To Dampen the Power System Oscillations by a Supplementary Controller Design in a Multi- Machine Power system

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Abstract: *This paper introduces a new approach the nonlinear dynamic model of a multi-machine power system incorporated with an interline power flow controller (IPFC) to improve the damping oscillations of a power system. The performance of the IPFC was tested with a GAMSF DC voltage regulator, compared with the Conventional IPFC controllers under various operating conditions. Time-domain simulation analysis revealed that the newly developed GAMSF DC voltage regulator has excellent capability to dampen low-frequency oscillations in multi-machine power systems.*

Key Words: **IPFC, GAMSF, Conventional, Multi-machine, low frequency oscillations.**

1. INTRODUCTION

One phenomenon that is currently of great interest and of essential concern in the power industry is the stability of low-frequency oscillations (LFOs) at frequencies ranging from 0.2 Hz to 2 Hz [1–4].

In 2013, Anubha Prajapati and Kanchan Chaturvedi discussed the various FACTS devices such as the static var compensator (SVC), the static synchronous compensator (STATCOM), and the unified power flow controller (UPFC). They explained how these devices, by adding a supplementary signal, can prove useful to damp oscillations, thereby improving the small signal stability of power systems. A new concept of the FACTS controller for series compensation is the interline power flow controller (IPFC), which has the unique capability of controlling power flow among multiple lines [5].

Interline Power Flow Controller (IPFC), is the latest representative of the Voltage Source Converter (VSC) based FACTS devices, and was proposed by Gyugyi with Sen, and C. D. Schauder [6, 7]. To ensure accuracy and desirable operations of damping oscillations, the damping controller of low-power frequency oscillations in the power system should be estimated for a nonlinear dynamic model. Because power systems are highly nonlinear and stochastic in nature, fixed parameter-based conventional supplementary controllers are not suitable for IPFC. Therefore, development of a flexible controller is needed. Fuzzy logic controllers, which use the trial and error method for the formation of fuzzy sets, are used for IPFC because they provide better functionality, performance, adaptability, reliability, and robustness. This encouraged us to design a sophisticated genetic algorithm-based multistage fuzzy (GAMSF) DC-voltage regulator for the IPFC. This regulator can help not only investigate the possibilities of damping of LFOs but also enhance dynamic stability. Hence to compare the performance of GAMSF DC voltage regulator in the presence of the conventional IPFC controllers for multi-machine power system.

2. GA-BASED FUZZY DAMPING CONTROLLER

Here, a modified GA-based MSF (GAMSF) controller is proposed to dampen LFOs of power systems. The proposed GAMSF controller can take into consideration uncertainties that may arise during power system operation conditions [6–9]. This control strategy combines fuzzy PD and the integral controller with fuzzy switches. The fuzzy PD stage is used to penalize fast change due to the corresponding practical constraints. The integral stage is used to reject zero steady-state error. It is important that the fuzzy sets are carefully designed and organized in order for the fuzzy rule-based control system to perform well [10-15] Fuzzy system effort and cost can be reduced by adopting a modified GA based on the hill climbing method; this can help tune optimally the membership functions in the proposed MSF controller. The structure of the proposed strategy for the GAMSF DC-voltage regulator is shown in Fig. 1. In this structure, input values are converted to truth-value vectors. 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. Controller performance under very heavy loading of power systems (δ>70deg) can be improved using a static switch in the controller output that can increase the applied control signal.

