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Optimal Supplementary Controller Design for IPFC to Damp Low-Frequency Oscillations in Power Systems

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Abstract: **In this paper, the use of interline power flow controller (IPFC) on damping low –frequency oscillations (LFOs) are discussed and a new genetic algorithm(GA)-based multistage fuzzy (MSF) DC-Voltage regulator is proposed for IPFC to dampen low- frequency oscillations in (Double line) power system. The suggested control strategy is estimated under various operating conditions, and then it is compared with conventional controllers to determine its effectiveness. Time-simulation studies proved the robust performance of the proposed regulator.**

Index Terms: **Flexible AC transmission systems (FACTS), IPFC, low-frequency oscillation (LFO), genetic algorithm (GA)-based multistage fuzzy (MSF) DC-voltage regulator**.

I. Introduction

Currently, in the power industry, the stability of low-frequency oscillations (LFOs) at frequencies of 0.2–2 Hz is of great interest and crucial concern [1–4].

A.prajapati , Kanchan Chaturvedi, Ch.Lokeshwar Reddy and S.Venkateshwarlu etc all discussed different FACTS devices static VAR compensator (SVC),static synchronous compensator(STATCOM),and unified power flow controller (UPFC).The article discussed how these devices could prove useful to damp oscillations, simply by adding a supplementary signal, which can in turn improve a power system's small signal stability. The FACTS controller's new concept for series compensation is interline power flow controller (IPFC). The IPFC can control power flow among multiple lines [5-18].

IPFC is the most recent happening of voltage source converter based FACTS devices, which was suggested by L.Gyugyi,Song Y.H. and k.Sen [11,12]. When the damping controller of a power system's low-power frequency oscillations is estimated for a nonlinear dynamic model, it allows damping oscillations to be accurate as well as achieve desirable operations. The highly nonlinear and stochastic nature of power systems makes fixed parameter-based conventional supplementary controllers unsuitable for IPFC, thereby necessitating the development of a flexible controller. In Fuzzy logic controllers for formation of fuzzy sets trial and error method are used, these are used for IPFC to supply better functionality, reliability, adaptability and robustness. This provoked us to develop the refined genetic algorithm based multistage fuzzy(GAMSF)DC-voltage regulator for IPFC, which can study the practicability of damping of LFOs, besides enhancing the dynamic stability.

II. GA- Based Fuzzy Damping Controller

In this section, we propose a modified GA-based MSF (GAMSF) controller that can help dampen a power system's LFOs as well as can take into consideration uncertainties arising during power system operations [6–9].A arrangement of fuzzy PD and integral controller with switches is used by this approach. The fuzzy PD stage can eliminate fast change arising from the corresponding practical constraints, whereas the integral stage can eliminate zero steady-state error. The fuzzy rule-based control system can show good performance when the fuzzy sets are carefully designed and organized [10-15].The work involved and cost of a fuzzy system can be further reduced utilizing a hill-climbing-based modified GA method: in addition this method optimally adjusts the membership functions in the suggested MSF controller.

The proposed arrangement, where input values are converted to truth-value vectors, of the GAMSF DC-Voltage regulator is shown in Fig.1. As is done with a single-stage fuzzy logic controller, the output truth-value vectors are not defuzzified to crisp values but are instead passed onto the next stage as a truth value vector input. During heavy loading condition of power systems (δ >70deg), the performance of a controller can be improved with a static switch in the output controller, which can enhance the functional control signal.

Membership functions in this work are expound as triangular separation having seven segments from -1 to +1 with "0" defining the membership function centered "0"and so on. The portions are also uniformity about the zero membership functions, as shown in Fig.2.

