Robust Primary Control of AC Micro-Grid and Analysed Effect of Noise

Bhuvnesh Rathor[1], Mahendra Bhadu[2], S.K.Bishnoi[3]

***Abstract*-This paper investigates the effect of random measurement noise in grid connected microgrid. The primary control of grid-connected microgrid with four distribution generations (DG) units, is performed with and without measurement noise. The different power system stabilizers (PSSs) structures are utilized in primary control action for synchronous machine rotor speed and rotor angle control. The comparison of time-domain response having without any PSS, with conventional PSS (Delta Omega PSS and Delta Pa PSS), MB-PSS and robust Fuzzy Logic based PSS, is done. Using a typical test microgrid model, the performance of robust controller as a power system stability agent is accessed via time domain simulation of the test microgrid model on MATLAB/Simulink platform.**

***Index Terms*-Microgrid, Fuzzy logic Control, power System Stabilizer, Multi Band Power System Stabilizer, Noise.**

I. INTRODUCTION

The modern power system is very complex, widely distributed inter-connected non-linear system. The interconnection of ac micro-grids, with the main or principle control grid is quite difficult task because of technical as well as economical reasons. Because of versatility, aggressive speculation costs and adaptable operation, non-renewable energy source era advancements have been the most widely recognized decision for supply of power in these remote grids. With the exhibited specialized and sparing practicality of greener era advancements in light of wind, sun oriented, hydrogen and hydro control, coordinating these advances has turned into a need in microgrids [1].

A microgrid can be depicted as a cluster of loads, Distributed Generation (DG) units and energy management system (ESSs) worked in coordination to reliably supply power, associated with the host power system at the distribution level at a solitary single point of connection, it's called Point of Common Coupling (PCC). In a microgrid system, the power will be accessible from nearby sustainable power sources and primary power organizes. Proper control plans are required to permit smooth trade of energy. This enables the microgrid to carry on as a load or a generator [2].

The microgrid system can be associated with the grid by alternating current (AC) and direct current (DC) connections. Some of sustainable power sources generate DC output, for example, photovoltaic cells and some operate at AC mode yet with variable frequency, for example, wind farms. The control scheme is personally worried about the energy and power balance in a microgrid. The three fundamental parameters that ought to be controlled to match acceptable standards are frequency, voltage and power quality [2].

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At present, exertion is being put into the design of special protection schemes and control systems that ensure reliable, secure and economical operation of microgrid in either grid-connected or stand-alone mode[3]-[5].

The most pertinent challenges in microgrid protection and control incorporate are bidirectional power flow, stability issues, modelling, low inertia, uncertainty[1].Fully centralized and completely decentralized control schemes can be accomplished by means of a various levelled control conspire comprising of three control levels: primary, secondary, and tertiary [1], [6]-[8].

It is inferred that the transient stability assessment relies on upon the entrance level of DG and the kind of technology embraced in DG. Higher entrance of DG can enhance the transient stability as well as minimizes the power transferred through transmission lines [9]. However, it has been also found that higher infiltration of wind turbines farms can seriously influence the transient stability of the system under grid faults. The higher DG infiltration levels, the system transient stability during faults is debased and synchronism might be lost. The expanding enthusiasm for coordinating irregular sustainable power sources into micro-grids presents major challenges from the perspectives of reliable operation and control. By and large, the oscillation duration and maximum rotor angle deviation are diminished with infiltration level if proper control of micro-grid takes place [10]-[12].

From the focuses tended to over, one ought to reason that proper control schemes should to be embraced keeping in mind the end goal to keep up grid stability under disturbances. As of late, power system stabilizer (PSS) is received in [13], to improve transient stability of the standalone microgrid system. The primary level controlling is related with the operation of the micro-grid itself.

This paper investigates the effect of random measurement noise and its mitigation of grid connected microgrid having four distribution generations (DG) units. The various types of PSS with optimally tuned parameters, are used in the primary control mode of Microgrid to mitigate the effect of noise as well as stability enhancement of complete system. The time-domain response with cases, i.e. without PSS and having different PSSs, are compared. Using a typical test microgrid model, the performance of robust controllers as a noise mitigating agent is assessed on MATLAB/Simulink platform. After comparing the time domain responses, a final conclusion is made for random measurement noise and without any noise scenarios of microgrid.

The rest of the paper is structured as follows. In section II, the brief theory regarding modeling of micro-grid has been discussed. Section III presents the controlling of micro-grid, in which the design and tuning procedure of various controllers have been discussed. Section IV discuss about the measurement noise present in the system. The analysis of simulation results and discussions can be found in Section V.

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Finally the paper concludes in Section VI, followed by references.

