

Tutorial-7: Sunday, 23<sup>rd</sup> August 2020, 15:00-17:30 CET.

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## Electrical Machines and Converters Experimental Loss Determination and Uncertainty Analysis

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### Tutorial Abstract:

Experiments play a major role in the research of motors and converters. The properties and efficiencies of the motors and converters are verified through experiments. The continuous improvement of the efficiency of the devices and distorted electrical waveforms create specific challenges for the task. This tutorial introduces the typical efficiency determination methods for converters and motors, highlights the corresponding international standards and analyses the measurement uncertainty using real case studies.

Efficiency is the ratio of the output power to the input power and can be directly determined by measuring the input and output powers. This input-output method is troublesome when the efficiency of the device is high because the uncertainty of the losses is approaching infinity when the efficiency is approaching unity. Therefore, loss segregation methods or calorimetric methods are recommended for high efficiency devices, but in practice the input-output method is the only viable method for regular use. One objective in this tutorial is to understand the limitations of the input-output method.

Uncertainty analysis is a basic tool in science, but it has been ignored in the field of electric motor systems. The accuracy of the power measurement in the case of pulse-width-modulation (PWM) has been a controversial topic. Here, the measurement uncertainty determination methodology in electrical (sinusoidal and PWM-supply) and mechanical power measurements is presented, and the loss and efficiency uncertainties of converters, motors and motor systems are analyzed.

### Biographies:



**Dr. Lassi Aarniovuori** (SM'19) received M.Sc. degree in industrial electronics and D.Sc. degree in electrical drives from Lappeenranta University of Technology (LUT), Lappeenranta, Finland, in 2005 and 2010, respectively. Dr. Aarniovuori has conducted research into various industrial and academic research projects at LUT-University. He was a Marie Curie Fellow with the School of Engineering and Applied Science, Aston University, UK during 2017-2019. Currently, he is serving as an Adjunct Professor of Electric Motors and Drives at LUT. His current research interests include the field of electric motor drives, especially high-speed motor drives, harmonic power analysis, simulation and modelling of electric drives, efficiency measurements, and calorimetric measurement systems.



**Mr. Hannu Kärkkäinen** received his M.Sc. degree in electrical engineering from Lappeenranta University of Technology, Finland, in 2015, where he currently works as a junior researcher with the Department of Electrical Engineering. His research interests include electric drive systems, particularly loss and efficiency measurements and analysis of the motors and drives. Currently, Mr. Kärkkäinen is finalizing his D.Sc. thesis from the field of theory and methodology used in determination of electrical drive system losses and efficiency.