Sandro Rubino

Nationality: Italian **Date of birth:** 23 Jan 1990 **Gender:** Male

Phone number: (+39) 3351539898 **Email address:** sandro.rubino@polito.it

LinkedIn: https://www.linkedin.com/in/sandro-rubino-4776a3b1/?originalSubdomain=it

Website: https://www.polito.it/en/staff?p=sandro.rubino

Work: Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino (Italy)

WORK EXPERIENCE

Assistant Professor with Tenure Track

Politecnico di Torino [1 Oct 2022 – Current]

City: Torino | **Country:** Italy

Assistant Professor in Electric Drives and Electrical Machines

Assistant Professor with Time Contract

Politecnico di Torino [30 Sep 2019 – 30 Sep 2022]

Address: Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino (Italy) | **Website:** https://www.polito.it/index.php?lang=en | **Email address:** sandro.rubino@polito.it | **Name of unit or department:** Dipartimento Energia "G. Ferraris" - **Business or sector:** Education

Assistant Professor in Power Electronics, Electrical Machines and Electric Drives

EDUCATION AND TRAINING

Doctor of Philosophy (PhD) in Electrical Engineering

Politecnico di Torino [31 Oct 2015 – 7 May 2019]

Address: Corso Duca degli Abruzzi, 24, 10129 Torino (Italy) | **Website:** https://www.polito.it/index.php?lang=en | **Field(s) of study:** Engineering, manufacturing and construction: • Electricity and energy | **Final grade:** Cum Laude | **Level in EQF:** EQF level 8 | **Type of credits:** ECTS | **Number of credits:** 180 | **Thesis:** High Performance Control Techniques for Multiphase eDrives

The PhD focused on the design, development, and testing of high-performance torque control algorithms for multiphase motor drives.

Master of Science (M.Sc.) in Electrical Engineering

Politecnico di Torino [Sep 2012 – Nov 2014]

City: Torino | **Country:** Italy | **Website:** https://www.polito.it/?lang=en | **Field(s) of study:** Engineering, manufacturing and construction: • Electricity and energy | **Final grade:** Cum Laude | **Level in EQF:** EQF level 7 | **Type of credits:** ECTS | **Number of credits:** 120 | **Thesis:** Virtual Synchronous Generator (VSM)

Bachelor of Science (B.Sc.) in Electrical Engineering

Politecnico di Torino [Sep 2009 – Sep 2012]

City: Torino | **Country:** Italy | **Website:** https://www.polito.it/?lang=en | **Field(s) of study:** Engineering, manufacturing and construction: • Electricity and energy | **Final grade:** Cum Laude |

Level in EQF: EQF level 6 | **Type of credits:** ECTS | **Number of credits:** 180 | **Thesis:** 4-Quadrant Thyristor AC/DC Converter

LANGUAGE SKILLS

Mother tongue(s): Italian

Other language(s):

English

LISTENING C1 **READING** C1 **WRITING** C1

SPOKEN PRODUCTION C1 **SPOKEN INTERACTION** C1

Levels: A1 and A2: Basic user; B1 and B2: Independent user; C1 and C2: Proficient user

DIGITAL SKILLS

Microsoft Word / Microsoft Excel / Microsoft Powerpoint / Google Drive / Microsoft Office / Skype / Outlook / LinkedIn / Power Point / Motivated / Analytical skills / Team-work oriented / Social Media / Organizational and planning skills / Written and Verbal skills / Internet user

DRIVING LICENCE

Driving Licence: AM

Driving Licence: B

CONFERENCES AND SEMINARS

[21 May 2017 – 24 May 2017] Miami (Florida, USA)

2017 IEEE International Electric Machines and Drives Conference (IEMDC) The speaker in an oral session.
Presented research article:
S. Rubino, R. Bojoi, M. Mengoni and L. Zarri, "Optimal flux selection for multi three-phase machines in normal and fault conditions," *2017 IEEE International Electric Machines and Drives Conference (IEMDC)*, 2017, pp. 1-8, doi: 10.1109/IEMDC.2017.8002313.

[1 Sep 2017 – 5 Oct 2017] Cincinnati (Ohio, USA)

2017 IEEE Energy Conversion Congress and Exposition (ECCE) The speaker in an oral session.
Presented research article:
S. Rubino, R. Bojoi, S. A. Odhano and P. Zanchetta, "Model predictive direct flux vector control of multi three-phase induction motor drives," *2017 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2017, pp. 3633-3640, doi: 10.1109/ECCE.2017.8096644.

[20 May 2018 – 24 May 2018] Niigata, Japan

2018 International Power Electronics Conference (IPEC-Niigata 2018 -ECCE Asia) The speaker in an oral session.
Presented research article:
A. Tenconi, **S. Rubino** and R. Bojoi, "Model Predictive Control for Multiphase Motor Drives – a Technology Status Review," *2018 International Power Electronics Conference (IPEC-Niigata 2018 -ECCE Asia)*, 2018, pp. 732-739, doi: 10.23919/IPEC.2018.8507960.

