Electrical Power and Energy Systems 57 (2014) 350–357

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Analysis and assessment of VSC excitation system for power system stability enhancement

Jiawei Yang[a], Zhu Chen[a], Chengxiong Mao[a], Dan Wang[a,*], Jiming Lu[a], Jianbo Sun[b], Miao Li[b], Dahu Li[b], Xiaoping Li[b]

[a] State Key Laboratory of Advanced Electromagnetic Engineering and Technology, Huazhong University of Science and Technology, Wuhan, China
[b] Hubei Electric Power Company, Wuhan, China

ARTICLE INFO

Article history:
Received 5 September 2012
Received in revised form 4 December 2013
Accepted 10 December 2013

Keywords:
Excitation system
Power system stability
Power system damping
Transient stability

ABSTRACT

The voltage source converter (VSC) excitation system is a novel excitation system based on pulse-width modulation (PWM) voltage source converter, which is proposed as improved alternatives to the conventional thyristor excitation systems. This paper aims to provide theoretical confirmation of power system stability enhancement by the VSC excitation system. The reactive current injected to generator terminals by the VSC excitation system can be controlled flexibly. Its capability of enhancing power system stability is investigated in this paper. The simplified model of VSC excitation system suitable for use in system stability studies is developed. An extended Philips–Heffron model of a single-machine infinite bus (SMIB) system with VSC excitation system is established and applied to analyze the damping torque contribution of the injected reactive current to the power system. This paper also gives a brief explanation on why the VSC excitation system can enhance the transient stability in light of equal area criterion. The results of calculations and simulations show that the injected reactive current of VSC excitation system contributes to system damping significantly and has a great effect on the transient stability. When compared with conventional thyristor excitation systems, the VSC excitation system can not only improve the small-signal performance of the power system, but also can improve the system transient stability limit.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

The generator excitation system, which provides direct current to the synchronous machine field winding, is the most important and effective means to maintain the stability of power systems. Since the 1960s, the static excitation systems based thyristor converters (thyristor excitation systems) have been extensively used, for its ability of producing almost instantaneous response and high ceiling voltages. This system has a very small inherent time constant and is easily maintainable [1]. However, the modern power systems are interconnected each other to give and take the electric power and have become much more complicated than decades ago. The presence of system instability is becoming more prominent and thyristor excitation systems with conventional PSS are not sufficient to suppress the wide range (0.1–3.0 Hz) power oscillations any more. On the other hand, the long distance power transfer with heavy load seems to be more susceptive to poor damping [2]. Studies show that the thyristor excitation system cannot provide enough damping even if PSS is equipped. Furthermore, the thyristor excitation systems have following disadvantages:

(1) Commutation failure is a very frequent malfunction in thyristor converters, which is mainly caused by the ac side faults resulting in severe voltage drops [3].
(2) Thyristor converters always absorb reactive power uncontrollably in the amount of about 60% of the real power, whether the output conduction is positive or negative.
(3) The system input voltage is dependent on the terminal voltage of the generator. During system-fault conditions causing depressed generator terminal voltage, the available excitation system ceiling voltage is reduced [1]. And with only excitation control, the system stability may not be maintained if a large fault occurs close to the generator terminal [4].

Over the past decades, most of the work on excitation system focuses on exploring new control algorithms of excitation controllers, such as nonlinear control and artificial intelligence [4–8]. Little has changed about the excitation power part. With the recent development of power electronics, a novel excitation system based on pulse-width modulation (PWM) voltage source converters (VSC

---

* Corresponding author. Tel./fax: +86 027 8754 2669.
E-mail addresses: youngjawie@hust.edu.cn (J. Yang), wangdan@mail.hust.edu.cn (D. Wang).

0142-0615/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijepes.2013.12.011

Nomenclature

δ	power angle of the generator
ω, ω_0	rotor speed and base speed
P_m	prime mover output power
P_e	active electrical power delivered by the generator
D, H	damping constant and inertia constant of the generator
E_q', E_q	(transient) EMF in the quadrature axis
T_{d0}'	d-axis transient short circuit time constant
E_{fd}, U_{fd}	equivalent no-load EMF in the excitation coil and field voltage
V_t	generator terminal voltage
V_b	Infinite bus voltage
I_t, i_{td}, i_{tq}	stator current

x_d, x_d'	d-axis reactances
x_q, x_q''	q-axis reactances
x_T, x_L	reactance of the transformer and transmission line
L, C_{dc}	interface inductor and dc-side capacitor of the rectifier
V_{dc}	dc-side bus voltage
i_{Sabc}, i_{Sdq}	input currents of the rectifier
I_{fd}	field current
I_S	injected active current
m_d, m_q	control variables of the rectifier
d	duty ratio of the chopper
K_R	ratio of the excitation transformer
K_C	gain of the excitation amplifier

