Control System of Voltage Source Converter to Interconnect Offshore AC Hub With Multiple Onshore Grids

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I- Introduction

This paper presents the control scheme of voltage source converter to establish an offshore AC hub to integrate several wind power plants at multiple onshore grids. Offshore AC hub can be formulated by connecting offshore wind power plants that are within the vicinity of 20 km from each other and far from shore. In this research, reference frequency and voltage of the offshore network are controlled by three voltage source converters. Droop control system is designed to share power among the converters. A power flow algorithm is developed to determine the required droop gains according to the contribution factor of each converter to share power. Vector control method is used for developing voltage source converter control system. For design verification, system is modelled and simulated in MATLAB/Simulink.

II- System Architecture

- Control of offshore network frequency through more than one converter
- Multiple slack sources in the offshore network
- Reactive power management by controlling reference voltage at multiple terminal through VSC
- Power balancing principle is similar to network having synchronous machine
  - Frequency control → Active power
  - Voltage control → Reactive Power

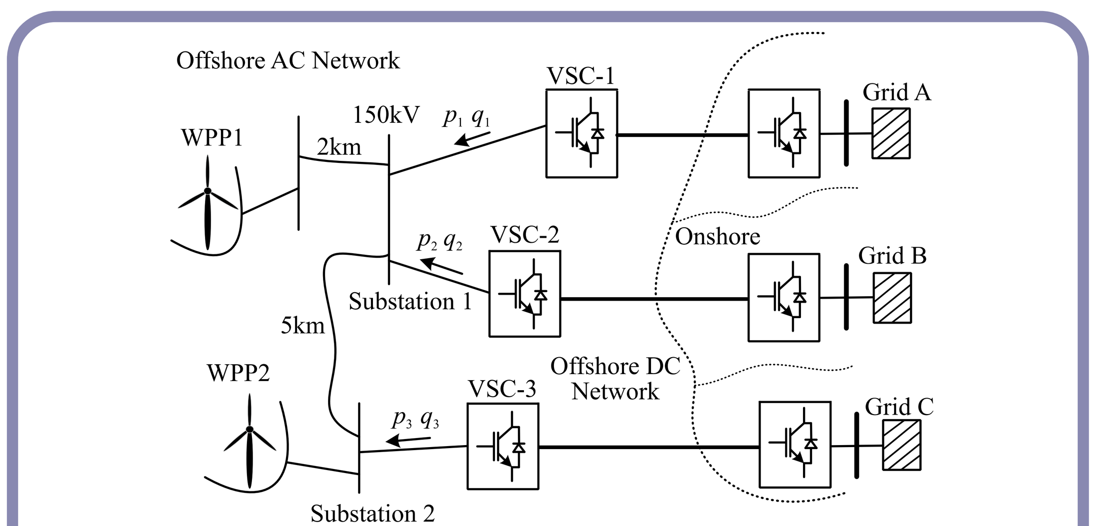


Figure 1. Configuration of offshore AC network to integrate wind power plants using VSC-HVDC system at several onshore grids

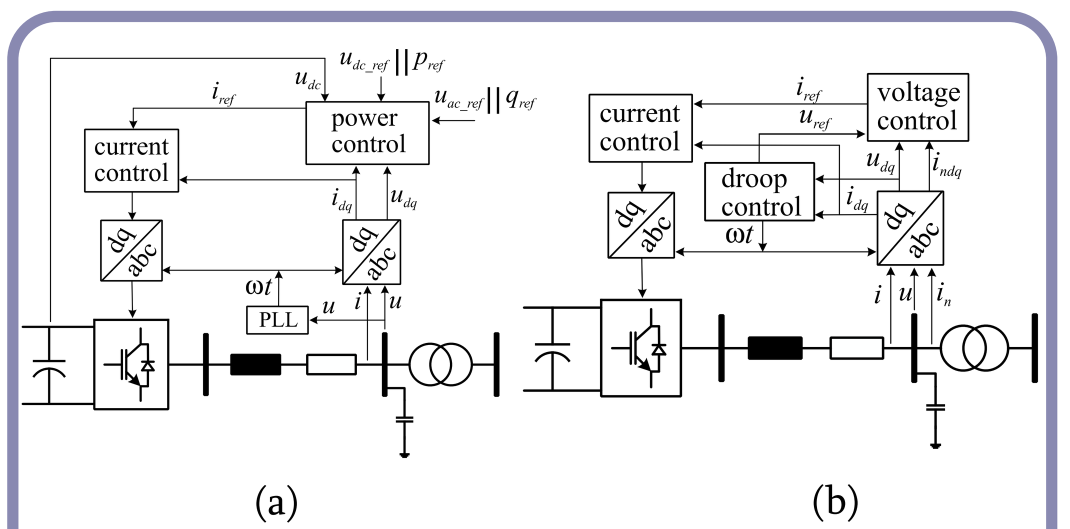


Figure 2. Converter control block diagram, (a) onshore side converter, and (b) offshore side converter

