Simulation of Novel Technique for DC Drive for Crane Application

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Abstract: **This paper presents the simulation of novel technique for dc drive for crane application. In crane drive, it consists of three motors for three operations. For hoisting, bridge and trolley. The brief idea of crane drive is discussed. The main concept of novel technique is discussed and simulation results are shown for all three configurations. Main features and benefits for the novel technique is finally concluded.**

***Index Terms*— bridge, crane, DC-DC converter, hoist, PWM, trolley.**

I. Introduction

Application of the transport machines in automated production systems makes a new demand for their control systems simultaneously development of the control systems of electrical drives, basing on microprocessors and applying power electronic converters, enables to obtain better properties of the transport machines. In crane drives, the best performance was offered by dc motors, either as a rotating Ward-Leonard or static four quadrant control. The dynamic performance of the controlled dc motor is very good; this is obtained by controlling the torque and the field independently.

In the part of the DC-DC chopper there are different power topologies are available like controlled rectifier, Buck chopper, H-bridge chopper, etc. In the crane drive application the power topology must be decided with several considerations. Because in the crane drive it requires consecutive operation in the forward and reverse direction, so converter needs to control the voltage across the motor armature in the both direction with very fast dynamic response.

Here in this paper the novel dc-dc converter introduced which has a several advantages, those are suitable for the particular crane application.

II. Block Diagram of Crane Drive

In the crane drive it requires three different motors for three different tasks like for hoisting, bridge and trolley as shown if fig.1. 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.

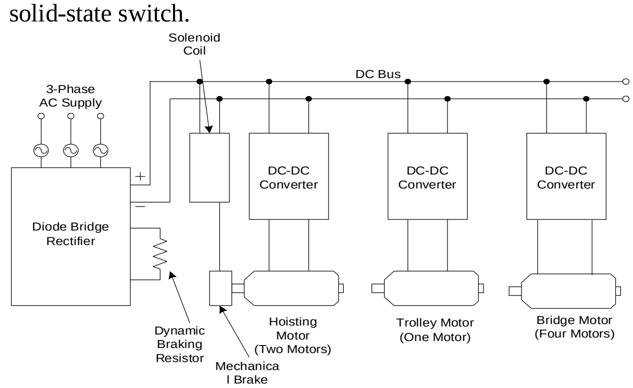


Fig.: - 1 Basic Block Diagram of Crane Drive

III. Proposed Novel Technique for Hoist Configuration

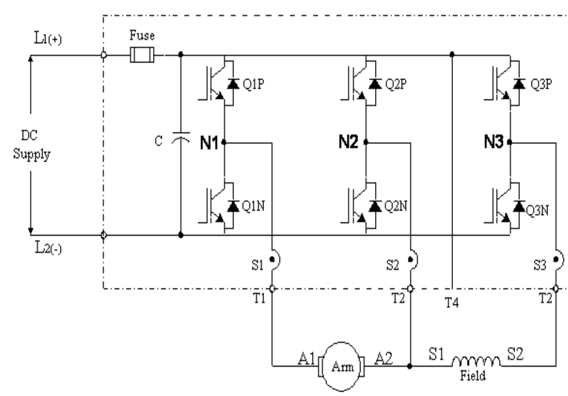


Fig.2 Proposed Technique for the Speed Control of DC Series Motor for hoist configuration

Fig.2 shows the power topology for the reversible dc

* This work was carried out at Amtech Electronics (I) Ltd. Gandhinagar, India.

series motor drive foe hoist configuration; it 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 winding when the torque is in the usual direction for balancing the load on the hoist. This substantially reduces the heating in the semiconductor devices that controls T_2. This technique is able to give the four-quadrant operation, means it can produce either positive or negative torque irrespective of whether the motor is running in the forward or in the reverse direction. The controller is therefore able to absorb energy from the motor when it is providing torque in such 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 as it recovers some energy from the load and returns it to the dc supply.

