PARIS 2022
Study Committee C1
Power System Development and Economics
Paper 10811_2022

Combined HVDC System Approach for Offshore Wind Power Integration and Interconnection

Y. Jiang Hafner, S. S, S. R. Choudhury
Hitachi Energy

Motivation

- multi-terminal (MT) HVDC systems are emerging as a viable solution to integrate large OWFs
- the interconnection of OWFs increases system flexibility and functionality

Method/Approach

- The simulations are performed in PSCAD EMTDC

System Description

. HVDC Link 1 and 2 shown in Figure 1-a represent state-of-art solutions for offshore wind power integration. By adding interconnecting cables and few DC switch equipment in the offshore stations, there two independent HVDC links will be interconnected and formulate a MTDC with increased flexibility and functionality

. Another possible scenario is that there exists one interconnector as shown in Figure1-b. Due to the change of power generations and consumptions, the power transmission between the two inter-connected areas become less demanding. In this case, the existing HVDC cable and onshore converters may be effectively utilized for offshore wind power integration by adding two offshore stations

Figure 1-a. Interconnect two HVDC Links

Figure 1-b: Adding two wind farms and two HVDC converters

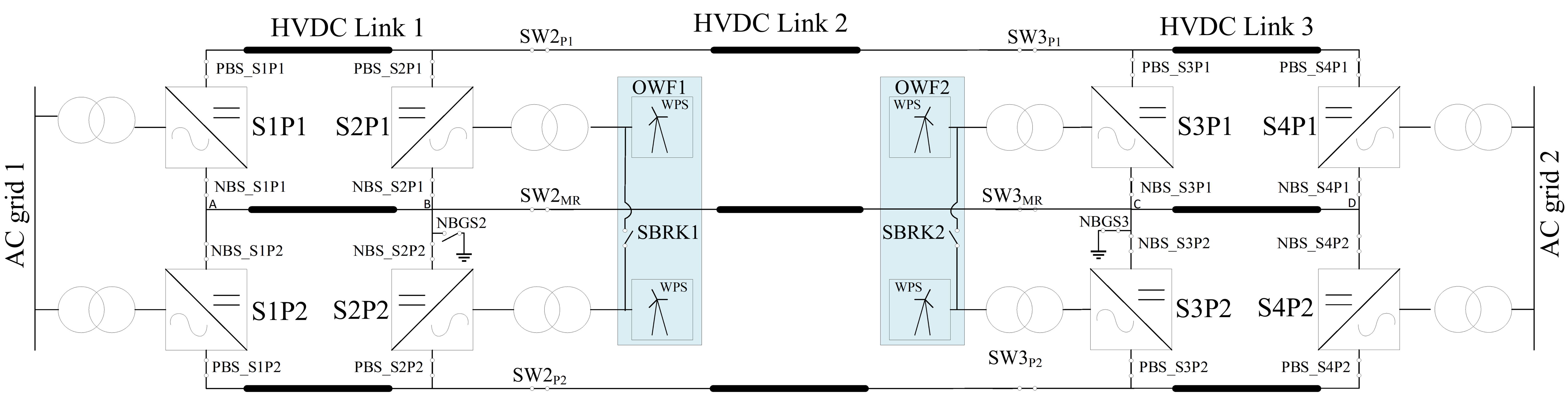

Figure 2. Bi-polar four terminal configuration for HVDC system

CM	Station 1		Station 2		Station 3		Station 4	
	S1P1	S1P2	S2P1	S2P2	S3P1	S3P2	S4P1	S4P2
(a)	U_{DC}	U_{DC}	FV	FV	FV	FV	P	P
	P	P	FV	FV	FV	FV	U_{DC}	U_{DC}
(b)	U_{DC}	U_{DC}	FV	FV	FV	FV	U_{DC}	U_{DC}

Table 1: Possible control modes for various converter stations
(a) MTDC
(b) Separate Bipolar configuration

http://www.cigre.org

Combined HVDC System Approach for Offshore Wind Power Integration and Interconnection
Continued

