New Serial and Parallel Sin+Cos PSS1A PSS Design and Analysis

Sang-Seung Lee†, Shan-Ying Li*, Gwang- Soo Jang*, Jong-Keun Park*, Seung-Il Moon* and Yong-Tae Yoon*

Abstract - This paper proposes a new series and parallel Sin+Cos PSS (power system stabilizer) for the purpose of improving the existing PSS1A's performance. The purpose of the PSS is to enhance the damping of power system oscillations through injection of auxiliary signals for an excitation control terminal. The proposed series and parallel Sin+Cos PSS is connected adding the Sin+Cos terms additionally with the serial and parallel connection in a conventional PSS1A. The proposed controller is aimed at considering the damping of oscillation when it changes parameter fluctuations or operational load variations in a power system. The electric power system used is the KEPCO system and the voltage of the power transmission line is 154kV and 345kV. The PSCAD/EMTDC package is used to authorize the effect of the proposed controller. Simulations were shown by and compared with the waveforms for frequency, voltage and electric power.

Keywords: Damping, KEPCO system, PSCAD/EMTDC, PSS1A Type PSS, Series and parallel Sin+Cos PSS

1. Introduction

Unfortunately, power outages and exceptional events take place in unexpected ways [1, 2]. As a result of a blackout occurring throughout all the regions in South Korea, a restorative procedure had been assigned by the KPX (Korea Power Exchange). Black-start generators assigned by these rules are of the typically used hydro type to energize the remote nuclear and thermal generators through primary restorative transmission (PRT) in the case of a wide area blackout. KEPCO power systems has adopted the "all open" switching strategy except for the circuit breakers that are closed in PRT lines to make the procedure simple following a wide area blackout, which is the same strategy that is used in power systems throughout the world. PRT lines can be supplied by two cases of energization [3]. The first line involves the main energized transmission line. The second line deals with the subsidiary energized transmission.

In South Korea, the power system can be divided into 7 geographical areas that take geographical boundaries into account, which are 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 [4].

After a blackout, the power is reenergized to the power restoration line (PRL) from a black-start generator during these periods, taking into account power, angle and terminal voltage, etc., for the fluctuation of waveforms. To provide relief from these oscillations, a new series and parallel Sin+Cos PSS (power system stabilizer) for the damping of a power system during power restoration after a blackout in South Korea is presented.

This PSS structure has the parallel addition of series and parallel Sin+Cos term with conventional Lead-Lag PSS. Conventionally, the power system stabilizer (PSS) is used to enhance the damping of power system oscillations through excitation control.

Here the only used input to the stabilizers is the shaft speed. Conventional PSS1A PSS is used to enhance the damping of power system oscillations through excitation control, and to use inputs to the stabilizers as a shaft speed [5].

The main objectives of this paper are to demonstrate that the setting of the proposed series and parallel Sin+Cos PSS module can be effectively damped. The resulting power systems simulated results will be shown by using a PSCAD/EMTDC tool.

