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Research on control system of a novel coil assisted reluctance motor

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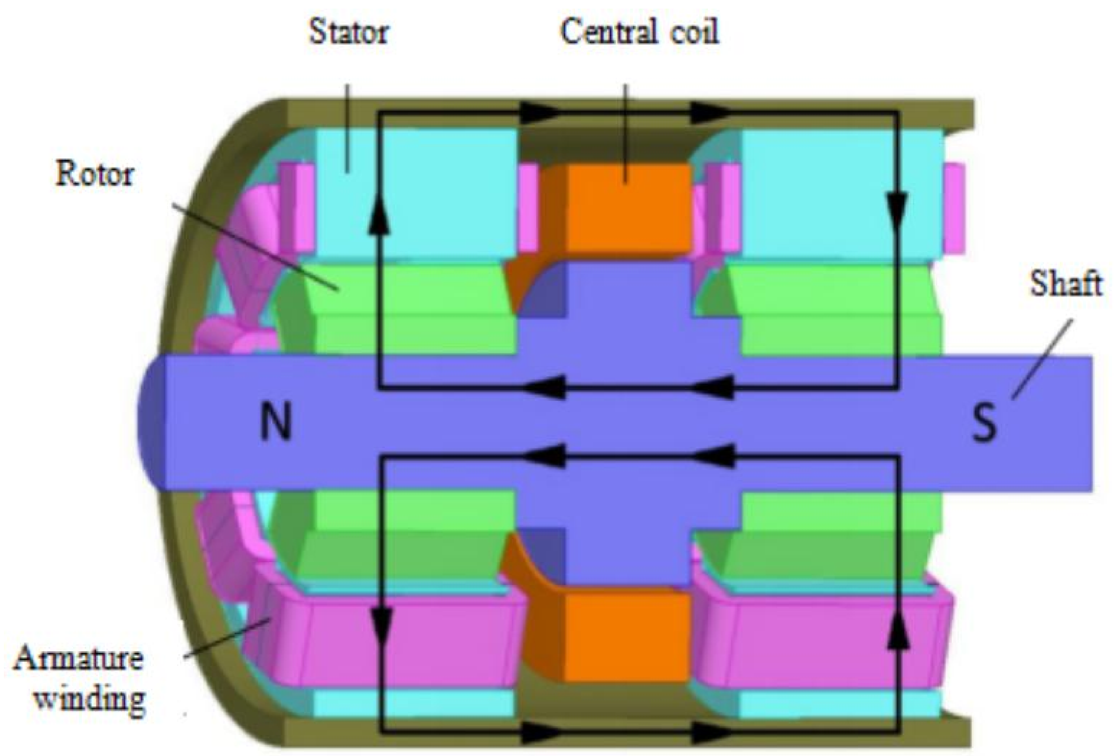
Background

Based on the switched reluctance motor and BLDC, a novel coil assisted reluctance motor(CARM) which has new structure and principle is proposed.The permanent magnet doubly salient motors own permanent magnet, however, in high temperature and high pressure environment, there is a demagnetization phenomenon, and the magnetic flux could not be changed easily. The electric excitation reluctance motor can effectively solve this problem.

Analysis of Motor Structure and Mathematical Model

CARM Structure

The motor is mainly composed of stators, rotors, shaft, armature windings, enclosure and excitation coil. The excitation coil is between two sets of stators, and windings are on the stator salient pole. A 9/6 type structure is chose as pole pairs of stators and rotors, which is different from traditional switched reluctance motor. There are nine stator poles with phase windings and six rotor poles. This 9/6 type determines that the motor is a three-phase motor, and this kind of structure not only meets the commutation ability, but also reduces the difficulty of the control circuit.



The armature winding produces the main magnetic field and the excitation coil generates an auxiliary magnetic field. The magnetic flux produced by windings and excitation coils travels through the guide and shaft to the rotors and then to the stators, and finally it forms a closed loop with the enclosure. According to the minimum reluctance principle, energized windings produce tangential stress in the air gap to drive the rotor rotate.

