# DESIGN OF PID-PSS WITH GLOBAL SIGNAL INPUT TO DAMP OSCILLATION IN MULTI-MACHINE POWER SYSTEMS

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***ABSTRACT***

*The stability of the power system has become a main concern in an operating system. Power System Stabilizer (PSS) is a device that can control signal of a generator's excitation system to damp oscillations in the power system. In this paper, PID controller equipped with PSS with input signal from others generator. PID-PSS was implemented on multi-machine power system, model of Phillips-Heffron scheme is used for the stability analysis that has been widely used as a machine model. Genetics Algorithm method was proposed to tune PID controller and lead-lag compensation parameter, this technique gives the parameter controller. A comparison study is introduced when using PID controller, only using PSS, using PID-PSS with local input signal and when using PID-PSS with global input signal. By giving a small disturbance in the system, dynamic stability of power systems becomes focused. The results shows that using PID-PSS with global input signal better ensures the stability and performance of the power system rather than when only using PID, only using PSS, or using PID-PSS with local input signal.*

***KEYWORDS:*** *genetic algorithms, GUPFC, Multi-machine, PID, PSS, stability*

## I. INTRODUCTION

The stability of the power system has become a major concern in an operating system. The concern stems from the fact that in the steady-state conditions, the average speed should be the same for all generators. The power system should be able to maintain a balanced operating conditions and the system is able to return to normal operating conditions when a disturbance occurs [1].

Lead-lag PSS has been used since the 1960s is lacking broad to damp low frequency oscillations in the rotor [2]. To analyze small signal stability, Philip-Heffron model with a conventional lead-lag PSS has been used extensively [3]. Damping power system oscillations inter areas are an important concern for the security of the system operation. Power system stabilizer (PSS) is the most widely used device to solve oscillation stability problem and increase the damping of power system when a disturbance occurs [4].

Genetic algorithms (GA), widely applied in the power system stabilizer has been getting a lot of attention [5, 6]. Genetic algorithms are search algorithms based on natural selection and natural genetics. This algorithm is useful for problems that require effective and efficient searches, and can be used widely in the control system. Genetic algorithms can be used to get the right solution to solve problem of one or many variables.

Different type of controllers like Proportional-derivative (PD), Proportional-integral (PI), Proportional-Integral-Derivative (PID) and lead-lag was designed to stabilize the system. The lead-lag controller is very commonly used for simple implementation as a traditional controller. PID which is a combination of proportional, integral and derivative is prominent type controllers [7].

The design of a PID power system stabilizer using hybrid PSO-BFA has been applied to a typical single machine infinite bus power system. The simulation results of the system for the deviations in the speed and the angle demonstrated that the designed optimal PID-PSS based hybrid PSO-BFA optimization method is capable of guaranteeing the stability and performance of the power system better than the classical PID controllers and the PID-PSS based BFA only [8].

The selection of the input signal becomes an important factor in the ability of the control devices to damp inter-area oscillations. Many studies have been conducted to discuss and find solutions to determine the feedback signal as input signal for PSS and FACTS devices that provide maximum effect on the system [9].

In this paper, a multi-machine was considered and the system model for it was done. PSS with PID and lead-lag controllers with local input signal and global input signal considered to damp oscillation. Then, based on this controller a comparison was done between different structures of controllers and input signal with respect to speed deviation and angle deviation. The parameter of the controllers was tuned using genetic algorithms.

## II. NETWORK EQUATION

The performance of the proposed PID-PSS controller and tuning method using genetics algorithm is tested on a multi-machine system as shown in figure.1. The system consists of 3 machines and 3 buses.

Assume that the power system network admittance matrix can be written as $Y_t$ :

$$\begin{bmatrix}\bar{I}_1\\ \bar{I}_2\\ \bar{I}_3\end{bmatrix} = \begin{bmatrix}\bar{Y}_{11} & \bar{Y}_{12} & \bar{Y}_{13}\\ \bar{Y}_{21} & \bar{Y}_{22} & \bar{Y}_{23}\\ \bar{Y}_{31} & \bar{Y}_{42} & \bar{Y}_{43}\end{bmatrix} = \bar{Y}_t \begin{bmatrix}\bar{V}_1\\ \bar{V}_2\\ \bar{V}_3\end{bmatrix} \quad (1)$$