[23 Sep 2018 – 27 Sep 2018] Portland (Oregon, USA)

2018 IEEE Energy Conversion Congress and Exposition (ECCE) The speaker in an oral session.
Presented research articles:
1) A. Boglietti, R. Bojoi, **S. Rubino** and M. Cossale, "Load Capability of Multiphase Machines under Normal and Open-Phase Fault Conditions," *2018 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2018, pp. 242-247, doi: 10.1109/ECCE.2018.8558418.
2) **S. Rubino**, R. Bojoi, E. Armando and A. Tenconi, "Model Predictive Direct Flux Vector Control of Surface Permanent Magnet Motor Drives," *2018 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2018, pp. 5458-5465, doi: 10.1109/ECCE.2018.8557450.

[12 May 2019 – 15 May 2019] San Diego (California, USA)

2019 IEEE International Electric Machines & Drives Conference (IEMDC) Co-author of the tutorial "Control of AC eDrives: from theory to implementation".

[9 Sep 2019 – 10 Sep 2019] Turin, Italy

2019 IEEE 10th International Symposium on Sensorless Control for Electrical Drives (SLED) Local organizing committee

[29 Sep 2019 – 3 Oct 2019] Baltimora (Maryland, USA)

2019 IEEE Energy Conversion Congress and Exposition (ECCE) The speaker in an oral session.
Presented research article:
S. Rubino, R. Bojoi, D. Cittanti and L. Zarri, "Decoupled Torque Control of Multiple Three-Phase Induction Motor Drives," *2019 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2019, pp. 4903-4910, doi: 10.1109/ECCE.2019.8912502.

[11 Oct 2020 – 15 Oct 2020] Detroit (Michigan, USA)

2020 IEEE Energy Conversion Congress and Exposition (ECCE) The speaker in an oral session.
Presented research articles:
1) E. Armando, A. Boglietti, S. Musumeci, **S. Rubino**, E. Carpaneto and D. Martinello, "Measurement of Rotor Thermal Time-Constant for Permanent Magnet Synchronous Machines," *2020 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2020, pp. 4246-4252, doi: 10.1109/ECCE44975.2020.9235959.

[17 May 2021 – 20 May 2021] Hartford (Connecticut, USA)

2021 IEEE International Electric Machines & Drives Conference (IEMDC) The speaker in an oral session.
Presented research article:
S. Rubino, E. Armando, R. Bojoi and L. Zarri, "Fault-Tolerant Torque Control Based on Common and Differential Mode Modeling for Multi-Three-Phase Induction Machines," *2021 IEEE International Electric Machines & Drives Conference (IEMDC)*, 2021, pp. 1-8, doi: 10.1109/IEMDC47953.2021.9449509

[10 Oct 2021 – 14 Oct 2021] Vancouver (British Columbia, Canada)

2021 IEEE Energy Conversion Congress and Exposition (ECCE) The speaker in an oral session.
Presented research article:
S. Rubino, F. Mandrile, L. Tolosano, E. Armando and R. Bojoi, "Direct Flux and Load Angle Vector Control of Permanent Magnet Synchronous Motors," *2021 IEEE Energy Conversion Congress and Exposition (ECCE)*, 2021, pp. 4668-4675, doi: 10.1109/ECCE47101.2021.9595616

[5 Sep 2022 – 8 Sep 2022] Valencia, Spain

2022 International Conference on Electrical Machines (ICEM) The speaker in an oral session.
Presented research articles:
1) E. Armando, A. Boglietti, F. Mandrile and **S. Rubino**, "Torque Control Accuracy Using Different Techniques for Determination of Induction Motor Rotor Time Constant," *2022 International Conference on Electrical Machines (ICEM)*, Valencia, Spain, 2022, pp. 572-578, doi: 10.1109/ICEM51905.2022.9910671.ù
2) O. Stiscia, M. Biasion, **S. Rubino**, S. Vaschetto, A. Tenconi and A. Cavagnino, "Iron Losses and Parameters Investigation of Multi-Three-Phase Induction Motors in Normal and Open-Phase Fault Conditions," *2022 International Conference on Electrical Machines (ICEM)*, Valencia, Spain, 2022, pp. 793-799, doi: 10.1109/ICEM51905.2022.9910784.
3) E. Armando, A. Boglietti, F. Mandrile, E. Carpaneto and **S. Rubino**, "A Detailed Analysis of the Electromagnetic Phenomena Observed During the Flux-Decay Test," *2022 International Conference on Electrical Machines (ICEM)*, Valencia, Spain, 2022, pp. 767-773, doi: 10.1109/ICEM51905.2022.9910822.

[15 May 2023 – 18 May 2023] San Francisco (California, USA)

2023 IEEE International Electric Machines & Drives Conference (IEMDC) 1) The speaker in a tutorial session.
Presented research tutorial:
S. Rubino, and R. Bojoi**,** "Design and Implementation of Decoupled Torque Controllers for Multi-Three-Phase Motor Drives".

2) The speaker in an oral session.
Presented research article:
S. Rubino, F. Mandrile, L. Tolosano, E. Armando and R. Bojoi, "An Experimental Test Procedure for Magnetic Model Identification of Multi-Three-Phase Induction Motors," *2023 IEEE International Electric Machines & Drives Conference (IEMDC)*, San Francisco, CA, USA, 2023, pp. 1-7, doi: 10.1109/IEMDC55163.2023.10238961.

