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Improved IGBT Chopping of DC-Link Series Brushless DC Motor Drive Strategy Small Intermediate Circuit Capacitor

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Abstract: *In this thesis describes solar PV system worn for pumping system in order to gain the maximum benefits from solar source along with also gives soft starting of BLDC motor. The model is inured study manifold parameter alternative effects upon the PV array in conjunction with operating temperature along with solar irradiation level. This paper accommodates an analysis regarding the photovoltaic system's interpretation in real time in addition to the factor disturbing it such Temperature along with Irradiation. BLDC Motor speed is regulated all the way through inverter. The VSI is regulated via fundamental frequency switching, escaping the losses owing to high-frequency switching, in regulate to augment the efficiency of the proposed system.*

Keywords: STC (Standard Test Condition) PWM (Pulse Width Modulation) PMSM (Permanent Magnet Synchronous Motor) PMBLDCM (Permanent Magnet Brushless DC Motor).

I. INTRODUCTION

Brushless DC motors (BLDCM) have been widely used in many fields, such as aerospace, electric vehicles, household appliances and so on, due to their simple structure and high power density. However, the torqueripple restricts its application in high-precision control system,especially the commutation torque ripple.In motoring operation, the torque ripple reduction ofBLDCM has been widely investigated and some good controlstrategies have been presented.

These strategies mainly include pulse width modulation (PWM) technique voltage vector selection method and the control strategy based on DC-DC converter and so on. Braking state is another important state in the operation of BLDCM. To some extent, electric braking can reduce the size of mechanical braking device, alleviate the mechanical wear, and increase the flexibility of braking torque control.Particularly, the development of electric vehicle has made electric braking attract ever greater attention. However, in braking operation, there exists not only the commutation torque ripple, but also the problems of braking torque controllability and braking energy regeneration.

In braking operation, the current circuit and the variationtrend of the current have changed compared with those inmotoring operation. Thus, there is large difference in thetorque control between these two operation modes. Aelectric braking control method based on bipolar H-PWM_LPWM modulation pattern is proposed ,where themotor's phase inductance and inverter's switch are utilized toform a boost circuit and the regenerative braking is realized bychanging the switching sequence of the inverter.

On this base,in order to reduce switching times, a regenerative brakingcontrol strategy using unipolar H-OFF_L-PWM pattern is presented a control strategy based on hybridswitching state is proposed. This strategy divides eachmodulation cycle into two stages and different switching statesare selected at every stage to reduce switching losses. The comparison and analysis are made on regeneration capabilityof braking energy under unipolar and bipolar modulationpatternsWhen the BLDCM drive system is supplied by the single-phase AC source, in order to keep the DC-link voltage constant, the output terminal ofthe diode rectifier usually needs to be equipped with a large electrolytic capacitor.

II. LITERATURE REVIEW

In (Oct. 2015), "A torque ripplecompensation technique for a Low-Cost brushless DC motor drive,"H. K. SamithaRansara and U. K. Madawala, Observes that For the motor systems supplied by single-phase AC source,aiming to achieve current smooth control and reduce the drivesystem volume at the same time, some control methods areproposed to reduce the DC-link capacitance.Among of them, a novel DC-link topology of the BLDCMdrive is proposed.

In (2016) "A review of the condition monitoring of capacitors in power electronic converters," H. Soliman, H. Wang and F. Blaabjerg, says when the BLDCM drive system is supplied by the single-phase AC source, in order to keep the DC-link voltage constant, the output terminal of the diode rectifier usually needs to be equipped with a large electrolytic capacitor. However, the existence of the large DC-link capacitor reduces the power density of the converter.

