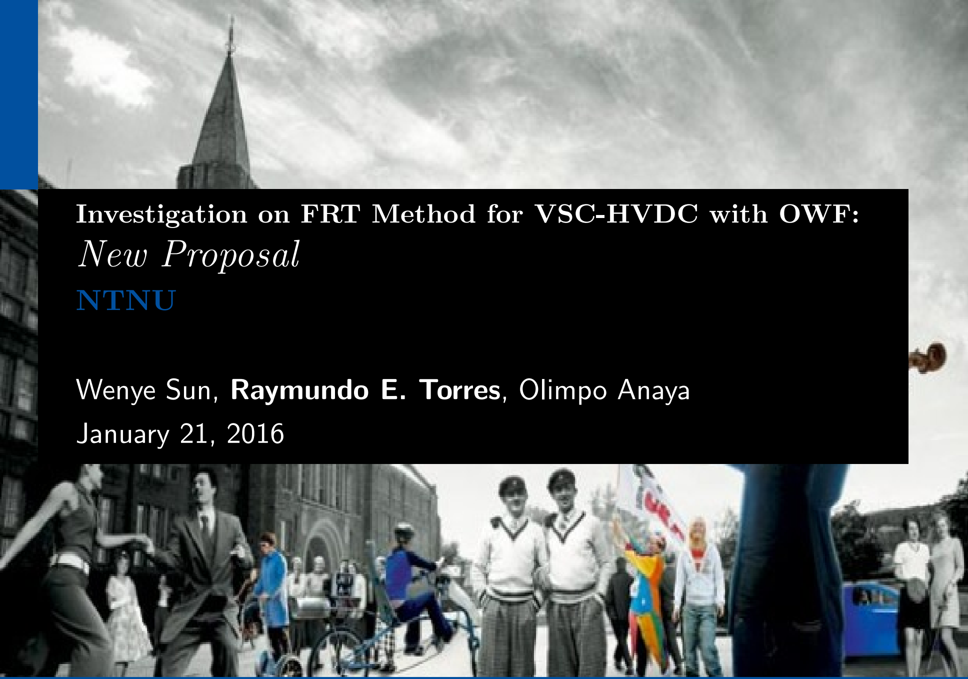

Investigation on FRT Method for VSC-HVDC with OWF: *New Proposal*

NTNU

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Outline

1. Motivation
2. Fault ride through problem
3. Reference system
4. Fault-ride Through Methods
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   - Power Setpoint Adjustment
   - Active Current Reduction
   - Offshore Voltage Reduction
5. Proposed Method for FRT
6. Summary
7. Conclusion

Background

Keywords

- Fast development of wind energy in last 20 years
- At end of 2014, total wind power installed around the world was 370 GW.
- The trend is going to offshore, because of good wind condition and less visual impact.
- VSC-HVDC transmission is the latest technology for connecting distant offshore wind farms.

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FRT problem

- When a fault occurs at the ac grid, the onshore converter is unable to transmit all the active power to the ac grid, however OWF still inject active power to offshore converter
- This results in power imbalance that will charge the capacitance in the dc-link.
- Without any actions, this will result in a fast increase of the dc voltage, which may damage the HVDC equipment.

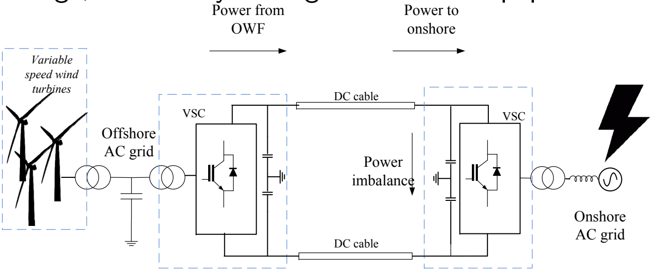

Figure : Fault effect on power transfer

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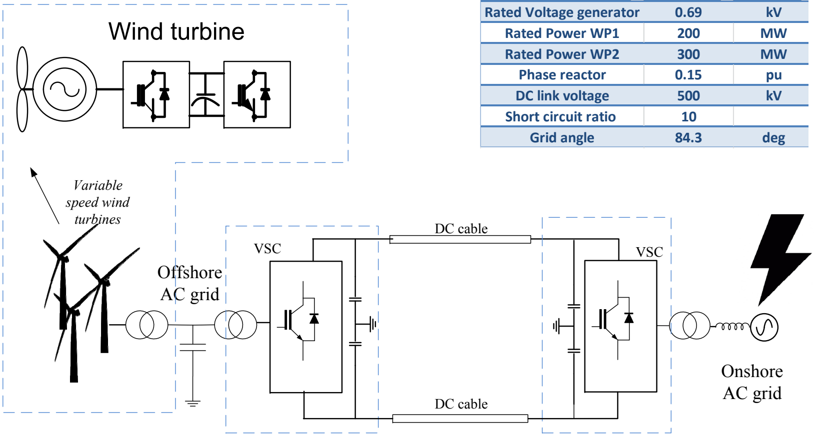
Reference system