VOLUNTEERING

[11 Oct 2020 – 15 Oct 2020] Detroit (Michigan, USA)

Topic Chair for 2020 IEEE Energy Conversion Congress and Exposition (ECCE) By direct assignment by the Industrial Drive Committee (IDC) of the Industry Applications Society (IAS), I played the role of Topic Chair (TC) for the 2020 IEEE Energy Conversion Congress and Exposition (ECCE) conference. In detail, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-tracks:
H02 – Induction Motor Drives
H13 – Electrical Drives for Aerospace and Traction Applications

[10 Oct 2021 – 14 Oct 2021] Vancouver (British Columbia, Canada)

Topic Chair for 2021 IEEE Energy Conversion Congress and Exposition (ECCE) By direct assignment by the Industrial Drive Committee (IDC) and Electric Machines Committee (EMC) of the Industry Applications Society (IAS), I played the role of Topic Chair (TC) for the 2021 IEEE Energy Conversion Congress and Exposition (ECCE) conference. In detail, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-tracks:
H01 – Electric Drives (General)
G04 – Other Synchronous machines (PMSM and Wound Field)

[1 Jun 2022 – 3 Jun 2022] Anchorage (Alaska, USA)

Topic Chair for 2022 IEEE International Symposium on Industrial Electronics (ISIE) By direct assignment by the Organizing Committee of the 2022 IEEE International Symposium on Industrial Electronics (ISIE) conference, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-track:

- Electrical Machines & Industrial Drives

[9 Oct 2022 – 13 Oct 2022] Detroit (Michigan, USA)

Topic Chair for 2022 IEEE Energy Conversion Congress and Exposition (ECCE) By direct assignment by the Industrial Drive Committee (IDC) of the Industry Applications Society (IAS), I played the role of Topic Chair (TC) for the 2022 IEEE Energy Conversion Congress and Exposition (ECCE) conference. In detail, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-tracks:

H02 – Induction Motor Drives

H03 – PM and IPM motor drives

[5 Sep 2022 – 8 Sep 2022] Valencia, Spain

Session Chair for 2022 International Conference on Electrical Machines (ICEM) By direct assignment by the Organizing Committee of the 2022 International Conference on Electrical Machines (ICEM) conference, I was Session Chair for the following oral session:

- Electrical drives 3

[15 May 2023 – 18 May 2023] San Francisco (California, USA)

Topic Chair for 2023 IEEE International Electric Machines & Drives Conference (IEMDC) By direct assignment by the Organizing Committee of the 2023 IEEE International Electric Machines & Drives Conference (IEMDC) conference, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-track:

- Thermal, Materials and Efficiency Issues

[15 May 2023 – 18 May 2023] San Francisco (California, USA)

Session Chair for 2023 IEEE International Electric Machines & Drives Conference (IEMDC) By direct assignment by the Organizing Committee of the 2023 IEEE International Electric Machines & Drives Conference (IEMDC) conference, I was Session Chair for the following oral sessions:

- Electrical Drives 4
- Electrical Drives 5

[29 Oct 2023 – 2 Nov 2023] Nashville (Tennessee, USA)

Topic Chair for 2023 IEEE Energy Conversion Congress and Exposition (ECCE) By direct assignment by the Industrial Drive Committee (IDC) of the Industry Applications Society (IAS), I played the role of Topic Chair (TC) for the 2023 IEEE Energy Conversion Congress and Exposition (ECCE) conference. In detail, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-track:

H03 – Electric Drives (General)

[1 Sep 2024 – 4 Sep 2024] Torino (Italy)

Topic Chair for 2024 International Conference on Electrical Machines (ICEM) By direct assignment by the Organizing Committee of the 2024 International Conference on Electrical Machines (ICEM) conference, I was responsible for managing the review process (assignment of reviewers and evaluation of contributions in submitted conference proceedings) for the following sub-track:
- TT5 - Electric Drives

[2017 – Current]

Reviewer for IEEE, IET and MDPI Journals I am an active reviewer for several IEEE, IET and MDPI Journals. The following is the list of my review activities (updated 12/11/2023).
67 IEEE Transactions on Industrial Electronics
19 IEEE Transactions on Power Electronics
17 IEEE Journal of Emerging and Selected Topics in Power Electronics
10 IEEE IAS Publications
9 IEEE Transactions on Energy Conversion
3 IET Electric Power Applications
2 Energies
2 IEEE Transactions on Transportation Electrification
2 World Electric Vehicle Journal
1 Applied Sciences
1 IEEE/ASME Transactions on Mechatronics
1 Machines

HONOURS AND AWARDS

[Oct 2020] Industrial Drive Committee (IDC) of Industry Applications Society (IAS)

