POWER QUALITY STUDIES OF A STAND-ALONE WIND-POWERED WATER INJECTION SYSTEM WITHOUT PHYSICAL INERTIA

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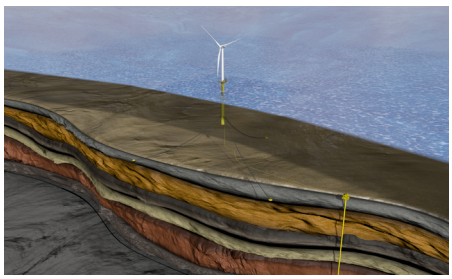
Abstract

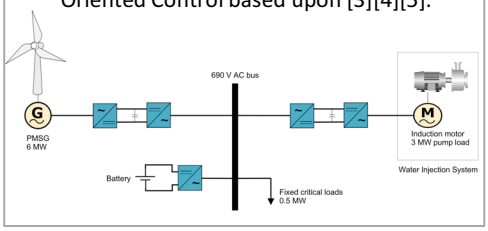
A model of a wind-powered microgrid for applications in oil & gas industries is presented in this poster. The model is used to simulate the power quality during common wind scenarios and important aspects as black start and Fault Ride-Through (FRT) capability. The controller tuning has been carefully chosen in order to maximize power production while minimizing fluctuations.

Concept: Wind-powered Water Injection [1]

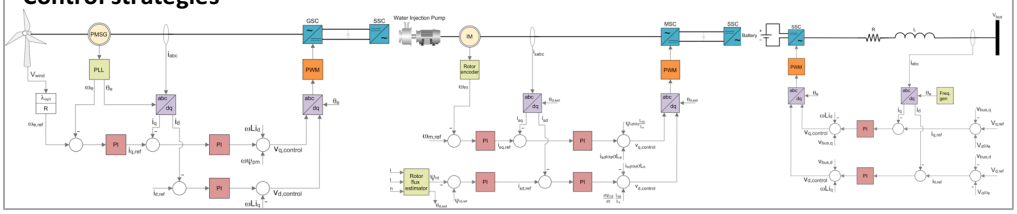


Proposed topology

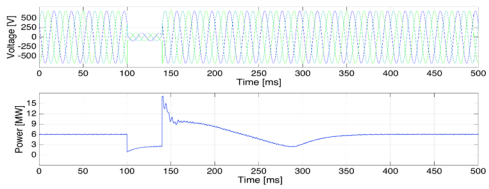
- 6 MW offshore Permanent Magnet Synchronous Generator (PMSG) wind turbine [2].
- The main load: centrifugal pump driven by a 3 MW Induction Motor Drive.
- 0.5 MW fixed critical load: pitch and yaw drives, control- and communication systems and lightning and climate conditioning systems.
- A battery storage is responsible for supplying the critical loads during low wind conditions, and the control of main bus voltage magnitude and frequency.
- The VSC control systems utilize Field Oriented Control based upon [3][4][5].



Control strategies

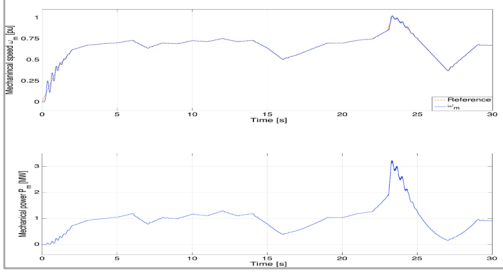


Wind Turbine simulations



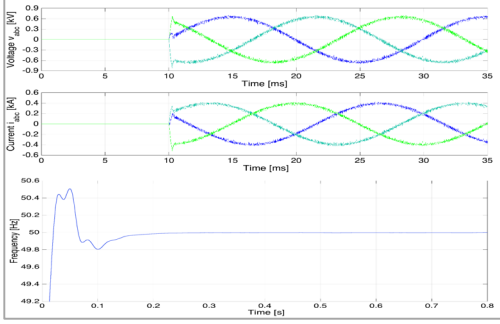
1. The ability of PMSG to follow the optimal speed.
2. The corresponding output power.
3. The harmonic current distortion provided by the PMSG at PCC.
4. Fault ride-through analysis: 40 ms fault, 0.15 pu voltage.

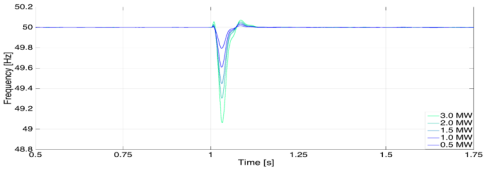
Water Injection System simulations



1. The ability induction machine to follow the optimal speed during power fluctuations.
2. The corresponding mechanical output power
3. The harmonic distortion of the VSD input current.

Battery System simulations





1. Voltage and current when the battery performs a black start after 10 ms.
2. The voltage frequency during the black start.
3. Voltage frequency response during a sudden load change in the system which occurs after 1 s.

Conclusions

- Simulations have shown the generator to be able to follow a rapidly changing speed reference, with a close to optimal power production. Note that the pitch controller limits the speed of the wind turbine after 48 s when the wind speed rises above the base speed.
- The total current harmonic distortion of the PMSG is measured to be 0.91%, which is clearly within the IEEE 519 recommendations.
- A fault ride-through analysis showed that the PMSG can withstand a 40 ms fault with 0.15 pu voltage at the point of common coupling. The power peak after fault clearing is due to increased current.
- The induction motor is to able to follow a rapidly changing speed reference, which represents the fluctuating power production from the wind turbine. Some oscillations are observed at very large fluctuations, but this is expected due to the fast dynamics of the high speed motor.
- The total current harmonic distortion at the point of common coupling of the main bus and the VSD is measured to be within the distortion limit of 8% in IEEE 519.
- A black start of the system has been proven possible through simulations. The voltage magnitude and frequency is rapidly set to the rated values by the battery when the black start is initiated.
- The battery is able to keep the rated voltage magnitude and frequency in case of rapid load change or sudden loss of wind power.
- Simulations at rated conditions suggest a current up to 3.0 kA at the PCC that the battery must be able to absorb.

References

[1] DNV GL, «WIN WIN Joint Industry Project: Wind-powered water injection,» DNV GL, Høvik, 2016.

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[3] A. Årdal, *Feasibility studies on integrating offshore wind power with oil platforms.* Master's thesis, Department of Electrical Engineering, NTNU, Trondheim, 2011.

[4] R. Nilsen, TET4120 Electric Drives, Department of Electrical Engineering, NTNU, Trondheim, 2016.

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