Design and Control for Linear Machines, Drives, and MAGLEVs—Part II

THIS is the Guest Editorial of the second issue of the special section on "Design and Control for Linear Machines, Drives, and MAGLEVs" of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS. Of this issue, the 14 papers are presented. The subjects of these papers embrace the main subjects of interest of the scientific community related to LEMs, ranging from innovative procedures for the optimal design of such machines, to their analysis with finite elements, to advanced control techniques, suitably devised for specific applications.

As for the analysis and design of LEMs, Lu *et al*. [item 1) in the Appendix] propose novel partitioned-primary hybrid excited flux-switching linear machines with unaligned and aligned structures, based on the idea of separating armature windings and excitation windings into two parts of the partitioned-primary. The main advantages of such machines with respect to the classic ones are the wide speed operation and the robust secondary. Pan *et al.* [item 2) in the Appendix] starting from an electromagnetic field and the thermal field model, proposes the exploitation a genetic algorithm for the optimization design of an air-core monopole linear motor. The methodology uses the cooling capacity and the size as constraints, while it sets thrust density, thrust fluctuation mover's mass and motor constants as optimizations targets. Zhao *et al.* [item 3) in the Appendix] present a novel method based on a combination of the mesh deformation and nonconforming mesh connection techniques, so as to accelerate the optimal design of linear motors using transient finite-element computation. One fast remesh-free mesh deformation method is employed to deform the mesh, and one mesh connection technique is adopted to make the solution continuous across the interface of stator and mover meshes. It can save enough time to study the dynamic drive performance of linear motors. Liu *et al.* [item 4) in the Appendix] propose first the modeling and the analysis of a magnetically suspended rotor system with a hybrid magnetic bearing; and second, a generalized notch filter which is designed to generate synchronous current so that the electromagnetic force counteracts precisely the permanent magnetic force. Chen *et al*. [item 5) in the Appendix] analyze the flux characteristics and the normal force of the double-sided switched reluctance linear machine under the asymmetric air gap. The magnetic flux-linkage model and the thrust model are established by analytical polynomial. Three-dimensional finite-element method simulation and the experimental study with the prototype hardware are provided. Zhang *et al.* [item 5) in the Appendix] propose a double-sided toroidal-winding linear permanent magnet Vernier machine (LPMVM), and analyze the thrust ripple sources for this type of machine. Two indexes [amplitude difference (AD) and phase shifting (PS)] are defined to quantify the thrust ripple caused by the AD and the PS among three-phase electromotive force, respectively. Cheng *et al*. [item 7) in the Appendix] present a tubular linear switched reluctance actuator (TLSRA), used to propel linear compressors with oscillatory motion. The proposed TLSRA possesses the advantages of higher force density and shorter magnetic flux paths in comparison with conventional LSRAs. Eckert *et al*. [item 8) in the Appendix] address the electromagnetic model of a specific topology of a coreless linear tubular actuator developed for semiactive and active suspension systems, consisting of two quasi-Halbach arrays of permanent magnets and a moving-coil armature. Such a kind of tubular motor offers the following advantages: low moving-mass, low force ripple, reduced magnetic losses, and high force density. Wang *et al*. [item 9) in the Appendix] propose a design method of a segmental secondary linear switched reluctance motor, which is characterized by the modular magnetic circuit structure and the independent operation of multimover units. A sensitivity analysis of the critical geometric parameters is performed and the guidelines for selection of the best dimension parameters are given. Yoon *et al*. [item 10) in the Appendix] present the design of a novel low noise, high-force linear motor for precision positioning applications, such as in semiconductor lithography. A new magnetic design is proposed permitting to achieve low noise and vibration, by reducing high spatial-frequency magnetic field components.

As for the control techniques, Li *et al*. [item 11) in the Appendix] present a high-performance design method of the current inner-loop realizing the precise thrust force control of permanent magnet linear synchronous motor drives. It not only regulates the current in order to control the electromagnetic thrust, but also injects the compensation current to suppress the thrust ripple. The current controller is designed by utilizing an improved predictive current control method. Du *et al.* [item 12) in the Appendix] present a discrete-time model of permanent magnet linear motor (PMLM) obtained on the basis of Euler's discretization. Afterward, by using the traditional linear sliding mode control (SMC) method, a discrete-time linear SMC law is designed and the corresponding stability issue of closed-loop system is addressed. Wang *et al*. [item 13) in the Appendix] propose an improved indirect field oriented control scheme for linear induction motor (LIM) traction drives. Moreover, the performance of different control schemes of LIM are discussed with consideration of the limitations of traction inverters. Wang *et al*. [item 14) in the Appendix] present a

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second-order sliding-mode model reference adaptive system (MRAS) observer for speed estimation in the sensorless-vector-controlled drives for medium-low speed magnetic levitation (MAGLEV) applications. The performance of the proposed speed estimation scheme is compared to the classic MRAS based on Luenberger observer developed from the rotating induction motor.

