motor Drive" *IEEE Transactions* On Industrial Electronics And Control Instrumentation, Vol IECI-22, No. 2, May'95.

[21]. Muhammad H. Rashid, "Regenerative Characteristics of DC Chopper Controlled Series Motors" *IEEE Transactions* On Vehicular Technology, Vol. Vt-33, No. 1, February 1984.

[22]. Parviz Famouri, Wils L. Cooley, “Design of DC Traction Motor Drives for High Efficiency Under Accelerating Conditions” *IEEE Transaction*s On Industry Applications, Vol. 30, No. 4, July / August 1994.

[23]. Sailendra N. Bhadra, Nisit K. De, And Ajit K. Chattopadhyay, Regenerative Braking Performance Analysis of a Thyristor-Chopper Controlled DC Series Motor IEEE TRansactons On Industrl Electronics And Control Instrumentation, Vol. Ieci-28, No. 4, November 1981.

LIST OF PUBLICATION

PAPER PRESENTED

- D.Tandel, A.N.Patel, V.Patel, *"Simulation of the Novel scheme of DC Drive for Electrical Hoist Application"*, NUCONE 2008, National Conference on Current Trends in Technology, Nirma Institute of Tech., Ahmedabad, 27-29 Nov. 2008, pp. 250-255

- D. N. Tandel, A. N. Patel, Vinod Patel, *"Simulation programming and analysis of the Novel Technique for DC Drive for Electric Hoist application"*, ICEESPEEE09, International conference on electrical energy system & power electronics in emerging economies-2009, SRM University, Chennai, 16-17 Mar. 2009.

PAPER SUBMITTED

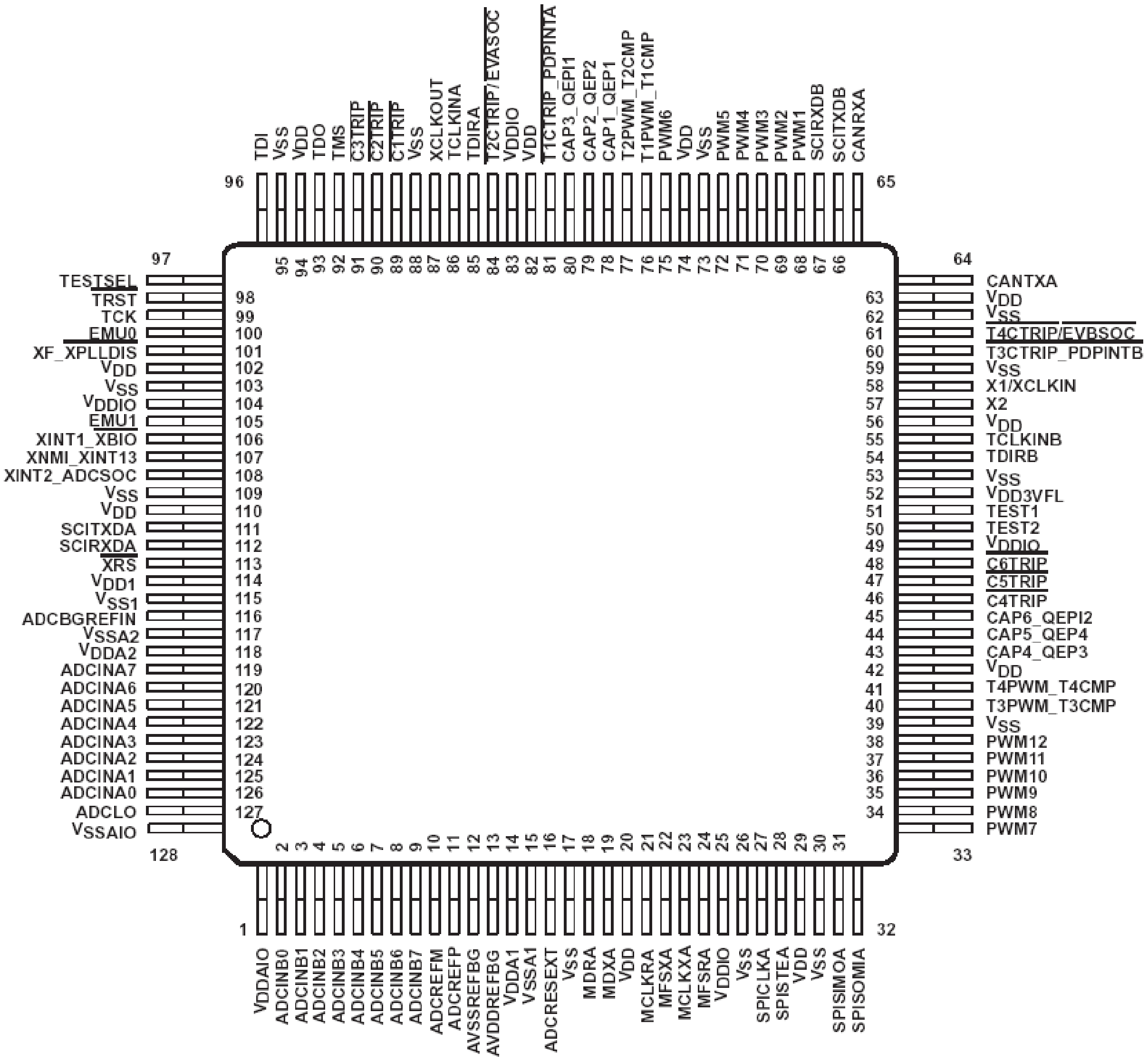
- D. N. Tandel, A. N. Patel, Vinod Patel, *"Simulation of novel technique for dc drive for crane application"*TECHPOS2009, International conference for technical postgraduates,2009, University of Malaya, 14-15 December 2009.

