

Índice general

Resumen	iii
Índice general	xv
1 Introducción	1
1.1 Motivación	1
1.2 Objetivos	2
1.3 Organización y desarrollo de la tesis	4
2 Estado del arte	7
2.1 Introducción	7
2.2 Fallos en máquinas eléctricas rotativas	8
2.3 Magnitudes para la monitorización del estado de las máquinas eléctricas rotativas	18
2.4 Modelado de máquinas eléctricas rotativas	23
2.5 Técnicas de diagnóstico de fallos basados en la monitorización de la corriente	47
2.6 Sistemas de prototipado rápido	61
3 Resultados	67
3.1 Introducción	67
3.2 Modelo del aerogenerador	69
3.3 Modelo híbrido FEM-analítico de la máquina eléctrica	70
3.4 Optimización de la obtención de las inductancias: Sparse Subsparse Learning (SSL) y polinomio de interpolación trigonométrica	76
3.5 Optimización del modelo analítico: Enfoque del tensor de devanados	85

3.6	Implementación en sistema HIL	106
3.7	Técnicas de diagnóstico: algoritmo de Goertzel	108
4	A Review of Techniques Used for Induction Machine Fault Modelling	119
4.1	Abstract	119
4.2	Introduction	120
4.3	Models based on coupled circuits	124
4.4	Models based on magnetic circuits	133
4.5	Models based on FEM	137
4.6	Hybrid models	139
4.7	Conclusions	140
5	Low Computational Cost Hybrid FEM-Analytical Induction Machine Model for the Diagnosis of Rotor Eccentricity, based on Sparse Identification Techniques and Trigonometric Interpolation	155
5.1	Abstract	156
5.2	Introduction	156
5.3	System equations	160
5.4	Proposed method for computing the coupling parameters of the faulty IM via sparse identification and trigonometric interpolation polynomial	163
5.5	Results	172
5.6	Fault diagnosis analysis	174
5.7	Experimental validation	185
5.8	Conclusions	187
5.9	HIL OP4500 main features	188
6	Analytical Model of Induction Machines with Multiple Cage Faults Using the Winding Tensor Approach	193
6.1	Abstract	193
6.2	Introduction	194
6.3	Analytical model of the SCIM	197
6.4	Primitive reference frame of the SCIM	201
6.5	Analytical model of the SCIM in healthy state	211
6.6	Analytical model of the SCIM with rotor cage faults	216
6.7	Experimental validation	223
6.8	Conclusion	235
6.9	Commercial IM	236
6.10	Current Clamp	237
6.11	Computer features	237

7	Low-Cost Diagnosis of Rotor Asymmetries of Induction Machines at Very Low Slip with the Goertzel Algorithm Applied to the Rectified Current	243
7.1	Abstract	243
7.2	Introduction	244
7.3	Narrow-Band Frequency Analysis of the Rectified Current Signal	249
7.4	Optimized Implementation of the Goertzel Algorithm Applied to the Rectified Current Signal	251
7.5	Experimental Validation	259
7.6	Conclusions	267
7.7	Three-phase Induction Motor	268
7.8	ESP32 Development Board	268
8	Conclusiones	273
8.1	Conclusiones	273
8.2	Principales aportaciones	275
8.3	Líneas futuras de investigación	276
	Bibliografía	279