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A Robust Control Strategy to Improve Transient Stability for AC-DC Interconnected Power System with Wind Farms

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***Abstract*—In view of the variable parameters that affect the transient stability of electromagnetic torque and mechanical torque balance in AC-DC system, and the uncertainty of wind power in large-scale interconnection of wind farm. This paper proposes a linear parameter varying (LPV) robust feedback control method for transient stability of interconnected systems. The proposed LPV robust feedback control method uses the DC channel power control and the mechanical power in the interconnected system as the control target to improve the transient stability of the interconnected system with wind farm channel. Firstly, aiming at the strong nonlinear characteristics of the interconnected system, the power balance and the wind power output uncertainty in the transient process, the transient process is designed as a linear model of variable parameters. Then, the H∞ robust output feedback controller is designed according to the LPV model. The transient stability control strategy topology and transfer function of the interconnected system are proposed. Finally, the proposed scheme is verified by an interconnected system formed by four equal-value grids through AC and DC lines in a digital simulation platform. The results show that the LPV robust feedback control model proposed in this paper has better response characteristics and transient stability control effects for interconnected systems with wind power weak sending-end system.**

***Index Terms*—AC/DC transmission, interconnected power systems, linear parameter varying, robust control, sending-end system, transient stability, wind power generation.**

I. Introduction

WITH the rapid and efficient implementation of the global energy Internet strategy, the power generation scale and capacity of renewable energy, such as wind power and photovoltaic power in China, are continuously increasing [1], [2]. The rapid construction of wind farm in the western and northern regions and power transmission channels from west to east have enabled the large-scale interconnection of wind power AC-DC transmission channels between Northwest, North China, Northeast and Shandong Power Grids. In such kind of large interconnected power grid, the gird for power sending usually reverses in load and the power-sending in a large scale [3], [4]. However, it may cause stability problems by real power fluctuating when a serious fault or transient processing occurs in a regional weak sending-end system with large-scale wind power sending out. Thus, it is necessary to deeply study the stability characteristics and control mechanism of the delivery system containing large-scale wind power.

The system formed by the interconnection of multiple provincial AC/DC channels puts forward higher requirements for the regulation ability of transient and steady state. And interconnected systems need to have the ability to traverse severe transient transitions. For the voltage stability control in AC and DC systems, domestic and foreign scholars have conducted some researches. Reference [5] simulated the transient stability of large power grids at different time scales based on continuous time domain tracking algorithm. In [6], a transient stability control model based on LPV tracking method for controlling cost minimization target was proposed, which transformed transient stability control problem into sensitivity matrix inequality problem solving problem. For the voltage stability control problem in DC distribution network, a flexible voltage control strategy considering distributed energy storage was proposed to improve the inertial response capability of the DC grid to the AC grid in [7]. For the sending-end system of hydropower clusters, reference [8] proposed an AC-DC voltage-frequency coordinated control strategy to improve system voltage stability and frequency stability.

In addition, in the study of power systems stability, the stability problem of sending-end system by wind and fire combined with multi-terminal AC and DC transmission channels is particularly prominent. And it is necessary to comprehensively consider the control strategies including many safety and stability problems such as transient stability, small disturbance stability and sub-synchronous oscillation [9], [10]. Simultaneously, it is also necessary to solve AC-DC systems, wind power and thermal power coordinated dispatching problem [11], [12]. Currently, there are few studies on the stability of wind-fire combined with sending-end system, especially

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for the study of transient stability control of large-scale wind power access systems [13]–[15]. Among those, reference [14] believes that the fast recovery characteristics of the active crossover and doubly-fed wind turbines with the wind-fire angle curve are not conducive to the stability of the power angle of the system. Reference [15] considers that wind and fire interaction has uncertain wind power.

