SIMULATION PROGRAMMING & ANALYSIS OF THE NOVEL TECHNIQUE FOR DC DRIVE FOR ELECTRIC HOIST APPLICATION

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Abstract: **This paper presents the simulation and analysis of novel technique for the speed control of the dc series motor in both directions. The main focus is on the dc drive for the hoist application. The different techniques are discussed and also compared with the proposed novel technique. Simulation of the novel technique is also done and apparent benefits of novel technique are concluded.**

Key words: **dc drive, crane**

I. INTRODUCTION

DC Drive has a history of applications in the crane industries, with the application of the dc series motor because of its high starting torque. For the particular hoist application the cycle of forward and reverse direction operation is very fast so the dynamic response of the drive must be very quick in both directions.

The dynamic performance of the dc motor is very good when the speed and torque of the motor controlled independently [1]. So to improve the dynamic performance it is necessary to control the armature and field current control independently.

In the area of dc drive different techniques are available for the speed control or say dc voltage control like; controlled rectifier, buck chopper, H-bridge chopper, etc. in the hoist application technique must be decided with several considerations. In the hoist application it requires consecutive operation in the forward and reverse direction, so converter needs to control the voltage across armature in both directions with very dynamic response.

In the operation of the hoisting mode the energy management in the appropriate direction is always advantageous. In the crane drive for whole operation it includes hoisting motor, trolley motor and the bridge motor. So the released energy during the regeneration from the hoisting motor can be fed to trolley or bridge motor for power saving that is called the optimal energy management. For such requirement the controller must be operates in the 4-Q operation.

II. CONVENTIONAL TECHNIQUES

For the speed control of dc series motor different techniques are used and those are selected according to their individual advantages. The brief descriptions of some of them are explained with their features are discussed as below. Fig.-1 shows the controlled rectifier circuit for the speed control of the dc series motor. In this technique for the speed control or say to control the voltage across the armature the firing angle of the SCR is controlled.

1. Three Phase Controlled Rectifier

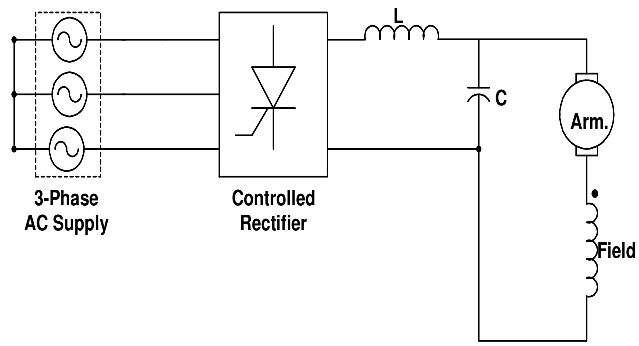


Fig.1 Three-Phase Controlled Rectifier for the Speed Control

The major advantage of the technique is that the speed control is achieved directly using controlled rectifier; means it does not requires any extra chopper for the speed control so the overall system becomes cheaper. Besides of that the disadvantage of this technique is the poor dynamic response and this technique require contactors for the speed reversal across the field or armature winding, so the reliability of the system is less and the higher maintenance. Due to the application of SCR the input p.f. of the system is very poor

2. *H-Bridge chopper:*

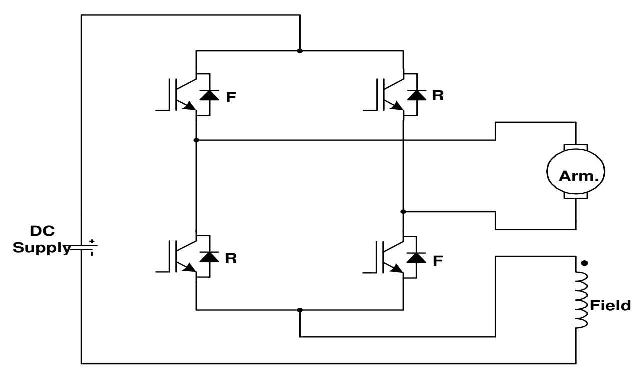


Fig.2 H-Bridge Chopper for the Speed Control of DC Series Motor

Fig.-2 shows the H-Bridge chopper configuration for the speed control of the dc series motor. In this technique four IGBTs are used for feeding the power to the windings of the motor. For the speed control in the forward direction two switches (named as F in the figure) are modulated with appropriate pulses with the PWM or other modulated technique using close loop PI controller.

The major advantage of this technique is that it does require any external contactor across the field or armature for the speed reversal so the cost and the reliability of the system is good.

But as discussed above to get the better dynamic performance it requires independent armature and field current control, which is not possible using this technique.

