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A Cooperative Control Strategy for AC Fault Ride Through of Offshore Wind Power Based on AC Voltage Fluctuation

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Aiming at the problem of low voltage ride through of offshore wind power through flexible direct transmission systems, a cooperative control strategy for AC fault ride through of offshore wind power based on AC voltage fluctuations is proposed, which monitors the AC voltage changes of onshore receiving converter stations in real time. When the bus voltage decreases due to AC faults, the reactive power control strategy of onshore receiving converter stations immediately adjusts the reactive power setting value, and the flexible direct system generates additional reactive power to maintain the AC bus voltage amplitude; At the same time, according to the low-voltage voltage limiting control strategy, the voltage amplitude of the AC bus of the offshore converter station is adjusted in real time, combined with the unique low voltage ride through capability of wind turbines, to achieve preliminary power balance of the flexible DC system. When the voltage amplitude of the AC bus of the offshore converter station is set to the low voltage ride through limit of the offshore wind turbine, the energy consumption resistor device is put into use to absorb the excess active power that cannot be balanced by the flexible and straight system, and achieve AC fault ride through of the system.

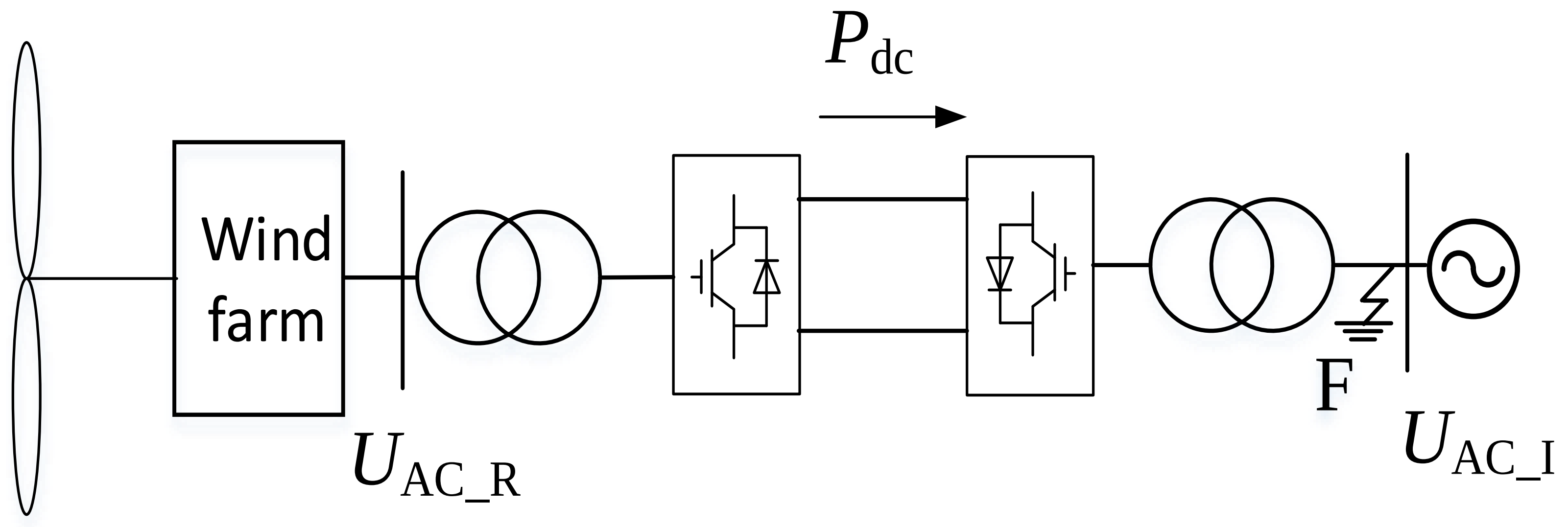
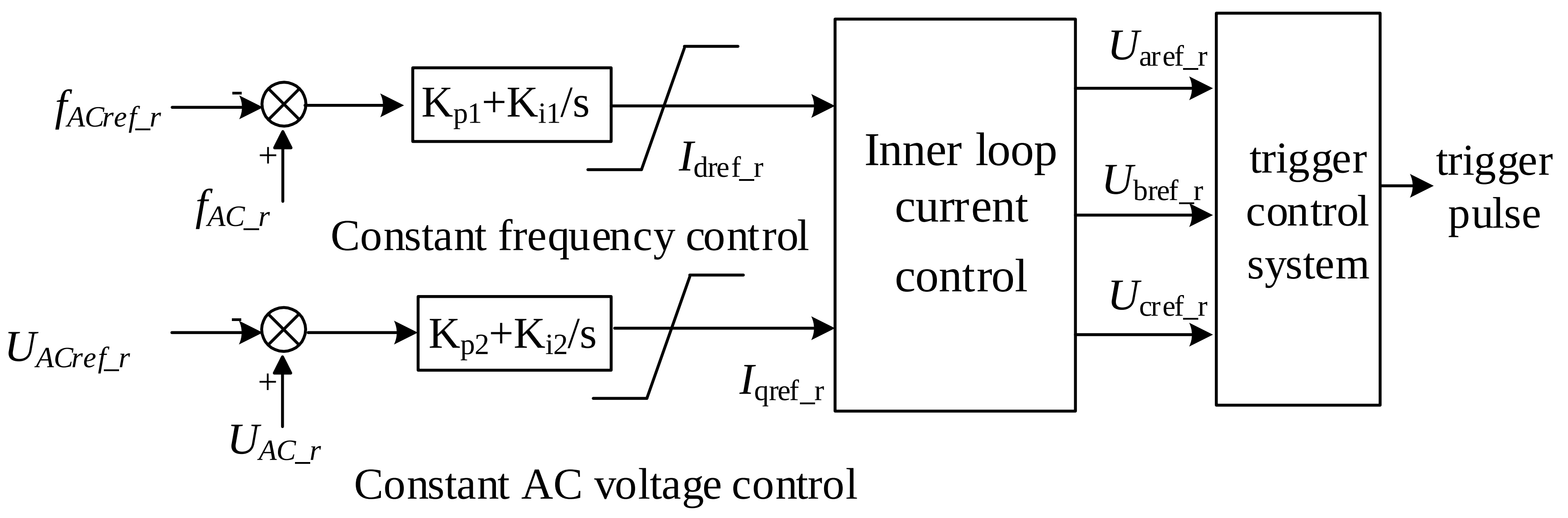
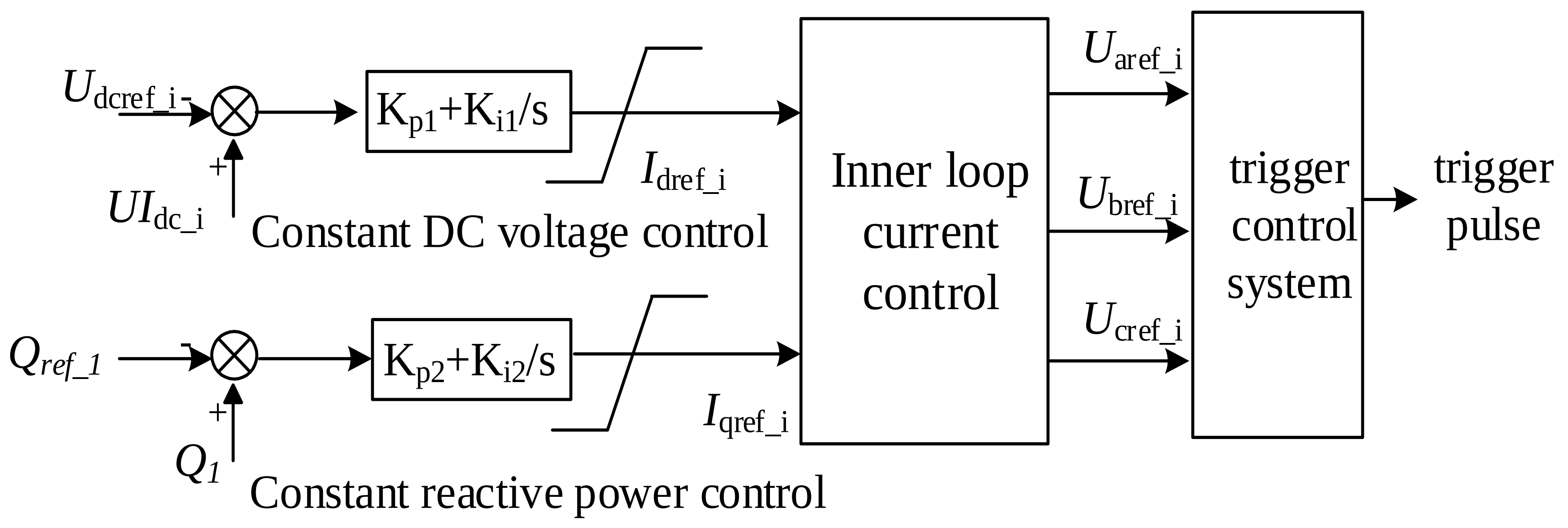


