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Damping Analysis using IEEEST PSS and PSS2A PSS

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Abstract - This paper scrutinized the damping effects of installing the prototype PSSs by a transient analysis for eight buses of faults in the South Korean power system. The PSSs used have the ω-PSS blocks for IEEEST model with a single input and the ω+power PSS blocks for PSS2A model with dual inputs. The simulation tool was a TSAT (Transient Security Assessment Tool) developed by Powertech Labs Inc. The voltages of the transmission line for simulations were 765kV and 345kV, and the faults for eight cases were sequenced by considering the open state and the close state of the lines. In the simulations, the three-phase line to ground (L-G) fault generated different points for each region. The simulations were compared to the cases of no PSS, partial IEEEST and PSS2A, absolute IEEEST, and absolute PSS2A to show that the power system oscillation can be effectively damped by PSS modules. Simulations were conducted to confirm the effectiveness for the KEPCO (Korea Electric Power Corporation) power system.

Keywords: IEEEST Type PSS, KEPCO (Korea Electric Power Corporation) Power System, PSS2A Type PSS, Transient Security Assessment Tool (TSAT)

1. Introduction

Power outages and exceptional events in the power system may occur unexpectedly at any time. To cope with these outages or events, a supplementary control signal in the excitation system and/or the governor system of a generating unit is used to provide extra damping for the system and thus improve the unit's dynamic performance. Power system stabilizers (PSSs) aid in maintaining power system stability and in improving dynamic performance by proving a supplementary signal to the excitation system.

The evaluation of power system security investigates the ability of the switching actions and the circuit breaker operation of power equipments under continuous system operation such as disturbances for the circuit fault. That is, whether thermal overloads, voltage and current, etc. are going to be retained within the tension of the equipment, and whether the dynamic characteristics such as frequency, voltage and braking characteristics, etc. of the equipment are going to be retained within the limit value of the system operation by disturbances.

The stability of a power system means that a system can retain its synchronizing power in the event of disturbances such as power transmission equipment breakdown, generator shedding, and large load opening. If the phase differences of a synchronous machine are confined to a limit margin, the power system will stabilize by maintaining synchronizing power. However, if excessive phase differences due to disturbances occur, the power system will become unstable because it will be unable to maintain synchronizing power. In a stability analysis, power system stability is evaluated and estimated from the transient stability index, critical fault clearing time, and damping index, etc. If the oscillation continues, unaffected by suitable countermeasures, the generator will oscillate severely, or become unstable and breakout. Therefore, the system should be separated immediately.

A generator must be equipped with PSS to supply additional signal for the exciter terminal to improve the damping of the system. An auxiliary signal is injected into the exciter input of the generator in a power system and the algorithm applied to the PSS provides a damping effect as follows. First, a traditional PSS (Lead-Lag Compensator) is divided by a speed input PSS, a frequency input PSS and a power input PSS. These PSSs were developed by F. P. deMello and C. Concordia. This handles the basic key ideas for the frequency response characteristics of a power system stabilizer, which uses an auxiliary input signal, and deals with the gap both at the tuning side and at the performance side. Despite the potential of modern control techniques, electric power companies still prefer the traditional Lead-Lag PSS structures. This may be due to a convenient parameter adjustment for the control (tuning) of

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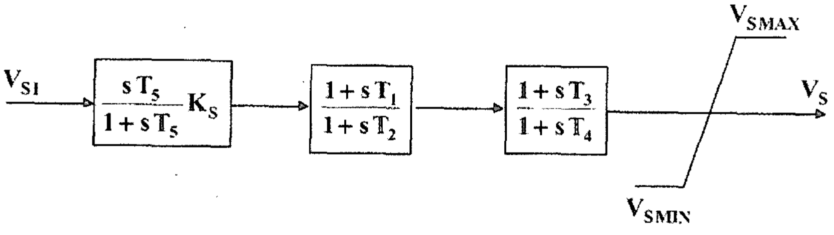