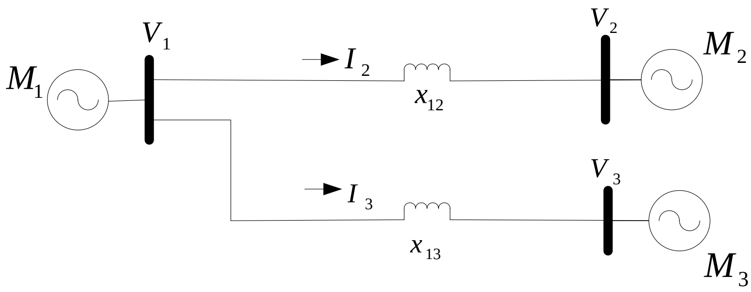


**Figure 1.** System configuration as case study

## III. LINEARIZED MODEL

A mathematical equation of a synchronous generator is linearized by neglecting internal resistance and sub-transient of the generator and neglecting the function of the governor ($T_M = 0$), so the equation becomes:

$$\Delta\dot{\delta} = \omega_0 \Delta\omega$$

$$\Delta\dot{\omega} = \frac{-\Delta T_e - D\Delta\omega}{M}$$

$$\Delta\dot{E}'_q = \frac{-\Delta E_q + \Delta E_{fd}}{T'_{D0}}$$

$$\Delta\dot{E}'_{fd} = -\frac{1}{T_A}\Delta E_{fd} - \frac{K_A}{T_A}\Delta V_T \quad (2)$$

Equation 2 can be simplified into the state variable equation of the power system :

$$\dot{x}_n = A_n x_n \quad (3)$$

Where A is the system matrix and B is the input matrix. The model of the system in state space form without any controllers can be expressed as follows:

$$\begin{bmatrix} \Delta\dot{\delta} \\ \Delta\dot{\omega} \\ \Delta\dot{E'}_q \\ \Delta\dot{E}_{fd} \end{bmatrix} = \begin{bmatrix} 0 & \omega_0 & 0 & 0 \\ -\frac{K_1}{M} & -\frac{D}{M} & -\frac{K_2}{M} & 0 \\ -\frac{K_4}{T'_{d0}} & 0 & -\frac{K_3}{T'_{d0}} & \frac{1}{T'_{d0}} \\ -\frac{K_A K_5}{T_A} & 0 & -\frac{K_A K_6}{T_A} & -\frac{1}{T_A} \end{bmatrix} \times \begin{bmatrix} \Delta\delta \\ \Delta\omega \\ \Delta E'_q \\ \Delta E_{fd} \end{bmatrix} \quad (4)$$

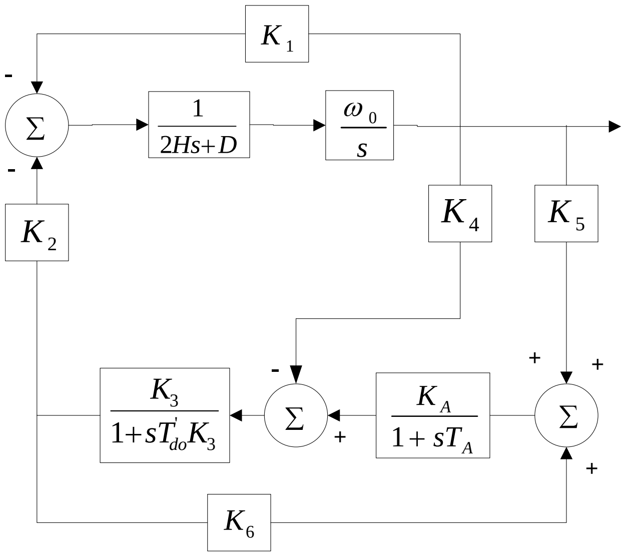


**Figure 2.** Phillips-Heffron model of power system

## IV. PID-PSS CONTROLLER DESIGN

LCC techniques is used to design PSS. This technique consists of gain, washout, one or more stages of phase compensation block and PID control block as shown in Figure 4. PID-PSSL controller and PID-PSSI each has an input signal $\Delta\omega_1$ for PID-PSSL and $\Delta\omega_{13}$ for PID-PSSI. The transfer function of each controller is as follows:

$$U_{PID-PSS} = K_{PSS}\left(\frac{sT_W}{1+sT_W}\right)\left(\frac{1+sT_1}{1+sT_2}\right)\left(\frac{1+sT_3}{1+sT_4}\right)G_c(s) \quad (5)$$