Conference Paper Award - 2019 IEEE Energy Conversion Congress and Exposition (ECCE) The IDC-IAS Awards Subcommittee first considered all submissions in proceedings conference submitted in track H – Electric Drives of the 2019 IEEE Energy Conversion Conference Congress and Exposition (ECCE), held in Baltimore (Maryland, USA) on 29 September –
03 October 2019. Subsequently, these contributions in conference proceedings were taken into account only those expanded and submitted to the international journal IEEE Transactions on Industry Applications. Finally, six evaluation criteria were considered for judging each research article competing for the prize: i) readability, ii) use of figures and images, iii) instruction, iv) broad interest, v) importance and vi) impact on the scientific landscape. Following the above award methods and rules, the IDC-IAS Awards Commission Subcommittee has decided to award the ECCE - Best Conference Paper Award to the following work of which I am the main author:
'**S. Rubino**, R. Bojoi, D. Cittanti and L. Zarri, "Decoupled Torque Control of Multiple Three-Phase Induction Motor Drives," 2019 IEEE Energy Conversion Congress and Exposition (ECCE), 2019, pp. 4903-4910, doi: 10.1109/ECCE.2019.8912502'
and whose corresponding post-conference version in the international journal IEEE Transactions on Industry Applications is as follows:
'**S. Rubino**, R. Bojoi, D. Cittanti and L. Zarri, "Decoupled and Modular Torque Control of MultiThree-Phase Induction Motor Drives," in IEEE Transactions on Industry Applications, vol. 56, no. 4, pp. 3831-3845, July-Aug. 2020, doi: 10.1109/TIA.2020.2991122.

[Oct 2022] Industrial Drive Committee (IDC) of Industry Applications Society (IAS)

Conference Paper Award - 2021 IEEE Energy Conversion Congress and Exposition (ECCE) The IDC-IAS Awards Subcommittee first considered all submissions in proceedings conference submitted in track H – Electric Drives of the 2021 IEEE Energy Conversion Congress and Exposition (ECCE), held in Vancouver (British Columbia, Canada) on 10 October – 14 October 2021. Subsequently, these contributions in conference proceedings were considered only those expanded and submitted to the international journal IEEE Transactions on Industry Applications.
Finally, six evaluation criteria were considered for judging each research article competing for the prize: i) readability, ii) use of figures and images, iii) instruction, iv) broad interest, v) importance and vi) impact on the scientific landscape.
Following the above award methods and rules, the IDC-IAS Awards Commission Subcommittee has decided to award the ECCE - Best Conference Paper Award to the following work of which I am the main author:
'**S. Rubino**, F. Mandrile, L. Tolosano, E. Armando and R. Bojoi, "Direct Flux and Load Angle Vector Control of Permanent Magnet Synchronous Motors," 2021 IEEE Energy Conversion Congress and Exposition (ECCE), 2021, pp. 4668-4675, doi: 10.1109/ECCE47101.2021.9595616'
and whose corresponding post-conference version in the international journal IEEE Transactions on Industry Applications is as follows:
'**S. Rubino**, L. Tolosano, F. Mandrile, E. Armando and R. Bojoi, "Flux Polar Control (FPC): A Unified Torque Controller for AC Motor Drives," in IEEE Transactions on Industry Applications, vol. 59, no. 4, pp. 4140-4163, July-Aug. 2023, doi: 10.1109/TIA.2023.3270110.'

[6 Nov 2020] IEEE Italy Section PES Chapter of IEEE Power and Energy Society (PES)

IEEE Italy Section PES Chapter – Best PhD Thesis Award Chapter PE31 of the IEEE Italy Section PES Chapter has decided to award the 'Best PhD Thesis Award' for the best PhD thesis completed in 2018 and discussed in 2018/2019.
The Commission has decided to reward the following doctoral thesis presented and discussed by me:
"High Performance Control Techniques for Multiphase eDrives"

[17 Dec 2021] IEEE Italy Section IES Chapter of IEEE Industrial Electronics Society (IES)

IEEE Italy Section IES Chapter – Best PhD Thesis Award IEEE Italy Section IES Chapter has decided to award the 'Best PhD Thesis Award' for the best PhD thesis discussed in 2018/2019.
The Commission has decided to reward the following doctoral thesis presented and discussed by me:
"High Performance Control Techniques for Multiphase eDrives"

PROJECTS

[Dec 2022 – Current]

Scientific Manager of the International Project 'Sustainable and Efficient Motor Drive System for E-mobility Applications (SEMDY)' More than 70% of the energy losses in the electric vehicle propulsion system occurs in the electrical machine and the inverter. Additionally, elements with high values of Environmental Load Unit (ELU) are used in these two components. In this project, an advanced control of electrical machines toward improving inverter and electrical machine efficiency will be developed. The optimization process will not be limited to purely software and both the inverter and electrical machine hardware optimizations will be investigated. The optimization of the hardware will be done taking into account sustainability aspects of the different design alternatives, so that energy saving, and vehicle range is improved together with the development of a sustainable hardware in both electrical machine and inverter.

Partners:

- CHALMERS TEKNISKA HOEGSKOLA AKTIEBOLAG

- POLESTAR PERFORMANCE AB
- POLITECNICO DI TORINO

Link: https://www.polito.it/en/research/scenario/research-database?progetto=248/2023

[Jun 2023 – Current]

Scientific Manager of the Research Contract “Electric Motor Drivers Design” The research contract focused on the electrification of the Naval Propulsion.