Component	Value	Unit
Rated Voltage generator	0.69	kV
Rated Power WP1	200	MW
Rated Power WP2	300	MW
Phase reactor	0.15	pu
DC link voltage	500	kV
Short circuit ratio	10	
Grid angle	84.3	deg



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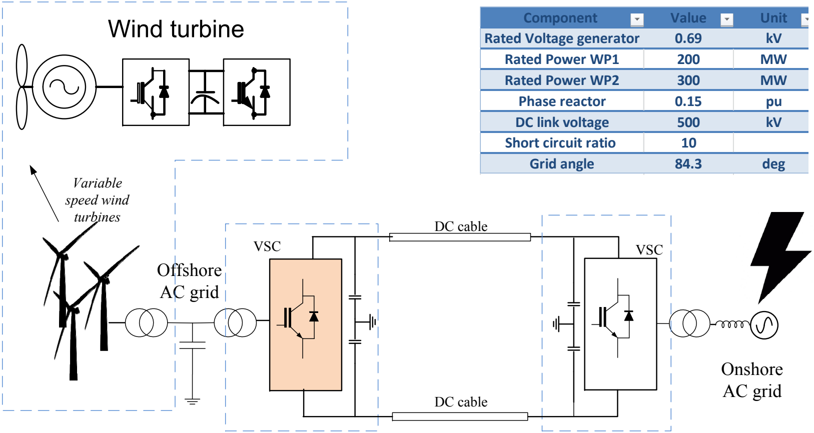
Offshore converter controller



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VSC-HVDC - Offshore converter controller

Control Objective

Generate a three-phase voltage with constant amplitude and frequency for offshore wind farm grid.

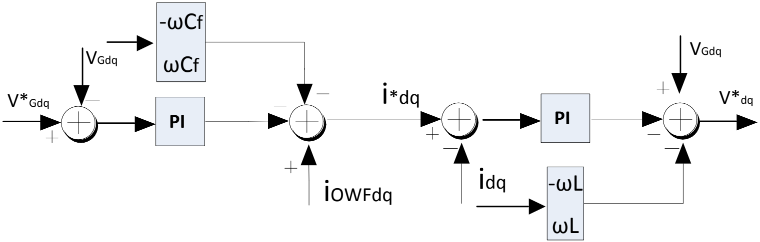
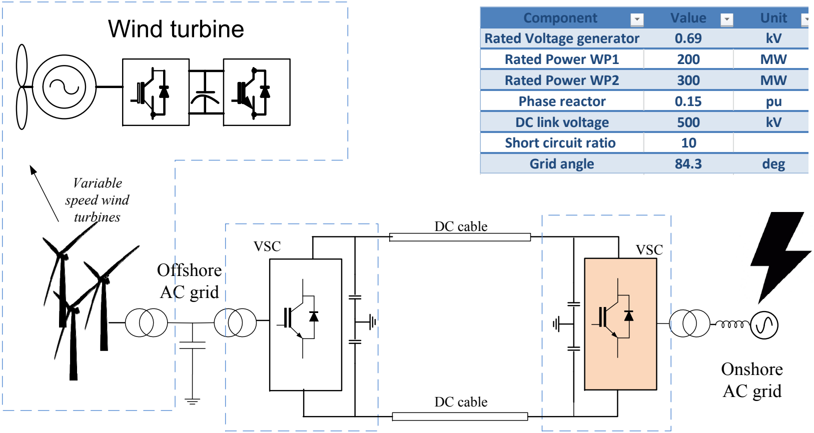


Figure : Offshore converter controller

Onshore converter controller



Component	Value	Unit
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Phase reactor	0.15	pu
DC link voltage	500	kV
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VSC-HVDC - Onshore converter control design

Control Objective

- Regulate dc-link voltage and reactive power.
- Provide reactive power compensation during onshore grid fault.