Fig. 1: Flexible DC Transmission System of Offshore Wind Power



（a） Offshore converter station



（b） Onshore converter station

Figure 2: Basic Control Strategy

ΔU represents the voltage fluctuation of the AC system, ΔQ is the reactive power exchanged between the DC system and the AC system, and $S_{SC\min}$ is the minimum short-circuit capacity of the AC system.

$$\Delta U = \frac{\Delta Q}{S_{SC\min} - \Delta Q} \bullet 100\%$$

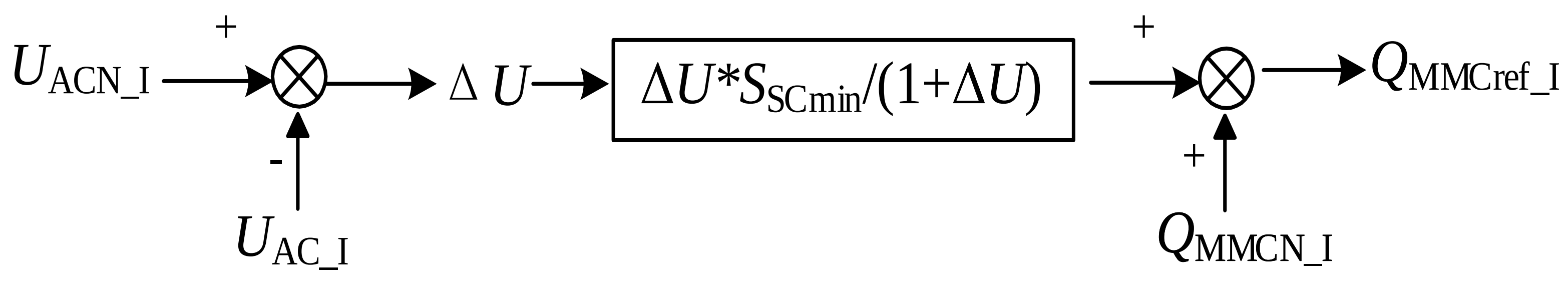


Fig. 3: Fixed Reactive Power Correction Control of Onshore Receiving Converter Station

The low-voltage voltage limiting control block diagram is shown in Figure 4, which monitors the AC bus voltage of the onshore receiving end converter station in real time, applies its variation to the low-voltage voltage limiting link, and limits the AC bus voltage of the offshore sending end. In order to not affect the rated value of the system during steady-state operation, the low-voltage voltage limiting output value is compared to the rated value, and the set value of the AC bus voltage of the offshore sending end converter station is determined.

$$K = \frac{\Delta U}{U_{ACN\_I}}$$

$$U_{ACN1\_R} = 1\text{-}KU_{ACN\_R}$$

In order to quickly respond to changes in the AC bus voltage of the onshore receiving end converter station, the slope K of the flexible AC system submodule capacitor energy storage speed can be segmented and adjusted to control the response speed.

