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Generator operations of asynchronous induction machines connected to ac or dc active/passive electrical networks

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Abstract

The paper analyses generator operations of asynchronous machines when they are connected to a passive electrical network either directly or by an intermediate static power converter. The analysis is performed by taking into account the saturation phenomena of the main magnetic circuits of the machine. Mathematical models of both physical configurations are given and their non-linearities are evidenced. The paper investigates the existence of periodical solutions related to stable operations of the systems. Numerical and experimental results support the theoretical analysis.

Keywords: Generator operations; Asynchronous machines; Saturation; Mathematical models

1. Introduction

In recent years generator operations of asynchronous machines have been the subject of some of our applied researches. The idea has been suggested by various considerations. The evolution of alternative sources of electrical energy (for example, solar and wind energy) that imply weak distributed and disconnected electrical networks requiring self-adjusting operating conditions, suggests the use of low maintenance, high reliability and low cost machines. The growing use of asynchronous machines in electrical drives for industrial and traction applications implies not only traditional motor operations but also generator and plug braking operations.

An analysis of technical literature has shown that motor operations of asynchronous induction machines have been widely studied both when they operate with or without intermediate electronic power converters. By contrast, generator operations have been dealt with less often. This lack of knowledge may, perhaps, also be the cause of the poor practical use of asynchronous generators. For this reason we have prepared a theoretical and experimental research programme, devoted to a thorough investigation of the different aspects of generator behaviour, both on passive and active electrical networks, i.e.

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Nomenclature

$\boldsymbol{i}'_{\mathrm{r}}$	space vector of rotor currents, referred to stator windings
$\boldsymbol{i}_{\mathrm{s}}$	space vector of stator currents
$\boldsymbol{I}'_{\mathrm{r}}$	steady state vector of rotor current referred to stator windings
$\boldsymbol{I}_{\mathrm{s}}$	steady state vector of stator current
ℓ	leakage inductance with reference to stator phase
$L_{\mathrm{m}}^{\mathrm{t}}$	trigonometric air-gap inductance for saturated machines
$L_{\mathrm{m}}^{\mathrm{g}}$	differential air-gap inductance for saturated machines
p	pole-pair number
r'_{r}	rotor phase resistance
r_{s}	stator phase resistance
R_{u}	load resistance
T_{el}	electromagnetic torque
T_{R}	rated value of T_{el}
$\boldsymbol{v}$	space vector of stator voltages

Greek letters

ϑ	angular rotor position
Φ_{m}	amplitude of air-gap flux space vector
ω_{r}	angular speed of rotor
ω_{n}	rated value of ω_{r}
Ω	armature voltage pulsation

self-excitation, self-sustaining oscillations and steady-state operating frequencies on passive networks; slip regions, air-gap magnetic flux densities and variable frequency operating conditions on active networks. The research programme is now in progress. We are convinced that the results so far obtained will be useful for explaining the most interesting aspects of generator behaviour of asynchronous induction machines and, therefore, for increasing their use in those practical applications where these machines appear to better satisfy users' requirements related to performances, buying prices and maintenance costs. Basically, we have found that in all cases generator operations imply air-gap magnetic flux densities that are higher than those corresponding to motor operations (for example [1]). This situation implies that when traditionally designed machines are used, saturation may occur in their main magnetic circuits. Therefore, theoretically, analysis of generator operations should be performed by means of suitable mathematical models that take into account saturation phenomena. We have found that it is possible to carry out a model which is very simple but at the same time fully satisfactory for practical purposes. It has been presented in a previous paper [2]. The model gives, moreover, rise to simple feeding algorithms for digital control applications. By means of this mathematical model we have evaluated the necessary conditions for obtaining stable generator operations on passive electrical networks. These operations can, however, be really attained only if the system is capable of self-excitation. Self-excitation occurs only if rest conditions of the system are not all identically nil. The physical system, represented by an asynchronous generator and its passive electrical network, has a mathematical model set-up by non-linear differential equations. On the basis of finite initial conditions, their solutions can lead to limit cycles or focal