SENSORLESS CONTROL OF PERMANENT MAGNET TRACTION MOTOR USING HF SIGNAL INJECTION METHOD

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***Abstract*— In electric vehicles, different types of motors are used. For high efficiency, quick dynamic response, high torque density and high power density, a permanent magnet traction motor is used. Control of the permanent magnet traction motor depends on accurate rotor position information, which is usually acquired using mechanical position sensors. The sensorless control technology is an effective way to solve the problems in sensor control. In this paper, the sensorless control techniques of a permanent magnet motor for the rotor's initial position, zero-low speed range are described.**

Keywords—HF injection method, Permanent magnet synchronous motor,

I.INTRODUCTION

At present, social development, energy and the environment are two major themes. To avoid air pollution, global warming and achieve clean environments, electric vehicles are introduced. AC speed control system has been improved to replace the DC speed control system. The synchronous motor has advantages over the speed controls such as a high-power factor, small inverter capacity and the small moment of inertia. The advantages of the synchronous motor speed control system are obvious in the high-power AC transmission system. With the development of permanent magnet materials, a permanent magnet synchronous motor (PMSM) and the brushless DC motor (BLDCM) have a high-power density, large torque inertia ratio and fast dynamic response speed, this type of motor used in various areas. However, the existing position sensor can not only increase the motor volume and rotation inertia of the shaft, but also reduce the power density of the motor. The sensorless control system is to obtain information about the rotor position by examining the voltage and current of the motor port in real time. In this paper, estimation approaches and advancements in sensorless permanent magnet traction systems of electric vehicles are analyzed.

II.PROPOSED SYSTEM

Sensorless Control Scheme for Rotor Initial and Low Speed Position Detection

As a major difficulty facing the sensorless control technology, starting torque and stability of the motor, the position detection of the motor rotor at zero and low speed is a significant influencing factor. In a sensorless control strategy, the rotor position is found out by using the salient pole characteristic of the motor, saturation characteristic of the magnetic circuit or polarity of the magnetic circuit. These methods are summarized in Figure 1

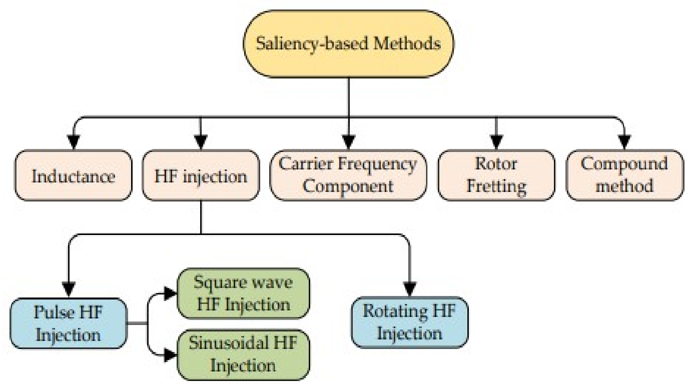


Fig.1 Sensorless strategies for initial and low speed

High Frequency (HF) Injection Method

HF injection method is dependent on the salient features of the motor rotor position, rather than the motor model of the counter electromotive force. It makes the most effective rotor position estimation method for zero-speed and low-speed operation of the PMSM. The injection method of HF pulse signal under the low speed operation is close to when the rotor is stationary. The motor at low speed operation is made to extract the HF response current through the high-pass filter. Then the cross-saturation effect should be taken into consideration when the motor is running.

Typically, the injected HF signals have rotating HF voltage signals, rotating HF current signals, and pulse HF voltage signals. Though pulse HF voltage signal injection an excellent performance in static and dynamic speed regulation, the system with a rotating HF voltage signal injection method is more achievable.

Rotating HF Injection Method

The working principle of rotating HF carrier signal injection method is used in the IPMSMS positionless sensor control. This method is to inject a three-phase symmetrical high frequency sinusoidal voltage signal at the stator end of IPMSM. Then obtain the information on the rotor position by detecting and processing the HF response signal in the α-β coordinate system. The block diagram of the rotating HF Injection Method is presented in Figure 2.