In (Sep. 2017) "Series IGBT chopping strategy to reduce DC-Link capacitance for brushless DC motor drive system," C. L. Xia, P. F. Li, X. M. Li, and T. N. Shi,saysthat for the motor systems supplied by single-phase AC source, aiming to achieve current smooth control and reduce the drive system volume at the same time, some control methods are proposed

In (Jan. 2018), "Inverter power control based on DC-Link voltage regulation for IPMSM drives without electrolytic capacitors," N. Zhao, G. Wang, D. Xu, L. Zhu, G. Zhang, and J. Huo, carried out the motor drive system is only consisted by the single-phase diode rectifier and the three phase full-bridge inverter. This approach can obviously compress the volume of motor drive systems, but the output voltage of the diode rectifier is fluctuant, which cannot meet the requirements of the smooth operation of the BLDCM. For the motor systems supplied by single-phase AC source, aiming to achieve current smooth control and reduce the drivesystem volume at the same time, some control methods are proposed.

In (Apr. 2019)"A position sensor less control strategy for the BLDCM based on a Flux-Linkage function," W. Chen, Z. B. Liu, T. N. Shi, and C. L. Xia says **B**rushless DC motors (BLDCM) have been widelyused in many fields, such as aerospace, electric vehicles,household appliances and so on, due to their simple structureand high power density.

In (Mar. 2018) "Simplified finite controlSet-Model predictive control for matrix Converter-Fed PMSM drives," M. Siami, D. Arab Khaburi and J. Rodriguez,says thatto solve the problems caused by the usage of large DC-link capacitors, capacitor-less motor drives have become hot research directions in recent years. Apparently, the matrix converter is a typical AC-AC converter without DC link capacitors.

III. METHODOLOGY OF TORQUE RIPPLE MINIMIZATION FOR BLDC MOTOR

BLDC motor creates a trapezoidal back-EMF, and in this way, the energized current waveform is ideally rectangular-moulded. The phase resistances of the stator windings are thought to be equivalent. The self and mutual inductances are consistent independently of rotor position because of surface mounted permanent magnet rotor topology. The rotor-induced currents are dismissed and the damper windings are additionally not present. The identical circuit of BLDC motor appears in Figure 3.1.

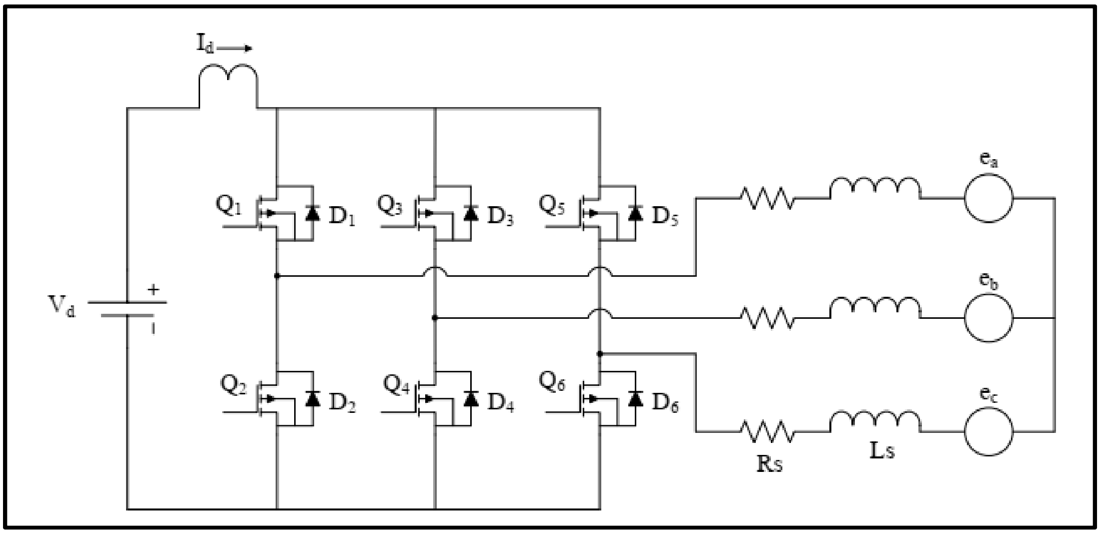

Figure 3.1 Equivalent Circuit of BLDC motor

The dynamic machine model is exceptionally straightforward in contrast with that of a sinusoidal machine. The BLDCM has three stator windings and permanent magnets on the rotor. Its voltage condition of three windings with phase variables can be given in the accompanying structure:

$$\begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} + s \begin{bmatrix} L_s & M & M \\ M & L_s & M \\ M & M & L_s \end{bmatrix} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} + \begin{bmatrix} e_{a1} \\ e_{b1} \\ e_{c1} \end{bmatrix}$$