Performance nder diffrent disturbances

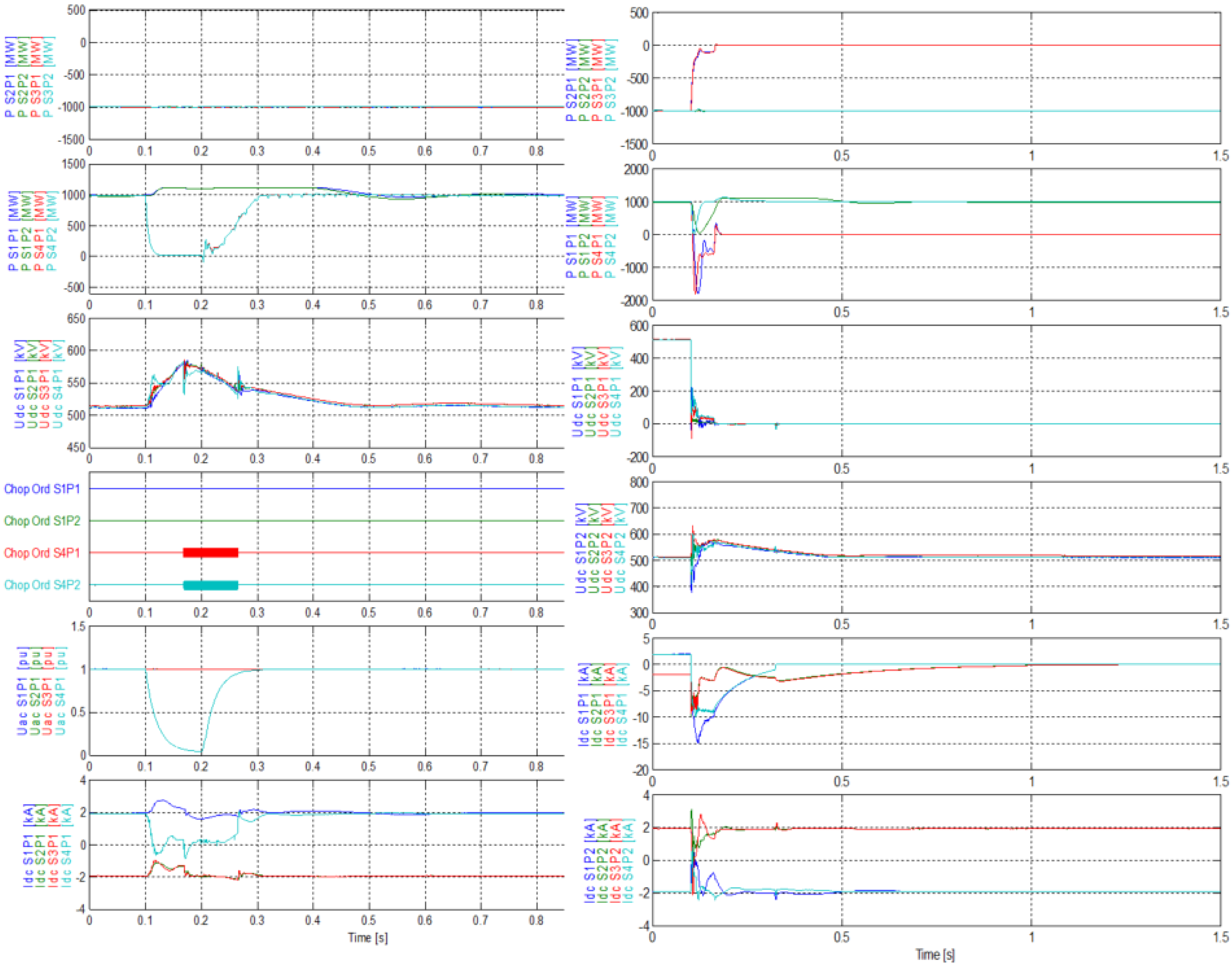

Figure 3: Left side: AC Fault at AC system 2; Right side: DC pole cable fault
(1) Active power at PCC of each offshore converter;
(2) Active power at PCC of each onshore converter;
(3) Positive pole voltage;
(4) left: Chopper order signal for each onshore converter; right: Negative pole voltage;
(5) left: Grid voltages at PCC for all stations in per unit, right: DC line current for positive pole converters;
(6) left: DC line current for positive pole converters; right: DC line current for negative pole converters

PARIS 2022

Study Committee C1

Power System Development and Economics

Paper 10811_2022

Combined HVDC System Approach for Offshore Wind Power Integration and Interconnection Continued