III- Simulation and Analysis

$$\omega_1 = \omega_0 - k_{f1}p_1 \qquad u_1 = u_0 + k_{u1}q_1$$
$$\omega_2 = \omega_0 - k_{f2}p_2 \qquad u_2 = u_0 + k_{u2}q_2$$
$$\omega_3 = \omega_0 - k_{f3}p_3 \qquad u_3 = u_0 + k_{u3}q_3$$

$$\omega = \omega_0 - \frac{k_{f1}k_{f2}k_{f3}}{k_{f1}k_{f2} + k_{f1}k_{f3} + k_{f2}k_{f3}}$$

$$\Delta\omega = \omega_0 - \omega = k_{f1}p_1 = k_{f2}p_2 = k_{f3}p_3$$

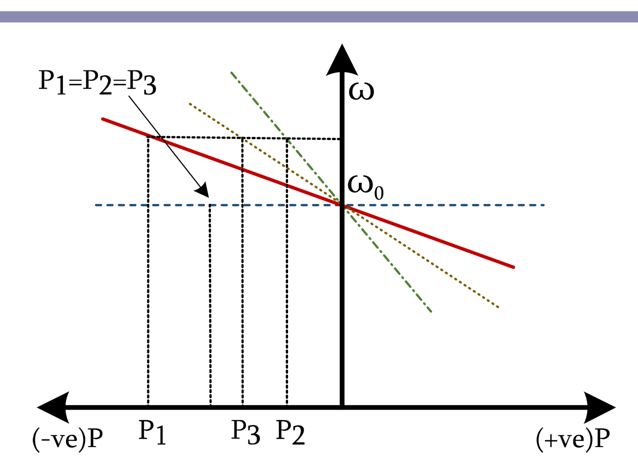


Figure 3. Frequency droop for sharing active power among converters

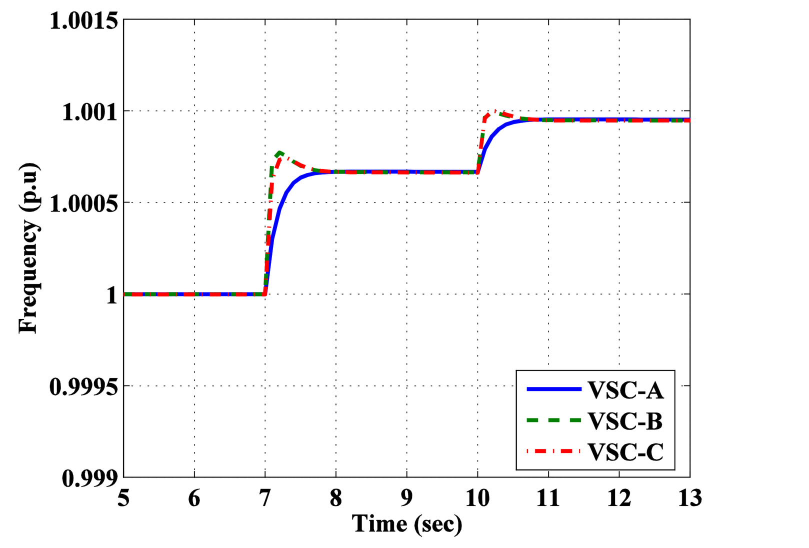
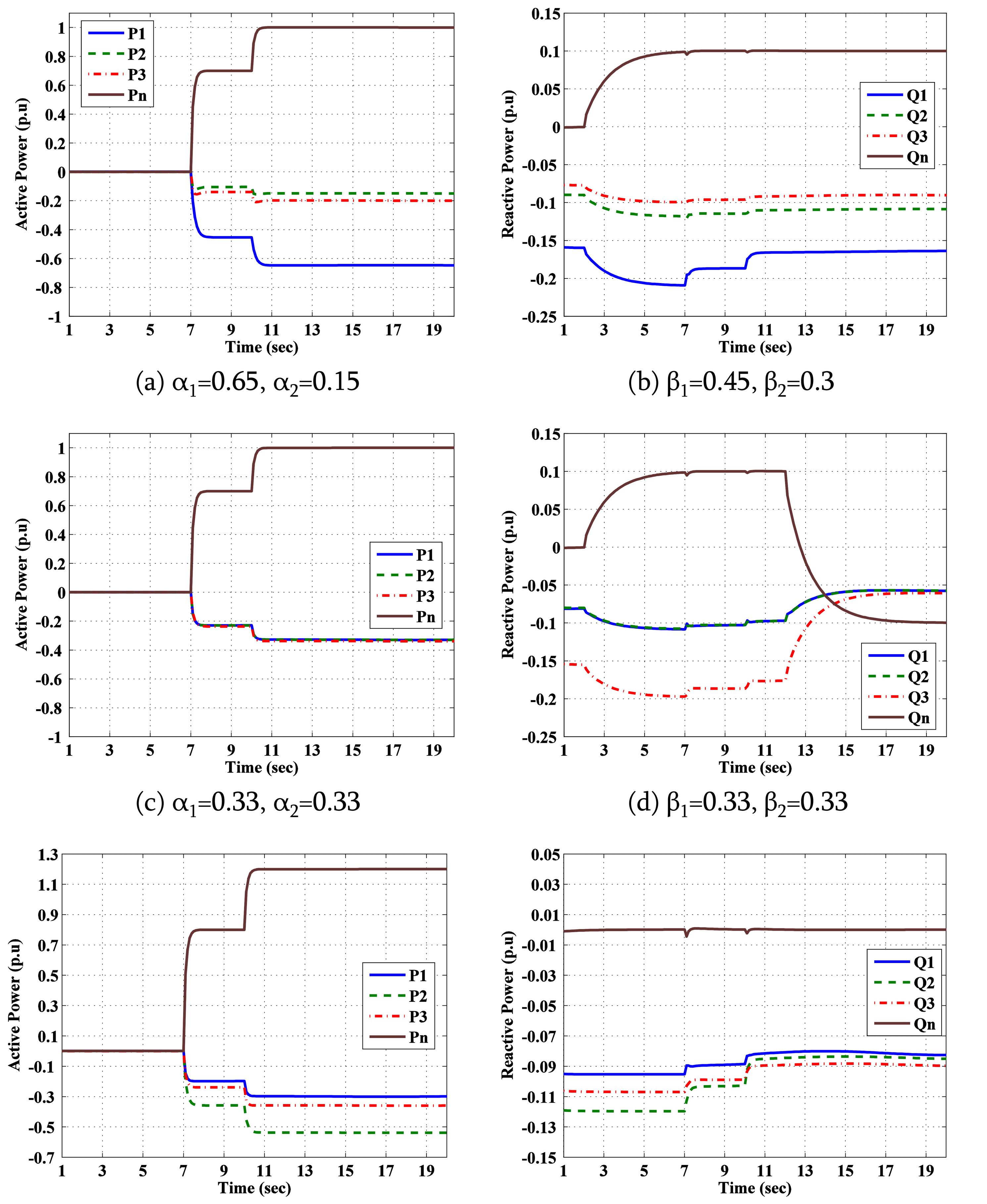


Figure 4. Offshore network frequency response at α_1=0.65, α_2=0.15, β_1=0.45, β_2=0.3

$$(1-\beta_1)q_1 - \beta_1(q_2+q_3) = 0$$
$$(1-\beta_2)q_2 - \beta_2(q_1+q_3) = 0$$

$$b_{1n}u_n k_{u1}q_1 + b_{2n}u_n k_{u2}q_2 + b_{3m}u_m k_{u3}q_3 = 0$$



(a) α_1=0.65, α_2=0.15 (b) β_1=0.45, β_2=0.3

(c) α_1=0.33, α_2=0.33 (d) β_1=0.33, β_2=0.33

(e) α_1=0.25, α_2=0.45 (f) β_1=0.32, β_2=0.33

Figure 5. Active and reactive power response of voltage source converters at different power sharing factor

IV- Conclusion

- The presented control scheme can be employed to connect large offshore wind power plant with multiple onshore grid, hereby, easing the trade between countries and reduce the stress on the international interconnectors
- In contrast with the multi-terminal HVDC transmission system, the presented configuration do not require DC circuit breaker, and the protection can be done via AC circuit breaker.
- Power sharing among converters is achieved without communication
- Offshore AC hub capacity could be higher than a single VSC-HVDC capacity
- Frequency can be used as a signal for the wind farms to reduce the power generation in case of faults

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