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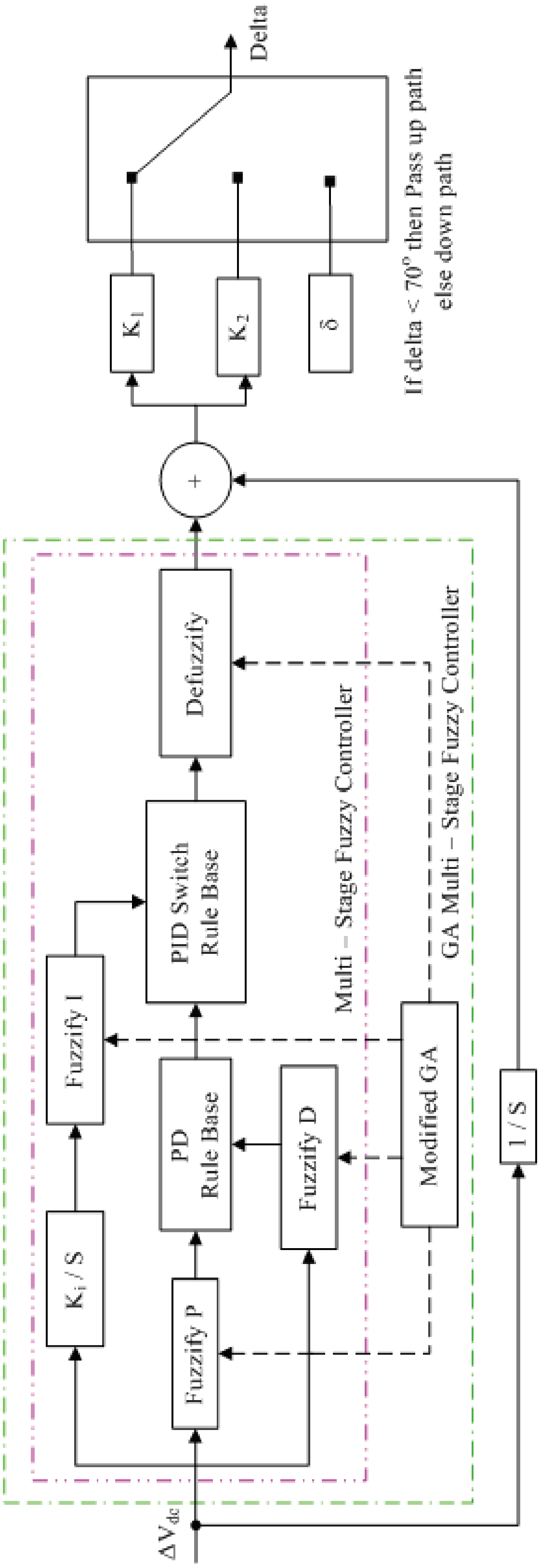

Figure 1. Design of suggested GAMSF DC-voltage regulator.

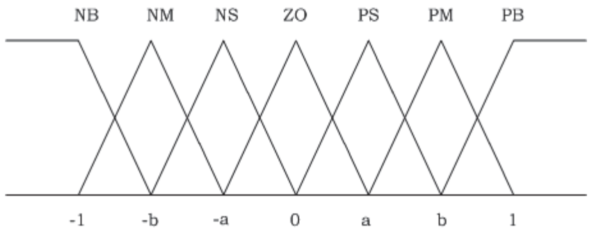

Figure 2. Symmetric fuzzy partition.

NB-negative big
NM-negative medium
NS-negative small
ZO-zero
PS-Positive small
PM-positive medium
PB-positive big

III. Simulation of the Proposed Controller in the Double-Line(SMIB) Power System

IPFC with Double-line (SMIB)Power system shown by a linearized transfer function model, as reproduced in Figs. 3 and 4. Simulating the Phillips–Heffron linearized transfer function model can validate the obtained results with the aid of the MATLAB/Simulink toolbox.

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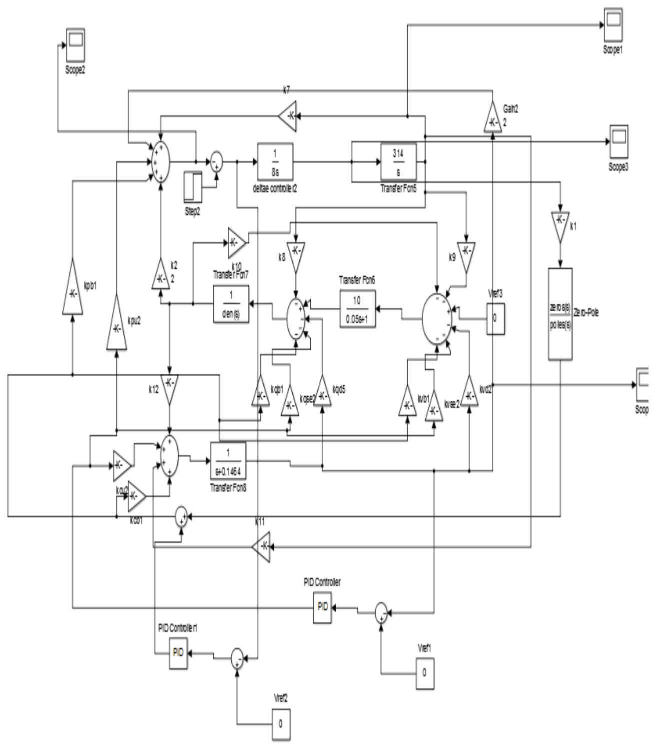


Figure 3. SMIB Simulink model with IPFC and conventional controller

The disturbance (step input)is given and the out put response can be represented using $\Delta\delta$, $\Delta\omega$, ΔPe

and ΔV_{dc} representing deviation in rotor angle, deviation in angular frequency deviation in P_e and capacitor voltage deviation V_{dc} respectively.