II. Modelling Of Microgrid

A. System Structure

Figure 1 demonstrates a single line diagram of the AC microgrid test power system, which is associated with a 20kV, 50Hz and the short-circuit capacity at the PCC is expected as 1000 MVA. The distribution transformer of 1200 MVA capacity is connected to main grid system by a static switch. Bus B-G is appointed as the swing Bus. The system likewise incorporates four Distributed Energy Resources (DERs) and the total installed capacity is 24.5MW. The areas and capacities of the DERs interconnected to the system are as per the following:

• A 6 MVA micro hydro-generator connected to Bus B-D.
• A 6 MVA Diesel engine generator connected to Bus B-D.
• A 4.5 MW micro wind-turbine generator connected to Bus B-W.
• A 8MW PV Farm connected with to B-PV.

This system was modelled by corresponding mathematical equations on Matlab/Simulink environment.

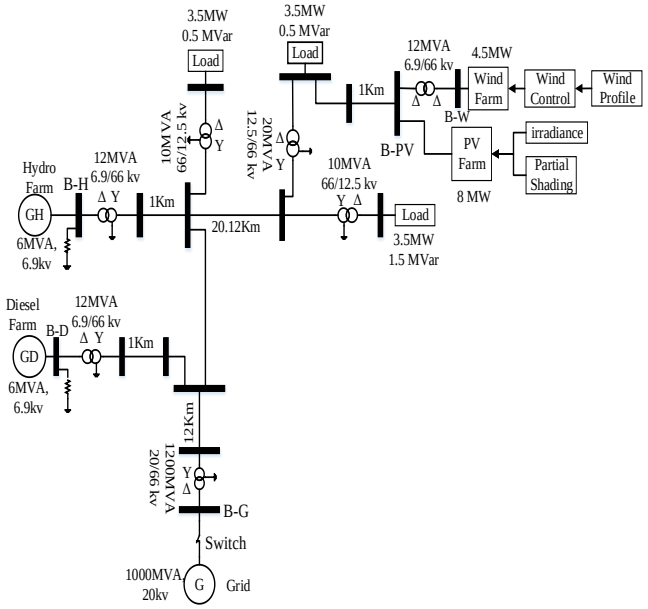


Fig. 1. Single Line Diagram of Microgrid System

B. Parameter Setting

The various sources, transmission lines, distribution transformer, feeders, and loads were modelled with the help of SimPowerSystems tool box available in Matlab/Simulink. Meanwhile, the models of DERs in this paper were determined through related mathematical equations and were built up as individual blocks. These models are described as follows.

The Generalised Synchronous generator with PSS connected model is appeared in Figure 2. The hydro and diesel engine generator governing system model are taken as mentioned in [14], [15]. The PV Farm and Wind Farm models are outlined in Figure 3[14]. At long last, the related parameters were set tuned in Matlab/Simulink to analyze further.

PV Farm produces energy corresponding to three components: the size of the area (A) covered by the PV farm, the efficiency (η) of the solar panels and the irradiance data (Id) appear in figure 4.