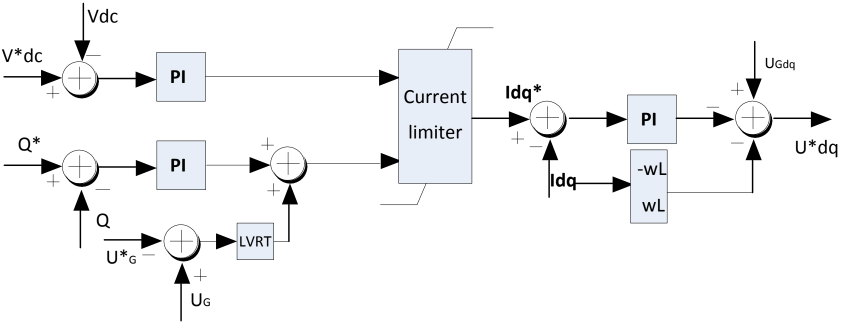
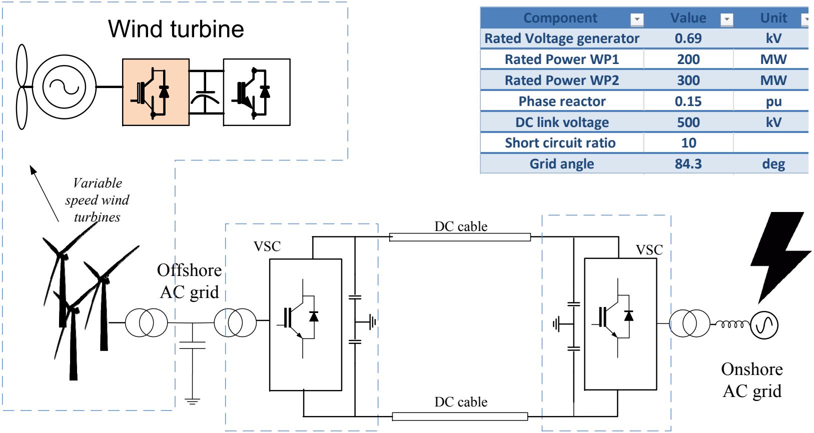


Figure : Onshore converter control design

Wind Turbine - GSC control design



Component	Value	Unit
Rated Voltage generator	0.69	kV
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Phase reactor	0.15	pu
DC link voltage	500	kV
Short circuit ratio	10	
Grid angle	84.3	deg

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Wind Turbine - GSC control design

Control Objective

Extract the maximum power from wind turbine.

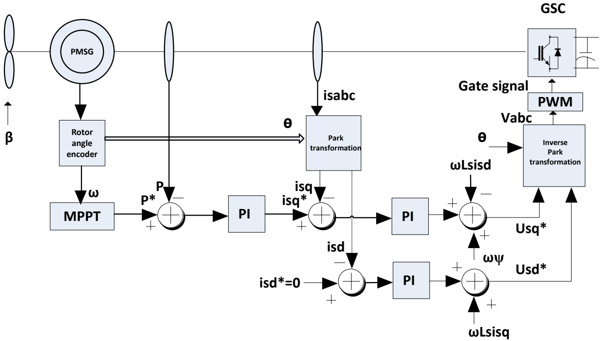

Figure : Generator side converter control design

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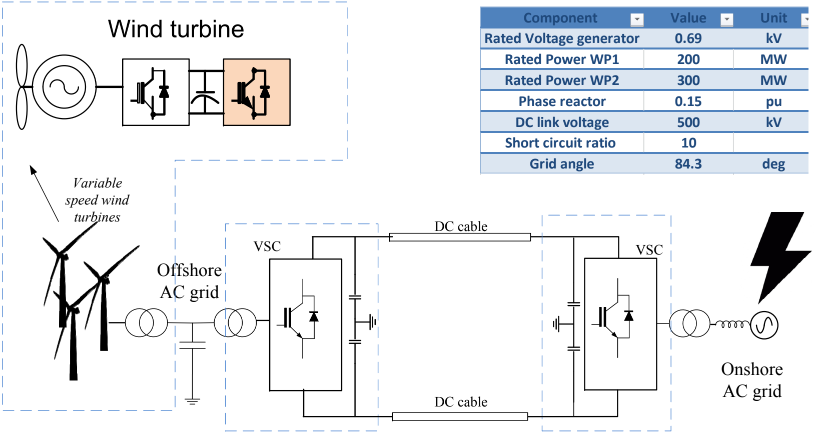
Wind Turbine - ACGSC control design

Component	Value	Unit
Rated Voltage generator	0.69	kV
Rated Power WP1	200	MW
Rated Power WP2	300	MW
Phase reactor	0.15	pu
DC link voltage	500	kV
Short circuit ratio	10	
Grid angle	84.3	deg



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Wind Turbine - ACGSC control design

Control Objective

Regulate the back-to-back converter dc voltage and reactive power.