The AC-DC transmission system has the characteristics of fast response and flexibility, and can improve the transient stability of the AC-DC interconnect system under large disturbances and emergency situations. For the control strategies of AC/DC transmission systems. The software and hardware design of the wide-area damping control strategy was proposed in [16] to verify the effectiveness of improving system stability by simulation analysis in a test platform consisting of multi-machine interconnected power systems. In reference [17], aiming at the traditional power generation unit and multi-terminal high-voltage DC converter unit in the integrated AC/DC grid, an algorithm for adaptively determining the generator droop coefficient was proposed to improve the stability margin of the system under different load conditions. Presently, several typical methods were proposed for the stability study of HVDC converter DC systems, i.e., eigenvalue analysis [18], frequency domain analysis and linear optimal control [19], etc.

In summary, most of the current researches are aimed at large-scale interconnection systems formed by multiple ultra-high-voltage and ultra-high voltage AC/DC transmission channels. There are few transient stability optimization control problems involving multiple provincial large-grid interconnected systems with weak power transmission and high power and high uncertainty wind power.

In this paper, the engineering practice of wind power transmission through multi-terminal AC-DC channel is taken as the research background. An interconnection system LPV model is formed by interconnecting wind power multi-terminal AC and DC channels. By selecting the eigenvalue pair measurement output and error optimization processing, a reduced-order interconnected grid transient robust output feedback controller is obtained. Finally, the four-zone interconnected system model is used as the case study to evaluate the performances of the control strategy. The simulation results show that the proposed control strategy can effectively improve the transient stability of the wind power transmission grid and the entire interconnection system.

II. LPV Model of Interconnected System

The research object of this paper is the stable optimization control problem of transient process of interconnected power grid formed by large-scale wind power transmission via multi-terminal AC-DC channel. When a serious fault occurs in the large-scale interconnected system formed by the wind power transmission channel, the mechanical and electromagnetic power balance characteristics in the power grid can be changed by adjusting the mechanical torque input of hydropower, thermal power and other power sources of each regional power grid in the interconnected system to meet system transient stability requirements. Due to the strong nonlinearity of the transient stability of the interconnected system, the linear control method of the system can only be effective within certain range in the transient process time scale [20]. The output power of the interconnected system exhibits stronger nonlinearity and time-varying characteristics when the mechanical power and electromagnetic power in the interconnected system fluctuate, that is the interconnected system at this time is a variable parameter system.

An LPV state equation for an interconnected large-scale system with large-scale wind power transmission can be expressed as:

$$\begin{bmatrix} \dot{\boldsymbol{x}} \\ \boldsymbol{z} \\ \boldsymbol{y} \end{bmatrix} = \begin{bmatrix} \boldsymbol{A}(\rho) & \boldsymbol{B}_1(\rho) & \boldsymbol{B}_2(\rho) \\ \boldsymbol{C}_1(\rho) & \boldsymbol{D}_{11}(\rho) & \boldsymbol{D}_{12}(\rho) \\ \boldsymbol{C}_2(\rho) & \boldsymbol{D}_{21}(\rho) & \boldsymbol{0} \end{bmatrix} \begin{bmatrix} \boldsymbol{x} \\ \boldsymbol{\omega} \\ \boldsymbol{u} \end{bmatrix} \tag{1}$$

where ρ is the variable parameter of the control systems such as DC triggering angle, wind power output, motor rotor speed and power angle of the interconnected power system; $\boldsymbol{x}$ is the state variable of the interconnected power grid; $\boldsymbol{u}$ is the input variables of regional grid active and reactive power; $\boldsymbol{\omega}$ is the load disturbance in the interconnected system; $\boldsymbol{z}$ is the charged active and reactive output in the system; $\boldsymbol{y}$ is the measured active and reactive output of the interconnected system.

According to the actual engineering situation of the interconnected power system formed by wind power weak sending-end system, the following conditions are satisfied during establishment of the system variable parameter model:

1) Time-varying parameters of the interconnected system and its rate of change is bounded, satisfying $\rho = \beta \in [\bar{\rho}, \rho] = \Theta$ and $\dot{\rho} = \beta \in [\bar{\beta}, \beta] = \dot{\Theta}$.

2) The matrix functions of the state equation of the variable parameter interconnected power system described by (1) are continuous on Θ. Moreover, $\boldsymbol{D}_{12}$ and $\boldsymbol{D}_{21}$ satisfy full column rank and full row rank condition.

