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청평양수 발전기의 PSS 파라메터 튜닝 및 시뮬레이터를 이용한 성능검증

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Application of a Digital PSS to 220MVA Pumped Storage Unit and Its Validation Using Real-Time Digital Simulator

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Abstract - This paper describes practical tuning methods and testing of a digital PSS, which uses both frequency and power, with the 220MVA Chungpyung P/P #1 in the KEPCO system to enhance the damping of local modes. In the first step, the objective phase of PSS is computed through a phase leading function to provide compensation between the exciter reference point and the generator air-gap torque before tuning the PSS's time constants. In addition, eigenvalue analysis was used to determine a range of PSS's gain, whichis the more useful for field testing rather than a single gain value. The Real-Time Digital Simulator was used to verify safe operations of the PSS in the presence of disturbances, such as AVR step and three phase fault.

1. Introduction

Power System Stabilizer (PSS) tuning and its application have been studied and applied to power systems around the world since the 1960s. The basic reasons for tuning PSS parameters are to compensate for the phase lag due to the power system, generator, and excitation system, and to provide electrical torque in phase with speed via the excitation system and generator [1]. However, the difficulties of both tuning the PSS parameters and their application to the power system deriving from the complexity of the power system and the wide range of operating points had made authorities reluctant to use a PSS.
In spite of these difficulties, excellent PSS tuning guides for a single-input PSS have been suggested [2][3], and dual input PSSs have been reported as an alternative for successful operation [4]. The dual-input PSS, which uses power and frequency as inputs, has many advantages over a single-input PSS, such as the speed-input PSS or power-input PSS, because it provides a damping torque for the power system on a wider range of frequencies of concern and is less sensitive to shaft torsional oscillation. Nonetheless, problems remain to be dealt with in a dual-input PSS. Although tuning of dual input PSS has been performed for hundreds of units without major complications, the dual-input PSS uses two such inputs and high-order filters, which make it difficult for the engineers to determine the required, properly tuned PSS parameters.
We present effective and practical tuning methods and application of a dual-input digital PSS. Objective phase of PSS is firstly computed through a phase leading function to provide compensation between the exciter reference point and the generator air-gap torque before tuning the PSS's time constants. In addition, eigenvalue analysis was used to determine a range of PSS's gain, which is the more useful for field testing rather than a single gain value.
Finally, the Real-Time Digital Simulator was used to verify safe operations of the PSS in the presence of disturbances, such as AVR step and three phase fault at the near bus.

2. Design of PSS Parameter

2.1 System Modeling

Figure 1 shows one machine and an infinite bus, which represents Chungpyung P/P #1 with its power system and this is used throughout this paper for tuning the PSS parameters. It was assumed that the unit has loading conditions of 200 MW and 0.0 MVAR at which point the total system gain is at its highest and in the least stable condition [2]. The excitation system of Chungpyung P/P #1, is static, as shown in Fig. 2. The model parameters of the generator and excitation system are in the Appendix.
The generator and excitation system parameters through the characteristic testingwere used so that reliable PSS parameters could be determined. To validate the model parameters of the generator and excitation system, the AVR step test, which is implemented to give the small-step voltage into the summing junction of the AVR reference, was simulated in terms of both armature voltage, V_t, and generator field voltage, Efd. Figure 3 shows the results of the simulation. The response of the excitation system proved to be well-damped after 5% AVR step change.

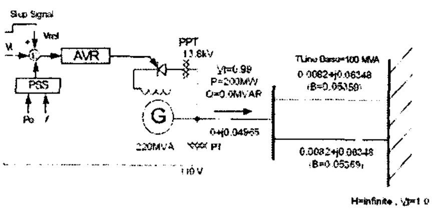


Fig. 1 One machine and Infinite Bus System used for the Tuning of Chungpyung P/P #1's PSS

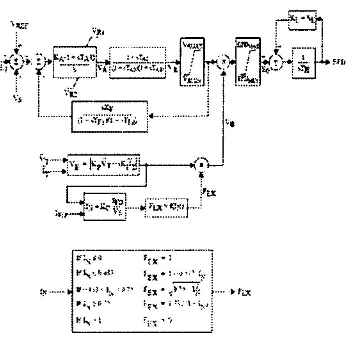


Fig. 2 The Excitation System Model of Chungpyung P/P #1 (EXPIC1)

