

# Intelligent Wide Area Signals Based on Damping of Power System Oscillations

L.Heamkumar <sup>1</sup>, E.Sheeba Percis <sup>2</sup>

P.G. Student, Department of Electrical & Electronics Engineering, Dr.M.G.R. Educational & Research Institute,  
Maduravoyil, Chennai, Tamil Nadu, India<sup>1</sup>

HOD, Department of Electrical & Electronics Engineering, Dr.M.G.R. Educational & Research Institute, Maduravoyil,  
Chennai, Tamil Nadu, India<sup>2</sup>

**ABSTRACT:** This paper has illustrated the need of wide area damping controllers (WADCs) of generators connected to a grid to damp the power system wide area oscillations created by the severe disturbance and power market variations, at the system operating condition, which interacting with Power system Stabilizers (PSSs), to maintain the stability margin. Studies are based on the simulation of Four areas, 11-bus power system in which one test case is investigated, that two generators out of four in the test system, fails to damp the oscillations completely. The result was observed by monitoring generators speed and voltage signals. Wide area oscillation damping controller is ensured, herein a concept of virtual generator is introduced to exploit the realization that a group of coherent synchronous generators in power system can be controlled as a single generating unit for achieving wide-area damping control objective. The implementation of VGs based WADCs is made possible by the availability of Wide-area measurements (WAMs) from Phasor Measurement Units (PMUs) using the PSO.

**KEYWORDS:** Wide area damping controllers (WADCs), Power System Stabilizers (PSSs), Virtual Generators(VGs), Power System Stability, Dig SILENT Power Factory, Automatic voltage regulator (AVR), Particle Swarm Optimization (PSO) Algorithm.

## I. INTRODUCTION

The inter area oscillation is the large part in the generation grid network. It involves two coherent groups of generators swinging against each other at 1 Hz or less. The oscillation frequency is approximately 0.3 Hz. The most common control action to enhance damping of power system oscillations is the use of power system stabilizers (PSS). Even though several FACTS devices have been implemented and installed in practical power systems such as static VAR compensator (SVC), thyristor controlled series capacitor (TCSC), and thyristor controlled phase shifter (TCPS). A rotor speed of remote generator is used as wide area measurement signal in this paper. The signal is detected and transmitted by the Phasor measurement unit (PMU). The wide area signal inputs to the local power system stabilizer (PSS) to regulate the generator excitation and enhancing the power system damping. The gains of the wide area controller are determined by solving linear matrix inequalities (LMI). The LMI solving method is introduced for the wide area control of power systems.

## II. LITERATURE REVIEW

The Literature survey had been done and it was published as literature survey on intelligent wide area signals based damping of power system oscillations using the virtual generators in IRJET Journal, Volume – 02, Issue : 08 | Nov 2015 with the serial number e – ISSN : 2395 – 0056, p – ISSN : 2395 – 0072.

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### III. PSO TECHNIQUE

Particle swarm optimization algorithm, which was tailored for optimizing difficult numerical functions. It is capable of mimicking the ability of human societies to process knowledge [14]. It has roots in two 15 main component methodologies: artificial life (such as bird flocking, fish schooling and swarming); and, evolutionary computation. Its key concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. Its paradigm can be implemented in simple form of computer codes and is computationally inexpensive in terms of both memory requirements and speed.

It lies somewhere in between evolutionary programming and the genetic algorithms. Vectors are taken as presentation of particles since most optimization problems are convenient for such variable presentations. The principle of stability is adhered to since the population changes its state if and only if the best group value changes [15,16]. PSO is the search method to improve the speed of convergence and find the global optimum value of fitness function.

### IV. AUTOMATIC DATA EXCHANGE DIGSILENT & MATLAB

The choice of using MATLAB and DIGSILENT together consists from the difficult task of implementing both the optimization algorithm and the power system analysis in one application. The DIGSILENT has the advantage of easily determining the Eigen values of the system necessary for the study and analysis of power system stability. It should be noted that the simultaneous use of the two platforms lies in the need to evaluate each particle modeled by the optimization algorithm in MATLAB as a multi-objective function which is based on the Eigen values of the system obtained using DIGSILENT platform.