III. Transient Robust Output Feedback Control Model of Interconnected Systems

The transient process control of the interconnected system described by (1) in the previous section can be described as (2). During a large disturbance, an LPV controller $\boldsymbol{K}$ can be found as:

$$\begin{cases} \dot{\boldsymbol{x}}_k = \boldsymbol{A}_k(\rho)\boldsymbol{x}_k + \boldsymbol{B}_k(\rho)\boldsymbol{y} \\ \boldsymbol{u} = \boldsymbol{C}_k(\rho)\boldsymbol{x}_k + \boldsymbol{D}_k(\rho)\boldsymbol{y} \end{cases} \tag{2}$$

The controller $\boldsymbol{K}$ is capable of stabilizing the system of (1), while minimizing the H_∞ performance index γ of the system.

The necessary and sufficient conditions for the existence of the interconnected system transient stability linear parameter-varying robust output feedback optimal controller $\boldsymbol{K}$ is the existence of parameter-dependent symmetric positive definite matrix $\boldsymbol{R}$ and $\boldsymbol{S}$, which causes the following linear matrix inequality.

$$\begin{cases} \begin{bmatrix} \boldsymbol{N}_{\mathrm{S}} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{I} \end{bmatrix} \begin{bmatrix} \boldsymbol{A}^{\mathrm{T}}\boldsymbol{S}+\boldsymbol{S}\boldsymbol{A}+(\mathrm{d}\boldsymbol{S}/\mathrm{d}t) & \boldsymbol{S}\boldsymbol{B}_1 & \boldsymbol{C}_1^{\mathrm{T}} \\ \boldsymbol{B}_1^{\mathrm{T}}\boldsymbol{S} & -\gamma I & \boldsymbol{D}_{11}^{\mathrm{T}} \\ \boldsymbol{C}_1 & \boldsymbol{D}_{11} & -\gamma \boldsymbol{I} \end{bmatrix} \\ \begin{bmatrix} \boldsymbol{N}_{\mathrm{S}} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{I} \end{bmatrix} < \boldsymbol{0} \\ \begin{bmatrix} \boldsymbol{N}_{\mathrm{R}} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{I} \end{bmatrix}^{\mathrm{T}} \begin{bmatrix} \boldsymbol{R}\boldsymbol{A}^{\mathrm{T}}+\boldsymbol{A}\boldsymbol{R}-\dot{\boldsymbol{R}} & \boldsymbol{R}\boldsymbol{C}_1^{\mathrm{T}} & \boldsymbol{B}_1 \\ \boldsymbol{C}_1\boldsymbol{R} & -\gamma \boldsymbol{I} & \boldsymbol{D}_{11} \\ \boldsymbol{B}_1^{\mathrm{T}} & \boldsymbol{D}_{11}^{\mathrm{T}} & -\gamma \boldsymbol{I} \end{bmatrix} \\ \begin{bmatrix} \boldsymbol{N}_{\mathrm{R}} & \boldsymbol{0} \\ 0 & \boldsymbol{I} \end{bmatrix} < \boldsymbol{0} \\ \begin{bmatrix} \boldsymbol{R} & \boldsymbol{I} \\ \boldsymbol{I} & \boldsymbol{S} \end{bmatrix} > \boldsymbol{0} \end{cases} \tag{3}$$

where $\boldsymbol{N}_{\mathrm{S}}$ and $\boldsymbol{N}_{\mathrm{R}}$ are the matrixes with full column rank, and satisfy:

$$\begin{cases} \boldsymbol{N}_{\mathrm{S}} = \ker\left[\boldsymbol{C}_2 \quad \boldsymbol{D}_{21}\right] \\ \boldsymbol{N}_{\mathrm{R}} = \ker\left[\boldsymbol{B}_2^{\mathrm{T}} \quad \boldsymbol{D}_{12}^{\mathrm{T}}\right] \end{cases} \tag{4}$$

$\boldsymbol{D}_k$ can be solved by solving the matrix inequality in (3), and other control matrix $\boldsymbol{A}_k$, $\boldsymbol{B}_k$, $\boldsymbol{C}_k$, $\boldsymbol{D}_k$ can be reached by solving the matrix equation. In the large disturbances process of the interconnected system, due to the small-time scale [21] of the electromagnetic transient process, a robust transient stability controller can be constructed to avoid solving matrix inequalities and matrix equations online. The transient stability controller is in a strictly regular form, i.e., $\boldsymbol{D}_k = \boldsymbol{0}$. Then, based on the constructed transient stability controller, the solution of the matrix equation is further constructed to find other control matrices. The solution steps are as follows:

Step 1: Solve matrix inequality of (3), to reach $\boldsymbol{R}, \boldsymbol{S}$ and γ.

