Title of the Proposal
Advances in Design and Control for Linear Machines and Drive Systems

Presenter(s) (Title, name, affiliation)

<table>
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<tr>
<th>Name</th>
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Brief description (Not more than 600 words)

The main subject of the tutorial is linear induction motors (LIMs). Starting from a brief structural description of such motors, their main applications will be exposed in the tutorial with specific reference to MAGLEV (Magnetically Levitation) vehicles, urban people movers (such as linear metro, light railway, etc.), launchers, actuators for industry and automotive, etc. As a first step, the main differences between rotating and linear induction motors will be highlighted, focusing on the aspects of static and dynamic end effects as well as transversal edge effects. The typical structure of LIMs will be treated, with specific reference to secondary sheet and primary winding configurations.

Single-sided LIMs (S-LIMs) and Double-sided ones (D-LIMs) will be described in detail, focusing on normal force effects. Design criteria of LIMs will be specifically exposed, emphasizing the main differences with the classic rotating induction motor design, caused by the presence of large air-gaps, high leakage inductances as well as the end effects. Both static and dynamic models of LIMs will be introduced, including the so-called end-effects, magnetic saturation, non-linear traits influenced by PWM modulation, and so on. Suitable parameter estimation methods will be then described. Afterwards, control techniques specifically devised for LIMs, like field-oriented control, input-output feedback linearization control, active disturbance rejection control, model predictive control, efficiency optimization control, etc., will be introduced in detail. Finally, sensorless techniques with strong robustness capability specifically developed for LIMs will be shown.

Presentation duration (2.5 hours in total)

- Introduction on Linear Motors (LMs)
  - History and categories of LMs 10 minutes
  - Potential applications of LMs 15 minutes
- Design of LIMs
  - Key points/characteristics of LIMs 15 minutes
  - Equivalent circuits of LIMs 10 minutes
  - Design and performance of LIMs 10 minutes
  - Several LIM prototypes 15 minutes
• Parameter Estimation of LIMs
• Control Techniques for LIMs
  o Loss minimization control
  o Model predictive control
• Sensorless Techniques for LIMs
  o Challenge and opportunity
  o Model reference adaptive system
  o Full-order Luenberger observer
  o Robust Kalman filter
• Conclusions

Outline (The outline shall provide a concise description of the covered topics and subtopics, omitting unnecessary details; not more than 600 words)

• Introduction on Linear Motors (LMs)
  o History and categories of LMs
  o Potential applications of LMs
• Design of LIMs
  o Key points/characteristics of LIMs
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Motivation and Focus (Briefly explain why this topic is important for industrial IES community and outline the learning outcomes; not more than 600 words)

Various Linear machines have remarkable application prospect in more and more industrial applications, which are superior for the ability to realize the conversion of electrical energy to linear motion mechanical energy (or vice versa) directly through electromagnetic forces. However, for the special structure of cut-open magnetic circuit, large air-gap length, and half-filled slots, there are still some crucial problems to be resolved in order to acquire high performance. The tutorial aims to share the advancements in the linear machine topologies, integrated modelling, multi-objective optimization techniques, and high-performance control strategies and its emerging applications in transportation, energy conversion systems, and so on. Researchers and engineers from electrical, mechanical and information fields may find it
useful when dealing with transportation motor and drive related design, optimization and control development, mechanical design and analysis, etc.

**Brief CV (Photo, name, email, and short CV)**

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**Prof. Wei Xu** received the double B.E. degree from Tianjin University (TJU), China, in July 2002, and M.E. degree from TJU in March 2005, and the Ph.D. degree from Institute of Electrical Engineering, Chinese Academy of Sciences (IEECAS), in July 2008, respectively, all in electrical engineering. His research interests focus on electromagnetic design and control algorithm of linear machines, permanent magnet machines, brushless doubly-fed induction machines (BDFIMs), and so on.

From 2008 to 2012, he made Postdoctoral Fellow with University of Technology Sydney, Vice Chancellor Research Fellow with Royal Melbourne Institute of Technology, Japan Science Promotion Society Invitation Fellow with Meiji University, respectively. Since 2013, he has been Full Professor with State Key Laboratory of Advanced Electromagnetic Engineering in Huazhong University of Science and Technology, China.

Prof. Xu has been one IEEE Senior Member since 2013, and one Fellow of the Institute of Engineering and Technology (IET) since 2018. Since 2014, Prof. Xu has been invited to make more than ten-time Keynote Speaking in International Conferences. Meanwhile, as one Guest Editor, Prof. Xu has been invited to organize more than ten-time Special Issues in peer review high-quality Journals, such as IEEE Transactions on Industrial Electronics. As the principle speaker, he has been invited to given five-time Tutorial about Linear Machines and Drive Systems in IEEE leading conferences, including IEEE Industrial Electronics Conference (IECON, Oct. 2018), IEEE International Conference Electrical Machines and Systems (ICEMS, Aug. 2018), International Conference on Electrical Machines (ICEM, Aug. 2020), respectively.

Prof. Xu served the General Chair for 2021 International Symposium on Linear Drives for Industry Applications (LDIA 2021) in Wuhan, China, and will serve the General Chair for 2023 IEEE International Conference on Predictive Control of Electrical Drives and Power Electronics (PRECEDE 2023) in Wuhan, China. He has been the Founding Chair for IEEE IES Wuhan Chapter since 2018. He has also been the International Steering Committee (ISC) Member for linear machines and drives. Meanwhile, Prof. Xu has been Associate Editor for several leading IEEE Transactions Journals, such as IEEE Transactions on Industrial Electronics, IEEE Transactions on Vehicular Technology, IEEE Transactions on Energy Conversion, and so on.
Prof. Xu is now leading one research group, Center for Energy Conversion System (CECS, http://machinececs.seee.hust.edu.cn/), including 6 staff and over 40 PhD/ME students, for the development on high performance of electrical machines (particularly linear machines) and drive systems based on transportation, wind generation, servo, etc. He has more than 110 papers accepted or published in IEEE Journals, two edited books published by Springer Press, one monograph published by China Machine Press, and more than 150 Invention Patents granted or in pending, all in the related fields of electrical machines and drives.

Relevant publications (* Corresponding author)