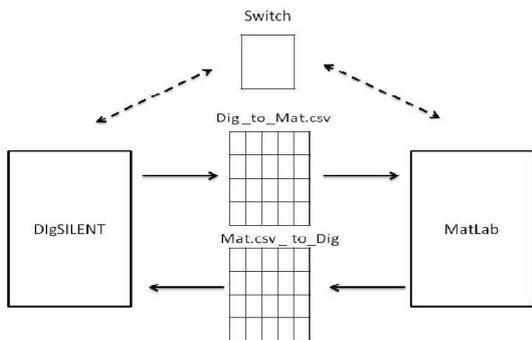


Fig 1: Automatic data exchange

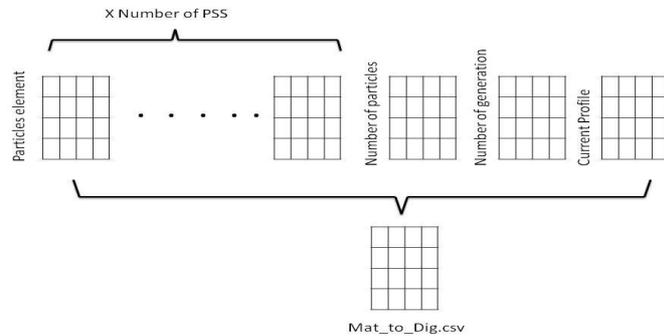


Fig 2 : Mat\_to\_Dig.csv structure

### V. DESCRIPTION OF THE STUDY SYSTEM

All four generating units were represented identically by detailed generator and fast static exciter models. All loads were represented as constant impedances. The tie line impedance was varied by changing the number of tie in service. Power transfer between the two areas was created, either by an uneven split of the total system load.

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## VI. SINGLE LINE DIAGRAM IN DIGSILENT