Step 2: With the given real-time variable parameters, real-time parameter variation $\boldsymbol{R}, \boldsymbol{S}$, can be reached and $\boldsymbol{R}, \boldsymbol{S}$ satisfy the following equation:

$$\begin{aligned} \boldsymbol{A}_k = -\boldsymbol{N}^{-1}\Big\{ & \boldsymbol{A}^{\mathrm{T}} - \boldsymbol{S}\frac{\mathrm{d}\boldsymbol{R}}{\mathrm{d}t} - \boldsymbol{N}\left(\frac{\mathrm{d}\boldsymbol{M}}{\mathrm{d}t}\right)^{\mathrm{T}} + \\ & \boldsymbol{S}\left[\boldsymbol{A}+\boldsymbol{B}_2\boldsymbol{F}+\boldsymbol{L}\boldsymbol{C}_2\right]\boldsymbol{R} + \\ & \gamma^{-1}\boldsymbol{S}\left[\boldsymbol{B}_1+\boldsymbol{L}\boldsymbol{D}_{21}\right]\boldsymbol{B}_1^{\mathrm{T}} + \\ & \gamma^{-1}\boldsymbol{C}_1^{\mathrm{T}}\left[\boldsymbol{C}_1+\boldsymbol{D}_{12}\boldsymbol{F}\right]\boldsymbol{R}\Big\}\boldsymbol{M}^{-\mathrm{T}} \end{aligned} \tag{5}$$

In the above:

$$\boldsymbol{D}_k = \boldsymbol{0} \tag{6}$$

$$\boldsymbol{M} = \boldsymbol{R}, \boldsymbol{N} = \boldsymbol{R}^{-1} - \boldsymbol{S} \tag{7}$$

$$\boldsymbol{B}_k = \boldsymbol{N}^{-1}\boldsymbol{S}\boldsymbol{L} \tag{8}$$

$$\boldsymbol{F} = -(\boldsymbol{D}_{12}^{\mathrm{T}}\boldsymbol{D}_{12})^{-1} \times [\gamma \boldsymbol{B}_2^{\mathrm{T}}\boldsymbol{R}^{-1} + \boldsymbol{D}_{12}^{\mathrm{T}}\boldsymbol{C}_1] \tag{9}$$

$$\boldsymbol{C}_k = \boldsymbol{F}\boldsymbol{R}(\boldsymbol{M})^{-\mathrm{T}} \tag{10}$$

$$\boldsymbol{L} = [\gamma \boldsymbol{S}^{-1}\boldsymbol{C}_2^{\mathrm{T}} + \boldsymbol{B}_1\boldsymbol{D}_{21}^{\mathrm{T}}] \times (\boldsymbol{D}_{21}\boldsymbol{D}_{21}^{\mathrm{T}})^{-1} \tag{11}$$

IV. Transient Stability Control Strategy Under Wind Power Uncertainty

In order to establish an LPV transient control strategy for interconnected systems, an LPV model for transient process of sending-end system during large disturbances process of the interconnected system must be established. Firstly, Jacobi's linearization method [22], [23] is used to linearize several equilibrium points of the nonlinear model during transient process and to obtain a set of linearization model, which is used to approximate the nonlinearity of the interconnected system. If the equilibrium point selection density is enough, the linearization model can accurately express the nonlinear model of the interconnected systems. In this paper, the design point parameter is determined as the power balance θ_{r} (per unit value) of the total active input and output during large disturbances of the interconnected system, and the uncertainty of the total wind power output in the system.