excitation system for short) has been proposed to improve the power system stability performance. The PWM converters have lots of attractive features when compared with tranditional thyristor converters, such as low harmonic distortion, bidirectional power flow, nearly sinusoidal input current, and controllable power factor [9]. Fig. 1 illustrates a typical topology of VSC excitation system, which consists of a front-end rectifier, a back-end chopper and an excitation transformer. The primary function of the rectifier is to maintain the dc capacitance voltage constant. Thus, the field voltage is regulated by the chopper only. In addition, the reactive power exchanged between the rectifier and the generator terminal can be controlled flexibly. That is to say, the VSC excitation system can not only provide field voltage like tranditional thyristor excitation systems, but also has a supplementary reactive power injector (RPI) connected in shunt with the generator terminals. The operation of the RPI is inherently fast, and with appropriate control, it can have a great effect on the alternator performance within fractions of a cycle of the normal rotor oscillation. So VSC excitation system has capacity to better maintain power system stability than tranditional thyristor excitation systems. It is worth mentioning that the performance of VSC excitation system is superior to the combination of thyristor excitation system and SVC/STATCOM. For example, the front-end rectifier is a boost converter, so the field voltage is still adequate even if the terminal voltage drops sharply. At this point, the performance of VSC excitation system is equivalent to separately excited systems. Although the VSC excitation system is expensive than tranditional thyristor excitation systems at present, it will be widely used in the near future as the cost of power electronic devices go down.

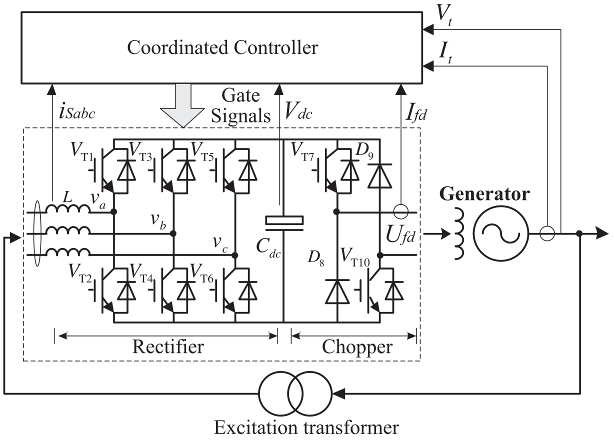

Fig. 1. Schematic of VSC excitation system.

Considerable efforts have been done to improve power system stability through regulating the field voltage in literatures [5–11]; therefore this paper concentrates on investigating the capability of the RPI to enhance power system stability. Most of the previous works on power system stability enhancement by VSC excitation system are based solely on the time-domain simulation [12–14]. This paper attempts to provide theoretic verification for the previous studies. By use of extended Philips–Heffron model, the damping torque contribution of the RPI to the power system is analyzed, so as to present an analytical explanation on why the VSC excitation system can improve system damping and small-signal stability. This paper also gives a brief investigation of the RPI effect on transient stability in light of the equal area criterion. The rest of this paper is organized as follows: Section 2 describes the simplified model of the VSC excitation system and the overall model of a single machine infinite-bus (SMIB) system installed with the VSC excitation system. The extended Philips–Heffron model and damping torque contribution of the RPI are presented in Section 3. The nonlinear simulation results of the small-signal stability improvement by VSC excitation system are also shown. In Section 4, the capability of the RPI to transient stability enhancement is evaluated. Finally, some conclusions are presented in Section 5.

2. Power system model

2.1. Simplified model of VSC excitation system

The dynamic model of the three phase rectifier corresponds to a non-linear and coupled system. Various control strategies have been proposed to get the performance of VSC improved. Fig. 2 shows the control strategy of the rectifier and chopper. The current state feedback control method [9] is employed to control the active

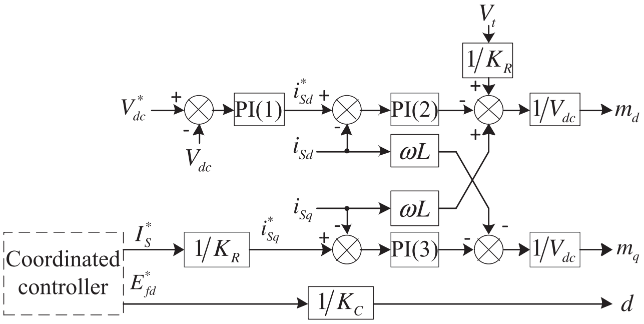

Fig. 2. The control strategy of rectifier and chopper.

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات