

To Dampen the Low Frequency Oscillations in the Power System Using the Supplementary Controller Design For the IPFC

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ABSTRACT: This paper discusses the implementation of the interline power flow controller (IPFC) to damping low-frequency oscillations (LFOs) and proposes a new particle swarm optimization based multistage fuzzy (PSOMSF) DC-voltage regulator for the IPFC to dampen LFOs in power systems. The effectiveness of the proposed control strategy is evaluated under different operating conditions compared with genetic algorithm based multistage fuzzy (GAMSF) DC-voltage regulator. The robust performance of the proposed regulator has been demonstrated through time-simulation studies.

KEYWORDS: Flexible AC transmission systems (FACTS), genetic algorithm (GA)-based multistage fuzzy (MSF) DC-voltage regulator, IPFC, low-frequency oscillation (LFO), particle swarm optimization (PSO) based multistage fuzzy DC-voltage regulator.

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I. INTRODUCTION

One phenomenon that is presently of great interest and of vital 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, AnubhaPrajapati and KanchanChaturvedi 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 described how these devices, by adding a supplementary signal, can prove useful to damp oscillations, thus 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 exceptional capability of controlling power flow among multiple lines [5].

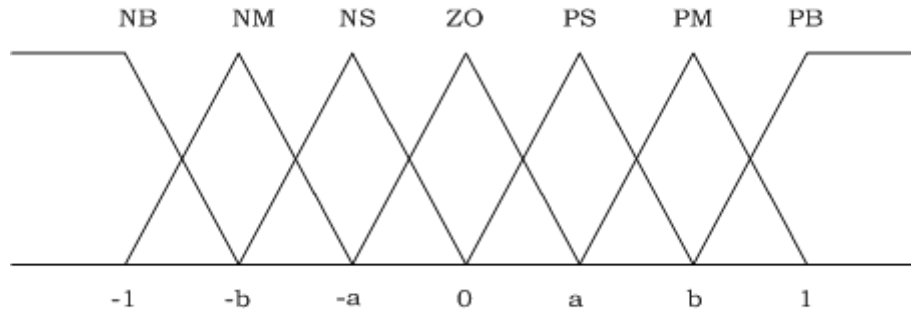
Interline Power Flow Controller (IPFC), is the latest representative of the Voltage Source Converter (VSC) based FACTS devices, and was proposed by Gyugyi with Sen, and C. D. Schauder [6]. To ensure accuracy and desirable operations of damping oscillations, the damping controller of low-power frequency 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 motivated us to design a sophisticated particle swarm optimization-based multistage fuzzy (PSOMSF) DC-voltage regulator for the IPFC. This regulator can help not only investigate the possibilities of damping of LFOs but also enhance dynamic stability.

In 2001, Kennedy J and Eberhart R et al [7] presented the Particle swarm optimization algorithm, which is tailor-made for optimizing difficult numerical functions; based on the metaphor of human social interaction, it is capable of imitating the ability of human societies to process knowledge. This method has roots in two component methodologies: artificial life (such as fish schooling, bird flocking, and swarming) and evolutionary computation. Its main concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. Its paradigm can be employed in a very simple form of computer codes and it is computationally economical in terms of both speed and memory requirements.

II. PARTICLE SWARM OPTIMIZATION (PSO) BASED MULTISTAGE FUZZY DC-VOLTAGE REGULATOR

As Clerc M *et.al.* reported in 2005 [8], particle swarm optimization technique can be used to solve many of the problems such as GA, and it does not have the limitations of GAs. It has also been found to be robust in solving problem featuring non-linearity, non-differentiability and high dimensionality. Particle swarm optimization technique is the search method to improve the speed of convergence and find the global optimum value of fitness function. PSO is more suitable to deal with the problem of lacking experience or knowledge than other searching methods, when the phenomena being analyzed are describable in terms of rules for action

and learning processes. Thus, reduce fuzzy system effort and cost, a PSO method is used to tune the membership functions optimally in the proposed MSF controller. Fig.2 shows the structure of the proposed strategy for the PSOMSF DC-voltage regulator. In this structure, the input values are converted to truth-value vectors and applied to their respective rule bases. The output truth-value vectors are not defuzzified to crisp value as with a single-stage fuzzy logic controller, but are passed onto the next stage as a truth value vector input. To improve controller performance under very heavy loading of power systems ($\delta > 70^\circ$), a static switch is used in the controller output to increase the applied control signal. In this effort, all membership functions are defined as triangular partitions with seven segments from -1 to 1 . Zero is the center membership function, which is centered at zero. The partitions are also symmetric about the zero membership function as shown in Fig.1.