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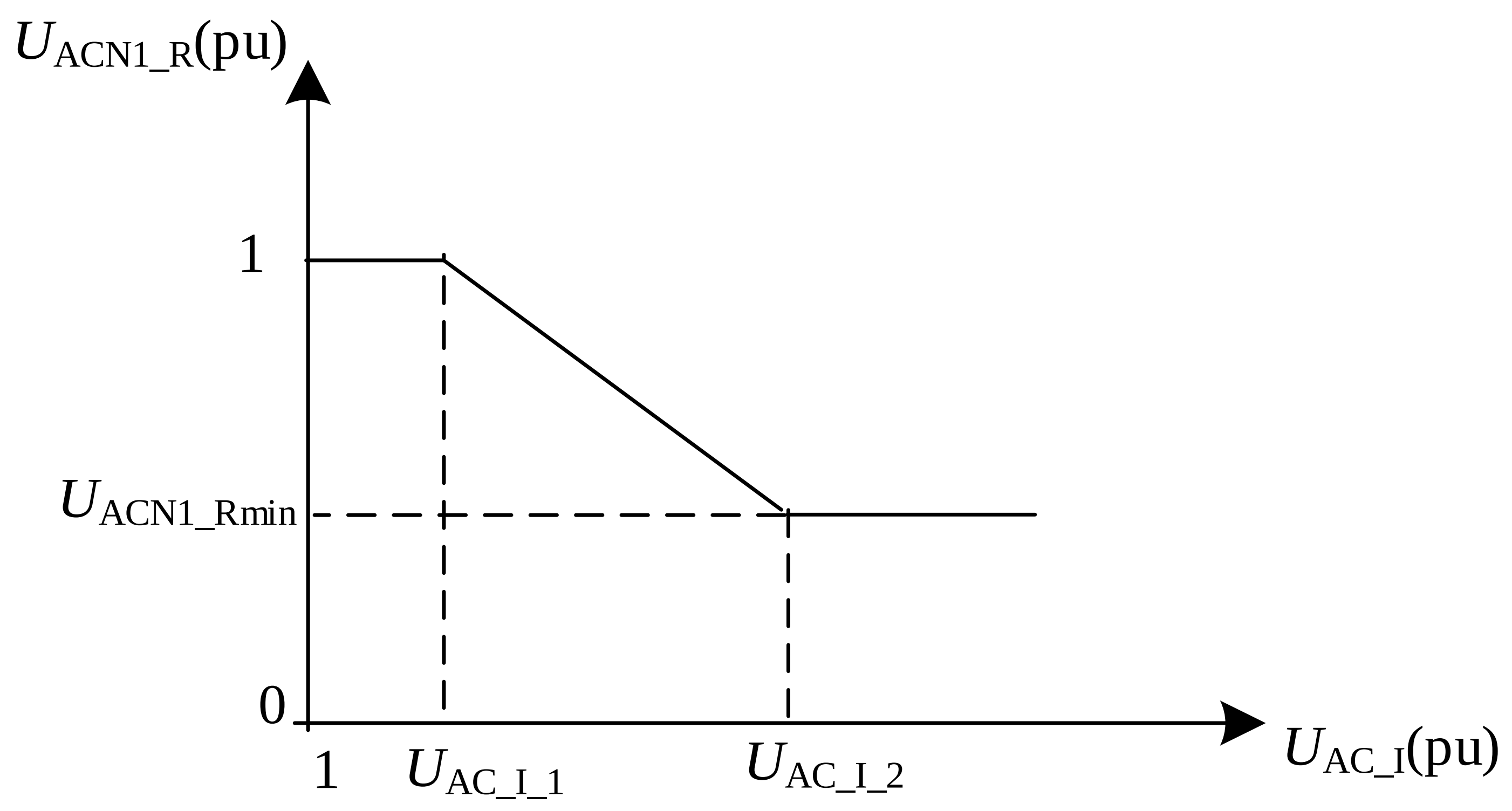