Mathematical Model

The voltage equation of phase k is:

$$u_p = R_p i_p + i_p \frac{dL_p}{dt} + i_f \frac{dL_{pf}}{dt} + L_p \frac{di_p}{dt} + L_{pf} \frac{di_f}{dt}$$

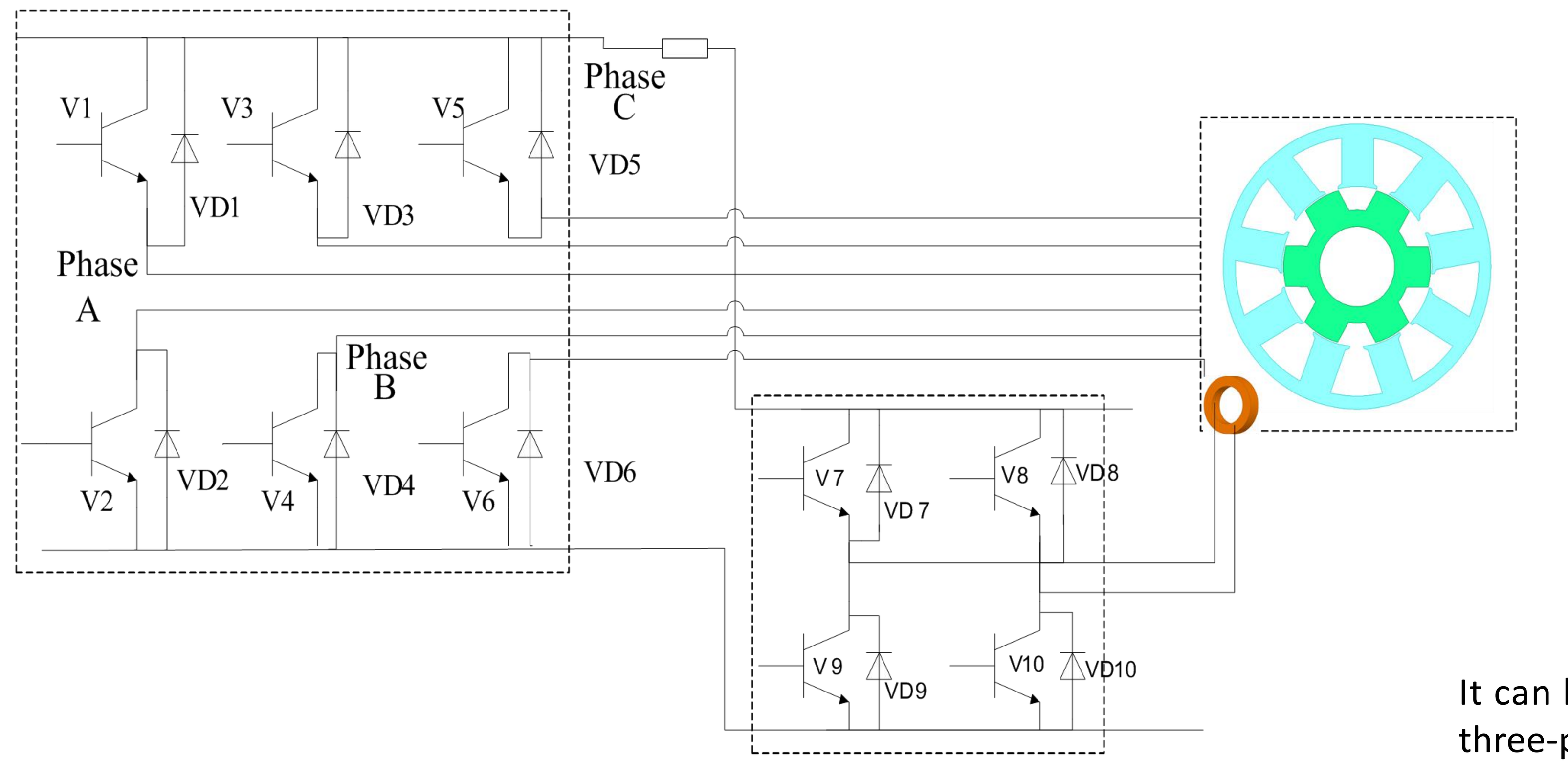
The electromagnetic torque equation of CARM is:

$$T_p = T_{pr} + T_{pe} = \frac{1}{2} i_p^2 \frac{dL_p}{d\theta} \pm i_p i_f \frac{dL_{pf}}{d\theta}$$

The flux equation is:

$$\psi = \psi_{pr} + \psi_{pe}$$

Analysis of Control Strategy



CARM has both the characteristics of BLDC motor and the switched reluctance motor.

Because of the special structure as well as the nonlinear and strong coupling characteristics, its control system adopts double sets of power inverter module. Using asymmetric half bridge circuit for the armature winding to control three phase current, and adopting full bridge circuit for the control of excitation current.

In order to reduce the cost of control system, one power supply is used to double inverter module groups. The direction of excitation magnetic field can be changed by controlling the direction of excitation current. The size of the excitation current can also be changed to control the strength of the excitation magnetic field.

Different angle conduction law

On the basis of standard angle control, in order to improve the starting torque, speed and response time, this paper presents a three-phase six-state control method.