NB: Negative big, PB: Positive big, ZO: Zero, NM: Negative medium, PM: Positive medium NS: Negative small, PS: Positive small

Fig.1: Symmetric fuzzy partition.

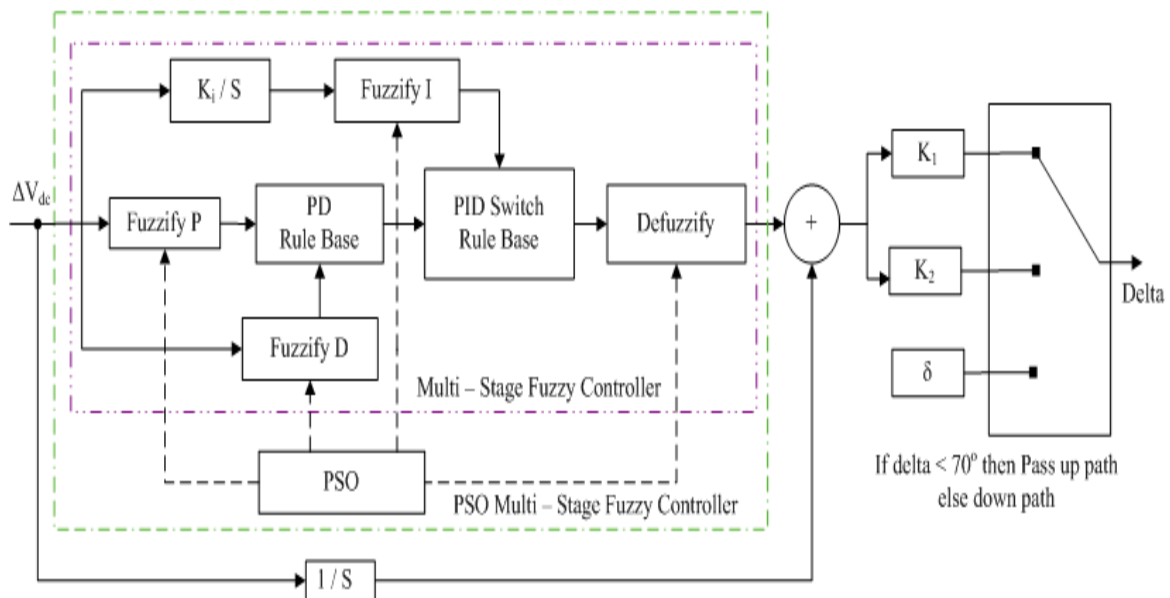


Fig.2: Structure of the proposed PSOMSF DC-voltage regulator

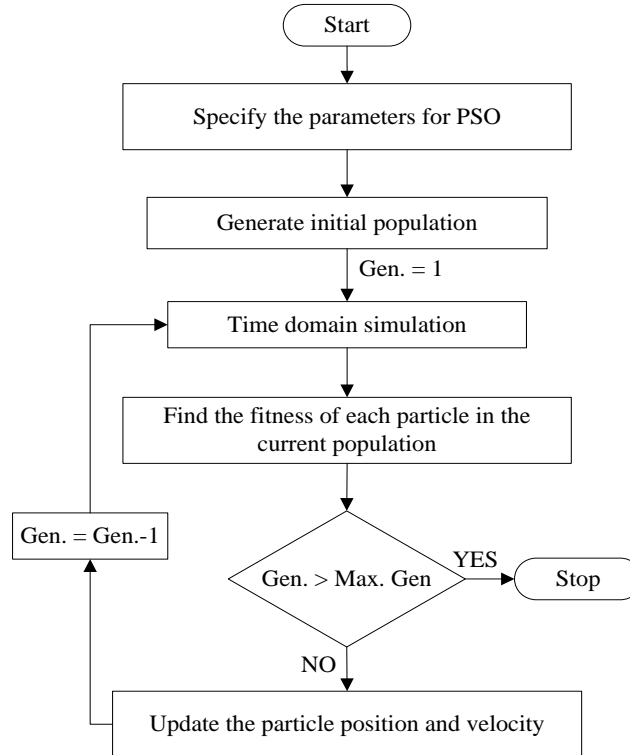


Fig.3: Flowchart of the PSO approach for optimization

III. SIMULATION OF THE PROPOSED CONTROLLER IN THE SMIB POWER SYSTEM.

The SMIB power system with IPFC can be represented by a linearized transfer function model, as shown in Figs. 4 and 5. The result is validated by simulating the Phillips–Heffron linearized transfer function model using the MATLAB/Simulink toolbox.