Fig. 1. IEEEST type PSS

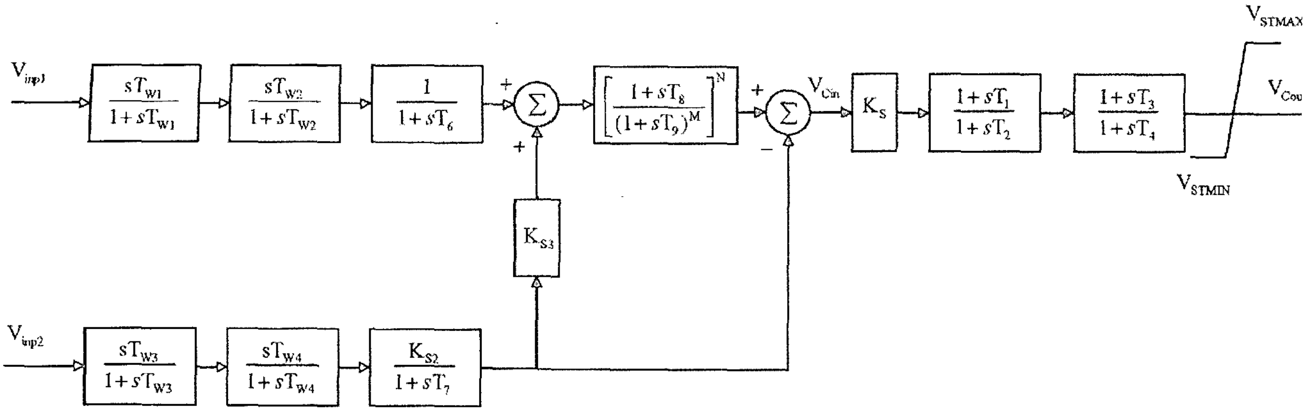


Fig. 2. PSS2A-dual type PSS

the traditional power system stabilizer [1-6]. Second, some approach methods are basic to the modern control theory and the nonlinear control theory, which has been applied to nonlinear PSS design problems [6-12].

In this paper, the transient stability problems of a power system stabilizer (PSS) in the Korean power system were analyzed by using the TSAT (Transient Security Assessment Tool) program. The PSSs were the IEEEST and the PSS2A [13], [14]. The voltages of the power transmission lines for simulation were 765kV and 345kV, and the fault points were about 8 buses, considering the off state and the on state of the line. The PSSs will be applied to Korean power systems in 2005; they will be either the IEEEST type or the PSS2A type and this will be discussed in the next section.

2. Power System Stabilizer Model

In this section, two types of power system stabilizers were considered: 1) a single input PSS shown in Figs. 1 and 2) a dual-input PSS shown in Fig. 2. The forms of the PSS that apply to the Korean power system are the IEEEST and PSS2A types. First, the IEEEST type uses an angular velocity ω only by input. As the name implies, the speed-based power system stabilizer relies on the measurement of the generator shift speed for generating the stabilizing signal. Second, the PSS2A type has dual structures that use two signals of angular velocity ω and power p. The effect from inserting PSS in diverse areas at bus terminals were found to be different from the various damping effects that were produced by the two types of PSSs.

Four types of PSSs were applied for the case study. However, not all attached PSSs were applied to every generator. The IEEEST PSS and the PSS2A PSS were attached for some buses. The IEEEST type PSS and the PSS2A type PSS were attached to all generators.

3. Korean Power System

The structure of the KEPCO (Korea Electric Power Corporation) consists of divisions in 7 geographical areas with different geographical boundaries; the Gyeongin northern area, the Gyeongin southern area, the Yeongdong area, the Jungbu area, the Yeongnam area, the Honam area, and the Jeju Island area. The power system on Jeju Island is currently connected to the mainland via a 100km-long submarine transmission system, comprised of HVDC (High Voltage Direct Current) cables between Haenam in Honam and North-Jeju on Jeju Island.

