DOCTORAL THESIS IN
STOCKHOLM, SWEDEN 2003

A Low-Leakage Linear Transverse-Flux Machine for a Free-Piston Generator

WAQAS ARSHAD

Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the on Wednesday the 11th June 2003, at 12:00 a.m. in

KTH ROYAL INSTITUTE OF TECHNOLOGY

Abstract

The presented work is about a new low-leakage lineartransverse-flux electrical machine.The machine is dimensionedfor a free-piston generator. The intended application is inseries-hybrid vehicles. The free-piston generator is anintegration of a free-piston combustion engine with a linearelectrical machine. It provides benefits in e±ciency,emissions and multi-fuel capabilities, to name a few. Thesecombustion benefits are only possible if the total mover massis kept quite low (e.g.&#8804 4 kg for a 50 kW unit). Thelimited mover mass and competitiveness demands result in a verystringent set of specifications for the electrical machine.

Most existing electrical machine topologies arepreliminarily investigated. Of these only a transverse-fluxmachine (TFM) is found to be promising. Even for the case ofthe TFM, a factor 2 improvement in the performance indices ofthe existing TFMs is required. Different surface-mounted TFMsare investigated for improvement. It is found that theanalytically acceptable solutions fail during thethree-dimensional finite-element analysis (3D-FEM). Thesedesigns suffer from a very significant pole-to-pole armatureleakage flux in the stator. Similar design improvements for theburied-magnets TFMs are also investigated. Fortunately, in thiscase a promising design is derived. This design exhibits lowleakage and is verified with FEM analysis. A down-scaledone-phase 1.7 kW proof-of-concept TFM of this design isdimensioned. It is analysed thoroughly, both analytically aswell as by 3D-FEM computations. It is found that for thisparticular prototype the design suffered from saturation. It isshown how this design can be modified to yield the desiredforce with the allowed mover mass. The efficiency is found tobe only slightly lower than the demands but a poor power factoris noted.

The prototype is built. Unfortunately, all the desiredmeasurements could not be carried out. This is because thebuilt-machine sufferedwith two major manufacturing defects.The magnets are found to be demagnetised to about 50% of theirmanufactured value. It is also found that the translator poleson the average are 7% longer (in the axial direction) than thestator poles. Low values of no-load induced voltage and forceare thus measured. The correlation between the manufacturingdefects and the measurements is established. Due toinsufficient measurement data, this relationship is mainly ofan indicative nature only. A more correct picture requiresconstruction of a new prototype. Still, the results do pointtowards a near fulfillment of the objectives. Other addressedtopics include, an investigation into a separate free-pistongenerator project with reduced specifications, application ofthe presented work to renewable energy sources like wind- andwave-energy and a brief introduction to the free-pistonapplication aspects.

ISBN: 91-7283-535-4 | Trita-ETS 2003-08 | ISSN 1650-674X
http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-3563

Keywords:Free-Piston Generators, Linear Machines,Transverse-Flux Machines, Hybrid Vehicles, Electrical MachinesDesign.

Keywords

Free-piston generators, linear machines, transverse-flux machines, hybrid vehicles, electrical machines design

ISBN: 91-7283-535-4 | Trita-ETS 2003-08 | ISSN 1650-674X
http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-3563