

Effects of Generator's Under-Excited Operation on Power System Low-Frequency Oscillation

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Abstract

In this paper, the wavelet method is applied to identify the time-varying frequency and damping ratio based on the PMU recorded data during Pingwei generator's under-excited operation. The relation of oscillation frequency and damping ratio with the variation of reactive power is then attained. Furtherly, the damping torque is used to analyze the reason for easily oscillation during generator's leading phase operation with an OMIB system. The effects of tie-line's reactive power on inter-area oscillation damping have also been studied and results of the 4-machine 2-area system are used to verify the conclusions.

Index terms— the degree of generator's under-excited operation; low-frequency oscillation; wavelet transform; frequency; damping ratio.

1 Introduction

With the continuous expansion of the scale of power grids and the establishment of UHV along with long-distance power transmission network, the problem of higher voltage of power system in valley period becomes important increasingly. Research shows that generator's under-excited operation has been applied gradually as a means for adjusting voltage because of its special excellences, including simple executive, security, economy, adjust continuously, etc.

Generator's under-excited operation belongs to the normal low-excitation synchronous operation state. Generator's capability of absorbing the capacitive reactive power, namely the degree of generator's underexcited operation is restricted by many factors such as stator end fever, the decrease of bus voltage of auxiliary power system, steady-state stability limit, transient stability limit, etc. Therefore, generator's capability of the leading phase operation should be determined scientifically during generator's leading phase operation. Only in this way can power system be ensured to operate safely under the leading phase mode. Reference [2][3][4] analyses on leading phase operation capacity of huge hydro generator and turbo generator; Reference [5] analyses the influence of generator's und Study on effects of generator's under-excited operation on static stability of the electric power system was calculating the static stability reserve coefficient at some degree of generator's under-excited operation which couldn't present the effects of time-varying reactive power on oscillation frequency and damping ratio. The wavelet method is applied in this paper to identify the time-varying oscillation frequency and damping ratio based on the PMU recorded data during Pingwei generator's under-excited operation, and the relation of oscillation frequency and damping ratio with the variation of reactive power has been attained; Furthermore, the damping torque is used to analyze the effect on low-frequency oscillation damping during generator's leading phase operation with an OMIB system. The effects of tie-line's reactive power on interarea oscillation damping have also been studied.

7 PINGWEI GENERATOR'S LOW-FREQUENCY OSCILLATION ACCIDENTS THE EFFECTS OF TIE-LINE'S REACTIVE POWER ON INTER-AREA OSCILLATION DAMPING

2 II.

3 PINGWEI GENERATOR'S LOW-FREQUENCY OSCILLATION ACCIDENTS a) Pingwei Generator's Low-frequency Oscillation Accidents

With two 720MVA transformers, Generator1, 2 of Pingwei generator are upgraded to 500 kV. They are connected to the main grid of Shandong province through the 500kV transmission line. The connection between Pingwei generators and the system is shown in Fig. 1.

4 Yuan Village power plant

5 Pingwei power plant

To Anhui province 500kV major grid To Anhui province 500kV major grid Fig. 2 (b-d) shows that during the period when generator's under-excited operation varies into lagging phase operation again after 10s, the internal and terminal voltage of generators decrease continuously, while the power angle increases continuously. After that, there comes another low-frequency oscillation accident. Based on the active power oscillation trajectory of generator during 4-14s in Fig. 2 (a), the continuous wavelet transform method is applied to identify the timevarying oscillation frequency and damping ratio. The results are shown in Fig. 3. Because of the ending effect, wavelet method has little influence on identified frequency error and has much influence on identified damping error. According to the method of area elimination of ending effect in reference [12], the effective damping ratio area can be seen in the solid line of Fig. 3 (b).

From Fig. 3, during generator's under-excited operation varies into lagging phase operation, with the increase of reactive power, the frequency of the low frequency oscillation increases and the oscillation damping increases from a negative to a positive accordingly. Therefore the system has turn to a system of small signal stability.