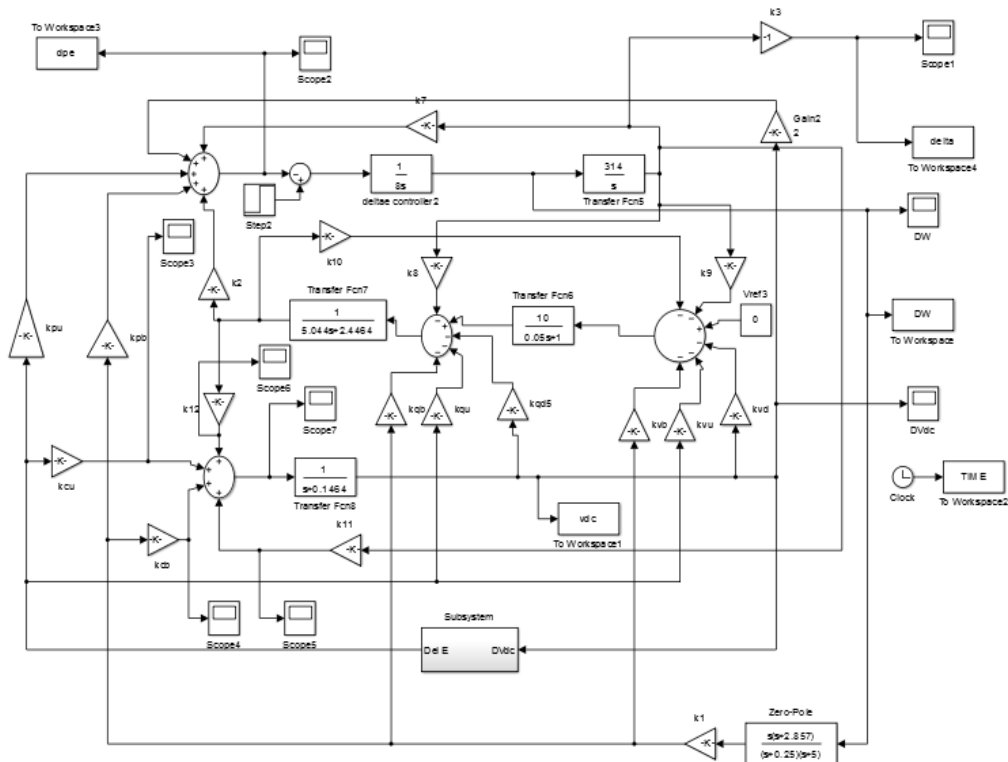


Fig.4: Simulink model of a single-machine infinite-bus system with IPFC and GMSF Simulink model.

