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New magnetic material impact in electric machine design: high speed operation and reduction of losses

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Abstract

The paper presents electrical actuator design considerations introduced by exploiting new magnetic material characteristics. The materials considered are amorphous alloy ribbons as well as neodymium alloy permanent magnets involving very low eddy current losses. Such materials enable electric machine operation at higher frequencies compared with the standard iron laminations used in the traditional magnetic circuit construction and provide better efficiency.

Keywords: Finite element method; Iron losses; Permanent magnet machines; Equivalent circuit parameters

1. Introduction

Recent technological advances in new materials have been very promising for the development of new electrical machine structures exhibiting increased performance [1]. So the permanent magnets have been extensively used to replace the excitation winding in synchronous machines with the advantages of simple rotor design without field windings, slip rings and exciter generator, avoiding heat dissipation in the rotor and providing higher overall efficiency [4]. The rotor design can be distinguished in three main types according to the magnet position, namely the "interior" [2], the "peripheral" [3] and the "claw pole" type. In this paper the peripheral type machine structure has been adopted [5,6].

At the stator side, the material considered are amorphous alloy ribbons involving very low eddy current losses. Such materials enable electric machine operation at higher frequencies compared with the standard iron laminations used in the traditional magnetic circuit construction and provide better efficiency.

The authors propose the study of a permanent magnet machine prototype based on such materials through a design procedure involving three steps. In a first step the typical design procedure is conveniently adapted in order to include the new magnetic material properties. In a second step the machine characteristics are checked by means of a detailed field calculation through finite-element techniques. In a third step a prototype is constructed in order to validate the machine performance. Low losses and high volumic power associated with high speed and converter machine operation are the main advantages of such applications [5,7].

2. New material characteristics

Standard silicon iron laminations, which have dominated magnetic circuits at low frequency applications (50 Hz), cannot be used in high frequencies enabled by power electronic converter developments (a few kHz) due to the high iron losses associated. Such losses are mainly due to eddy currents as the lamination width is no more compatible with the respective skin effect depth.

In this range of frequencies ferrites and amorphous alloy ribbons seem to provide important advantages due to their low eddy current losses. Technological developments enabled production of such materials with high saturation induction approaching 1 T and very reduced coercive force, providing the possibility of conception of high speed actuators with very attractive performance.

Moreover technological advances in permanent magnet materials enabled production of neodymium alloy magnets with magnetisation attaining 1.25 T and coercive force of 10^5 A/m.

Combination of such materials, that is high magnetisation permanent magnets in the rotor parts and amorphous alloy ribbons in the stator parts, is expected to enable new machine designs, with light structure, high rotor speed and

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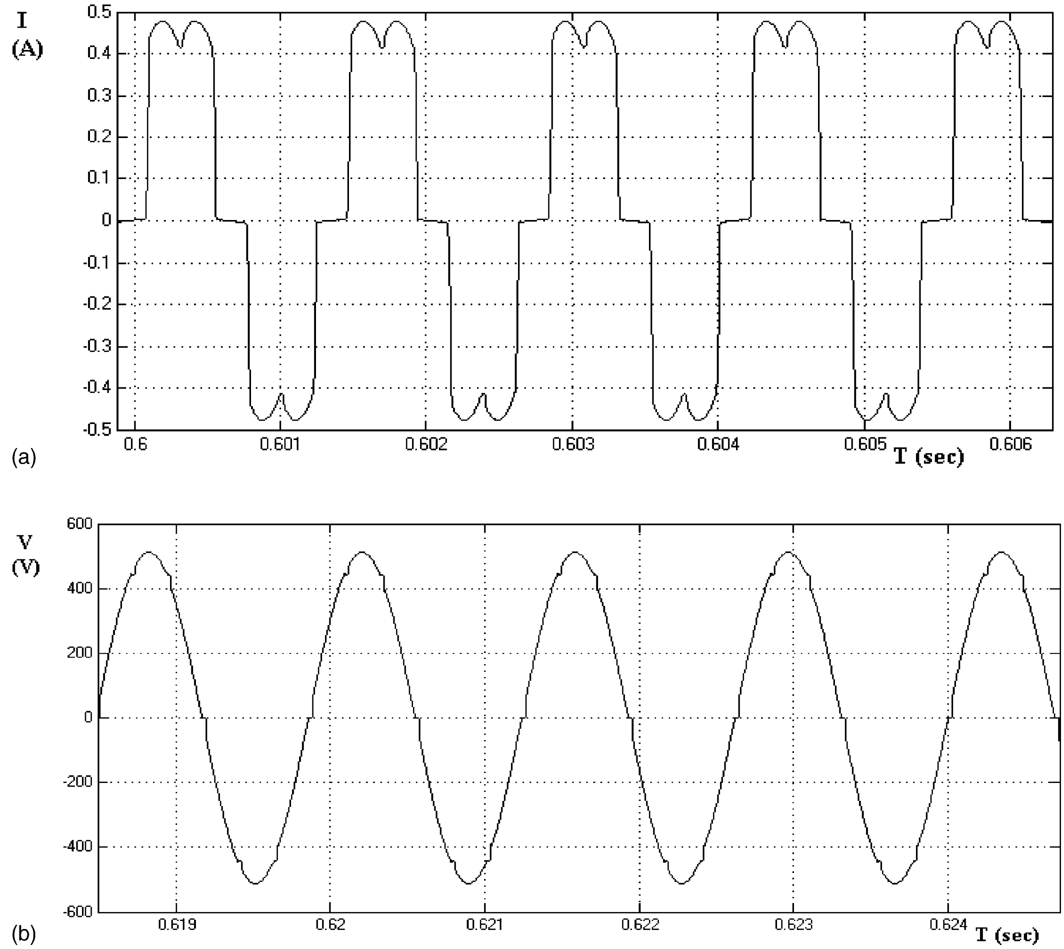

