RESUMEN

En los procesos industriales, y principalmente en aquellos de producción continua, es imprescindible implementar programas de mantenimiento preventivo y predictivo, a fin de evitar paradas indeseadas y disminuir costos de reparación. En muchos de estos procesos los motores de inducción (MI) constituyen un componente fundamental, lo que lleva al gran interés por parte de la industria de desarrollar técnicas de mantenimiento predictivo de carácter no invasivo para estas máquinas. Por otra parte, a la hora de analizar faltas en un accionamiento eléctrico constituido por el conjunto motor-carga, generalmente son mayores los problemas asociados a la carga impulsada que los del propio motor. Por esta razón, en el desarrollo de estrategias de diagnóstico es muy importante discriminar el origen de la falta (mecánico o eléctrico), como también detectar y diagnosticar correctamente las faltas asociadas a la carga.

El objetivo de la presente tesis es el estudio de la detección y el diagnóstico de faltas de origen mecánico en accionamientos con MI, particularmente el análisis de técnicas de detección y diagnóstico de faltas debidas a desbalances mecánicos, desalineación, excentricidad, y su discriminación de estas con aquellas que ocasionan faltas de características similares, particularmente las debidas a rotura de barras del rotor.

Para ello se presentan modelos matemáticos del accionamiento, el cual incluye el modelo del MI y la carga impulsada. Se modelan además los efectos causados por la presencia de irregularidades en la carga: desbalance, desalineación en el acoplamiento motor-carga, y excentricidad. Mediante estos modelos se realiza el análisis por simulación de diferentes técnicas de detección de faltas basadas en la medición de variables eléctricas.

Las estrategias estudiadas y simuladas son luego validadas experimentalmente a partir de datos obtenidos en bancos de ensayos que permiten emular las faltas particulares en estudio, y de mediciones realizadas en la industria. En lo referente a las faltas originadas debido a desalineación, los resultados obtenidos son comparados con estrategias comúnmente usadas en la industria: vibraciones mecánicas y termografía infrarroja.

Se propone también un observador adaptivo de estructura variable que permite estimar velocidad y par de carga, en base a las mediciones de tensiones y corrientes del motor. Con esta propuesta se obtiene una estimación de la perturbación de par de carga, que puede usarse para el diagnóstico de faltas, como también para su compensación en el caso de un accionamiento a lazo cerrado.

Se presenta además dos aplicaciones para el diagnóstico automático de faltas mediante el uso de redes neuronales no supervisadas del tipo mapa auto-organizados (*Self-Organizing Maps* - SOM). Dichas aplicaciones permiten la clasificación de las faltas con una mínima interpretación por parte del especialista. En cuanto a la primera red, se creó e implemento en el diagnóstico de faltas producidas por desbalances mecánicos en máquinas accionadas mediante motores de inducción y por desalineación entre los ejes motor-carga. La segunda red, se creó e implemento bajo la necesidad de detectar las faltas que presentan síntomas de características similares, es decir, que poseen en el análisis del espectro de la corriente las mismas frecuencias características de faltas, como ser el caso de barras rotas y cargas oscilantes de baja frecuencia.

Los resultados obtenidos en el presente trabajo de tesis afirman la posibilidad de detección de faltas de origen tanto eléctrico como mecánico mediante las técnicas estudiadas, basadas en la medición de variables eléctricas.

ABSTRACT

In industrial processes, mainly in those of continuous production, it is necessary to implement preventive and predictive maintenance programs in order to prevent unwanted stops and reduce repair costs. In many of these processes, induction motors (IM) constitutes a major component, leading to great interest from industry to develop non-invasive predictive maintenance techniques for these machines. On the other hand, when analyzing faults in an electric drive consisting of motor-load set, problems associated with the driven load of the motor are generally more important than those of the electric machine itself. For this reason, the development of diagnostic strategies is very important to distinguish the origin of the fault (mechanical or electrical) as well as to detect and correctly diagnose the faults associated with the load.

The objective of this thesis is to study the detection and diagnosis of mechanical faults in actuators with MI, and particularly the analysis of techniques to detect faults due to mechanical unbalance and misalignment.

With this aim, a mathematical model of the drive, which includes the IM model and the driven load, is presented. The effects of the of irregularities in the load, particularly imbalance and misalignment in the motor-load coupling are also included in the model. Using these models, a simulation analysis of different fault detection techniques based on measurement of electrical variables is performed.

Studied and simulated strategies are then validated experimentally, using data from bench testing to emulate the faults studied and measurements made in the industry. The results of these strategies are compared with commonly used strategies in the industry: mechanical vibration and infrared thermography.

An adaptive variable structure observer (sliding mode observer) to estimate speed and load torque is also proposed. The estimation is performed using the measurements of voltages and currents and the motor model. This proposal provides an estimate of the disturbance load torque which can be used to diagnose faults, as well as for compensation in case of a closed-loop drive.

A method for automatic diagnosis of faults using unsupervised neural networks is also presented. This method allows the classification of faults with a minimal interpretation by the specialist.

The obtained results affirm the possibility of detecting faults of both electrical and mechanical origin through the techniques studied, based on the measurement of electrical variables.

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