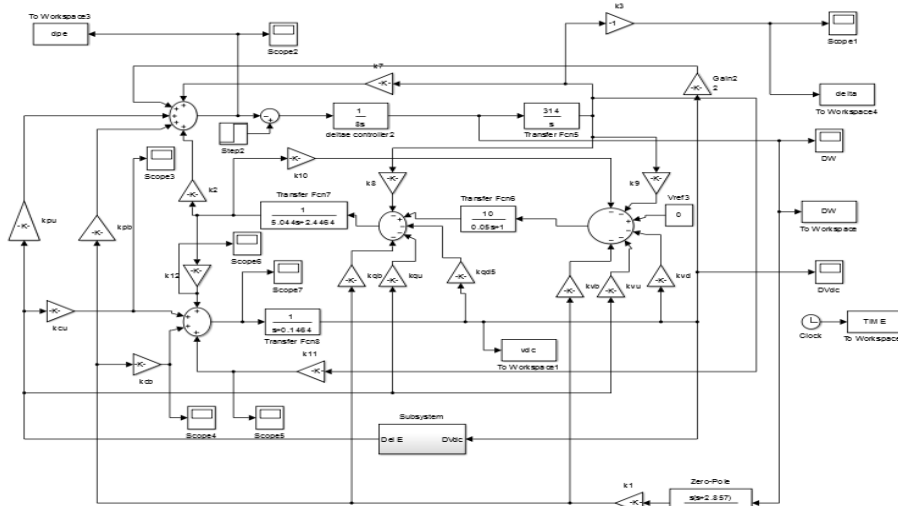


Fig.5: Simulink model of a single-machine infinite-bus system with IPFC and PSOMSF Simulink model.

The disturbance is given as a step input, and the output response can be represented using $\Delta\delta$, $\Delta\omega$, ΔP_e and ΔV_{dc} which indicate the rotor angle deviation, the angular frequency deviation, deviation in electrical power and deviation in capacitor voltage respectively. The systems shown in Figs.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 4 $P_e = 1.1$, $Q_e = 0.28$, $V_t = 1.032$)

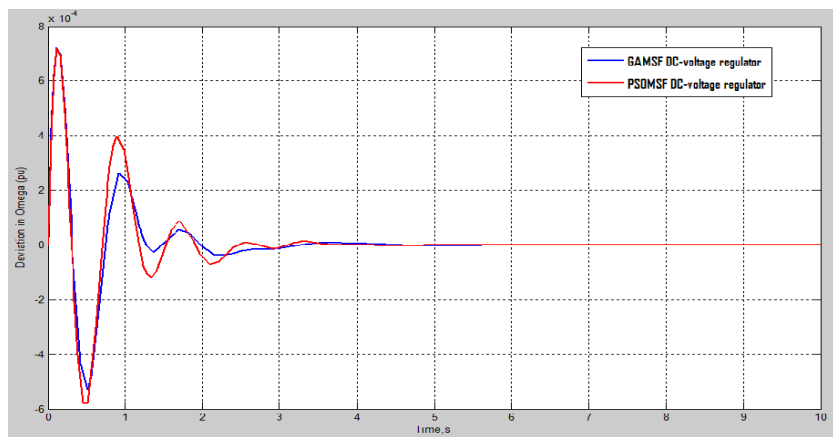


Fig.6. Time response of $\Delta\omega$ with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 1

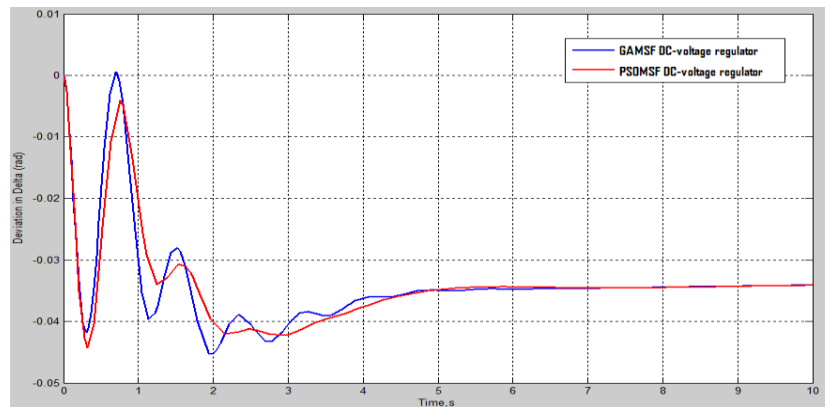


Fig.7. Time response of $\Delta\delta$ with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 1

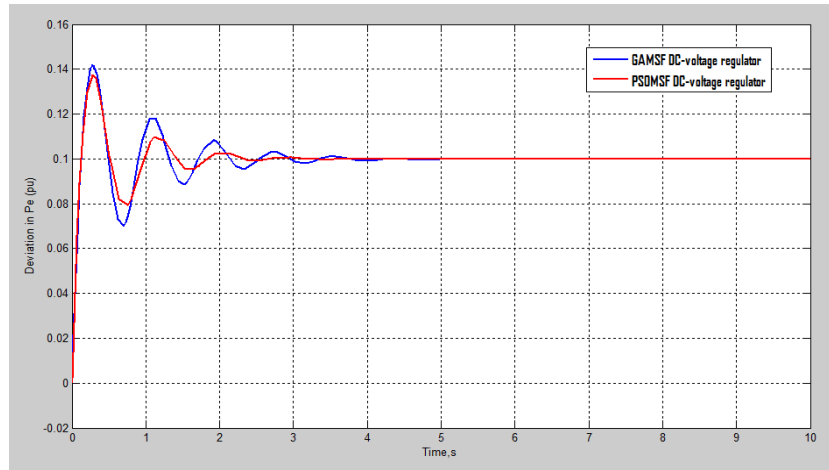


Fig.8. Time response of ΔP_e with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 1