For the speed control of the motor Pulse Width Modulation (PWM) is used to produce an output voltage by controlling the duty cycle of the top and bottom IGBTs on each leg. The pulse frequency is typically 1 kHz, which is high enough for the inductance of the motor winding to act as a very effective smoothing choke. The current has 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.2, 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 across the Q3N provides a free wheel path for current entering terminal when Q3N is not conducting.

Referring to the fig2, 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.

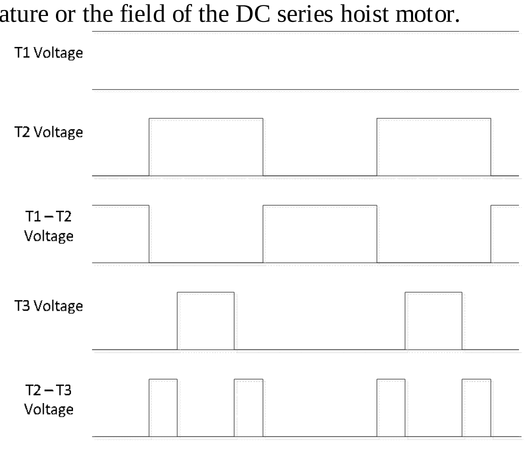


Fig.3 Pulse Width Modulation Waveforms for hoist

Fig.3 shows the voltage pattern for the forward operation. Here in this technique Q1P and Q1N are used for deciding the direction the motor rotation. When Q1P is in on state the operation will done in the forward direction and when Q1N is in on state the operation will be done in reverse direction. When Q1P is ON the N_1 node (T_1 terminal) will come at the positive potential of the dc supply, which shows in the fig.4. Q2P and Q2N switches are modulated as per the required voltage across the motor armature. The voltage at the T_2 terminal is decided by the modulation of these two switches. The voltage across the armature will be the difference potential at T_1 terminal voltage and T_2 terminal voltage. In the same way the difference between the T_2 terminal voltage and T_3 terminal voltage will appear across the field winding.

IV. PROPOSED NOVEL TECHNIQUE FOR BRIDGE AND HOIST CONFIGURATION

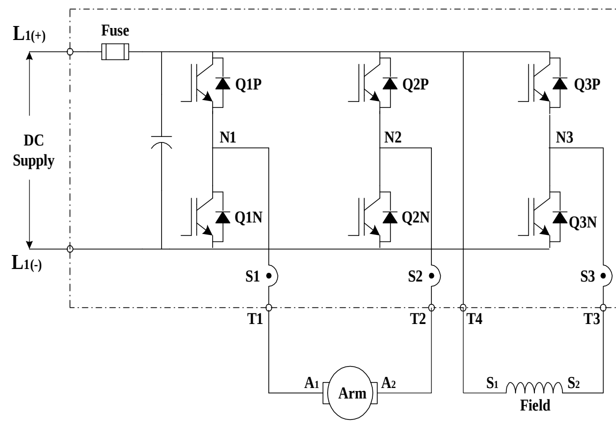


Fig.4 Proposed Technique for the Speed Control of DC Series Motor for bridge and trolley configuration

Fig.4 shows the power topology for the speed control of dc shunt motor for bridge and trolley configuration. By comparing the fig.2 with the fig.4, 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.

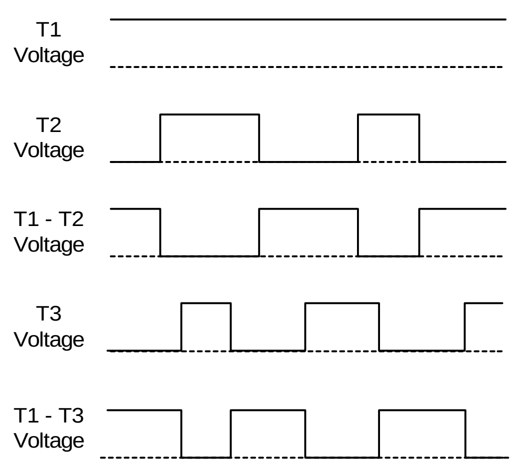


Fig.5 Pulse Width Modulation Waveforms for bridge and trolley

Fig.5 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).

