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Simulation Of PMSM Vector Control System Based On Propeller Load Characteristic

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Abstract:- *In this paper the implementation of the vector control systems for a variable-speed 4088kW PMSM (Permanent Magnet Synchronous Motor)in ship electric propulsion systems has been studied. At the basis of analysis of the mathematical model of the PMSM and the principle of vector control, two methods for modeling and simulating of PMSM system based on the Current Hystersis PWM (Pulse Width Modulation) and SVPWM (Space Vector Pulse Width Modulation) are proposed. Then the speed control performance of the 4088kW propulsion motor with propeller load was proved by simulation. The results show that the system have good response performance in the process of the motor start or speedup and the method used SVPWM can reduce the torque ripple compared with the Current Hystersis pwm.*

I. INTRODUCTION

With the development of permanent magnetic materials and control technology, permanent magnet synchronous motor has been applied into the electric ship propulsion fields .The PMSM have some advantages such as high efficiency, high power density, high torque/inertia ratio[1].Nowadays, there are two most important AC motor control techniques : the direct torque control and the vector control. In the paper[2],the DTC driving scheme with PMSM for ship propulsion system has been modeled. The bang – bang DTC control method has some disadvantages especially for the large torque ripple and the degraded performance at low speeds. The SVPWM method as a new control technique for reducing the torque ripple has been introduced. The SVPWM with DTC method is adopted to control the speed of the induction motor (1.1kW) in the ship propulsion system [3]. In paper of [4], it simulation the PMSM Vector Control system based on the SVPWM. But the load of the motor in the simulation system is not based on the propeller characteristic. The features of the propeller was showed in [5].
The 4088kW PMSM vector control system has been studied in this paper.The simulation results shows the performance at the motor rated condition and comparison it with the method of Current Hystersis PWM and SVPWM

II. THE MATHEMATICA MODEL OF PMSM

The PMSM equations are developed in rotating reference Frames, Assumptions in developing the mathematical model are:
1)Saturation is neglected
2)Eddy currents and hysteresis effects are neglected
3)Balanced three phase currents are assumed
Rotating reference frame (d-q) machine equations as follows:
Stator voltage equations are:

$$u_{sd} = R_s i_{sd} + \frac{d\psi_{sd}}{dt} - \omega_r \psi_{sq} \qquad (1)$$

$$u_{sq} = R_s i_{sq} + \frac{d\psi_{sq}}{dt} + \omega_r \psi_{sd} \qquad (2)$$

Stator magnetic flux linkage equations are:

$$\psi_{sd} = L_d i_{sd} + \psi_f \qquad (3)$$

$$\psi_{sq} = L_q i_{sq} \qquad (4)$$

Electromagnetic torque equation is:

$$T_e = \frac{3}{2} n_p \left(\psi_{sd} i_q - \psi_{sq} i_d \right) \qquad (5)$$

Motor movement equation is:

$$T_e = T_L + B \frac{\omega_r}{n_p} + \frac{J}{n_p} \frac{d\omega_r}{dt} \qquad (6)$$

Where u_{sd}, u_{sq}, i_{sd}, i_{sq}, L_d, L_q are respectively the voltage, current and inductance on d, q axis. R_s, , ω_r, ψ_f are the stator resistance, electric angular speed and permanent flux, respectively. T_e, T_L, B, n_p and J represent electro-magnetic torque, load torque, viscous friction coefficient, number of pole pairs and total moment inertia of rotor and load, respectively.