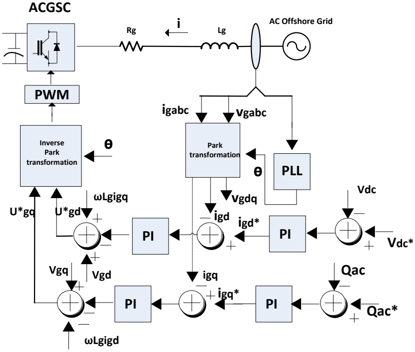

Figure : AC grid side converter control design

Wind Turbine - Pitch control

Control Objective

Limit the power output at rated value.

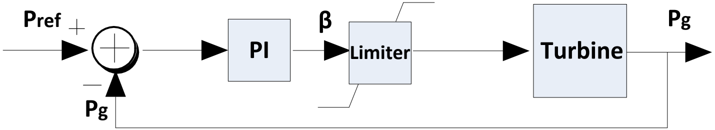

Figure : Pitch control design

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FRT Methods

A brief review of the FRT methods.

1. Chopper Resistor
2. Power Setpoint Adjustment
3. Active Current Reduction
4. Offshore Voltage Reduction

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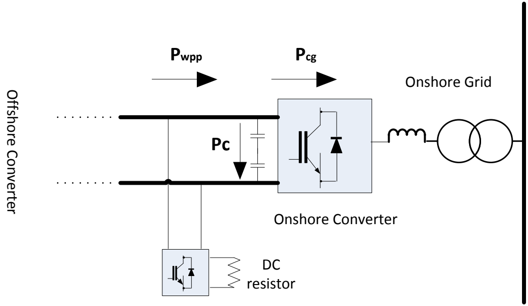
FRT Method I- Chopper Resistor

Work principle of chopper resistor

A dc chopper consists of a dc resistor directly controlled through a power electronics switch, e.g. GTO, IGBT. The main function of dc chopper is to limit the dc voltage by dissipating the excess power as heat.



$$R_{chop} = \frac{(1.1V_{dc_{rated}})^2}{P_{rated}}$$

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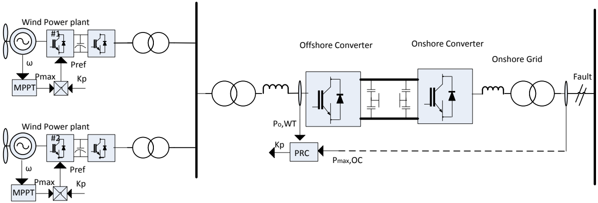
FRT Method II - Power Setpoint Adjustment

Work principle of Power setpoint adjustment method

The principle of this method is to reduce the power setpoint of each wind turbine when onshore fault occurs.

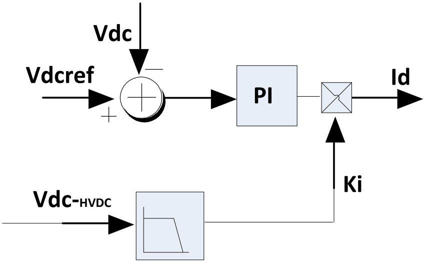


$$K_p = \frac{P_{max}, OC}{P_o, WT}$$

FRT Method III - Active Current Reduction

Work principle of active current reduction method

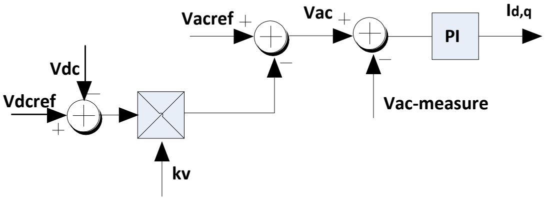
The WT output power is blocked via wind turbine ACGSC controller using a reduction factor. The reduction factor decreases linearly as the voltage increases up to an specific upper limit.



FRT Method IV - Offshore Voltage Reduction

Work principle of offshore voltage reduction

This method calculates the required droop by measuring the dc voltage at the offshore converter, so it is a communication-less scheme with a fast response.



$$V_{ac} = V_{ac_{ref}} - k_v(V_{dc_{ref}} - V_{dc})$$

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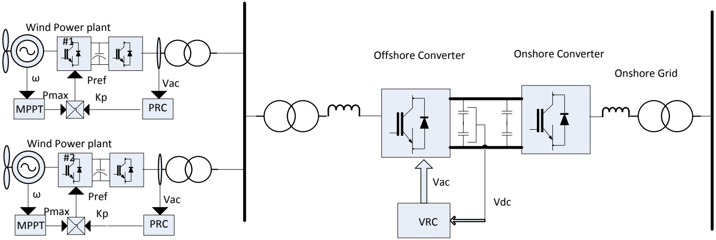
Proposed method FRT