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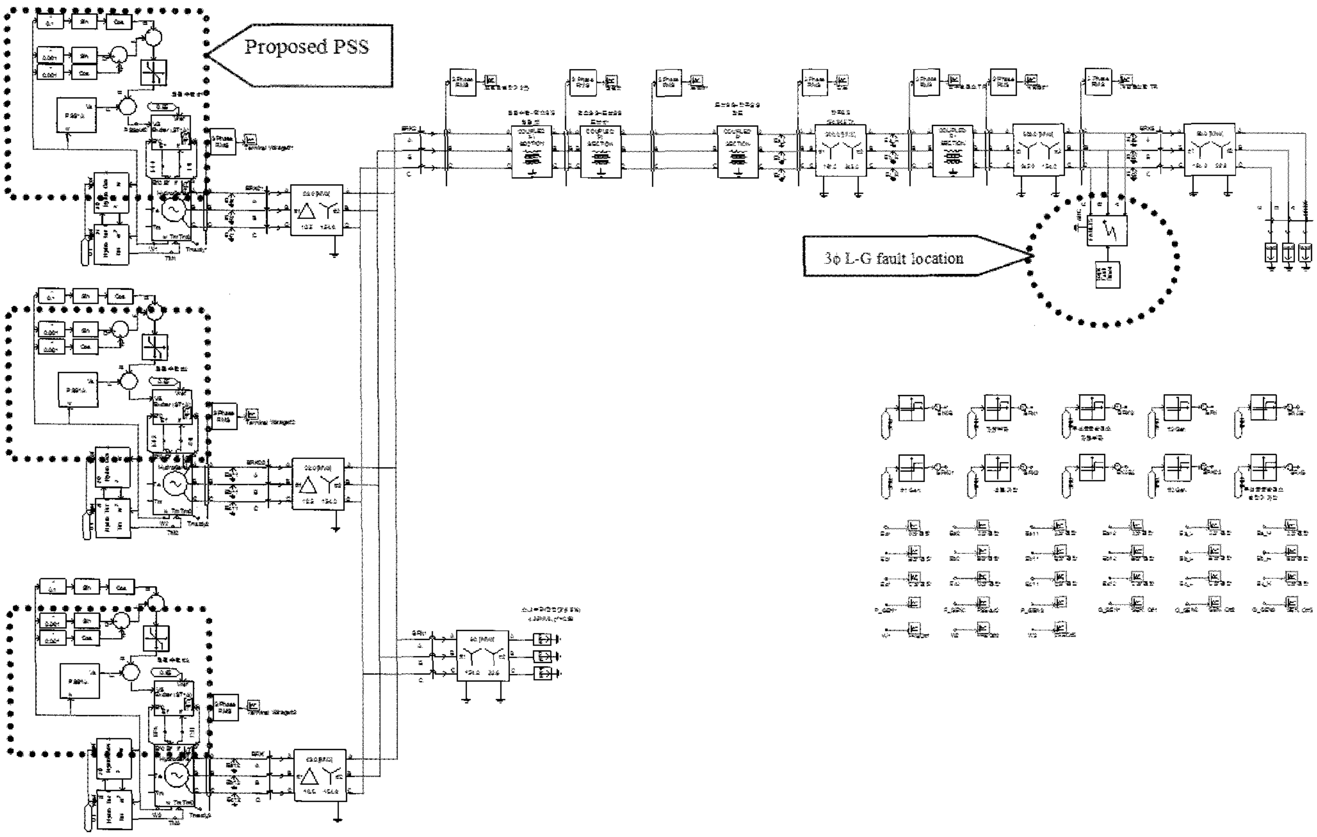


Fig. 1 PSCAD/EMTDC line diagram for main transmission line in the Northern Gyeongin area

2. PSCAD/EMTDC Power System Model

2.1 PSCAD/EMTDC diagram for 7 regions in Korea

Fig. 1 shows the main transmission line from three black-start generators, and this area is located in the northern part of the Gyeongin area in South Korea. The first line involves the main energized transmission line in the northern part of the Kyung-In area in South Korea and the transmission line voltages are 154kV and 345kV HVAC. The second line deals with the subsidiary energized transmission line in the northern part of the Gyeongin area in South Korea and the transmission line voltages are 154kV and 345kV HVAC. For the simulation, the 3-phase L-G location is connected with a fault breaker at the near end point of the PRT line for the purpose of the insertion in a power system to fault.

Fig. 2 shows a one-line diagram in the southern part of the Gyeongin area in South Korea.

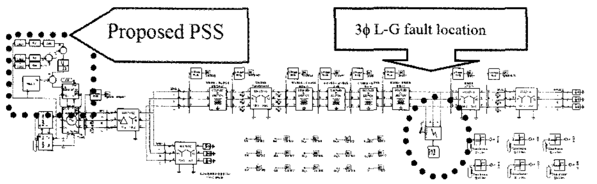


Fig. 2 PSCAD/EMTDC diagram for main transmission line in the Southern Kyung-In area

The power system stabilizer used here consists of one PSS module, for the purpose of enhancing the damping of power system oscillations through excitation control, and using inputs to the stabilizers as a shaft speed. The 3-phase L-G location for the simulation is connected with a fault breaker at the near mid point of the PRT line for the intention of the insertion in a power system to fault.