According to the principle of balance control for mechanical power and electromagnetic power in the power system transient process, (0.05, 0.07, 0.09, 0.11, 0.13) is taken for θ_{r} and (0.04, 0.8, 0.12, 0.16, 0.20) is taken for V_{a}.

Through the network partitioning of the transient process of the interconnected system and the linearization of the design point, and considering the range of θ_{r} and V_{a}, N linear models are obtained. The nonlinear model of the transient process of the actual interconnected system can be obtained from the interpolation between linearization models.

When there is a large disturbance in the system and a greater mechanical power input than the electromagnetic power, the system frequency increases. Similarly, when the mechanical power is less than the electromagnetic power, the system frequency decreases. To achieve stable system power from unbalance to rebalance, the transient control target of the interconnected system is set to the fastest power balance speed and the minimum amplitude of the oscillation. The target of the transient control strategy of the interconnected system is shown in Fig. 1.

Those weighting functions are selected according to the following parameters. The control model of the adjustable output power in the interconnected system $\boldsymbol{H}$ is

$$\boldsymbol{H} = \left[\frac{s}{0.05s+1}, \frac{1}{0.05s+1}\right]^{\mathrm{T}} \tag{12}$$

Two delay transfer functions τ_1 and τ_2 for system power control are

$$\tau_1 = \tau_2 = \frac{-0.01s+1}{0.01s+1} \tag{13}$$

The physical meaning indicates that the delay time from the power control command issuing to the change of power supply is 80 ms.

The ideal model for power control based on the system power imbalance is

$$H_{\theta\mathrm{r}} = \frac{5.33}{s^2+3s+5.33} \tag{14}$$

where, $H_{\theta\mathrm{r}}$ is the ideal response of the generator set's output power.

Power tracking error weighting function is

$$W_{\theta\mathrm{e}} = \frac{0.03s+1.97}{2.5s+1} \tag{15}$$

where, $W_{\theta\mathrm{e}}$ is the penalty of system power supply power control to the frequency variation tracking error. The higher

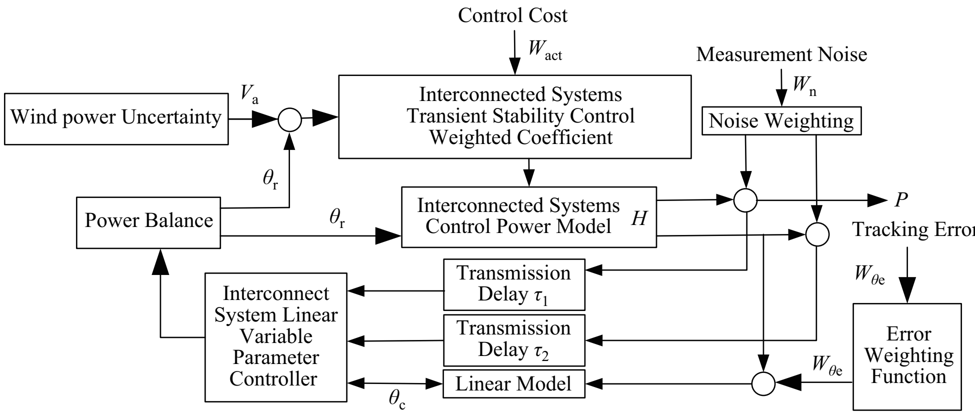

Fig. 1. Structure of transient stability control strategy.

the maximum power angle difference in the system, the higher the penalty is. The control of the cost weighting function is

$$\boldsymbol{W}_{\mathrm{act}} = \begin{bmatrix} 1/15 & 0 \\ 0 & 1/5 \end{bmatrix} \tag{16}$$

where, $\boldsymbol{W}_{\mathrm{act}}$ indicates that the change in system power output is no more than 15%, and the rate of power regulation does not exceed 5%/s.

The measured noise weighting function is

$$\boldsymbol{W}_{\mathrm{n}} = \begin{bmatrix} 0.05 & 0 \\ 0 & 0.01 \end{bmatrix} \tag{17}$$

where, $\boldsymbol{W}_{\mathrm{n}}$ is the noise variance during the measurement of reactive power and active power imbalance q and θ_{r} in the interconnected system.