The guest editors hope that this special section could be of interest for people coming from both the academia and the industry who work in the area of LEMs. They are grateful to all the authors who have contributed to this special section, making it possible, and to all the reviewers who have spent their time studying and commenting these contributions. We would also like to thank Prof. L. Franquelo, Editor-in-Chief for the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, for his support.

APPENDIX
RELATED WORK

1) Z. Zeng and Q. Lu, "Investigation of novel partitioned-primary hybrid-excited flux-switching linear machines," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9804–9813, Dec. 2018.
2) D. Pan, L. Li, and M. Wang, "Modeling and optimization of air-core monopole linear motor based on multi-physical fields," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9814–9824, Dec. 2018.
3) Y. Zhao, X. Xiao, and W. Xu, "Accelerating the optimal shape design of linear machines by transient simulation using mesh deformation and mesh connection techniques," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9825–9833, Dec. 2018.
4) J. Liu, X. Xu, and S. Chen, "Synchronous force elimination in the magnetically suspended rotor system with an adaptation to parameter variations in the amplifier model," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9834–9842, Dec. 2018.
5) H. Chen and W. Yan, "Flux characteristics analysis of a double-sided switched reluctance linear machine under the asymmetric air gap," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9843–9852, Dec. 2018.
6) H. Zhang, B. Kou, Z. Q. Zhu, R. Qu, J. Luo, and Y. Shao, "Thrust ripple analysis on toroidal-winding linear permanent magnet Vernier machine," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9853–9862, Dec. 2018.
7) X. Xue, K. W. E. Cheng, and Z. Zhang, "Model, analysis, and application of tubular linear switched reluctance actuator for linear compressors," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9863–9872, Dec. 2018.
8) P. R. Eckert, A. F. Flores Filho, E. A. Perondi, and D. G. Dorrell, "Dual quasi-Halbach linear tubular actuator with coreless moving-coil for semiactive and active suspension," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9873–9883, Dec. 2018.
9) D. Wang, D. Zhang, X. Du, and X. Wang, "Unitized design methodology of linear switched reluctance motor with segmental secondary for long rail propulsion application," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9884–9894, Dec. 2018.
10) J. Y. Yoon, J. H. Lang, and D. L. Trumper, "Fine-tooth iron-core linear synchronous motor for low acoustic noise applications," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9895–9904, Dec. 2018.
11) M. Wang, R. Yang, C. Zhang, J. Cao, and L. Li, "Inner-loop design for PMLSM drives with thrust ripple compensation and high-performance current control," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9905–9915, Dec. 2018.
12) H. Du, X. Chen, G. Wen, X. Yu, and J. Lü, "Discrete-time fast terminal sliding mode control for permanent magnet linear motor," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9916–9927, Dec. 2018.
13) K .Wang, Y. Li, Q. Ge, and L. Shi, "An improved indirect field-oriented control scheme for linear induction motor traction drives," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9928–9937, Dec. 2018.
14) H. Wang, X. Ge, and Y.-C. Liu, "Second-order sliding-mode MRAS observer-based sensorless vector control of linear induction motor drives for medium-low speed maglev applications," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9938–9952, Dec. 2018.

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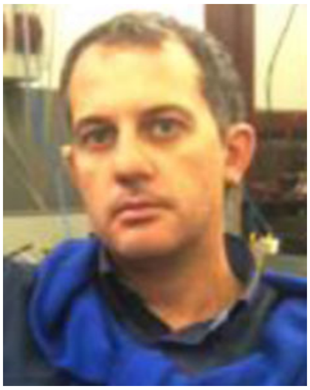

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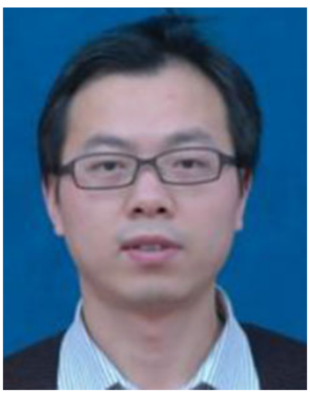

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