Intelligent Agent Based Remote Tuning of Power System Stabilizer through Computer Network

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Abstract-- In this paper, an intelligent agent based on-line remote tuning of PSS parameters has been proposed to ensure the maximum stabilization effect through the excitation control by PSS. A fuzzy logic PSS has been considered as the target PSS for the experimental studies on the 5kVA laboratory generator system. The standard PSS tests have been performed on the laboratory system by the personal computer based remote intelligent agent through the computer network. For the evaluation of control performance, the monitoring of generator oscillations has also been performed for a step change of reference voltage activated by the remote agent through the computer network. The remote tuning has been successfully accomplished by the proposed intelligent agent based method. For the communication between the remote agent and the fuzzy logic PSS at the site, the file sharing system has been utilized on the virtual private network(VPN).

Keywords: Intelligent agent, remote tuning, fuzzy logic PSS, computer network, virtual private network(VPN).

I. INTRODUCTION

DUE to the increasing size and complexity of electric power systems, electric power systems are often operated with a lower stability margin. Therefore, the stability enhancement is one of the most important issues for the reliable operation of electric power systems. Excitation control is well known as one of the effective means to enhance overall power system stability[1,2]. In our previous studies[3-9], we have proposed fuzzy logic power system stabilizers(FLPSS) to enhance the overall power system stability through the excitation control. In order to ensure the expected stabilization effect through excitation control, the on-line modification of PSS parameters is inevitable. On-line modification of PSS parameters is readily available because most of the PSSs have been already replaced to the micro-processor based digital ones.

In this paper, an intelligent agent based remote tuning of the PSS parameters has been proposed to ensure the maximum stabilization effect through the excitation control. A fuzzy logic PSS(FLPSS) has been considered as the target PSS for the experimental studies on the 5kVA laboratory generator system.

For the remote tuning, the standard PSS tests have been performed on the laboratory system by the remote intelligent agent supervising the PSS operation through the computer network. During the PSS standard tests, the generator real power output has been monitored at the site following a step change of the AVR reference voltage. The monitored generator output has been sent to the remote agent through the computer network for the evaluation of PSS control performance and also for the required modification of PSS parameters to ensure the reliable generator operation. The successful remote tuning has been demonstrated in the experimental studies on the laboratory system. For the communication between the remote intelligent agent and the fuzzy logic PSS at the site, the file sharing system has been utilized on the virtual private network(VPN).

II. CONFIGURATION OF INTELLIGENT AGENT BASED REMOTE TUNING SYSTEM

Fig. 1 illustrates the basic configuration of the proposed intelligent agent based remote tuning system for the power system stabilizers.

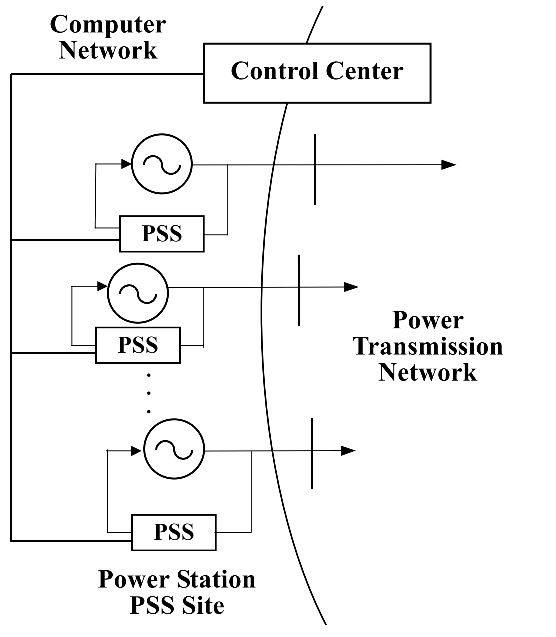

Fig. 1. Intelligent agent based remote tuning system through computer network

For the remote tuning of each PSS parameters, the PSS standard tests should be performed regularly at the PSS sites

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by the commands sent from the proposed intelligent agent at the control center. The generator real power output signal is monitored at the site following the step changes of the AVR reference voltage. The monitored signal is sent to the intelligent agent at the control center for the evaluation of the PSS control performance and the following modification of the PSS parameters to ensure more reliable generator operation.