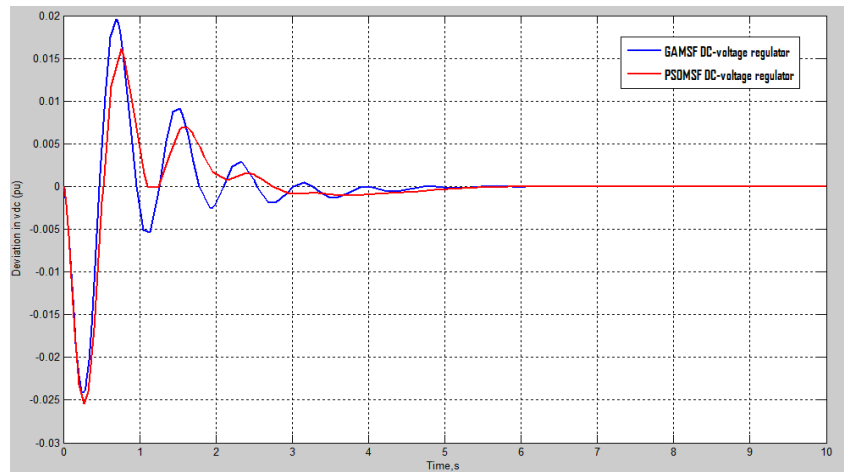


Fig.9. Time response of ΔV_{dc} with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 1

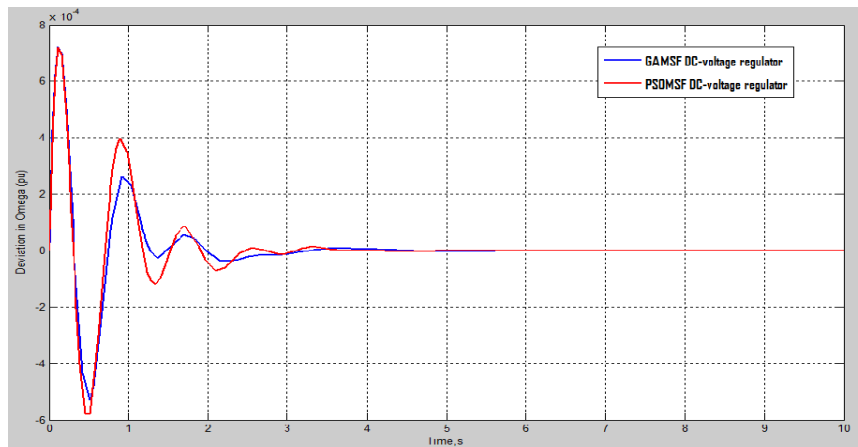


Fig.10. Time response of $\Delta \omega$ with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 7

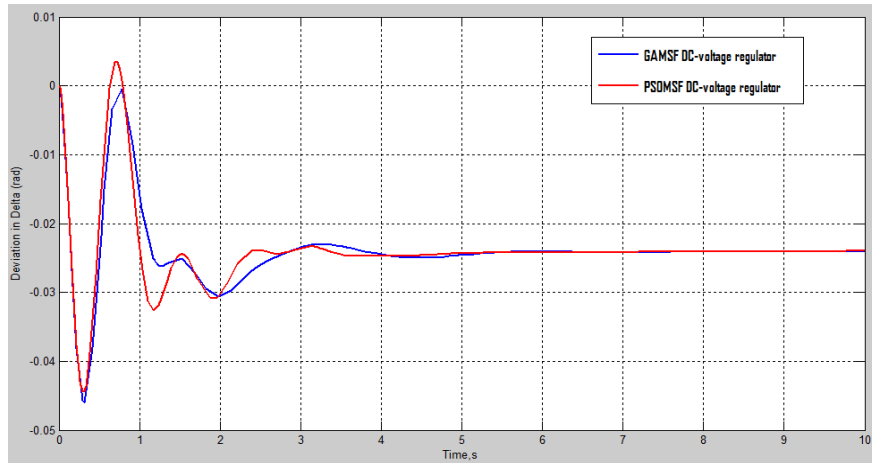


Fig.11. Time response of $\Delta\delta$ with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 7

