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A Modified Energy Conservation Circuit for Chopper fed DC Motor Drive

***Abstract**. Some of the Industrial DC motor drives use four quadrant chopper. This letter proposes a new scheme of chopper configuration which leads to energy conservation in DC motor drive. The proposed scheme needs some modifications in the switching device configuration such as combining a MOSFET switch with a relay and this modification leads to energy saving. The simulation results show the superiority of the new method suggested in this letter.*

***Streszczenie.** W artykule przedstawiono nową topologię choppera, pozwalającą uzyskać oszczędność energii w napędzie z silnikiem DC. Proponowana zmiana polega dołączeniu przekaźników do obwodów tranzystorów MOSFET. Zaprezentowano wyniki symulacyjne. (**Zasilanie napędu z silnikiem DC z choppera z obwodem oszczędzającym energię**)*

Keywords: *Energy Conservation, DC Motor Drive, Four Quadrant Chopper.*
Słowa kluczowe: oszczędność energii, napęd z silnikiem DC, chopper czterokwadrantowy.

1. Introduction

In industries, DC motor drives are still used for some applications due to their good performance and high efficiency. Energy conservation in DC motor drives leads to reduction in electricity cost of the industry and also considerable reduction in power demand for the country. Industries use the DC motor drive mainly for forward and reverse motoring and regeneration. Four quadrant chopper is used in some of the DC motor drives for forward and reverse motoring.

The conventional circuit configuration for four quadrant chopper is shown in figure 1 and it uses four switches. Due to their low cost, MOSFETs are used as switches in the chopper. For forward motoring, switches M1 and M2 are ON, and M3 and M4 are OFF. For reverse motoring, switches M3 and M4 are ON and M1 and M2 are OFF.

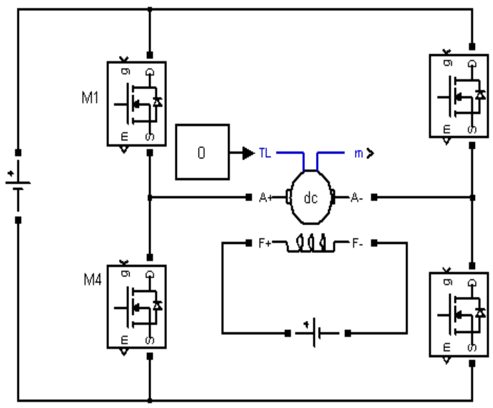

Fig.1. Circuit diagram of Conventional system

In the proposed technique, MOSFET switch is combined with the relay and it is shown in figure 2. In this configuration, switch M1 and M3 are paralleled with Relay of 0.01Ω ON state resistance. If the forward motoring and reverse motoring operation is needed alternatively within a very short period (within a minute), the motor can be operated with ordinary four switch chopper configuration which is mentioned above. If either the forward motoring or reverse motoring operation is needed continuously for a long duration (more than a minute) then the relay across one of the conducting switch can be operated instead the conducting switch to conserve energy, since the conduction loss in the relay is less than that of the MOSFET switch.

For long duration forward motoring, Relay 1 is kept continuously on and conventional duty cycle control is done on M2 and other devices are kept in OFF state. For long duration reverse motoring, Relay 2 is kept continuously on and conventional duty cycle control is done on M4 and other devices are kept in OFF state. The Voltage stress across the switch does not vary in the proposed system compared to conventional this is evident from figure 3 and figure 4 which shows the voltage stress across the switches. The maximum voltage stress across the switch is 500 V. Matlab simulation is done to find out the switch conduction loss assuming MOSFET switch's on state resistance (Rd on) is 0.27Ω and Relay on state resistance is 0.01 Ω.

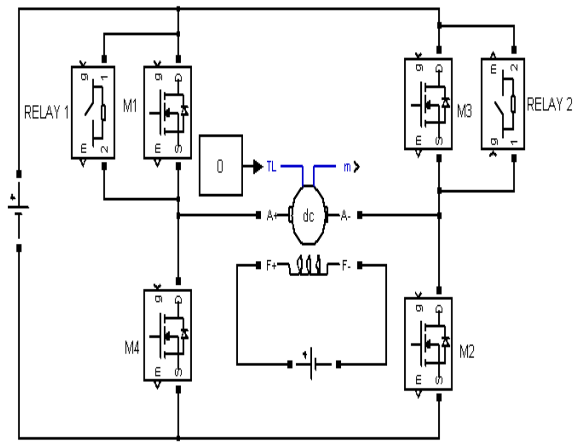

Fig.2. Circuit diagram of Proposed system

Table 1. Simulation Results for 5HP DC motor

Load Current (A)	Conventional Circuit Total Conduction Loss during Long duration Forward Motoring (W)	Energy Saving Circuit Total Conduction Loss during Long duration Forward Motoring (W)	% Conduction Loss Savings
2	2.16	1.12	48.14
5	13.5	7	
10	54	28	
15	121.5	63	
20	216	112	

Table I shows the simulation readings for conduction loss in conventional and proposed configuration of four switch chopper in long duration forward motoring in a 500V, 15 Hp DC motor. Figure 5 shows the conduction loss Vs load current curve for the table 1 readings. From these readings, it is clear that 48.14% of the conduction loss is reduced in the proposed system compared to conventional system .