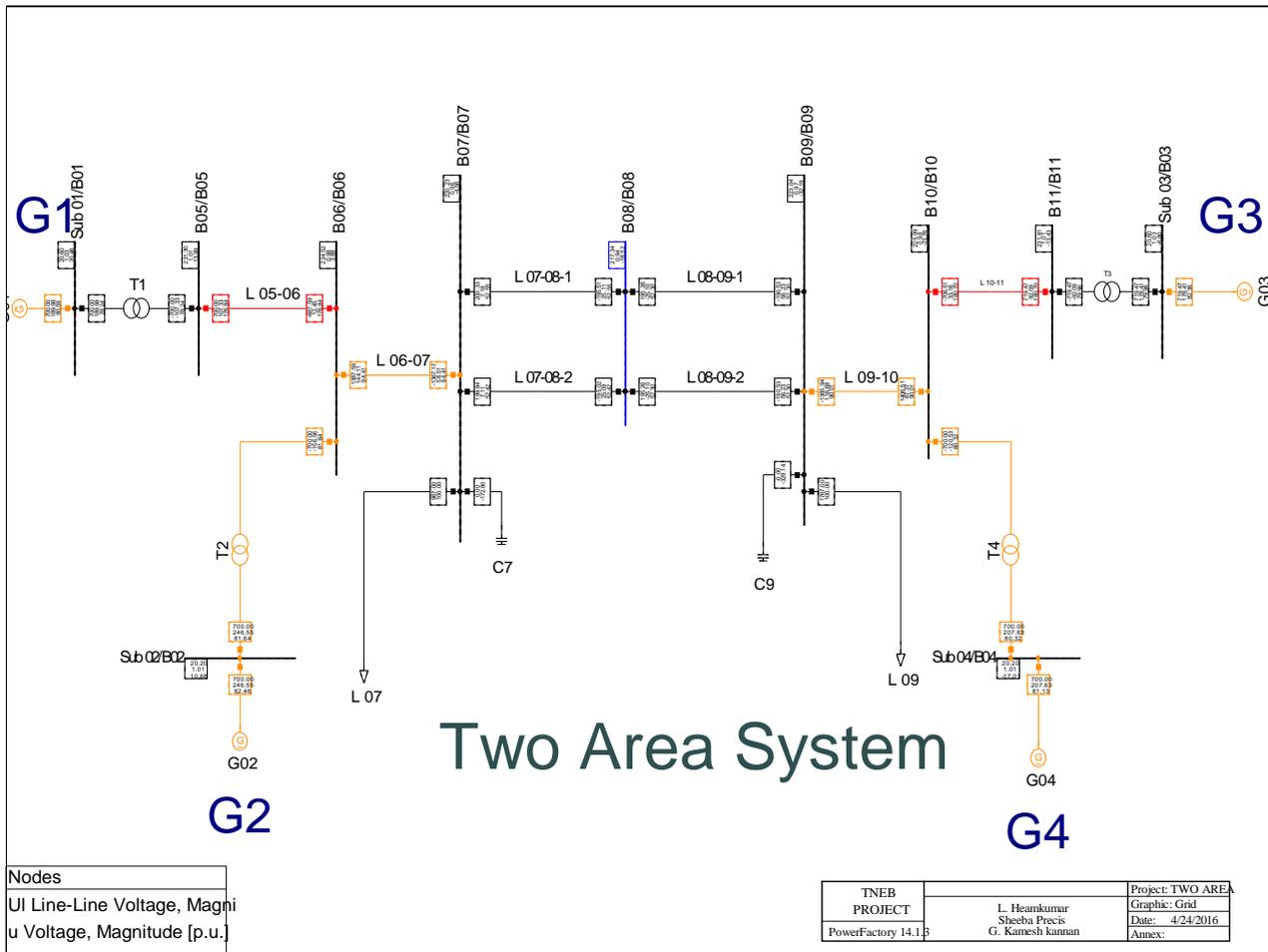


Fig 3: Load Flow Study

## VII. EFFECT OF TIE LINE IMPEDANCE AND POWER FLOW IN DIGSILENT

An example with the system operating with area, Transformer and the generator units and load details are shown in the below table.

Transformer	1	2	3	4
Rated MVA	100	100	100	100
Pri kV	22	22	22	22
Sec kV	230	230	230	230

Table 1: Transformer Data

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Generator	1	2	3	4
Rated MVA	600	600	600	600
kV	22	22	22	22
Power Factor	0.98	0.95	0.95	0.98
Type	Steam	Steam	Steam	Steam
Speed	3600 rpm	3600 rpm	3600 rpm	3600rpm
Xd	1.5423	1.3455	1.5125	1.3565
X'd	0.4876	0.1198	0.1813	0.3456
Xq	1.0969	1.8645	1.2578	1.4567
X'q	0.4969	0.5469	0.5321	0.4544
Xl	0.1336	0.3521	0.3742	0.2398
T'd0	8.96	6.00	5.89	
T'q0	0.476	0.535	0.60	0.347
Stored Energy	4364 MW-s	6403 MW-s	5756 MW-s	6765MW-s

Table 2: Generator Data

## VIII. SYSTEM GENERATORS WITH CONSTANT EXCITATION CONTROL

There are three rotor angle modes of oscillation. These mode shapes (normalized eigenvector components corresponding to rotor speeds of the four machines). From the mode shapes, the 0.63 Hz mode is the inter-area mode, with Generator G1 and G2 of the area 1 swinging against generators G3 and G4 of area 2. The 1.07 Hz mode is the inter-machine oscillation local to area 1, with G1 swinging against G2. The third rotor oscillation mode, with a frequency of 1.09 Hz, is the inter-machine oscillation local to area 2, with G3 swinging against G4. Thus in an asymmetric generation between two areas in the test system, power flow in tie line and the phase difference between the generating units is slightly less than 180 degrees. The generating units in the receiving area oscillate with higher amplitude than the ones in the sending area. Results of time domain simulation for the system with above case are illustrated.