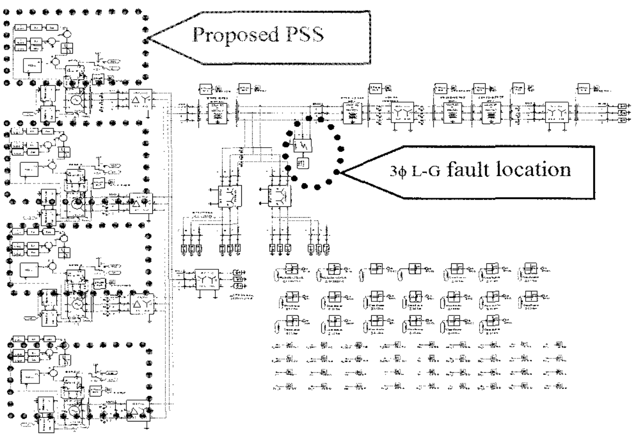


Fig. 3 PSCAD/EMTDC diagram for subsidiary transmission line in the Young-Dong area

Fig. 3 depicts the Youngdong area, and is located in the northeastern part of South Korea. The first line involves the main energized transmission line for the Youngdong area in the northeastern part of South Korea, and the voltages of the transmission line are 154kV and 345kV HVAC. For the simulation, the 3-phase L-G location is connected with a fault breaker near the starting point of the PRT line for the purpose of the insertion in a power system to fault.

Fig. 4 presents the Jungbu area using a PSCAD/EMTDC block diagram, and includes a black-start generator, a transformer, and a main transmission line. For the simulation, the 3-phase L-G location is connected with a fault breaker at the mid point of the PRT line for the purpose of the insertion in a power system to fault.

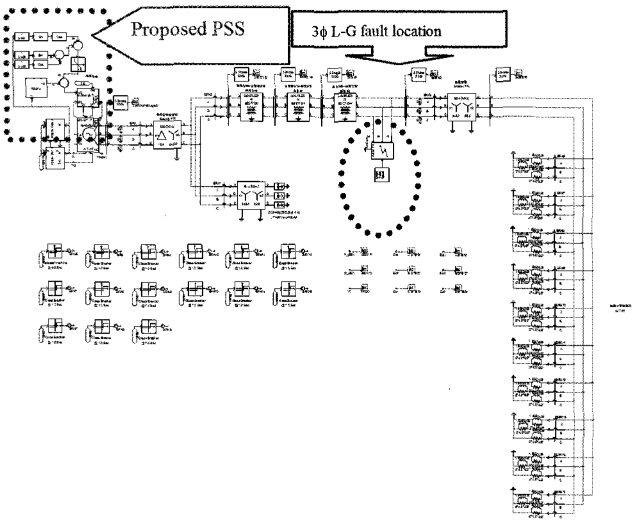


Fig. 4 PSCAD/EMTDC diagram for main transmission line in the Jung-Bu area

Fig. 5 shows the Yeongnam area, and is located in the southeastern part of South Korea. The 3-phase L-G location is connected with a fault breaker near the mid point of the PRT line for the purpose of the insertion in a power system to fault.

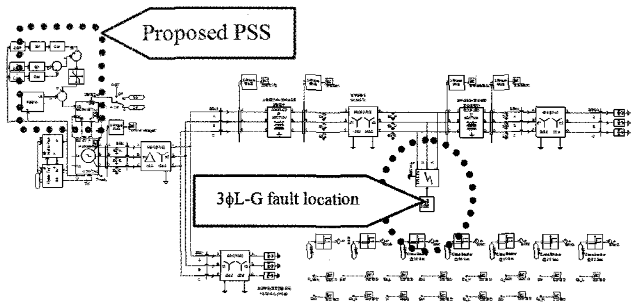


Fig. 5 PSCAD/EMTDC diagram for main transmission line in the Yeongnam area

Fig. 6 illustrates a PSCAD/EMTDC diagram showing the power supply to the main transmission line from two black-start generators and this area is located in the southwestern part of South Korea. For the simulation, the 3-phase L-G location is connected with a fault breaker near the mid point of the PRT line for the purpose of the insertion in a power system to fault. As the major island in Fig. 7, Jeju is a large island located in the southernmost part. Among the seven regions, only Jeju has a HVDC interconnection.