Power sales sold 32,732 GWh of electricity in 1980 and electricity sales reached 278,451 GWh in 2002, an 8.5-fold increase in 20 years. Annual sales during the past decade have averaged 10% annual growth, except for minus growth in 1998 caused by an economic crisis. On the other hand, 10.7% growth was recorded in 1999 as the economy recovered. Economic recovery further boosted electricity consumption in 2000 to a record 11.8% yearly.

However, the economic downturn during 2001 and 2002 slowed electricity sales growth rates to 7.6% and 8%, respectively. The per capita consumption of electricity stood at 859kWh in 1980. The figure reached 5,444 kWh by 2002, boosted by continuous economic expansion. When compared to the per capita consumption in advanced countries, Korea still has very high growth potential for electricity sales. Sales revenue in 2002 exceeded 20.57 trillion won, a 3.6% increase from 2001. Simultaneously, the average sales unit price, i.e. sales revenue divided by sales volume, was 73.88 won/kWh, down 4.1% from 2001. The breakdown of the electricity consumption was 51.9% by industry, 33% by the public and service (mainly commercial) sectors, and 15.2% by residential customers. The consumption trend in Korea demonstrates a move toward the typical consumption types of advanced countries, as the proportion of industrial use decreases while households are taking a greater proportion of the total consumption. Meanwhile, direct load interruption using the internet has been reinforced as a power contingency program. These multi-faceted efforts enabled KEPCO to curb peak demand by 2,170 MW and to save 450GWh electricity in 2002.

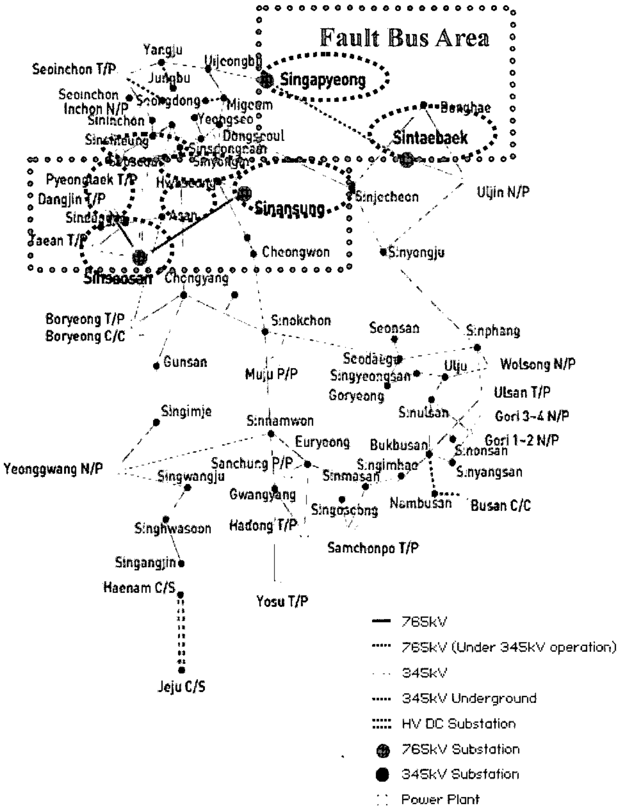


Fig. 3. Power system map in South Korea.

Since KEPCO was established in January 1982, consumer prices in Korea have risen 166%, but electricity rates have only risen 2.0% over the same period. The average price of electricity sold to consumers was 73.88 won/kWh at the end of 2002.

4. Fault Cases

Simulation time was 10 seconds. In Case 1, a 3-phase fault happened in 1 second in DangjinTP7 (bus number 6020, 765kV). The line between DangjinTP7 bus (bus number 6020, 765kV) and Sinseosan7 bus (bus number 6030, 765kV) on 1.083 seconds trips. Fault periods were 4.98 cycles.