6 b) Damping Torque During Oscillation

To make it simple, the impact of generator's under-excited operation on oscillation damping torque is studied on an OMIB system. From Reference [13], electromagnetic torques variation $e T$ consists of two () 1 2 1 e e e s D T T T k T T j h ? ? ? ? ? ? ? ? = + = + (1)

Suppose that the excitation system () 1 A e A k G s T s = + is in one-order inertia. Where, A k and A T are the gain and inertial time constant of the excitation system respectively. According to reference [13],

s T ? and D T ? are shown as follows: 2 5 2 3 6 0 1 A s d A k k k T k k k T T h ? ? = ? + ? (2) () () 2 5 3 0 2 2 3 6 0 1 A A d D A d A k k k T k T T k k k T T h ? ? + = ? + ? (3)

Where, () 2 1 2 q d q d d q E U x x k cos U x x k ? ? ? ? ? ? ? ? = + ? ? (4) 2 d k U sin x ? ? ? = (5) 3 d d k x x ? ? ? = (6) 0 5 0 q t d d t q d x U x k U cos sin U x x ? ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? (7) 0 6 0 t q e t d U x k U x ? ? = ? (8) d d e x x x ? ? ? = + (9) q q e x x x ? ? = + (10)

Where 0 q d q d q d E , , x , x , x , x , T ? ? ? ? ? ? ? ? are

7 PINGWEI GENERATOR'S LOW-FREQUENCY OSCILLATION ACCIDENTS THE EFFECTS OF TIE-LINE'S REACTIVE POWER ON INTER-AREA OSCILLATION DAMPING

Take the 4-machine 2-area system shown in Fig. 4 as an example. Its network and generators possess the same parameters as those in reference [14]. In the case of two-axis generator model with power system stabilizer and constant impedance load model, the total active power load and total reactive power are 2734MW and 200MVar respectively. MVA?namely the active power from bus 8 to bus 9 is 390.3MW and the reactive power from bus 8 to bus 9 is -15.9Mvar. By the use of the small signal analysis tool (SSAT), inter-area oscillation mode of the system is the oscillation between generating units G1, G2 and generating units G3, G4. The oscillation frequency of the mode is 0.7032Hz and damping ratio is 1.55%.

While active power from bus 8 to bus 9 is a constant, the reactive load of bus 7 and 9 varies. The change of inter-area oscillation damping with variation of the tie-line's reactive power is simulated and studied. The change of inter-area oscillation damping with variation of the tie-line's reactive power Fig. 5 shows that oscillation damping is higher with the tie-line's positive reactive power's increase, and vice versa. When tie-line's reactive power is negative, which is in the reverse direction of active power, will give rise to inter-area oscillation negative damping/poor damping.

As generating units of area 1 and area 2 are coherent, therefore generating units of area 1 and area 2 can be aggregated into an equivalent, and bus 7 and 9 can be regarded as near zones of the equivalent. The original system is equivalent to a 2-machine system. So when tie-line's reactive power is in the reverse direction of active

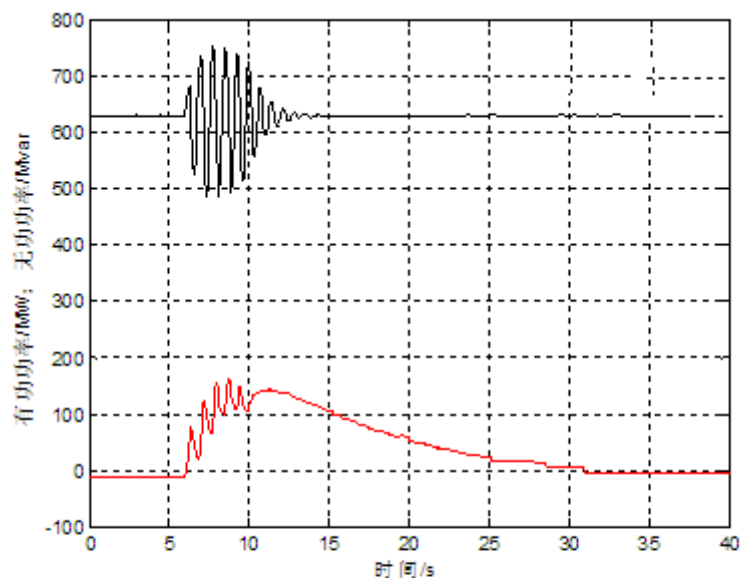
power, it can bear a resemblance to generator's under-excited operation. The increase of negative reactive power is not conducive to the damping of the system.

IV.

8 Conclusion

The wavelet method is applied in this paper to identify the time-varying frequency and damping based on the PMU recorded data during Pingwei generator's under-excited operation, and the relation of oscillation frequency and damping ratio with the variation of reactive power has been attained; Furthermore, the damping torque is used to analyze the reason for easily oscillated during generator's leading phase operation.