Partners:

- FINCANTIERI SPA
- POLITECNICO DI TORINO

[Oct 2021 – Dec 2022]

Scientific Manager of the Research Contract "Development of an unified torque control embedded system for AC electric motor drive in automotive application" Politecnico di Torino has developed a unified torque control capable of driving all three-phase electric motors (asynchronous and synchronous machines). Also, it has consolidated experience in the design of power electronics (inverters and DC/DC converters). The aim of this activity is to demonstrate the effectiveness of the above-mentioned torque control strategy for traction applications with power up to 100 kW. The activity will focus on the implementation and testing of the proposed torque controller via a rapid prototyping system. Furthermore, fault-tolerant control techniques will be studied to ensure the smoothness of the torque/speed transition and the operation of the system in the event of a fault. The testing activity will be carried out on the electrical benches of the Polytechnic of Turin. It will include the procedure for characterizing the electrical machines (flux maps and efficiency maps). Politecnico di Torino will define and supply the inverter and electric motor used in this research project.

Partners:

- PUNCH TORINO SPA
- POLITECNICO DI TORINO

[Jun 2021 – Dec 2021]

Scientific Manager of the Research Contract "Direct flux control for induction motors used in vacuum pump applications" The research contract focused on the implementation and validation of robust sensorless control for induction motor drives for vacuum pump applications.

Partners:

- CAPETTI ELETTRONICA SRL
- POLITECNICO DI TORINO

[Mar 2020 – Dec 2020]

Scientific Manager of the Research Contract "Robust starting closed loop control for IPM synchronous motor system and self-commissioned Direct Flux Control (DFC) algorithms for Synchronous Reluctance (SynchRel) motors for fan drive applications" The research contract focused on the implementation and validation of a robust starting closed-loop control for IPM synchronous motor drives for fan applications.

Partners:

- GREAT LAKES ELECTRIC LLC
- POLITECNICO DI TORINO

[Dec 2021 – Sep 2022]

Scientific Manager of the Research Contract "Robust Direct Flux Control (DFC) algorithms for Permanent Magnet-assisted Synchronous Reluctance- (PM-SyR) motors and Synchronous Reluctance (SyR) motors for fan drive applications" The research contract focused on the implementation and validation of robust speed control for Permanent Magnet-assisted Synchronous Reluctance (PM-SyR) motors and Synchronous Reluctance (SyR) motors for fan drive applications.

Partners:

- GREAT LAKES ELECTRIC LLC
- POLITECNICO DI TORINO

HOBBIES AND INTERESTS

Pastry Chef

Rowing

PUBLICATIONS

[2024]

A Detailed Analysis and Guidelines for the Induction Motor Flux-Decay Test Ac motor drives are becoming increasingly popular in the field of industrial processes and transportation electrification. Currently, many industrial applications are based on induction machines supplied by inverters and controlled with field-oriented control techniques. Such techniques require the knowledge of the machine parameters to ensure the correctness of the torque control both in dynamic and steady-state conditions. In particular, an accurate determination of the induction motor rotor time constant is crucial. Therefore, this article analyses in detail the physical phenomena involved during the flux-decay test used for the rotor time constant determination. The reported analysis has been performed on a 15 kW induction motor. The transient of the machine's back-electromotive force (back-emf) has been critically analyzed during its evolution, finding a link between its evolution in time and the magnetic phenomena that occur both in the stator and the rotor. In particular, the effects due to the lamination saturation, the stator and rotor leakage inductances, and the stator iron losses have been associated with the transient evolution of the machine's back-emf.

IEEE Transactions on Industry Applications, vol. 60, no. 1, pp. 123-131, Jan.-Feb. 2024.

[2023]

Flux Polar Control (FPC): A Unified Torque Controller for AC Motor Drives Transportation electrification is leading to an impressive development of electric drives (eDrives) using either synchronous- (SM) or induction- (IM) motors. However, these eDrive solutions need high-performance torque controllers that must be easy to tune and able to deal with saturated machines. Besides, the torque regulation must be linear for the entire operating speed range, including deep flux-weakening (FW) operation with maximum torque per volt (MTPV) limitation. According to the current state-of-the-art, the torque controllers for traction applications are mainly based on control schemes like current vector control (CVC), direct torque control (DTC), or the more recent direct flux vector control (DFVC). However, these solutions employ inner control loops whose performance depends on the machine's inductances, thus requiring the execution of demanding tuning procedures to adapt the control parameters to the machine's operating point. Moreover, CVC-based torque controllers sometimes rely on demanding multi-dimensional calibrated maps to linearize the torque regulation and simultaneously perform FW operation with MTPV. In contrast with the torque control solutions mentioned above, this article proposes a unified torque controller for ac motors based on inner flux- and load angle- control loops since their performance is independent of the machine's inductances, i.e., magnetic saturation phenomena. Also, the torque linearization relies on a simple calibrated map providing maximum torque production under inverter current- and voltage-constraints. Experimental results are presented for four different eDrives using both SMs and IM, validating the unifying feature and demonstrating the high dynamic performance of the proposed torque controller.

