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Genetic Algorithm based controllers for Robust stability Enhancement of interconnected Power System with wind power penetration

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Abstract: *This work proposes genetic algorithm-based power system stabilizers for conventional generators and genetic algorithm-based PI controllers for double fed induction generators (DFIGs) for enhancing dynamic stability of inter connected power system. This approach is developed to examine the robust stability analysis of power systems, such as power systems with wind power penetrations and fault conditions. The proposed approach has several advantages compared with our previous work. In the proposed method the parameters of DFIG controllers and power system stabilizers are tuned using genetic algorithm by maximizing fitness function, this function is formulated as a reciprocal of integral time area error (ITAE) of speed deviations of generators. Proposed controller is tested on a classical 4-generator 11-bus test power system, performance is compared with new set approach (Km theory). Results demonstrated that the proposed controller is effectively damping the oscillations compared with new set approach.*

Index Terms- *Robust stability analysis, D-stability, value set, mapping theory, Km theory, wind power penetration.*

I. INTRODUCTION

Power system engineering forms a vast and major portion of electrical engineering studies. It is mainly concerned with the production of electrical power and its transmission from the sending end to receiving end as per requirements, incurring a minimum amount of losses. The power often changes due to the variation of load or due to disturbances. For these reasons, the term power system stability is of utmost importance in this field. It is used to define the ability of the system to bring back its operation to steady state condition within a minimum possible time after having undergone any transience or disturbance. Ever since the 20th century, till the recent times, all major power generating stations over the globe has mainly relied on AC system as the most effective and economical option for generation and transmission of electrical power.Renewable energy sources, wind power in particular, provides a growing proportion of electricity in many countries. Among the renewable energy technologies that are being developed, variable speed wind turbines employing Doubly Fed Induction Generator (DFIG) is the most popular technology in currently installed wind turbines [1-2]. The high penetration grid-connected wind power has brought great concern for power system small-signal stability, due to the dynamic characteristics and the uncertainty of the wind power generation. Much work has been done to investigate the dynamic characteristics of the wind power generation on power system stability [3-7]. The varying wind powers give rise to the parametric uncertainties of the system linear models for small signal stability analysis. Apparently, stability analysis of such systems should take into account the parametric uncertainties,which is the subject of parametric robust stability analysis [8].

One classic robust stability analysis method, namedstructured singular value (SSV) theory [9], proved useful in large-scale power systems [10-13], which gives a sufficient condition for robust stability evaluation. Recently, the stability radius theory was developed in robust small-signal stability analysis considering uncertain wind powers [14-15]. Since relatively little work had unraveled the combined impact of each uncertain parameter on system stability in large-scale power systems, the polynomial theory was developed in our recent work [16] to analyze each uncertainty's impact by inspection of the value set plot.Among the above works, only the Hurwitz stability problem has been considered. However, power system small signal stability analysis prefers the D-stability, which is known as the damping ratio constraint, and the D-stability analysis methods need to be developed for power system robustness analysis.

One weakness of our previous work [16] is that the magnitude of the value sets det( ) grows rapidly as frequency and system order grow. The model order reduction is hence necessary, especially for the large-scale power system. This large number issue may cause the numerical stability problem in some cases. And there is a remaining problem in [16] that the mapping theorem for det( )fails to evaluate stability when the value set plot contains the origin, since it only gives a sufficient condition. Moreover, if the power system is not robustly stable, the parameter analysis in [16] becomes invalid. In [17], they develop a robust stability analysis method and apply it to the power systems with wind power penetration. First, the parametric power system modeling is briefly introduced, including the development of the parametric state matrix representation and the standard M(s)-Δ model. Next, to fix the large number problem and avoid the approximation of the model order reduction, a new solution is presented, working directly with the return difference det(I − M(s)Δ) rather than the previous det(I − M(s)Δ). And the new return difference approach can extend to the robust D-stability analysis.

Therefore, even though the power system is not robustly stable, the parameter analysis is still available. Then, for stability evaluation, the celebrated zero exclusion principle is extended to the value sets of det(I − M(s)Δ). And the mapping theorem is applied to calculate the value set plot of det(I − M(s)Δ). Later, to reduce the conservativeness of the mapping theorem, the multi-variable stability margin theorem is presented to give a necessary and sufficient condition for stability evaluation. Finally, in the case study, the proposed method is applied to power systems with wind power penetration, and simulation results show that the value set plotof det(I − M(s)Δ) carries sufficient stability information and permits one to analyze the respective impact of each parameter on stability.

