Field-Oriented Control of Permanent Magnet Synchronous Motor Drive System Using Matrix Converter

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*Abstract:-***In this paper a Field-Oriented Control of permanent magnet synchronous motor (PMSM) drive system using adapted hysteresis current control based on matrix converter is presented. The matrix converter is an arrangement of controlled semiconductor switches that connects directly the three-phase source to the three-phase load. This converter has several attractive features that have been research in the last two decades. To increase use of input voltage assets, input voltages are split into 12 divisions within one cycle. An adapted current controller collected of two nested current hysteresis control is evaluated in detail. According to the outputs of current controller and division of input voltages, a proper input voltage must be selected to increase or decrease output current of matrix converter. The division table is evaluate and moderately deduced. Finally, simulation system is designed. Simulating results illustrate that Field-Oriented Control of PMSM drive system using adapted hysteresis current control based on matrix converter has the quality of practicability and efficiency, which brings out theoretical fundamentals of experimentation.**

Keywords: - **Field-Oriented Control, matrix converter, PMSM, hysteresis current control**

I. INTRODUCTION

PERMANENT magnet synchronous motors (PMSM) have originated well-known applications in variable speed drives due to a number of features with high efficiency, high power density and fast dynamics. The spacious variety of applications of PMSM drives with different performance necessities makes it necessary to come up with different motor control approaches. Providentially the PMSM have advantage of effective under a spacious range of current control schemes, thus convention various objectives according to their application necessities [2],[3]. This is mainly due to innate possibilities of PMSM stem from their rotor structures and magnets distribution. In fact a uniform air gap in combination with a magnetic saliency (i.e., the machine inductances along the direct and quadrature axes being different Lq > Ld) can be obtained when the rotor magnets are placed inside the rotor body. The information provides the motor strength of high speed operation, maximum torque per ampere control, defeat minimization control and power factor control by motor field-oriented control. Because of its advantages such as simplicity, dynamic performance and overload capacity. Permanent magnet synchronous motor is broadly used in industry, CNC machine tools and aviation [4][5]. As a kind of decoupling control method, Field-Oriented Control of AC motors has similar performance as DC motors, which is trend of AC motors [6].

The ac/ac matrix converter has many advantages. For example, it uses only nine bi-directional switches and does not require any dc links. In accumulation, it has a high-power-factor sinusoidal input current, bi-directional power flow and low switching frequency on each power device. The matrix converter has received extensive consideration in recent years. Different switching instructions for an ac/ac matrix converter have been projected to accomplish sinusoidal input and output current wave forms .A matrix converter based field-oriented control of permanent magnet synchronous motor with hysteresis current control is designed. Divisions of input voltage and outputs of adapted current controller are evaluated in detail. Also, on and off of power switches of matrix converter is deduced.

II. IGBT - BIDIRECTIONAL SWITCH

The matrix converter requires a bidirectional switch able to block voltage and conduct current in both directions. Unfortunately, there are no devices currently available, so separate devices need to be used to assemble appropriate switch cells.

A. Comprehension with Remote Semiconductors

The diode bridge bidirectional switch cell arrangement consists of an insulated gate bipolar transistor (IGBT) at the center of a single-phase diode bridge [7] arrangement as shown in Fig. 1. The main use of this both current commands are passed by the equal switching device, therefore one gate driver is essential per switch cell. Device losses are quite high since there are three devices in each conduction path. The way of current through the switch cell cannot be controlled. This is the drawback, the various advanced commutation methods described presently necessitate of this. The common emitter bidirectional switch cell array consists of two diodes and two IGBTs linked in anti parallel as shown in Fig. 2(a). The diodes are integrated to present the reverse blocking capacity. There is a number of compensation in using this array when compared to the earlier example. In the first it is possible to independently control the way of the current. Transfer losses are also condensed since only two devices take the current at any one time. In that one probable disadvantage is that each bidirectional switch cell requires a remote Power supply for the gate drives. The common collector bidirectional switch cell array is shown in Fig. 2(b). The transfer losses are the same as for the common emitter configuration. An often-quoted improvement of this method is that only six remote power supplies are required to supply the gate drive signals [8]. But, in practice, additional Constraints such as the need to minimize drift inductance mean that operation with only six remote supplies is commonly not practicable. For that reason, the common emitter configuration is commonly chosen for creating the matrix converter bidirectional switch cells. Both the common collector and common emitter configurations can be use without the essential common link, but this link does provide some transient benefits during switching. In the common emitter configuration, the central link also allows both devices to be controlled from one remote gate drive power supply.