$$\begin{bmatrix} i_{\alpha i} \\ i_{\beta i} \end{bmatrix} = \begin{bmatrix} I_p \cos\omega_i t + I_m \cos(-\omega_i t + 2\theta_e) \\ I_p \sin\omega_i t + I_m \sin(-\omega_i t + 2\theta_e) \end{bmatrix} = I_p e^{j(\omega_i t)} + I_m e^{j(-\omega_i t + 2\theta_e)} \tag{1}$$

$$I_p = \frac{v_i L_p}{\omega_i \left(L_p^2 - L_m^2\right)}, I_m = \frac{-v_i L_m}{\omega_i \left(L_p^2 - L_m^2\right)} \tag{2}$$

$$\begin{bmatrix} u_{\alpha i} \\ u_{\beta i} \end{bmatrix} = \begin{bmatrix} L_p + L_m \cos(2\theta_e) & L_m \sin(2\theta_e) \\ L_m \sin(2\theta_e) & L_p - L_m \cos(2\theta_e) \end{bmatrix} p \begin{bmatrix} i_{\alpha i} \\ i_{\beta i} \end{bmatrix} \tag{3}$$

where, $u_{\alpha i}$ and $u_{\beta i}$ are the α-β axis components of the HF response voltage, respectively.

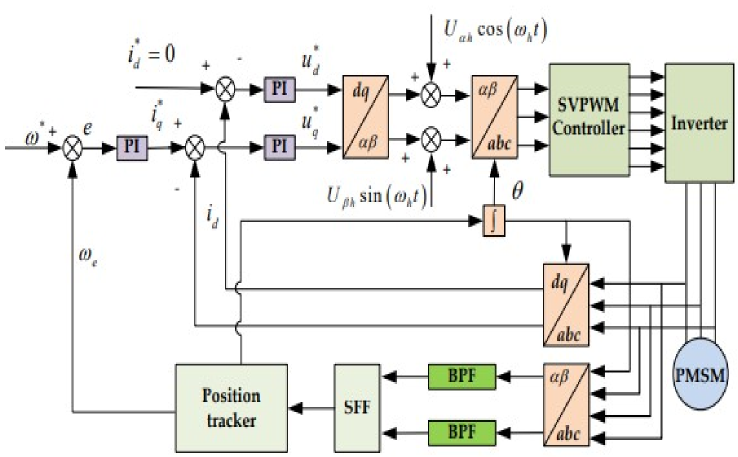


Fig.2 Block Diagram of rotating HF Voltage injection method

Pulse HF Injection Method

The interior permanent magnet synchronous motor (IPMSM) contains a structural salient pole, but the surface permanent magnet synchronous motor (SPMSM) contains a saturated salient pole. By means of HF pulse voltage injection, the initial rotor position can be detected. The stator voltage equation of IPMSM in a two-phase rotating coordinate system is:

$$\begin{bmatrix} u_d \\ u_q \end{bmatrix} = R_s \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \omega_e \begin{bmatrix} 0 & -L_q \\ L_d & 0 \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} L_d & 0 \\ 0 & L_q \end{bmatrix} p \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} 0 \\ \omega_e \psi_f \end{bmatrix} \tag{6}$$

where,

u_d and u_q -- d-q axis components of the stator voltage
i_d and i_q -- d-q axis components of the stator current
p -- differential operator
R_s --the stator armature winding resistance.
ω_e -- electric angular velocity
ψ_f -- permanent magnetic flux.

$$\begin{bmatrix} i_{di} \\ i_{qi} \end{bmatrix} = \begin{bmatrix} \frac{L_? - \Delta L \cos(2\Delta\theta)}{L_d L_q} v_i \cos\omega_i t \\ \frac{-L_m \sin(2\Delta\theta)}{L_d L_q} v_i \cos\omega_i t \end{bmatrix} \tag{7}$$

where, Lp = (Ldi + Lqi)/2,
Lm = (Ldi − Lqi)/2,
Δθ = θe − θe(est).
idi and iqi are the d-q axis components of the HF response current,
vi is the amplitude of the injected signal,
ωi is the frequency of the injected signal,
θe is the rotor electrical angle

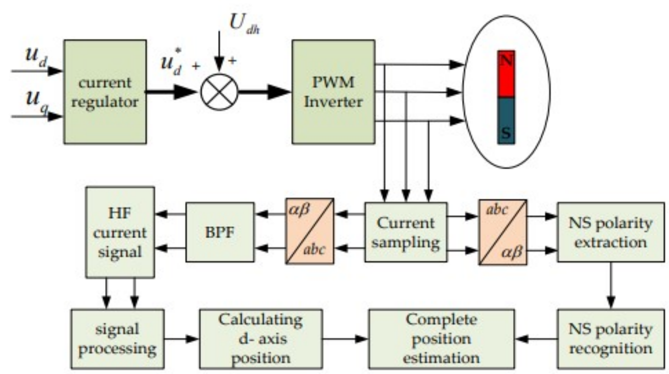


Fig.3 Block Diagram of the Square Wave HF injection method.