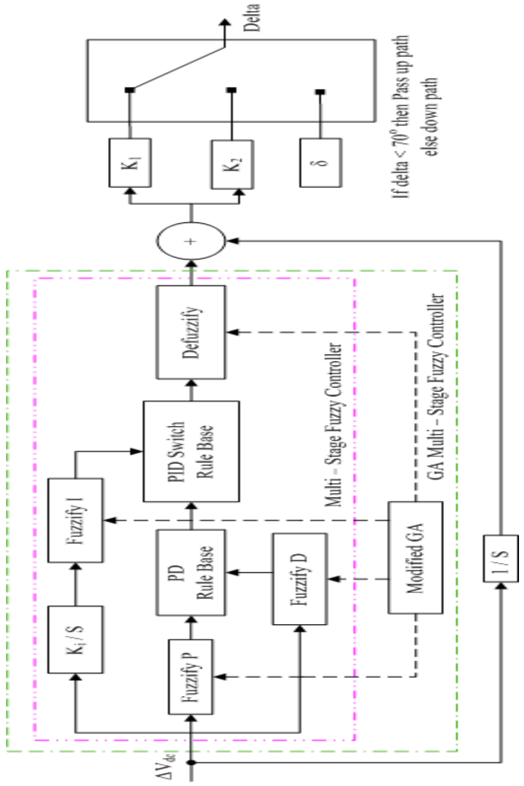

Fig -1: Structure of the proposed GAMSF DC-voltage regulator.

Here, all membership functions are defined as triangular partitions with seven segments from –1 to 1, where zero defines the membership function that is centered at zero. The partitions are also symmetric about the zero membership function, as shown in Fig.2.

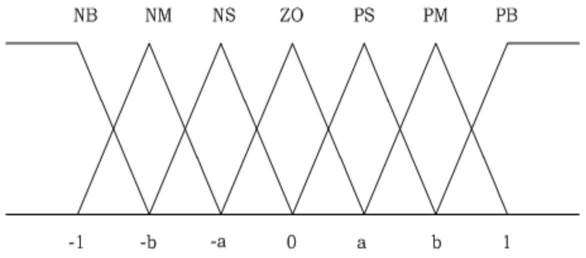

Fig -2: Symmetric fuzzy partition.

NB: negative big

NM: negative medium

NS: negative small

ZO: zero

PS: positive small

PM: positive medium

PB: positive big

3. SIMULATION OF THE PROPOSED CONTROLLERS

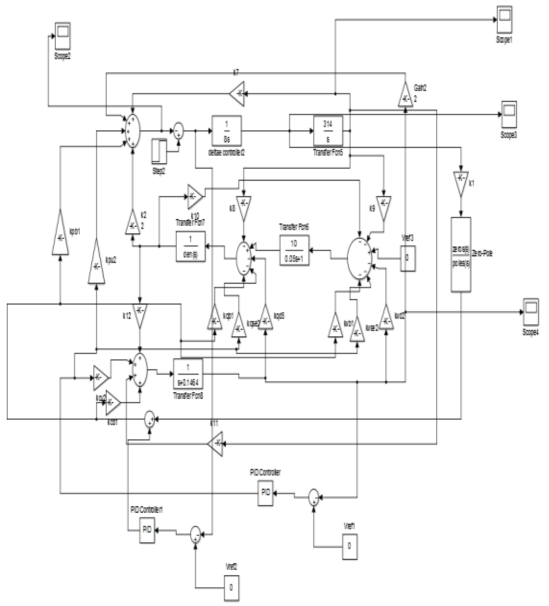

Fig -3: Simulink model of Conventional IPFC controller

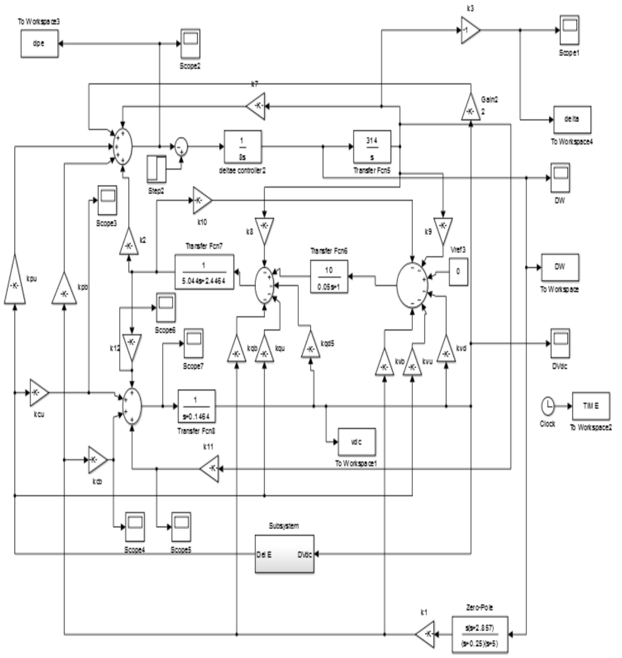

Fig -4: Simulink model of GAMSF DC voltage Regulator

In the analysis we have taken standard IEEE 30 Bus 6 Generator power system. The IPFC is implemented between buses 2-5 and 2-6 and generator 1 is taken as reference generator.