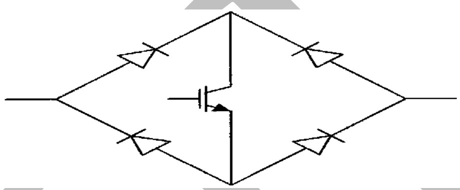


Fig.1. Diode bridge bidirectional switch cell.

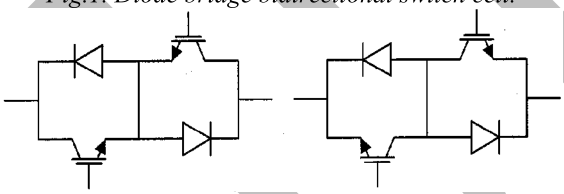


Fig. 2. Switch cell. (a) Common emitter back to back. (b) Common collector back to back.

III. CURRENT CONTROL OF MATRIX CONVERTER

Structure of three phases-three phases matrix converter based field-oriented control of permanent magnet synchronous motor with adapted current control is shown in figure3. *abc* are the three input voltages of matrix converter and *ABC* are three output phases of matrix converter. i_A^*, i_B^* *and* i_C^* are references of permanent magnet synchronous motor stator currents, i_A, i_B and i_C are real stator currents. Real stator currents are compared correspondingly with their references. With the instantaneous input voltage division and select correct input voltage, power switches of matrix converter are set on or off by division table. Subsequently, error between the real stator current and its reference is constrained

A. FUNDAMENTALS

The matrix converter is a single-stage converter which has an array of m × n bidirectional power switches to attach in a straight line, an m - phase voltage source to an n - phase load. The matrix converter of **3 × 3** switches, shown in Fig. 3, has the highest sensible significance because it connects a three-phase voltage source with a three-phase load, normally a motor. In general, the matrix converter is fed by a voltage source and designed for this reason, the input terminals should not be short circuited. In additional, the load contains normally an inductive nature and, for this reason, an output phase should not at all be opened.

Defining the switching function of a single switch.

$$S_{pq} = \begin{cases} 1, & \text{Switch}S_{pq}\text{closed} \\ 0, & \text{Switch}S_{pq}\text{ open} \end{cases} \quad p = a,b,c \quad q = A,B,C \tag{1}$$

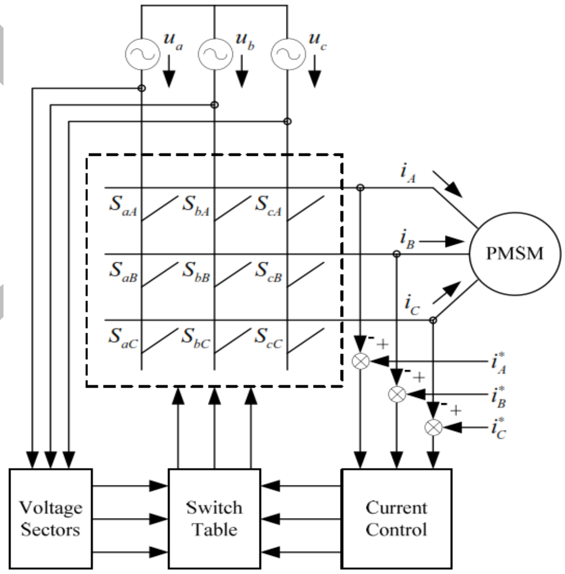


Figure .3.Structure of Field Oriented Control of MC-PMSM

The constraints discussed above can be expressed by

$$S_{aq} + S_{bq} + S_{cq} = 1(q = A,B,C) \tag{2}$$

With these limits, the 3× 3 matrix converter has 27 probable switching states.