The different transient states of the interconnected systems are under different power imbalances. To restrain the system transient oscillation as fast as possible, with the transient stability control strategy of the system, the design points of the interconnected system are shown in Table I. The system operating mode is under the rated load condition at this moment.

TABLE I
PARAMETERS SELECTION OF VARIABLE PARAMETERS MODEL POINTS

Parameter	Value (p.u.)				
Power Balance	0.04	0.06	0.08	1.0	1.2
Wind Power Uncertainty	0.05	0.1	0.15	0.20	0.25

With the transient stability control strategy shown in Fig. 1, the design points of the system power balance and the wind power output uncertainty in Table I are selected, and the transient stability controller solving method is used to fix S. The basis function is selected as

$$f(\theta_{\mathrm{r}}, V_{\mathrm{a}}) = \left[1, V_{\mathrm{a}}/120, (V_{\mathrm{a}} - 15)/30, \left[(V_{\mathrm{a}} - 15)/30\right]^2\right] \tag{18}$$

Finally, a matrix inequality group consisting of 41 linear matrix inequalities is obtained. By solving 330 decision variables, the solution is $\gamma = 0.017$ and the closed-loop maximum pole amplitude is 200. The 8^{th} order LPV robust controller is obtained.

V. SIMULATION AND RESULT ANALYSIS

Taking the four-area interconnected power system shown in Fig. 2 as the case study, the LPV-based transient stability robust controller is used to simulate the whole transient process of the interconnected system. G1, G2, G3 and G4 in Fig. 2 are the equivalent parameters of the four regional power grids respectively. G1 is the wind power sending-end system, which is connected to the other three provincial power grids through one DC transmission line and two AC transmission lines.

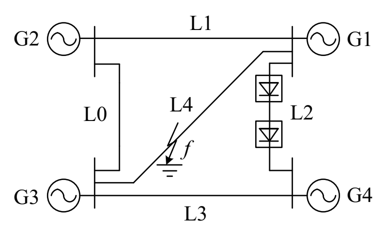

Fig. 2. Four-area interconnected power system structure.

The equivalent load of G2 grid is 1200 MW; the equivalent loads of G1, G3 and G4 grid are all 2400 MW. The grid power of G2 is 2400 MW, of which the wind power is 1000 MW. The grid power of G2, G3 and G4 are respectively 1600 MW, 1600 MW and 1400 MW. Under rated stable operation, the wind power delivered by L1, L2 and L4 are respectively 500 MW, 500 MW and 400 MW.

A. Transient Stability Control Strategy Response Characteristic Simulation Analysis

The system power balance control instructions and power response are shown in Fig. 3. To verify the robustness of the control strategy, an unmolded dynamic process is added during system large disturbances, i.e. adding 25% uncertainty to the wind power output parameter in the system. The system power balance control response is shown in Fig. 4.

As shown in Fig. 3, in general, when the power control instructions of interconnected systems are issued, the lag of power response leads to the delay of power response, which is about 5–7 s.

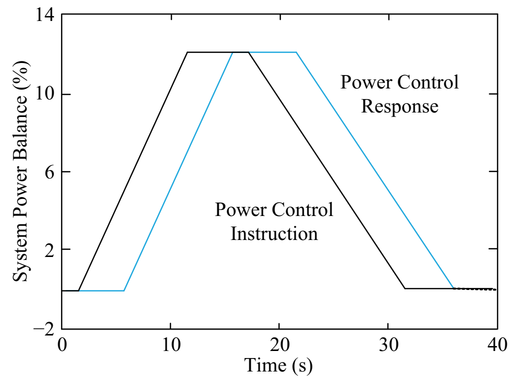

Fig. 3. Interconnected system power control instructions and responses.

