Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Method for testing output limit of AVR in AC exciter excitation system

To cite this article: Yingfeng Zhu *et al* 2020 *J. Phys.: Conf. Ser.* **1550** 042018

Method for testing output limit of AVR in AC exciter excitation system

Yingfeng Zhu[1*], Yongming Zhang[2], Xiaosu Xie[1] and Xunkui Yuan[1]

[1]State Grid Shandong Electric Power Research Institute, JiNan, 250003, China

[2]Shan Dong Zhong Shi Yi Tong Group Limited Corporation, JiNan, 250003, China

[*]Corresponding author's e-mail: yf_zhu@hotmail.com

Abstract. The excitation system of synchronous generator plays an important role in the static and dynamic stability of power system. 'Guide for modelling generator excitation system' requires that the excitation system of new generators should be modelled and remodelled when the excitation system is upgraded. Testing the output limit of AVR is an important content of modelling. Considering inability of tetsing the output limit of AVR in AC exciter excitation system, this paper analyzes the reason using test data firstly, then proposes a new method to test the output limit of AVR, by modifying the maxim firing angle, the output limit can be got, the new method is verified during modelling test of a 145MW generator finally.

1. Introduction

With the development of power construction, China's power system has entered a stage of large network, high voltage and large-capacity generator, the stability of generators is crucial to the stability of power system[1]. The excitation system provides field current, which is responsible to establish stator voltage, by controlling the excitation system, the value of stator voltage can be changed, so excitation system has a large impact on the stability of the generator[2].

'Guide for modelling generator excitation system'(DLT1167) requires that the excitation system of new generator should be modelled, and the excitation system should be remodelled when its hardware or software is upgraded. Testing the output limit is an important content of the modelling test, and the output limit can be calculated by doing the large step test of stator voltage[3].

The common used varieties of excitation system are AC exciter, DC exciter and potential source static excitation system. For the AC exciter excitation system, output of AVR can regulate the field voltage of exciter, then this field voltage can influence the stator voltage of generator[4]. Rated field voltage of exciter is much smaller than the rated field voltage of generator, when doing the large step test, the field current reduces to zero before the firing angle reaches its maxim value, so the output limit of AVR can't be tested.

This paper proposes a method to test the output limit of AVR in AC exciter excitation system by modifying the firing angle temporarily, the method is verified during modelling a 145MW generator's excitation system.

2. Requirements of modelling AC exciter excitation system

2.1. Configuration of AC exciter excitation system

Figure 1 shows the configuration of the AC exciter excitation system, the source has many forms, for example, it may be a auxiliary exciter with fixed voltage, or may be a excitation transfer from the stators of generator[5]. AVR samples stator voltage and stator current of generator, and after calculating, it output the firing angle value to the thyristor rectifier, which can regulate field voltage of exciter, consequently, stator voltage of exciter which is also field voltage of generator can be changed, stator voltage of generator can be regulated finally.

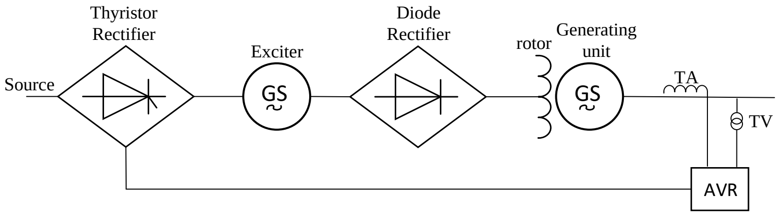

Figure 1. Schematic diagram of AC exciter excitation system

2.2. Criteria of modelling Excitation system in AC exciter excitation system

The steps of establishing measured mathematical model of excitation system are as follows: collect data to determine the mathematical model of excitation system firstly, then write testing scheme based on collected data and do the test, finally establish measured mathematical model of excitation system by organizing the testing data[3][6]

For the AC exciter excitation system, the output limit of AVR($U_{Rmax}U_{Rmin}$)is one content of the modelling tests, they can be derived by the following equations:

$$U_{R\max} = \frac{1.35 \cdot K_{ep} \cdot U_{ae} \cdot \cos\left(\alpha_{\min}\right)}{U_{efb}} \qquad U_{R\max} = \frac{1.35 \cdot K_{ep} \cdot U_{ae} \cdot \cos\left(\alpha_{\max}\right)}{U_{efb}} \tag{1}$$

Where K_{ep} is drop coefficient of source in figure 1 during force excitation, U_{ae} is rated line voltage of the source in figure 1 with generator's rated power, U_{efb} is the base value of exciter's field voltage, α_{max} α_{min} are maxim and minimum values of the power rectifier.