Standard angle conduction law

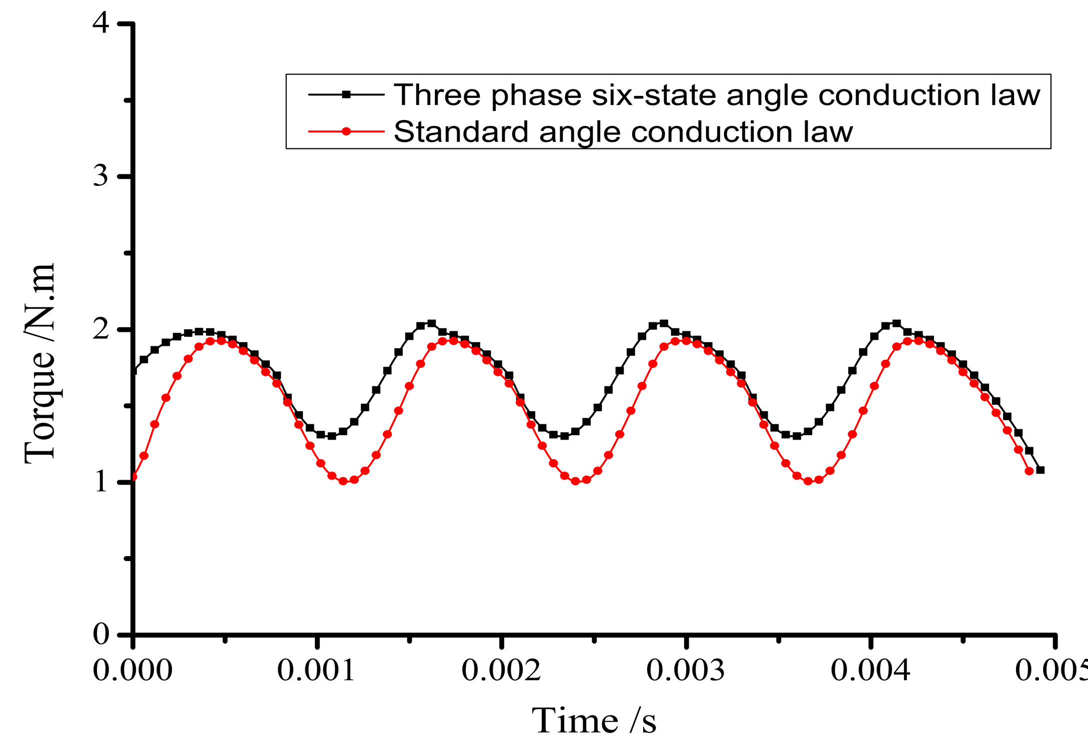
Rotor position	conducting phase
[2°,16°]	A
[22°,36°]	B
[42°,56°]	C

Three phase six-state angle conduction law

Rotor position	conducting phase
[2°,6°]	AC
[6°,16°]	A
[22°,26°]	AB
[26°,36°]	B
[42°,46°]	BC
[46°,56°]	C

In order to obtain greater torque, each phase conduction time should be longer, no braking torque .

The position where stator tooth center line and the rotor slot center line is aligned is defined as 0°.The conduction angle is 14°.

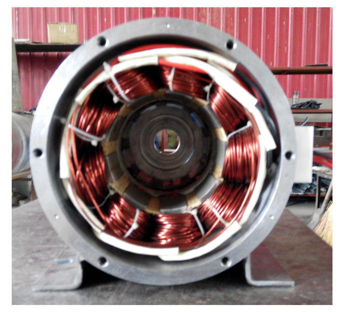


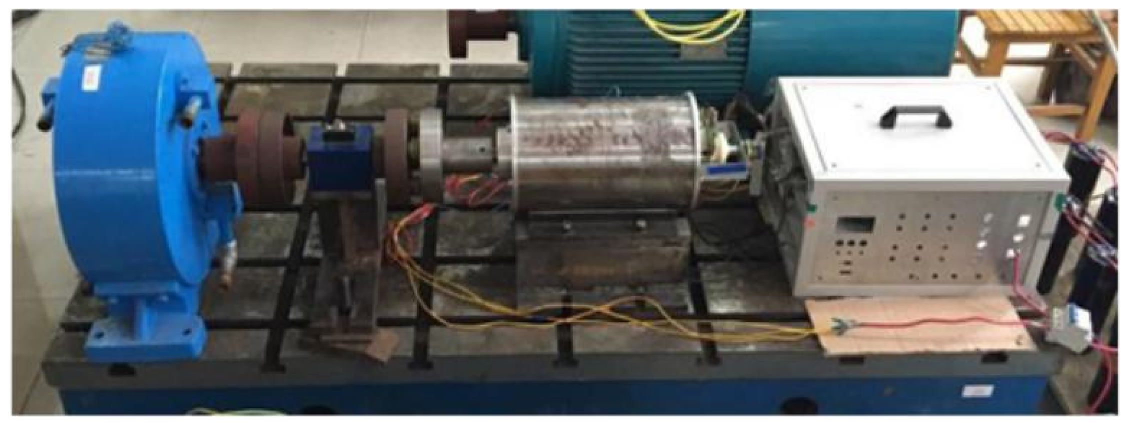
It can be seen that the overall torque is significantly improved in the three-phase six-state conduction mode, especially the minimum torque is greatly improved and the torque ripple is greatly suppressed.