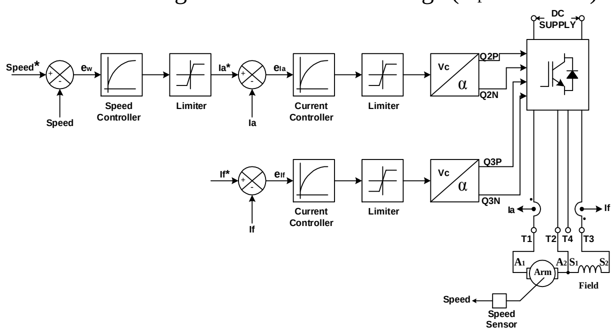


Fig.6 Close-loop controller block diagram

Fig.6 shows the controller for the close-loop speed control of the dc series motor, which consists outer speed PI controller followed by the inner armature current PI controller. The output of this series PI controller is compared with the 1kHz carrier signal to generate PWM for the Q2P and Q2N switches. Other independent field current PI controller is used to balances the field current. The output of the field current PI controller is compared with the 1kHz carrier signals to generate PWM for the Q3P and Q3N switches.

V. SIMULATION OF PROPOSED TECHNIQUE FOR HOIST APPLICATION

To verify the proposed topology it is simulated with the Psim software tool with close loop PI controller as shown in fig. 7. This fig shows only the power topology with motor connections and required sensors. This simulation is done 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.

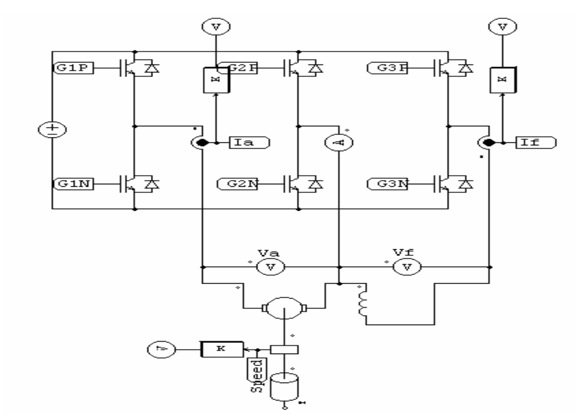


Fig.7 Power Circuit of the Proposed Technique for hoist

Fig.8 shows the close-loop circuit components for simulations, it consists of speed PI controller, inner armature current controller and independent field current controller. The output of the armature current compare with the 1kz carrier signals and generated PWM is given to the Q1P and Q1N, and the output of field current controller is also compare with same carrier signal and given to the Q3P and Q3N.