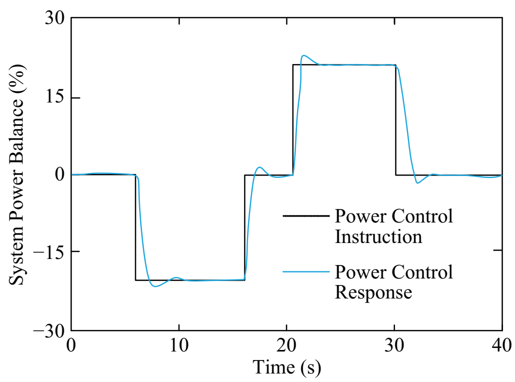

Fig. 4. Response of power control under uncertainty of wind power.

From Fig. 4, it can be seen that the power gap in interconnected systems suddenly changes at a certain level due to the uncertainty of wind power during the whole transient process. The total power control response in interconnected systems can track the reference instructions better. The adjusting time range is 2 s to 5 s. When the power point required by the command is reached, the time period does not exceed 25% of the previous adjusting time when the next command arrives, which makes the system have good robustness and tracking performance.

B. Simulation and Analysis of Transient Stability Control Performance of Interconnected Systems

To verify the control effect of the LPV robust control method, a robust controller based on full-order observer (FOO) is designed as a comparison, and the weight functions are set to the same as the control weights. And the designed controller order is the same as the original system.

Assuming the initial state of the system is normal operation, the LPV robust controller and the FOO robust controller are added to the DC rectification side of the four-zone interconnected power system [24], [25]. The system is disturbed at 0.5 s when a three-wire short-circuit ground fault occurs at point f on the AC tie line L4, and the fault duration is 0.15 s, and the fault is removed at 0.65 s. The simulation analysis of the transient control stability of the transient process under disturbance is given.

Assuming the power balance in the system during the fault is 8%, and the uncertainty of the wind power output parameter is 10%. The changing trends of DC power and input mechanical power of interconnected systems under two robust controllers are shown in Fig. 5 and Fig. 6.

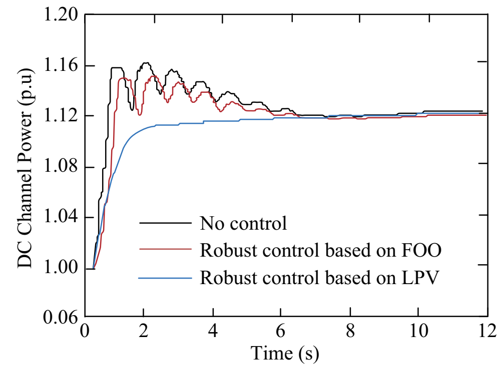

Fig. 5. DC channel power control during transient process ($\theta_r = 0.08$, $V_a = 0.10$).

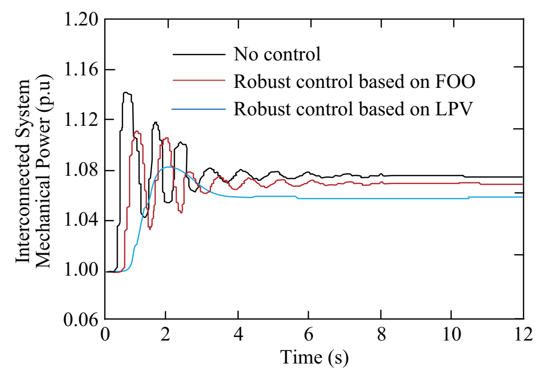

Fig. 6. Mechanical power control during transient process ($\theta_r = 0.08$, $V_a = 0.10$).

During the transient process, the tie lines between G2 and G4 are out of operation, and the DC tie lines operate independently. At this moment, the wind power transmitted by the regional grid G2 to the G4 needs to be transferred to the DC lines and other AC lines to ensure the power balance in the interconnected system.

The transmission power of the flow line cannot be increased rapidly and steadily, which will cause a large increase in the power angle and frequency of the generator in the G2 of the wind power sending-end system. In severe cases, a large-scale abandoned wind will occur, and even an emergency state such as a unit will be removed. However, uncoordinated transient stability control actions of the regional power grids in the interconnected power may further deteriorate the system frequency and eventually cause the system collapse [26].

It can be seen from Fig. 5 and Fig. 6 that both the LPV-based robust controller and the FOO-based robust controller can effectively suppress interference. In the transient process under the two control strategies, the DC channel power reaches a steady state at 6.5 s; the mechanical power control reaches a steady state at 8 s. The LPV-based transient robust controller exhibits better control quality, which can effectively suppress low-frequency oscillations in interconnected systems.