In this work, we proposed Genetic algorithm-based controllers for (a systematic approach) for enhancing the dynamic stability of power system.

II. Introduction of Power System Stabilizers & PI type controllers for DFIG

Fig. 1 represents a transfer function block diagram of the system, through which an electrical torque is produced in response to speed deviation signal, Δω; whereas GEP(s) is a transfer function of the system whose output is electrical torque and input is stabilizing signal (upss). In order to increase damping of oscillations, a PSS utilizing shaft speed deviation as input signal must compensate for the phase-lag of GEP(s) to produce a component of the torque in phase with speed deviation. The transfer function of a PSS is represented as:

$$u_{PSS} = K_{PSS}\frac{sT_w}{1+sT_w}\left(\frac{1+sT_{1PSS}}{1+sT_{2PSS}}\right)\left(\frac{1+sT_{3PSS}}{1+sT_{4PSS}}\right)\Delta\omega$$

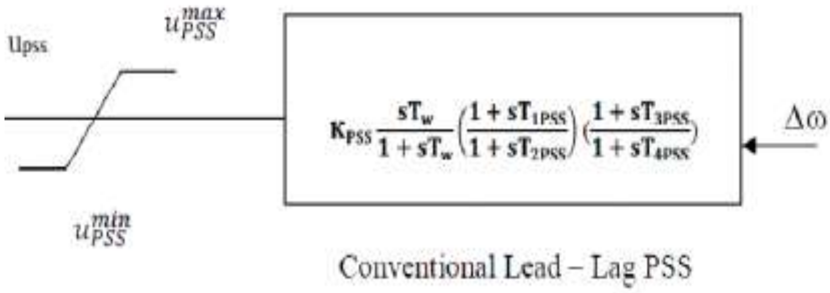

Fig.1. Block diagram representation of Conventional Power System Stabilizer.

where KPSS is stabilizer gain, Tw is washout time constant and T1,T2,T3,T4 are time constants of the lead–lag networks. In this structure, the washout time constant Tw and the time constants T2PSS, T4PSS are usually pre specified. In this study, Tw = 5 s and T2PSS, T4PSS = 0.1 s: The controller gain, KPSS and time constants, T1PSS, T3PSS, remain to be determined. The speed deviation Δω is available and used as the input signal to PSS. This makes the design of controller easy for implementation.

Doubly fed Induction generator is one of the most non conventional energy source, for this DFIG we have stator side controllers and Rotor side controllers. In this paper, PI type controllers are preferred, that means, it consists of Proportional and Integral controller.

III. GENETIC ALGORITHM BASED PARAMETER TUNNING OF STABILIZERS AND DFIG CONTROLLERS

In this paper, Genetic algorithm is used for the optimization of PSS parameters and DFIG controller parameters. Fig.2 shows the schematic diagram of proposed controller, from this it is clear that genetic algorithm receives frequency error as an input and generates 22 output parameters for the proposed controllers. The output variables are listed in the figure.2.For our optimization, the following fitness function is proposed:

$$\text{Fitness}=\frac{1}{10*ITAE},$$

For acquiring better performance, number of generation, population size, crossover rate and mutation rate is chosen 100, 150, 0.97 and 0.08, respectively.