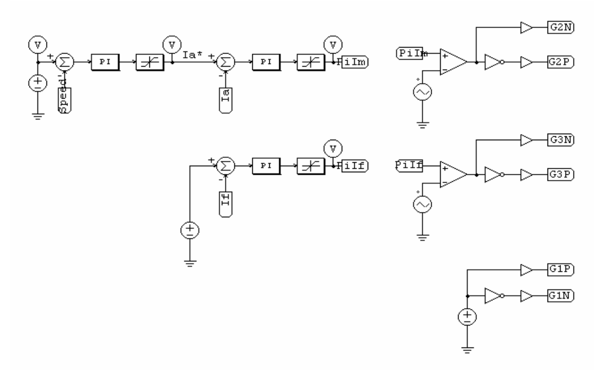


Fig.8 Control Circuit of the Proposed Technique

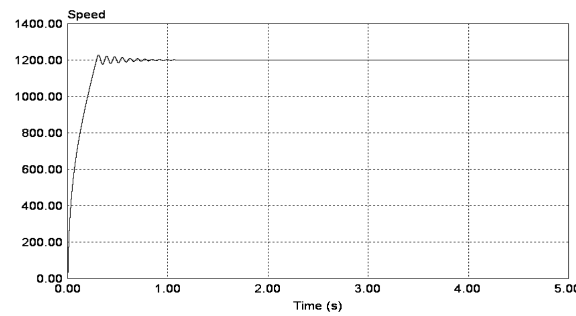
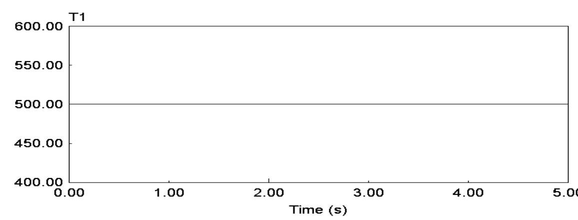
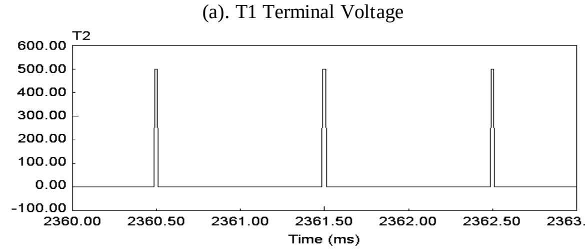


Fig.9 speed of the motor with 1200-rpm reference

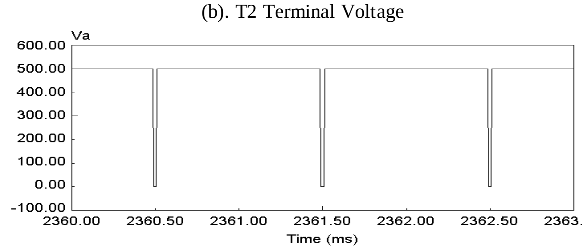
Fig. 9 shows the speed of the motor at the no load when the reference speed is set to 1200rpm, as shown in fig. 9 motor speed is matched with the reference speed very fast.



(a). T1 Terminal Voltage



(b). T2 Terminal Voltage

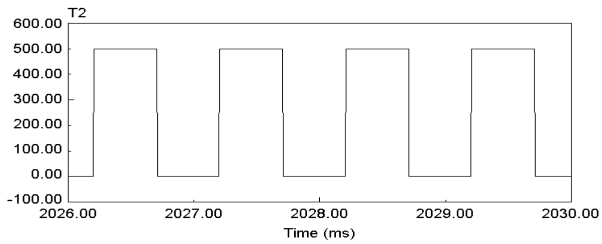


(c). Voltage across Armature

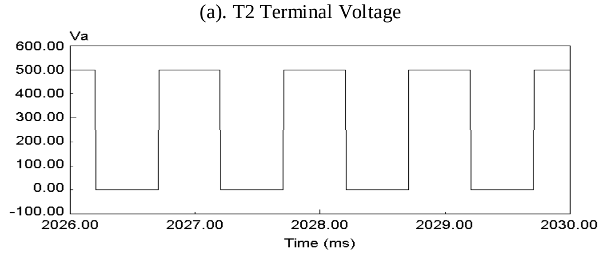
Fig.10. Armature voltage waveform for 1200rpm

Fig. 10 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 at the armature.

Fig.11 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.3. At this speed also the field current is same as the maximum range and armature current is reduced.