Simultaneously, to verify the robustness of the system, the control strategy control effect test is carried out under the worst condition of the system state ($\theta_r = 0.12$, $V_a = 0.25$). The proposed transient stability strategy control effect is shown in in Fig. 7 and Fig. 8.

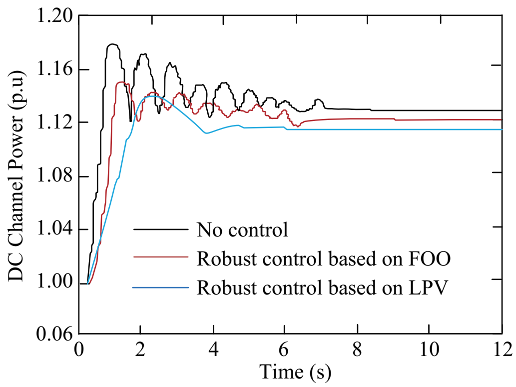

Fig. 7. DC power control effect in transient process ($\theta_r = 0.12$, $V_a = 0.25$).

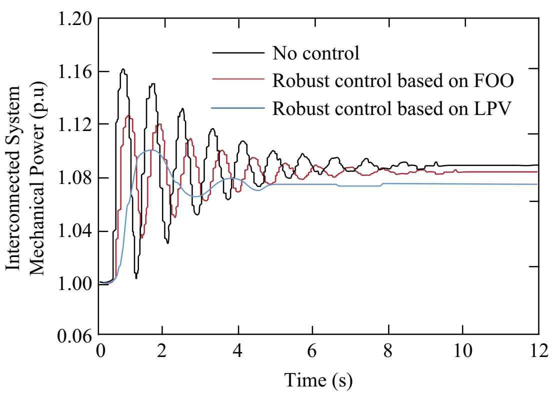

Fig. 8. Mechanical power control effect in transient process ($\theta_r = 0.12$, $V_a = 0.25$).

It can be seen from the simulation results that the DC channel power stability control time in the transient process is 7 s, the mechanical power stability control response time is 9.5 s. The response time is slightly lower than the general disturbance scenario, and the stable oscillation amplitude is slightly higher than the general disturbance. In the scenario, the system can still maintain good control performance and has certain conservativeness. The established LPV-based robust feedback control model makes full use of the short-time overload capability of the DC wind power transmission channel to effectively suppress the change of power balance in the interconnected system. And through the rapid control of DC line power and synchronous machine output, the transient stability of the interconnected system is greatly improved.

VI. Conclusion

Aiming at the problem of robust optimization control for strongly nonlinear transient processes of interconnected systems, which contain multiple AC/DC large-scale wind power transmission channels and multiple regional grids. A new transient stability control method for solving its H∞ optimal robust controller algorithm based on the transient multi-parameter point-linearization model is proposed. This paper has made the following contribution and obtained the simulation results.

1) According to the nonlinear characteristic of the transient process of the interconnected system, a linearized equation of state and its constraints for the variable parameters of interconnected systems are proposed.

2) For the interconnected system LPV equation of state, the H∞ optimal controller model of system transient stability control is designed, and the optimal transient controller model and its solving algorithm are established based on the robust output feedback control algorithm.

3) Considering the system component control parameters in the transient process of the interconnected system, the system linear variable parameter model is established by designing the parameters of different power balance and wind power uncertainty in the transient process of the system.

4) Taking the interconnected system consisting of four regional equivalent networks as the case study, a simulated analysis is made on power control of the three-phase short circuit of the AC wind power channel during transient process in the interconnected system, which contains multiple AC-DC wind power channels and weak sending-end system. The result shows that the transient stability control algorithm proposed in this paper has a strong suppression effect on the transient process.

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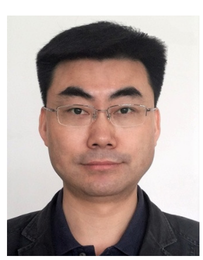

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