Where L=self-inductance, M=mutual inductance between phases, v=applied phase voltage, S=Laplace operator and e= phase back EMF's. Since

$$i_{a1} + i_{b1} + i_{c1} = 0 \quad Mi_{b1} + Mi_{c1} = -Mi_{a1}$$

Substituting equation (4.3) in (4.1), the state variable form of the equation is

$$L_s \begin{bmatrix} \frac{di_{a1}}{dt} \\ \frac{di_{b1}}{dt} \\ \frac{di_{c1}}{dt} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} - \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} - \begin{bmatrix} e_{a1} \\ e_{b1} \\ e_{c1} \end{bmatrix}$$

Where Ls=L-M is the equation self-inductance per phase. The torque and mechanical equation are

$$T_e = \left(\frac{P}{2}\right) \frac{e_{a1} i_{a1} + e_{b1} i_{b1} + e_{c1} i_{c1}}{\omega_r}$$

$$J\left(\frac{P}{2}\right) \frac{d\omega_r}{dt} = T_e - T_l$$

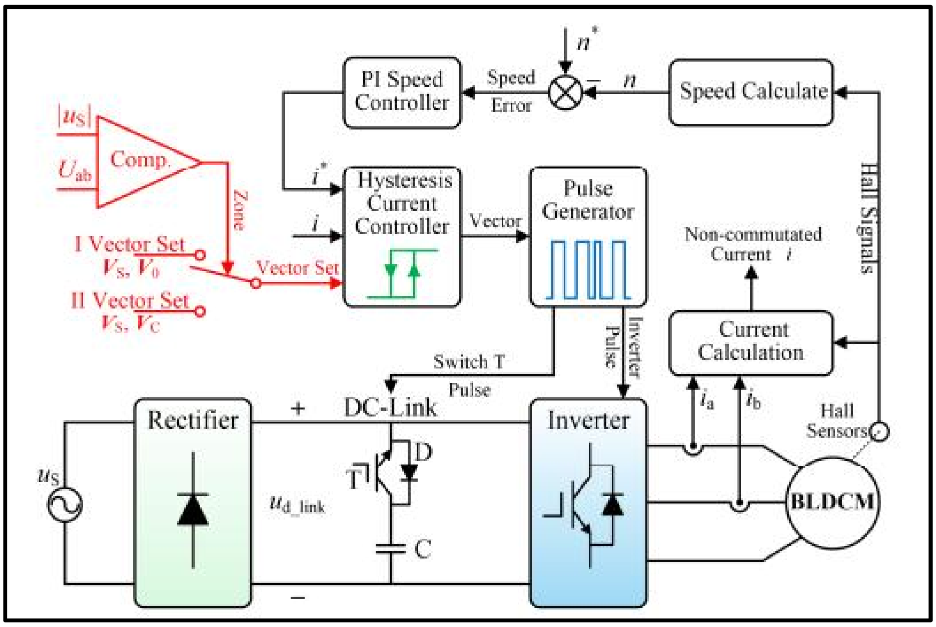

Fig. 3.2 Schematic of the controller of proposed strategy

Equation (4), (5), and (6) describes the complete dynamic model of the BLDCmotor. Where J = moment of inertia of rotor shaft and load, ia1,ib1,ic1are thephase currents,