Functions for enhance onshore grid resilience

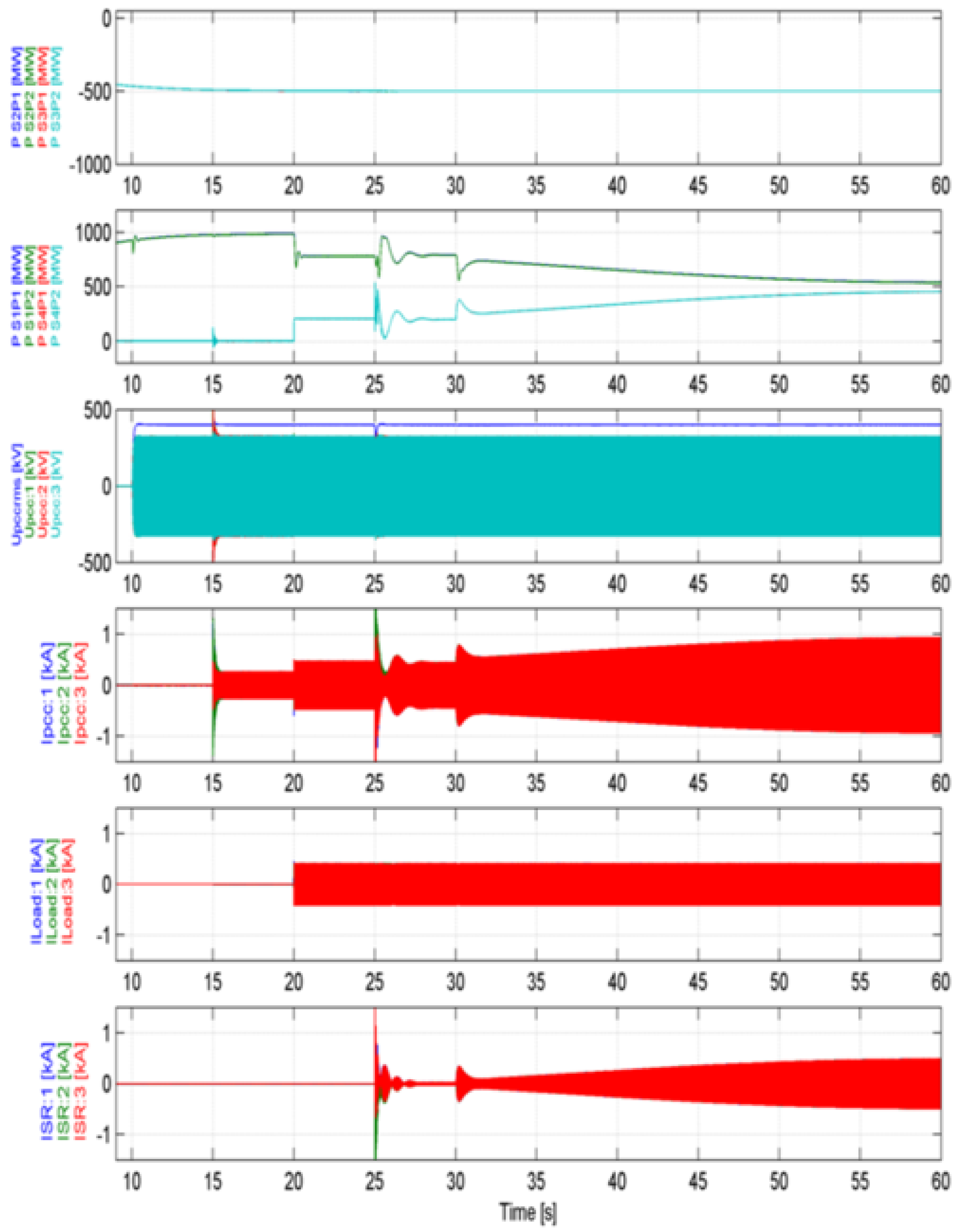

Figure 5: Black start AC grid 2
(1) Active power at PCC of each offshore converter;
(2) Active power at PCC each onshore converter;
(3) S4P1 PCC voltage
(4) S4P1 PCC current
(5) Current on load connected to S4P1 restored ac grid
(6) Current on generator connected to S4P1 restored AC grid