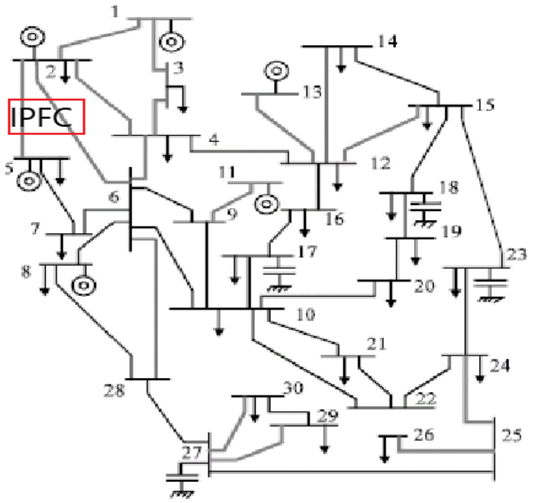

Fig –5: Standard IEEE 30 Bus 6 Generator system Equipped with IPFC

The systems shown in Figs. 3, 4 and 5 are simulated with a step disturbance of 0.1pu under various operating conditions (operating point 1: P_e =0.8, Q_e=0.15, V_t=1.032; operating point 7: P_e =1.15, Q_e =0.3, V_t =1.032). The results are shown in Figs. 6–21.

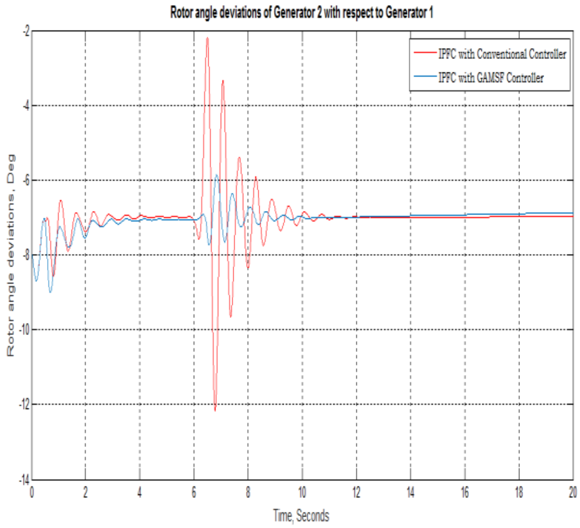

Fig -6: Time response of Δδ with conventional controllers, GAMSF DC- voltage regulator, generator 2 with respect to generator 1.

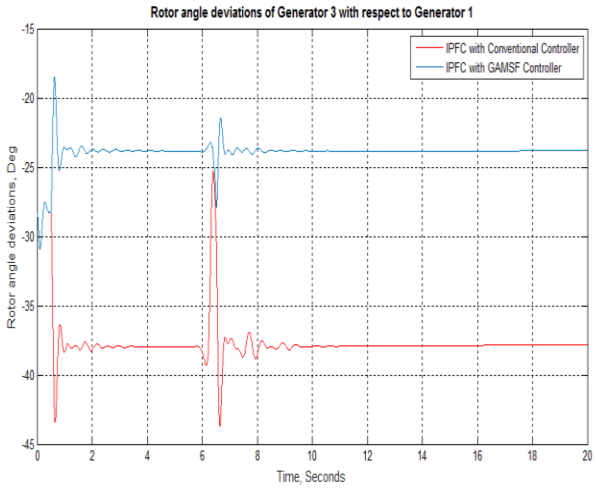

Fig -7: Time response of Δδ with conventional controllers, GAMSF DC- voltage regulator, generator 3 with respect to generator 1.

