International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Load Frequency Control of Single Area Power System with Microgrid using Fuzzy Logic and Virtual Inertia Control

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Abstract: ***Load frequency control (LFC)is one of the center piece in electrical power system and it is important to keep system frequency at scheduled values. Microgrid (MG) have led to vast efforts to expand their penetration in electric power system. It transfers power to multi area power system using power electronics devices. Due to this overall system inertia is reduced and this reduces the frequency/voltage stabilization. This paper proposes a hybrid ac/dc MG with thermal unit as utility grid and effect of virtual inertia is studied with classical Proportional Integral Derivative (PID) and fuzzy control (FC). The effectiveness of the virtual inertia control concept in stability improvement is verified. The coordination control algorithm is proposed for stable power system under various solar power generations and load conditions. The simulation and results are done by using SIMULATION MATLAB package software.***

Keywords: Load frequency control, Virtual inertia, fuzzy logic

1. Introduction

A MG is a coalition of number of Renewable Energy Resources (RES), energy storage, and domestic loads, which can be distinguish as an independent system with the capability to operate in either grid-connected or isolated mode, thus reducing an immense burden on the utility grids [1,2]. LFC is an important parameter in electrical power system design and operation. The objective of the LFC in an interconnected power system is to maintain the frequency of each area within limits and to keep tie-line power flows within some pre-specified tolerances by adjusting the MW outputs of the generators to accommodate fluctuating load demands [3]. However, RESs exchange power to the MG through inverters/converters. The power electronic interface based RESs will reduce the overall system inertia and cause lack of frequency/voltage stabilization to a microgrid compared with traditional synchronous generators [4]. To handle the drawback introduced by inverter-based generators in MG, one of the modern solutions is to rival the action of synchronous generators virtually into the MG, thus improving the system stability and resiliency. In the literature, limited works were conducted to consider the impact of the virtual inertia Distributed Energy Resources (DER) on interconnected decentralized power system LFC design. A thermal power plant model for dynamic simulation of the LFC of electric power systems is presented in [5]. In the model, MW response of the thermal power plant is represented using two components. One is the slow component responding to the MW demand change from the LFC, and the other is the fast component due to the primary frequency (governor) control. This paper presents a fuzzy application to the area of LFC using fuzzy gain scheduling of Proportional Integral (PI) controllers. The study has been designed for a two-area interconnected power system. Using variable values for the proportional and integral gains in the controller unit, the dynamic performance of the system is improved. A comparison among a conventional PI controller, some other fuzzy gain scheduling controllers and the proposed Fuzzy Gain scheduling of PI (FGPI) controller is presented, and it has been shown that the proposed FGPI controller can generate the best dynamic response following a step load change. In this study (PID) control, Fuzzy Control and Virtual Inertia Fuzzy Control (VIFC) perspectives have been applied in Single area grid connected MG power system with variable load frequency control model to eliminate the frequency fluctuations experienced in electric energy.

2. Single area power system with microgrid

Naturally, power systems have complex and multi-variable structures. Also, they consist of many different control blocks. Most of them are nonlinear and/or non-minimum phase systems [6] Power systems are divided into control areas connected by tie lines. There are two different control actions in interconnected two area power systems: primary speed control and supplementary or secondary speed control actions. The initial coarse readjustment of the frequency is made by primary speed control. By its actions, the various generators in the control area track a load variation and share it in proportion to their capacities. The speed of the response is limited only by the natural time lags of the turbine and the system itself. Supplementary speed control makes the fine adjustment of the frequency by resetting the frequency error to zero through an integral action. The relationship between the speed and load can be adjusted by changing a load reference set point input. The layout of power system is shown in figure 1. As shown the system is consists of microgrid composed of single bus bar, solar cell, diesel engine, battery energy sources.

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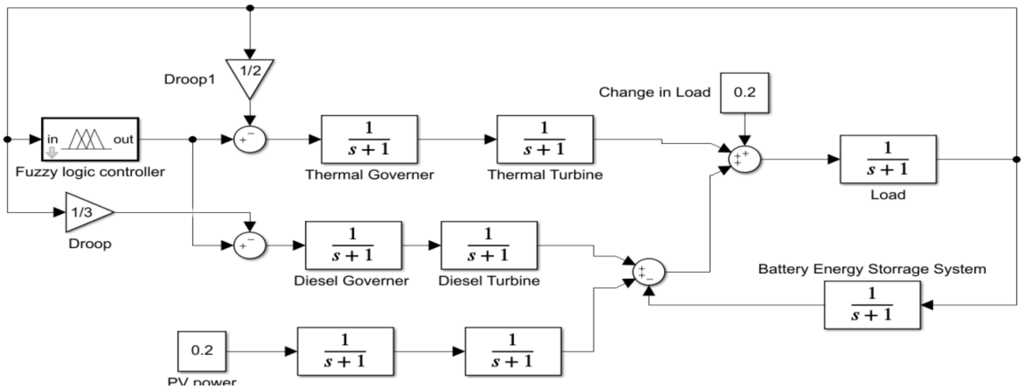