Fig.4: Low Voltage Limiting Control of Offshore Converter Station

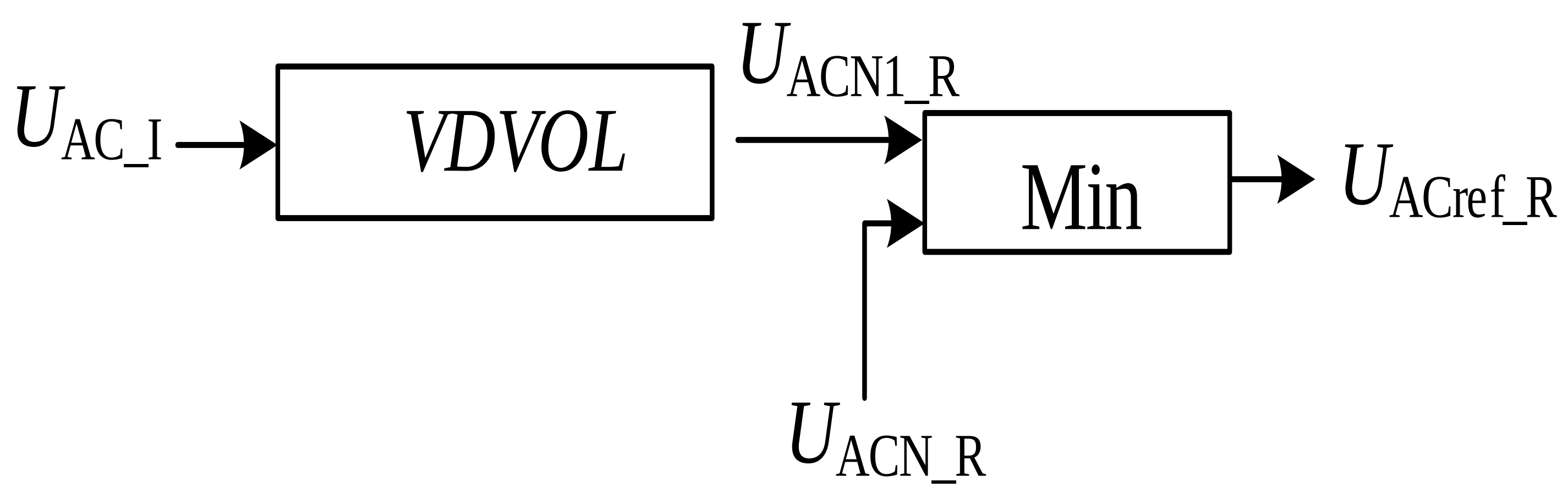

Fig.5 : Low Voltage Limiting Control of AC Bus Voltage in Offshore Converter Station

Based on the PSCAD/EMTDC simulation platform, a true bipolar flexible and straight system simulation model is built as shown in the figure. The system parameters are shown in the table

Parameters	offshore	onshore
U_{dc}（kV）	500	500
P_{dc}（MW）	1500	1500
Submodule capacitance value（mF）	9	9
Submodule number	468	468
ICBT Parameter（kV/kA）	4.5/3	4.5/3
Bridge arm reactor L_C（mH）	120	120
capacity of transformer（MVA）	2×850MVA	3×570MVA
Transformer short-circuit impedance（pu）	0.16	0.14
Rated voltage on the grid side of the trans-former（kV）	66	525
Rated voltage on the valve side of the trans-former（kV）	290.9	290.9