III. VECTOR CONTROL PRINCIPLE.OF PMSM

From the equations of (3), (4) and (5) the electro-magnetic torque can be expressed as:

$$T_e = \frac{3}{2} n_p \left(\psi_f i_{sq} + (L_d - L_q) i_{sd} i_{sq} \right) \qquad (7)$$

The basic idea of vector control is as follows: through the coordinate transformation, decompose the PMSM stator current *is* into two components field current component *isd* and its vertical torque current component *isq*. From the equation (7), when the *isd* = 0, the electro-magnetic torque *Te* will be:

$$T_e = \frac{3}{2} n_p \psi_f i_{sq} \tag{8}$$

So the relationship of electromagnetic torque *Te* and *isq* is linear, in speed regulating process,as long as maintain the field current component *isd* =0 and control the *isq* meanwhile, a good dynamic characteristic of the *Te* can be obtained

IV HYSTERESIS BAND CURRENT CONTROL PWM

Hysteresis band control PWM is basically an instantaneous feedback current control method of PWM where the actual current continually tracks the command current within a hysteresis band. The operation of the hysteresis current control is explained by circuit shown in figure 4.8. The purpose of the current controller is to control the load current by forcing it to follow a reference one. The load currents are sensed and compared with the respective reference currents, the error signal passes through three independent hysteresis comparators having hysteresis band H. The output error currents of comparator are used to active the inverter power switches. Based on band, there are two types of current controllers, namely, fixed band hysteresis current controller and sinusoidal band hysteresis current controller. Here we are concentrating on fixed band current controller

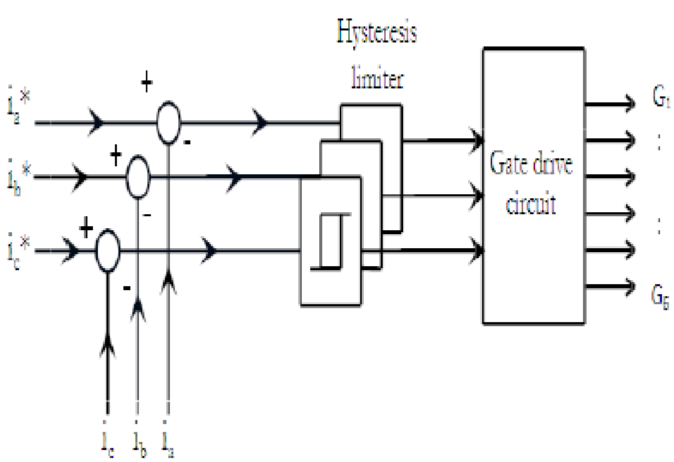

Fig 1.Basic circuit diagram of hysteresis controller

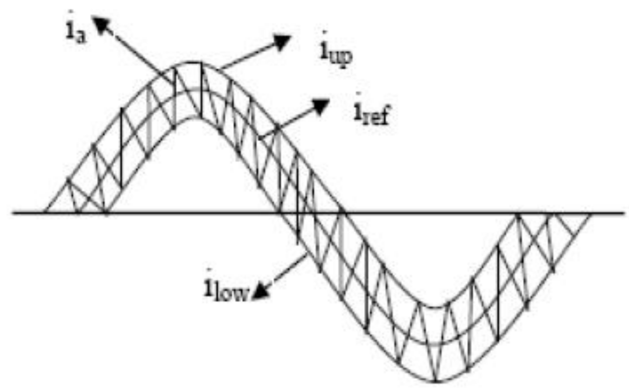

Fig 2.Hysteresis controller control structure

The waveform of fixed band hysteresis current controller is shown in figure 2. In the fixed band scheme, the hysteresis band is fixed over the fundamental period.The mathematical equations for fixed band control are given as follows:

Iref = Imax Sin wt

I up = Iref + H

I lo = Iref - H

Where iup is the upper band, ilo is the lower band, and H is the hysteresis band limit. From figure 2, if ia >iup, then NA=0, which means that inverter output is negative in order to reduce line current. Similarly if ia< ilo, then NA=1, where the inverter voltage is positive, in order to increase the load current

V SPACE VECTOR PULSE WIDTH MODULATION (SVPWM)

The space vector modulation is a highly efficient way to generate the six PWM signals necessary at the power stage for two level inverter. The circuit model of a typical three phase voltage source PWM inverter (two-level inverter) is shown in fig. 3.