The output limit $U_{Rmax}U_{Rmin}$ can be calculated by doing the large step test, the test requires generator to operate with no load, output values can be derived by the following equations:

$$U_{R\max} = U_{ef1} + \mathrm{K}_C \cdot \mathrm{I}_{ef1} \qquad U_{R\min} = U_{ef2} + \mathrm{K}_C \cdot \mathrm{I}_{ef2}$$

Where U_{ef1},U_{ef2} are the maxim and minimum values of generator's field voltage, U_{ef1},U_{ef2} are the unit's field currents corresponding to the maxim and minimum field voltage, K_C is the commutation voltage loss coefficient. Especially only when the firing angle reaches its limiting value can the output value of AVR be derived.

3. The provided method to test output limit of AVR in AC exciter excitation system

3.1. The problem when testing the output value

Table 1 shows the fundamental parameters of a 145 MW generator with AC exciter excitation system, and it use a auxiliary exciter as source in figure 1. Compared to the generator, the field current value is much smaller than the generator, as a result, the field current will reduce to 0 quickly when doing the large step test.

Figure 2 shows the waveforms of stator voltage, exciter's field voltage and exciter's field current during large step test. The test is implemented under 70% rated stator voltage, and the step value is 20% rated voltage. At t_1, the down step order is given, the minimum field voltage of exciter U_{ef2} is -124V, At t_2, the up step order is given, the maxim field voltage of exciter U_{ef1} is 496 V, the measured voltage of auxiliary exciter U_{p1} is 418 V instead of rated voltage 330V. The real firing angle correspond to U_{ef2} can be derived by the following equation approximately:

Table 1. Parameters of a 145 MW generator ant its exciter

Parameters	Symbol	Unit	Value
Rated power	P	MW	145
Rated voltage	U_g	KV	13.8
Rated current	I_g	A	7137
Rated field voltage	U_{fn}	V	243.6
Rated field current	I_{fn}	A	1492.2
Rated capacity of exciter	S_{en}	KVA	423
Rated voltage of exciter	U_e	V	265
Rated current of exciter	I_e	A	1595
Rated field voltage of exciter	U_{efn}	V	85.5
Rated field current of exciter	I_{efn}	A	23.5
Rated capacity of auxiliary exciter	S_p	KVA	13.2
Rated voltage of auxiliary exciter	U_p	V	330
Rated current of auxiliary exciter	I_p	A	23
Maxim firing angle of AVR	α_{max}	°	130
Minimum firing angle of AVR	α_{min}	°	20

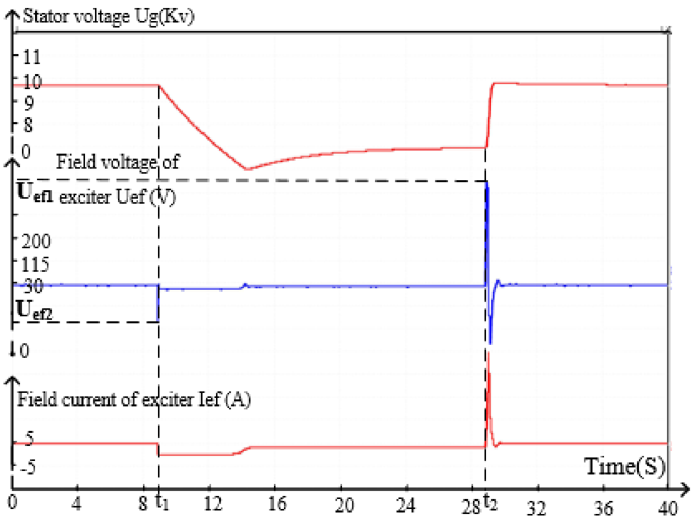

Figure 2. Waveforms of large step test

$$\alpha_{\max 1} = \arccos\left(\frac{U_{ef2}}{1.35 \cdot U_{p1}}\right) = 102.7^{\circ} \quad \alpha_{\min 1} = \arccos\left(\frac{U_{ef1}}{1.35 \cdot U_{p1}}\right) = 28.4^{\circ} \tag{2}$$

Compared to the setting angle, the minimum angle α_{min1} is slightly bigger than α_{min}, this is caused by the function of field current limit, which is used to protect the exciter, nothing to do with test method, U_{ef1} can be used to calculate the output limit in (1).

