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# Damping of low-frequency oscillations and improving power system stability via auto-tuned PI stabilizer using Takagi–Sugeno fuzzy logic

Lokman H. Hassan [a,*], M. Moghavvemi [a], Haider A.F. Almurib [b], K.M. Muttaqi [c], H. Du [c]

[a] Centre for Research in Applied Electronics (CRAE), Department of Electrical Engineering, University of Malaya, Kuala Lumpur, Malaysia
[b] Department of Electrical and Electronic Engineering, University of Nottingham Malaysia Campus, Selangor, Malaysia
[c] Endeavour Energy Power Quality and Reliability Centre, School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, New South Wales, Australia

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ABSTRACT

This paper proposes a Takagi–Sugeno (TS) fuzzy gain-scheduling PI stabilizer to damp the power system low-frequency oscillations and enhance power system stability. The work describes the construction of appropriate fuzzy membership functions and rules for a Power System Stabilizer (PSS) so that its proportional and integral gains can be automatically tuned in real-time to react to changes in the system operating conditions. To find the optimal number and locations of required stabilizers, this paper uses the participation factor method. Simulation results on a practical power system demonstrate that the proposed stabilizer is effective in damping low-frequency oscillations as well as improving system dynamic stability and voltage profile. In addition, the proposed approach provides superior performance when compared to a conventional PI PSS.



## 1. Introduction

Low-frequency oscillations in a power system affect the system stability, the operating efficiency of the power system and restrict the operating capability of power transmissions [1]. In order to solve this problem, engineers and researchers have been continually tasked to find simple, effective and economical strategies of stabilizing the power system. Hence, the Power System Stabilizer (PSS), by which a supplementary stabilizing signal is added to the excitation system, emerged as a simple and cost-effective approach [2,3].

Different control techniques such as modern and conventional control have historically been utilized by many researchers for designing PSS. By using these techniques, PSS can provide optimal performance for the nominal operating condition and nominal system parameters. However, a modern power system is a large, nonlinear and complex system and it is subject to different kinds of events which result in many uncertainties. Considering their limitations, it is difficult to effectively solve low-frequency oscillations problem when one depends only on these conventional and linear optimal control approaches.

To avoid these limitations, other types of modern control techniques like adaptive controller [4] and $H_\infty$ control system [5,6] were proposed to improve damping. By using these techniques the system response will not be affected by system parameter variations and this in turn will result in a robust performance.

Fuzzy logic system as an artificial intelligence technique has efficiently been proposed by researchers to design PSS [7]. It has been reported that fuzzy logic-based adaptive stabilizers outperform conventional stabilizers [8,9] and standard fuzzy logic stabilizers [10]. Lu et al. [8] proposed an adaptive stabilizer using a Takagi–Sugeno (TS) type fuzzy logic signal synthesizer to combine the stabilizing signals obtained from two designed linear stabilizers based on two system operating condition. In Ref. [9], Two fuzzy logic systems were developed to approximate two unknown nonlinear differential equations which represent the power system model. Lyapunov's synthesis method governs the adaptation of the fuzzy logic systems. In Ref. [10], a direct adaptive fuzzy logic stabilizer with a small rule-base was proposed. The controller parameters were estimated using the variable-structure algorithm. However, [8–10] applied to a single machine infinite bus system, and small multi-machine power systems [8,10]. In Ref. [8], the large power system was installed with only one stabilizer.

TS fuzzy system is computationally more efficient than Mamdani fuzzy system [11] and Gain-scheduling controllers as an adaptive controllers are robust and also well suited to practical applications [12]. Therefore, in this paper the two approaches have been combined to develop a TS fuzzy gain-scheduling PI stabilizer for damping low-frequency oscillations. As direct measurement of a generator rotor speed is not available and to protect against

* Corresponding author.
*E-mail addresses:* lokmanhadi@siswa.um.edu.my, lokmanhadi@gmail.com (L.H. Hassan).

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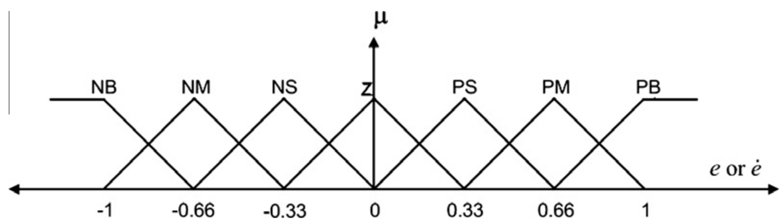