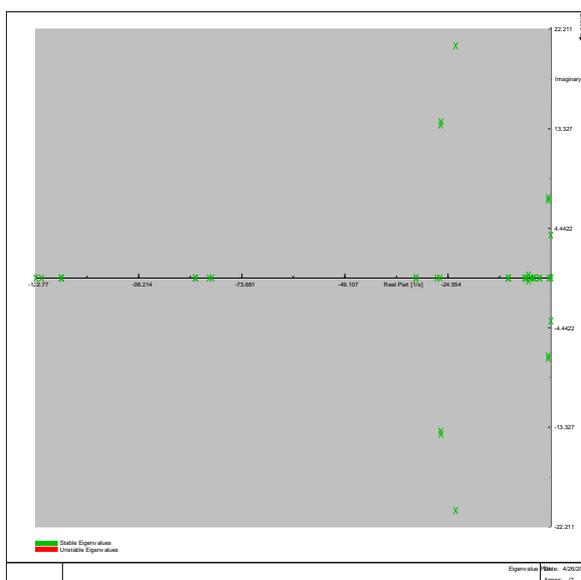


Fig 4: Eigen Value in the plot

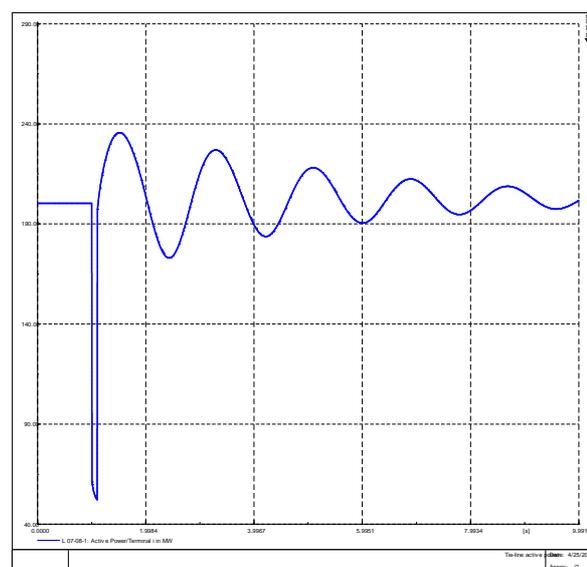


Fig 5: Tie – Line Active Power

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Mode	Real Part 1/s	Imaginary part rad/s	Magnitude 1/s	Angle Deg	Damping Frequency Hz	Period S	Damping 1/S	Damping Ratio	Damping time constant S	Ratio A1/A2
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-36.92	0.00	36.92	180.00	0.00	0.00	36.92	1.00	0.03	0.00
3	-36.86	0.00	36.86	180.00	0.00	0.00	36.86	1.00	0.03	0.00
4	-34.74	0.00	34.74	180.00	0.00	0.00	34.74	1.00	0.03	0.00
5	-33.95	0.00	33.95	180.00	0.00	0.00	33.95	1.00	0.03	0.00
6	-32.54	0.00	32.54	180.00	0.00	0.00	32.54	1.00	0.03	0.00
7	-32.67	0.00	32.67	180.00	0.00	0.00	32.67	1.00	0.03	0.00
8	-25.23	0.00	25.23	180.00	0.00	0.00	25.23	1.00	0.04	0.00
9	-26.42	0.00	26.42	180.00	0.00	0.00	26.42	1.00	0.04	0.00
10	-0.62	6.68	6.70	95.32	1.06	0.94	0.62	0.09	1.61	1.79
11	-0.62	-6.68	6.70	-95.32	1.06	0.94	0.62	0.09	1.61	1.79
12	-0.63	6.90	6.93	95.21	1.10	0.91	0.63	0.09	1.59	1.77
13	-0.63	-6.90	6.93	-95.21	1.10	0.91	0.63	0.09	1.59	1.77
14	-0.14	3.39	3.40	92.38	0.54	1.85	0.14	0.04	7.09	1.30
15	-0.14	-3.39	3.40	-92.38	0.54	1.85	0.14	0.04	7.09	1.30
16	-5.43	0.00	5.43	180.00	0.00	0.00	5.43	1.00	0.18	0.00
17	-5.47	0.00	5.47	180.00	0.00	0.00	5.47	1.00	0.18	0.00
18	-4.03	0.00	4.03	180.00	0.00	0.00	4.03	1.00	0.25	0.00
19	-3.26	0.00	3.26	180.00	0.00	0.00	3.26	1.00	0.31	0.00
20	-0.38	0.00	0.38	180.00	0.00	0.00	0.38	1.00	2.62	0.00
21	-0.02	0.00	0.02	180.00	0.00	0.00	0.02	1.00	56.95	0.00
22	-0.04	0.00	0.04	180.00	0.00	0.00	0.04	1.00	23.90	0.00
23	-0.20	0.00	0.20	180.00	0.00	0.00	0.20	1.00	4.94	0.00
24	-0.20	0.00	0.20	180.00	0.00	0.00	0.20	1.00	5.12	0.00

Table 3: System modes with Constant excitation control

The results correlate well with those of the eigen value/vector analysis. The Eigen values of the system state matrix and the state variable that have high participation in each mode. The system being stable with some oscillating modes with a frequency range.