After discussing all about two techniques it is easy to understand that no one from those both techniques can provide all required characteristics for the hoist application. So here in this paper one technique is proposed which satisfies all required characteristics, like it gives independent speed and torque control as well as the same power topology can use for the speed reversal without any external contactors.

III. PROPOSED NOVEL TECHNIQUE

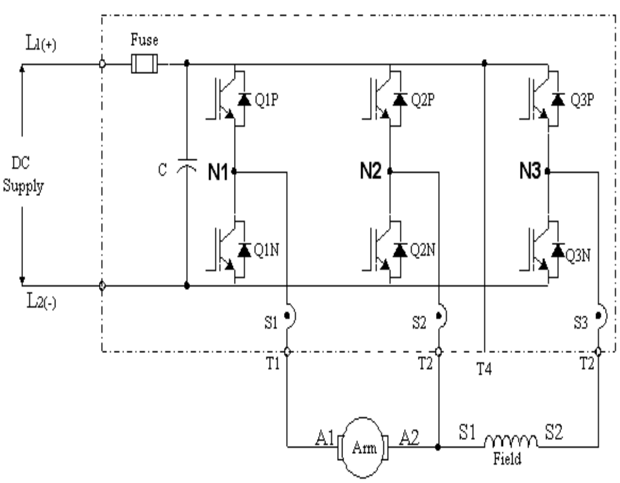


Fig.3 Proposed Topology for the Speed Control of DC Series Motor

Fig.3 shows the power topology for the reversible dc series motor drive, 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 1kHz, 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.3, 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 fig3, 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.

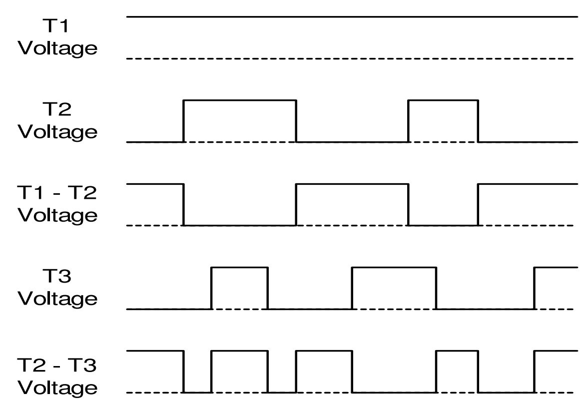


Fig.4 Pulse Width Modulation Waveforms

Fig.4 shows the required 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.

Fig.5 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.

