This paper presents a Takagi-Sugeno (TS) synchronous generator unit model intended for application in an auto-
tuning power system stabilizer. The model takes into account all three process variables that can affect synchronous
machine dynamics regarding stability - beside usually used active and reactive power (P and Q) it includes also line
reactance ($x_m$). It is shown that the proposed model gives very good results in spite of simple third order local
model used as the consequent part of the proposed TS structure. This makes the model appropriate for implementa-
tion on simple microprocessor platforms. Because P, Q and $x_m$ are included as TS model premises, it is enough to
identify parameters of models in consequent part of TS model off-line. In this way possible numerical instability is
avoided, which is common to adaptive PSSs that calculate controller’s parameters directly from on-line identified
plant parameters.

**Key words:** Modelling, Electrical machines, Takagi-Sugeno model, Power system stabilizer

1 INTRODUCTION

Power system stabilizers (PSSs) are used as a part of the synchronous generator automatic voltage regulators
(AVRs) in order to damp out the low frequency local and system power oscillations. Today’s AVRs commonly in-
clude so called conventional PSSs (CPSS), where the term conventional in this context means nonadaptive. Although
modern types of CPSS like IEEE PSS2B and PSS4B [1] can be very effective in damping both local and system
power oscillations, tuning of these two types of PSS can be time consuming and requires expert knowledge dur-
ing commissioning. Additionally, problems with CPSS may occur when a CPSS properly tuned for one operating
regime, has to operate in another very different regime.

To resolve these problems a number of methods, mainly in the field of adaptive control, has been proposed. Some
of the commonly used methods are gain scheduling, indirect and direct adaptive control using artificial intelligence
(mostly neural networks and fuzzy logic) [2]. The largest group of the proposed adaptive PSSs consists of indirect
defining power system stabilizers [2],[3-8]. Those PSSs provide better dynamic performance over a wide range
of operating conditions, but they suffer from the significant drawback of requiring model parameter identification,
state observation and feedback gain calculations in real-
time. Errors in parameter identification can significantly degrade performance and eventually cause the instability
of the overall control algorithm. The additional drawback of a number of adaptive stabilizers presented in the last
two decades is the fact that they require implementation in floating point arithmetic despite the facts that today’s
digital AVRs, within which PSSs typically have to be imple-
mented, are mostly implemented in 16 or 32-bit fixed
point processors. Thus additional hardware modifications
of the existing AVR s need to be done in order to implement such algorithms. The mentioned drawbacks could be reason why, despite of numerous adaptive PSS proposed in the last two decades, vary few of them have been used in the practice. The problems related to the conventional and adaptive PSSs have motivated researchers to recently propose simpler solutions [9], [10]. Our work is also motivated by this paradigm.

In this paper we propose a relatively simple Takagi-Sugeno (TS) fuzzy model of synchronous generator unit, which is suitable for use in an easy-to-implement autotuning power system stabilizer. The motivation of using TS fuzzy model is rooted in its ability to accurately model nonlinear system behavior with a relatively small number of linear models [11, 12]. Smooth transitions between these linear models are achieved by using fuzzy rules. The proposed TS model combines active power, reactive power and line reactance signals as premise variables. Due to the fact that these three signals completely describe the state of synchronous generator units [13, 14], the proposed PSS can use off-line TS model identification process and provide satisfactory performance over the wide range of operation conditions. Similar fuzzy solutions, that can be found in literature, mainly use only signals of active and reactive power as premise variables [6, 15], and therefore they require on-line parameter estimation.

The rest of the paper is structured as follows. Section 2 describes TS fuzzy model structure, the mathematical model of synchronous generator unit and developing process of the proposed TS model of the synchronous generator unit. Section 3 shows simulation results of the proposed TS synchronous generator unit model as well as simulation results of the newly proposed autotuning PSS utilizing the proposed TS model. Conclusions are given in Section 4.