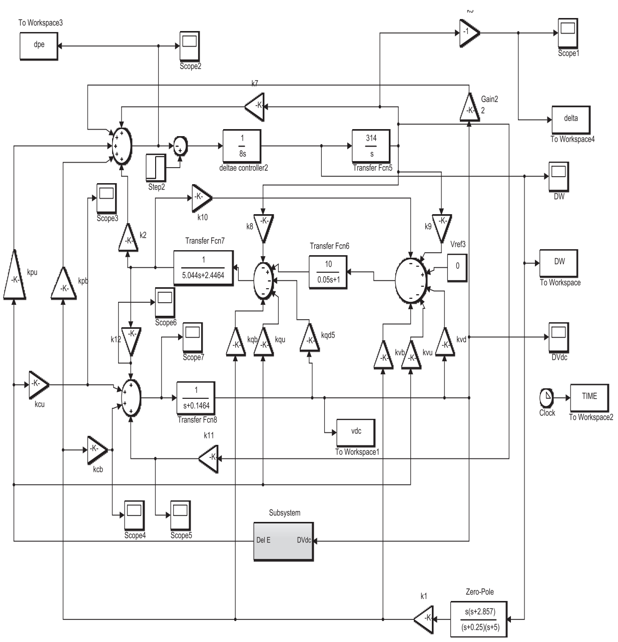
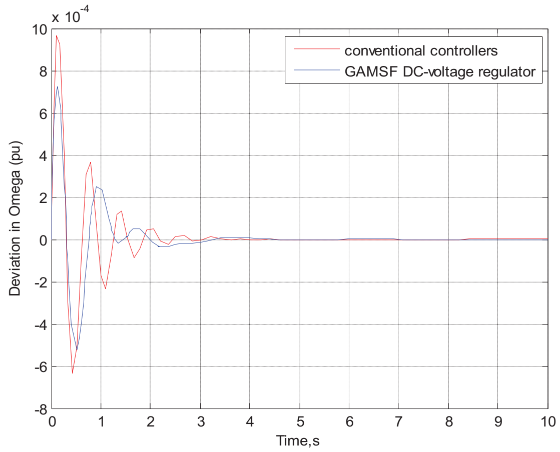
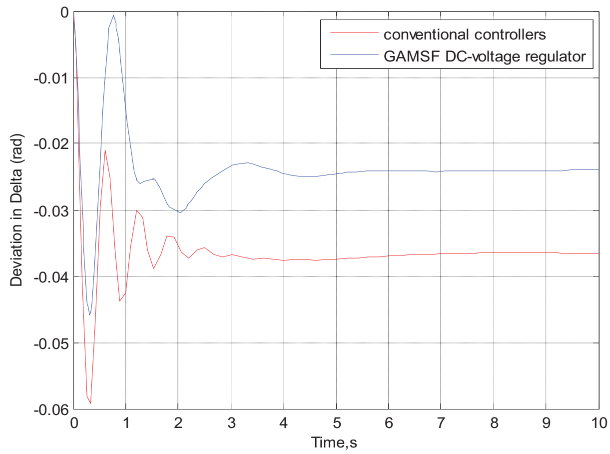


Figure 4. Simulink model of a single –machine infinite –bus system with IPFC and GAMSF Simulink model.

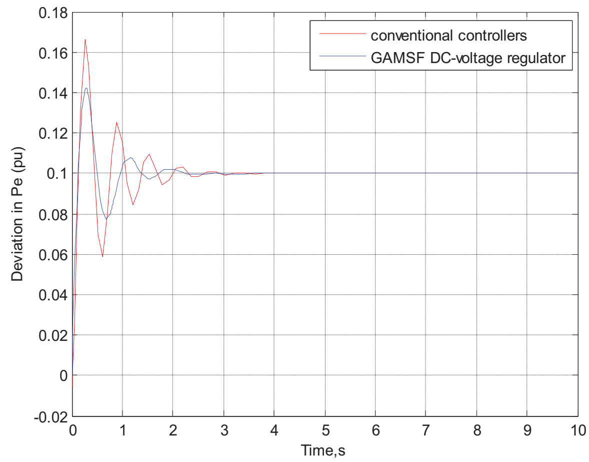
Fig. 3 and Fig.4. represent systems that are simulated with a step disturbance 0.1 perunit under different conditions:at point 1 P_e considered as 0.8, Q_e considered as 0.15, and V_t considered as 1.032; at point 4:P_e considered as 1.1, Q_e considered as 0.28,and V_t considered as 1.032. The results obtained are shown in Figs. 5and 6.