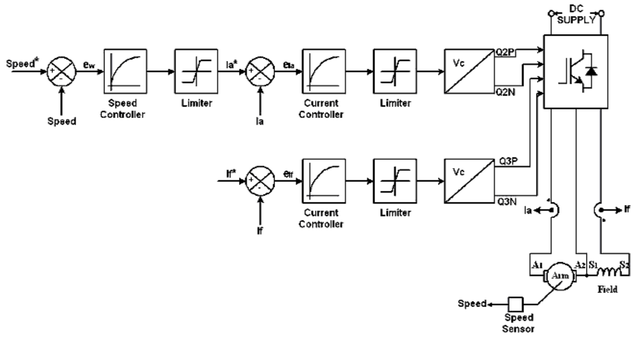


Fig.5 Close-loop speed control of dc series motor

IV. FLOW CHART FOR THE CLOSE-LOOP CONTROL

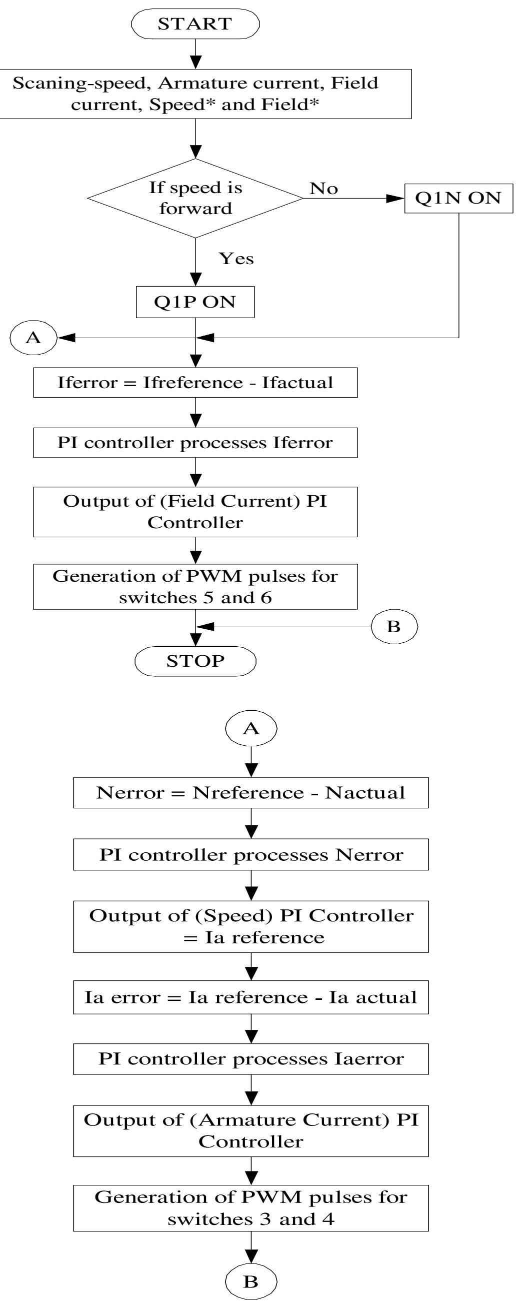


Fig.6 Flow chart for the close-loop control

V. SIMULATION OF THE PROPOSED TECHNIQUE

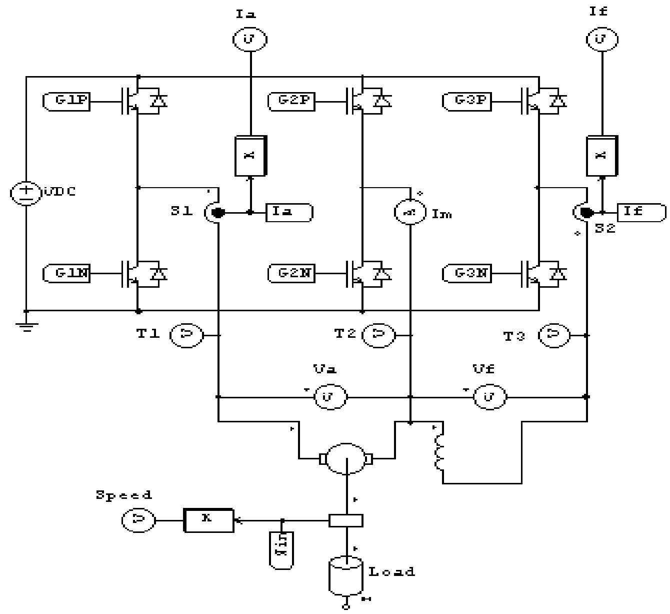


Fig. 7 Power Circuit of the Proposed Topology

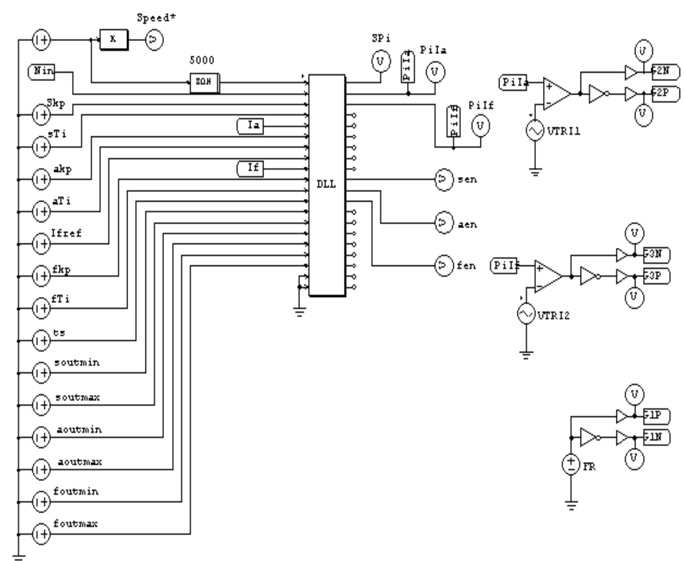


Fig. 8 Control Circuit of the Proposed Topology

To verify the proposed technique it is simulated with the Psim software tool with close loop PI controller as shown in fig. 7. Fig 7 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 modulation of IGBTs.

Fig.8 show the controller for the close-loop control of dc series motor the PI controller is programmed as per the shown flowchart in fig.6 in the **'c'** lalguage and linked with the DLL block in the Psim.