B. Divisions of Input voltage

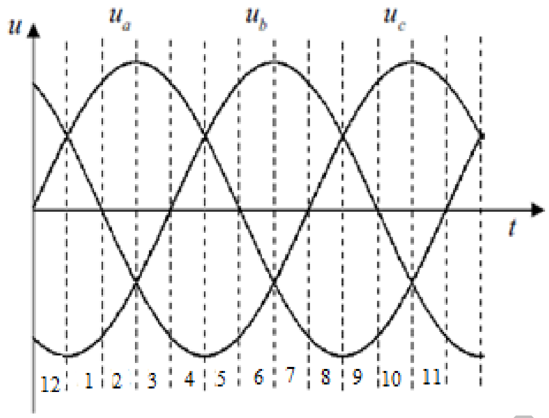


Figure.4.Input voltage divisions

To increase use of input voltage assets, input voltages are split into 12 divisions within one cycle as shown in figure 4. In every division, there are a maximal voltage, a minimal voltage and a middle voltage,as shown in Table I. In this paper, we will choose one of the three voltages in one division to increase or decrease the stator current according to their outputs of adapted current control.

C. Adapted Hysteresis current control comparator

Here, we set up an adapted current controller composed of two nested current hysteresis comparators, as shown in figure5. i_q^* $(q = A, B, C)$ is the reference of stator current and *iq* is the real stator current. In the meantime, ΔI_1 is the inner bandwidth, and ΔI_2 is the outer bandwidth. Kq_1 is output of inner comparator.*Kq2* is output of outer comparator.

Table 1: Divisions of Input Voltages

Voltage Section	Voltages of Three Phases	Middle Voltage
1	$u_a > u_c > u_b$	$u_c > 0$
2	$u_a > u_c > u_b$	$u_c < 0$
3	$u_a > u_b > u_c$	$u_b < 0$
4	$u_a > u_b > u_c$	$u_b > 0$
5	$u_b > u_a > u_c$	$u_a > 0$
6	$u_b > u_a > u_c$	$u_a < 0$
7	$u_b > u_c > u_a$	$u_c < 0$
8	$u_b > u_c > u_a$	$u_c > 0$
9	$u_c > u_b > u_a$	$u_b > 0$
10	$u_c > u_b > u_a$	$u_b < 0$
11	$u_c > u_a > u_b$	$u_a < 0$
12	$u_c > u_a > u_b$	$u_a > 0$

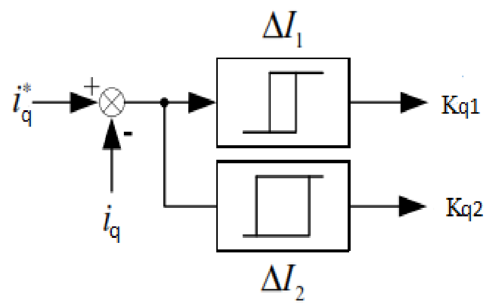


Figure 5.Current Comparator

We observed the results, comparator gives 4 output values of *Kq2 Kq1* (they are 00, 01, 10 and 11) for every stator current. Also, there are 4×4×4=64 outputs considered for three phases in one voltage division. For one cycle, there are 12×64=768 outputs. About these 768 outputs only suitable 27 probable switching states of three phase's matrix converter. Switching states are determined by means of such convention,

1) If Kq2 Kq1 = 00, the q output of MC is coupled with minimum input voltage to decrease stator current speedily.

2) If Kq2 Kq1 = 01 , the q output of MC is coupled with middle input voltage in so far as possibly, so that stator current decreases slowly. If middle input voltage is negative, q output is coupled with middle input voltage. If middle input voltage is positive output conserve its earlier connection.

3) If Kq2 Kq1 = 10 , the q output of MC is coupled with middle input voltage in so far as possibly, so that stator current increases slowly. If middle input voltage is positive, q output is coupled with middle input voltage. If middle input voltage is negative, q output conserve its earlier connection.

4) If *Kq2 Kq1* = 11, the q output of MC is coupled with maximal input voltage to increase stator current speedily.

Designed for illustration, in voltage division 9, $u_c > u_b > u_a$, and $u_b > 0$. Condition $K_{A2} K_{A1} = 00$,

$K_{B2} K_{B1} = 11$, and $K_{C2} K_{C1} = 01$, A output should be coupled with a input voltage, B with c and C with a .In voltage division 10, $u_c > u_b > u_a$, and $u_b<0$. Condition $K_{A2}K_{A1}$=00, $K_{B2} K_{B1}$=11, and $K_{C2} K_{C1}$=01, A output should be coupled with a input voltage, B with c and C with b.