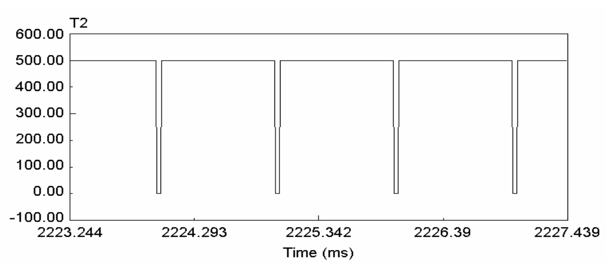


(a). T2 Terminal Voltage

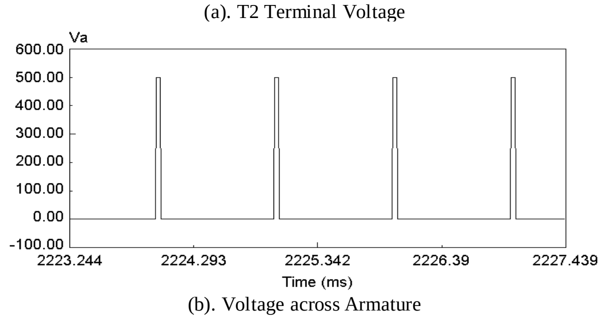


(b). Voltage across Armature

Fig.11 Armature voltage waveform for 600rpm



(a). T2 Terminal Voltage



(b). Voltage across Armature

Fig.12 Armature voltage waveform for 50rpm

Fig.12 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).

VI. SIMULATION OF PROPOSED TECHNOQUE FOR BRIDGE AND TROLLEY CONFIGURATION

Fig.13 shows the simulation circuit for bridge and trolley configuration. The control circuit for these two configurations is same as for hoist configuration.

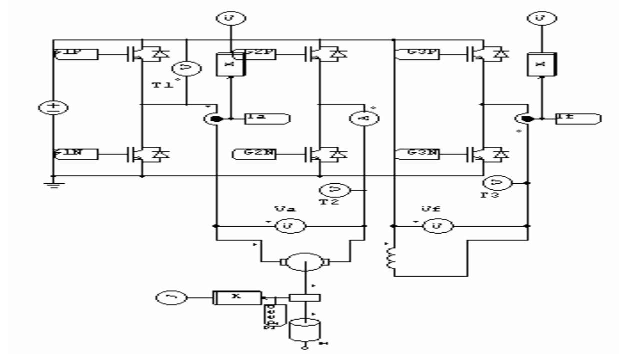


Fig.13 Power Circuit of the Proposed Technique for bridge and trolley

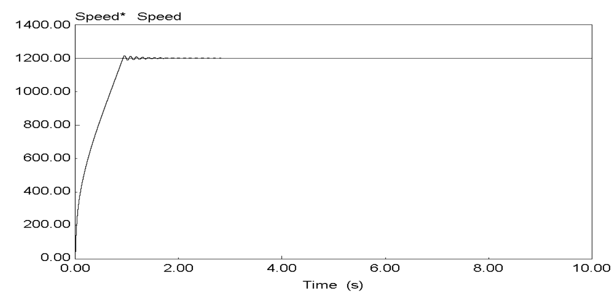
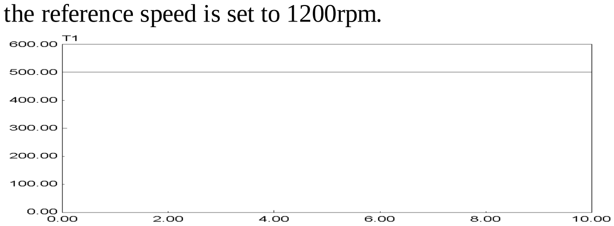
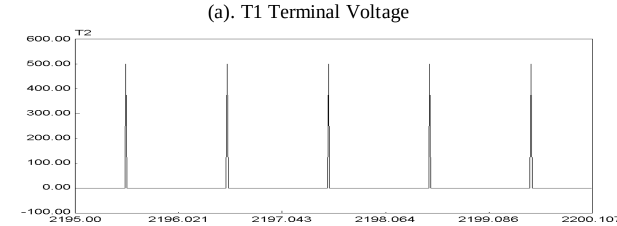


Fig.14 speed of the motor with 1200-rpm reference

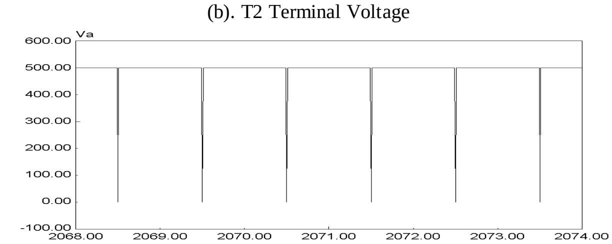
Fig. 14 shows the speed of the motor at the no load when the reference speed is set to 1200rpm.



