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IECON 2022 Tutorial Proposal

Title of the Proposal:

Electromechanical Systems Fault Diagnosis and Prognosis

- Presenter(s):

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- Brief description:

Condition monitoring is of high concern in industrial applications since it minimizes the downtime and improves the reliability, availability, safety and productivity. Among the various available techniques for electric machines and drives condition monitoring, phase current analysis has several advantages since it is a non-invasive technique that avoids the use of extra sensors. Moreover, the electrical signals (for instance, the stator current) are usually available and inexpensive to measure. Stator currents processing-based faults detection and diagnosis of electric machines and drives has received intense research interest for several decades. Moreover, the International Standard "ISO FDIS 20958" dealing with "Condition monitoring and diagnostics of machine systems - Electrical signature analysis of three-phase induction motors" sets out guidelines for the online techniques recommended for the purposes of condition monitoring and diagnostics of machines, based on electrical signature analysis. Hence, many studies have shown that supervising the current spectrum could perform fault monitoring. Most of the used faults detection and diagnosis techniques perform spectral analysis, such as Fourier or MUSIC techniques. Although these techniques exhibit good results in stationary conditions, they are not well suited for a majority of electric machines and drives. Indeed, these applications environment is predominantly non-stationary due to transients or variable speed operations. In this context, the involved signals are usually non-stationary, embedded in noise, and can contain closely spaced frequencies. It is then obvious that faults detection and diagnosis in such applications are challenging tasks that need using specific signal processing tools.

In conjunction with faults diagnosis, remaining useful life (RUL) is very crucial for prognosis, taking place as the primary measure of systems health assessment. It is mainly based either on the estimation of useful time until the system complete failure or on the provision of a probability or any other important information indicating its current operational performance. Its evaluation involves the use of different modeling paradigms, depending on the system complexity as well as the availability of the operating history, including all anomaly events. In this context, data-driven evaluation is a very common promising solution in case of unavailability of the physical modeling process. In data-driven training procedures, the precise RUL estimation process depends on two main characteristics, namely: (i) complete run-to-failure historical sensor measurements and (ii) truly attributed labels to each event. However, for electric machines and drives machines, collecting these large deterioration patterns seems most likely impossible due to their long lifetime. Conversely, it seeks to recover patterns of progressive damage propagation by imposing accelerated life tests to collect patterns similar to real ones as an alternative solution. Moreover, even if these data are correctly stored, real labels are still missing and short lifespan could not be considered as a ground truth label.

In this challenging context, this tutorial aims to present main advances in both signal processing techniques for electric machines and drives faults diagnosis and prognosis. All these techniques will be evaluated and compared and their advantages and drawbacks highlighted.

- Duration:

2h

- Outline:

1. Introduction: Challenges and Locks
2. Faults Detection and Diagnosis
   - Industrial failure overview
   - Faults effects
   - Faults signatures
   - Faults detection and diagnosis method (simulations and experiments)
3. Failure Prognosis and Remaining Useful Estimation
   - State of the review: Challenges and issues
   - Focus on machine learning-based approaches (case studies)
4. Summary and Conclusions

- Motivation and Focus:

This tutorial should be interesting to IES member and in particular to IECON attendees as it is dealing with topical and timely problems concerning the availability of electromechanical systems. Indeed, fault diagnosis and prognosis are keywords of several proposed special sessions. In this context, this tutorial is definitely useful for some special sessions attendees to briefly acquire backgrounds and basics of signal processing and machine learning-based approaches for electromechanical systems (electric machines, drives, and auxiliaries such as storage, etc.) condition monitoring and prognosis (RUL estimation).

-Brief CV:

Mohamed Benbouzid (S'92–M'94–SM'98–F'20) received the and Ph.D. degree in electrical engineering from the National Polytechnic Institute of Grenoble, Grenoble, France 1994, and the Habilitation à Diriger des Recherches degree from the University of Amiens, France, in 2000.

After receiving the Ph.D. degree, he joined the University of Amiens, Amiens, France where he was an Associate Professor of electrical engineering. Since September 2004, he has been with the University of Brest, Brest, France, where he is a Full Professor of electrical engineering. Prof. Benbouzid is also a Distinguished Professor and a 1000 Talent Expert at the Shanghai Maritime University, Shanghai, China. His main research interests and experience include analysis, design, and control of electric machines, variable-speed drives for traction, propulsion, and renewable energy applications, and fault diagnosis of electric machines.

Prof. Benbouzid is an IEEE and IET Fellow. He is the Editor-in-Chief of the International Journal on Energy Conversion and the Applied Sciences (MDPI) Section on Electrical, Electronics and Communications Engineering. He is a Subject Editor for the IET Renewable Power Generation. (Email:Mohamed.Benbouzid@univ-brest.fr)

Demba Diallo (M'99–SM'05) received the M.Sc. and Ph.D. degrees in Electrical and Computer Engineering, from the National Polytechnic Institute of Grenoble, France, in 1990 and 1993, respectively.

He is currently Full Professor of Electrical Engineering at Université Paris-Saclay, and is member of the Group of Electrical Engineering of Paris, France. He is director of the French National Research Network on Electrical Engineering. He is also a 1000 Talent Expert at the Shanghai Maritime University, Shanghai, China. His current area of research includes fault diagnosis, fault-tolerant control and energy management. The applications are related to more electrified transportation systems (EV and HEV) and microgrids with renewable energies.

Prof. Diallo has served as Editor for the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY from 2007 to 2019. He is currently an Editorial Board Member of Energies (MDPI). (Email: Demba.Diallo@geeps.centralesupelec.fr)

- **Relevant publications:**

[1] M.E.H. Benbouzid, (Ed), *Signal Processing for Fault Detection and Diagnosis in Electric Machines and Systems*, ISBN 978-1-83953-025-8, 284 p., IET, London 2020.

[2] T. Berghout, L.H. Mouss, T. Bentrcia and M.E.H. Benbouzid, "A semi-supervised deep transfer learning approach for rolling-element bearing remaining useful life prediction," *IEEE Transactions on Energy Conversion*, vol. 37, n°2, pp. 1200–1210, June 2022.

[3] H. Habbouche, Y. Amirat, T. Benkedjouh and M.E.H. Benbouzid, "Bearing fault event-triggered diagnosis using a variational mode decomposition-based machine learning approach," *IEEE Transactions on Energy Conversion* vol. 37, n°1, pp. 466–474, March 2022.

[4] T. Berghout, M.E.H. Benbouzid, S.M. Muyeen, T. Bentrcia and L.H. Mouss, "Auto-NAHL: A neural network approach for condition-based maintenance of complex industrial systems," *IEEE Access*, vol. 9, pp. 152829–152840, 2021.

[5] Z. Li, T. Wang, Y. Wang, Y. Amirat, M.E.H. Benbouzid and D. Diallo, "A wavelet threshold denoising-based imbalance fault detection method for marine current turbines," *IEEE Access*, vol. 8 n°1, pp. 29815–29825, 2020.

[6] M. Zhang, T. Wang, T. Tang, M.E.H. Benbouzid and D. Diallo, "An imbalance fault detection method based on data normalization and EMD for marine current turbines," *ISA Transactions*, vol. 68, pp. 302-312, May 2017.