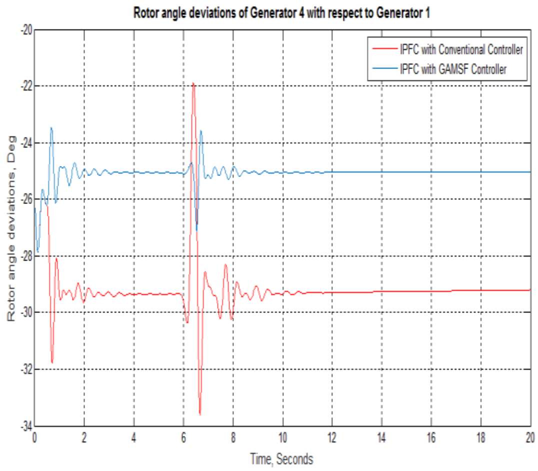

Fig -8: Time response of Δδ with conventional controllers, GAMSF DC- voltage regulator, generator 4 with respect to generator 1.

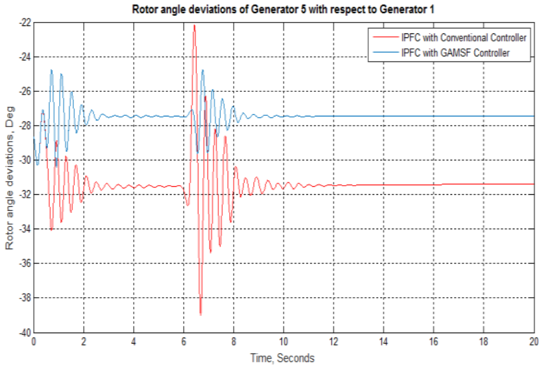

Fig -9: Time response of Δδ with conventional controllers, GAMSF DC- voltage regulator, generator 5 with respect to generator 1.

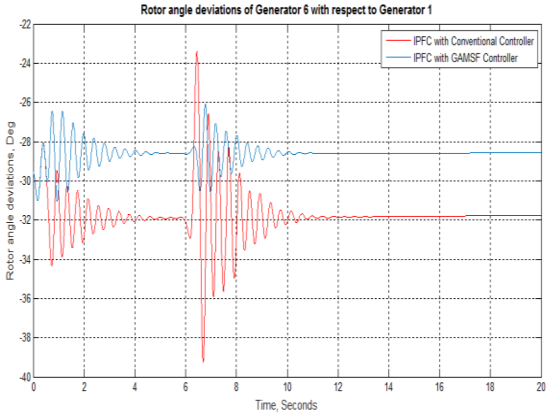

Fig -10: Time response of Δδ with conventional controllers, GAMSF DC- voltage regulator, generator 6 with respect to generator 1.

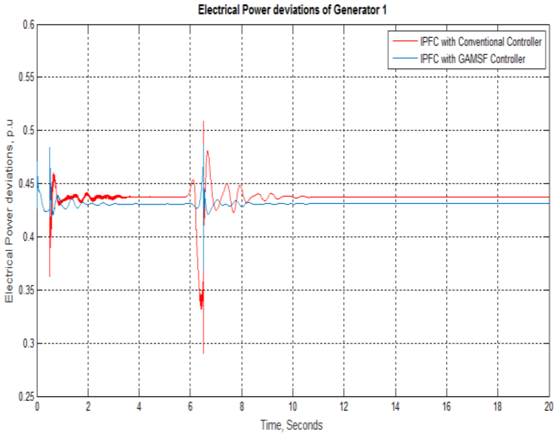

Fig -11: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 1.

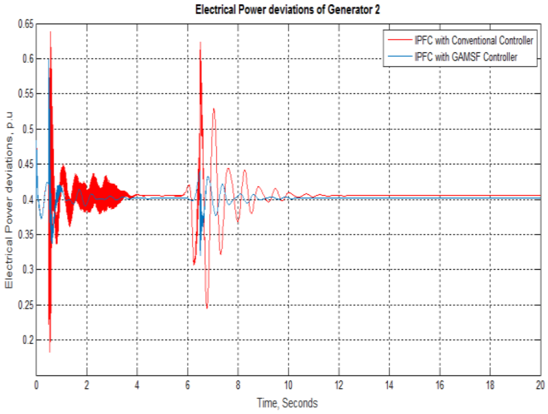

Fig -12: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 2.