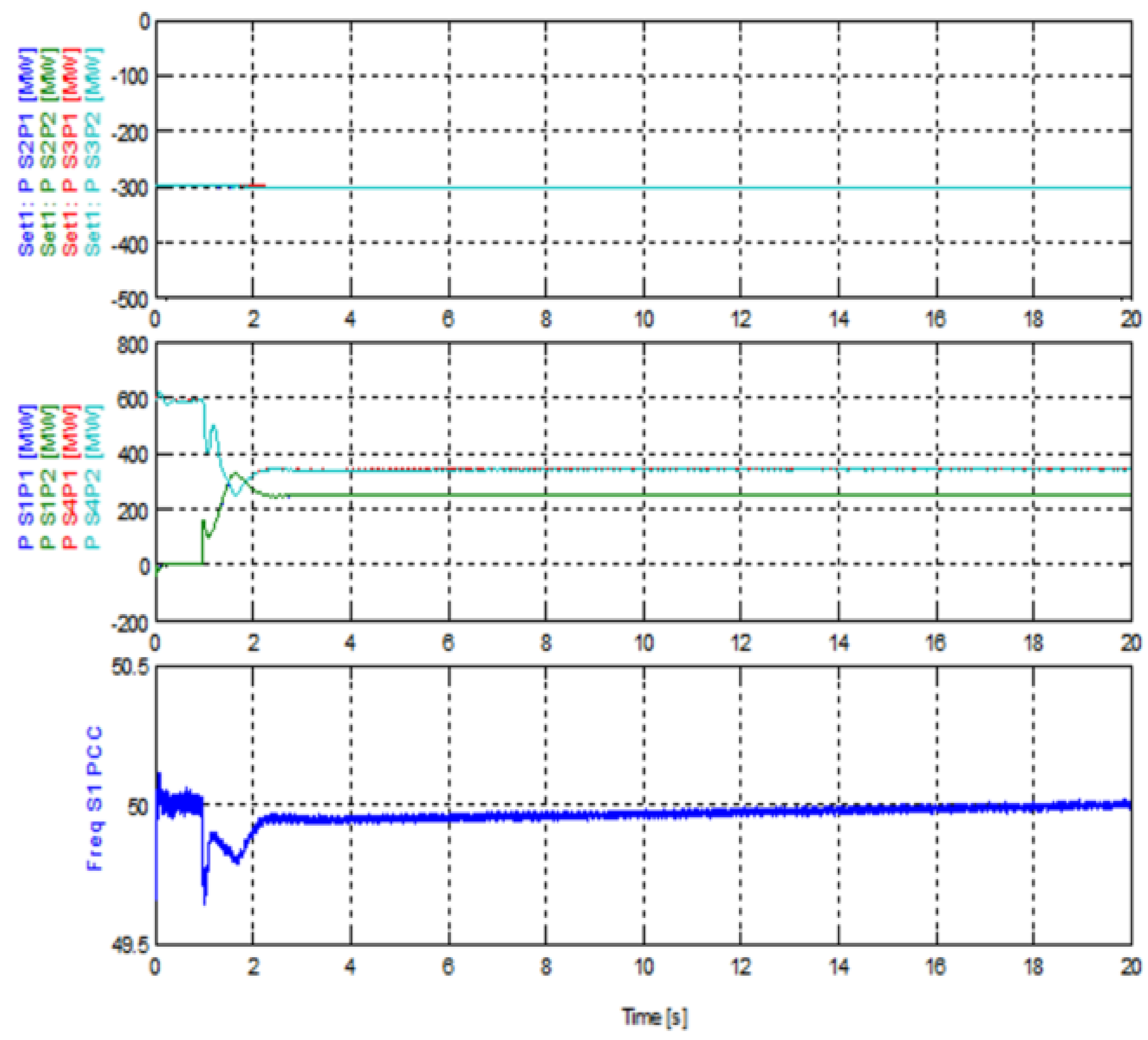

Figure 6: support AC grid 1 frequency control
(1) Active power at PCC of each offshore converter, (2) Active power at PCC of each onshore converter, (3) Frequency in AC grid 1

- Permanently shutting down one onshore or offshore converter may not affect the operation of offshore wind power generations depending on the total wind power level, which shows a clear advantage compared with standard point-to-point offshore wind integration.
- A cable fault on the neutral conductor will not affect the MT HVDC system operation. A cable fault on the pole conductor requires temporary outage of the respective pole in order to isolate the fault.
- The connection between the two offshore stations (S2 and S3) creates the interconnection between two AC grids, which makes it possible for the respective onshore station to perform black start and frequency support.
- In general, the paper shows that the four terminal HVDC system based on connecting two PtP HVDC links for offshore wind power integrations can not only increase the availability of wind power but also increase the functionalities/capability such as black start one onshore grid; providing frequency control on one onshore grid. Considering that severe disturbances seldom occur at the same time in both AC grids, the increased functionalities will significantly increase both AC grids resilience without significantly cost increase compared with the two PtP HVDC links

Conclusion

- A four terminal HVDC system based on the connection of two HVDC Links built for integrating offshore wind powers has been studied in this paper. By simulation in PSCAD/EMTDC with detailed main circuit and control as real systems it is demonstrated that this small multi-terminal HVDC system still maintains the power flow control flexibility as one HVDC inter-connector, while maximizing the availability of offshore windpower.
- It is shown by simulation that with suitable chopper design and control, an AC fault in one onshore grid will hardly affect the operation of all other stations.