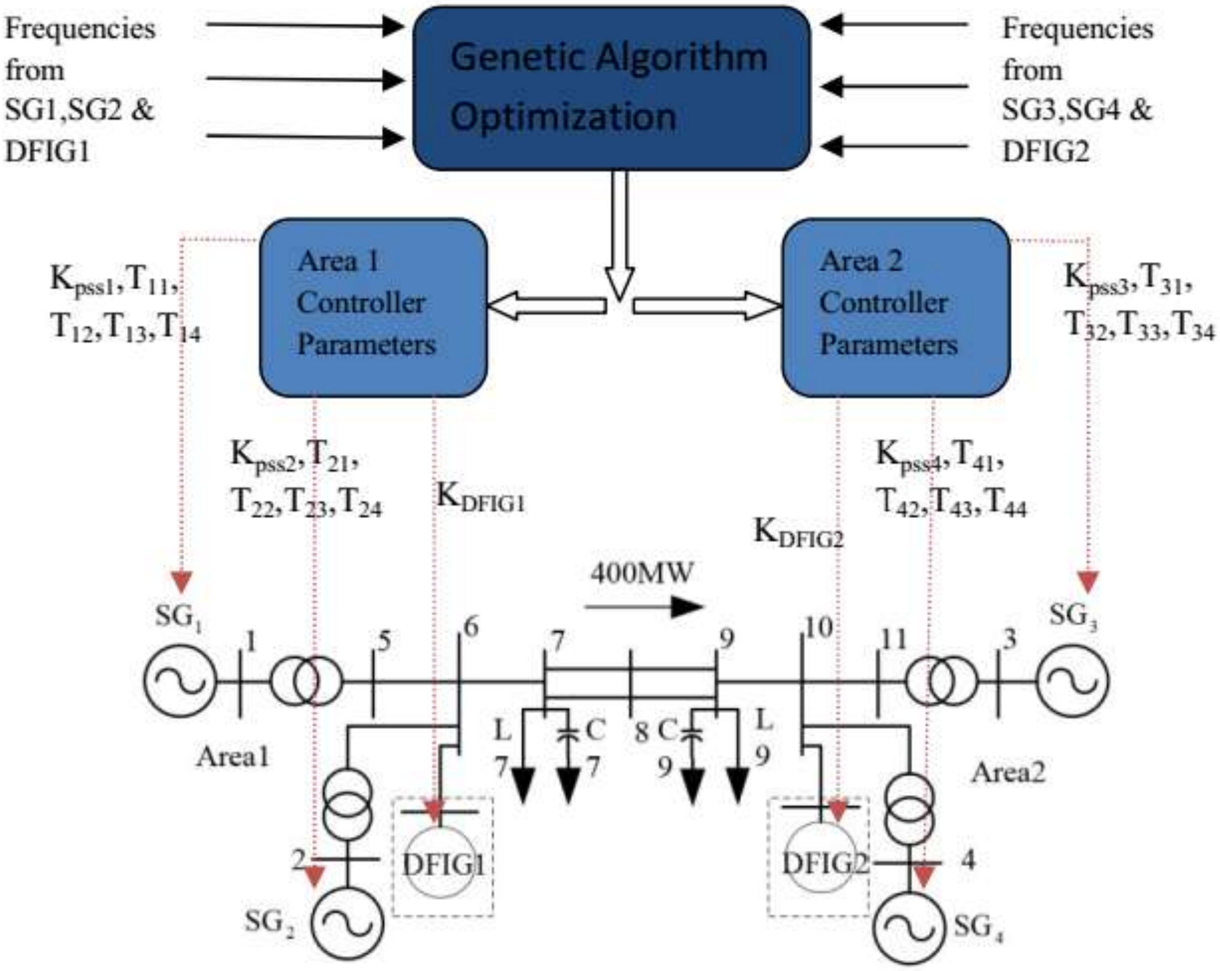

Fig.2 proposed method Implementation on Test system

IV. SIMULATION DIAGRAM & RESULTS

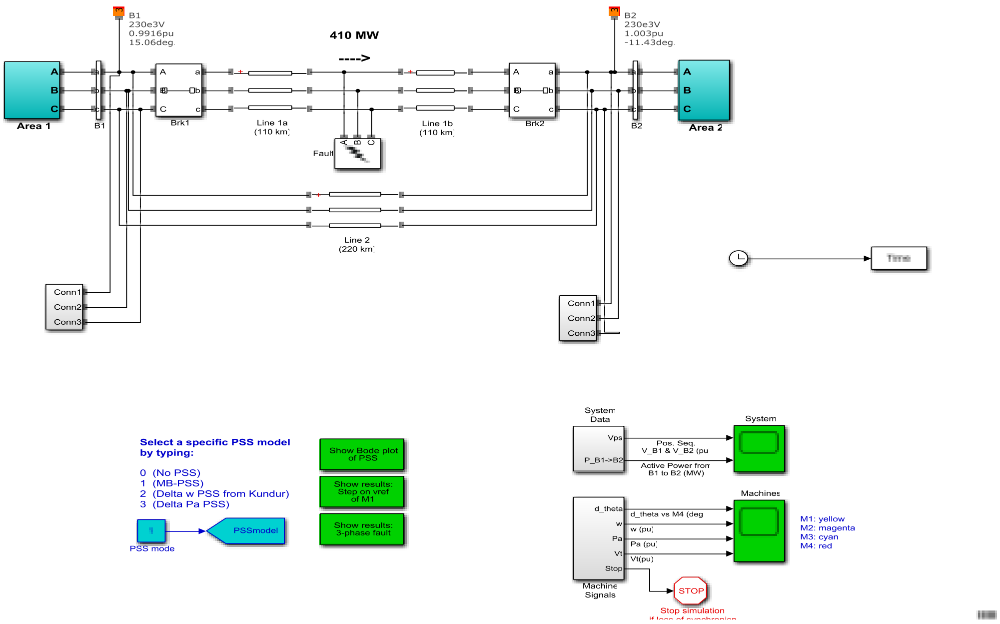

Fig.3. Simulation diagram of Test system with proposed method

The simulation diagram of proposed method is shown in fig.3. This system is subjected to two types of disturbances one is wind power penetration and another is three phase fault. In the simulation wind power penetration is created at 1 second of time and three phase is created between 5 to 6 seconds. The results of fig.3 are shown in figures 4 to 18. Here blue colour wave form is the response with conventional controllers, red colour wave form indicates the response of interconnected system with new set approach method and black colour represents the response of interconnected system with proposed method of controllers.