Fig. 1. Permanent magnet machine supplying a resistive load through a rectifier: (a) phase current–time variation; (b) phase voltage–time variation.

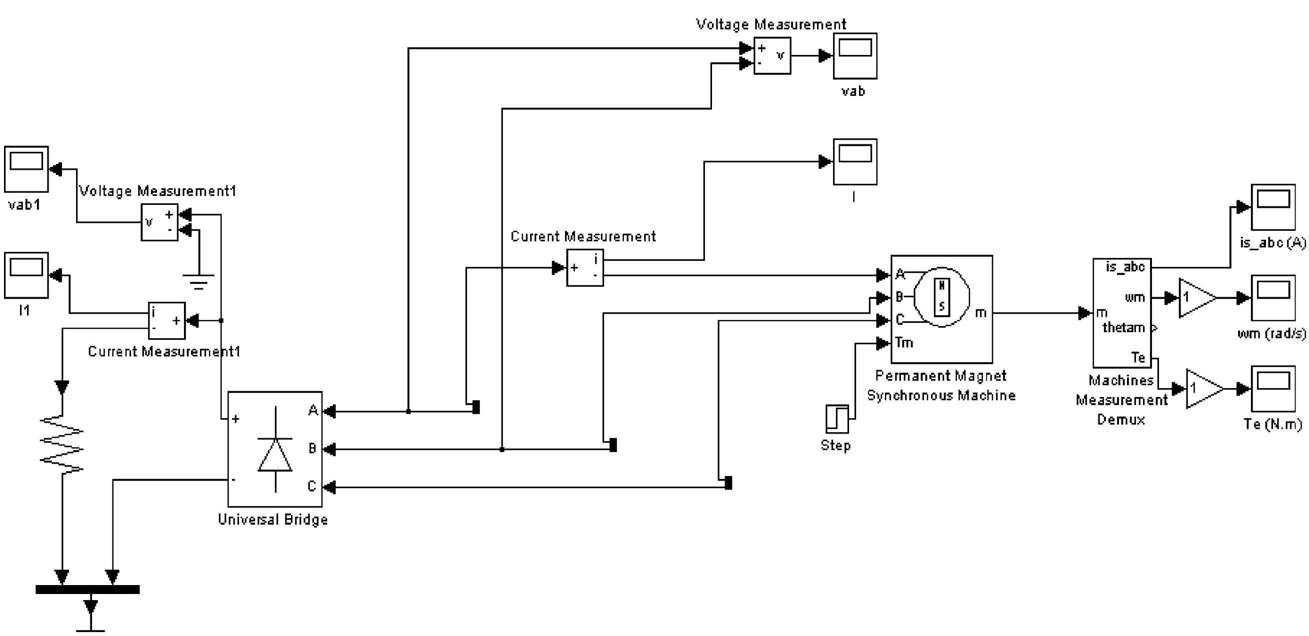

Fig. 2. Configuration of the standard machine supplying a resistive load through a rectifier.