where,

$$G_c(s) = \left(K_p + \frac{K_i}{s} + K_d s\right) \quad (6)$$

Parameter values which are used for compensator are : $K_{PSS}, K_{PID} = 0{,}1 - 50$; $T_1, T_3 = 0{,}2 - 1{,}5\ s$; $T_2, T_4 = 0{,}02 - 0{,}15\ s$. Washout parameter $T_W$ taken at 10 s [12]. PSS optimal parameters such as gain $K_{PSS}$ and time constant $T_1, T_2, T_3$ and $T_4$ formulated into an objective function based Modal Analysis and then optimized using GA. Control signal ($u_{PID-PSS}$) becomes:

$$u_{PID-PSS} = H_{PID-PSSL} * \Delta\omega_1 + H_{PID-PSSI} * \Delta\omega_{13} + H_{PID-PSSI} * \Delta\omega_{12} \quad (7)$$

where,
$\Delta\omega_{13} = \Delta\omega_1 - \Delta\omega_3$
$\Delta\omega_{12} = \Delta\omega_1 - \Delta\omega_2$

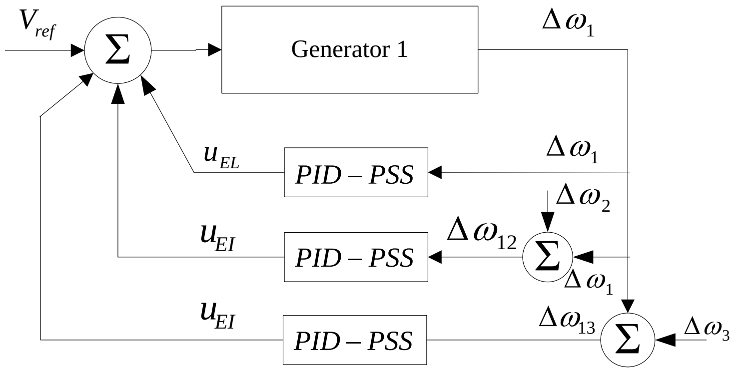


**Figure 3.** Scheme of PID-PSS controller with input signal $\Delta\omega_1$, $\Delta\omega_{12}$ and $\Delta\omega_{13}$

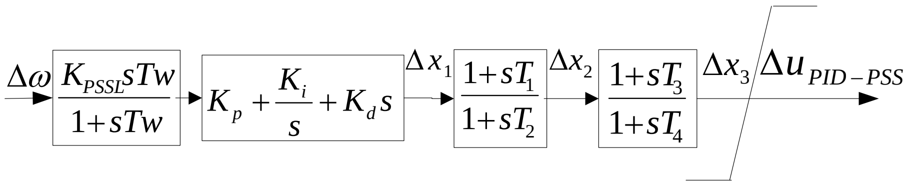


**Figure 4.** PID-PSS controller structure

From Fig. 4 we can describe the equation of PID-PSS controller structure as follows:

$$\dot{\Delta x}_1(s) = \frac{M.K_{PSS}.\frac{K_i}{\omega_o} - K_{PSS}.K_d K_1}{M.T_W}.\Delta\delta + \frac{K_{PSS}\left(M.K_p - D.K_d\right)}{T_W}.\Delta\omega - \frac{K_{PSS}.K_d K_2}{M.T_W}.\Delta E'_q - \frac{\Delta x_1}{T_W} \quad (8)$$

$$\dot{\Delta x}_2(s) = K_{PSS}.T_1\frac{\left(M.\frac{K_i}{\omega_o} - K_d.K_1\right)}{M.T_W.T_2}.\Delta\delta + K_{PSS}.T_1\frac{\left(M.K_p - D.K_d\right)}{M.T_W.T_2}.\Delta\omega - \frac{K_{PSS}.T_1.K_d K_2}{M.T_W.T_2}.\Delta E'_q - \frac{T_W - T_1}{T_W.T_2}.\Delta x_1 - \frac{1}{T_2}.\Delta x_2 \quad (9)$$

$$\dot{\Delta x}_3(s) = K_{PSS}.T_1.T_3.\frac{\left(M.\frac{K_i}{\omega_o} - K_d.K_1\right)}{M.T_W.T_2.T_4}.\Delta\delta + K_{PSS}.T_1.T_3.\frac{\left(M.K_p - D.K_d\right)}{M.T_W.T_2.T_4}.\Delta\omega - \frac{K_{PSS}.T_1.T_3.K_d K_2}{M.T_W.T_2.T_4}.\Delta E'_q - \frac{T_3(T_W - T_1)}{T_W.T_2.T_4}.\Delta x_1 - \frac{T_2.T_3}{T_2.T_4}.\Delta x_2 - \frac{\Delta x_3}{T_4} \quad (10)$$