2 TAKAGI-SUGENO MODEL OF SYNCHRONOUS GENERATOR UNITS

2.1 Takagi-Sugeno Fuzzy Model Structure

A Takagi-Sugeno (TS) structure can be used both as a plant model [6], or as a regulator, [15, 16]. In Takagi-Sugeno model approach [11, 12] a plant is described by a set of simple local linear regression models, each valid for particular operating area. The plant model output is a combination of local models outputs according to fuzzy rules, which are defined with variable determining operating area (premise variables). The fuzzy rules are structured as follows:

\[ R_i: \text{if} \ [x_1(k) \text{ is } F_i^1] \& \ldots \& [x_n(k) \text{ is } F_i^n] \text{ then } y'(k+1) = p_{i0} + p_{i1}m_1(k) + p_{in}m_n(k), \]
\[ i = 0, 1, \ldots, nr, \]  

where:

- \( R_i \) - \( i \)-th inference rule,
- \( x_j \) - \( j \)-th premise variable,
- \( F_{ij} \) - fuzzy set defined on the universe of discourse of the variable \( x_j \), used in \( i \)-th inference rule
- \( y_i \) - output of the \( i \)-th input/output (I/O) local models
- \( p = [a_1a_2 \ldots a_nb_1b_2 \ldots b_n c_2 \ldots c_{nc}] \) - parameters of \( i \)-th I/O local model
- \( m^T(k) = [-y(k) \ldots -y(k-na+1) u(k-d) \ldots u(k-d-nb+1) \zeta(k-1) \ldots \zeta(k-nc)] \)

- regression vector where \( u \) represent input of the model, \( y \) output of the model and \( d \) is process dead time, \( nr \) - number of fuzzy rules.

For given values of the premise variables \( x_j(k) \), the final output of the fuzzy plant model \( \hat{y} \) is inferred by taking the weighted average of the local model outputs \( y_i \):

\[ \hat{y}(k+1) = \frac{\sum_{i=1}^{nr} \mu_i (x(k)) y_i(k+1)}{\sum_{i=1}^{nr} \mu_i (x(k))} \]

where:

\[ \mu_i (x(k)) = \bigwedge_{j=1}^{nx} \mu_{ij} [x_j(k)] \]

are membership functions of the fuzzy set \( F_{ij} \).

It means that a local model in the consequent part of each fuzzy rule describes plant dynamics for the operating area depending on the premise part. A value of premises defines a rule weigh (5), which indicate the contribution of the \( i \)-th rule to the model output.

In a process of defining structure of local linear models in consequent part of TS model as well as premise variables, mathematical model of the plant has to be taken into account.

2.2 Physical Mathematical Model of the Generator Unit

As a starting point for the design of the power system stabilizer based on fuzzy model, machine-infinite bus system model will be used (Fig. 1). Such a model is generally described by the 7th order nonlinear model given by the
Linearization of the model (7) gives well-known Hefron and Filipps model [18] given by equations (8) and graphically depicted in Fig. 2.

\[
\Delta E_{q} \frac{1}{K_3} + sK_4 T_{dlv} = -K_4 \Delta \delta + \Delta e + K_8 \Delta V_m \\
\Delta \omega \left( s + \frac{\omega_s}{m} \right) = \frac{1}{T_m} \left[ \Delta T_{f} - K_2 \Delta E_{q} - K_1 \Delta \delta - K_9 \Delta V_m \right] \\
\Delta V_y = K_5 \Delta \delta + K_6 \Delta E_{q} + K_7 \Delta V_m
\]

It can be seen that the model relates the variables of electrical torque, speed, angle, terminal voltage, field voltage and flux linkages. Constants $K_1 - K_6$ depend on the machine system parameters (inertias, reactances, time constants) and the operating condition (i.e. the value of active power, reactive power and line reactance).

From the block diagram shown in Figure 2, input-output model needed for TS model consequent part can be obtained. If we want to use TS model in PSS model, then PSS output signal $\Delta u_{PSS}$ has to be used as the model input, while any signal that contains active power oscillations can be used as the model output. In the proposed solution, the signal of integral of accelerating power $\Delta P_{acc}$ has been chosen as the model output. This signal is derived within signal processing module from frequency of the terminal voltage and a high-pass filtered integral of electrical power as in [21]. This signal, which actually represents estimated rotor speed signal ($\Delta \omega$), is used due to good establishment in conventional PSS2B type of PSS.