In Case 2, a 3-phase fault happened in 1 second in Sinanseong7 bus (bus number 4010, 765kV). The line between Sinanseong7 bus (bus number 4010, 765kV) and Sinseosan7 bus (bus number 6030, 765kV) on 1.083 seconds trips. Here, fault periods were 4.98 cycles.

In Case 3, a 3-phase fault happened in 1 second in Singapyeong7 bus (bus number 1020, 765kV). The line between Singapyeong7 bus (bus number 1020, 765kV) and Sinanseong7 bus (bus number 4010, 765kV) on 1.083 seconds trips. Fault periods were 4.98 cycles.

In Case 4, a 3-phase fault happened in 1 second in Singapyeong7 bus (bus number 1020, 765kV). The line between Singapyeong7 bus (bus number 1020, 765kV) and Sintaebaek7 bus (bus number 5010, 765kV) on 1.083 seconds trips. Fault periods were 4.98 cycles.

In Case 5, a 3-phase fault happened in 1 second in Hwaseong3 bus (bus number 4400, 345kV). The line between Hwaseong3 bus (bus number 4400, 345kV) and Asan3 bus (bus number 6950, 345kV) and the line between Hwaseong3 bus (bus number 4400, 345kV) and AsanS bus (bus number 6951, 345kV) on 1.100 seconds trips. The fault periods were 6 cycles.

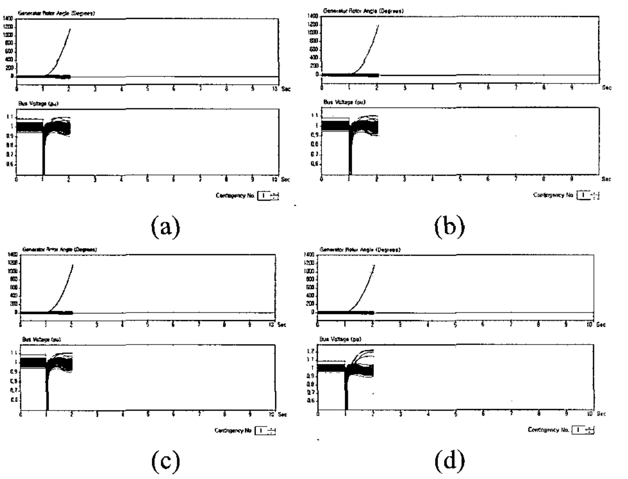
In Case 6, a 3-phase fault happened in 1 second in Hwaseong3 bus (bus number 4400, 345kV). The line between Hwaseong3 bus (bus number 4400, 345kV) and Seoseoul3 bus (bus number 4600, 345kV) and the line between Hwaseong3 bus (bus number 4400, 345kV) and SeoseoulS bus (bus number 4601, 345kV) on 1.100 seconds. The fault periods were 6 cycles.

In Case 7, a 3-phase fault happened in 1 second in HwaseongS bus (bus number 4401, 345kV). The line between HwaseongS bus (bus number 4401, 345kV) and PyeongtagTP3 bus (bus number 4450-1, 345kV) and the line between HwaseongS bus (bus number 4401, 345kV) and PyeongtaekTP3 bus (bus number 4450-2, 345kV) on 1.100 seconds trips. Fault periods were 6 cycles.

In Case 8, a 3-phase fault happened in 1 second in HwaseongS bus (bus number 4401, 345kV). The line between HwaseongS bus (bus number 3650, 345kV) and HwaseongS bus (bus number 4401-1, 345kV) and the line between Sinansan3 bus (bus number 3500, 345kV) and HwaseongS bus (bus number 4401-2, 345kV) on 1.100 seconds trips. Fault periods were 6 cycles.