APPENDIX – A

OVERVIEW OF DSP TMS320F2811

DSP TMS320F2811 PIN ASSIGNMENT

The TMS320F2810, TMS320F2811, TMS320C2810, and TMS320C2811 128-pin PBK low-profile quad flat-pack (LQFP) pin assignments are shown in figure.



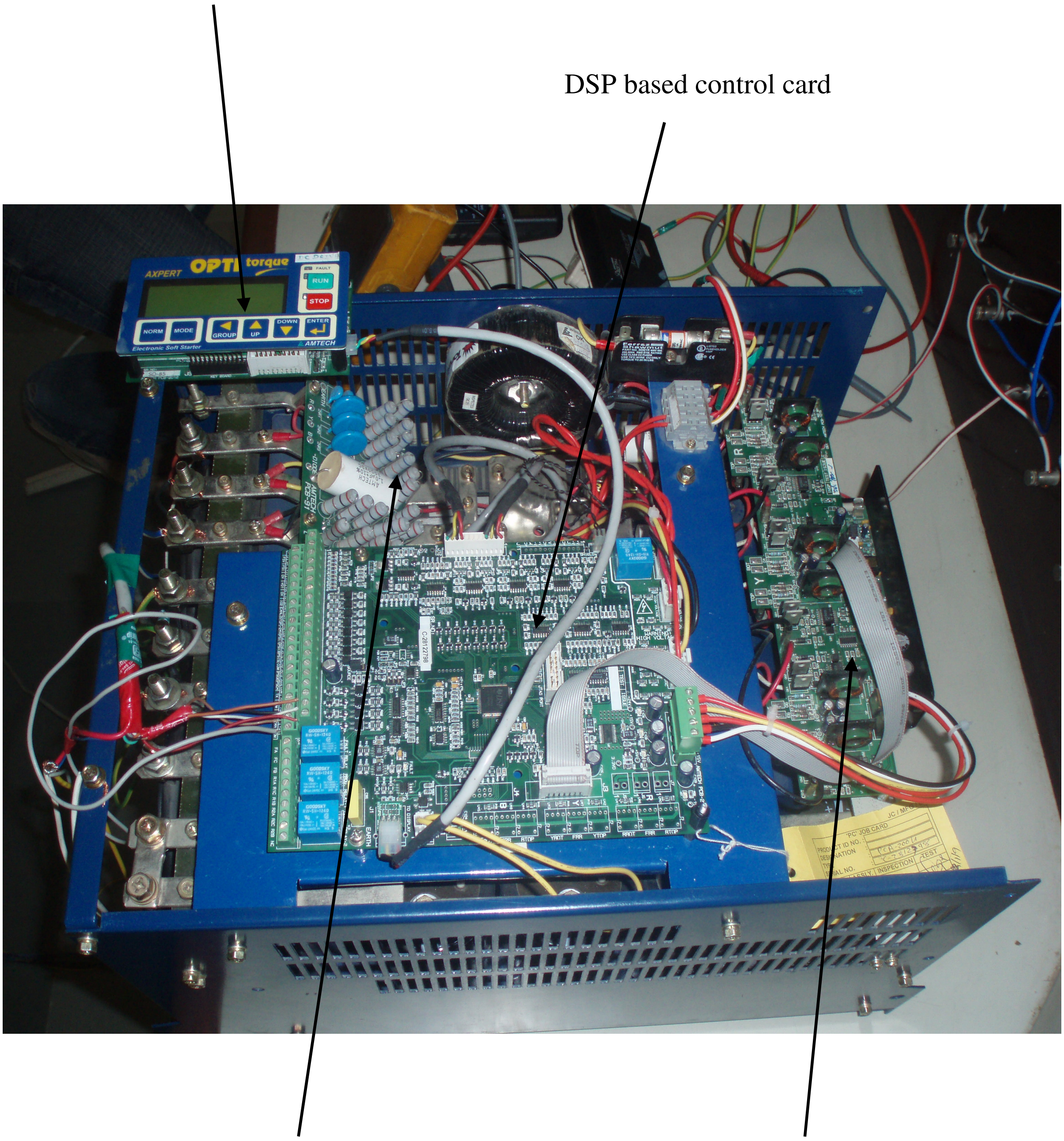
The C28x. DSP generation is the newest member of the TMS320C2000. DSP platform. The C28x is source code compatible to the 24x/240x DSP devices, hence existing 240x users can leverage their significant software investment. Additionally, the C28x is a very efficient C/C++ engine, hence enabling users to develop not only their system control software in a high-level language, but also enables math algorithms to be developed using C/C++. The C28x is as efficient in DSP math tasks as it is in system control tasks that typically are handled by micro-controller devices. This efficiency removes the need for a second processor in many systems. The 32 x 32-bit MAC capabilities of the C28x and its 64-bit processing capabilities, enable the C28x to efficiently handle higher numerical resolution problems that would otherwise demand a more expensive floating-point processor solution. Add to this the fast interrupt response with automatic context save of critical registers, resulting in a device that is capable of servicing many asynchronous events with minimal latency. The C28x has an 8-level-deep protected pipeline with pipelined memory accesses. This pipelining enables the C28x to execute at high speeds without resorting to expensive high-speed memories. Special branch-look-ahead hardware minimizes the latency for conditional discontinuities. Special store conditional operations further improve performance.