As can be seen from Fig. 2 synchronous generator input-output model with PI type AVR included, is of the third order. Namely, with PI type AV AVR included, the closed

![Diagram](image-url)
loop from $\Delta u_{PSS}$ to the signal of electrical power $\Delta P_{el}$ can be described as a second order transfer function. To obtain signal of rotor speed $\Delta \omega$, which is in the proposed structure of PSS chosen as the model output signal, signal of $\Delta P_{el}$ have to pass through the summation and the integrator. This makes transfer function from $\Delta u_{PSS}$ to $\Delta \omega$ to be of the third order.

2.3 Premise Part of the TS Model of Generator Unit

As aforementioned, $K_1 - K_6$ depend on the machine system parameters and the operating condition. Taking into account the fact that machine system parameters don’t (or slightly) vary with time, constants $K_1 - K_6$ depend only on the operating condition defined with three variables: active power ($P$), reactive power ($Q$) and line reactance, represented with value of equivalent reactance ($x_m$). These three variables are therefore used as premise variables in TS model.

Signals $P$ and $Q$ are available in standard AVR and can be used directly as inputs to the TS model. On the other hand equivalent reactance $x_m$ is typically not available, and therefore it should be estimated.

The equivalent reactance $x_m$ represents the reactances of the transmission lines between unit terminals and infinite bus. An estimation method presented in [22] is used within the TS model. In that method the equivalent reactance, seen from the unit terminals, is evaluated using the local measurements (terminal voltage $V$, $P$ and $Q$). The identification procedure starts whenever dynamic oscillations in those measurements are detected. After a large disturbance, which necessarily follows change of $x_m$, the new reactance is estimated in relatively short time (200-500 ms). The estimation algorithm doesn’t give accurate value of the reactance but chooses the closest one to it among predefined values. The algorithm can be summarized in the following steps:

1. Phase angle between terminals voltage $V_g$ and infinite bus voltage $V_m$ is calculated from expression

$$\Delta \delta_e = \tan^{-1} \left( \frac{P}{U_m^2 Q} \right) = f(x_m) \tag{10}$$

3. For $n$ predefined values of $x_m$ the value of phase angle $\delta_e$ is calculated from equation:

$$\delta_e = \tan^{-1} \left( \frac{P}{U_m^2 Q} \right) = f(x_m) \tag{10}$$

is derived from equations for the power conditions along a line between the power plant and the load centre:

$$P = \frac{U_g U_m}{x_m} \sin \delta_e \tag{11}$$

$$Q = \frac{U_g^2}{x_m} - \frac{U_g U_m}{x_m} \cos \delta_e \tag{12}$$

4. Difference between minimum and maximum value of all $\Delta \delta_e$, signals and measured signal $\delta_e$ is calculated for the next $1/f_n$ seconds, where $f_n$ represents the synchronous generator nominal frequency. The closest agreement between the phase-angle variation, calculated with an assumed $x_m$, value, and the measured phase-angle variation $\delta_e$ determines the $x_m$ value for generator. As the result the algorithm gives the number that defines line reactance.

The fact that the reactance $x_m$ cannot be identified during steady state operation is only a minor handicap. A significant change of $x_m$ is usually associated with a disturbance anyway. The accuracy of the identification depends on the number of predefined values of $x_m$. Normally, the selection of 2 to 4 values covering an appropriate range is mostly adequate.

To define membership functions of selected premise variables their physical characters have to be considered. Signals of active and reactive power change smoothly through the operating area of synchronous machine during normal operation. Relationship between parameters $K_1$ to $K_6$ and values of $P$ and $Q$ is approximately linear during those changes. On the other hand, equivalent reactance $x_m$ changes its value discontinuously (between 2-4 different values). Additionally, relationships between parameters $K_1$ to $K_6$ and equivalent reactance $x_m$ is generally nonlinear. Considering that, membership functions of premises are defined as follows.