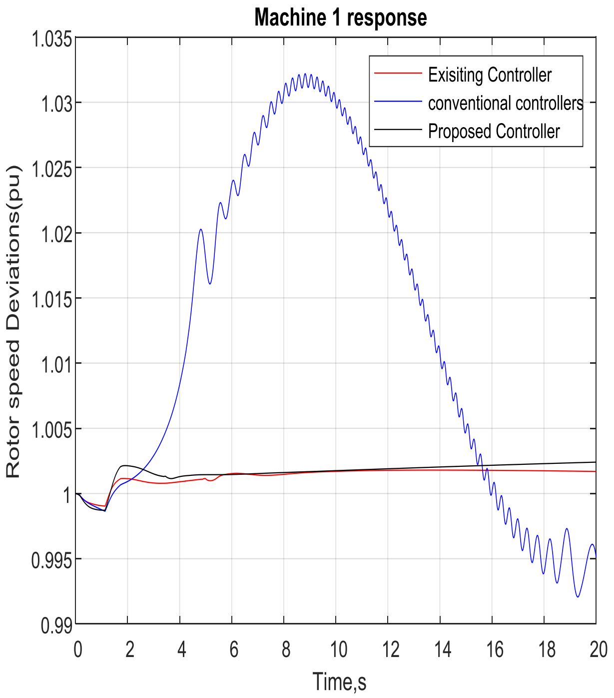

Fig.4.Time response of rotor speed deviations of machine 1

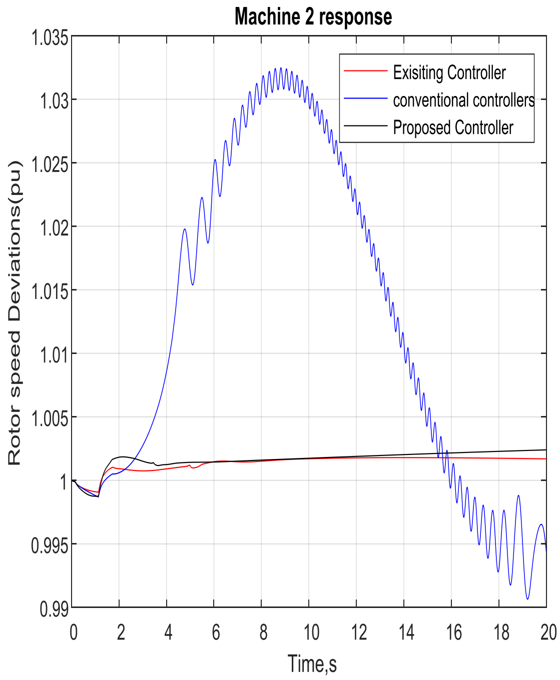

Fig.5.Time response of rotor speed deviations of machine 2

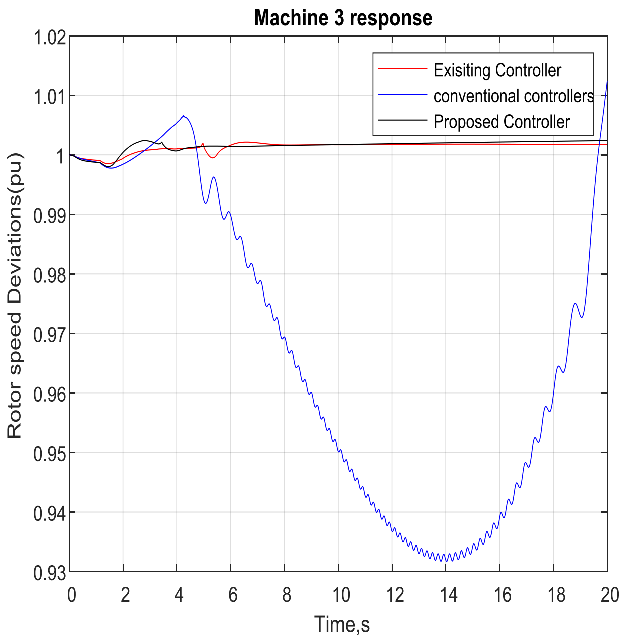

Fig.6.Time response of rotor speed deviations of machine 3

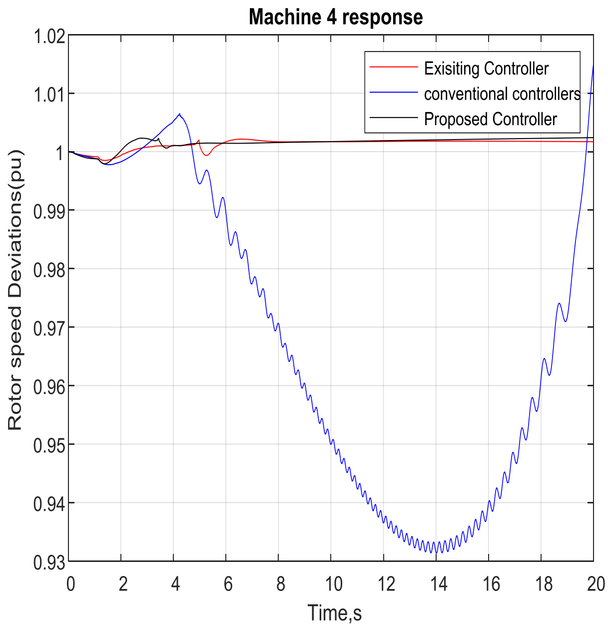

Fig.7.Time response of rotor speed deviations of machine 4

Fig.4-7 indicates the time response of rotor angle deviations (pu) of machines 1 to 4 respectively. From these figures it is clear that new set approach-based controllers (Existing controller) are exhibiting better performance compared with conventional controllers. But the proposed controller is far better than both the controllers, that means damping the oscillations effectively compared with the remaining controllers.