For PV generation-

$$V_1 = \frac{1}{3}(V_{ab} - e^{-j\times\frac{2\pi}{3}}.V_{bc}) \quad (1)$$

$$S_{pv} = Id \times A \times \frac{\eta}{100} \quad (2)$$

$$I_a = \frac{2}{3} \times \frac{S_{pv}}{V_1} \quad (3)$$

$$I_b = e^{-j\times\frac{2\pi}{3}} \times I_a \quad (4)$$

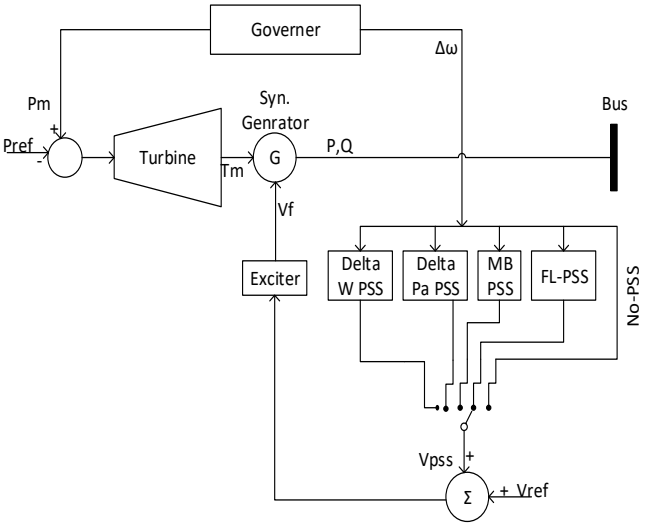


Fig. 2. Generalised Synchronous generator model With PSS

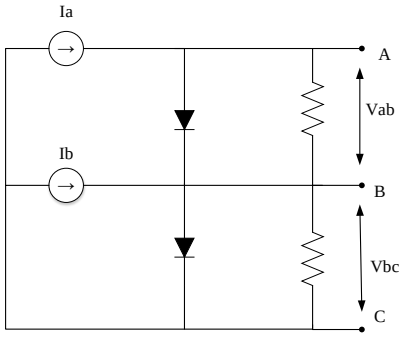


Fig. 3. Generalised model of PV and Wind Farm Power Source

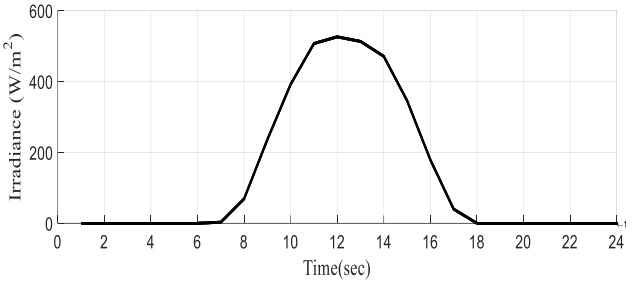


Fig. 4. Solar Irradiance Profile

At the nominal value of wind speed (Wn), the wind farm produces the nominal power (Pn). The wind farm trips from the network when the wind speed surpasses the maximum

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wind value, until the twist returns to its nominal value. Wind profile data, used in this paper, appear in figure 5.

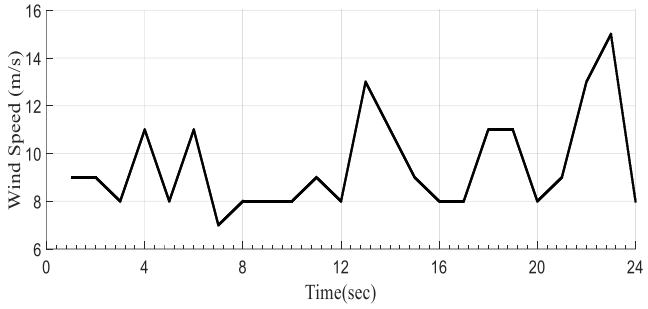


Fig. 5. Wind Profile

For Wind generation-

$$V_1 = \frac{1}{3}(V_{ab} - e^{-jx\frac{2\pi}{3}}.V_{bc}) \quad (5)$$

$$S_w = \frac{Pn}{(Wn)^3} \times 10^6 \quad (6)$$

$$I_a = \frac{2}{3} \times \frac{S_w}{V_1} \quad (7)$$

$$I_b = e^{-jx\frac{2\pi}{3}} \times I_a \quad (8)$$

III. CONTROLLING OF MICROGRID

The controlling of microgrid is done with the following stabilizers.

A. *Conventional PSS (CP-PSS)*

The nonexclusive structure of conventional PSSs is as appeared in figure 6. Tuning of parameters of PSS includes the four time constants of the two lead-lag compensator block, addition the gain and the washout block [19].

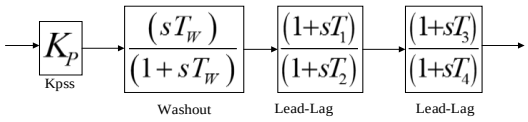


Fig. 6. Conventional PSS (CPSS)

B. *Multi-Band PSS (MB-PSS4B)*

The MB-PSS is spoken to by the IEEE St. 421.5 PSS 4B sort model. It represents to a structure in view of various working frequency bands. Three separate bands, individually devoted to the low, intermediate and high frequency modes of oscillations, are utilized as a part of this delta-omega (speed input) PSS. The low band is ordinarily connected with the power system global mode, the intermediate with inter-area modes, and the high with the local modes. Each of the three groups, is made out of a differential channel, a gain, and a limiter [16].

C. *Fuzzy logic control Power System Stabilizer (FL-PSS)*

Fuzzy logic can be named as the superset of Boolean logic that has been stretched out to deal with concept of partial truth values between "totally false" and "totally true". For controlling non- linear systems, fuzzy logic is perfect since it can deal with data in a precise way. The controller has acknowledged base, a fuzzification and defuzzification interface and a decision-making logic. Figure7 represents the essential block of the fuzzy logic controller (FLC). Data about all the input and output allotments are contained in the learning base module. The algorithm to change over the linguistic control conspire into a programmed control plan is given by the FLC [17].

In the traditional control strategy, the measure of control is resolved in connection to various information inputs utilizing asset of equations to express the whole control handle. Expressing human involvement as a scientific equation is a troublesome errand. Fuzzy logic gives a simple tool to decipher this experience into reality.

Fuzzy logic controllers (FLC) are run based controllers. The structure of the FLC looks like that of acknowledge based controller aside from that the FLC uses the standards of the fuzzy set theory in its data representation and its logic. The fundamental setup of the FLC can be just represented in four sections. [17]

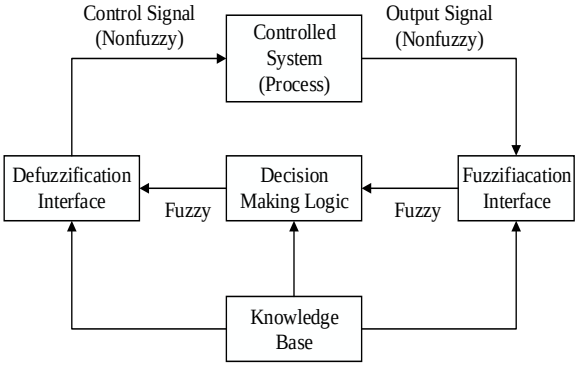


Fig. 7. Fuzzy Logic Controller

• Fuzzification module – the functions of which are in the first place, to peruse, measure, and scale the control variable (speed, acceleration power) and second, to change the deliberate numerical values to the corresponding linguistic (fuzzy variables with fitting membership values).