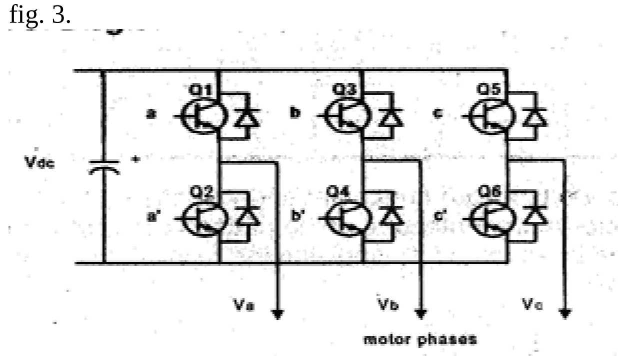

Fig 3 Three phase voltage source PWM inverter

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The Space vector PWM can be implemented by the following steps:
Step1: Determine V_{α}, V_{β}, V^{*} , and angle (α)
Step2: Determine time duration T1, T2, T0.
Step3: Determine the switching time of each Transistor.

VI. PROPELLER LOAD CHARACTERISTIC

The resistance moment of the propeller has the opposite direction with the turning direction of the propeller. Thus, the propulsion motor must supply effective moment to overcome the resistance moment and produce the electro-magnetic torque in order to make the propeller turn at the command speed. According to the work principle of the propeller, the load torque that produced by it can be written as:

$$T_L = K_t \rho n^2 D_p^{\;5} \qquad (9)$$

Where ρ(kg/m3), *n*(r/s) and *Dp*(m) are the seawater density, speed of the propeller and diameter of the propeller,respectively. *Kt* represent the propeller torque coefficient, which varied as a function of advance ratio. At the free navigation when the ship having full load and the speed achieves the command speed , the ship reaching steady state in static water. This moment the advance ratio is constant and the *Kt* is constant. So, the load torque produced by the propeller is approximately proportional to the square of the propeller speed.

VII. SIMULATION OF THE VECTOR CONTROL MODEL WITH THE PROPELLER LOAD

Two methods that generate the pulse signal to drive the IGBT are introduced, one is the Current Hysteresis PWM method and the other is the SVPWM .The simulation model are Fig 4 and Fig 5 respectively

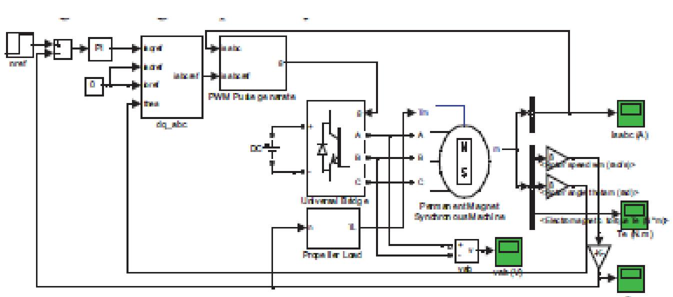


Fig. 4. Simulation model of vector control system (current hysteresis pwm)

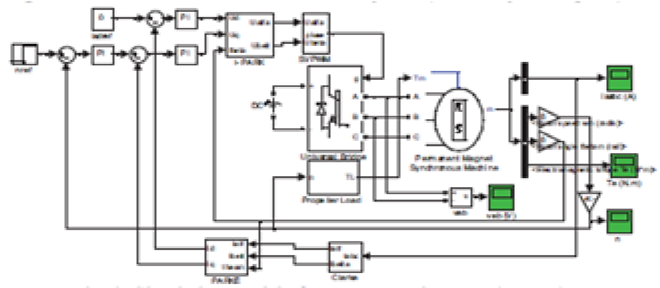
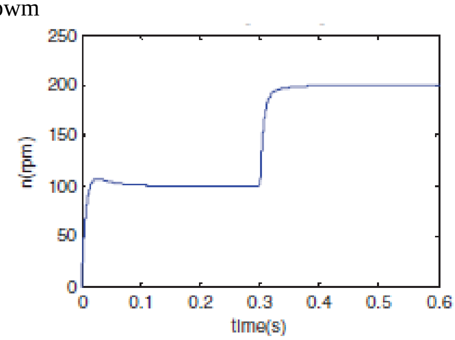