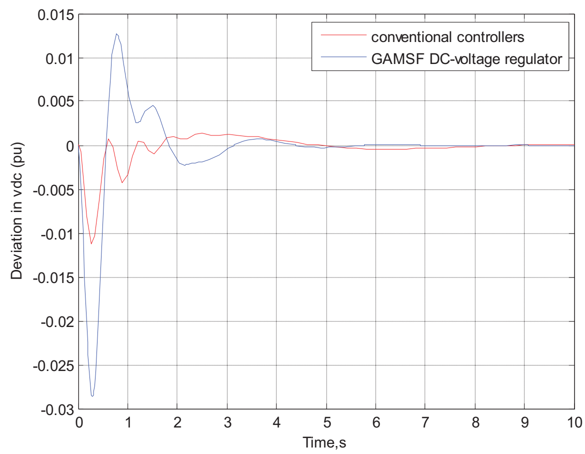
(a)



(b)

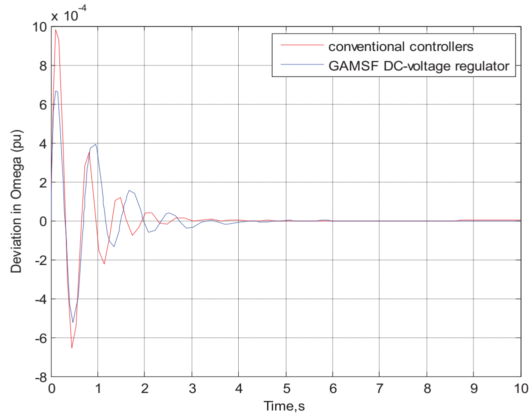


(c)

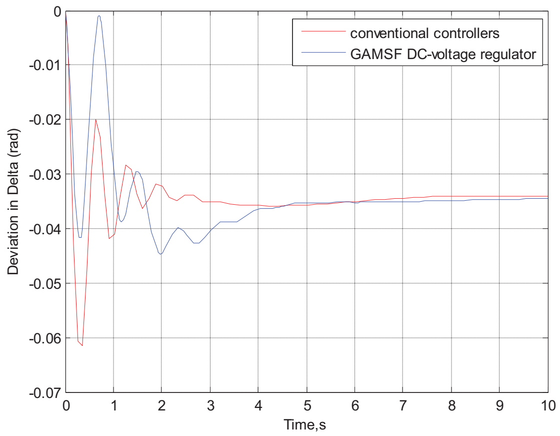


(d)

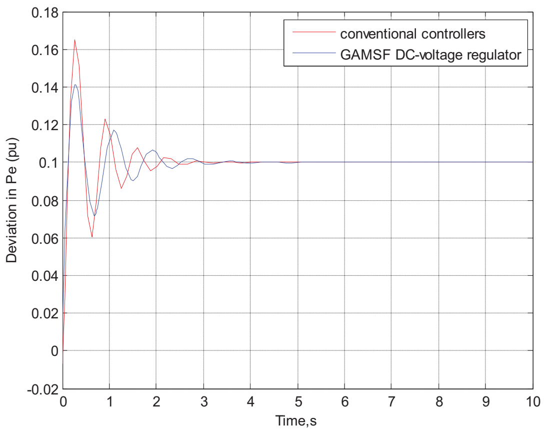
Figure 5. Time responses of (a) Δω,(b) Δδ, (c) ΔP_e, (d) of ΔV_{dc} With conventional controller and the GAMSF DC-Voltage regulator at operating point 1.



(a)

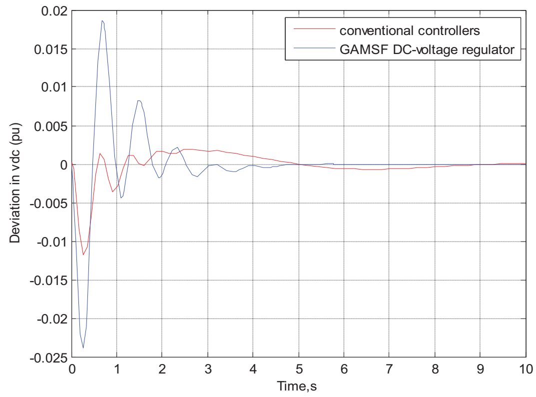


(b)



(c)

Figs. 5 and 6 show the $\Delta\omega, \Delta\delta, \Delta Pe$ and ΔV_{dc} plots at different operating points with the GAMSF DC-Voltage regulator compared with IPFC having conventional controllers. These figures show that IPFC with a GAMSF DC-voltage regulator is more effective than conventional controllers.



(d)

Figure 6. Time responses of (a) $\Delta\omega$, (b) $\Delta\delta$, (c) ΔP_e , and (d) of ΔV_{dc} With conventional controllers and the GAMSF DC-Voltage regulator at operating point 4.

IV. Conclusions

This paper presented robust GAMSF DC-Voltage regulator to damp low-frequency oscillations. The presented controller's effectiveness was tested on an SMIB Power system and compared with conventional IPFC controllers under various operating conditions. The results shown the effectiveness and performance of the controller proposed in this paper. The proposed controller's simple design procedure and robust performance make it potentially useful for future practical implementations.

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