• Knowledge base - this incorporates the meanings of the membership functions characterized for each control variables and the essential rules that indicate the control objectives utilizing linguistic variables.

• Inference mechanism – it ought to be fit for simulating human decision making and affecting the control actions based on fuzzy logic.

• Defuzzification module – which changes over the gathered choice from the linguistic variables back the numerical values.

TABLE I. MEMBERSHIP FUNCTIONS FOR FUZZY VARIABLES

NB	Negative Big
NM	Negative Medium
NS	Negative Small
ZE	Zero
PS	Positive Small
PM	Positive Medium
PB	Positive Big

The fuzzy power system stabilizer utilized in this work has two inputs and a single-output [18], [19]. The two inputs are change in rotor speed and rate of change of rotor speed though output of fuzzy logic controller is a voltage signal. The stabilizing signals are figured utilizing the standard fuzzy membership functions relying on these variables [17], [20].

Centre of region strategy is utilized for defuzzification. Each of the input and output fuzzy variables is allocated

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seven linguistic fuzzy subsets changing from negative big (NB) to positive big (PB). Membership functions for the inputs and output are appeared in figure 8 to figure 10. The membership functions of the input and output variables have half cover between nearby fuzzy subsets.

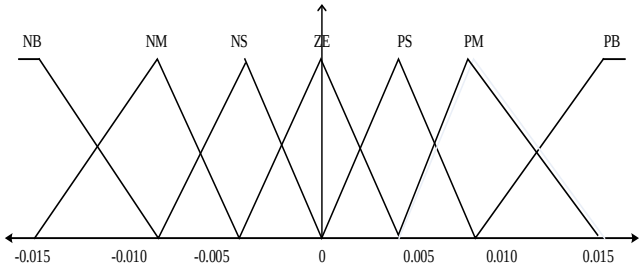


Fig. 8. Membership function plot of speed deviation (dw)

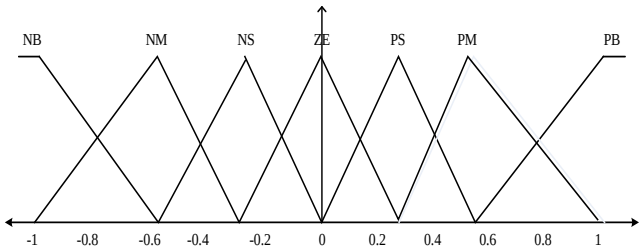


Fig. 9. Membership function plot of acceleration Power (Pa)

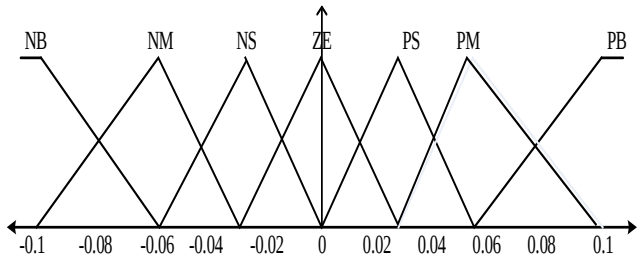


Fig. 10. Membership function plot of Output Voltage (Vstab)

With two input variables each consisting of seven membership function labels, a (7x7) decision table is constructed as appeared in Table II.

TABLE II. DECISION TABLE OF 49 RULES

Speed Deviation(dw)	Acceleration Power (Pa)						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	ZE	ZE	PM	PB	PB
PS	NM	NS	PS	PM	PM	PB	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	ZE	PM	PB	PB	PB	PB

Decision surface plot of membership function of FL-PSS of table II, is shown in figure 11.