3.1 Controller design

Based on the proposed strategy, the correspondingcontroller is designed, which is mainly composed of a PI Speed controller, a zone determination and a hysteresis currentcontroller. The overall structure of the controller is shown in fig. 3.3 as shown in fig. 3.3, the motor speed n is calculated by the hall signals. A pi regulator is used as the speed controller,which outputs the reference value i^* of the current controller.In addition, two current sensors are used to measure the phase currents of bldcm, and the non-commutation phase current $i$can be calculated with the phase currents and the hall signals.The zone determination outputs the zone information by comparing the value of $|u_S|$ and u_{ab}. By capturing the zerocrossing points of u_S and measuring the amplitude of the acvoltage u_m, the instantaneous value of the rectifier output voltage can be derived as

$$|u_S(m)| = |U_m \sin(2\pi f T_s m)|$$

Where, $f$is the grid frequency, T_s is the control cycle, and m is the value of the control cycle counter, which is cleared at thebeginning point of each T_R (namely, the zero crossing point of u_S). Assuming that the coefficient of the phase back-EMF is k_e, the average line voltage can be expressed as -

$$U_{ab} = 2(iR + E) = 2iR + \frac{\pi k_e n}{15}$$

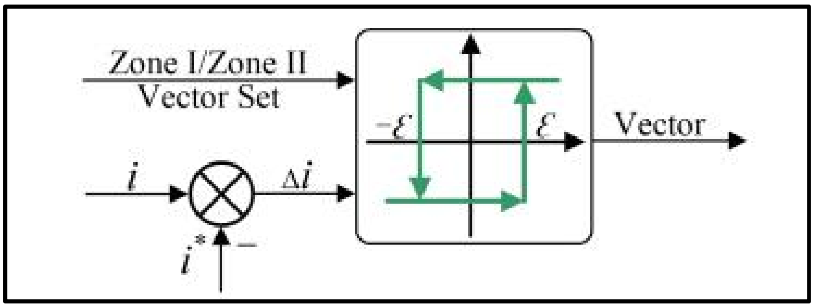

Fig. 3.3. Schematic of the hysteresis current controller.

IV. RESULT ANALYSIS

The experimental results indicate that the proposed strategy can control the BLDCM to operate steadily with lower switching frequency compared with the two traditional strategies. Hence the proposed strategy makes significance in improving the efficiency of the converter.

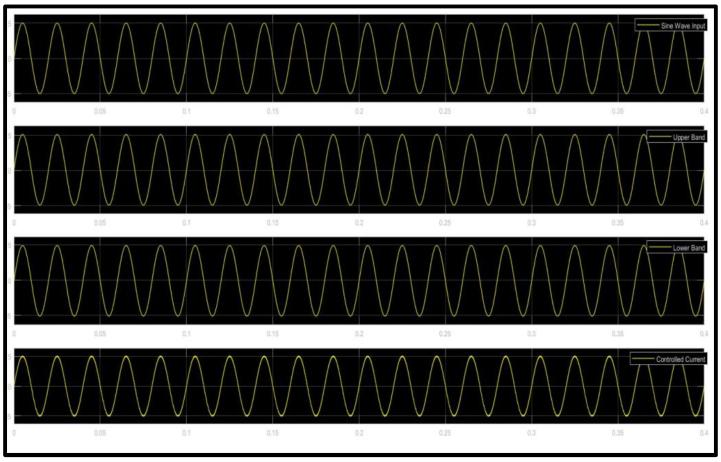

Figure 4.1 Hysteresis Controller Output for Sine wave Input Band, Upper Band, Lower Band, Controlled Current

The current controller is a common hysteresis controller but different vector sets are used in the two zones., the vector set of the zone I is composed of the vector VS and V0, while the vector set of the zone II is composed of the vector VS and VC. The schematic of the hysteresis current controller isshown in Fig. 9, where current deviation is $\Delta i = i - i^*$, and the bandwidth is 2ε, which satisfies $0 < \varepsilon$ I. In the zone I, it can be found that $|uS| > 2iR+2E$. When $\Delta i<-\varepsilon$, the vector VS is selected by the hysteresis controller.