## V. THE OBJECTIVE FUNCTION

The objective function used in this study calculates the parameter controls that would put eigenvalue matrix systems are on the left axis imaginary optimized using GA. The parameter may be selected to minimize the following objective function:

$$J_1 = \sum_{\sigma_i \geq \sigma_0} (\sigma_0 - \sigma_i)^2 \quad (11)$$

Where $\sigma_i$ is the real part of the *i*th eigenvalue, and $\sigma_0$ is a chosen threshold. The value of $\sigma_0$ represents the desirable level of system damping. This level can be achived by shifting the dominant eigenvalues to the left of $\sigma_0$. The condition $\sigma_i \geq \sigma_0$ indicates that the value of $J_1$ expresses the condition where the system is unstable or poorly damped. The value of $\sigma_0$ as denoted in figure 5 shows that the system is relatively stable. The ideal real eigenvalue lies in $\sigma_i \leq \sigma_0$ as shown in Fig. 5

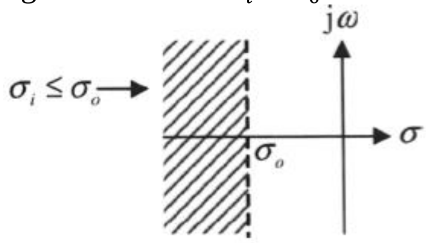


**Figure 5.** Eigenvalue location for $J_1$ objective function.

$J_2$ is the objective function for the maximum overshoot, the parameters can be selected using the following objective function:

$$J_2 = \sum_{\zeta_i \geq \zeta \sigma_0} (\zeta_0 - \zeta_i)^2 \tag{12}$$

Where $\zeta_i$ is damping ratio of the *i*th eigenvalue. The value of damping ratio is supposed to be in $\zeta_0 \geq \zeta_i$ as shown in Fig 6.

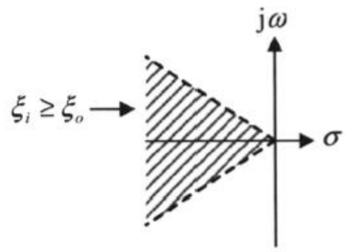


**Figure 6.** Eigenvalue location for $J_2$ objective function

In this work, the value of $\sigma_0$ and $\zeta_0$ are taken at -0.3 and 0.2 respectively [14].
Using Genetic Algorithm, we can assign the dominant close-loop eigenvalue to lie close to value of the objective function. The steps of the genetic algorithm can be explained as follows:

a. Initialize population. This is done randomly and only one time when start the genetic algorithm. This results in a population initialization beginning with a chromosome number that corresponds to what we expect.
b. Evaluation. It is the process of calculating the fitness value of each chromosome which exists.
c. Selection. Through this process it gives birth to a new generation in which the chromosomes are derived from earlier chromosomes.
d. Crossover. This process will produce offspring that are different from the parents. This process is done by taking a parent in pairs and will produce offspring with the same amount as the parent.
e. Mutations. This process also will also produce offspring in which the amount depends on the number of random numbers that are less than the probability of mutation.
f. Evaluation. This process was repeated to calculate the fitness of each chromosome.
g. Perform repetitions again from step b, when a stopping criterion has been achieved, the genetic algorithm is completed.

## VI. RESULT AND DISCUSSION

Dynamic models of multi-machine consist of 3 Generators 3 Buses which will be the object of this investigation has been described in the previous discussion. The system will be given additional external equipment which is expected to improve the system performance when a disturbance occurs in the system.
In the initial condition, a step disturbance given to the system by 0.1 pu after the system operates for 1 second with condition systems without any damping controllers. These conditions aim to see the

response and determine ability of the generator to respond to the disturbance without giving additional controllers.

In this discussion, it will be used as a reference point to see the performance of an additional control is given as a comparison that aims to make the generator can back the synchronization operation with the time it takes to return to its initial state faster and produced smaller overshoot.