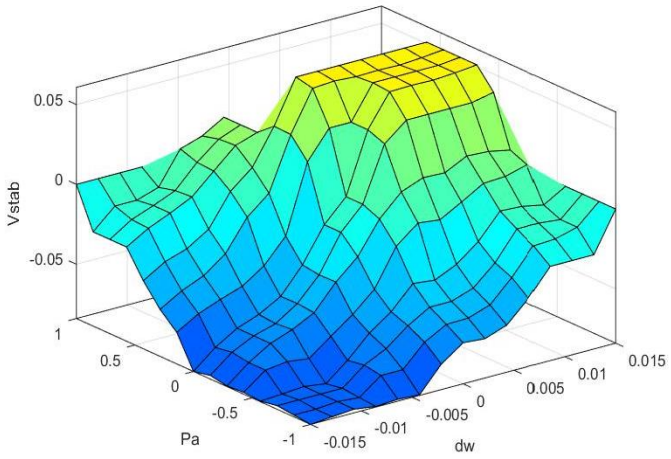


Fig. 11. Decision surface of FL-PSS

IV. NOISE IN SYSTEMS

Noise is random in nature and undesirable type of energy that enters the power systems and interferes with the electrical signal. Noise can be delegated inward internal and external noise. White noise or a Gaussian noise which exists in all frequencies. The common source of noise which influences systems is normally white noise. The likelihood thickness capacity of white noise ordinary distribution known as Gaussian dispersion. Its energy phantom thickness is level and involves all frequency in systems; a random signal is viewed as 'white noise' and it is seen to have a level range over the scope of frequencies [21]. In any case, the data transmissions are affected by this noise. In matlab/simulink, the noise is produced by the random signal [21], [22].

V. RESULTS AND DISCUSSIONS

To analysis the damping execution of proposed fuzzy controller, a three phase fault having a span of (12/60) *sec* is being connected in the grid connect of 12 *km* transmission line at t=4*sec*.The performance of the FL-PSS is evaluated by applying a three-phase line to ground fault, on the transmission line in grid connected microgrid power system model.

The rotor speed deviation for diesel farm generator and hydro farm generator are depicted in figures 12 and figure 13, with various types of controllers used as stabilizers. It can be found. The simulation results shows, the fuzzy logic based controller and MB-PSS gives the better dynamic response over the regular power system stabilizer (Delta W and Delta Pa). The system with fuzzy logic control system based stabilizer (FL-PSS) seems to be the best at given operating point.

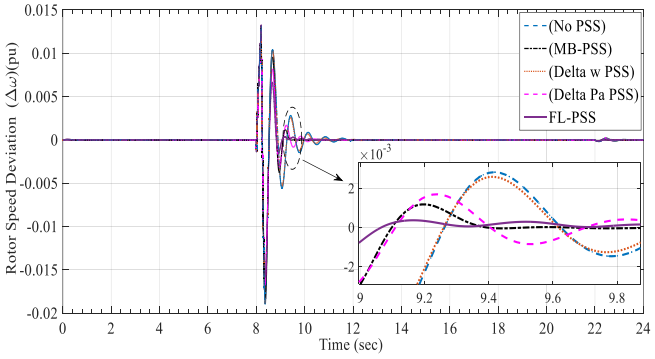


Fig. 12. Rotor Speed Deviation (Δω) of Diesel Generator (pu)

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The rotor speed deviation overshoot values and faulty recover settling time of damping of diesel genrator and hudro genrator rotor are show in Table III and Table IV. The fuzzy logic PSS, reduced the overshoot and clear the fault in minimum time. Improve the stability of the microgrid by the PSSs and reduced the faulty time and overshoot damping values of rotor speed deviation and avtive power of the diesel and hydro synchronous genrator.

TABLE III. DIESEL GENRATOR ROTOR SPEED DEVIATION

Controllers	Without PSS	Delta w PSS	Delta Pa PSS	MB-PSS4B	FL-PSS
Settling Time (*sec*)	4	3.5	2.1	1.4	1.1
Maximum Overshoot (pu)	0.012	0.009	0.008	0.003	0.001

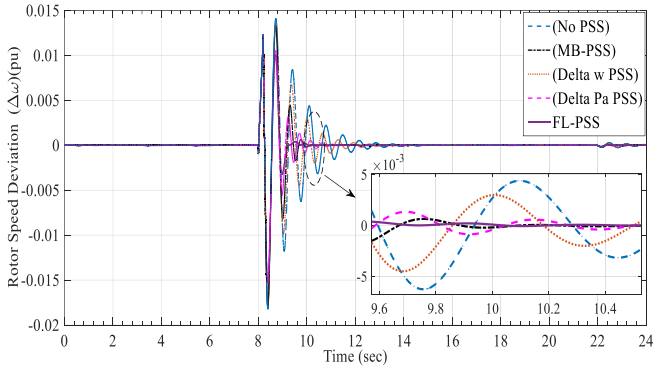


Fig. 13. Rotor Speed Deviation (Δω) of Hydro Generator (pu)

TABLE IV. HYDRO GENRATOR ROTOR SPEED DEVIATION

Controllers	Without PSS	Delta w PSS	Delta Pa PSS	MB-PSS4B	FL-PSS
Settling Time (*sec*)	5.5	3.5	2.8	1.2	1
Maximum Overshoot (pu)	0.014	0.010	0.009	0.004	0.001

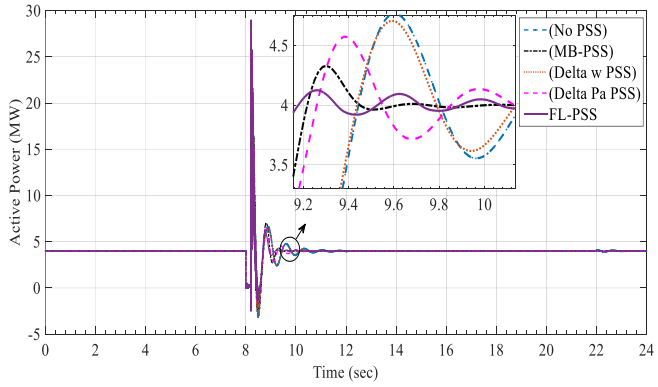


Fig. 14. Active Power by Diesel Farm in MW

Diesel and Hydro farm active power damping and fault recover settling time show in Table V and Table VI. Minimum damping overshoot values mean that the maximum power transfer by the generator of energy farm.

