부스트 컨버터를 가진 정지형 여자기의 과도 안정도 해석

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TRANSIENT STABILITY ANALYSIS OF STATIC-EXCITER WITH BOOST CONVERTER

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Abstract - This paper deals with the design and evaluation of a new static-exciter for generator excitation systems to improve the steady-state and transient stabilities. It increases or maintains the generator field current by boosting the field voltage in the case of an input AC line voltage drop during and immediately after a fault. The validity of the proposed excitation system is verified with computer simulation. The simulation results of the stability analysis on the generator with the proposed exciter is better than that of a conventional static exciter and a conventional AC exciter. Also, this proposed exciter can be simply implemented and controlled by modern power electronics technology.

NOMENCLATURE

H	=	generator inertia constant,
X_T	=	equivalent line impedance,
ω_r	=	speed,
E_g	=	generator terminal voltage,
δ	=	generator angle,
E_B	=	infinite bus voltage,
P_m	=	turbine power,
T_g	=	generator time constant,
P_e	=	electric power.

I. INTRODUCE

The basic function of an excitation system is to provide direct current to the synchronous machine field winding. Also, the excitation system performs control and protective functions essential to the satisfactory performance of the power system by controlling the field voltage and thereby the field current. Since the 1960's, static exciters based thyristor rectifiers have been widely used, which can produce almost instantaneous response and high ceiling voltages. The high speed and large gain in these exciters improve the system transient stability considerably. And this system has a very small inherent time constant. In addition, it is inexpensive and easily maintainable. However, because exciter input voltage is dependent on the terminal voltage of the generator, during system-fault conditions causing depressed generator terminal voltage, the available exciter ceiling voltage is reduced. In the viewpoint of transient stability, a AC-exciter in which the exciter input power comes from the shaft of the generator is more stable than a static exciter. To solve this problem for static exciters the compound source exciters are proposed and used, but the compound source exciter is not normally justified. Also, a self-dual excited synchronous machine has been proposed in order to enhance the generator stability. A self-dual excited synchronous machine consists of a generator and two field windings. One of the two field windings is fed from the machine terminals through a thyristor bridge while the other is fed from a constant external DC source. But the machine has two different field windings that makes it complex. In this paper, a new excitation system to improve the stability of the generator is presented. This system has a few extra components compared to the static exciter. Under normal operating conditions, the thyristor rectifier of this system controls the generator terminal voltage. Under the fault condition with the reduced input line voltage the field voltage can be stepped up to maintain or to increase the field current by the boost converter. The effectiveness of a proposed system is verified by the simulation and the experimental results using 50 KVA generator coupled with the DC motor. The simulation results of the step response tests on the proposed exciter are the same as those of the static exciter under normal operating input voltage, and it is shown that a proposed system is better than the static exciter in terms of the generator stability enhancement.

II. PROPOSED STATIC EXCITER WITH BOOST CONVERTER

A. Classical Static Exciter

The following figure is a classical static exciter. This exciter consists of a synchronous generator and controller and converter. In this system, excitation power is supplied through a transformer from the generator terminals. This system has a very small inherent time constant. However, the maximum exciter output voltage is dependent on the input AC voltage. Then during system-fault conditions which causes a depressed generator terminal voltage, the available exciter ceiling voltage is reduced. In addition, the conventional static exciter is inexpensive and easily maintainable.

B. Classical AC Exciter

Fig. 2 shows an AC exciter that consists of a PMG(Permanent Magnet Generator) with controlled rectifier and exciter generator with non-controlled rectifier. In this system, the exciter is on the same shaft as the turbine generator. The ac output of exciter is rectified by either a controlled or non-controlled rectifier to produce the direct current needed for the generator field. The rectifiers may be stationary or rotating. In the view point of stability, this system is more stable than a static exciter because excitation power is not supplied from the generator terminals.