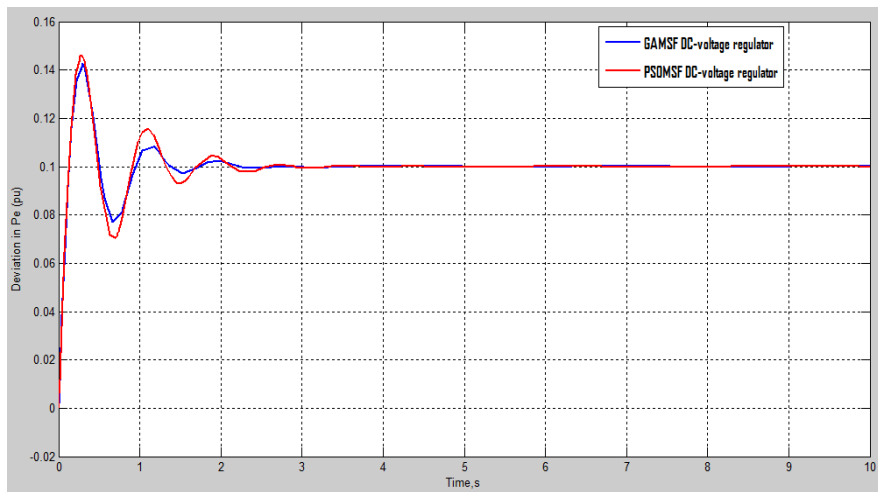


Fig.12. Time response of ΔP_e with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 7

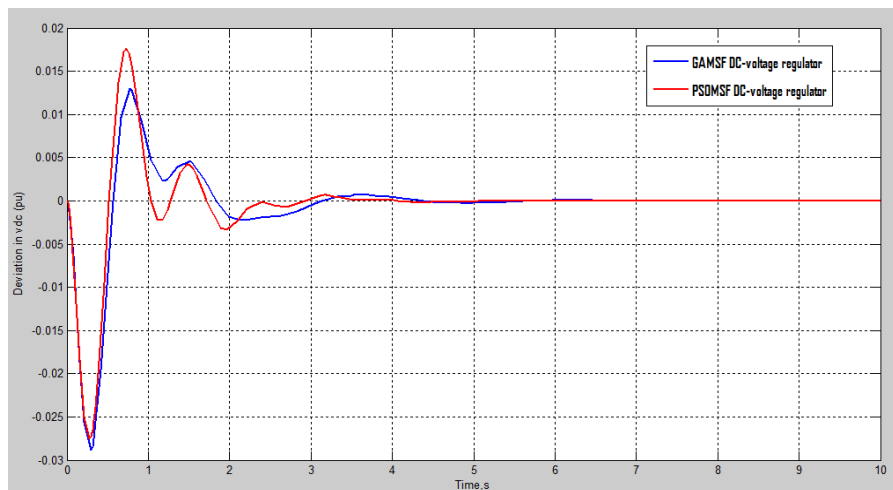


Fig.13. Time response of ΔV_{dc} with GAMSF DC-voltage regulator and PSOMSF DC-voltage regulator at operating point 7

Fig.6 to Fig.13 shows the $\Delta\omega$, $\Delta\delta$, ΔP_e and ΔV_{dc} plot at various operating points with PSOMSF DC voltage regulator in comparison with IPFC with GAMSF DC voltage regulator. From these Figures we concluded that IPFC with PSOMSF DC voltage regulator has better damping rate compared with GAMSF DC-voltage regulator.

IV. CONCLUSIONS

In this paper, a new PSOMSFC DC-voltage regulator has been proposed. The efficacy of the proposed controller has been tested on an SMIB power system and compared with GAMSFC DC-voltage regulator under different operating conditions. The results validate that the proposed controller is effective and displays excellent performance. The simple design technique and robust performance of the proposed controller have the potential to make it useful for practical implementation.

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