IEEE Transactions on Industry Applications, vol. 59, no. 4, pp. 4140-4163, July-Aug. 2023

[2023]
A Detailed Analysis and Guidelines for the Induction Motor Flux-Decay Test Ac motor drives are becoming increasingly popular in the field of industrial processes and transportation electrification. Currently, many industrial applications are based on induction machines supplied by inverters and controlled with field-oriented control techniques. Such techniques require the knowledge of the machine parameters to ensure the correctness of the torque control both in dynamic and steady-state conditions. In particular, an accurate determination of the induction motor rotor time constant is crucial. Therefore, this paper analyses in detail the physical phenomena involved during the flux-decay test used for the rotor time constant determination. The reported analysis has been performed on a 15 kW induction motor. The transient of the machine's back-electromotive force (back-emf) has been critically analyzed during its evolution, finding a link between its evolution in time and the magnetic phenomena that occur both in the stator and the rotor. In particular, the effects due to the lamination saturation, the stator and rotor leakage inductances, and the stator iron losses have been associated with the transient evolution of the machine's back-emf.

IEEE Transactions on Industry Applications, doi: 10.1109/TIA.2023.3297983.

[2022]
Accurate Induction Machines Efficiency Mapping Computed by Standard Test Parameters The extensive electrification process that is taking holds in several applications makes increasingly necessary the virtualization of electric components for energetic and performance assessments during the system design stage. For this purpose, this article proposes a straightforward methodology for computing the efficiency maps of induction machines (IMs) operated in wide torque-speed ranges. The modeling approach is based on the IM equivalent circuit defined in the rotor dq coordinates. The procedure allows computing a set of efficiency maps at different machine temperatures and supply voltage levels, both for motor and generator operation modes. The equivalent circuit parameters at different frequencies and voltages are determined by means of the well-known no-load and locked-rotor tests, thus including in the modeling the machine nonlinearities, skin effect and the iron losses. The proposed methodology has been validated on a 10 kW, four-pole IM. The comparison between computed and experimental efficiency maps for different operating conditions, confirm the validity of the proposed methodology.

IEEE Transactions on Industry Applications, vol. 58, no. 3, pp. 3522-3532, May-June 2022

[2022]
Fault-Tolerant Torque Controller Based on Adaptive Decoupled Multi-Stator Modeling for Multi-Three-Phase Induction Motor Drives Among the multiphase solutions, multi-three-phase drives are becoming more and more widespread in practice as they can be modularly supplied by conventional three-phase inverters. The literature reports several control approaches to perform the torque regulation of multi-three-phase machines. Most of such solutions use the vector space decomposition (VSD) approach since it allows the control of a multi-three-phase machine using the conventional control schemes of three-phase drives, thus reducing the complexity of the control algorithm. However, this advantage is practically lost in the case of open-three-phase faults. Indeed, the postfault operation of the VSD-based drive schemes requires the implementation of additional control modules, often specifically designed for the machine under consideration. Therefore, this article aims to propose a novel control approach that allows using any control scheme developed for three-phase motors to

perform the torque regulation of a multi-three-phase machine both in healthy and faulty operation. In this way, the previously mentioned drawbacks of the VSD-based control schemes in dealing with the faulty operation of the machine are avoided. Moreover, the simplicity of the control algorithm is always preserved, regardless of the machine's operating condition. The proposed solution has been experimentally validated through a 12-phase induction motor, rated 10 kW at 6000 r/min, using a quadruple-three-phase configuration of the stator winding.

IEEE Transactions on Industry Applications, vol. 58, no. 6, pp. 7318-7335, Nov.-Dec. 2022

[2021]

A Novel Matrix Transformation for Decoupled Control of Modular Multiphase PMSM Drives When multiphase drives are used for specific applications, the modular solutions are preferred as they use consolidated power electronics technologies. The literature reports two modeling approaches for multiphase machines having a modular configuration of the stator winding. The first approach is the vector space decomposition (VSD) that models the energy conversion as for an equivalent three-phase machine. The main alternative to the VSD is the multistator (MS) modeling that emphasizes machine modularity in terms of torque production. Both approaches have advantages and disadvantages for multiphase machines with a modular structure. Therefore, this article aims to combine the VSD and MS approaches, defining a new matrix transformation and, hence, developing a new modeling approach for multiphase machines with a modular structure. The proposed transformation allows a decoupled and independent torque control of the sets composing the machine, preserving the torque regulation's modularity. Together with a new vector control scheme, it has been applied to a modular permanent magnet synchronous machine (PMSM) with a nonstandard spatial shift between windings. Experimental results are presented for a nine-phase PMSM prototype with a triple-three-phase stator winding configuration.

IEEE Transactions on Power Electronics, vol. 36, no. 7, pp. 8088-8101, July 2021

[2021]

Modular Vector Control of Multi-Three-Phase Permanent Magnet Synchronous Motors Recent developments in power electronics are making the multiphase machines a competitive alternative to the conventional three-phase counterparts. Due to their fault-tolerant features, multiphase drives represent a robust technology in high-power/high-current, safety-critical applications. Besides, their introduction to transportation electrification is gaining importance. Among the multiphase solutions, the multi-three-phase machines are receiving a lot of attention by the industry since they use the well-consolidated three-phase technology, thus reducing the design time and also the cost. Therefore, this article proposes a modular vector control scheme for multi-three-phase permanent magnet synchronous motors. The proposed solution uses a modular modeling approach for the independent and decoupled torque control of each three-phase unit, allowing the implementation of torque-sharing strategies among the three-phase sets of the machine. The developed modular control has been validated on a nine-phase permanent magnet machine.