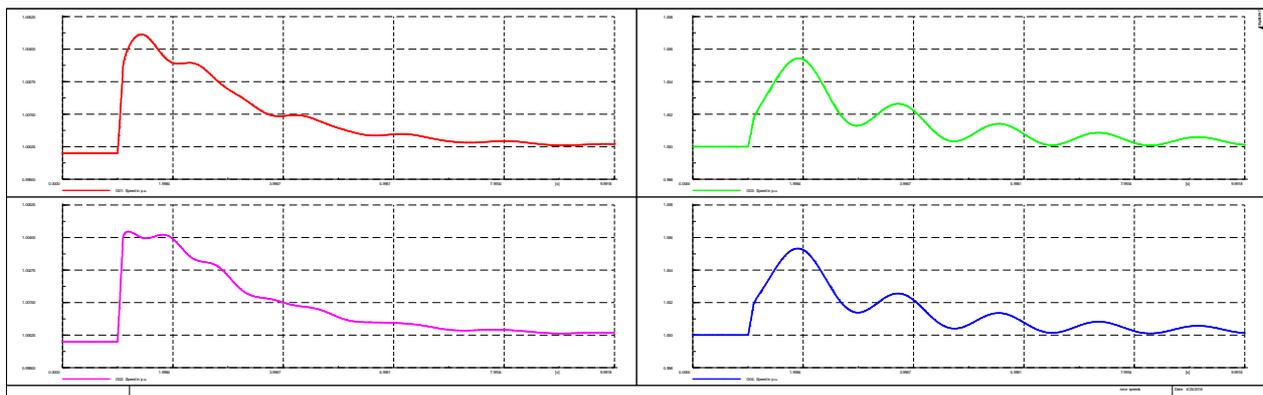


Fig 6: Rotor Speed of all the generators

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## IX. SYSTEM GENERATORS WITH IEEE TYPE AC4A EXCITATION CONTROL

The Type AC4A alternator-supplied controlled-rectifier excitation system is quite different from the other type ac systems. This high initial response excitation system utilizes a full thyristor bridge in the exciter output circuit. The Automatic voltage regulator AVR controls the firing of the thyristor bridges. The exciter alternator uses an independent voltage regulator to control its output voltage to a constant value. The transient loading effects on the exciter alternator are included. The excitation system stabilization is frequently accomplished in thyristor systems by a series lag-lead network rather than through rate feedback.