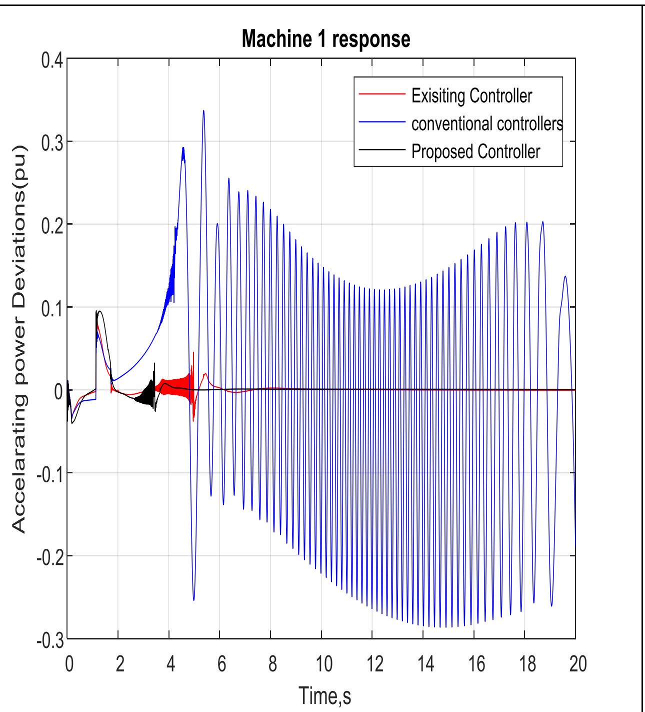

Fig.8.Time response of Accelerating power deviations of machine 1

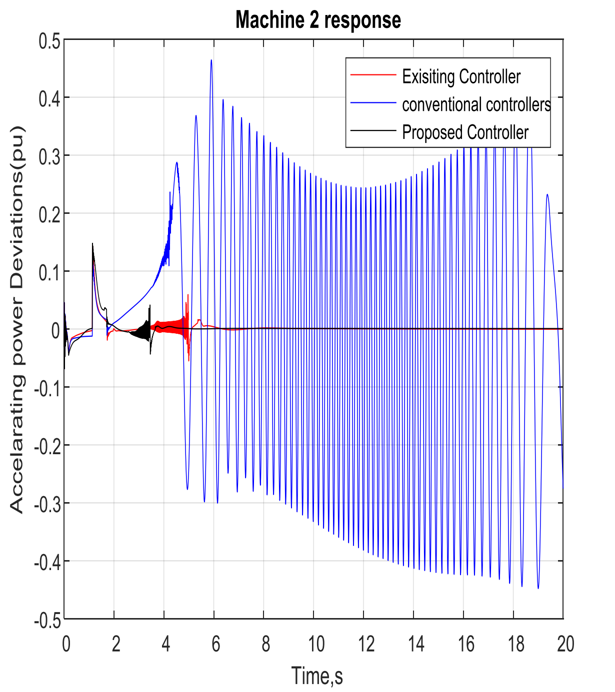

Fig.9.Time response of Accelerating power deviations of machine 2

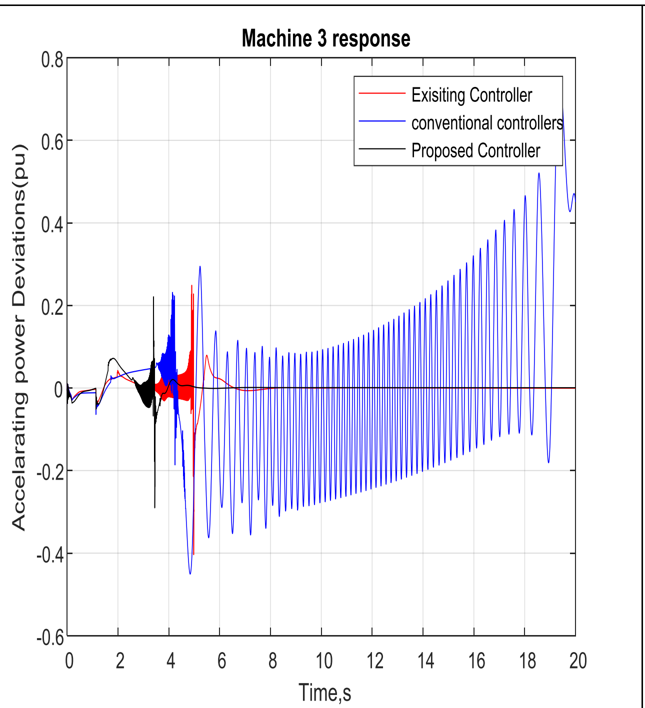

Fig.10.Time response of Accelerating power deviations of machine 3

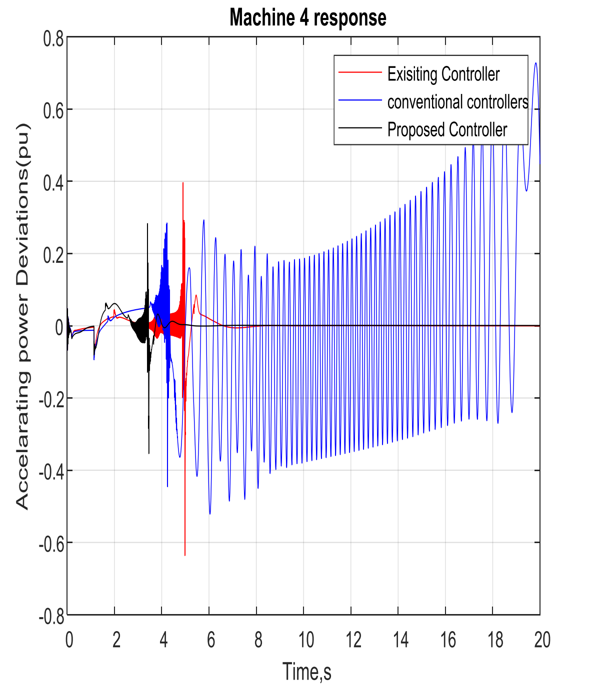

Fig.11.Time response of Accelerating power deviations of machine 4

Fig.8-11 indicates the time response of Accelerating power deviations (pu) of machines 1 to 4 respectively. From these figures it is clear that new set approach-based controllers (Existing controller) are exhibiting better performance compared with conventional controllers. But the proposed controller is far better than both the controllers, that means damping the oscillations effectively compared with the remaining controllers.