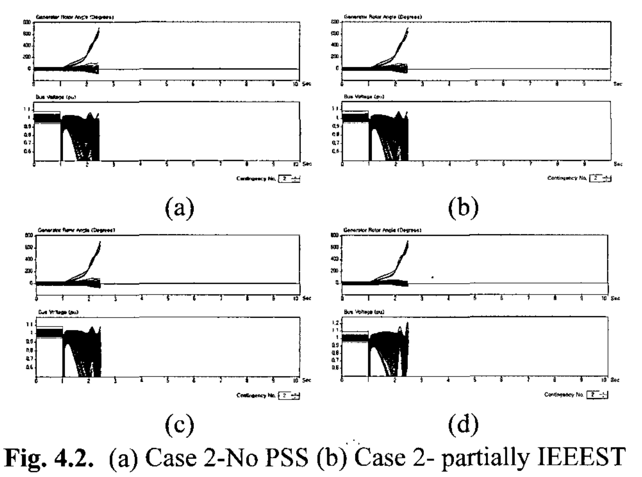
5. Simulation Results

Figs 4.1(a)-4.8(a) represent the waveforms for simulations when PSS was not installed. Figs 4.1(b)-4.8(b) show the waveforms for the cases when the IEEEST Type PSS and the PSS2A Type PSS were installed at some places. Figs 4.1(c)-4.8(c) represent the waveforms for the cases when IEEEST Type PSS was installed at all parts with existing traditional forms. Figs. 4.1(d)-4.8(d) represent the waveforms for the cases when PSS2A Type PSS was installed in all generators.



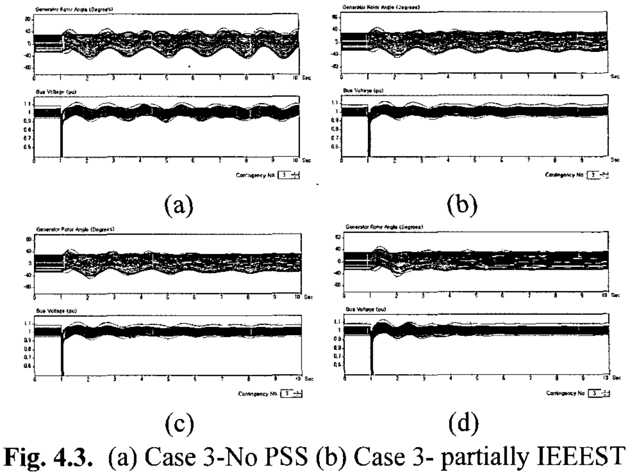
(a) (b) (c) (d)

Fig. 4.1. (a) Case 1-No PSS (b) Case 1- partially IEEEST and PSS2A (c) Case 1-all IEEEST type (d) Case 1-all PSS2A type



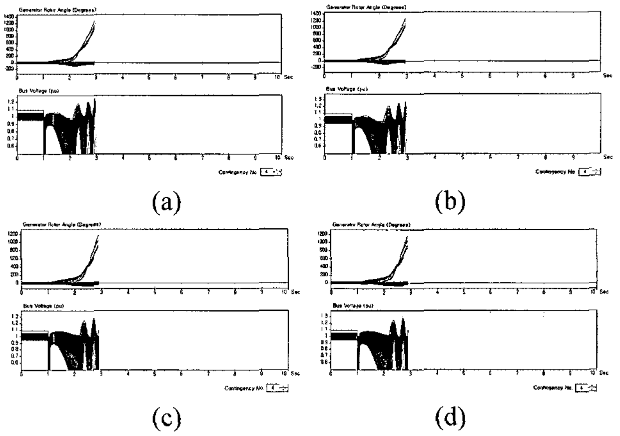
(a) (b) (c) (d)

Fig. 4.2. (a) Case 2-No PSS (b) Case 2- partially IEEEST and PSS2A (c) Case 2-all IEEEST type (d) Case 2-all PSS2A type



