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Demagnetization diagnosis in permanent magnet synchronous motors under non-stationary speed conditions

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ABSTRACT

Permanent magnet synchronous motors (PMSMs) are applied in high performance positioning and variable speed applications because of their enhanced features with respect to other AC motor types. Fault detection and diagnosis of electrical motors for critical applications is an active field of research. However, much research remains to be done in the field of PMSM demagnetization faults, especially when running under non-stationary conditions. This paper presents a time–frequency method specifically focused to detect and diagnose demagnetization faults in PMSMs running under non-stationary speed conditions, based on the Hilbert Huang transform. The effectiveness of the proposed method is proven by means of experimental results.

1. Introduction

Industry constantly demands products that are faster and more reliable. In this context, for some critical applications, permanent magnet synchronous motors (PMSMs) possess characteristics superior to induction motors. PMSMs are becoming widely applied in high performance positioning and variable speed applications because of their attractive features. Powerful rare earth magnet materials that are now cost-effective, such as Sm–Co and Nd–Fe–B, greatly enhance their properties. PMSMs possess a higher power density than induction motors with equivalent ratings. Advantages of PMSMs include high-speed operation, precise torque control, compactness, high power to weight ratio and high efficiency. Every day they are gaining ground in the automotive, robotics and aeronautical industries [1]. Additional applications of PMSM include gearless elevators in low- and high-rise buildings, centrifugation equipment, as well as the medical, chemical and semiconductor industries, among others.

Many of the applications where PMSMs are applied are critical, as their faults could potentially cause plant shutdown, huge economic loss and even human casualties. Hence, fault detection and diagnosis is one of the most serious areas of concern in the electric drives research field. Therefore, accurate diagnosis of incipient faults in critical applications where PMSMs play an important role can significantly improve system availability and reliability.

A new trend and challenge in the electric drives industry is the design of fault tolerant control systems which provide control algorithms capable of maintaining stability and performance of the controlled system despite the occurrence of faults. To meet this objective, fault detection and diagnosis of electric drives has become an essential tool in most fault tolerant control system designs.

In order to measure the impact of faults, the transient process of the machine under fault conditions must be studied, since this state usually reflects the worst case scenario that the machine designers may face [2]. While there is already a plethora of literature on the study of induction motors, it nevertheless continues to be a dynamic field of investigation [3–7]. Recently, Gritli et al. [8] conducted an interesting study to detect rotor faults on doubly fed induction machines due to unbalanced rotor phase windings. In this study Gritli et al. take advantage of the multiresolution analysis capabilities of the discrete wavelet transform when the machine operates under load-varying conditions and apply a multiresolution fault indicator based on the mean power at different resolution levels to perform a quantitative evaluation of the fault degree.

Conversely, in the case of permanent magnet synchronous motors – whether dc or ac brushless – both drive control and fault detection are relatively novel fields of investigation [1,9–13].

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