Membership functions of $P$ and $Q$ have linear shapes with operating range divided into two or three areas (i.e. fuzzy sets). By validation and comparison of different numbers of areas we have found that two areas per variable are sufficient: $P_{high}$, $P_{low}$, $Q_{high}$, $Q_{low}$ (Fig. 3). Equivalent reactance $x_m$ need to have discontinuous membership function. By analyzing values of reactances measured on the real power plants during the annual maintenance, we have found that also two different values are
sufficient: low (0) and high (1) as shown in Fig. 3. Estimation method of \( x_m \) will therefore give one of two possible predefined \( x_m \) values. One of them will take the value of \( x_m \) measured (i.e. estimated) during commissioning, and the second one will be 0.2 p.u. greater or smaller than measured (depending on the measured value).

\[ R_{\text{low}} : \text{if } [P(k) \in P_{\text{low}}] \text{ and } [Q(k) \in Q_{\text{low}}] \text{ and } [x_m(k) \in x_{\text{low}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_{\text{high}} : \text{if } [P(k) \in P_{\text{high}}] \text{ and } [Q(k) \in Q_{\text{high}}] \text{ and } [x_m(k) \in x_{\text{high}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

Combination of those premise variables gives the premise part of the proposed TS model:

\[ R_1: \text{if } [P(k) \in P_{\text{low}}] \text{ and } [Q(k) \in Q_{\text{low}}] \text{ and } [x_m(k) \in x_{\text{low}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_2: \text{if } [P(k) \in P_{\text{low}}] \text{ and } [Q(k) \in Q_{\text{high}}] \text{ and } [x_m(k) \in x_{\text{low}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_3: \text{if } [P(k) \in P_{\text{high}}] \text{ and } [Q(k) \in Q_{\text{low}}] \text{ and } [x_m(k) \in x_{\text{low}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_4: \text{if } [P(k) \in P_{\text{high}}] \text{ and } [Q(k) \in Q_{\text{high}}] \text{ and } [x_m(k) \in x_{\text{low}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_5: \text{if } [P(k) \in P_{\text{low}}] \text{ and } [Q(k) \in Q_{\text{low}}] \text{ and } [x_m(k) \in x_{\text{high}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_6: \text{if } [P(k) \in P_{\text{low}}] \text{ and } [Q(k) \in Q_{\text{high}}] \text{ and } [x_m(k) \in x_{\text{high}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_7: \text{if } [P(k) \in P_{\text{high}}] \text{ and } [Q(k) \in Q_{\text{low}}] \text{ and } [x_m(k) \in x_{\text{high}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

\[ R_8: \text{if } [P(k) \in P_{\text{high}}] \text{ and } [Q(k) \in Q_{\text{high}}] \text{ and } [x_m(k) \in x_{\text{high}}] \text{ then } y(k+1) = a_1 y(k) + a_2 y(k-1) + b_1 u(k) + c \]

The final output of the TS fuzzy model is inferred by taking the weighted average of the local models outputs \( y_i \). Thus, the output signal of model (13) can be defined as [23]:

\[ y(k + d + 1) = \sum_{i=1}^{nr} v^i(k)y^i(k + d + 1) \]

where:

\[ v^i(k) = \frac{\mu^i(x(k))}{\sum_{j=1}^{nr} \mu^j(x(k))} \]

Considering only membership functions of \( P \) and \( Q \), the premise structure of the proposed TS model gives a surface limited with four flat surfaces (model 1 to 4 in Figure 4) representing four linear models. Involving \( x_m \) as premise variable of the TS fuzzy model, one more set of four linear

\[ A(q^{-1}, k)y(k + d + 1) = B(q^{-1}, k)u(k) + c(k) \]
models is added. In Fig. 4 this would look like another surface placed under the existing one. If we insert linear models (15) in equation (16) the following expression is obtained:

$$y(k + d + 1) = \sum_{i=1}^{nr} v^i(k) \left\{ - \sum_{j=1}^{na} a^i_j y(k - j + d + 1) + \sum_{j=1}^{nb} b^i_j u(k - j + 1) + e^i \right\}$$

which can also be written as:

$$y(k + d + 1) = - \sum_{j=1}^{na} \sum_{i=1}^{nr} a^i_j v^i(k) y(k - j + d + 1) + \sum_{j=1}^{nb} \sum_{i=1}^{nr} b^i_j v^i(k) u(k - j + 1) + \sum_{i=1}^{nr} c^i v^i(k).$$