When the active power is constant, the effects of tie-line's reactive power on inter-area oscillation damping have also been studied in this paper. When tieline's reactive power is in the reverse direction of active power, it can give rise to negative damping/poor damping, which causes inter-area oscillation of power system.



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Figure 1: Figure 1 :

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8 CONCLUSION

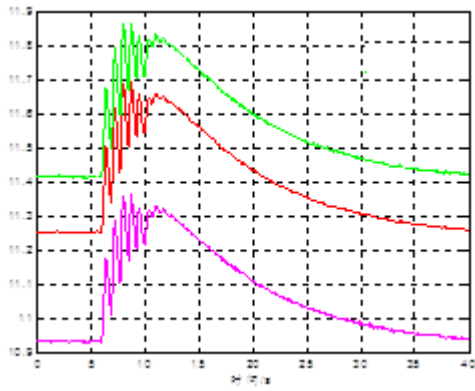
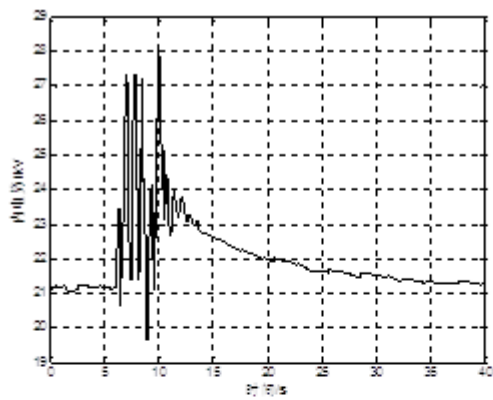


Figure 2:



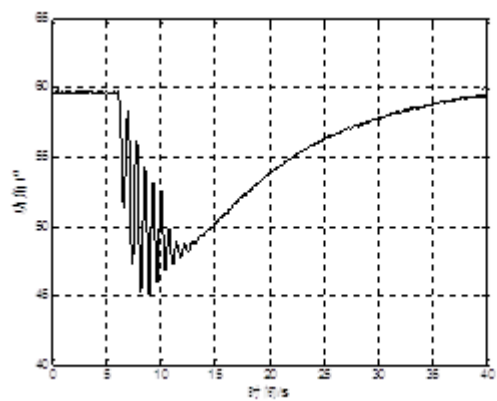
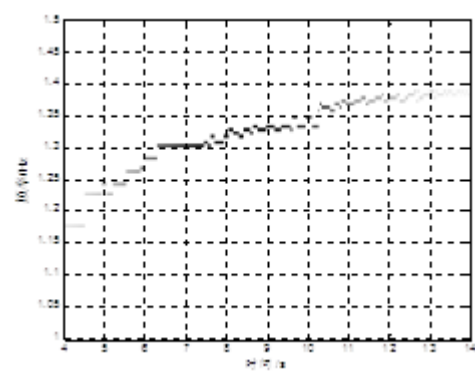


Figure 4:



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Figure 5: Figure 3 :

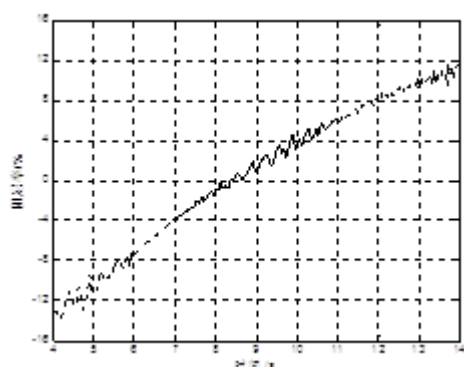


Figure 6:

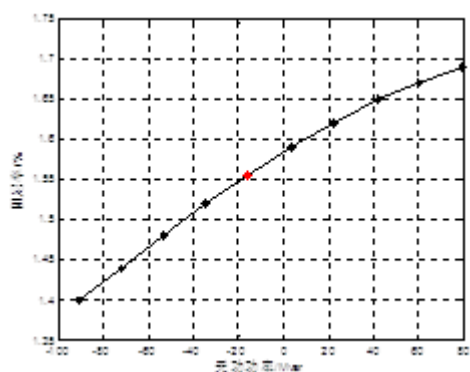


Figure 7:

Analyses The Effects Of Generator's Under-
Excitation Operation On Voltage And Reactive Power;
Reference [7]

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Manuscript received "Date here here" Excitation On
Stability Of Zhejiang Power System; Reference [6]

Figure 8:

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