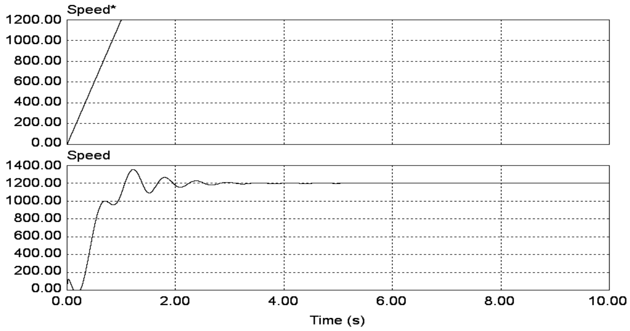


Fig. 9 speed of the motor with 1200-rpm reference

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.

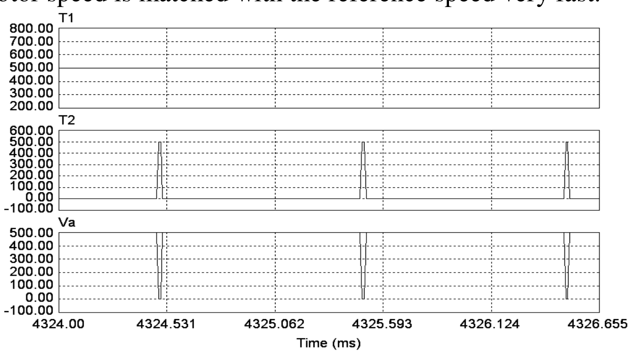


Fig.10 Voltage across the armature at 1200rpm reference

Fig. 10 shows the voltage pattern for the maximum speed and it also shows the voltage across the armature, is the difference between the T_1 terminal voltage and T_2 terminal voltage.

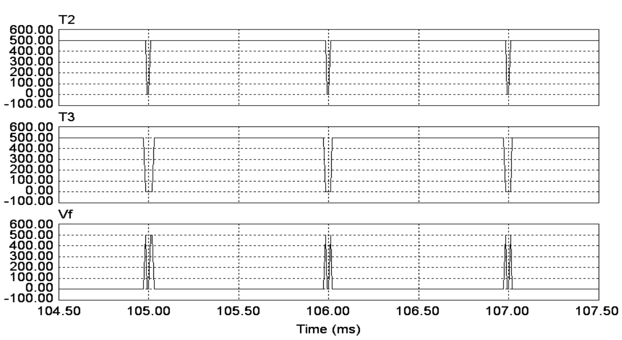
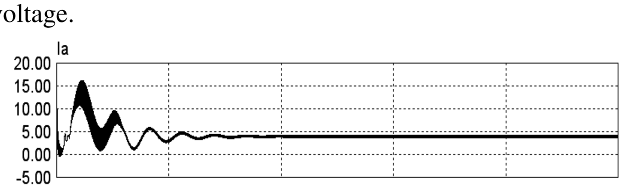
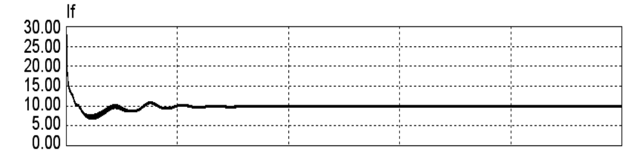


Fig.11 Voltage across the field at 1200rpm reference

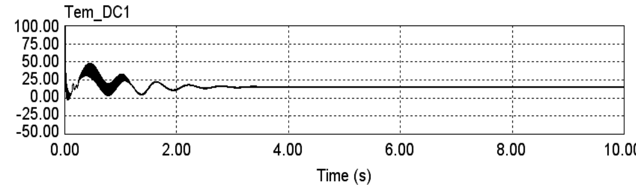
Fig.11 shows the voltage pattern for the maximum speed reference speed, as shows in fig the voltage across the field is the difference between the T_2 terminal voltage and T_3 terminal voltage.



(A) Armature Current



(B) Field Current



(C) Generated Motor Torque

Fig.12 Armature current, Field Current and motor torque waveform

Fig.12 shows the (a) armature current (b) field current and (c) Generated motor torque 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 or speed increases armature current will increases.

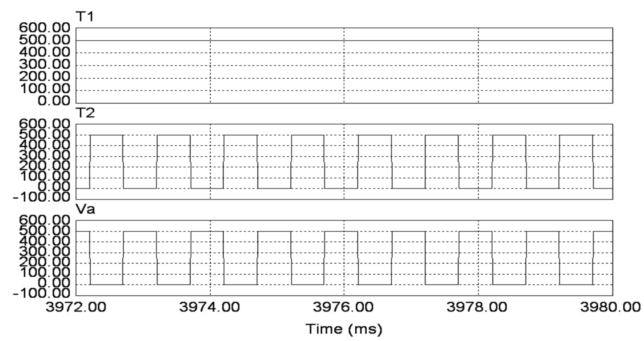


Fig.13 Voltage across the armature at 600rpm reference

Fig.13 shows the voltage pattern for the half speed reference, it shows that as reference speed decreases width of the T_2 terminal voltage waveform increases and the difference between the T_1 and T_2 terminal voltage decreases and as a result voltage across the armature decreases, this shows that this follows the same pattern as discussed in the fig. 4. At this speed also the field current is same as the maximum range and armature current is reduced.