For the evaluation of the PSS control performance, the following time-weighted quadratic performance index J is utilized by the intelligent agent at the control center.

$$J = \sum \Delta T^2 \Delta P_e^2 \qquad (1)$$

where ΔPe is the generator power deviation and ΔT is the sampling interval of the PSS.

Here, it must be noted that the proposed remote tuning system utilizes the virtual private network(VPN) for the communication among different network groups and also for the security reasons.

III. Fuzzy Logic Power System Stabilizer

The basic configuration of the fuzzy logic PSS is shown in Fig. 2. The real power output signal P_e from the generator is utilized to generate the stabilization control signal U_{PSS} for the excitation control system. The PSS is implemented by using a personal computer with a DSP board as shown later.

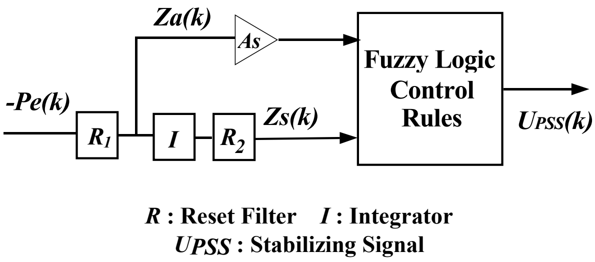

Fig. 2. Configuration of fuzzy logic power system stabilizer(FLPSS)

The speed and acceleration signals of the generator, derived from the real power signal P_e through the filtering shown in Fig. 2, are utilized to generate the PSS signal U_{PSS}. Here, Z_a and Z_s are the measures of the acceleration and the speed deviation of generator, respectively. The two dimensional information, i.e., Z_a and Z_s, is utilized to generate the PSS signal U_{PSS} to damp the generator oscillations.

In the fuzzy logic control scheme, the system state is defined by the speed/acceleration state $p(k)$. The operating point $p(k)$ is given by

$$p(k) = [\ Z_s(k),\ A_s Z_a(k)\ ] \qquad (2)$$

Then, the radius $D(k)$ is found as

$$D(k) = \sqrt{Z_s(k)^2 + (A_s \cdot Z_a(k))^2} \qquad (3)$$

The angle $\theta(k)$ is found as

$$\theta(k) = \tan^{-1}(A_s Z_a(k) / Z_s(k)) \qquad (4)$$

Note that Z_a and Z_s become zero at the final steady state once the study system is stabilized. Further note that A_s is simply a scaling factor for the acceleration signal Z_a.

The PSS signal U_{PSS} is given by

$$\begin{aligned} U_{PSS}(k) &= \frac{N(\theta(k)) - P(\theta(k))}{N(\theta(k)) + P(\theta(k))} \cdot G(D(k)) \cdot U_{max} \\ &= [1 - 2P(\theta(k))] \cdot G(D(k)) \cdot U_{max} \end{aligned} \qquad (5)$$

where U_{max} is the maximum size of the PSS signal.

In the above equation, the membership functions $N(\theta(k))$ and $P(\theta(k))$ give the angle membership functions for the deceleration control and also for the acceleration control, respectively. An additional membership function $G(D(k))$ is needed for the control signal. The function $G(D(k))$ mainly determines the size of the control signal. Fig. 3 illustrates both the angle and the radius membership functions.

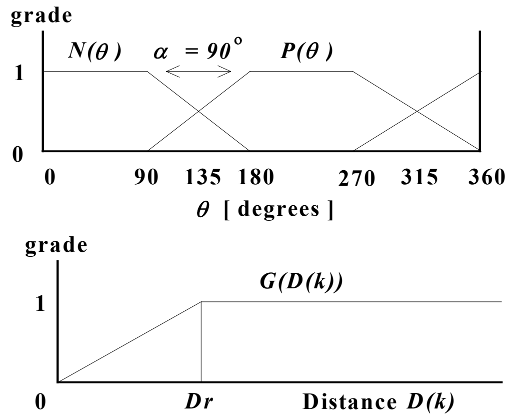

Fig. 3. Angle and radius membership functions

The FLPSS has three basic adjustable control parameters A_s, D_r, and the overlap angle α. The parameter α is fixed to 90 degrees and also the parameter Dr is fixed to 0.1 without any degradation of the control performance, because the control performance is mainly dominated by the ratio As/Dr.