The maxim angle α_{max1} is much smaller than α_{max}, this is caused by small exciter's field current, the current decreased to 0 before the firing angle reaches its maxim value, however the field current can be much bigger when the generator operates with rated power, so this test method can not test the output limit .

3.2. The proposed method to test output limit

As can be seen from the analysis in section 3.1, the inability of testing output limit of AVR is caused by maxim firing angle reaching a smaller value than setting value. The real output limit can be got by modifying the setting angle α_{max} to guarantee the firing angle reaches its setting value before the exciter's field current reducing to zero. α_{max} can be modified to a value slightly smaller than α_{max1} in (2) as α_{maxs}.

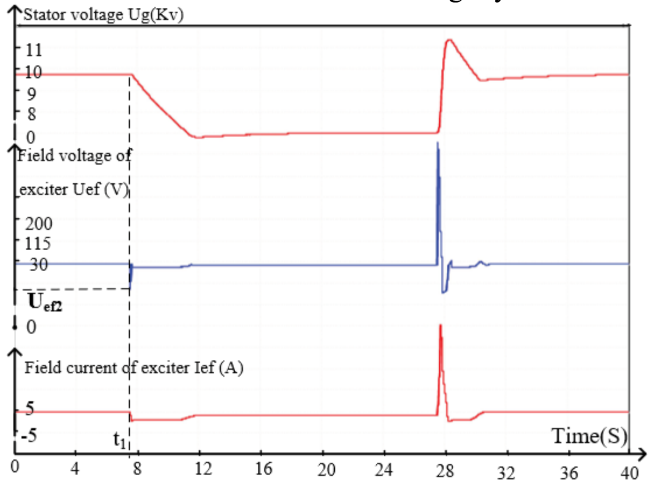

Figure 3. Waveforms of large step test with α_{maxs} setting to 100°

Figure 3 shows the waveforms of stator voltage, exciter's field voltage and exciter's field current during large step test with α_{maxs} setting to 100°.The test is implemented under 70% rated stator voltage, and the step value is 20% rated voltage. At t_1, the down step order is given, the minimum field voltage of exciter U_{ef2} is -84V.

$$\alpha_{\max 2} = \arccos\left(\frac{U_{ef2}}{1.35 \cdot U_{p1}}\right) = 98.6^{\circ} \quad (3)$$

The calculated α_{max2} is approximately equal to the newly setting value α_{maxs}. The field voltage loss can be derived by the following equation:

$$\Delta U_f = 1.35 \cdot U_{p1} \cdot \left(\cos\alpha_{\max s} - \cos\alpha_{\max 2}\right) = -13.6 \text{ V} \quad (4)$$

Then the minimum value of field voltage can be modified to U_{ef2s} as follow:

$$U_{ef2s} = 1.35 \cdot U_{p1} \cdot \cos\alpha_{\max} - \Delta U_f = -350 \text{ V} \quad (5)$$

And U_{ef2s} can be used to calculate the output limit of AVR with equation (1).

4. conclusion

Excitation system plays an important role in the stability of power system, the excitation system of new generator is required to be modelled, and remodelled when its hardware or software is upgraded. Considering the inability of testing output limit of AVR in AC exciter excitation system when modelling, this paper firstly analyzes reason of this inability, then proposes a new method to test the output limit of AVR, and this method is verified by the modelling test of a 145 MW generator.

References

[1] An,G.H., Wu,Y.J. (2008) Operation analysis of brushless excitation system of 330MW generators[J]. Power System and Clean Energy, 24(12): 45–47.
[2] He, R.K., Shen, F., Han, D., Han, Z.Y.(2007) The study of generator excitation system modelling and parameters estimation [J]. Power System technology, 31(14): 62–67.
[3] DLT1167, Guide for modelling generator excitation system[S]. Beijing: National energy administration, 2012
[4] DLT1166, Excitation system for synchronous machines-Models for power system studies [S]. Beijing: Standardization administration, 2008
[5] Chen, X.L. Modelling and characteristic analysis of IEEE excitation system model based on PSASP platform [D]. Beijing: North China Electric Power University, 2019

[6] Long, L.X., Xiong, D.N., Yang, H. (2015) Research on measurement and modelling of generator excitation system [J]. Shanxi Electric Power, 43(3): 47–52.