EERA DeepWind'19, Trondheim, 16.-18. January 2019

Electrical Collector Topologies for Multi-Rotor Wind Turbine Systems
Power Loss Calculations

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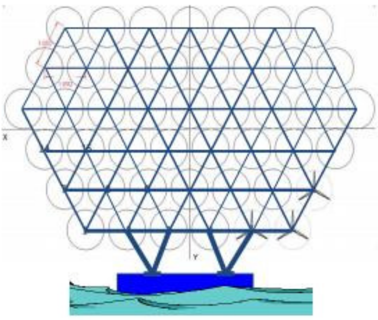
Introduction

- Increasing demand for new innovations in the wind power industry
- P. Jamieson proposed the Multi-Rotor Wind Turbine System (MRWTS) [1]
- Vestas has already installed a 4-rotor system in Denmark [2]

Objectives:
- Propose different electrical collector topologies for a MRWTS
- Develop appropriate control systems
- Develop a way of calculating power electronic losses

Vestas 4-rotor demonstrator turbine. Source: Vestas (www.vestas.com)



Proposed MRWTS in the FP7 INNWIND.EU project. Source: Innwind (www.innwind.eu)

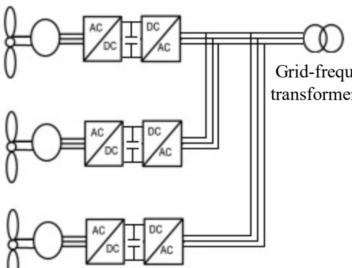
Methodology

- Perform a literature search in order to propose three different collector topologies
- Implement the topologies in Matlab/Simulink
- Implement controllers for the power converters used in the topologies
- Perform a literature search on power losses in power converters and implement a way of calculating power losses in Simulink
- Perform simulations and make comparisons of the topologies

Proposed topologies

Design considerations:
- Limit number of heavy transformers/power electronics
- Remain stable operation in case of fault in one rotor
- Compromise between controllability, efficiency and costs
- Be scalable, in terms of reaching 20 MW or more

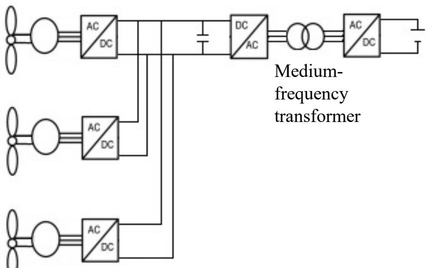
AC Cluster



Grid-frequency transformer

- One back-to-back converter for each turbine
- Allows individual optimised operating point
- High number of power electronics and large AC transformers

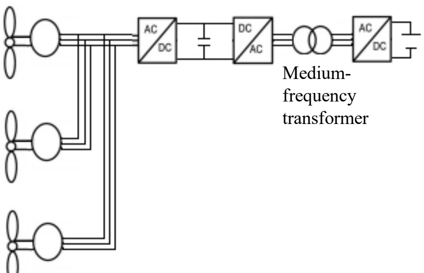
DC Cluster



Medium-frequency transformer

- Individual optimised operating point through individual converters
- DC-to-DC converter using medium frequency power converters may save space and weight
- High power DC-to-DC converters still not commercially available

Hybrid Cluster



Medium-frequency transformer

- Drastically reduces the number of power converters needed
- Issues regarding the controllability, one converter must control several turbines
- High power DC-to-DC converters needed

Control

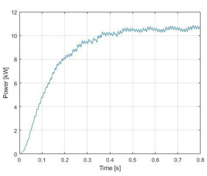
Machine side controller:
- Control active and reactive power
- Compares measured power to reference values
- PI controller in inner and outer loop

Grid side controller:
- Control DC link voltage
- Compare measured DC voltage to reference values
- PI controller in inner and outer loop

DC-DC converter controller:
- DC-to-AC converter equal control as the grid side controller in the AC cluster
- Can operate in non-grid frequency by customised PLL – island mode
- PI controllers used in the inner and outer loop to control the AC voltage

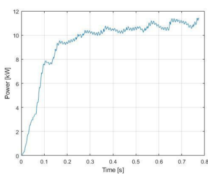
Simulation results

AC Cluster



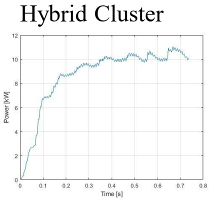
Power converter losses of 1.17 %

DC Cluster

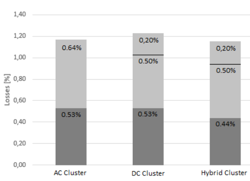


Power converter losses of 1.23 %

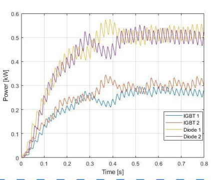
Hybrid Cluster



Power converter losses of 1.14 %



- Hybrid cluster experiences lowest losses
- High voltage side of DC-DC converter losses of just 20 %
- IGBT losses higher than diode losses
- Reasonable results according to theory



Loss calculation

Power electronic losses found by [3]:

Conduction losses — Switching/ Reverse recovery losses

- IGBT losses $P_{IGBT} = N \left(V_{sw0}(T_j)\cdot I_{C,av} + R_C(T_j) I_{C,rms}^2\right) + \left(E_{sw,on} + E_{sw,off}\right) f_{sw}$
- Diode losses $P_D = N \left(V_{D,0}(T_j)\cdot I_{D,av} + R_D(T_j) I_{D,rms}^2\right) + E_{sw,on} f_{sw}$

Simulink loss calculation method [4]:

1. Define IGBT/Diode module specifications in Matlab from datasheet
2. Obtain current and voltage measurement from the Simulink module
3. Divide signals in to IGBT and diode power loss calculation blocks
4. Compute desired energy or voltage Based on current and voltages, and the temperature in the device
5. Convert energy to power
6. Input power to the thermal model to obtain the temperature in the device

Conclusion and future work

Conclusion

- Similar results at a reasonable level
- Controllers work
- Power loss calculation method works
- Higher complexity needed to favour a topology

Future work

- Increase complexity in terms of number of turbines
- Develop controllers for dynamic conditions
- Investigate the use of medium frequency transformers

References

[1] P. Jamieson, et.al., (20015) , INNWIND.EU, Innovative Turbine Concepts – Multi-Rotor System
[2] Vestas Wind Systems A/S, (2016)), News release, Vestas challenges scaling rules with multi-rotor concept demonstration turbine
[3] R.A. Barrera-Cardenas, (2015), Doctoral thesis, Meta-parametrised meta-modelling approach for optimal design of power electronics conversion systems: Application to offshore wind energy
[4] Mathworks, Loss Calculation in a 3-Phase 3-Level Inverter Using SimPowerSystems and Simscape, https://www.mathworks.com/help/physmod/sps/examples/loss-calculation-in-a-three-phase-3-level-inverter.html

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