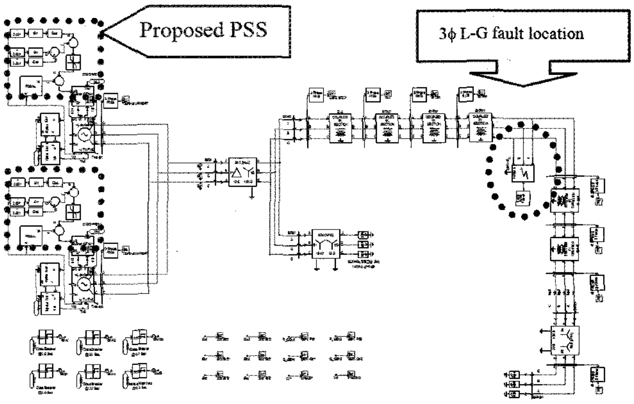


Fig. 6 PSCAD/EMTDC diagram for main transmission line in the Honam area

The connection method consists of a sea-line cable between Haenam in Honam and North-Jeju on Jeju Island. The black-start generators have one gas-turbine unit and two thermal units. The 3-phase L-G location is connected with a fault breaker near the end point of the PRT line for the purpose of the insertion in a power system to fault.

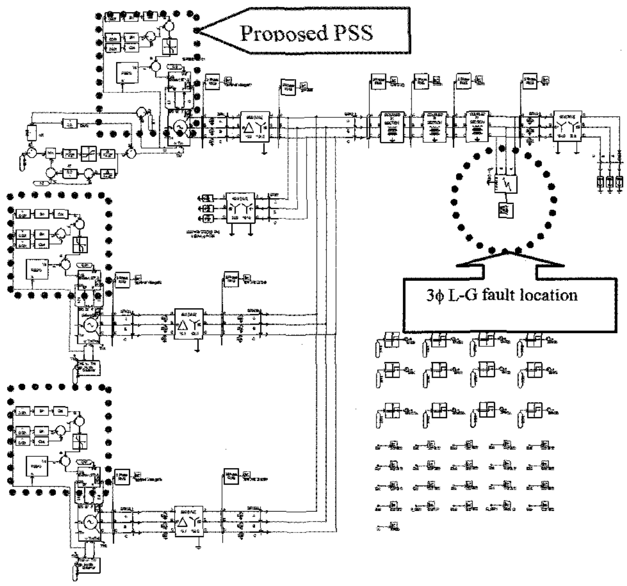


Fig. 7 PSCAD/EMTDC diagram for main transmission line on Jeju Island

3. Simulation results

As a first case, Fig. 8 shows a waveform without PSS and Fig. 15 represents the waveform of damping effect of the proposed series and parallel Sin+Cos PSS added on the PSS1A model in a PSCAD/EMTDC package. There was supplying of power through the main transmission line from the black-start generators in the northern part of the Gyeongin area (Seoul metropolitan area) in South Korea.

The simulations demonstrated were done for frequency. Compared to that without PSS, the frequency waveform was greatly improved. The oscillation for frequency in a power system was damped and moderately reduced by the setting of a PSS module.

As a second case, Fig. 9 depicts a waveform without PSS and Fig. 16 shows the waveform of damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package in the course of power supply through the main restoration transmission line from black-start generators in the southern part of the Gyeongin area (Seoul metropolitan area) in South Korea.

The frequency oscillation was greatly improved in the comparison to that without PSS control. This damping can be obtained by the setting of the parameters of the proposed PSS using a PSCAD/EMTDC package. The oscillation in the power system was damped and greatly reduced.

As a third case, Fig. 10 illustrates a waveform without PSS and Fig. 17 represents the waveform of damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package during power supply through the main restoration transmission line from black-start generators in the central part in South Korea. The fre-