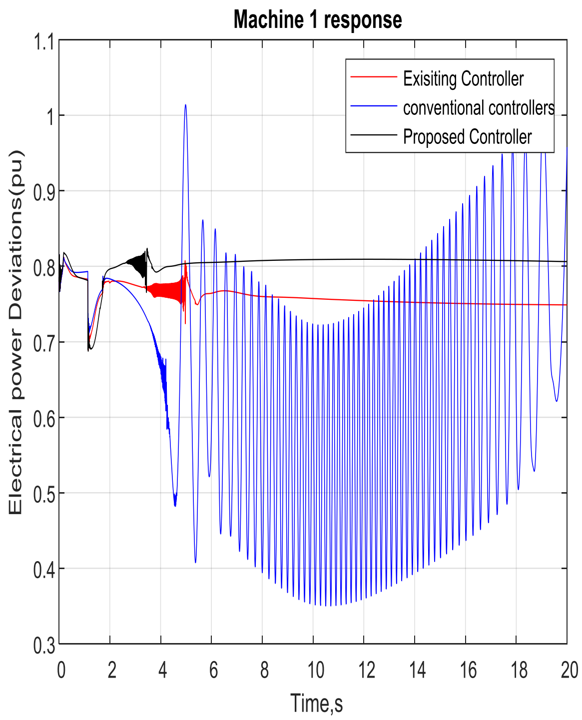

Fig.12.Time response of Electrical power deviations of machine 1

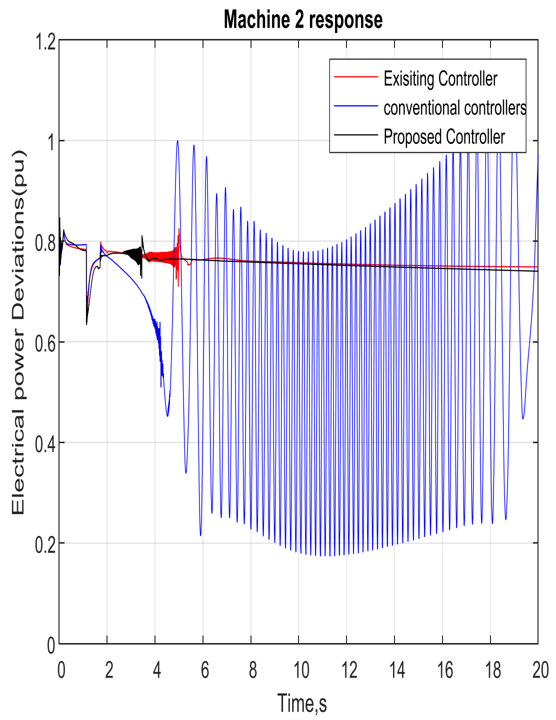

Fig.13.Time response of Electrical power deviations of machine 2

Fig.12-15 indicates the time response of Electrical power deviations (pu) of machines 1 to 4 respectively. From these figures it is clear that new set approach-based controllers (Existing controller) are exhibiting better performance compared with conventional controllers. But the proposed controller is far better than both the controllers, that means damping the oscillations effectively compared with the remaining controllers.