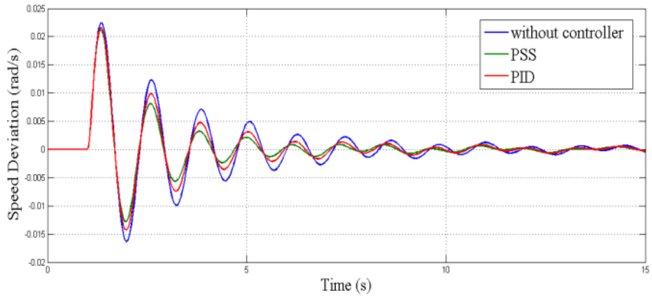


**Figure 7.** Speed deviation for PSS and PID controller.

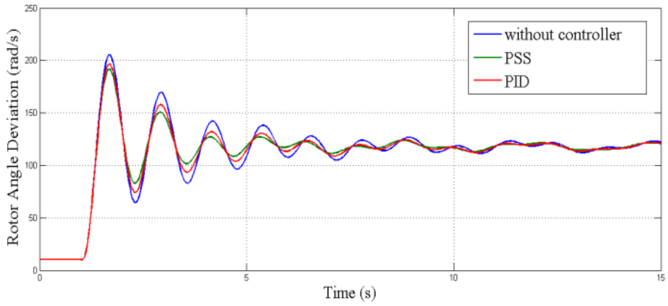


**Figure 8.** Rotor angle deviation for PSS and PID controller.

Figure 7 and figure 8 shows the result of the system without controllers, using PSS and using PID with response of speed deviation and rotor angle deviation respectively. PSS based lead-lag controller shows a better result than PID.

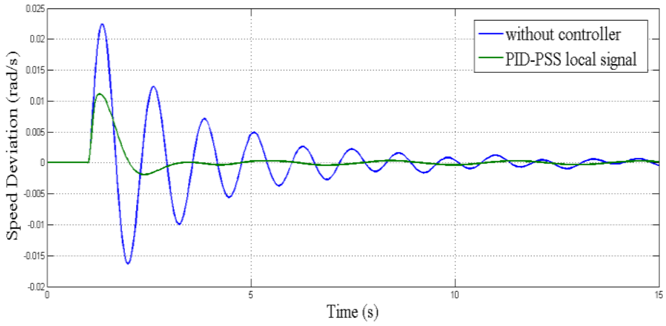


**Figure 9.** Speed deviation for PID-PSS local input signal.

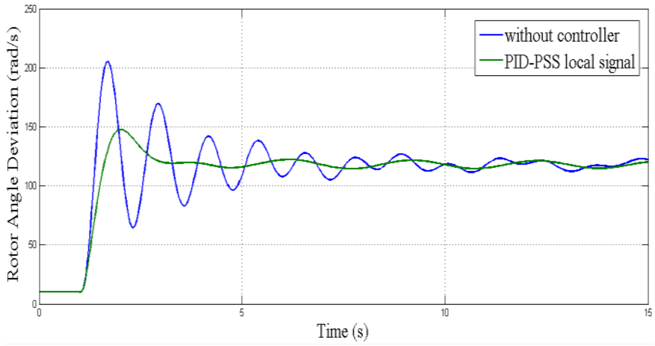


**Figure 10.** Rotor angle deviation for PID-PSS local input signal.

Figure 9 and figure 10 shows the results of the system with PID-PSS local input signal from generator 1. Response of speed deviation and rotor angle deviation shows that scheme controllers can give improvement to the system to damp oscillations.