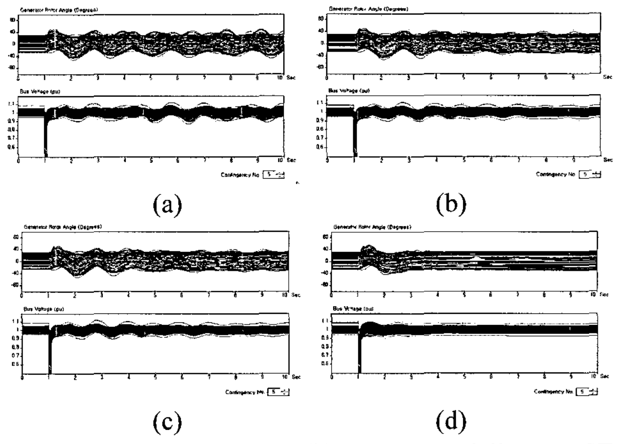
(a) (b) (c) (d)

Fig. 4.3. (a) Case 3-No PSS (b) Case 3- partially IEEEST and PSS2A (c) Case 3-all IEEEST type (d) Case 3-all PSS2A type



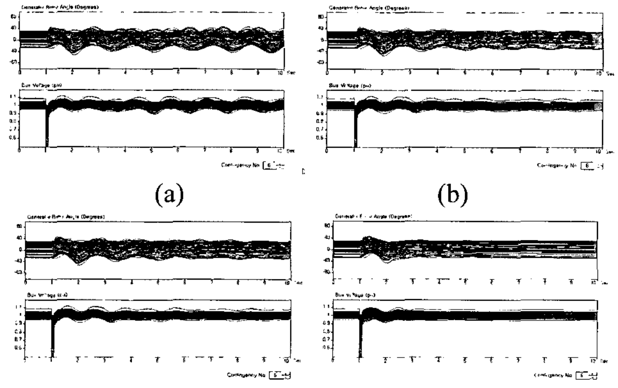
(a) (b) (c) (d)

Fig. 4.4. (a) Case 4-No PSS (b) Case 4- partially IEEEST and PSS (c) Case 4-all IEEEST type (d) Case 4-all PSS2A type



(a) (b) (c) (d)

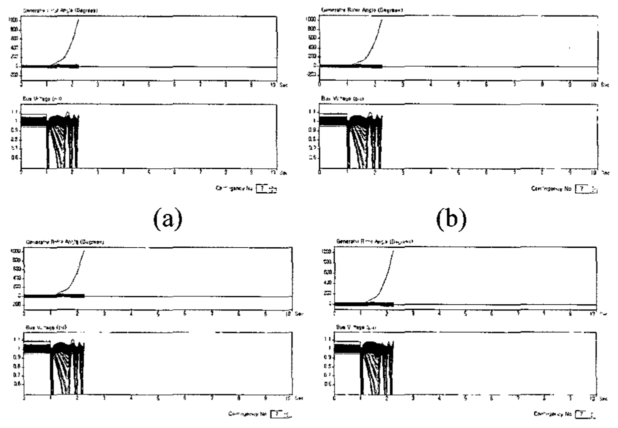
Fig. 4.5. (a) Case 5-No PSS (b) Case 5- partially IEEEST and PSS2A (c) Case 5-all IEEEST type (d) Case 5-all PSS2A type



(a) (b)

(c) (d)

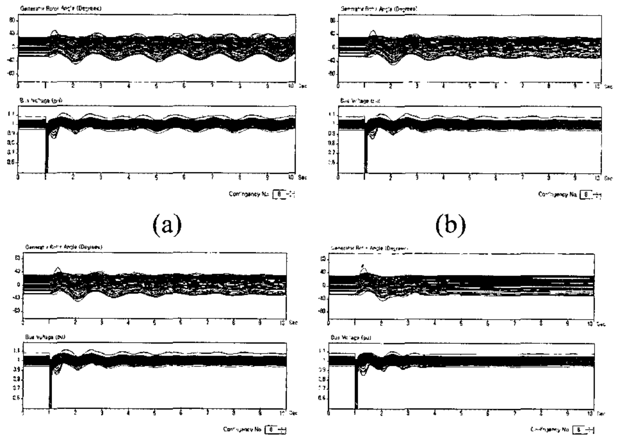
Fig. 4.6. (a) Case 6-No PSS (b) Case 6- partially IEEEST and PSS2A (c) Case 6-all IEEEST (d) Case 6-all PSS2A type