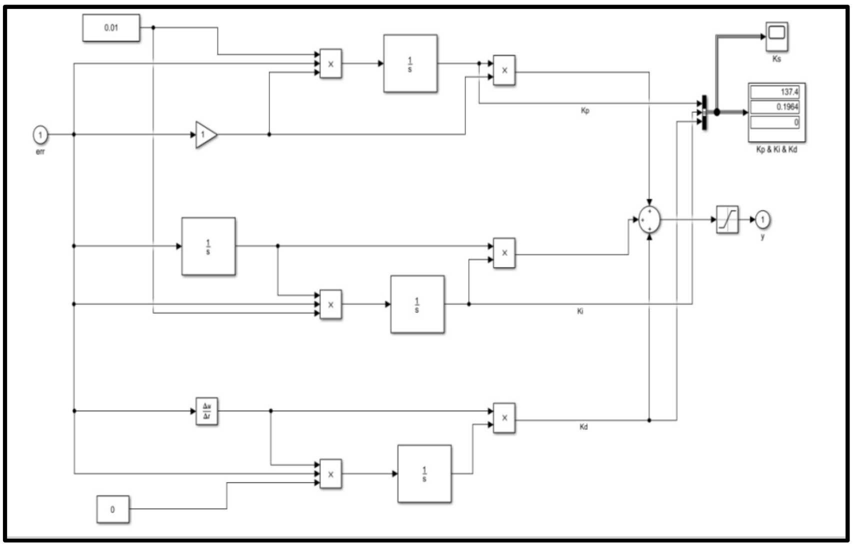

Figure 4.2 Adaptive PID Controller in BLDC Motor Drive

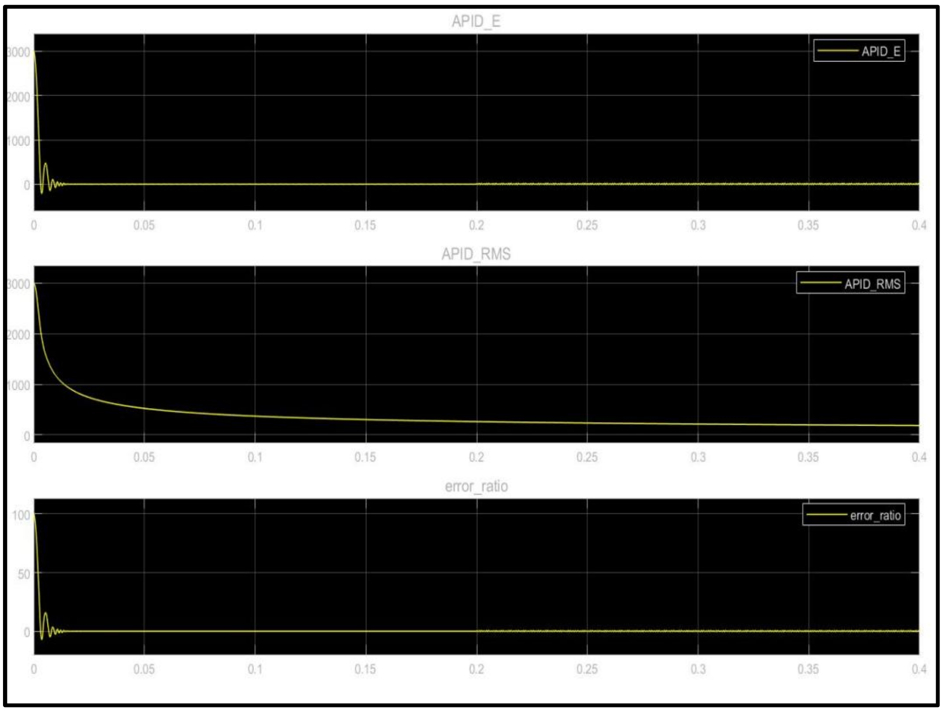

Figure 4.3 Error in the Adaptive PID Controller in speed of BLDC Moto

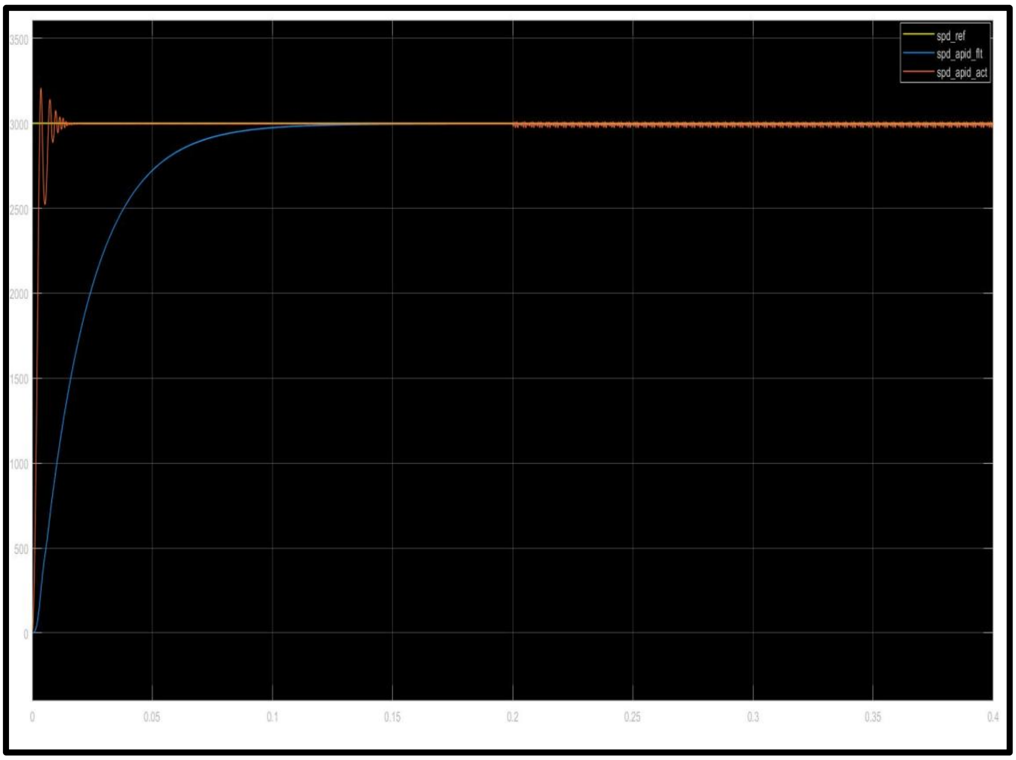

Figure 4.4 Speed Control Of Bldc Motor Drive Improved Igbt Chopping Of Dc-Link Series

For the brushless DC motor (BLDCM) drives equipped with small DC-link capacitor, the improved DC-link series IGBT chopping strategy is proposed to improve the efficiency of the converter and reduce the DC-link capacitance.Strategy can reduce the total switching times of the converter, which contributes to the improvement of the converter efficiency of the BLDCM system

V. CONCLUSION

For the brushless DC motor (BLDCM) drives equipped with small DC-link capacitor, the improved DC-link series IGBT chopping strategy is proposed to improve the efficiency of the converter and reduce the DC-link capacitance.

The experimental results indicate that the proposed strategy can control the BLDCM to operate steadily with lower switching frequency compared with the two traditional strategies. Hence the proposed strategy makes significance in improving the efficiency of the converter

5.1 Future Scope of Work

Compared with two traditional strategies, the proposed strategy has the following advantages: (1) Compared with strategy A, the proposed strategy makes the DC-link IGBT chopping in the zone II, and then the rectifier output voltage can supply to the BLDCM together with the small DC-link capacitor, which contributes to the reduction of the DC link capacitance. (2) Compared with two traditional strategies, the proposed strategy can reduce the total switching times of the converter, which contributes to the improvement of the converter efficiency of the BLDCM system.

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