FEATURES INCLUDING IN DSP TMS320F2811

1. High-Performance Static CMOS Technology
    - 150 MHz (6.67-ns Cycle Time)
    - Low-Power (1.8-V Core @135 MHz, 1.9-V
    - Core @150 MHz, 3.3-V I/O) Design
2. JTAG Boundary Scan Support
3. High-Performance 32-Bit CPU (TMS320C28x)
    - 16 x 16 and 32 x 32 MAC Operations
    - 16 x 16 Dual MAC
    - Harvard Bus Architecture
    - Atomic Operations
    - Fast Interrupt Response and Processing
    - Unified Memory Programming Model
    - 4M Linear Program/Data Address Reach
    - Code-Efficient (in C/C++ and Assembly)
    - TMS320F24x/LF240x Processor Source Code Compatible
4. On-Chip Memory
    - Flash Devices: Up to 128K x 16 Flash (Four 8K x 16 and Six 16K x 16 Sectors)
    - ROM Devices: Up to 128K x 16 ROM
    - 1K x 16 OTP ROM
    - L0 and L1: 2 Blocks of 4K x 16 Each Single-Access RAM (SARAM)
    - H0: 1 Block of 8K x 16 SARAM
    - M0 and M1: 2 Blocks of 1K x 16 Each SARAM
5. Boot ROM (4K x 16)

  - With Software Boot Modes
  - Standard Math Tables
6. External Interface (2812)
   - Up to 1M Total Memory
   - Programmable Wait States
   - Programmable Read/Write Strobe Timing
   - Three Individual Chip Selects
7. Clock and System Control
   - Dynamic PLL Ratio Changes Supported
   - On-Chip Oscillator
   - Watchdog Timer Module
8. Three External Interrupts
9. Peripheral Interrupt Expansion (PIE) Block. That Supports 45 Peripheral Interrupts
10. Three 32-Bit CPU-Timers

