A Survey Paper – Analysis of Direct Torque Control of Multi-phase (Six-phase) PMSM Drive

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***Abstract*— The Multi-phase Permanent magnet synchronous motor (PMSM) are used in many applications for variable speed control with rapid torque response. This paper describes the study of a modified direct torque control (DTC) for Multi-phase Permanent magnet synchronous motor having outstanding response of the DTC scheme with less computation time, robustness nature against the machine parameter changes. This paper present an analytical study of DTC control for Multi-phase Permanent magnet synchronous motor with DSP based and fuzzy logic.**

Keywords- Direct torque control, fuzzy logic, Permanent magnet synchronous motor,Digital signal processor.

I. INTRODUCTION

In the late 1990’s the basic concepts for the Direct Torque Control (DTC) technique for multi-phase machine is introduce, which is control the flux distribution and torque by controlling the voltage space vector properly in the machine have appeared. In the DTC control extra sensor are not required as well as the rotor position is also must in the vector control. The DTC used now-a-days in many industry because of;

- DTC control structure is simple.
- It is not depends on the rotor position sensor.
- Eliminate the current controller from the system.
- DTC techniques have inherent delays.

In the DTC control, the amplitude and rotating speed of stator flux is calculated which is the simplest methods by calculating the stator voltage and current, and it is totally independent from the stator resistance and motor parameters.The proposed DTC doesn’t need any additional PI controller, which maintains the simplicity inconventional DTC. Compared with FOC, DTC has the advantages of faster torque and flux regulation, elimination of current regulators and PWM generators, robustness to rotor parameters variation[4].

II. LITERATURE REVIEW

The basic idea of DTC is to control the torque and flux linkage by selecting one of the voltage vectors generated by a VSI in order to maintain flux and torque within the limits of two hysteresis bands.In the DTC technique, the error signal of the torque and flux is regulated by hysteresis controller. The output of hysteresis controllers accelerate the response of torque and flux linkage but the result with torque ripple severely at the same time. Also, torque reduction due to null vector voltage application is more evident at high speed than at low one. As a conclusion, an asymmetry regarding the speed appears in DTC applied to a PMSM. These effects are summarized as[6].

- Active Vector application: the higher the speed, the lower the effect on the torque control
- Null Vector application: the higher the speed, the higher the effect on the torque control.

In the DTC the voltage vector selection strategy is normaly used for proposed to find the stator flux position and the torque angle position to determine the information of the applied voltage vector and space vector modulation to generate it.In this control method the rms value of torque ripple is minimized than those of conventional DTC.In fact, by using the such type of method the output torque ripple is almost reduce up to 80%.The industrial application areas of the direct torque contro (DTC) scheme have been increased due to several features, namely, elimination of the mandatory rotor position sensor, less computation time, fast torque response and robustness against motor parameter variations[7].for low speed the torque control, having the quick change of angle which is obtained by controlling the zero voltage vector and at high speed it is not required where the rotor position sufficiently move to produce the torque value changes. According to theory of electromagnetic, torque of motor is proportional to the product of stator, rotor flux linkage amplitude and sinusoidal value of power angle, that isT =FrFs sin 6. To decrease torque ripples and enhance both the static and dynamic control performances of the system, a new PMSM DTC method based on the fuzzy control is proposed. The hysteresis controllers in conventional PMSM DTC is replaced by a Fuzzy controller which make the selection of voltage vector more reasonable and thus decrease the torque ripple[8]. The new method og DTC with the fuzzy is become also popular because of :

- It conducted on the stator reference frame side of machine
- For contol only initial rotor flux is required with the stator resistance
- In the DTC no current controller are required
- The type of switching is required depends on the error of flux and torque signal for defining the inverter

The method of speed control by DTC based on fuzzy control proposed decrease the torque ripple drastically at output and has faster torque response as compared to other methods. The inverter keeps the same state till the outputs of the hysteresis controllers change states. As a result, the ripples in flux and torque are relatively high when compared with those of the vector control drives. Furthermore, the switching frequency of the inverter is not constant; it changes with rotor speed, load torque and the bandwidth of the two hysteresis controllers [10]. In the PMSM manly two type of control method is used one is vector control and another is direct torque control (DTC). Vector control is actually control of phase and amplitude for a motor stator voltage or current vector at the same time [13].In DTC by the control of stator flux linkage and torque of motor speed is control.

The inherent advantages of using a PMSM drive are that it has a high ratio of torque to weight. The proposed sensor-less speed control and initial rotor position estimation algorithms of PMSM are implemented on a digital signal processor (DSP). Three basic techniques are reported in the literature for sensor-less rotor position estimation of PMSM drive [14].

The MATLAB simulation is used for modeling of multi-phase permanent magnet synchronous machine. Multi-phase PMSM have high efficiency because of no field current in stator and rotor which reduce the losses and increase the performance of output power. The modeling and experimental results confirm that both flux and torque linkage ripples are greatly reduced, even in the field weakening operation, while the switching frequency is almost fixed for different load torque and speed. All other advantages of the basic DTC are still retained [10].

III. MACHINE EQUATION

The voltage equation and flux linkage equation for the multi-phase PMSM drive is mention below In mathematical equations. The basic equation is given by,

$$[V_s]=[R_s][I_s]+d/dt(Ø_s) \quad (1)$$

In the study , a six-phase PMSM having two three phase windings so that the voltages equation for the multi-phase PMSM is as follows[1][2].

$$V_d=R_s.I_d+d/dt(Ø_d)-\omega_r Ø_q \quad (2)$$

$$V_q=R_s i_q+d/dt(Ø_q-\omega_r Ø_d \quad (3)$$

Where the direct and quadrature axis flux are

$$Ø_d =L_d I_d + Ø_f \quad (4)$$

$$Ø_q=L_q I_q \quad (5)$$

The mechanical torque equation of the six-phase PMSM is given by:

$$T_e =Jd/dt\ \omega_r + B\ \omega_r+T_l \quad (6)$$

By using the concept of DTC control for the multi-phase machine is the best dynamic response and the most efficient operation. Where J =inertia, B=damping coefficient and T_l =load torque of the multi-phase PMSM drive system .

IV. CONCLUSION

By use of switching with zero voltage vectors in DTC reduce the losses of control .perform the high speed operation having the low torque and flux ripples at the stator side.The DTC control with fuzzy in the MATLAB simulation has advantages ,

- Stable structure and efficient operation
- Torque ripple characteristic for the large speed is improved
- Fast dynamic response and steady state performance

However, the signal error is reduce and torque response is improved under the DTC control .

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