IV. Configuration Of Study System

Fig. 4 illustrates the basic configuration of the laboratory system. Fig. 5 shows its overview including the fuzzy logic PSS(FLPSS) and the monitoring system at the site. The PSS standard tests and the following remote tuning have been performed bythe intelligent agent from the remote control center through the computer network. The FLPSS has been developed in the Matlab/Simulink environment. The FLPSS has been set by using a personal computer(PC). A DSP board with AD/DA conversion interface is installed on the PC for the monitoring of real power output from the generator and also for the feedback of the generated PSS signal to the AVR.

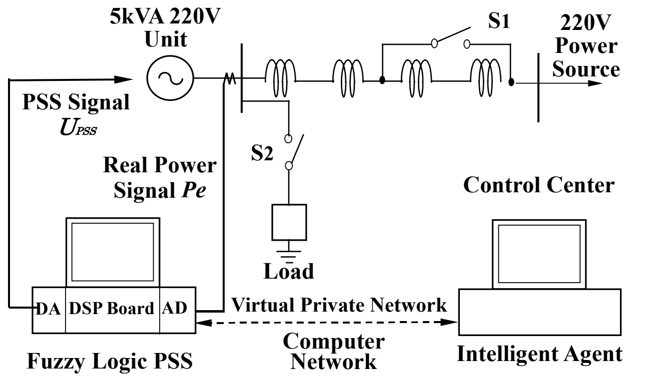

Fig. 4. Basic configuration of laboratory system

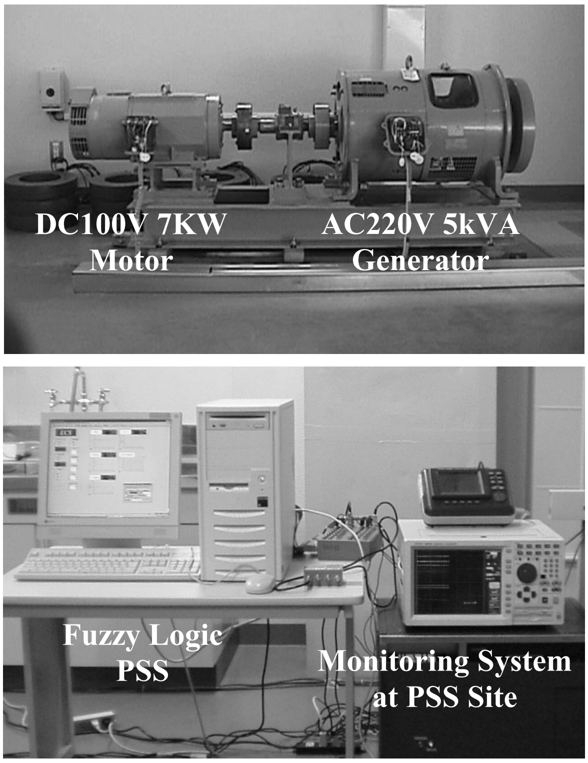

Fig. 5. Overview of laboratory system and fuzzy logic PSS

Fig. 6 illustrates the computer display on the intelligent agent at the control center. The PSS standard test have been performed from the control center by specifying the step changes of the AVR reference voltage. The test results have been monitored by the FLPSS at the site. The monitored results have been sent to the intelligent agent at control center through the computer network for the evaluation of the PSS performance and also for the required modification of PSS parameters. The tuning and the testing block perform the PSS standard tests and modifies the PSS parameters. The evaluation block displays the monitored results and also evaluates the PSS performance according to the performance index given by eqn.1.

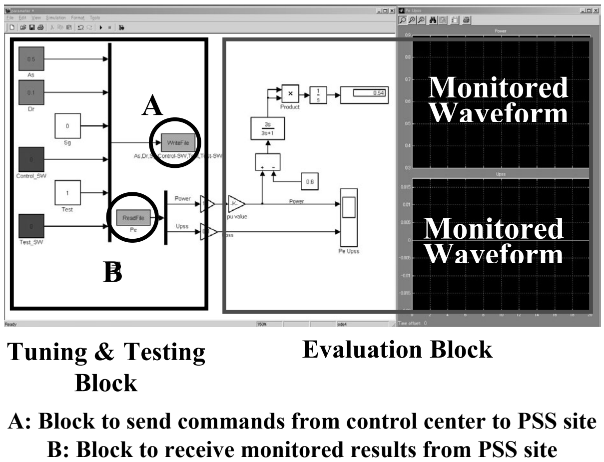

Fig. 6. Computer display on PC based intelligent agent at control center

V. Experimental Results

To demonstrate the efficiency of the proposed intelligent agent based remote tuning system, experimental studies have been performed on the laboratory system together with the virtual private network.