When the motor at high speed, using angle position control to achieve better torque closed-loop control and speed closed-loop control.

Exreriment

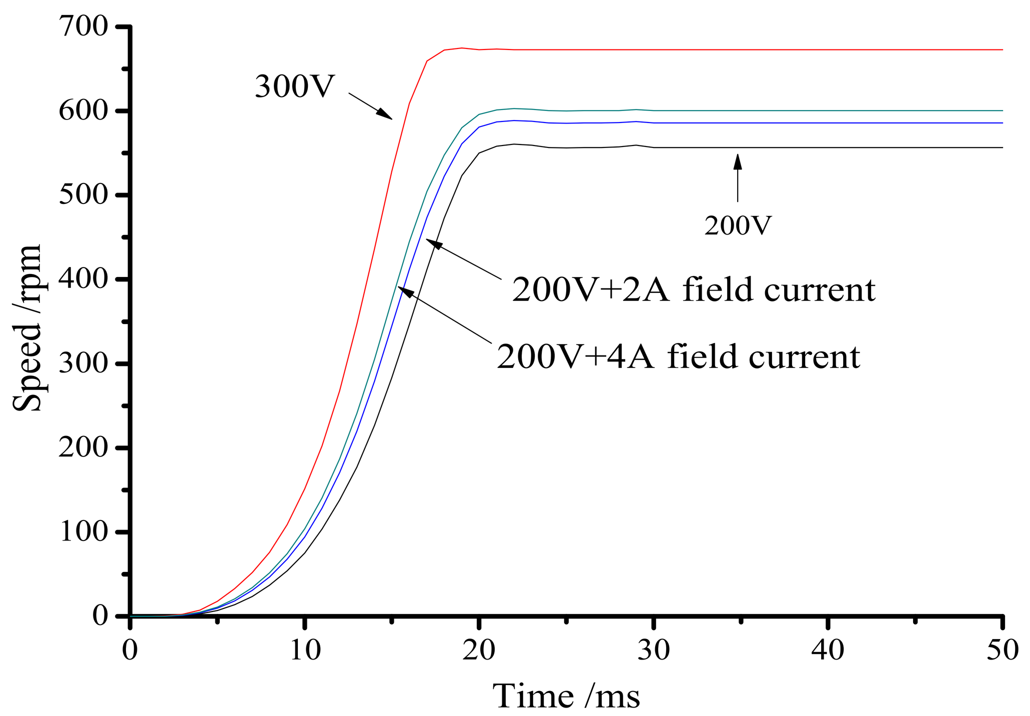
The test system mainly includes the motor, TMS320F28335DSP controller, photoelectric coupling sensors, current sensors, digital oscilloscopes and so on.This paper verifies the practicability of control system and control strategy of CARM.





As the magnetic flux density is not saturated, the higher the positive excitation current is, the higher the rotational speed will be.

As shown in the figure, when the armature voltage is constant, adjusting the excitation current can increase the speed range. Although reducing the armature voltage, increasing the excitation current can still meet the same speed requirements.



Conclusion

- The three-dimensional finite element method is used to analyze the electromagnetic characteristics of CARM. Based on the analysis of motion principle, the three-phase six-state control strategy based on the standard angle control method effectively increases the starting torque and reduces the motor The torque ripple.
- Through the excitation coil control, different armature voltage - excitation current matching program can be used in different speed requirements. Reduce the armature voltage on the bus side while increasing the excitation current to achieve the same speed requirements.
- The excitation current-torque direct control strategy makes CARM speed more stable, the torque ripple reduced, and the speed range increased. The stability and reliability of the system are verified by experimental test.
- Although two groups of inverter modules improve the control accuracy, that also increase the complexity of the control system and cost, so the application needs to be considered according to actual requirements.