Work principle of the proposed method

When a fault occurs, the dc voltage at the offshore converter will increase. This signal activates the offshore converter controller to control offshore ac voltage magnitude, implemented by block VRC.



$$V_{ac} = V_{ac_{ref}} - k_v (V_{dc_{ref}} - V_{dc}) \qquad K_p = \frac{V_{reduce}}{V_{rated}}$$

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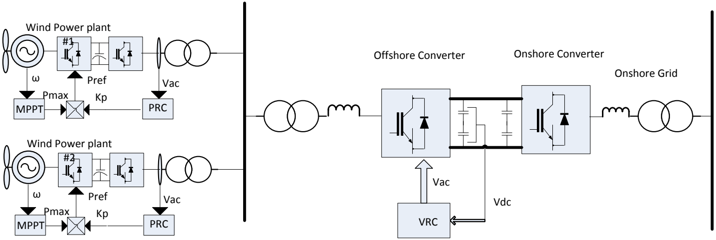
Proposed method FRT

Work principle of the proposed method

At the same time, wind turbines detect the offshore ac voltage magnitude reduction. Accordingly, a power droop factor is generated and sent to GSC to de-load active power.



$$V_{ac} = V_{ac_{ref}} - k_v(V_{dc_{ref}} - V_{dc}) \qquad K_p = \frac{V_{reduce}}{V_{rated}}$$

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Proposed FRT Method

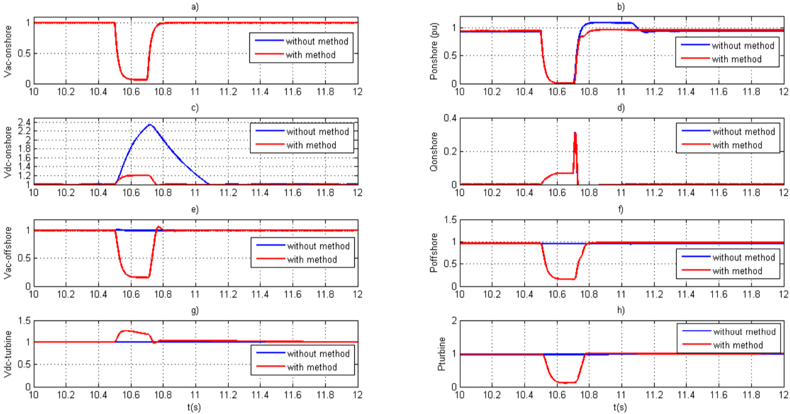

Figure : a)onshore ac voltage b)onshore active power c) onshore dc voltage d)onshore reactive power e) offshore ac voltage f)offshore active power g) dc-link WF h)active power turbine

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FRT Methods - Summary

	Fault ride through is achieve by	Advantages	Disadvantage
Chopper resistor	External resistor	Straight forward	Extra investment
Power setpoint adjustment	Signal to GSC and reducing wind turbines power	WF controller modification	Communication delay and rely on reliability of communication
Active current control	Signal to ACGSC and reducing wind turbines power	WF controller modification	Communication delay and electrical stress
Offshore voltage reduction	Decreasing offshore grid voltage and blocking output power from OWF	No communication delay, very fast reduction of OWFs power	Electrical stress on wind turbine drive train
Proposed method	Decreasing offshore grid voltage and reducing the output power form each wind turbine	No communication delay, very fast reduction of OWFs output power, no electrical stress	The performance of this method is affected by the measurement of OWF voltage.

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Conclusion

This paper proposed a FRT method for VSC-HVDC connected OWF system. There are some advantages compared with the described methods:

- The power reduction factor is generated by wind turbine itselft, so the communication delay is eliminated.
- This proposed method combines offshore voltage reduction method and wind turbine power set-point reduction method, so the dc voltage increase in back-to-back converter is reduced. Additionally, the electric stress on wind turbine is reduced.

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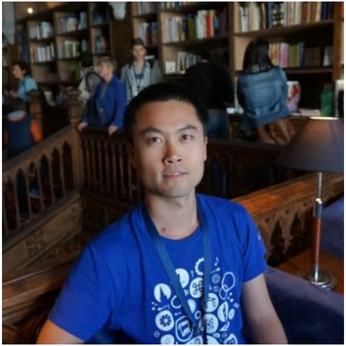

- This work was developed by Wenye Sun in his master thesis
- The European Wind Energy Master consortium is composed of four world leading universities in wind energy and offshore wind energy research and education: Delft university, DTU, NTNU and Carl von Ossietzky Universitt Oldenburg.
- Currently, Wenye Sun works for ABB, China.

Thank You

Questions?