A. Detailed Tuning of PSS Parameters at Site

Before the testing of the intelligent agent based remote tunig, detaild testings have been performed at the generator site to investigate the relation between the control parameter *As* of the fuzzy logic PSS and the stabilization performance. Fig. 7 illustrates the typical results, where the generator outputs are set to 2kW and 5kW, respectively.

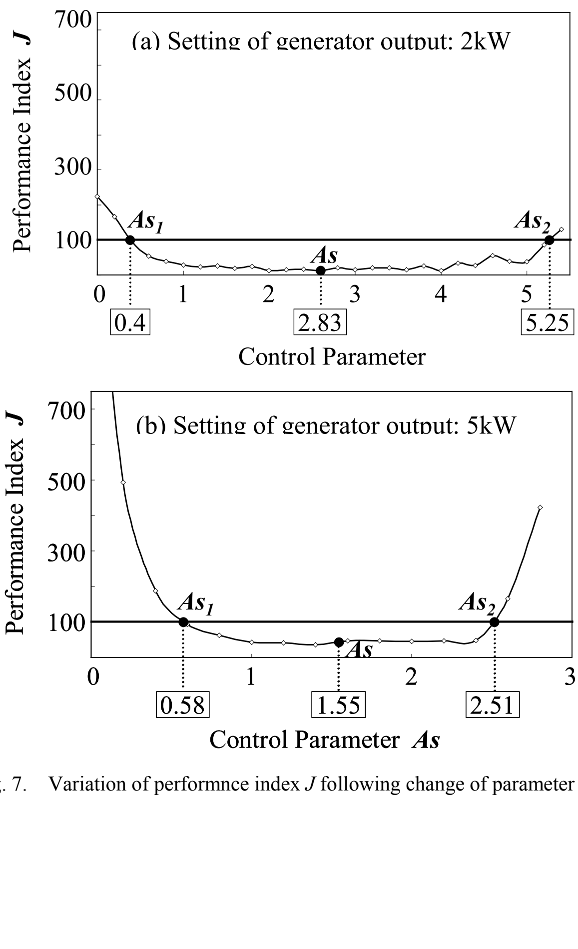

Fig. 7. Variation of performnce index *J* following change of parameter *As*

It must be noted that the value of the performance index J is 1741.6 without any PSS. The performance index J has a quite wide bottom within a certain range of the parameter As. Therefore, the robustness of the fuzzy logic PSS is clearly recongnized from the results. From the figure, the middle points of the range of parameter As are found as 2.83 and 1.55 for the output setting of 2kW and 5kW, respectively, where the performance index J is less than 100. These two values might be considered as the optimal setting of As at those two different generator operating points.

B. Intelligent Agent Based Remote Tuning of PSS Parameter

The automatic remote tuning of the PSS parameter As has been performed by the intelligent agent at the control center through the virtual private network. For the optimization of the parameter As, the PSS standard tests have been activated by the intelligent agent at the control center. To determine the optimal value for the parameter As, the quadratic approximation has been utilized as shown in Fig. 8.

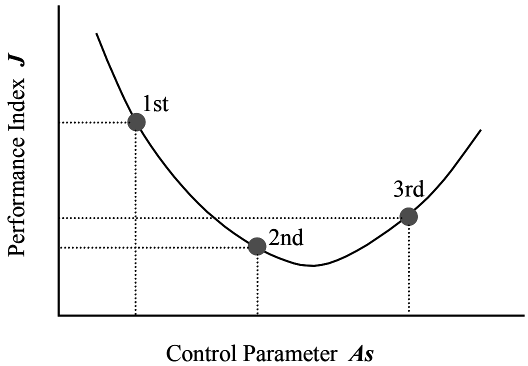

Fig. 8. Optimization of control parameter *As*

To reach the optimal setting of the parameter As, seven iterations of the standard tests have been required as shown in TABLE I.