C.. Modelling about Fault Condition

A generator output voltage of static exciter can be described as Eq.(1) when a transmission line is faulted. In Eq.(1), T_s is a time constant between a generator and a exciter; K is the coefficient corresponding to the kind of fault; t1 is a fault-starting time and t2 is a fault-ending time.

$$E_{g'} = E_g * e^{-T_s*K(t-t_1)} + E_g*(1-e^{-T_s*K(t-t_2)}) \quad (1)$$

III. EVALUATION OF A PROPOSED STATIC EXCITER

In this paper, in order to compare a conventional static exciter with a proposed static exciter with a boost converter, let's consider the transient stability of a thermal generation station consisting of 555MVA, 24KV, 60Hz unit supplying power to an infinite bus through two transmission circuits as shown in Fig.4. The initial system-operating condition of this system is as shown as follows;

$$E_g = 1.1626\angle 41.77^\circ, E_B = 0.90081\angle 0^\circ,$$
$$X_d = 0.3, H = 3.5 MWs/MVA,$$
$$P_m = 0.9, Q = 0.436.$$

The equation of motion or swing equation may be written as

$$p(\Delta\omega_r) = \frac{(P_m - P_e)}{2H} \quad (2)$$

$$p(\delta) = \omega_o \Delta\omega_r \quad (3)$$

In Fig.4, the transmission line experiences a solid three-phase fault at point F, and the fault is cleared by isolating the faulted circuit. In order to evaluate a proposed system, let us determine the critical fault-clearing time and critical fault-clearing angle by using numerical integration along the time response.

A. Case of a Conventional Static-Exciter

In the fault conditions of a conventional static exciter initial values are

$$E_g = 1.1626\angle 41.77^\circ, \ E_B = 0.90081\angle 0^\circ,$$
$$X_T = 0.7752, \ P_m = 0.9$$

the conditions of the system are following as:
During pre-fault conditions, electrical power is

$$P_e = 1.1626 * \frac{0.90081}{0.7752} \sin\delta$$
$$= 1.351 \sin\delta \qquad (4)$$

During fault conditions, electrical power is

$$P_e = \frac{1.1626 * e^{-T_g(t-t_2)} * 0}{0.45} \sin\delta \qquad (5)$$

During post-fault conditions, electrical power is

$$P_e = \frac{1.1626*(1-e^{-T_g(t-t_2)})*0.90081}{0.95} \sin\delta \qquad (6)$$

B. Case of Proposed Static Exciter

A proposed exciter initial values are the same as a conventional static exciter.

$$E_g = 1.1626\angle 41.77^\circ, E_B = 0.90081\angle 0^\circ,$$
$$X_T = 0.7752, \ P_m = 0.9$$

In the case of a proposed static exciter, assuming that a boost converter operates during a fault, in order to maintain a constant an exciter input voltage(in practice this assumption is valid). The conditions of the system are as follows:

During pre-fault conditions, electrical power is

$$P_e = 1.1626 * \frac{0.90081}{0.7752} \sin\delta$$
$$= 1.351 \sin\delta \qquad (7)$$

During fault conditions, electrical power is

$$P_e = \frac{1.1626 * 0}{0.45} \sin\delta \qquad (8)$$

During post-fault conditions, electrical power is

$$P_e = 1.1626 * \frac{0.90081}{0.95} \sin\delta$$
$$= 1.1024 \sin\delta \qquad (9)$$

Ⅳ. SIMULATION

Fig. 5 shows a rotor angle response of a conventional static exciter and a proposed exciter system when the fault-clearing time of the system shown in Fig. 4 is 0.05(sec.). In Fig. 5, 'A' is a static exciter and 'B' is a proposed exciter. Fig.6 shows a rotor angle response of a conventional static exciter according to different values of fault-clearing time. Fig.7 shows a rotor angle response of a proposed static exciter with a boost converter for different values of fault-clearing time. It can be seen that a proposed exciter has a longer clearing time margin than a conventional static exciter. Fig. 8 shows a critical transmission line reactance of a proposed static exciter and a conventional exciter. It can be seen that a proposed exciter has better critical reactance margin than a conventional static exciter. Since the time constant of the generator used in this paper is large, then only a small time difference for the clearing time between a proposed system and a conventional system appears. If the time constant of the generator is small, then a time defference for the clearing time between a proposed system and a conventional system will be large.

Ⅴ. CONCLUSION

In order to improve the generator stability under fault conditions, the new generator excitation system is proposed. The proposed exciter has better stability than a conventional static exciter. Under the normal input voltage the operating characteristics of the proposed excitation system is just same as the static exciter's. But under fault conditions the proposed excitatiojn system can boost the input voltage to maintain constant DC link voltage to be constant by the use of a boost converterr. The performance of the proposed exciter has been verified through computer simulation. Consequently, it has been verified that a proposed exciter has better stability characteristics for the generator compared to that of other excitation systems.

