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Exponential response electrical pole-changing method for a five-phase induction machine with a current sliding mode control strategy

Key words: Five-phase induction machine; Pole-change; Sliding-mode control; Exponential response; Torque ripple reduction

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Motivation

1. Electrical pole-changing technology leads to torque ripple and speed fluctuation despite broadening the constant power speed range of the multiphase induction (IM) system.

2. To reduce the torque ripple and speed fluctuation of the machine, we investigate an exponential response electrical pole-changing method for five-phase IM with a current sliding-mode control strategy.

Main idea

1. Current sliding-mode controllers, instead of conventional proportional integral (PI) controllers, are applied to adjust the current vectors.

2. Exponential current response achieves a smooth transition between the d_1-q_1 and d_2-q_2 planes.

Method

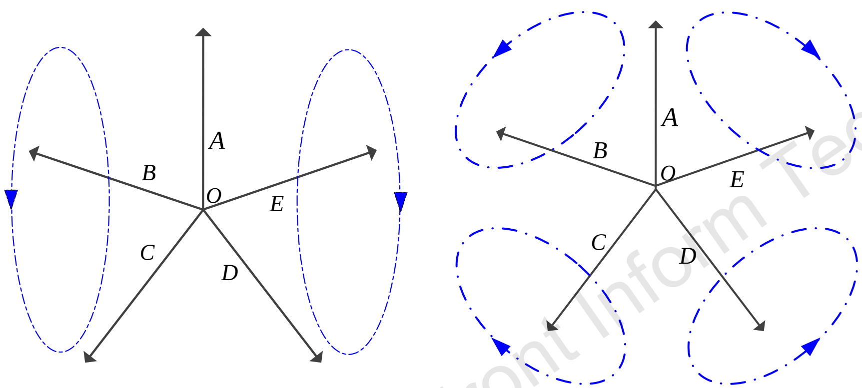
1. Introduce the structure and mathematical model of the five-phase induction machine. Two decoupled control planes are introduced.

2. Investigate the principle of electrical pole-changing and two electrical pole-changing methods, step response and exponential response.

3. Present electrical pole-changing with sliding-mode variable structure control.

Schematic

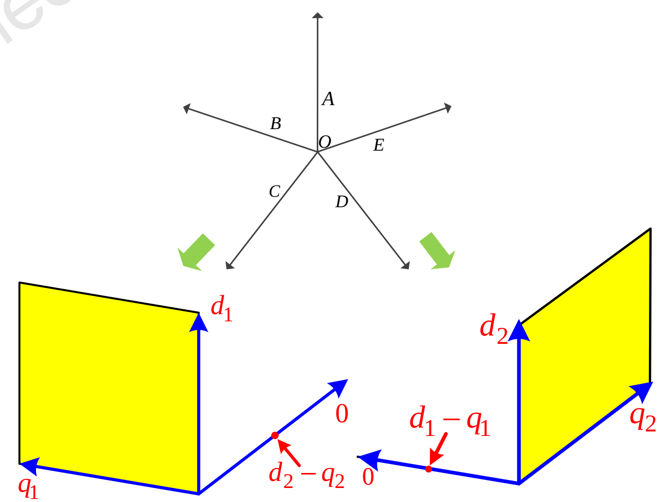
$$\begin{bmatrix} u_{sd1} \\ u_{sq1} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + L_{s1}p & \omega_1 L_{s1} & L_{m1}p & \omega_1 L_{m1} \\ -\omega_1 L_{s1} & R_s + L_{s1}p & -\omega_1 L_{m1} & L_{m1}p \\ L_{m1}p & (\omega_1 - \omega_r)L_{m1} & R_{r1} + L_{r1}p & (\omega_1 - \omega_r)L_{r1} \\ -(\omega_1 - \omega_r)L_{m1} & L_{m1}p & -(\omega_1 - \omega_r)L_{r1} & R_{r1} + L_{r1}p \end{bmatrix} \begin{bmatrix} i_{sd1} \\ i_{sq1} \\ i_{rd1} \\ i_{rq1} \end{bmatrix} ,\quad \begin{bmatrix} u_{sd2} \\ u_{sq2} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + L_{s2}p & \omega_2 L_{s2} & L_{m2}p & \omega_2 L_{m2} \\ -\omega_2 L_{s2} & R_s + L_{s2}p & -\omega_2 L_{m2} & L_{m2}p \\ L_{m2}p & (\omega_2 - 2\omega_r)L_{m2} & R_{r2} + L_{r2}p & (\omega_2 - 2\omega_r)L_{r2} \\ -(\omega_2 - 2\omega_r)L_{m2} & L_{m2}p & -(\omega_2 - 2\omega_r)L_{r2} & R_{r2} + L_{r2}p \end{bmatrix} \begin{bmatrix} i_{sd2} \\ i_{sq2} \\ i_{rd2} \\ i_{rq2} \end{bmatrix} .$$



