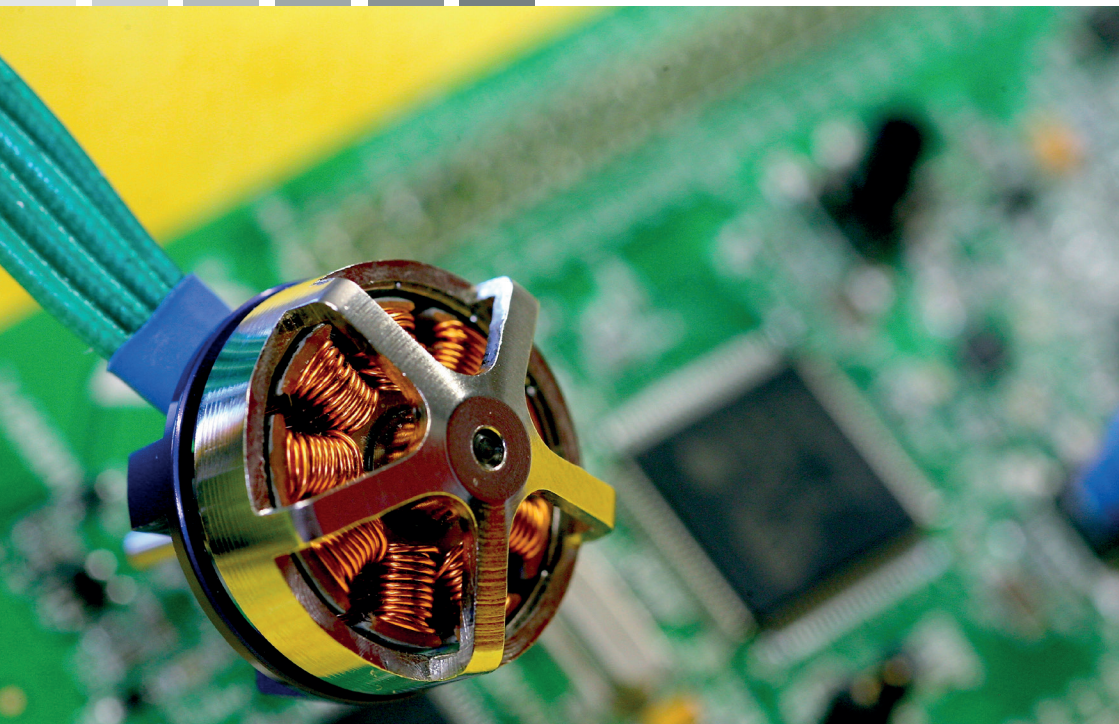


Direct Flux Control – A sensorless technique for star-connected synchronous machines

An analytic approach

Emanuele Grasso



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Emanuele Grasso

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*"In physics the truth is rarely perfectly clear,
and that is certainly universally the case in
human affairs. Hence, what is not surrounded
by uncertainty cannot be the truth".*

Richard Feynman

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To my sister Isabella and her three daughters, Irene, Noemi and Giulia.

Abstract

Synchronous machines have found wide application in a variety of technological fields, ranging from domestic to industrial, to transportation. In particular, Permanent Magnet Synchronous Machines, PMSMs, are the most common typology thanks to their higher power density and simpler construction. Hence, they have attracted scientific attention with the aim of optimizing their design and control strategies and, also, techniques for sensorless operation have received particular focus. In fact, eliminating the need for mechanical sensors skews in the advantage of using such machines due to the consequent reduction of space and cost of the driving system. Many techniques for the estimation of the electrical rotor position from electrical measurements have been proposed, either relying on the exploitation of the back-EMF voltage or on machine anisotropies. This work lies in this research field and proposes to offer a mathematical description of the so-called Direct Flux Control (DFC) sensorless technique. This technique, differently from the majority of other proposed approaches, exploits machine anisotropies by measuring the zero-sequence voltage of the machine, i.e. requiring measurements of the star-point voltage. After offering a mathematical derivation of the DFC technique for generic synchronous machines first and for PMSMs later, an experimental investigation is presented and results are commented. Finally, hints for further research works opened by investigations on the DFC technique are proposed.

Kurzzusammenfassung

Synchronmaschinen haben eine breite Anwendung in einer Vielzahl von technologischen Bereichen gefunden, die vom Haushalt über die Industrie bis hin zum Transportwesen reichen. Insbesondere Permanentmagnet-erregte Synchronmaschinen (PMSMs) sind dank ihrer hohen Leistungsdichte und der einfachen Konstruktion die am häufigsten verwendete Topologie. Daher haben sie wissenschaftliche Aufmerksamkeit auf sich gezogen mit dem Ziel, ihr Design und ihre Regelungsstrategien zu optimieren. Insbesondere Techniken für den sensorlosen Betrieb haben Aufmerksamkeit erhalten. So ist der Wegfall mechanischer Sensoren aufgrund der daraus resultierenden Platz- und Kostenreduzierung des Antriebssystems von Vorteil für den Einsatz solcher Maschinen. Eine Vielzahl an Techniken zur Schätzung der elektrischen Rotorposition aus elektrischen Messungen wurden in der Literatur vorgeschlagen, die entweder auf der Ausnutzung der rückinduzierten Spannung oder auf Maschinenanisotropien basieren. Die vorliegende Arbeit liegt in diesem Forschungsbereich und fokussiert sich auf eine mathematische Beschreibung einer sensorlosen Technik namens Direct Flux Control (DFC). Diese Technik wertet, anders als die meisten anderen vorgeschlagenen Ansätze, die Anisotropien der Maschine aus, indem sie die Nullsystemspannung der Maschine misst, d.h. sie erfordert Messungen der Sternpunktspannung. Nach einer mathematische Herleitung des DFC-Verfahrens, zunächst für allgemeine Synchronmaschinen und später für PMSMs, wird eine durchgeführte experimentelle Untersuchung vorgestellt und die Ergebnisse werden kommentiert. Abschließend werden Hinweise für weitere Forschungsarbeiten vorgeschlagen, die sich aus den Untersuchungen zur DFC-Technik ergeben.

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