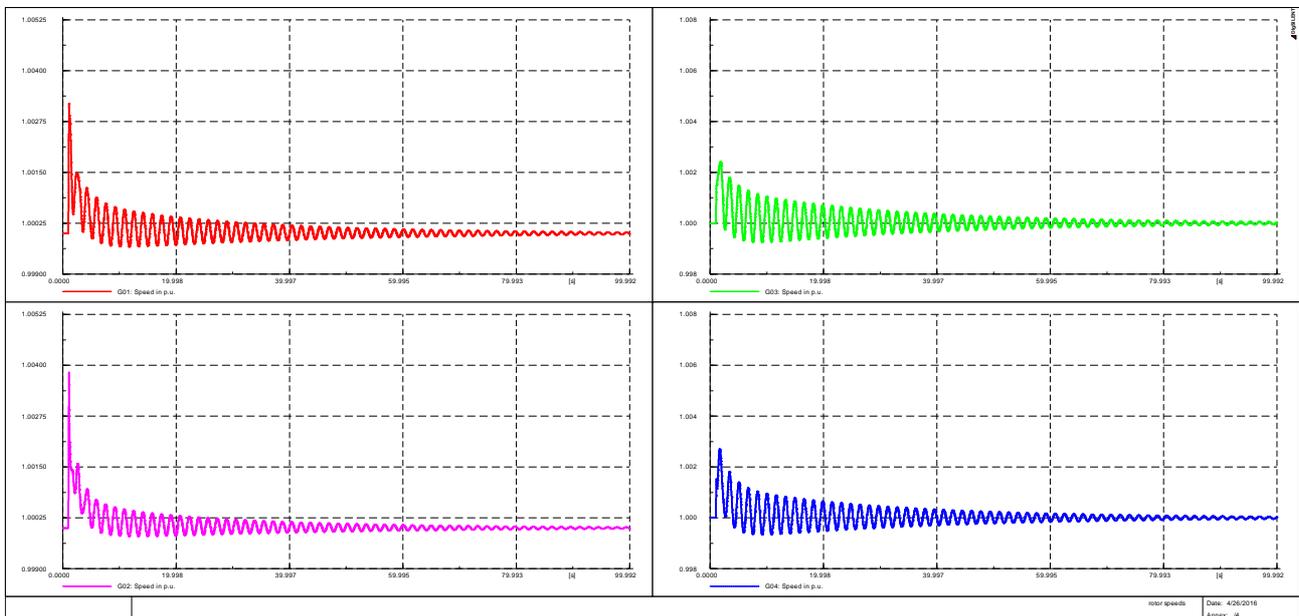


Fig 7: Rotor speed of the generator with AC4A excitation system

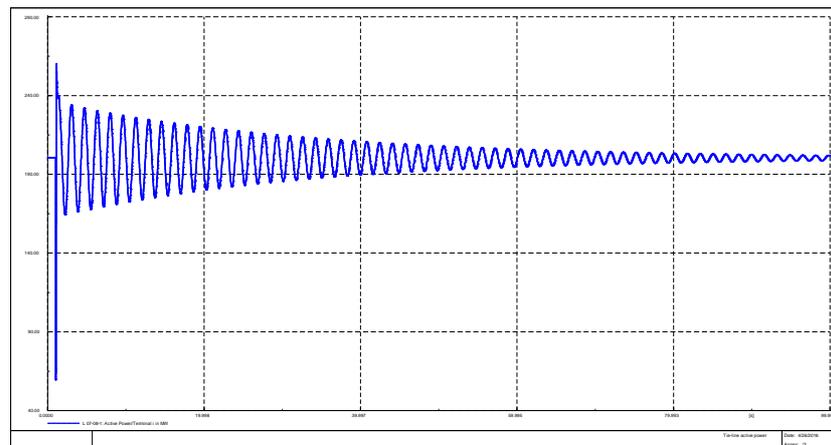


Fig 8: Tie Line Active Power with AC4A Excitation system

The time constant allow simulation of this control function. The overall equivalent gain and the time constant associated with the regulator and/or firings of the thyristor is simulated.

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## X. POWER SYSTEM STABILIZER (PSS)

The Generic Power System Stabilizer (PSS) can be used to damp the rotor oscillations of the synchronous machine by controlling its excitation. The oscillations, also called power swings, must be damped to maintain the system stability. The output signal of the PSS is used as an additional input to the Excitation System block. The PSS input signal can be either the machine speed deviation, acceleration power.