TABLE I
RESULT OF REMOTE TUNING FOR PSS PARAMETER *As*

(a) Generator operating point: 2kW

No. of Standard Test	*As*	Index *J* (x 100)
1	0.30	151.0
2	0.35	137.2
3	0.45	105.9
4	0.65	68.3
5	1.05	38.6
6	1.85	20.1
7	3.45	23.9
Optimal Setting	2.54	19.7

(b) Generator operating point: 5 kW

No. of Standard Test	*As*	Index *J* (x100)
1	0.30	315.6
2	0.35	276.1
3	0.45	172.4
4	0.65	110.7
5	1.05	31.0
6	1.85	26.2
7	3.45	850.5
Optimal Setting	1.46	25.3

The number of iterations required can be reduced by the modification of the interval of the parameter search. Here, it must be noted that the obtained optimal parameter As is very close to the mid-point value of the wider bottom area shown in Fig. 7 for both the generator operating point of 2kW and 5kW.

The monitored signals by the intelligent agent at the control center are illustrated in Fig. 9 and Fig. 10 for the generator operating point of 2kW and 5kW, respectively. In these figures, the monitored signals for the initial setting of As and also for the optimal setting of As are illustrated. In addition, the real power output ΔP_e and the PSS signal $Upss$ are illustrated from the top to the bottom.

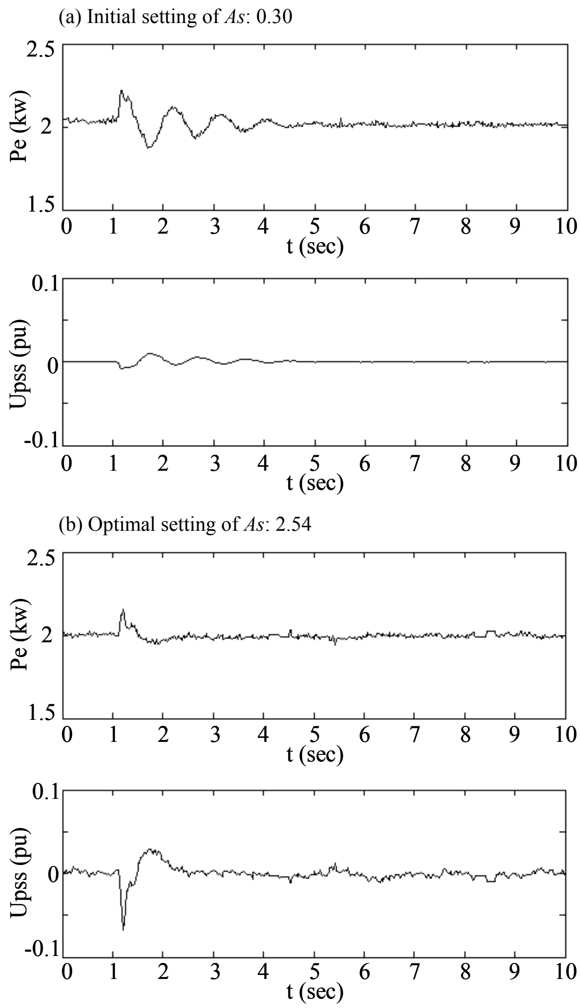

Fig. 9. Control performance of fuzzy logic PSS at generator operating point of 2kW

The maximum size of the PSS signal is set to 0.1pu throughout the experimental studies on the laboratory system. As shown in Fig. 9 and in Fig. 10, the control performance is highly improved by the proposed intelligent agent based remote tuning. From these figures, it might be concluded that the communication delay using the file sharing system through the virtual private network(VPN) between different network groups does not give any significant difficulty on the proposed intelligent agent based remote tuning.