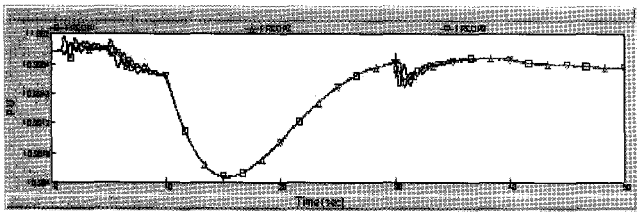


Fig. 8 Gyeongin northern area - without PSS

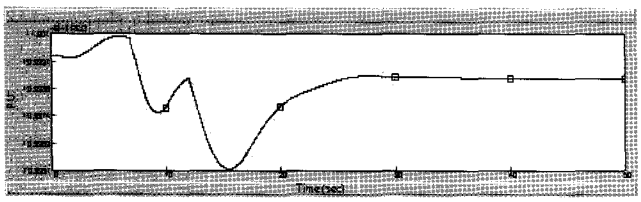


Fig. 9 Gyeongin southern area - without PSS

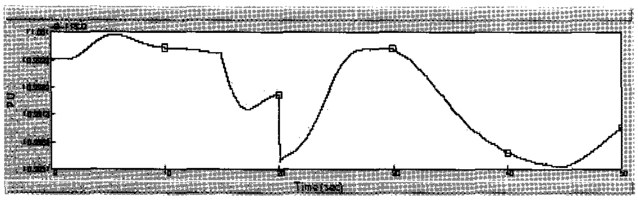


Fig. 10 Jungbu area - without PSS

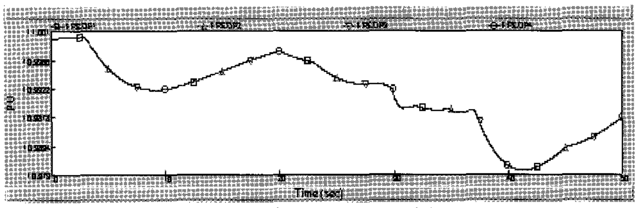


Fig. 11 Yeongdong area - without PSS

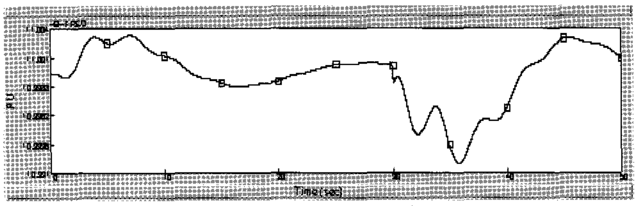


Fig. 12 Yeongnam area - without PSS

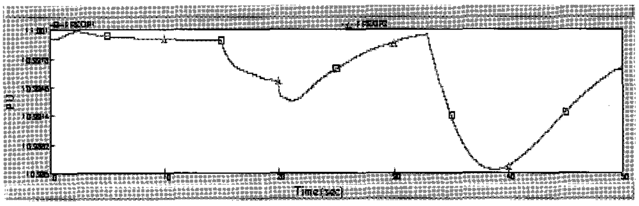


Fig. 13 Honam area - without PSS

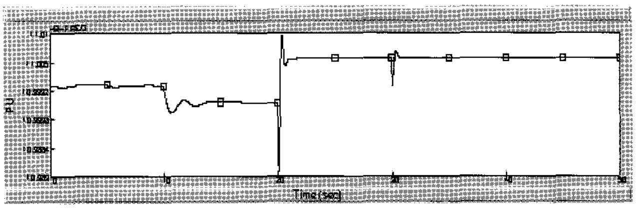


Fig. 14 Jeju Island - without PSS

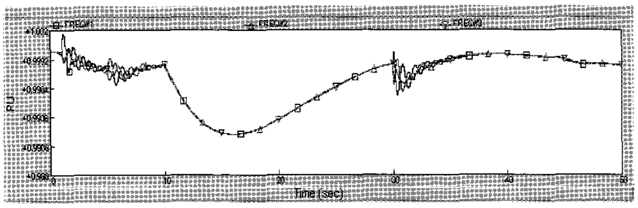


Fig. 15 Gyeongin northern area - with proposed PSS

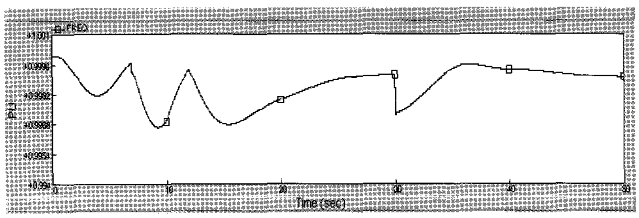


Fig. 16 Gyeongin southern area - with proposed PSS

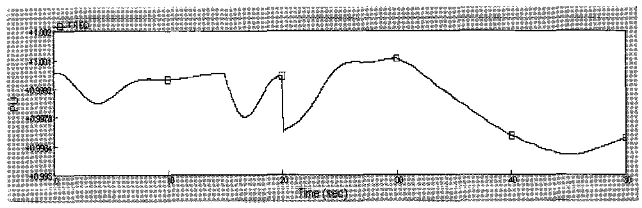


Fig. 17 Jungbu area - with proposed PSS

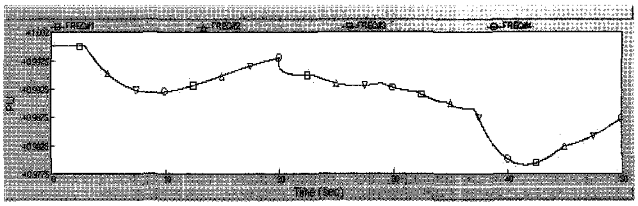


Fig. 18 Yeongdong area - with proposed PSS

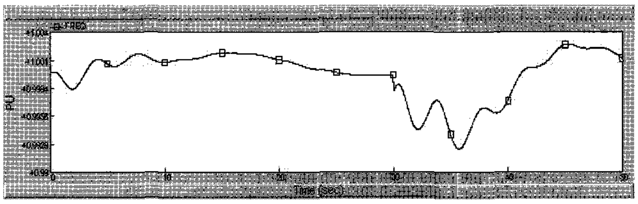


Fig. 19 Yeongnam area - with proposed PSS

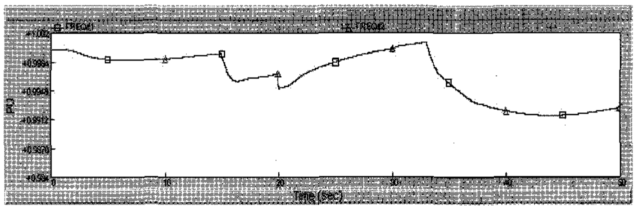


Fig. 20 Honam area - with proposed PSS

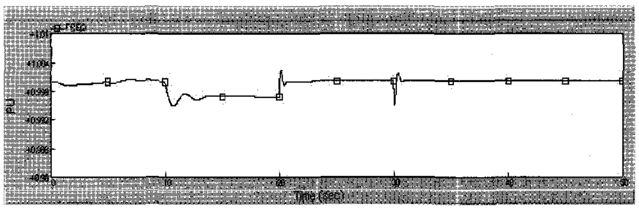


Fig. 21. Jeju Island - with proposed PSS

quency oscillation was greatly improved in the comparison to that without PSS control.

As a fourth case, Fig. 11 presents a waveform without PSS and Fig. 18 represents the waveform of damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package during power supply through the main restoration transmission line from black-start generators. This area is Yeongdong in the northeastern part of Korea. The frequency oscillation was very slightly improved in the comparison to that without PSS control.