Table 1 : Parameters of DC Electric Power Transmission

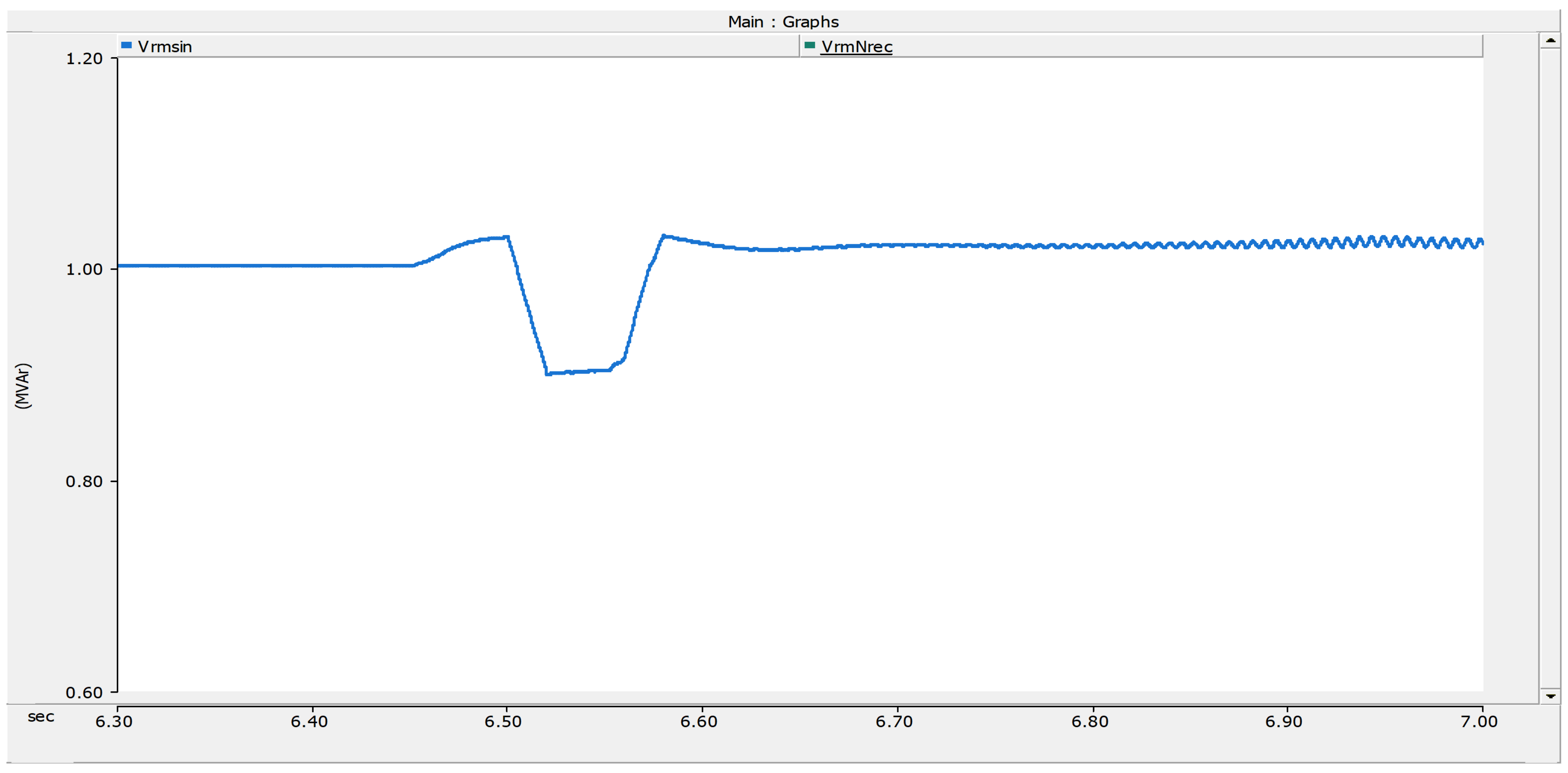

Fig.6： Simulation Waveform of Offshore

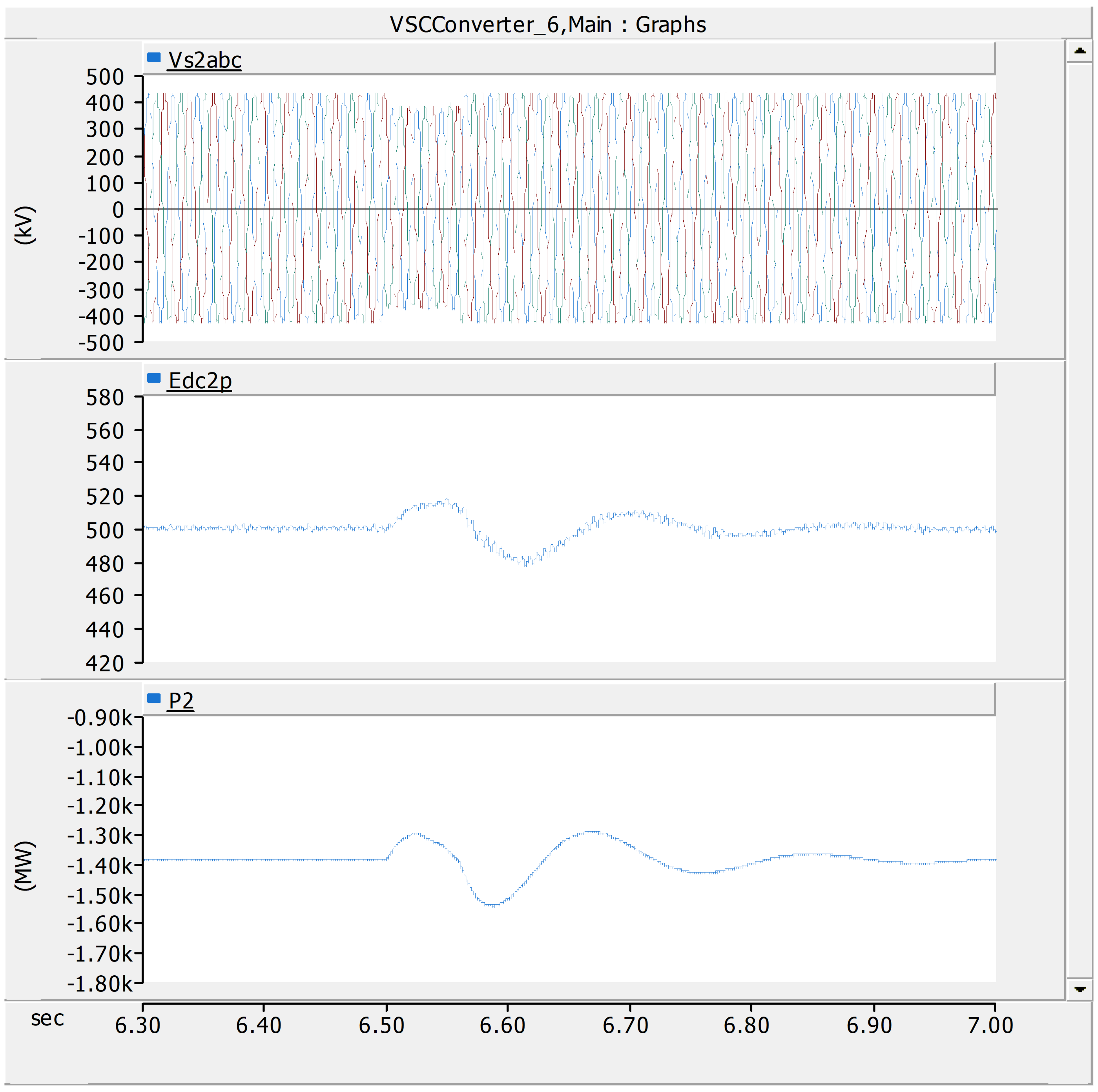

Fig.7 Simulation Waveform of Onshore

This method is based on the basic control strategy of the offshore wind power transmission system through flexible DC, and adds a low-voltage voltage limiting control and fixed reactive power correction strategy. It fully utilizes the low voltage ride through capability of the offshore wind turbine unit and the reactive voltage support capability of the flexible DC transmission system. Combined with the energy consumption resistor, it does not require fault detection, reduces the loss of the energy consumption resistor and its design parameter requirements. When the AC system at the onshore receiving end converter station fails, It can adjust the system power balance as much as possible and at the maximum speed per hour to ensure the safe and stable transmission of offshore wind power through flexible DC.