**Fig. 1.** Membership functions for the proposed controller of error and its time derivative.

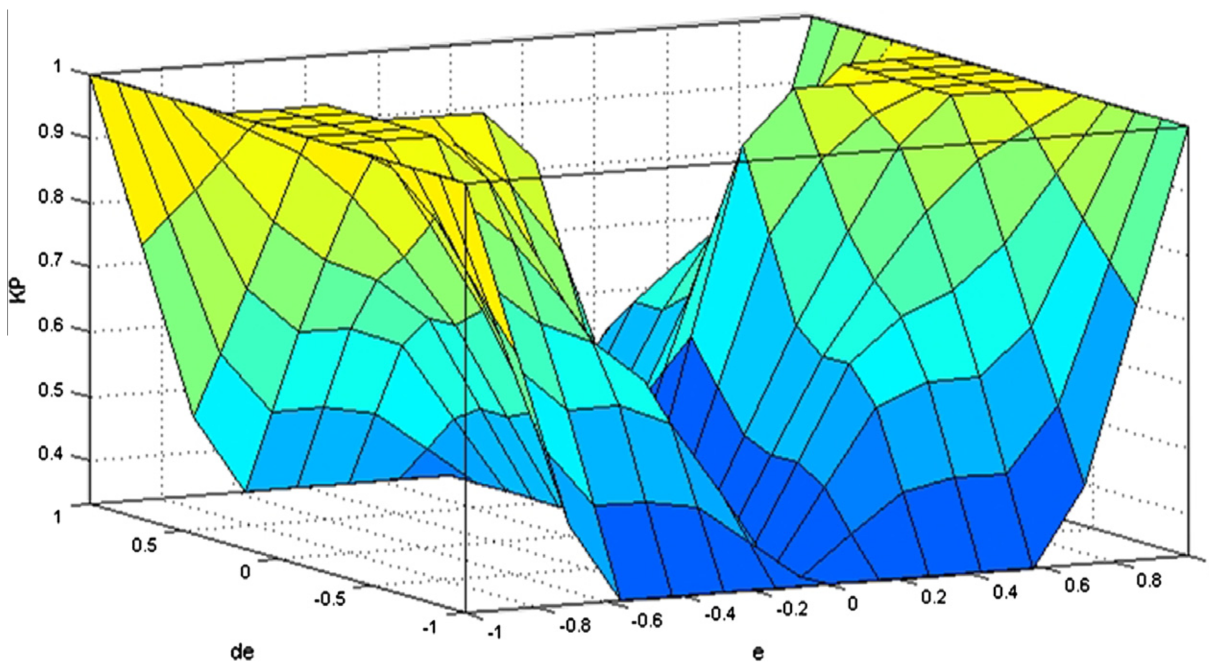


**Fig. 2.** Three dimensional plot for rule base of $K_P$.

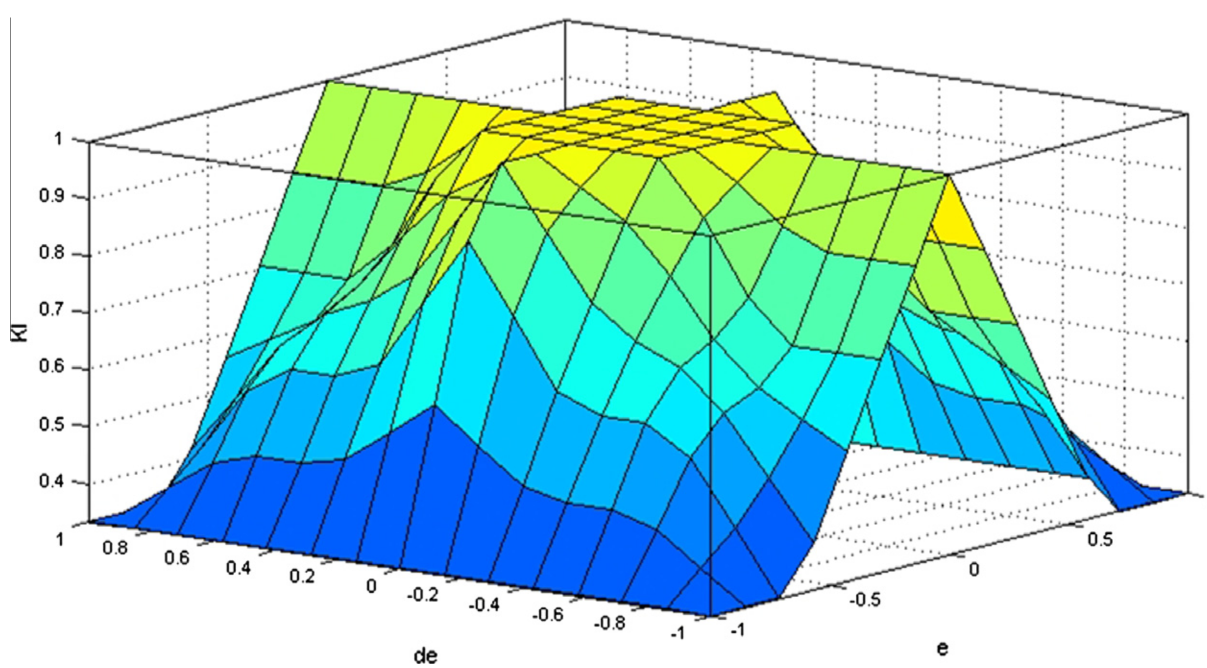


**Fig. 3.** Three dimensional plot for rule base of $K_I$.