OPTIMIZATION OF RELUCTANCE MOTOR DESIGN

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SUMMARY

Reluctance motors are used when we need a motor that runs at synchronous speed, not of large power and relatively cheap .In some aspects, reluctance motors have the advantages of squirrel- cage induction motors of being : cheap, robust and can be connected directly to the a.c. supply. They do not need d.c. excitation, as in synchronous motors and hence absence of brushes and brush gear.

However, they have the disadvantages of : low power factor (about 0.6) and small pullout torque developed (about half that delivered by induction motor having the same stator). The main applications of reluctance motors nowadays are in control systems, textile machines and in systems requiring rigidly constant speed working in explosive media.

In the last decade, new developments in design and construction of rotor configurations of reluctance motors have been introduced. This lead to improvements in performance and made reluctance motors more appealing for industrial applications. However, the newly developed rotors are much complex in analysis and design, than the conventional form of rotor with just saliency in the direct axis.

This thesis developed computer programs for obtaining

optimal design dimensions for a reluctance motor to give maximum required performance value e.g best power factor or maximum pull out torque,maximum stable operating region, or maximum output watts per active weight ... etc. The study is applied to three different rotor configurations. The first rotor construction is of the conventional form with saliency in the direct axis, the second is of cylindrical rotor with a radial slit in the d-axis and the third rotor configuration is a combination of the previous two constructions i.e. salient poles with radial slit in the d-axis.

The thesis starts by giving the analytical theory of the reluctance motors . It then gives the mathematical models to represent some reluctance motors. Basic equations are derived for the air gap field distribution, and then the torque developed relations, taking into account the magnetic field in the slit and inter-pole regions. All important motor dimensions have been obtained. Performance curves have been obtained via computer,and plotted using lotus program.

After surveying various methods of optimization programing, the mixed penalty technique has been chosen, as it is characterized by easy starting facilities and guaranties that any starting point remains satisfied throughout the computations.

LIST OF CONTENTS

LIST OF SYMBOLS

F : supply frequency , HZ

t : time

i_d, i_q : d-and q-axes component of the armature current, respectively.

I_d, I_q : r.m.s value of i_d and i_q ,respectively

$\hat{I}_d, \hat{I}_q$: amplitude of i_d and i_q ,respectively

p : number of pole pairs

R : stator resistance

V_d, V_q : d- and q- axes component of the applied voltage, respectively

V : r.m.s value of the applied voltage

$\hat{V}$: amplitude of the applied voltage

X_m : cylindrical rotor magnetizing reactance

C_d : direct axis reactance coefficient

C_q : quadrature axis reactance coefficient

X_d, X_q : d- and q-axes synchronous reactance ,respectively

X_σ : stator leakage reactance

ω	: angular rotor speed :	β	: load angle
n	: revolution per min.	ϕ	: phase angle between current and voltage
Co	: output coefficient	α	: pole arc / pole-pitch ratio
X(1)	: slit width / air gap	D	: motor bore diameter
X(2)	: active iron depth in	δ	: gap length under pole face (in salient-pole type)
X(3)	: iron length	t_1	: gap length under inter-pole zone
X(4)	: slot depth	S	: slit width
X(5)	: slot width	λ	: slit width / pole-pitch ratio
X(6)	: core depth	B	: flux density
X(7)	: pole arc / pole pitcl	μ_o	: permeability of free space
X(8)	: inter pole depth / p	J	: current density
		h_s	: slot depth
		b_s	: slot width
		K_f	: slot filling factor
		K_w	: winding factor
		K_i	: iron factor
		τ_s	: stator slot arc
		m	: no. of phases
		j	: $\sqrt{-1}$
		σ	: X_q / X_d

CHAPTER (1)

INTRODUCTION

1.1 GENERAL

Reluctance motors have been very successfully used in a wide variety of applications such as control systems , laboratories , domestic fields and can be used also in system of explosive media . In spite of their disadvantages of rather low power factor and low specific output. The advantages being : robustness , simplicity in construction , cheapness ,its capability of self starting even when loaded , and speed constancy . These merits have made such motor a natural choice for numerous applications.

REVIEW OF PUBLISHED LITERATURE

Earlier designs were restricted to the conventional salient pole type where saliency ratio was increased by several developments in its shape . Where saliency ratio was increased by increasing the reluctance in the quadrature axis as much as possible and reducing it in the direct axis.

LAWRENSON [1] , has introduced segmental type,in which complexity in design was avoided and saliency ratio was increased to a level that made practical utilization of this new type realizable.

(A)

(B)

Modificati

(A

(B

<u>MOHAMMEDEIN</u>[2] , has introduced an improved design of reluctance rotor, in which starting is achieved with no need for extra starting cage windings . Starting in this type is achieved by virtue of the induced currents in the rotors solid body and to provide the necessary synchronous torque after pulling into synchronism . The split of the rotor block into two stacks , with the direct axis of the first stack shifted from that of the second one by an angle . Synchronizing performance will depend in this case on the shift angle , in his experimental work the inter stacks shift angle was chosen to be equal to 45^{o} (elect.).

<u>EL- SHEBINY</u>[3] , used a field approach for designing the magnetic circuit ,and computer programs are used for numerical solutions to obtain optimized values of the form factors of magnetic field in air gap.

<u>CHALMERS AND MULKI</u>[4] Have developed new rotors consisting of solid steel in the form of a cylinder having effective magnetic saliency either by virtue of actual saliency or by flux barriers, so that at synchronous speed the rotor behaves as a reluctance motor. This solid rotors start by induction action without the need for a squirrel cage winding by virtue of eddy currents induced in the steel rotor body .

They produced two different features to improve the synchronizing performance .

In the first of these, depicted in Fig.(1.1-A) where a low resistance coil is added on the rotor direct axis.The coil sides of this coil are conveniently in the air spaces on the quadrature axis faces of the rotor.

In the second of these, depicted in Fig.(1.1-B) narrow axial slits are machined in the rotor surface . These slits may be either radial as shown or in parallel sets and they may be provided on either the direct or quadrature axes faces or on both sets of faces.

CHAPTER(2)

ANALYTICAL STUDY OF THE RELUCTANCE MOTOR

Consider the elementary reluctance motor shown in Fig.(2.1). To understand the principle of its operation . Assume the design to be such that the angle between the stator coil axis and rotor direct axis is θ . Hence, the minimum magnetic reluctance occurs at $\theta = 0$; and thus the rotor is in equilibrium position. But if the rotor is displaced in an anticlock-wise direction by an angle θ , where $0 < \theta < 90$, thus the air gap magnetic field will be deformed and torque will result in the clockwise direction tending to return the rotor to its equilibrium position.

At $\theta = 90$,the reluctance will be maximum and the rotor will be in an unstable position , at $\theta = 180$, the reluctance will be again at minimum value , and the initial position is restored , all these variations are illustrated graphically in Fig.(2.2).

The electro magnetic moment acting on the motor can be obtained, as the partial derivative of the electro magnetic energy with respect to the angle of displacement,assuming that the M.M.F and flux do not depend on displacement angle , which can be put in the form :