Fig. 5. Simulation model of vector control system (svpwm)

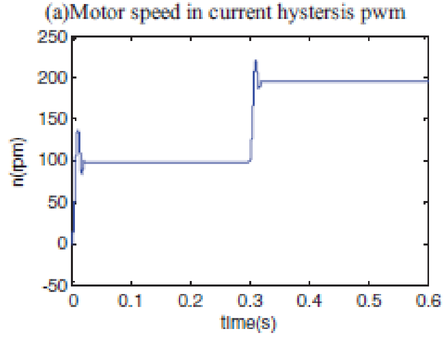
The parameters of the PMSM that used in this simulation model are:
Power rating: 4088kW
Rated voltage: 660V
Rated current: 4348A
Moment of inertia: 2000kg·m2
Rated torque: 195200N·m
Rated speed: 200 r/min
In the equation (9): 〉=1025 kg/m3, D_p =3.6 m, when the speed of the PMSM reaching 200 r/min, the speed of the propeller also reached 200 r/min, the electro-magnetic torque should be equal to the load torque that produced by the propeller. So the torque coefficient K_t can be calculated

$$K_t = \frac{195200}{1025\times\left(\frac{200}{60}\right)^2\times 3.6^5} = 0.028$$

The simulation results are Fig3 Motor speed in current hystersis pwm and svpwm

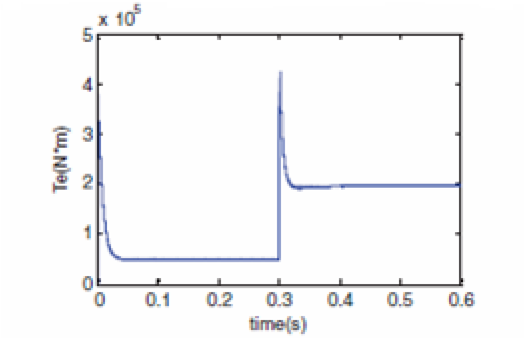


(a)Motor speed in current hystersis pwm

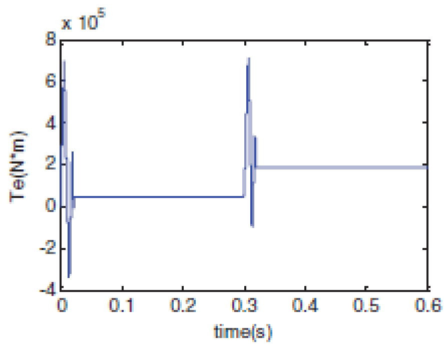


(b) Motor speed in svpwm

Fig. 4. Motor electromagnetic torque in current hystersis pwm and svpwm

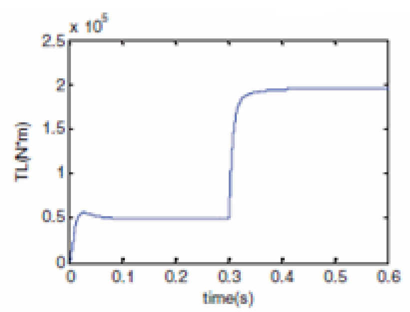


(a) Electromagnetic torque in current hystersis pwm

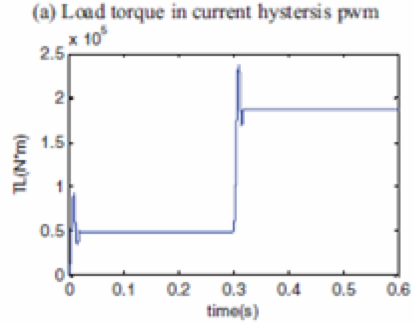


(b) Electromagnetic torque in svpwm

Fig. 5. Motor load torque in current hystersis pwm and svpwm

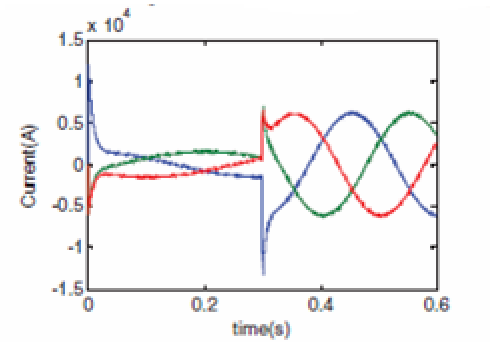


(a) Load torque in current hystersis pwm

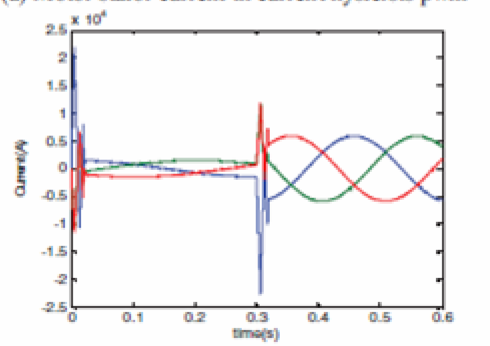


(b) Load torque in svpwm

Fig. 6. Motor stator current in current hystersis pwm and svpwm



(a) Motor stator current in current hystersis pwm



(b) Motor stator current in svpwm

The simulation process time was set to 0.6s.The initial set speed of the motor was 100rpm,and then the set speed was changed to 200rpm at t=0.3s. From the simulation waveforms of output speed (Fig.3)It can be seen the simulation process indicates that the system has good dynamic performance. Fig4. and Fig5. shows the motor electromagnetic torque and the propeller load torque, respectively.At the initial time motor electromagnetic torque almost reach at 