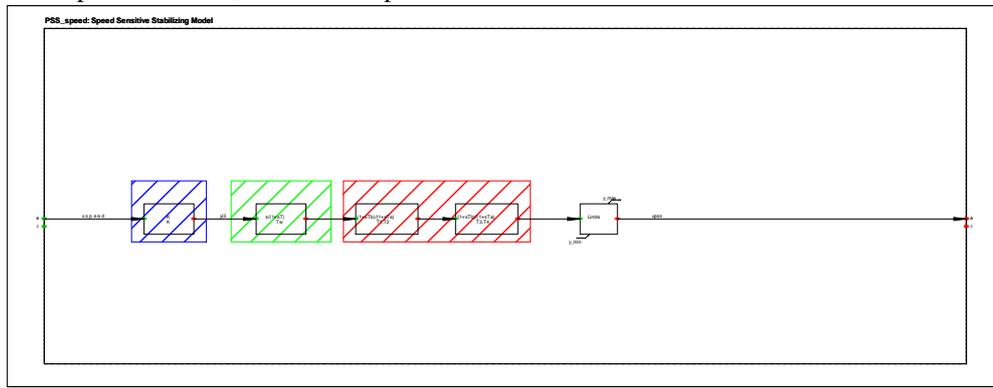


Fig 9: Generic Power Systems Stabilizer

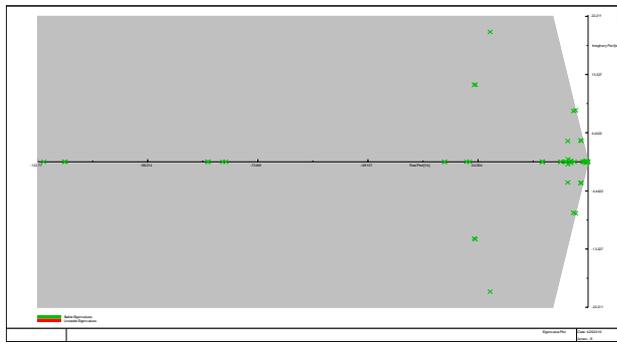


Fig 10: Eigen Value in the plot with PSS

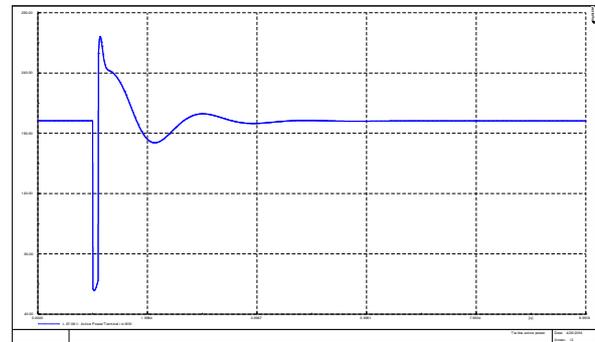


Fig 11: Tie Line Active Power with PSS

The model consists of a low-pass filter, gain, washout high-pass filter and an output limiter. The general gain can be determined with the amount of damping produced by the stabilizer. After optimal placing of the PSS, the generator characteristics was illustrated.

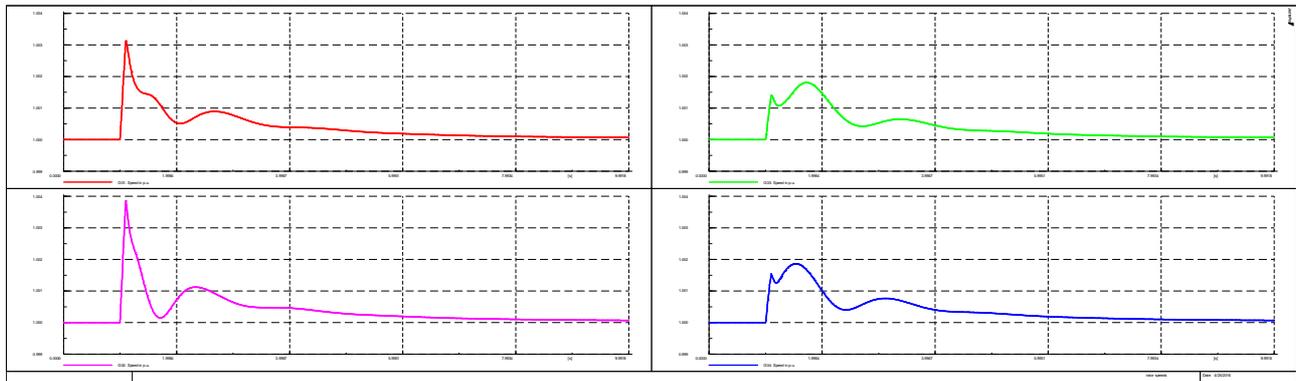


Fig 12: Rotor Speed of the generator with PSS.

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## XI. CONCLUSION

In this project, the case study was taken for fundamental studies to understand the behavior of power system oscillations. To damp these oscillations, power system stabilizer PSS was adopted. The problem of optimal tuning of PSS parameter using remote signals was determined, during an original method of using MATLAB and DiGSILENT Power Factory simulation packages in an automatic data exchange procedure. This automatic data exchange protocol solves Particle swarm optimization for PSS tuning. With results obtained from time domain simulations and modal analysis, enhancement of power system stability was ensured.

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