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Stability analysis of a multi-phase (six-phase) induction machine

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Abstract

The stability study of a multi-phase (six-phase) induction machine has been performed by applying the eigenvalues stability criterion to the small displacement equations obtained by linearization about an operating point. The eigenvalues provide a simple means of predicting the behavior of an induction machine at any balanced operating condition. The eigenvalues are dependent upon the parameters of the machine and it is difficult to relate analytically a change in an eigenvalue with a change in a specific machine parameter. It is possible, however, to identify an association between eigenvalues and machine variables. Therefore, in this paper, the stability of the machine under small perturbation of machine variables has been examined from the placement of the eigenvalues. The effect of common mutual leakage reactance, which depends upon the winding pitch and the displacement angle between the two three-phase stator winding sets, and the effect of harmonics have been included in this study.

Keywords: Analysis; Induction machine; Multi-phase; Modeling; Stability

1. Introduction

It was recognized first by Rogers [1] that an induction machine operating quite satisfactorily at normal speed might display an oscillatory response that is frequency dependent. The analysis was based on root locus technique. Fallside and Wortley [2] have also analyzed the instability of the induction motor fed by variable frequency inverter, neglecting the effect of harmonics. The effect of machine parameters on the stability of the system was also reported. Lipo and Krause [3] have performed the stability study of a rectifier–inverter induction motor drive system neglecting stator

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Nomenclature

T_l	load torque
P	number of poles
J	moment of inertia
ω_b	base speed
ω_k	speed of the reference frame
ω_r	speed of the rotor
p	differentiation w.r.t. time
v_{q1}, v_{d1}	q- and d-axis voltages of stator winding set I
v_{q2}, v_{d2}	q- and d-axis voltages of stator winding set II
λ_{q1}, λ_{d1}	q- and d-axis stator flux linkages of set I
λ_{q2}, λ_{d2}	q- and d-axis stator flux linkages of set II
λ'_{qr}, λ'_{dr}	q- and d-axis rotor flux linkages referred to stator
i_{q1}, i_{d1}	q- and d-axis currents of stator winding set I
i_{q2}, i_{d2}	q- and d-axis currents of stator winding set II
r_1	stator per phase resistance of set I
r_2	stator per phase resistance of set II
r'_r	rotor per phase resistance referred to stator
L'_{lm}	common mutual leakage inductance between the two stator winding sets
L_m	mutual inductance between stator and rotor
L_{l1}	leakage inductance per phase of stator winding set I
L_{l2}	leakage inductance per phase of stator winding set II
L'_{lr}	leakage inductance per phase of rotor winding referred to stator
x'_{lm}	common mutual leakage reactance between the two stator winding sets
x_m	mutual reactance between stator and rotor
x_{l1}	leakage reactance per phase of stator winding set I
x_{l2}	leakage reactance per phase of stator winding set II
x'_{lr}	leakage reactance per phase of rotor winding referred to stator
L'_{ldq}	mutual inductance between the d- and q-axis circuit of the stator windings
v'_{qr}, v'_{dr}	q- and d-axis rotor voltages referred to stator

voltage harmonics and using Nyquist stability criterion. Cornell and Lipo [4] have used transfer function techniques for the development of controlled current induction motor drives and study its stability. Macdonald and Sen [5] have developed a linearized small signal model of the current source inverter–induction motor drive to study the stability of the drive and provide a transfer function for different control strategies. Tan and Richards [6] have calculated the eigenvalues of double-cage induction motor using decoupled boundary layer model.

In these works, only the fundamental component of the inverter voltage has been taken into account neglecting the effect of harmonics. There is much evidence in the historic literature [7–10] dealing with the transient analysis that the transient behavior predicted using the conventional linearized model, although agrees qualitatively, deviates from the actual quantitatively. The cause