IEEE Transactions on Industrial Electronics, vol. 68, no. 10, pp. 9136-9147, Oct. 2021

[2021]

Flux-Decay Test: A Viable Solution to Evaluate the Induction Motor Rotor Time-Constant This article deals with the determination of the rotor time-constant of an induction machine by performing a flux-decay test in generic load conditions. The flux-decay transient occurs when the supply stator voltage is turned off suddenly. In this way, from the decay envelope of stator back-electromotive forces and, in the case of the wound rotor machine, from that of the rotor currents, the rotor time-constant can be extrapolated with a high level of accuracy. In this article, an in-depth analysis of this methodology is reported, whose validation has been carried out on both the squirrel cage and wound rotor motors. The estimated value of rotor time-constant can be used for the machine torque regulation, using the well-known control schemes presented in the literature and whose performance in the low-speed operation is affected by the detuning of this parameter. Since the inverter-fed motors nowadays characterize most of the share in the market of adjustable speed drives, experimental results concerning the flux decay test performed under the pulsewidth modulation supply are also presented.

IEEE Transactions on Industry Applications, vol. 57, no. 4, pp. 3619-3631, July-Aug. 2021

[2021]
Definition and Experimental Validation of a Second-Order Thermal Model for Electrical Machines This article proposes a second-order thermal model useful to predict the average winding temperature of electrical machines used in electrical drives. Both analytical and practical considerations are provided. The proposed model is first described, including the physical meaning of each thermal parameter. Then, an experimental procedure to properly calibrate the thermal parameters of the proposed model is presented in detail. Later, experimental results providing the validation of the proposed thermal model both in transient and steady-state thermal conditions are presented, including their in-depth analysis. Although the proposed thermal model is calibrated and validated on a totally enclosed fan cooled induction motor, it has general validity, such that it can be adopted for any electrical machine, regardless of windings type, e.g., distributed or concentrated. The simplicity of the proposed thermal model and its high accuracy in estimating the average winding temperature make it useful in electric drives, e.g., its implementation on motor control algorithms to perform proper overload strategies.

IEEE Transactions on Industry Applications, vol. 57, no. 6, pp. 5969-5982, Nov.-Dec. 2021

[2021]
A Test Procedure to Evaluate Magnets Thermal Time Constant of Permanent Magnet Machines Thanks to their high torque density, permanent magnet synchronous motors (PMSMs) currently represent the most competitive solution in the electrification processes involving transports and energy production. However, it is known how the torque production of PMSMs is strictly related to the temperature of the permanent magnets (PMs) since the latter affects control performance and efficiency. This issue thus makes necessary the thermal analysis of the machine under consideration. In this scenario, the determination of the PM's thermal time constant covers a pivotal role in implementing an accurate thermal model of PMSMs. Therefore, this article aims at proposing an experimental test procedure to evaluate the PM's thermal time constant of PMSMs. The proposed procedure can be applied to any PMSM type without being affected by factors such as rotor lamination, shaft, and PM distribution. In this way, accurate and reliable results are obtained. The experimental validation has been carried out on four PMSMs, with different rotor structures, sizes, power, and voltage/current levels. Experimental results demonstrate the validity of the proposed method.

IEEE Transactions on Industry Applications, vol. 57, no. 5, pp. 4694-4706, Sept.-Oct. 2021

[2020]
Modular Stator Flux and Torque Control of Multi-Three-Phase Induction Motor Drives The recent advancements of power electronics are encouraging the development of the multiphase drives in both transport electrification and energy production applications. Among the multiphase solutions, the “multi-three-phase” drives are gaining impressive attention from the industry since they can be configured as multiple three-phase units operating in parallel. In this way, the three-phase technologies can be used, leading to a significant reduction in the costs and design time. Although the multi-three-phase drives possess natural modularity in terms of both machine winding and power converter, few control solutions able to implement a modular regulation of the torque are available in the literature. Therefore, this article proposes a control scheme implementing an independent regulation of the stator flux amplitude and torque contribution belonging to each winding set of a multi-three-phase induction machine. The proposed control solution can manage the voltage and current constraints introduced by each inverter unit. Besides, torque-sharing strategies among the three-phase sets of the machine can be implemented. Experimental results are provided for a modular power converter feeding a 12-phase induction machine with a quadruple-three-phase configuration, thus demonstrating the effectiveness of the proposed solution.

IEEE Transactions on Industry Applications, vol. 56, no. 6, pp. 6507-6525, Nov.-Dec. 2020

[2020]
Decoupled and Modular Torque Control of Multi-Three-Phase Induction Motor Drives In recent years, the development of multi-three-phase drives for both energy production and transportation electrification has

gained growing attention. An essential feature of the multi-three-phase drives is their modularity since they can be configured as three-phase units operating in parallel and with a modular control scheme. The so-called multi-stator modeling approach represents a suitable solution for the implementation of modular control strategies able to deal with several three-phase units. Nevertheless, the use of the multi-stator approach leads to relevant coupling terms in the resulting set of equations. To solve this issue, a new decoupling transformation for the decoupled torque control of multi-three-phase induction motor drives is proposed. The experimental validation has been carried out with a modular power converter feeding a 12-phase induction machine prototype (10 kW, 6000 r/min) using a quadruple three-phase stator winding configuration.