(a). T1 Terminal Voltage



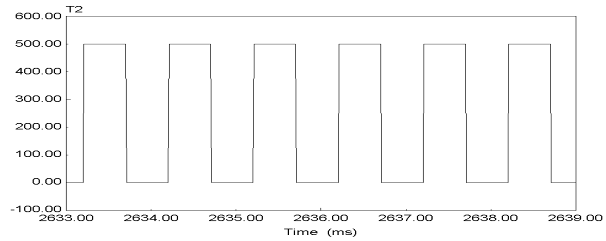
(b). T2 Terminal Voltage



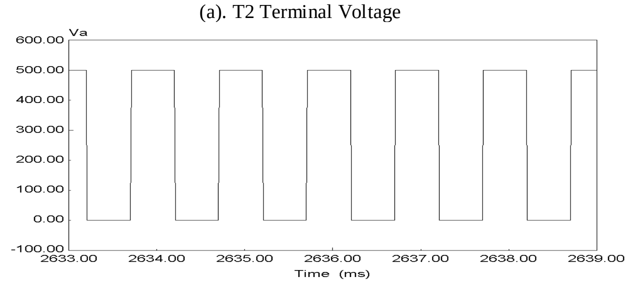
(c). Voltage across Armature

Fig.15. Armature voltage waveform for 1200rpm

Fig. 15 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 at the armature.

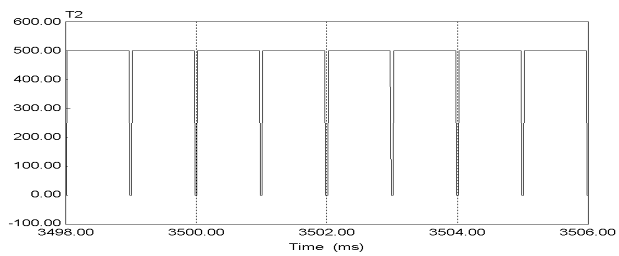


(a). T2 Terminal Voltage

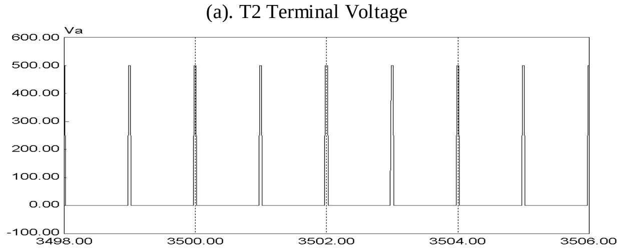


(b). Voltage across Armature

Fig.16 Armature voltage waveform for 600rpm



(a). T2 Terminal Voltage



(b). Voltage across Armature

Fig.17 Armature voltage waveform for 50rpm

Fig.16 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.3. At this speed also the field current is same as the maximum range and armature current is reduced.

Fig.17 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).

VII. 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. The proposed technique is able to control independent armature and field current control. And the dynamic response of such technique is also very fast for hoist as well as for bridge and trolley configuration that is shown in simulation results.

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.

REFERENCES

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

[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 Date: 28 Sep-4 Oct 1991 On page(s): 347-353

[3]. Kazimierz Gierlotka, Boguslaw Crzesik, Andrzej Nowak and Jozef' Wojnarowski, Tejas patel “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 Date: 17-20 Jun 1996 Volume: 2, On page(s): 1061-1065

[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. US

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