IV. System simulation and Experiment Results

MC- PMSM with adapted current control is designed with Mat lab/Simulink. PI is modified for speed controller whose output is current reference of q axes. Current reference of *d* axes is set 0.By *dq* / *ABC* coordinate transformation; stator current references of *ABC* are obtained. Once compare current references of *ABC* with their real values, we know how to get *Kq2 Kq1* of adapted current hysteresis comparators. In addition, through division of input voltages, we can decide switch state of MC.

APPENDEX

Motor Specifications:

$P = 2$,

$R_s = 2.875\Omega$,

$L_d = 8.5mH$,

$L_q = 8.2mH,$

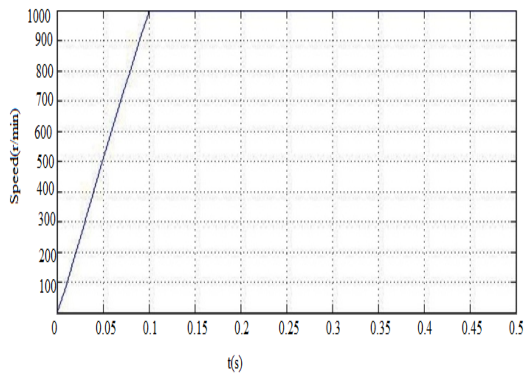
$J = 0.008Kg.m^2$,

$D = 0.0014N.m.s$,

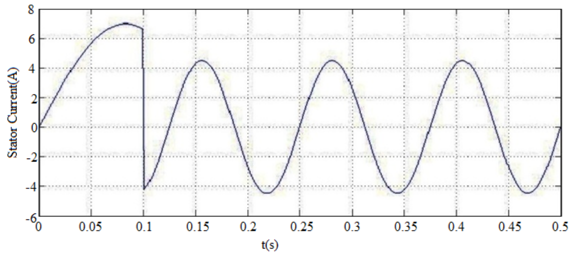
In the simulating system, $\Delta I_1 = 0.01$ A, $\Delta I_2 = 0.02$ A. Simulating results are shown in figure 6 shows the premeditated system performances of speed, torque, stator current and current of *d* axes when PMSM starting up and steady running with load $T_L = 6$ N.m.

1) Speed of PMSM can approach reference when starting up, steady running and speed varying, which accords with earlier analyzation.

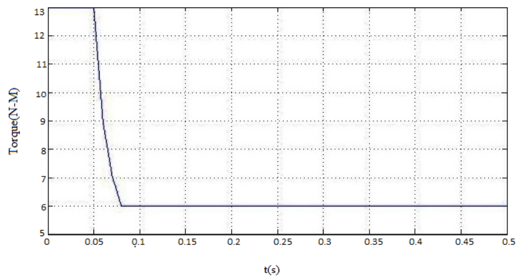
2) i_d is reserved a small value during starting up, steady running and speed varying with or without load, that is, field-oriented control is achieved. The designed MC-PMSM system of field-oriented control with adapted current control is practicable.



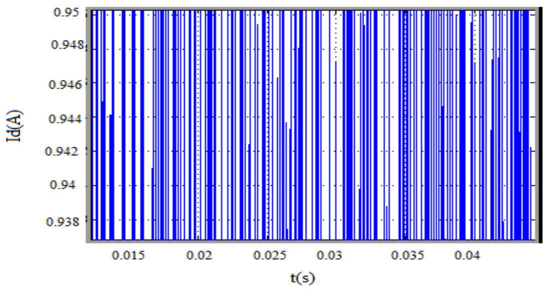
(a)Speed vs Time



(b)Stator Current vs Time



(c)Torque vs Time



(d) Current of d-axes

Fig.6.Simulation Results With load Torque

V. CONCLUSIONS

In this paper we obtained dynamic response, high efficiency, and low harmonic content of the PMSM. To increase use of input voltage assets, input voltages are split into 12 divisions within one cycle. An adapted current controller collected of two nested current hysteresis control is evaluated in detail. According to the outputs of current controller and division of input voltages, a proper input voltage must be selected to increase or decrease output current of matrix converter. The division table is evaluate and moderately deduced. Finally, simulation system is designed. Simulating results illustrate that Field-Oriented Control of PMSM drive system using adapted hysteresis current control based on matrix converter has the quality of practicability and efficiency, which brings out theoretical fundamentals of experimentation. In the overall simulation we observed the performance of the PMSM is good by using this adapted hysteresis current control.

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