(a) (b)

(c) (d)

Fig. 4.7. (a) Case 7-No PSS (b) Case 7- partially IEEEST and PSS2A (c) Case 7-all IEEEST type (d) Case 7-all PSS2A type



(a) (b)

(c) (d)

Fig. 4.8. (a) Case 8-No PSS (b) Case 8- partially IEEEST and PSS2A (c) Case 8-all IEEEST type (d) Case 8-all PSS2A type

Fig. 4.1(a) shows the waveforms for the cases when PSS was not installed in a generator and the generator rotor angle oscillated severely because of the fault. Fig. 4.1(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed in some locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.1(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.1(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to break out. The bus terminal voltages oscillated severely, as shown in Fig. 4.1(a)-4.1(d).

Fig. 4.2(a) depicts the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated excessively because of the fault. Fig. 4.2(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.2(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.2(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. The bus terminal voltages oscillated very severely as indicated in Fig. 4.2(a)-4.2(d).

Fig. 4.3(a) presents the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated very significantly because of the fault. Fig. 4.3(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was partially damped because of the fault. Fig. 4.3(c) indicates the waveforms for the case when the IEEEST Type PSS was installed at all places, and the generator rotor angle was moderately damped since fault occurred. Fig. 4.3(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was largely damped since fault occurred. The bus terminal voltages in Fig. 4.3(a) oscillated significantly. The bus terminal voltages in Fig. 4.3(b) were damped partially. The bus terminal voltages in Fig. 4.3(c) were damped moderately. The bus terminal voltages in Fig. 4.3(d) were damped greatly.

Fig. 4.4(a) shows the waveforms for the case when PSS was not installed in a generator and the generator rotor angle oscillated very excessively because of the fault. Fig. 4.4(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.4(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.4(d) indicates the waveforms when the PSS2A Type PSS was installed at all locations, and the generator rotor angle is greatly increased since fault occurred. As an end result, the waveforms turned to breakout. The bus terminal voltages oscillated very severely as shown in Fig. 4.4(a)-4.4(d).

Fig. 4.5(a) presents the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated very largely because of the fault. Fig. 4.5(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was partially damped because of the fault. Fig. 4.5(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was moderately damped because of the fault. Fig. 4.5(d) represents the waveforms for the case when the PSS2A Type PSS were installed at all locations, and the generator rotor angle was largely damped because of the fault. The bus terminal voltages in Fig. 4.5(a) oscillated largely. The bus terminal voltages in Fig. 4.5(b) were damped partially. The bus terminal voltages in Fig. 4.5(c) were damped moderately. The bus terminal voltages in Fig. 4.5(d) were damped significantly.

Fig. 4.6(a) indicates the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated very significantly because of the fault. Fig. 4.6(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was partially damped because of the fault. Fig. 4.6(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was moderately damped because of the fault. Fig. 4.6(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was largely damped because of the fault. The bus terminal voltages in Fig. 4.6(a) oscillated largely. The bus terminal voltages in Fig. 4.6(b) were damped partially. The bus terminal voltages in Fig. 4.6(c) were damped moderately. The bus terminal voltages in Fig. 4.6(d) were damped significantly.

Fig. 4.7(a) depicts the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated exceptionally because of the fault. Fig. 4.7(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.7(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. Fig. 4.7(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was greatly increased because of the fault. As an end result, the waveforms turned to breakout. The bus terminal voltages oscillated very severely as indicated in Fig. 4.7(a)-4.7(d).