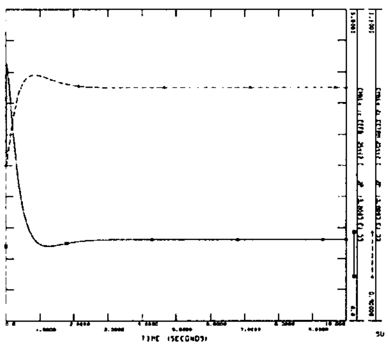


Fig. 3 The results of 5% AVR Step Test with Unit #1 Open-Circuits (Armature Voltage and Field Voltage of the Generator)

2.2 Phase Compensator Tuning

The digital PSS which is the dual-input type, takes advantage of the most widely used PSS structure, as shown in Fig. 4. It uses power and frequency and is calculated from armature voltage at the PSS input. The ramp-tracking filter in the middle of the PSS structure, shown in Fig. 4, plays an important role in determining the frequency response of the PSS. For the frequency input, it operates as a low-pass filter, which sharply attenuates the PSS gain in the high frequency range, such as occurs in the local mode. Conversely, for the power input, it operates as a high-pass filter reducing the low frequency gain, as occurs in inter-area mode.

Although the basic concepts of the dual-input PSS initially used accelerating power [4], it is practical for the design engineer to consider it to be two independent PSSs, a frequency-input PSSf and a power-input PSSp, to determine the PSS's time constants, which compose the phase compensator.

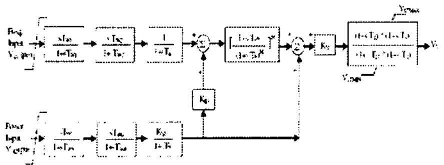


Fig. 4 The Model of Dual-Input PSS (PSS2A)

Phase compensator tuning is a very important part of the PSS tuning. In order to determine the proper time constants, the object phase is firstly computed by using large inertia method describe in [5]. After computing the objective phase, we selected the frequencyrange the PSS should cover as 0.1 to 2.0Hz. The frequency of the local mode of Chungpyung P/P #1 proved to be 1.34Hz with 0.0992 of damping ratio based on eigenvalue analysis.Also, 60 degree is selected for the maximum degree of phase leading compensation in order to consider transient performance. Even though the objective phase to be compensated is obtained, it is impossible to be covered exactly in the optimization process. We considered the phase compensation margin for 0.4 to 2.0Hz range as 10 degree (under compensation).
Figure 5 shows the objective phase and compensation margin of Chungpyung P/P #1's PSS.

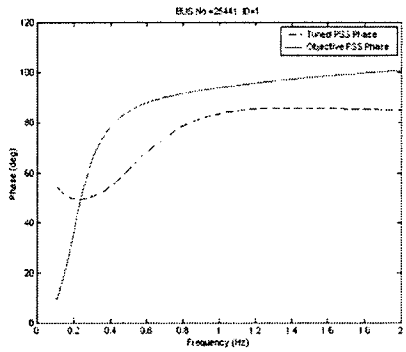


Fig. 5 The Phase Compensation Margin

2.3 Gain Tuning

As it is mentioned above, determination of the PSS gain has to not only be from analytical methods, but also from field testing, so as to obtain the gain that provides the best possible damping to the selected modes while keeping the noises from PSS at acceptable level. Table 1 shows the change of damping ratios (%) with increasing Gain, Ks, which are resulted from eigenvalue analysis.