IEEE Transactions on Industry Applications, vol. 56, no. 4, pp. 3831-3845, July-Aug. 2020

[2020]

Deadbeat Direct Flux Vector Control of Surface Permanent Magnet Motor Drives The predictive control algorithms for electrical drives are currently subject to considerable interest and development. In particular, the predictive torque control is a competitive solution that may replace in the future the conventional control schemes based on linear controllers. Therefore, this article proposes a predictive torque control for surface permanent magnet motor drives requiring a wide constant power range. The predictive algorithm uses a deadbeat direct flux vector control approach for the simultaneous control of the stator flux amplitude and torque-producing current component. The proposed control scheme is suitable for applications requiring a wide speed range with current and voltage constraints. The proposed deadbeat torque controller has been tested on a fractional slot permanent magnet machine and the experimental results demonstrate the full drive controllability, including deep flux-weakening operation with limitation of the load-angle.

IEEE Transactions on Industry Applications, vol. 56, no. 3, pp. 2685-2699, May-June 2020

[2020]

Stator Current-Sensorless-Modulated Model Predictive Direct Power Control of a DFIM With Magnetizing Characteristic Identification This article presents a direct power control method based on modulated model predictive control for a doubly fed induction machine. The modulated predictive control algorithm constructs an optimal voltage vector from two inverter states that give a minimum absolute error in the active and reactive power. This article focuses on the effects of magnetic saturation and its impact on the accuracy of computed reactive power when the stator current sensors are not installed. To reduce the impact of magnetic saturation on reactive power computation, the machine's magnetizing characteristic is identified through a self-commissioning scheme introduced in this article. The identified magnetizing curve is utilized to construct a full-state stator flux observer, which is used to accurately estimate stator currents that appear in the reactive power equation. Experimental results are presented to demonstrate the accuracy of the reactive power computation in the absence of stator current sensors while conserving the rapid transient response offered by a modulated predictive control strategy for active and reactive power regulation.

IEEE Journal of Emerging and Selected Topics in Power Elect., vol. 9, no. 3, pp. 2797-2806, 2021

[2020]

Overload Capability of Multiphase Machines Under Normal and Open-Phase Fault Conditions: A Thermal Analysis Approach Multiphase drives are convenient for high-power/high-current applications as they allow the reduction of the phase current for given rated power and phase voltage. Due to their redundant structure, the multiphase drives have intrinsic open-phase fault-tolerant operation capability. This situation may happen when one or more power electronic units are turned off after a fault event, and the drive configuration allows phase disconnection. In this case, the healthy machine phases can be overloaded to keep the torque constant and without any pulsations. The goal of the work is the evaluation of the thermal parameters of the stator windings of multiphase machines to be used in the analysis of both short thermal transients and steady-state operation, during normal and open-phase faults. The approach has general validity and can be applied to any ac multiphase machine having a distributed winding configuration. The prototype used for the experimental tests is an asymmetrical 12-phase induction machine, having four 3-phase stator sets with isolated neutral points. The stator windings thermal model is obtained experimentally, by considering the mutual heat exchange phenomena among the windings when one or more winding sets are disconnected. This thermal model allows at evaluating the proper machine overloading for short thermal transients and steady-state operation in case of open-phase faults.

IEEE Transactions on Industry Applications, vol. 56, no. 3, pp. 2560-2569, 2020

[2019]

Open-End Windings Induction Motor Drive With Floating Capacitor Bridge at Variable DC-Link Voltage The open-end winding configuration allows feeding an electric motor from two sides. If one of them is connected to an inverter closed on a floating capacitor and operates as a power conditioning system, it is possible to obtain several benefits over the traditional configuration, such as an increase in the constant-power speed range. However, the additional converter causes switching losses that reduce the total efficiency of the drive. In this paper, it is shown how to improve the efficiency of an induction motor drive with open-end windings by controlling the dc-link voltage of the floating bridge depending on the operating conditions. The set-point of the secondary dc link is not calculated as an explicit function of the motor speed, which could depend on many machine parameters, but it is generated by a robust closed-loop control that uses the actual motor state. The variable dc link allows improving the overall efficiency of the drive mainly around the base speed at high values of the torque. Experimental results are shown to confirm the effectiveness of the developed configuration.

IEEE Transactions on Industry Applications, vol. 55, no. 3, pp. 2741-2749, May-June 2019

[2018]

Model Predictive Direct Flux Vector Control of Multi-three-Phase Induction Motor Drives A model predictive control scheme for multiphase induction machines, configured as multi-three-phase structures, is proposed in this paper. The predictive algorithm uses a direct flux vector control scheme based on a multi-three-phase approach, where each three-phase winding set is independently controlled. In this way, the fault-tolerant behavior of the drive system is improved. The proposed solution has been tested with a multimodular power converter feeding a six-phase asymmetrical induction machine (10 kW, 6000 r/min). Complete details about the predictive control scheme and adopted flux observer are included. The experimental validation in both generation and motoring modes is reported, including open-winding postfault operations. The experimental results demonstrate full drive controllability, including deep flux-weakening operation.

IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 4394-4404, Sept.-Oct. 2018