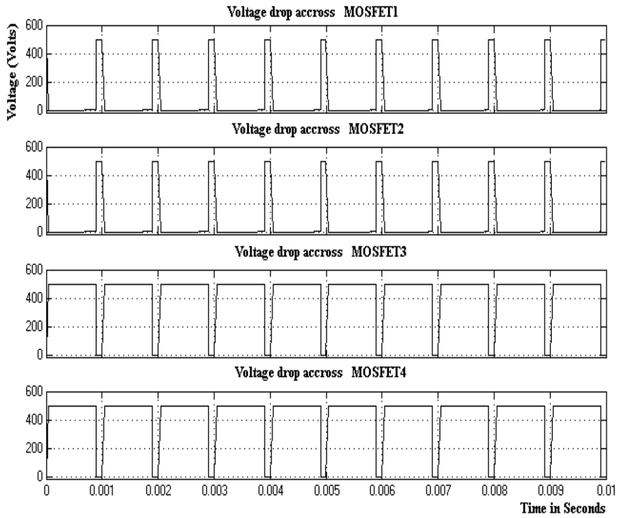

Fig.3. Voltage Stress across the MOSFET Switches in Conventional System

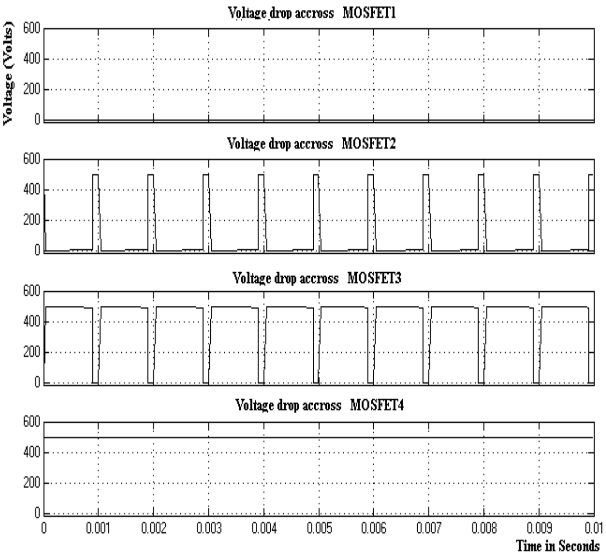

Fig.4. Voltage Stress across the MOSFET Switches in Proposed System

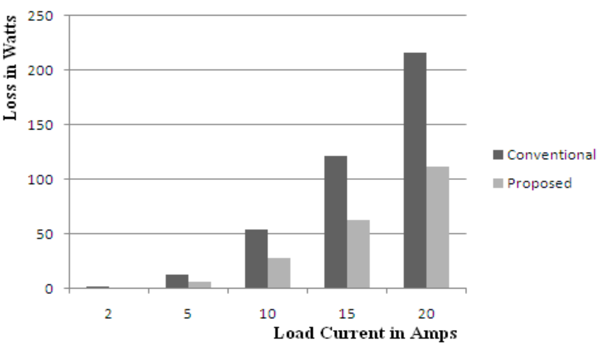

Fig.5. Conduction Loss comparision during long duration forward motoring

Table 2 shows the comparison of conventional circuit and energy saving circuit with respect to different parameters. The additional requirements for proposed circuit compared to conventional system are two relays and their pulse generating systems. The additional cost requirement for this is 200 rupees. The payback period for this system with different conditions are shown in table 3. The payback period for 20 Hours daily long duration forward or reverse motoring operation with 20A load current is 24 days and for 10 A load current is 96 days. The per kilowatt hour cost is assumed as rupees 4.

Table 2. Comparison of Conventional circuit and Energy saving circuit with respect to different parameters

Parameters	Conventional Circuit	Cost	Energy Saving Circuit	Cost
Total Switches	4	(4× 150) = 600	4	(4× 150) = 600
Total Relays	0	0	2	(2× 75) = 150
Voltage Rating of Each Switch	500 V	-	500V	-
Current Rating of Each Switch	20A	-	20A	-
Additional pulse generation requirement	Not Required	0	Required	50
Additional cost	-		200	

Table 3. Payback Period for Proposed System for various conditions

Pay Back Period in Days	20 Hours daily long duration forward or reverse motoring operation		10 Hours daily long duration forward or reverse motoring operation		5 Hours daily long duration forward or reverse motoring operation		1Hour daily long duration forward or reverse motoring operation	
	20A	10A	20A	10A	20A	10A	20A	10A
	24	96	48	192	96	357	481	1786

6.Conclusion

This letter has explained a simple scheme for energy conservation in DC motor drive that uses four quadrant chopper. Simulation results indicate the reduction in conduction loss and thereby conservation of energy.

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