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OPERATING CHARACTERISTICS OF INDUCTION MOTORS FED BY POLY-PHASE INVERTERS

インバータで駆動された誘導電動機の特性

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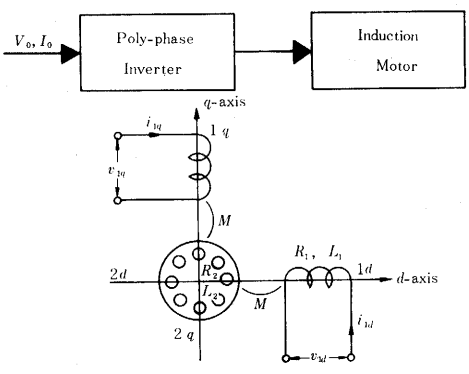
1. Introduction

In a previous paper[1], we reported about an analytical method to analize an induction-inverter motor system. With use of this method, the system can be regarded as a direct current machine and the characteristics of an induction motor under various oprating conditions can be computed by state trantition method.

In this paper, experimental results of operating characteristics of an induction motor fed by both six-phase and twelve-phase inverter are shown in comparison with theoretical results.

2. Comparison of the theoretical and experimental results

An inverter-induction motor system is shown in Fig. 1. With use of the frame of reference (α-β) co-ordinates which rotate discontinuously, the solutions for each state variables are obtained as follows.



$$\begin{bmatrix} v_{1d} \\ v_{1q} \\ v_{2d} \\ v_{2q} \end{bmatrix} = \begin{bmatrix} R_1+L_1P & & Mp & \\ & R_1+L_1P & & Mp \\ Mp & M\dot{\theta} & R_2+L_2P & L_2\dot{\theta} \\ -M\dot{\theta} & Mp & -L_2\dot{\theta} & R_2+L_2P \end{bmatrix} \begin{bmatrix} i_{1d} \\ i_{1q} \\ i_{2d} \\ i_{2q} \end{bmatrix}$$

Fig. 1 Inverter and induction motor

$$X(t)=H(t-nT)X(nT)$$
$$X(nT)=\mathcal{Z}^{-1}[(U-z^{-1}H(T))^{-1}] \qquad (1)$$

where,

$X=(e_s \ i_{1f} \ i_{2f})'$, $e_s=v_{1\alpha}/\sqrt{2}$

$i_{1f}=(i_{1\alpha}+ji_{1\beta})/\sqrt{2}$,

$i_{2f}=(i_{2\alpha}+ji_{2\beta})/\sqrt{2}$

$H(\lambda)$ = state transition matrix of the system.

The output torque T_0 of the motor is given by

$$T_0=2MR_e[j\overline{i_{1f}(t)} * i_{2f}(t)] \qquad (2)$$

The operating characteristics of the induction motor can be computed by Eqs. (1) and (2). The parameters of the motor tested are as follows.

2-poles, 0.75 kW, 3-phases, 200 V (line to line)
$R_1=2.78\,\Omega$, $L_1=L_2=0.213\,H$, $M=0.206\,H$,
$R_2=1.171\,\Omega$

Experimental results are shown in Fig. 2～Fig. 4 together with the theoretical ones. In these experiments, a three-phase bridge-type inverter is used as a six-phase inverter, and a twelve-phase inverter is constructed with two six-phase inverters. In Fig. 2, inverter input current waveforms are shown.

In Fig. 3, relations between average inverter

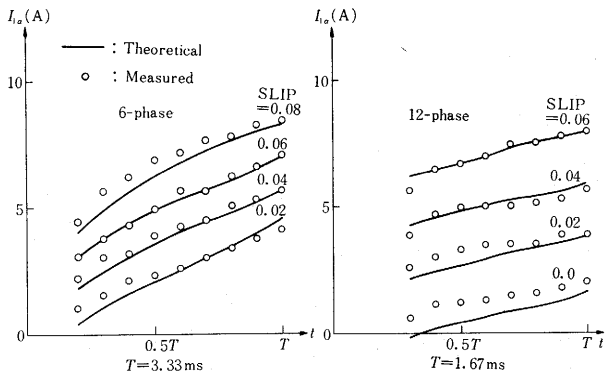


Fig. 2 Inverter input current

input current and rotor velocity are shown. In these figures, the theoretical curves are formed by the computed values from Eq. (1) plus measured values of inverter input current under no load condition. In the analysis, inverters are assumed to have ideal switching characteristics. Impulsive current during each commutation, magnetizing currents of transformers, and voltage drops in inverters are neglected. These losses are almost kept constant for various load conditions. So, the computed values plus the measured values of no load current are used as the theoretical values. The curves in Fig. 3 represent the characteristics which are obtained when the inverter-induction motor system is regarded as a direct current machine. The inverter input voltage V_0 is constant and thus $V_0 \bar{I}_0$ is the average inverter input power. In Fig. 4, inverter output current waveforms are shown.

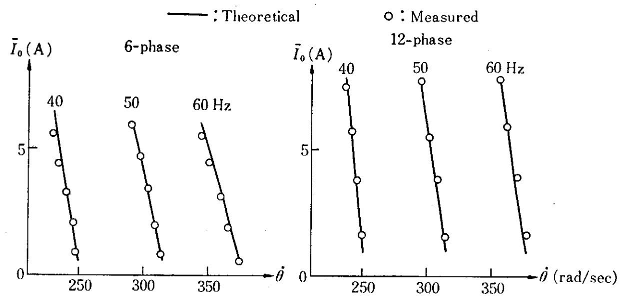


Fig. 3 Average input current and rotor velocity

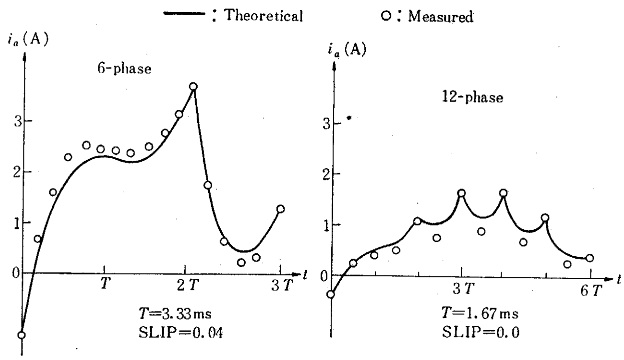


Fig. 4 Inverter output current

3. Transient characteristics

With use of the analytical method shown in this paper, transient characteristics can also be obtained. The electrical transients when rotor velocity is kept constant can be computed by Eq. (1). When the rotor velocity varies with time as in the case of starting transients, the equation of motion of the rotor should be taken into account. The equation of motion of the motor with load inertia J is given by

$$2MR_e[j\overline{i_{1f}(t)} * i_{2f}(t)] = J\frac{d\dot{\theta}}{dt} \qquad (3)$$

Eq. (3) includes a nonlinear term of currents. So, exact solutions are obtained only by numerical methods. However, system equations can be approximately linearized by the fact that the changes of the rotor velocity and torque are relatively small compared with the changes of currents over a sampling period. Once the system equations are linearized, the solutions can easily be obtained by state transition method.

Reference

1) HARASHIMA. F.: Analysis of Inverter-Induction Motor System. SEISAN-KENKYU, Vol. 20, No. 9 1968.