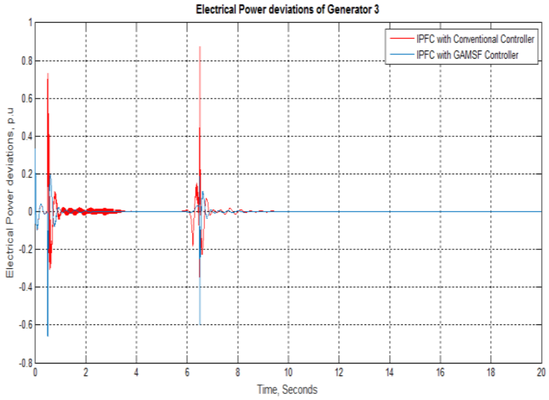

Fig -13: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 3.

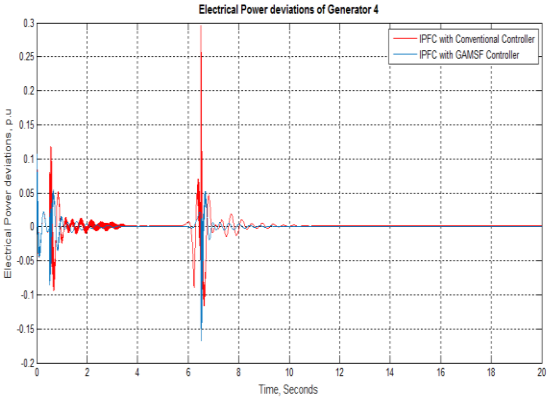

Fig -14: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 4.

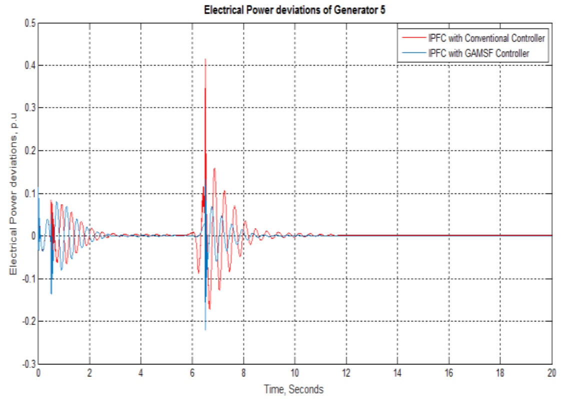

Fig -15: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 5.

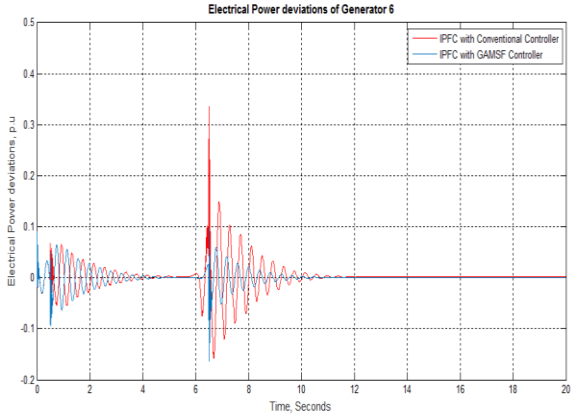

Fig -16: Time response of ΔPe with conventional controllers, GAMSF DC- voltage regulator, with respect to generator 6.

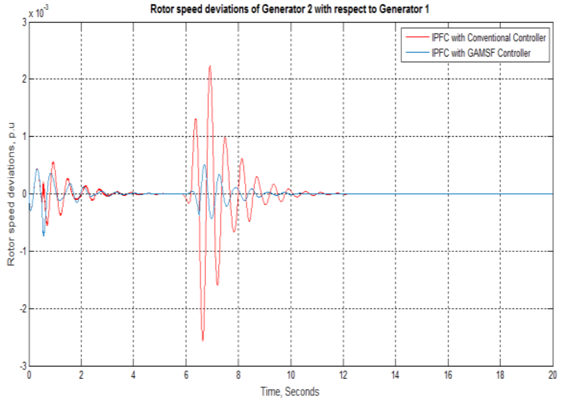

Fig -17: Time response of Δω with conventional controllers, GAMSF DC- voltage regulator, generator 2 with respect to generator 6.

