DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

# PhD - Public Defence

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| **Title:** | Synchronization Stability of Grid-Connected Converters under Grid Faults |
| **Location**: | Online |
| **Time**: | Tuesday August 11th at 13.00 |
| **PhD defendant**: | Mads Graungaard Taul |
| **Supervisor:** | Professor Frede Blaabjerg |
| **Co-supervisor:** | Professor Xiongfei Wang<br>Associate Professor Pooya Davari |
| **Moderator:** | Associate Professor Yongheng Yang |
| **Opponents**: | Professor Remus Teodorescu, Dept. of Energy Technology, Aalborg University (Chairman)<br>Professor Florian Dorfler, ETH ZOrich, Switzer1and<br>Professor Bikash C. Pal, Imperial College, London, England |

**The defence will be in English - all are welcome**

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**Abstract:**

Modern society sustainment and growth are entirely dependent on a stable and reliable supply of electrical energy that experiences no or very few power outages for an optimal function. The primary purpose of a modern power system is to deliver the requested power in an economical way with an acceptable level of reliability.

However, with the unprecedented increase in renewable energy sources and power-electronics-based generation, the overall reliability, and security of supply may be at risk, which implies unacceptable high customer interruption cost. This risk originates due to the fact that the primary frequency response provided by conventional synchronous machines will be significantly reduced or lost with a decreasing system inertia. With the gradual retirement of the synchronous generation, the power system robustness towards large disturbances such as short-circuit grid faults is reduced. To address these challenges, converter-based generators should aim to support the network during abnormal events and provide both frequency and voltage support. Yet, from real-world examples, system instabilities of large wind farms and photovoltaic power plants are reported, occurring due to instabilities in the converter synchronization control. To avoid such undesired events, it is essential that such instabilities can be predicted and accordingly prevented.

Therefore, to achieve a successful transition to a power electronics-based power system with green electricity conversion, models capable of assessing the large-signal synchronization stability of converter-based generation should be developed. This is lacking in the single-converter operation but also for large-scale multi-converter systems. To that end, the computational burden associated with performing a detailed transient stability study of a large-scale study is too time-consuming. Hence, reduced-order and aggregated models are needed to assess the large-signal synchronization stability on a large scale.

To address these issues, this Ph.D. project proposes models, necessary conditions, and modeling frameworks for large-signal synchronization stability of single-converter and multi-converter systems. Due to the nonlinear dynamics associated with the synchronization process of grid-following converters, nonlinear tools and numerical approximations are presented to estimate the sufficient conditions for transient stability. All models possess high reconstruction accuracies, which are verified through experimental tests. In this way, using the proposed reduced-order and aggregated models, the control parameters of the synchronization unit can be selected such to provide transient stability given an anticipated worst-case condition.

Since some severe grid faults may imply that no equilibrium point exists for the desired converter operation, control methods are proposed and revisited to address this. These either provide infinite damping of the synchronization dynamics or modify the converter operation to always provide a stable operating point during the fault with associated sufficient damping requirements.

Accordingly, by employing the presented models and control methods for enhanced transient instability assessment and prevention, future power electronics-based power systems may be designed and operated to reduce the experienced customer interruption costs and increase the power system security of supply and overall reliability.