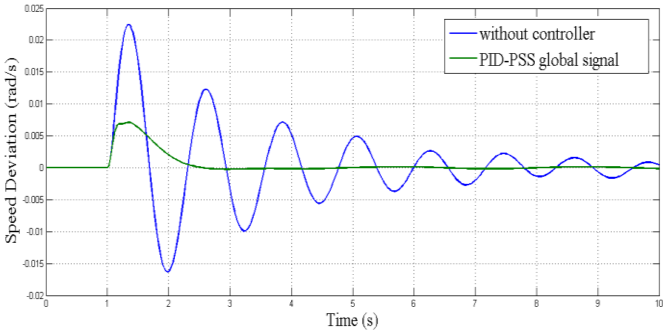


**Figure 11.** Speed deviation for PID-PSS global input signal.

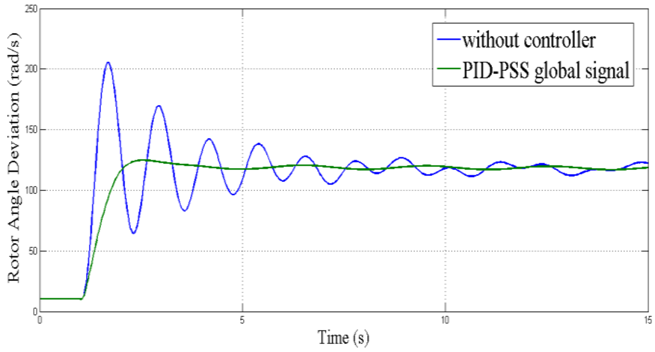


**Figure 12.** Rotor angle deviation for PID-PSS global input signal.

Figure 11 and figure 12 shows the result of a system with PID-PSS global input signal from generator 1, generator 2 and generator 3. In figure 13 and figure 14, the result shows a comparison of all scheme controllers. The PID-PSS controller shows a better result than all scheme controllers.

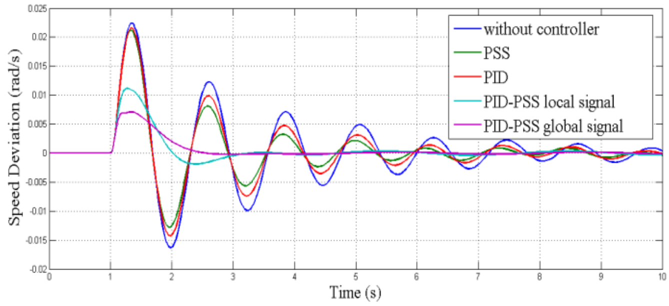


**Figure 13.** Comparison of speed deviation for all scheme controllers.

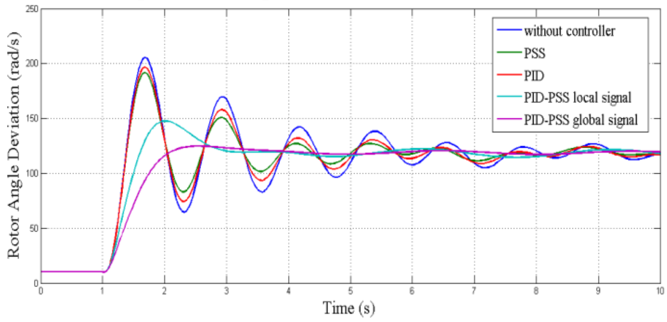


**Figure 14.** Comparison of rotor angle deviation for all scheme controllers.

## VII. CONCLUSIONS

In this paper, multi-machine installed PSS was simulated and the influence of PSS on the system was investigated. Four different scheme controller PSS with lead-lag, PID, PID combined lead-lag local input signal and PID combined lead-lag global input signal was implemented to the system and the results were than compared. The results shows that PID-PSS global input signal registered better results than all the schemes controllers for multi-machine case study consists of 3 machines 3 buses.

## VIII. FUTURE WORK

Based on the result that have been discussed in this paper, it is necessary to implement PID-PSS controller for larger systems and determines the global signal input that is most effective to damp the oscillation.

## APPENDIX

Table 1**.** Parameter system

| Parameter | Generator 1 | Generator 2 | Generator 3 |
|---|---|---|---|
| H | 20,09 s | 20,09 s | 118 s |
| $x_d$ | 0,19 | 0,19 | 0,41 |
| $x'_d$ | 0,0765 | 0,0765 | 0.173 |
| D | 0 | 0 | 0 |
| $x_q$ | 0.163 | 0.163 | 0,33 |
| $T'_{d0}$ | 7,5 s | 7,5 s | 7,5 s |
| $K_A$ | 20 | 20 | 100 |
| $T_A$ | 0,05 s | 0,05 s | 0,01 s |

Operation condition of the machine: P = 1,1 pu; Q = 1,5 pu (each machine). Initial condition of the machine:$\bar{V}_{1t} = 1{,}0\angle 9^0$; $\bar{V}_{2t} = 1{,}0\angle 5^0$; $\bar{V}_{3t} = 1{,}0\angle 0^0$

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