As a fifth case, Fig. 12 represents a waveform without PSS and Fig. 19 shows the waveform of a damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package in the course of supplying power through the main restoration transmission line from black-start generators. There was supplying of power through the main transmission line from black-start generators for the Yeongnam area in the southeastern part of South Korea. Among these resulting waveforms, the frequency oscillation was improved slightly in the comparison to that without PSS control.

As a sixth case, Fig. 13 indicates a waveform without PSS and Fig. 20 depicts the waveform of the damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package in the course of supplying power through the main transmission line from black-start generators for the Honam area in the southwestern part of South Korea. The damping effect of the proposed PSS was greatly improved in the comparison to that without PSS control. As a result, the oscillation in the power system was well damped and moderately reduced by the setting of a PSS module.

As a seventh case, Fig. 14 shows a waveform without PSS and Fig. 21 indicates the waveform of damping effect of the proposed PSS added on a PSS1A model of a PSCAD/EMTDC package. The frequency oscillation shown was greatly improved in the comparison to that without PSS control.

4. Conclusion

A new series and parallel Sin+Cos PSS (power system stabilizer) was proposed. This was composed of parallel structures. The proposed PSS strategy for the damping of a power system during restoration in the cases of 7 geographical areas in South Korea was applied. The damping characteristics of a PSS (power system stabilizer) were presented by using a PSCAD/EMTDC in electric power grids including black-start generators in South Korea. The tested power system was Korea's power system, and was simulated by a PSCAD/EMTDC tool. The oscillation for seven cases can be considerably damped or marginally reduced by the setting of the proposed model with a PSCAD/EMTDC package.