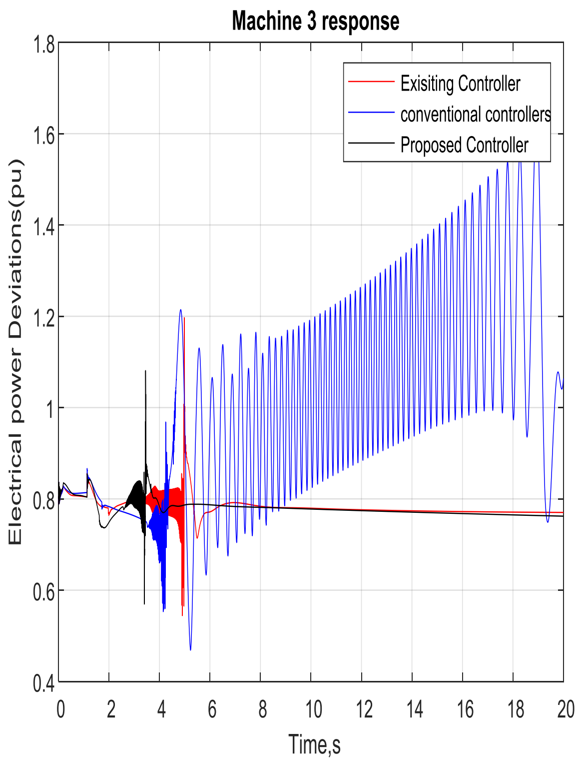

Fig.14.Time response of Electrical power deviations of machine 3

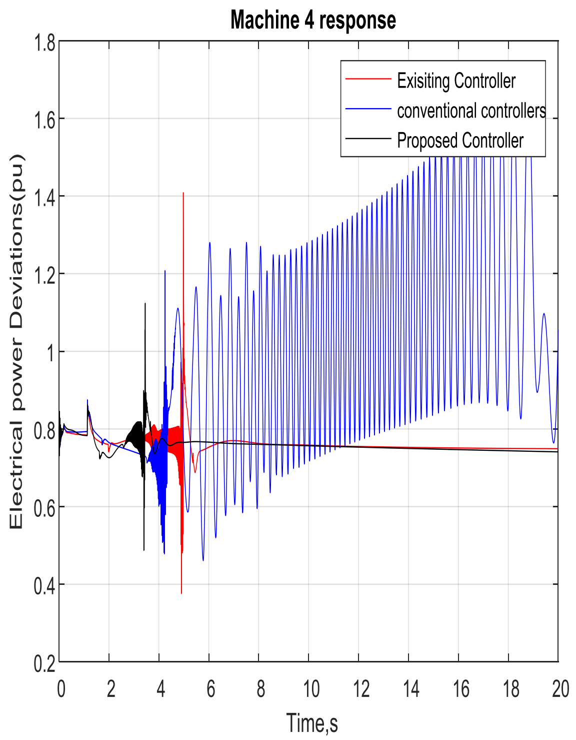

Fig.15.Time response of Electrical power deviations of machine 4

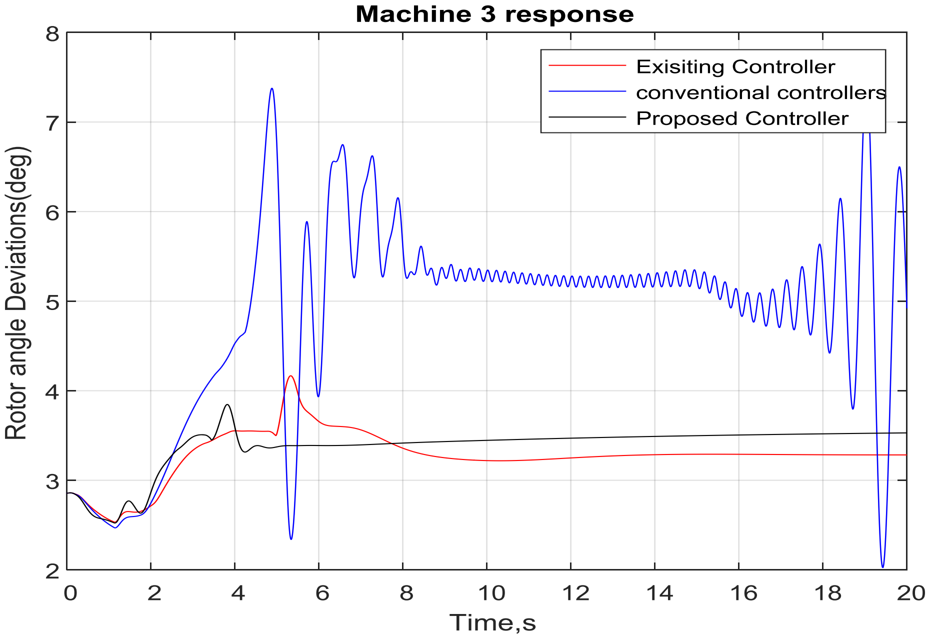

Fig.16. Time response of Rotor angle deviations of machine 3

Fig.16 indicates the time response of Rotor angle deviations (deg) of machine 3. From this figure it is clear that new set approach-based controllers (Existing controller) are exhibiting better performance compared with conventional controllers. But the proposed controller is far better than both the controllers, that means damping the oscillations effectively compared with the remaining controllers.

V. CONCLUSION

This paper proposes genetic algorithm-based power system stabilizers for conventional generating stations and PI type power controller for DFIG. Proposed method tested on 4 machine 11 bus system and the performance of proposed controller is compared with previous controllers. From the results it is clear that the proposed controller is effectively damping the oscillations compared with previous controllers and there by enhancing the stability of power system under wind power penetrations as well fault condition.

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