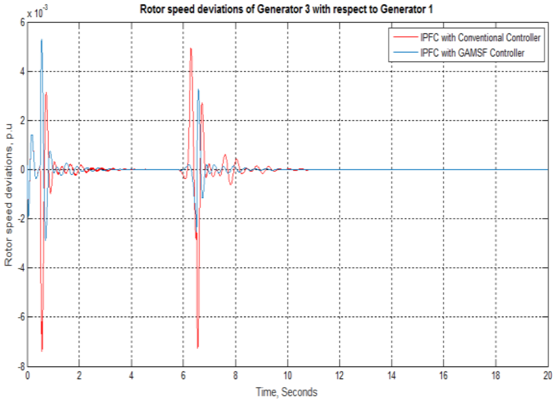

Fig -18: Time response of Δω with conventional controllers, GAMSF DC- voltage regulator, generator 3 with respect to generator 6.

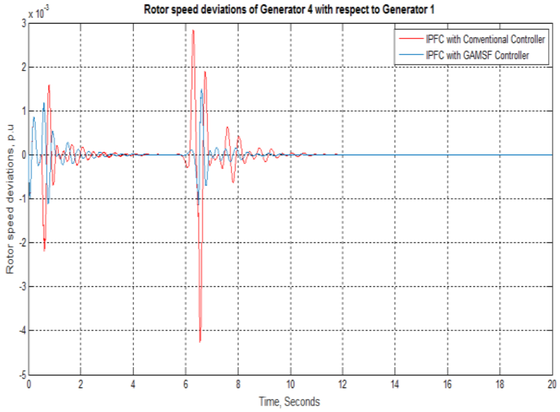

Fig -19: Time response of Δω with conventional controllers, GAMSF DC- voltage regulator, generator 4 with respect to generator 6.

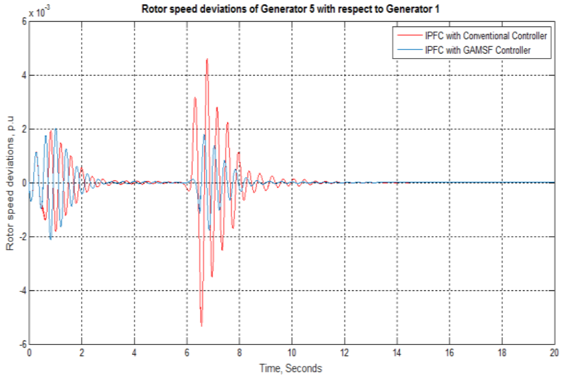

Fig -20: Time response of Δω with conventional controllers, GAMSF DC- voltage regulator, generator 5 with respect to generator 6.

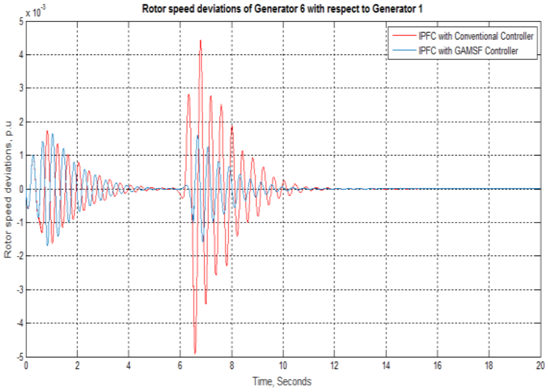

Fig -21: Time response of Δω with conventional controllers, GAMSF DC- voltage regulator, generator 6 with respect to generator 6.

4. CONCLUSION

In this paper, a new GAMSF DC-voltage regulator has been proposed. The effectiveness of the proposed controller has been tested on an Multi-machine power system and compared with conventional IPFC controllers under different operating conditions. The results demonstrate that the proposed controller is effective and displays good performance. The simple design procedure and robust performance of the proposed controller have the potential to make it useful for practical implementation.

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