Tutorial proposal

Title: Electric Spring (ES) – 2 hours

1. **Presenter(s):**

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2. **Brief description (What you are going to present?):**

As the energy crisis and environmental deterioration in the world are becoming more and more prominent, it is urgent to utilize alternative energy sources to replace the traditional fossil fuels. Solar and wind, as clean renewable energy sources (RESs), are currently largely used. However, their power delivery is intermittent and not entirely predictable. When such RESs are incorporated into the grid, the intermittency in their output power gives rise to a mismatch between power generation and demand that is liable to affect the quality of the electric service by altering the magnitude and possibly, the frequency of the supply voltage of the customer loads.
A new compelling way to mitigate the power quality issues caused by RES power intermittency is represented by electric spring (ES). It creatively applies the concept of mechanical spring to an electric load to stabilize the supply voltage magnitude at the customer side. The basic idea is to classify the customer loads into two categories: the critical load (CL) category -such as information centres and hospitals- that requires a well-stabilized voltage supply, and the non-critical load (NCL) category -such as water heaters and refrigerators- that accepts a certain tolerance on the voltage supply level. By adjusting magnitude and phase of its output voltage, an ES is able to exchange a suitable of active and reactive powers with NCL so as to keep constant the voltage magnitude and, then, the power absorbed by CL.
This tutorial plans to give a comprehensive presentation of the state-of-art on the ES technology, including the operational activities carried out on an ES setup.

3. **Outline (How you are going to use 2 hrs time to present your tutorial?):** *(up to 500 words)*

After a short introduction illustrating the problems posed by the RES proliferation, the tutorial focuses on ES as an effective solution to stabilize the distribution line AC voltage at the customer side. A comprehensive presentation of the main topologies of an ES and the main techniques devised for its control is given. Steady-state and dynamic characteristics of a customer load equipped with an ES are illustrated, together with some notes on its power sizing and control system design.
A detailed outline of the tutorial is as follows: 1) AC distribution line voltage issues, 2) ES concept, 3) ES implementation: versions (topologies), 4) ES implementation: control strategies, 5) ES steady-state behaviour and dynamic modelling, 6) ES power sizing and control system design, 7) Experimental setup and results, 8) ES vs. alternative solutions, 9) ES for DC line, 10) Conclusions and future work.

4. **Publications (Your publications relevant to the tutorial):**

1) *Q. Wang, M. Cheng, Y. Jiang, W. Zuo, and G. Buja, "A simple active and reactive power control for applications of single-phase electric springs," IEEE Trans. Ind. Electron., vol. 65, no. 8, pp. 6291–6300, Aug. 2018.*
2) *Q. Wang, M. Cheng, Z. Chen, and Z. Wang, "Steady-state analysis of electric springs with a novel δ control," IEEE Trans. Power Electron., vol. 30, no. 12, pp. 7159–7169, Dec. 2015.*
3) *Q. Wang, M. Cheng, Y. Jiang, "Harmonics suppression for critical loads using electric springs*

with current-source inverters," IEEE J. Emerging Sel. Topics Power Electron., vol. 4, no. 4, pp. 1362–1369, Dec. 2016.

4) *Q. Wang, D. Zha, F. Deng, M. Cheng, and G. Buja, "A topology of DC electric springs for DC household applications," IET Power Electron., vol. 65, no. 8, pp. 6291–6300, Aug. 2019.*
5) *Q. Wang, M. Cheng, and G. Buja, "Integration of Electric Springs and Multi-Port Transformers—A New Solution for AC Microgrids with Renewable Energy Sources," Energies 2017, vol. 10, no. 2, 193.*
6) *Q. Wang, F. Deng, M. Cheng, and G. Buja, "The state of the art of topologies for electric springs," Energies 2018, vol. 11, no. 7, 1724.*
7) *Q. Wang, P. Chen, F. Deng, M. Cheng, and G. Buja, "The state of the art of the control strategies for single-phase electric springs," Appl. Sci. 2018, vol. 8, no. 11, 2019.*
8) *Q. Wang, W. Zuo, M. Cheng, F. Deng, and G. Buja, "Performance improvement in the control of single-phase electric springs," J. Power Electron., vol. 65, no. 8, pp. 6291–6300, Aug. 2019.*
9) *Q. Wang, M. Cheng, Y. Jiang, "A Novel controller of electric springs based on Bode diagram optimization," Journal of Power Electron., vol. 16, no. 4, pp. 1396–1406, July 2016.*
10) *Q. Wang, W. Zuo, M. Cheng, F. Deng, and G. Buja, "Dead-beat control cooperating with state observer for single-phase electric springs," Appl. Sci. 2018, vol. 8, no. 12, 2335.*
11) *D. Zha, Q. Wang, F. Deng, M. Cheng, F. Deng, and G. Buja, "Regulation performance of multiple DC electric springs Controlled by Distributed Cooperative System," Energies 2019, vol. 12, no. 18, 3422.*
12) *Q. Wang, M. Cheng, Y. Jiang, F. Deng, Z. Chen, and G. Buja, "Control of three-phase electric springs used in microgrids under ideal and non-ideal conditions," 42nd Annual Conference of IEEE Industrial Electronics Society (IECON) 2016, 2247-2252. (Best Session Presentation Award)*

5. Presenter's biography (IEEE style):

Giuseppe Buja (LF'13) received the "Laurea" degree with honors in power electronics engineering from the University of Padova, Padova, Italy, where he is currently an honorary research scientist. He has carried out extensive research work on power and industrial electronics, originating novel solutions for design of power converters and electric drives, and pioneering the introduction of digital signal processing in the control of power electronics systems. His recent research interests are power electronics for emerging technologies, including wireless charging of electric vehicles and grid-integration of renewable energy sources. Dr. Buja received the IEEE IES Eugene Mittelmann Achievement Award "in recognition of his outstanding technical contributions to the field of industrial electronics," and the 2016 Best Paper Award from the IEEE TIE. He has served IEEE and other Associations in several capacities, including as General Chairman of the 20th Annual Conference of the IEEE IECON.

Qingsong Wang(S'14-M'17-SM'17) received the B.Sc. and M.Sc. degrees from the Department of Electrical Engineering, Zhejiang University, Hangzhou, China, in 2004 and 2007, respectively, and the Ph.D. degree from the School of Electrical Engineering, Southeast University, Nanjing, China, in 2016. From November 2015 to November 2016, he was a joint Ph. D student with the Department of Energy Technology, Aalborg University, Aalborg, Denmark, where he focused on electric springs. From July 2004 to July 2005, he was an engineer in Shihlin Electronic & Engineering Co., Ltd, Suzhou, China. From July 2007 to August 2011, he was an engineer in Global Development Center of Philips Lighting Electronics, Shanghai, China. In October 2010, he was promoted to be a Senior Engineer. From August 2011 to September 2013, he was a Lecturer in PLA University of Science and Technology, Nanjing, China. Since 2017, he has been with Southeast University, where he is currently an Associate Professor in the School of Electrical Engineering. Dr. Wang's research interests are focused in the areas of control and applications of power electronics to power systems.