The final expression for synchronous generator TS model can be defined from (19) as:

$$A(q^{-1})y(k + d + 1) = B(q^{-1})u(k) + c(k)$$

where:

$$A(q^{-1}) = 1 + \sum_{j=1}^{na} a_j q^{-j}$$

$$B(q^{-1}) = \sum_{j=1}^{nb} b_j q^{-j+1}.$$  \hfill (21)

Expressions for $a_i$ and $b_i$ are given with the following equations:

$$a_i(k) = \sum_{i=1}^{nr} a_i^j v^i(k),$$

$$b_i(k) = \sum_{i=1}^{nr} b_i^j v^i(k).$$  \hfill (22)

Obtained model (20) is time variant linear model that can be used within classical control scheme, like pole placement. Its parameters are calculated on-line according to (22) by applying previously identified values of the TS model consequent part parameters $a^i_j$ and $b^i_j$.

### 2.5 Identification Steps of the Consequent Part Models

Parameters $a^1_i$, $a^2_i$, $a^3_i$ and $b^1_i$ of each of the eight ARX models of the TS consequent part can be identified by using recursive least squares algorithm (RLS), [24]. Identification is performed by an embedded automatic procedure, which start identification of a local model only when the generator is in corresponding operating point defined by the TS premise part parameters. Other two conditions that have to be fulfilled to start identification are: 1) synchronous machine has to be in steady state, and 2) identification error signal (difference between measured and estimated output model signal) have to be greater then a predefined level (i.e. 4%). Identification procedure ends successfully when synchronous machine passes through all eight operating areas defined by the TS premise part. Parameter estimation process stops whenever one of the following conditions occurs: (i) transient state is detected, i.e. large change of the line reactance $x_m$ occurs; (ii) synchronous generator run out of operating point defined by TS model premise parts or (iii) identification error becomes less than defined. The last condition indicates the successful end of the identification procedure. Graphically the identification procedure is shown in Fig. 5.

![Fig. 5. Identification procedure of the TS model consequent part](image)
3 SIMULATION RESULTS

The nonlinear model of a real power plant is implemented in MATLAB/Simulink simulation environment for the purpose of testing proposed TS model. It consists of a single machine equipped with control systems and connected to infinite bus [25]. Synchronous machine block from MATLAB/Simulink SimPowerSystems [26] is used to represent a synchronous generator connected to an infinite bus (Three-phase programmable voltage source block) through a three-phase transformer and transmission lines. The ability of changing the line reactance is modelled as well. Equations used to simulate AVR and conventional PSS (IEEE type PSS2B) are given in [27].

3.1 TS model validation

MATLAB System Identification Toolbox is used to verify structure of the TS model consequent part. Verification was done through the identification of the simulated nonlinear plant by several different linear ARX structures. During the identification experiment a Pseudo Random Binary Signal (PRBS) with $T = 0.05$ s, $n = 11$ and amplitude 0.003 p.u. around the steady-state value was used as input signal $u_{PSS}$ to the nonlinear plant model. The signal of integral of accelerating power was recorded as the output signal. The results of the identification process are summarized in Table 1. The numbers in the end of ARX model names means number of ARX model parameters: ARX[na][nb][nc] where parameters na, nb and nc are given in (21).

| Model     | ARX310 | ARX422 | ARX720 | ARX210 |
|-----------|--------|--------|--------|--------|
| na, nb, nc| 3,1,0  | 4,2,2  | 7,2,0  | 2,1,0  |
| Fit [%]   | 99.40  | 99.62  | 99.81  | 98.41  |

It can be seen that difference between measured output signal (real $P_{acc}$) and ARX310 structure is only 0.6%. Comparison of Bode diagrams of considered ARX structures is shown in Figure 6. From Bode diagrams it can be seen that matching between ARX310 and ARX720 (which represent best matching to nonlinear plant model) in interesting frequency domain (0.5 to 3 Hz) is satisfying.

Figure 7 shows comparisons between the output signal of the proposed TS model $P_{acc, ident}$ and signal of integral of acceleration power obtained on simulated nonlinear power plant model ($P_{acc}$). Changes in reactive power $Q$ was realized by applying step changes in AVR reference voltage. Line reactance had low value ($x_{low}$). It can be seen that identification error in all operating condition is less then 4%. Such level of identification error is acceptable for autotuning power system stabilizer application.