Ⅵ. REFERENCE

[1] ANSI/IEEE Std. 421.1 1986, *An American National Standard/IEEE Standard Definitions for Excitation Systems for Synchronous Machines.* Approved June 13,1985.1

[2] JIEE Report, *Specification and Characteristics of Synchronous Generator Exciters*, JIEE (Japan) Technical Report No.536, 2. 1995.

[3] P. Kundur, *Power System Stability and Control,* McGraw-Hill, Inc., New York, 1993, pp. 315-340.

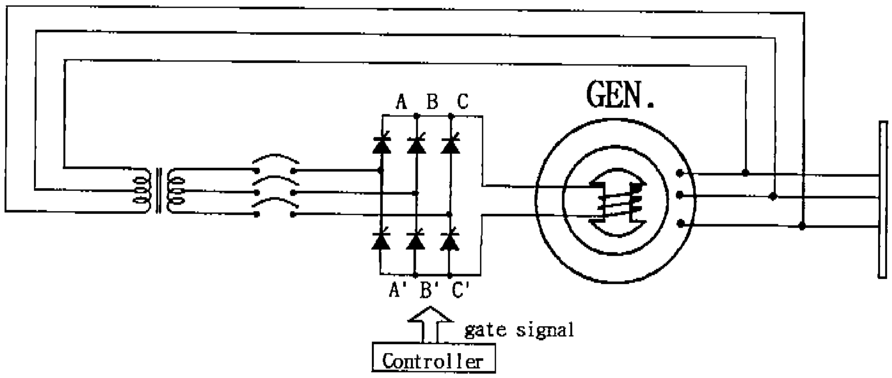


Fig. 1. Conventional static exciter.

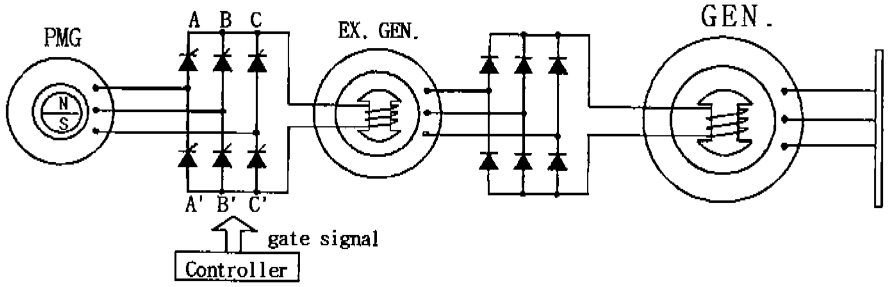


Fig. 2. Conventional AC exciter.

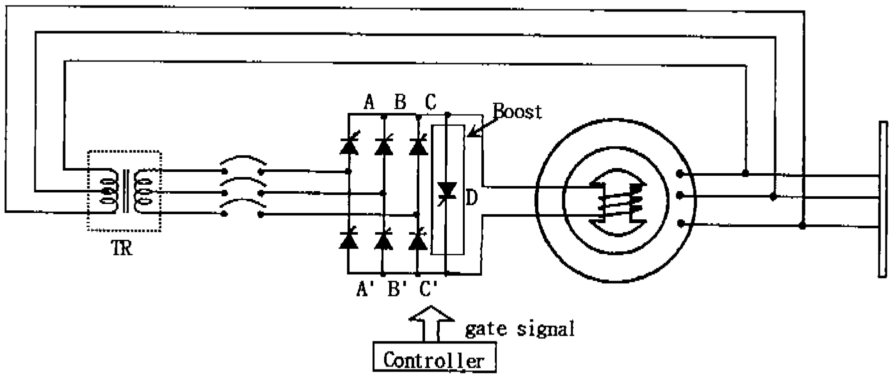


Fig. 3. Proposed next generation static exciter.