TABLE V. DIESEL FARM ACTIVE POWER IN MW

Controllers	Without PSS	Delta w PSS	Delta Pa PSS	MB-PSS4B	FL-PSS
Settling Time (*sec*)	3	2	1.8	1.5	1.35
Maximum Overshoot (MW)	3.2	2.8	2.5	1.5	0.5

The active power contribution or exchanges with main grid, of the various generating units are shown in figures 14 to 18. It can be seen from these results that the Conventional PSS (Delta PSS and Pa PSS) and MB-PSS exhibit nearly same damping capacities during active power exchange with the main grid.

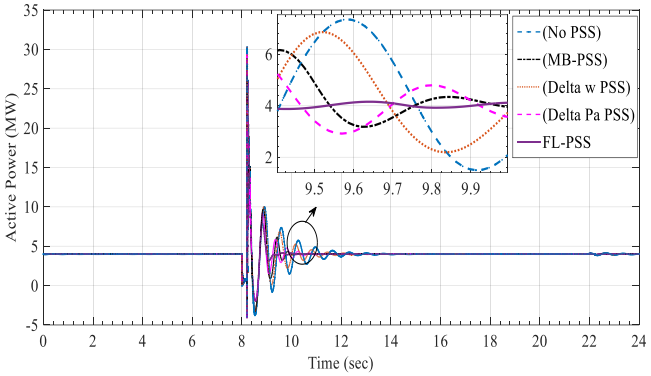


Fig. 15. Active Power by Hydro Farm in MW

TABLE VI. HYDRO FARM ACTIVE POWER IN MW

Controllers	Without PSS	Delta w PSS	Delta Pa PSS	MB-PSS4B	FL-PSS
Settling Time (*sec*)	4.2	3.8	3.6	1.9	1.1
Maximum Overshoot (MW)	6	5.5	2	1.2	0.2

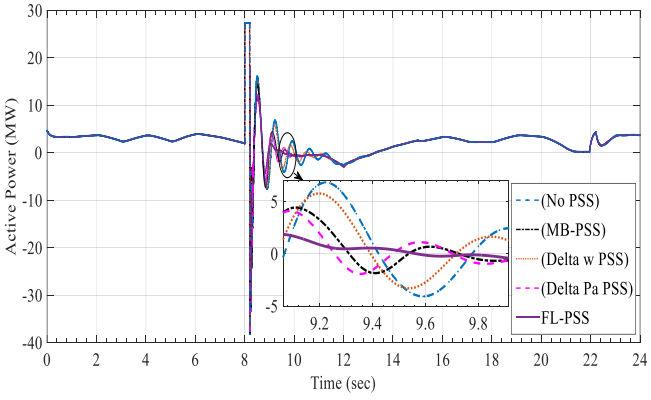


Fig. 16. Grid Active Power in MW

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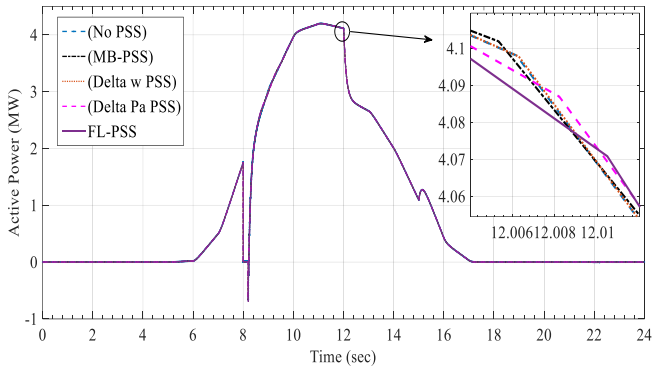


Fig. 17. Active Power by PV Farm in MW

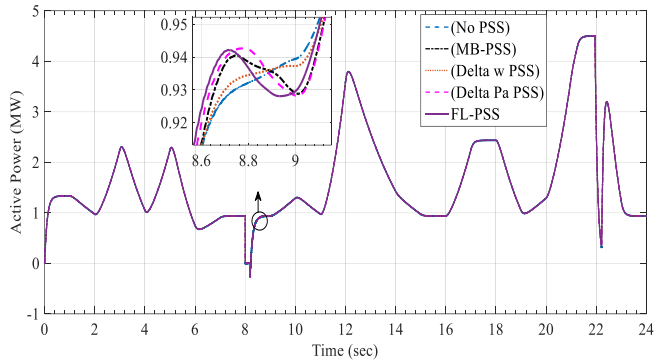


Fig. 18. Wind Farm Active Power contribution in MW

Figure 16 shows the grid active power scenario, in which the negative active power shows that the power is flowing from grid to microgrid and positive active power means active power is flowing from microgrid to grid. In addition to rotor speed deviation, the rotor angle deviation also respond in a same fashion, as shown in figures 19 and figure 20.