Carrier Frequency Component Method

The carrier frequency component-based logic operation method is shown in Figure 4. The transformation of the mathematical model, to establish the k-l shafting 45 degrees in advance of the α-β axis and to conduct the carrier frequency component current was obtained after filtering, whose envelope carried the information on rotor the position.

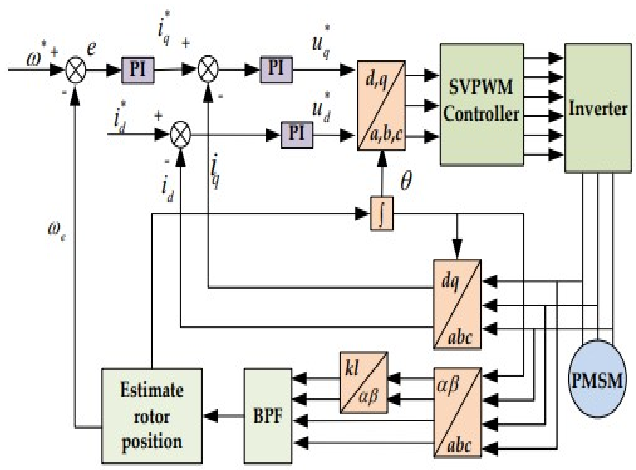
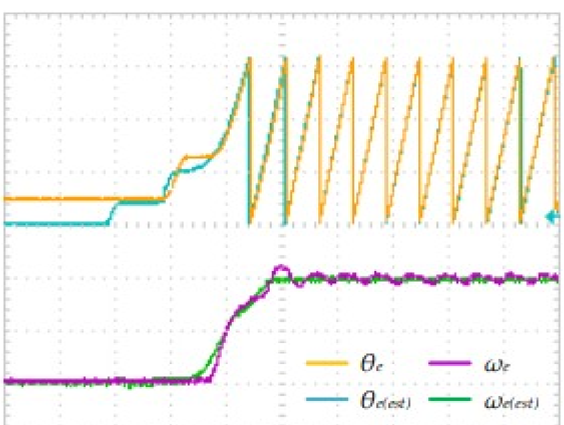
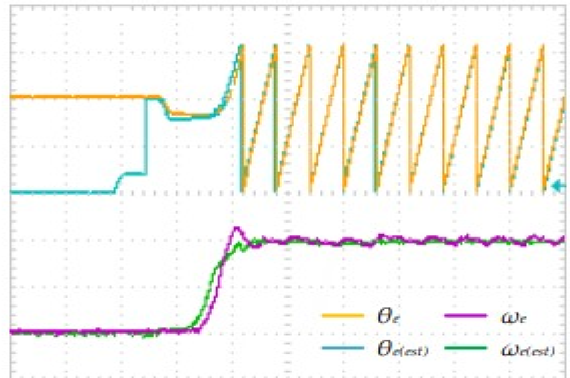


Fig..4 Block Diagram of the Carrier Frequency Component Method.

III.RESULTS AND DISCUSSION



(a)



(b)

Fig.5 Waveforms of sensorless estimation at zero-low speed. (Initial rotor angle: (a) 1 rad; (b) 4 rad)

Figure 5 shows the results obtained by combining the pulse HF signal injection method with the carrier frequency component method. Figure.5(a) and (b) are the sensorless starting waveforms of a given motor's starting angle of 1 rad and 4 rad, respectively. If the motor is given 60% load torque, and the target speed is 100 rpm. The proposed method can be used to find out the rotor position of SPMSM in a static state. After entering the steady-state operation stage, the find out speed can still track the actual speed well.

IV.CONCLUSION

Permanent magnet traction motor initial position and low speed, this method has high digital signal processing capacity. The rotor position can be measured by a sensorless technique, which has high-performance control of the permanent magnet traction motor. The sensorless control has a wide application in the field of electric vehicle traction systems. In general, the position sensorless control strategy of a permanent magnet traction motor, the motor parameters identification techniques, can realize the stable and reliable operation of the traction motor for EV. The traction motor for electric vehicle faces complex operation conditions, such as frequent start and stop, rapid acceleration and deceleration, which is supposed to operate in a wide speed range. The hybrid rotor position estimation methods for sensorless control should be analyzed to improve the reliability and the dynamic performance of the traction motor in the wide speed range.

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