Appendix

A.1 Power System Stabilizer (PSS1A)

A power system stabilizer (PSS) is used to enhance the damping of power system oscillations through excitation control. Here the only used input to the stabilizers is the shaft speed. Conventional PSS1A PSS utilized in Fig. A-1 is to enhance the damping of power system oscillations through excitation control, and to use inputs to the stabilizers as a shaft speed.

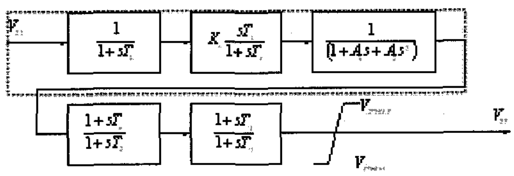
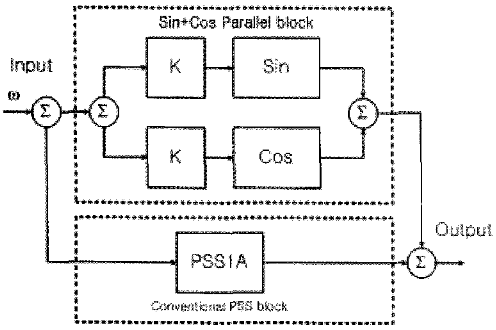
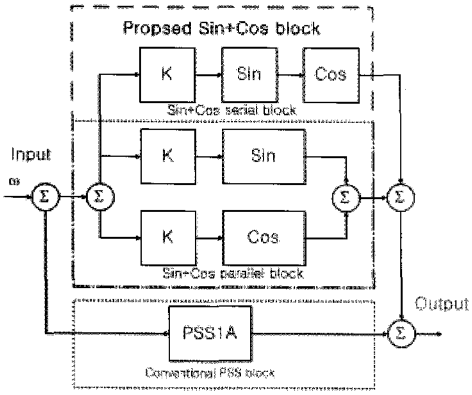


Fig. A-1 Conventional PSS1A PSS block diagram

A.2 Proposed Power System Stabilizer



(a) Parallel Sin+Cos PSS block diagram



(b) Serial Parallel Sin+Cos PSS

Fig. A-2 Proposed Sin+Cos PSS block diagram

$$u_{pss}(s) = K_s \frac{sT_5}{1+sT_5}\frac{1+sT_1}{1+sT_2}\frac{1+sT_3}{1+sT_4}\frac{1}{1+sT_6}\omega(s) \qquad \text{(A-1)}$$

In Fig. A-3, the proposed series and parallel Sin+Cos PSS is composed of the additional structure, with both a Sine+Cosine term and a conventional Lead-Lag PSS.

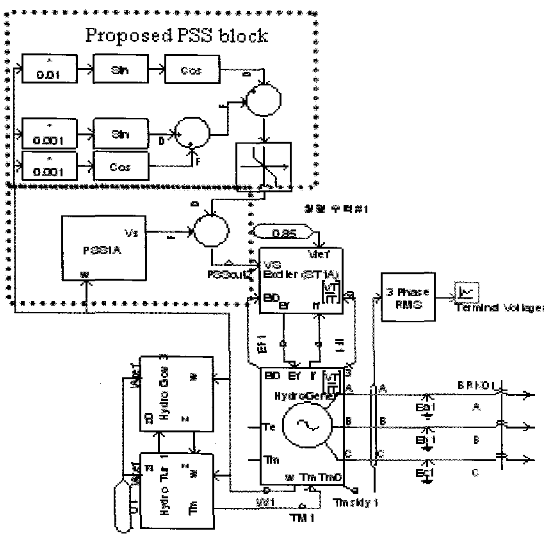


Fig. A-3 EMTDC/PSCAD block diagram of the proposed Sin+Cos PSS

Acknowledgements

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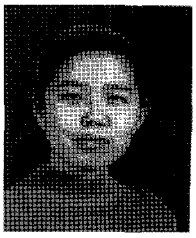

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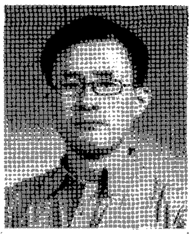

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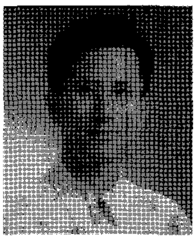

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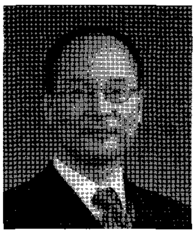

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