One pair of poles

Two pairs of poles

(a) Scheme of magnetic fields electrical pole-changing

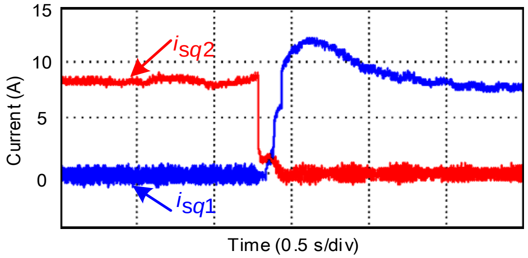


(b) Two decoupled control planes of the five-phase IM

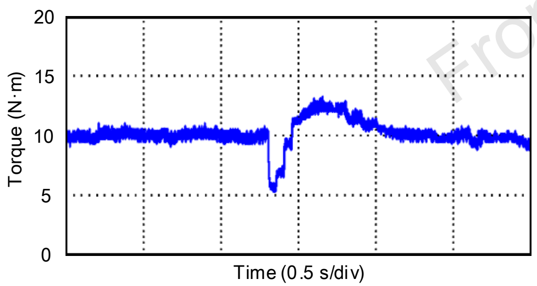
Fig. 1 Schematic of the five-phase induction machine driven system's electrical pole-changing

Major results

Three different electrical pole-changing methods of the five-phase induction machine are compared.

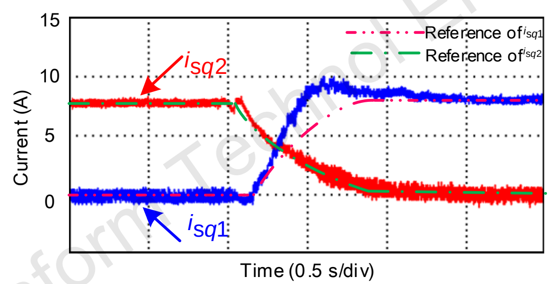


(a) Waveform of i_{sq1}、i_{sq2}

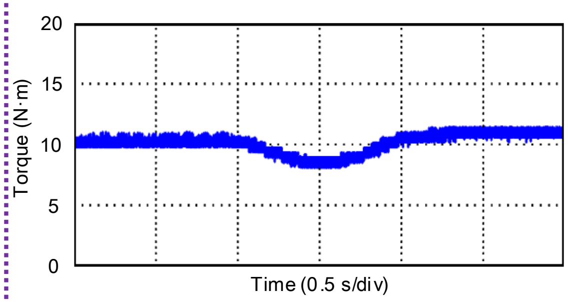


(b) Waveform of torque

Step response under PI controllers

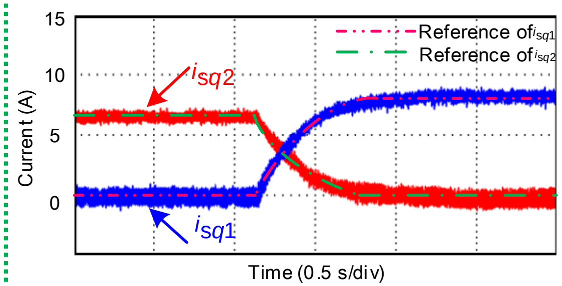


(a) Waveform of i_{sq1}、i_{sq2}

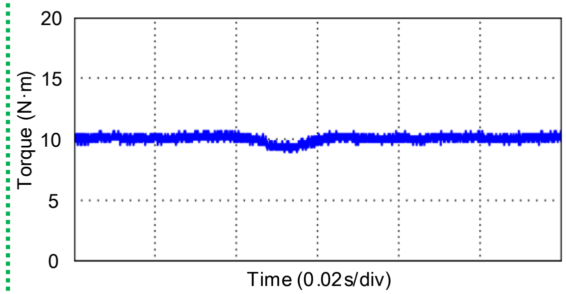


(b) Waveform of torque

Exponential response under PI controllers



(a) Waveform of i_{sq1}、i_{sq2}



(b) Waveform of torque

Exponential response under sliding-mode controllers

Conclusions

- In this paper, we have presented a detailed comparison of several five-phase IM pole-changing methods and proposed exponential response electrical pole-changing methods for five-phase IM with the current SMC strategy.

- Experimental results verify the exceptional performance of the proposed electrical pole-changing strategy.