4×105N*m ,so the motor accelerated to the command speed value. Meanwhile the load torque gradually increased ,when the motor speed arrived at the command value the electromagnetic torque was equal to the load torque.When the speed reached at the rated speed 200rpm, the torque is 2×105N*m. From the Fig6. the stator current peak value is 6000A. It indicated that with the SVPWM method the torque ripple is reduced.

VIII. CONCLUSION

The vector control technique for the 4088kW PMSM based propulsion applications has been discussed. By comparison of the two generate pulse signal methods in vector control system ,it's obvious that the SVPWM method can reduce the torque ripple. The simulation results shows that the control method for the PMSM in the marine propulsion system have good dynamic performance and it also beneficial for the research of the electric propulsion system.

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REFERENCES

[1] C.L.Ferreira and R.W.G.Bucknall, “Modelling and Real-time simulation of an Advanced Marine Full-Electric Propulsion System,” in *Proc. 2nd IEE Int. Conf. on Power Electronics,Machines and Drives*, Edinburgh,2004, pp. 574-579.
[2] G.Diamantis, “SIMULATION OF A SHIP PROPULSION SYSTEM WITH DTC DRIVING SCHEME,” in *Proc. 2nd IEE Int. Conf. on Power Electronics,Machines and Drives*, Edinburgh, 2004, pp.562-567.
[3] A.Kumar, “Direct Torque Control of Open-end Winding Induction Motor Driving Using the Concept of Imaginary Switching Times for Marine Propulsion Systems,” in *Proc. 31st Annu. Conf. of IEEE Industrial Electronics Society*, North Carolina, 2005, pp.1504-1509.
[4] T. T. Liu, “Simulation of PMSM vector control system based on Matlab/Simulink,” in *Proc. IEEE Int. Conf. on Measuring Technology and Mechatronics Automation*, Hunan, 2009, pp. 343-346.
[5] D. X. Shang, “Study on DTC-SVM of PMSM Based on Propeller Load Characteristic,” in *Proc. 7th World Cong. on Intelligent Control and Automation*, Chongqing, 2008, pp. 6445-6449.