Fig.14 shows the voltage pattern for the half reference speed, as shows in fig the voltage across the field is the difference between the T_2 terminal voltage and T_3 terminal voltage.

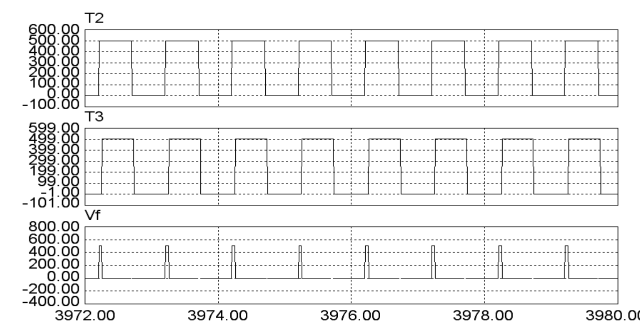
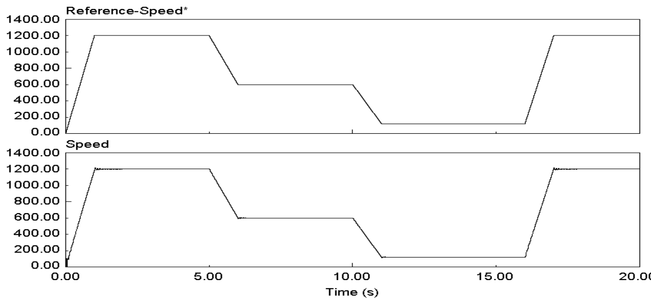
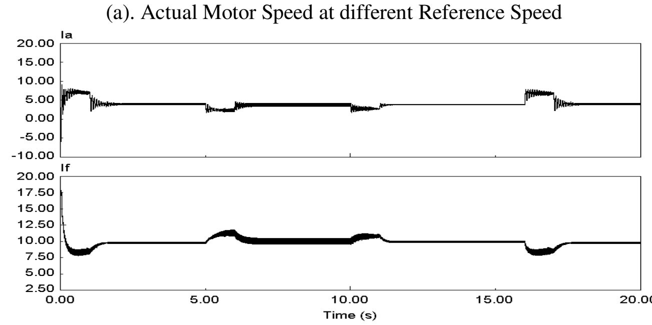


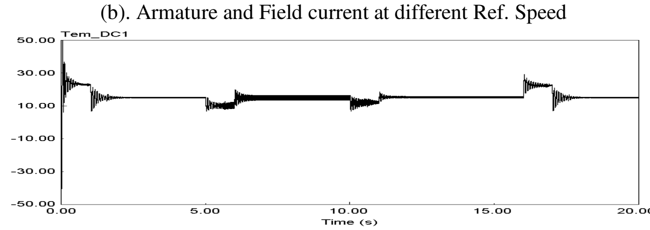
Fig.14 Voltage across the field at 600rpm reference



(a). Actual Motor Speed at different Reference Speed



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



(c). Generated Motor Torque at 15N-m Load Torque

Fig.15 Motor Response at 15N-m load with different Reference Speed

VI. COMPARISON OF DIFFERENT TECHNIQUES

Sr. No.		Technique-1	Technique-2	Proposed Scheme
1.	Switching Loss	Medium	Low	Medium
2.	Response	Fast	Low	Very Fast
3.	4-Q Operation	Not Possible	Possible	Possible
4.	Maintenance	Low	High	Very Low
5.	Independent Current Control	Not Possible	Possible	Possible

CONCLUSION

It is found that all techniques have certain merits and demerits according to particular application. But as far as the hoist application is concern, the major problem with the technique using H-Bridge topology is that the dynamic response of the system is medium as it is not applicable for the independent armature and field current control. And the problem with the technique using three-phase rectifier is that the time response is very slow and it requires external contactors for speed reversal as well as it is also not applicable for the independent armature and field current control. That is shown in the simulation also.

So in the hoist application one has to use the scheme, which is able to give higher torque at very low speed also for that the independent current control is necessary, and for these entire requirements the proposed technique is better solution, which can control the armature and field current independently. As it does not require any external contactors for speed reversal so the reliability and efficiency of the overall drive system is very high.

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 “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.

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