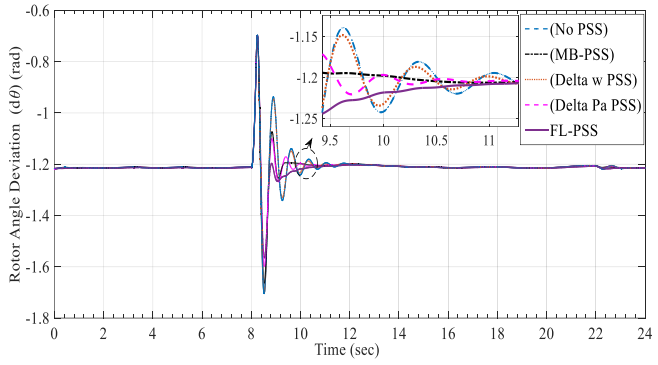


Fig. 19. Rotor Angle Deviation of Diesel Generator

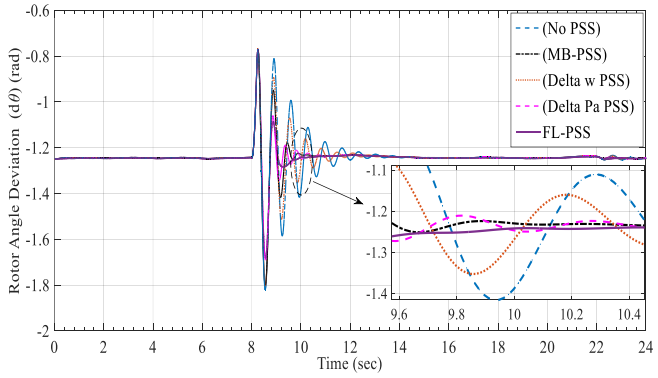


Fig. 20. Rotor Angle Deviation of Hydro Generator

With the consideration of random measurement noise in generator rotor speed deviation signal, the scenario changes and the system performances degraded further. To mitigate the effect of measurement noise, the various PSS are retuned.

The figures 21and 22 show the speed deviation of the diesel farm and hydro farm generator and figures 23 to 27 shows the active power contribution of various DERs under the consideration of random measurement noise.