3.2 Validation of the Identification Procedure

The identification procedure is presented in Fig. 8. The graph a) shows two input identification signals. Signal $u(t)$ is signal applied to AVR when identification process is active and signal $test_{PRBS}(t)$ is applied to AVR when identification process is not active in order to estimate error level. Both signals are of PRBS type with small enough amplitude and therefore they don’t induce any instabilities of the synchronous generator.
The graphs b) and c) show values of active and reactive power, respectively, and from them the operating point can be restored. It can be seen that synchronous generator passes through the four operating points defined by premise part of the first four rules of TS model (15). The graph d) represents measured and estimated $P_{\text{acc}}(t)$ signals together with $\text{Ident}_{\text{enable}}(t)$ signal which represents the state of the identification procedure. High level of $\text{Ident}_{\text{enable}}(t)$ signal indicates that the identification process is active.

The identification procedure can be shortened if the commissioning staff make the synchronous generator to operate in operating points defined by TS model premise part. However, if it is not possible to pass through all four operating points during the commissioning process, the identification procedure will automatically continue when a no visited operating point becomes active later during normal operation. When identification of all four ARX models for current line reactance value is done, the process of automatic tuning of PSS according to the pole placement control algorithm is performed and PSS is turned on.

If the line reactance estimation algorithm detects a sufficiently large line reactance change during the normal operation, the identification procedure is restarted in order to identify the remaining four TS consequent ARX models. The identification is performed during normal plant operation, when the system is in the steady-state and when it operates in operating points defined by TS premise parts. Duration of this second identification process can be shortened if an autotuning PSS structure embeds statistics of the synchronous unit the most frequent operating points. This way the operating point in TS model premise parts could be automatically changed to points in which synchronous unit operates the most frequently. Until the identification procedure of remaining four linear models is done, PSS operates with parameters optimally tuned during commissioning.

3.3 Proposed TS Model within an Autotuning PSS

When the identification of the TS model consequent part (15) is done and the parameters of the linear model (20) are obtained, an appropriate PSS can be designed. To calculate PSS parameters, the pole placement control strategy is used in this paper [28]. The structure of the proposed pole placement autotuning PSS is shown in Fig. 9. It should be said that other control approaches can be used as well.

The pole placement autotuning PSS based on the proposed TS model is implemented in the TI TMS320F2812 fixed-point DSP [29]. Its behavior has been investigated in comparison to the PSS2B PSS controller, through voltage reference step changes. Other validation cases like resistance to reactive power modulation when the mechanical power changes and behavior when the line reactance changes can be found in [29]. To perform fair comparison the conventional PSS2B was optimally tuned for nominal operating point of synchronous generator ($P = 1$ p.u., $Q = 0$, $x_m = x_m_{\text{low}}$).

Figures 10 and 11 show: a) signals of active power, b) signals of reactive power and c) control signals of PSSs.
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For the sake of comparison responses obtained by both proposed autotuning PSS and PSS2B are shown. While both PSSs provide similar responses in nominal operating point at which they were tuned (Fig. 10) and which is characterized by low value of the line reactance $x_m_{low}$, the proposed autotuning PSS provides better responses in another operating point characterized by high value of the line reactance $x_m_{high}$.

4 CONCLUSIONS

In the paper a new Takagi-Sugeno synchronous generator unit model intended for PSS application is proposed. The model takes into account all three variables that can affect synchronous machine behavior regarding stability: $P$, $Q$ and $x_m$. Therefore on-line estimation of model parameters becomes unnecessary. Probably only one or two identification processes during life time will be sufficient to obtain model parameters needed for design of an autotuning PSS.

Because of using the all three variables, proposed model is particularly suitable if direct calculation of PSS parameters (i.e. self tuning schemes) and possible numerical instability common to those schemes are to be avoided. The proposed Takagi-Sugeno model can be also used in other applications involving synchronous machine control.

Simulation results show that an autotuning PSS utilizing the proposed TS model obtains very good stabilizing effects. In comparison to optimally tuned conventional PSS2B, it shows better behavior in operating points that differ from point for which is PSS2B optimally tuned.

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A Takagi-Sugeno Fuzzy Model of Synchronous Generator Unit for Power System Stability Application

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