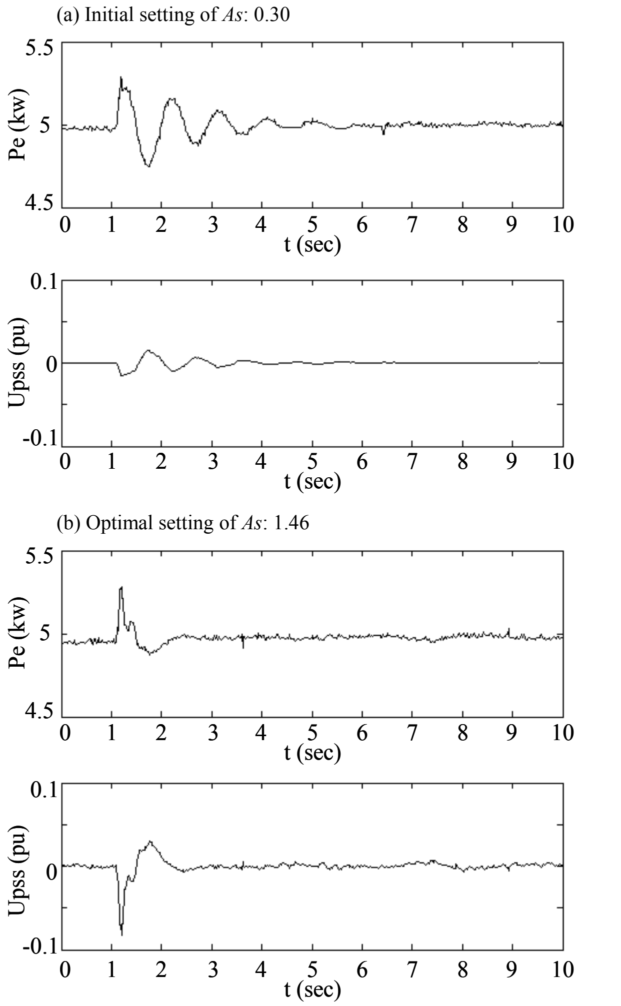

Fig. 10. Control performance of fuzzy logic PSS at generator operating point of 5kW

VI. Artificial Neural Network Based Real Time Tuning of PSS Parameter

After having the enough number of data set by the intelligent agent based remote tuning system, an artificial neural network based adaptive fuzzy logic PSS can be set up. The retraining of the neural network should be required only when the degradation of control performance is detected by the intelligent agent based remote tuning system at the control center.

Fig. 11 illustrates the configuration of the three-layered neural network utilized for the real time automatic tuning of the PSS parameter *As*. The input signal is the real power output from the generator and the output signal is the control parameter *As*.

The neural network has been trained by the data set obtained through the intelligent agent based remote tuning tests on the laboratory system. By using the trained neural network, the optimal setting of the parameter *As* can be achieved as clearly illustrated in Fig. 12. The parameter *As* is properly estimated for each one of the untrained data set. The neural network can be easily combined with the fuzzy logic PSS to shift the PSS to the adaptive fuzzy logic PSS.

Here, it must be noted that the training of the neural network is performed by the intelligent agent at the control center whenever the retraining is required and the retrained result is transferred to the corresponding adaptive fuzzy logic PSS for its renewal. Further studies are now ongoing to investigate the control performance of the adaptive fuzzy logic PSS.

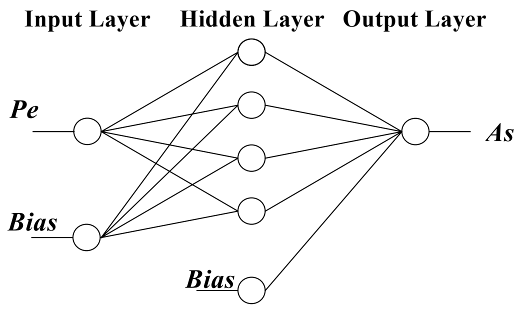

Fig. 11. Configuration of three-layered artificial neural network

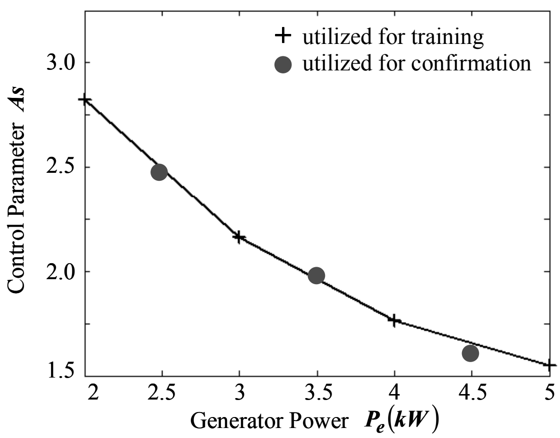

Fig. 12. Estimation of optimal parameter *As* by trained neural network

VII. Conclusion

Through the laboratory tests, the efficiency of the proposed intelligent agent based remote tuning system for the fuzzy logic PSS parameter has been demonstrated. The implementation of the proposed remote tuning system provides more reliable power system operation following the varieties of the system operating conditions. The testing of the adaptive fuzzy logic PSS is now ongoing for the further improvement of the generator stability.

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IX. BIOGRAPHIES

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