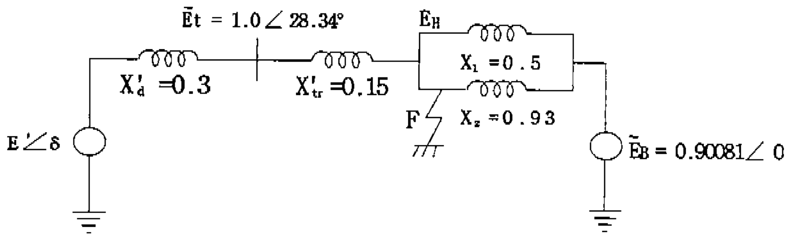
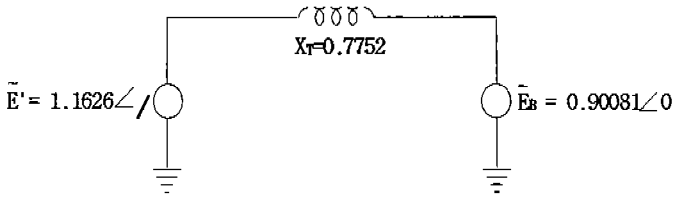


Fig. 4. Equivalent circuit of a thermal generating station.



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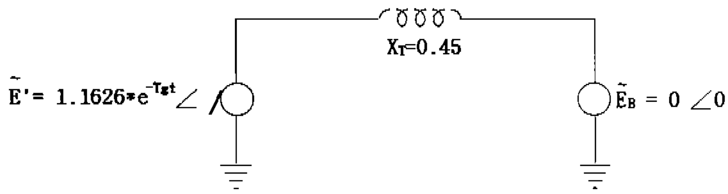

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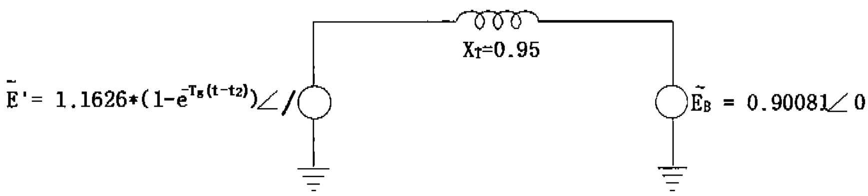

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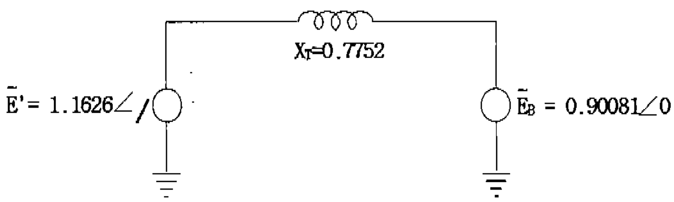

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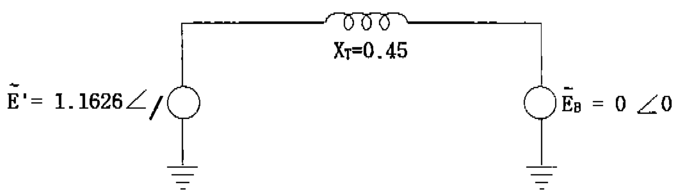

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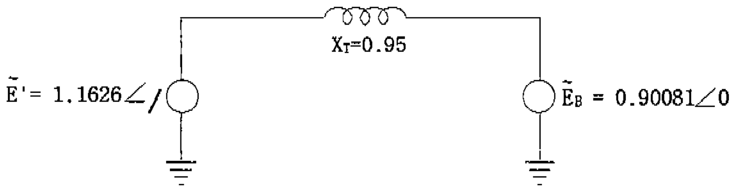

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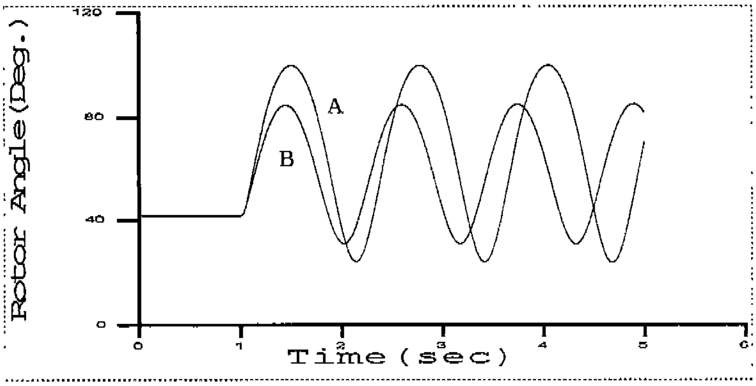

Fig. 5. Rotor angle response of a conventional static exciter and a proposed exciter system.(fault-clearing time : 0.05(sec.))