Fig. 4.8(a) illustrates the waveforms for the case when PSS was not installed in a generator, and the generator rotor angle oscillated very largely because of the fault. Fig. 4.8(b) represents the waveforms for the case when the IEEEST Type PSS and the PSS2A Type PSS were installed at some locations, and the generator rotor angle was partially damped because of the fault. Fig. 4.8(c) represents the waveforms for the case when the IEEEST Type PSS was installed at all locations, and the generator rotor angle was moderately damped because of the fault. Fig. 4.8(d) represents the waveforms for the case when the PSS2A Type PSS was installed at all locations, and the generator rotor angle was largely damped because of the fault. The bus terminal voltages in Fig. 4.8(a) oscillated largely. The bus terminal voltages in Fig. 4.8(b) were damped partially. The bus terminal voltages in Fig. 4.8(c) were damped moderately. The bus terminal voltages in Fig. 4.8(d) were damped significantly.

6. Countermeasures for Fault Currents

The fault current augmented in the 345kV system or in the 765kV system, which compose the backbone of a power system can be reduced by replacing the breaker, setting up the current limiting reactor, and separating the system, etc. The problems related to stability in these cases appeared to be relative structural vulnerability in the case of system separation. On the technological side, the fault current expresses the special quality of the reduction effect, the circulation of power flow and the security of the power system. On the economical side, the fault current becomes a way to lower the investment costs, the expense of maintenance and the loss expense, etc. The installation of a current limiting reactor for 345kV will help in coping, both technologically and economically. Therefore, the many-sided directions by the most suitable setup and by the operational method must precede the considerations of the economical side and of the reliability side for power supply.

7. Conclusion

In this paper, we examined 8 cases of faults to demonstrate the damping effects produced by IEEEST type and PSS2A PSS in Korean power systems in 2005. Results to apply and to examine by applying the PSSs are as follows:

(i) In the first case, PSS is not attached to all generators, and generators of the case 1, 2, 4 and 7 oscillate extremely and show a breakout. The generators of the cases 3, 5, 6 and 8 represent significant oscillation.

(ii) In the second case, the IEEEST PSS and the PSS2A PSS are partially attached to all generators, and the generators of the cases 1, 2, 4 and 7 oscillate significantly and lead to breakout. The generator of the cases 3, 5, 6 and 8 oscillate excessively and show partial damping effect.

(iii) In the third case, the IEEEST PSS is attached to all generators, and the generators of the cases 1, 2, 4 and 7 oscillate significantly and lead a breakout. The generators of the cases 3, 5, 6 and 8 oscillate excessively and show damping effect.

(iv) In the fourth case, the PSS2A PSS is attached to all generators, and the generators of the cases 1, 2, 4 and 7 oscillate significantly and lead to breakout. The generators of the cases 3, 5, 6 and 8 oscillate tremendously and show very large damping effect.

In conclusion, the fourth case demonstrated the best damping effect for which the PSS2A PSS is attached to all generators (Fig. 4.1(d) Case 1 - 4.8(d) Case 8-all PSS2A type).

Acknowledgements

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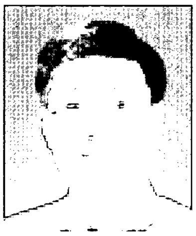

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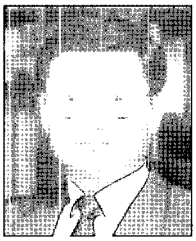

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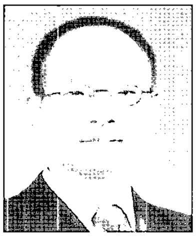

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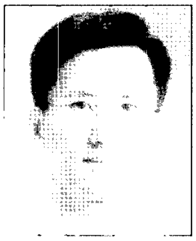

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