Negative Sequence Controllers to Reduce Power Oscillations During Electric Faults in the Offshore Wind Power Grid

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Main Objectives:
To reduce the power oscillations and subsequent dc voltage oscillations in the VSC-HVDC transmission connecting an offshore wind power plant to an onshore grid.

► To develop a PSCAD/EMTDC simulation model of an offshore WPP with VSC-HVDC connection to the onshore grid.
► To simulate the symmetrical and asymmetrical faults in the offshore grid and study the oscillations in the VSC-HVDC transmission system.
► To estimate the content of positive and negative sequence voltage and current components in real time using DSOGI filters.
► To propose a negative sequence current control algorithm and compare the results with the negative sequence voltage control algorithm.

System Layout and Single Line Diagram
A 400MW offshore wind power plant has been modeled as 4 aggregated wind turbines with full scale converters. VSC-HVDC transmission connects the offshore grid to the onshore grid.

VSC-HVDC Controllers
Onshore VSC Controller: Control of dc voltage and reactive power or ac voltage measured at the point of common coupling.

Offshore VSC Controller: Control of offshore grid terminal ac voltage and frequency.

Negative Sequence Controller (for offshore VSC Controller)
Negative Sequence Voltage Control: Negative sequence voltage references in the d and q axes are set to 0. The outer PI controller generates the negative sequence current references.

Negative Sequence Current Control: Negative sequence current references in the α and β axes are solved from the equations given below, in the stationary reference frame:

\[ V_{\alpha + \beta} + V_{\beta - \alpha} + V_{\alpha + \beta} + V_{\beta - \alpha} = 0 \]

The –ve sequence current references are transformed into the d-q axes components before applying to the controller.

Fault Simulations and Comparison of the Controller Performance
Electrical faults of both symmetric (LLLG & LLL) and asymmetric (LG, LLG & LLL) types were simulated at points A/B/C (shown in the layout).

Fault resistance of magnitude 0.10 pu and duration 150ms was used. DC voltage at the onshore VSC-HVDC terminal, power evacuated from the offshore grid and power injected into the onshore grid have been shown below for some selected cases.

Conclusion
► Negative sequence current controller is effective in decreasing the power and voltage oscillations in the VSC-HVDC system.
► Even in the case of symmetric faults, the peak overvoltage arising out of sudden power unbalance is reduced.
► However, the power and voltage oscillations could not be eliminated completely.