APPENDIX – B
HARDWARE PHOTOS

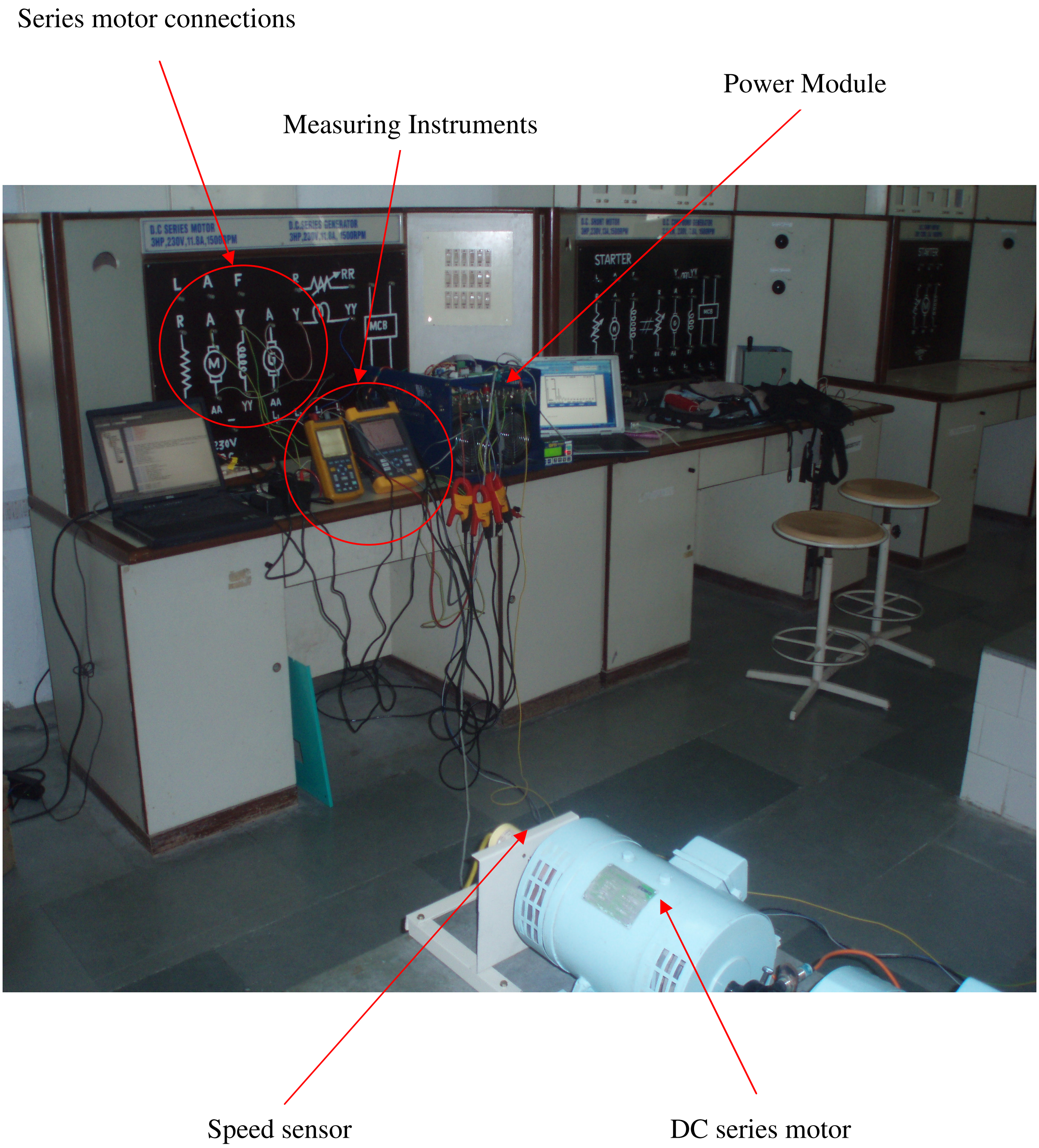


Display and Keypad (Axpert Communicator)

DSP based control card

Soft charge resistors

Gate driver card


Series motor connections
Power Module
Measuring Instruments
Speed sensor
DC series motor