Table. 1 Eigenvalues with Increasing Ks

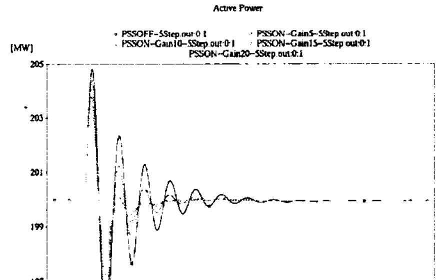
Ks Mode	Ks=0.0	Ks=15	Ks=30	Ks=45	Ks=60
1	1.34Hz (9.92%)	1.365Hz (31.5%)	0.789Hz (67.7%)	0.709Hz (64.5%)	0.608Hz (63.49%)
2	-	-	-	-	1.236Hz (85.38%)

Mode 1 is the local mode related to the electromechnical oscillation of Chungpyung P/P Unit #1, and Mode 2 is the control mode associated with the excitation system, especially the AVR. In the case of Ks=0.0, without the PSS, only the local mode is observed. The local mode is 1.34 Hz, and the damping ratio is 0.0992. As the PSS gain Ks is increased, the damping ratio of local mode also increases until approximately Ks=45.0. At Ks=60.0, another oscillation mode, called the control mode, occurs.

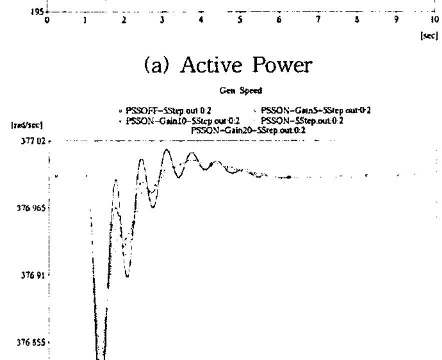
Unlike a conventional single-input PSS, such as a speed input PSS, the instability of the control mode was never detected even with large PSS gain in this dual-input PSS with increasing Ks. Instead, the damping ratio of the local mode, which would be thought to increase, decreases as Ks increases at values near Ks=45. In this paper, the value of Ks=15.0 is initially assumed to be the desirable value of PSS gain as it gives three times the gain margin to decrease the damping ratio of the local mode, which occurred at approximately Ks=45. The permanent value of PSS gain Ks, however, should be finally determined by a field test, taking into consideration all of the relevant factors. Therefore, the gain range in this case could be up to Ks=20.

3. Validation Using RTDS

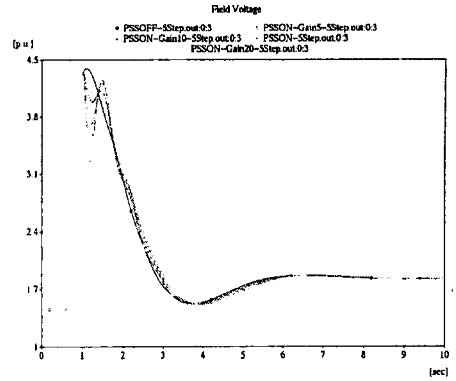
Before the dual-input parameters, are loaded into the PSS and are tested in an on-site test, some contingencies that could be anticipated or tested in the field test, must be simulated by running the transient time-domain stability program. For this purpose, Real-Time Digital Simulator was used in this study. Figure 6 shows the simulation results of 5% AVR step tests by varying the PSS gain Ks these would usually be scheduled for testing. As shown in Fig. 6 (a), the degree of damping of power oscillation is greatly enhanced as the PSS gain Ks is increased. Such results were anticipated by the damping ratio using the eigenvalue analysis