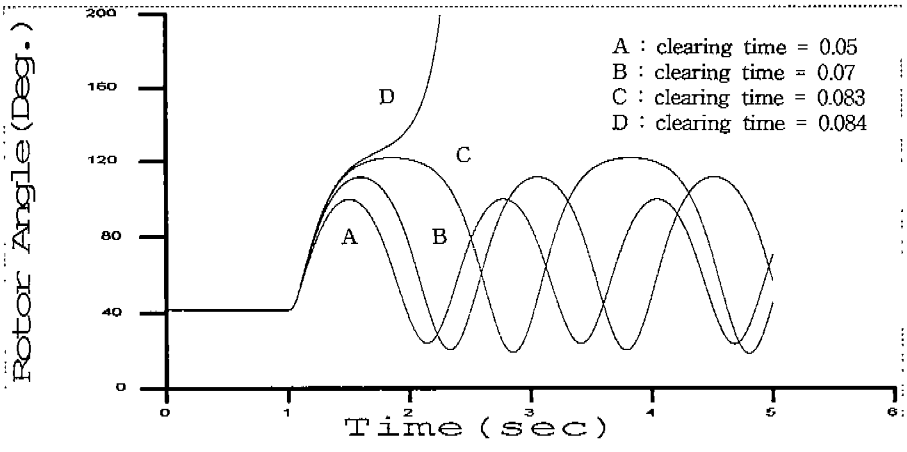

Fig.6. Rotor angle response of a conventional static exciter for different values of fault-clearing time.

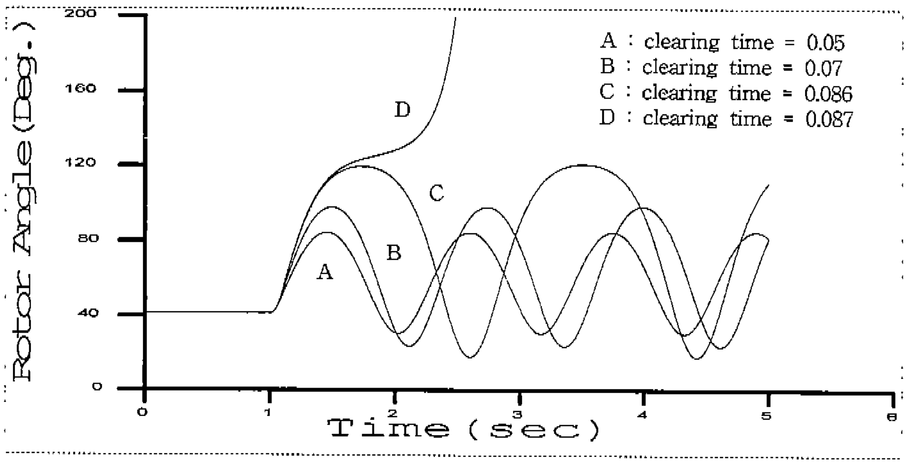

Fig.7. Rotor angle response of a proposed static exciter with boost converter for different values of fault-clearing time.

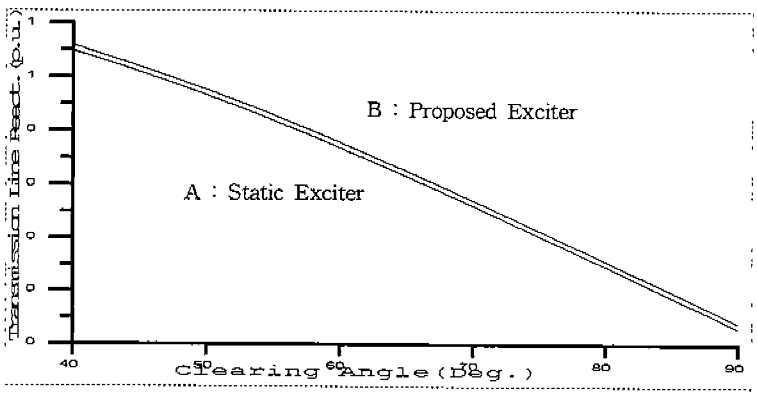

Fig. 8. Critical transmission line reactance of a proposed static exciter and a conventional exciter.