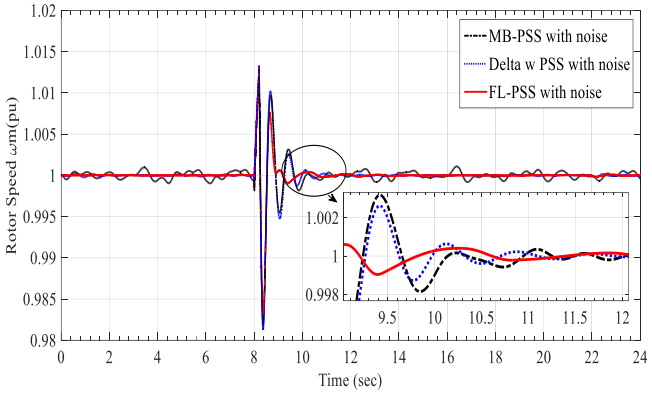


Fig. 21. Diesel Generator Rotor Speed (ω_m) (pu) with noise

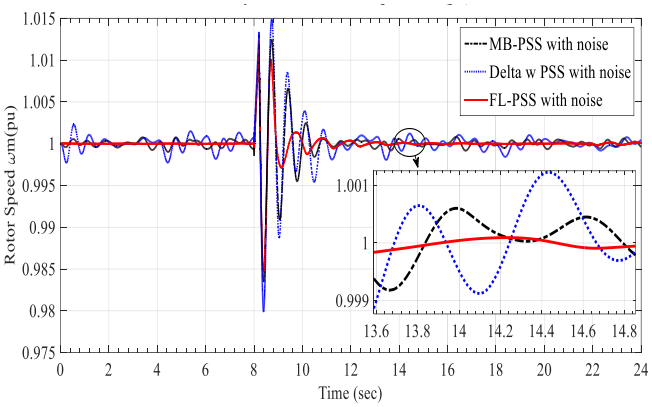


Fig. 22. Hydro Generator Rotor Speed (ω_m) (pu) with noise

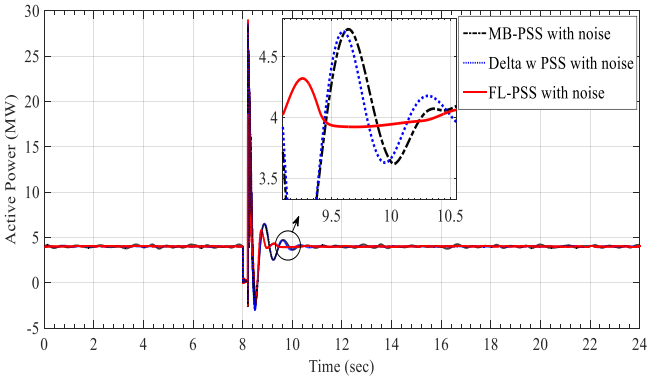


Fig. 23. Diesel Farm - Active Power contribution in MW with noise

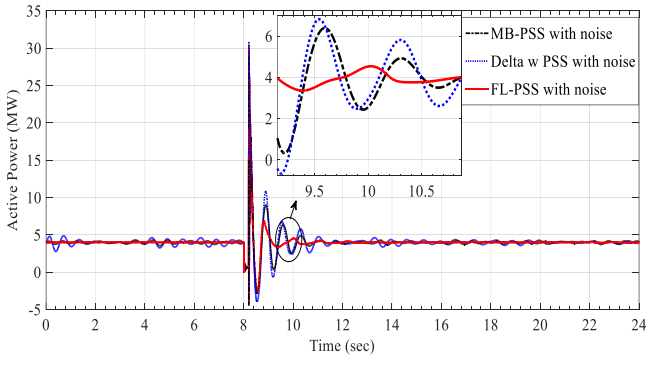


Fig. 24. Hydro Farm - Active Power contribution in MW with noise

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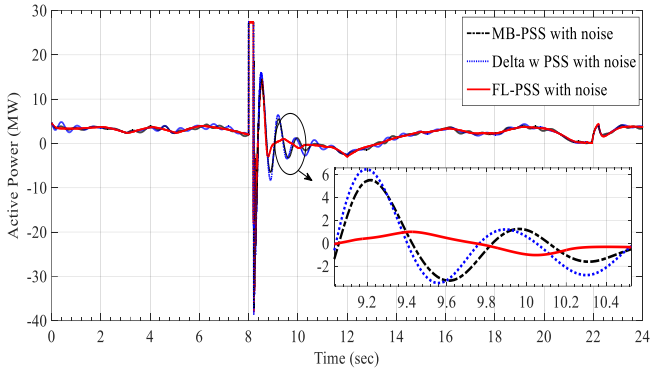


Fig. 25. Grid - Active Power scenario in MW with noise

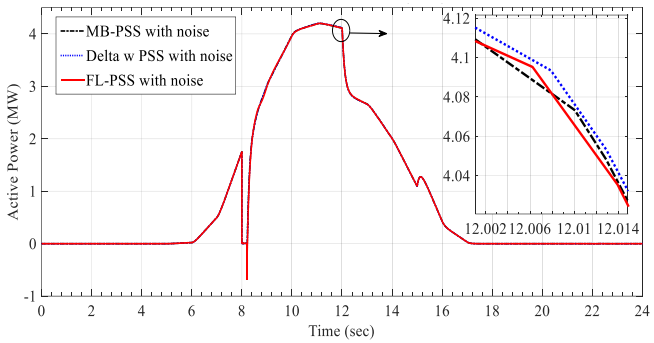


Fig. 26. PV Farm - Active Power contribution in MW with noise

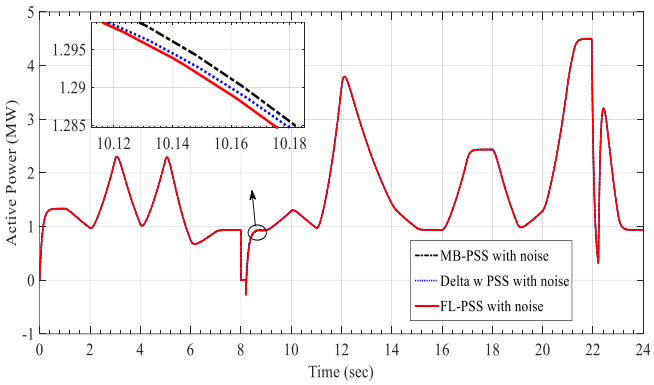


Fig. 27. Wind Farm - Active Power contribution in MW with noise

VI. Conclusion

This paper investigates the power system stability enhancement by primary control of grid connected microgrid with four distribution generations (DG) units. Various power system stabilizer (PSS) structures are utilized in primary control action. The time-domain response with cases, i.e. without PSS, with conventional PSS (Delta PSS and Pa PSS), MB-PSS and Fuzzy Logic based PSS are compared. After comparing the time domain responses, it is found that Fuzzy logic based stabilizer gives the best performance both without noise and with noise scenarios of microgrid. Further, the well-tuned MB-PSS gives better performance than the conventional lead-lag type PSS. The fuzzy logic control based stabilizer is able to mitigate the random measurement noise.

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