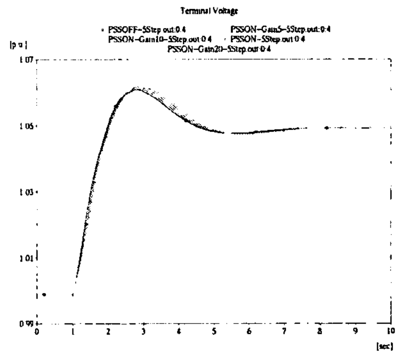
(a) Active Power



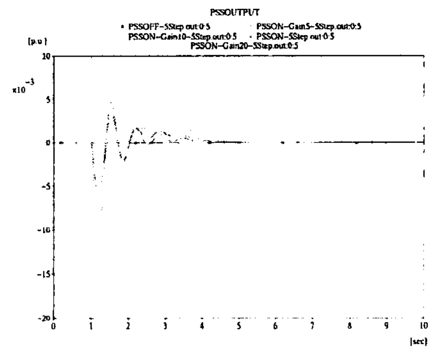
(b) Angle Speed



(c) Field Voltage



(d) Terminal Voltage



(e) PSS Output

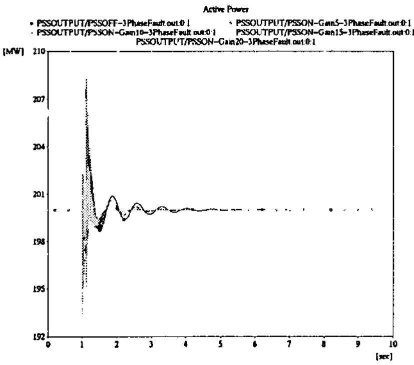
Fig. 6 The results for validation of PSS parameters in time domain simulation (5% AVR Step Test)

A more severe contingency, three phase fault, was applied on the bus near the PSS is installed, even though this test is not valid in real field.
Figure 7 also shows that the damping of power oscillation is highly enhanced as the gain, Ks, is increased. The magnitude of PSS' output is greater than that of AVR step test as shown in Figure 7 (c).

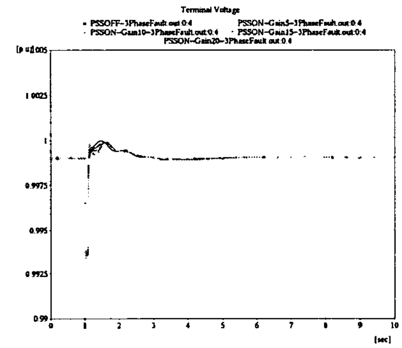
4. Conclusions

In this paper, effective useful tuning methods and application of a dual-input digital PSS to Chungpyung P/P #1in the KEPCO system are described. For the sake of better design of dual-input PSS parameters, eigenvalue analysis and time-domain simulation using

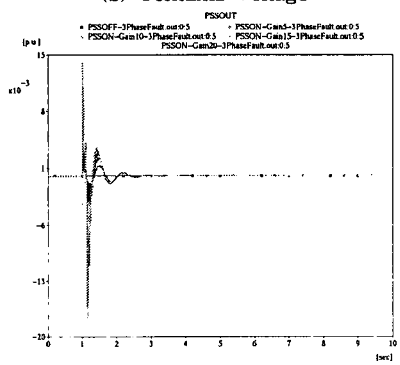
Real-Time Digital Simulator were used to determine a reliable PSS gain, Ks, and to verify the safe operation of the PSS in the presence of disturbances, such as the AVR step and three phase fault test. Only the PSS's parameters of a single-machine system were tuned in the paper, but similar approaches to those used in this paper can also be applied to multi-machine systems. In that case, more study will need to be given to the eigenvalue analysis



(a) Active Power



(b) Terminal Voltage



(c) PSS Output

Fig. 7 The results for validation of PSS parameters (Three phase fault)

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APPENDIX

1) GENERATOR PARAMETERS (220MVA, 13.8 KV)

Tdo' = 14.70 sec. Tdo" = 0.050 sec.
Tqo" = 0.150 sec. H = 4.8 D = 0.000
Xd = 0.9703 Xq = 0.4662 Xd' = 0.275
X" = 0.204 Xl = 0.150 S(1.0) = 0.1976
S(1.2) = 0.4083

2) EXCITATION SYSTEM PARAMETERS

TR = 0.000 KA=80 TA1=0.72
VR1=5.25 VR2=-5.25 VRMAX=5.25
VRMIN=-5.25 KF=0 TF1=0.1 TF2=0
EFDMAX=5.25 EFDMIN=-5.25

3) PSS PARAMETERS

TW1=TW3 = 2.0 TW2 ,TW4 = 0.0 T7 = 2.0
KS2 = 0.208333 KS3=1.00 T8 = 0.5
T9 = 0.10 N= 1 M=5
KS1 = 15.0 T1=0.046 T2=0.01
T3=0.5 T4=0.036 VSTMAX = 0.01 VSTMIN =-0.01