Figure 2.1: Model of Microgrid with Thermal unit

Table 1: Parameter taken in model

Name of parameter	Value
Thermal Governor time constant (t_{tg})	0.104
Thermal Turbine time constant (t_{tt})	0.39
Diesel Governor time constant ($_{tdg}$)	0.08
Diesel Turbine time constant ($_{tdg}$)	0.4
Solar Cell Inverter (T_{inv})	0.04
Solar Cell Filter (T_{filt})	0.004
D (p.u. MW/Hz)	0.015
2H (s)	0.1667

3. Virtual Inertia Control

The virtual inertia control strategy is based on the rate of change of frequency (RoCoF). It calculates the frequency deviation to add extra active power to the set-point. Utilization of power electronic inverters reduces overall system inertia, affecting the microgrid stability and resiliency and increases the uncertainties in the system. The virtual inertia block improves the shortage of inertia response from RES in a microgrid. Here $\triangle f$ is change in frequency, $\triangle P_{inertia}$ is change in virtual inertia power, T_{VI} is virtual inertia time constant.

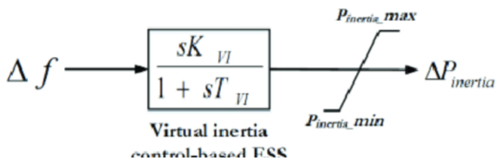

Figure 3.1: Virtual Inertia Control block

4. Fuzzy Logic Control

Fuzzy control is based on a logical system called fuzzy logic is much closer in spirit to human thinking and natural language than classical logical systems [7]. In this article, the basis of the selection of the Mamdani method is There are many features for the use of the fuzzy logic controller [8].The first of these uses fuzzy logic to control complex non-logical systems without performing mathematical analysis for them. Secondly, if there is any change in practice in power systems, we do not need to start from the first step. However, in this preference, some member functions and some rule bases can be added and removed. Combinations can also be made with conventional techniques to simplify fuzzy logic applications. However, controller in this paper consists of two inputs. The first input that represents as variable ACE is the area control error as shown in Figure 4.1, and the second input called variable Change in ACE Figure 4.2. While the output (Freq-Level) indicates the level of change in frequency due to increasing or decreasing in the load in Figure 4.3.

The basic design of the fuzzy controller requires three steps. The input variables are determined by assigning a single fuzzy set, a set with membership function (A), and a zero at another location. If the output variable is a fuzzy set, the maximum min and fuzzy relation with the composition expresses the desired control action. The fuzzy set of the output variable is solved by blurring to obtain a clear numerical value by the centroid method.

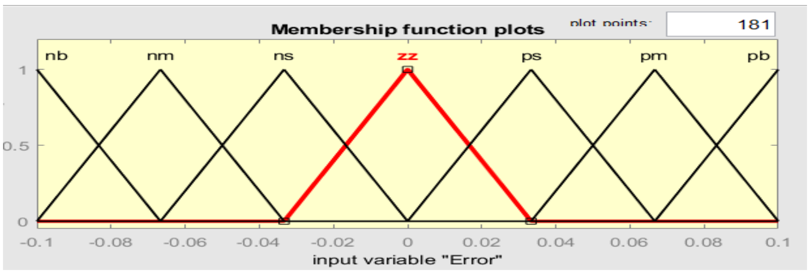

Figure 4.1: Membership function of frequency error

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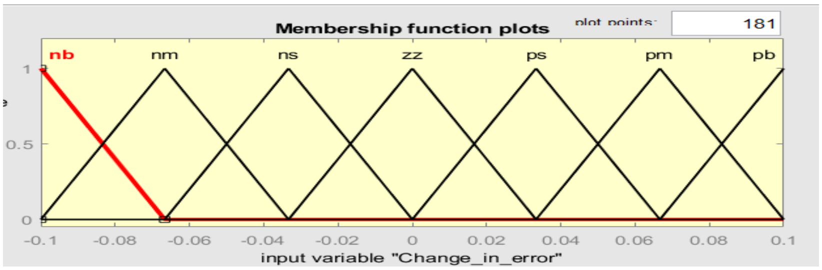

Figure 4.2: Membership function of change in error

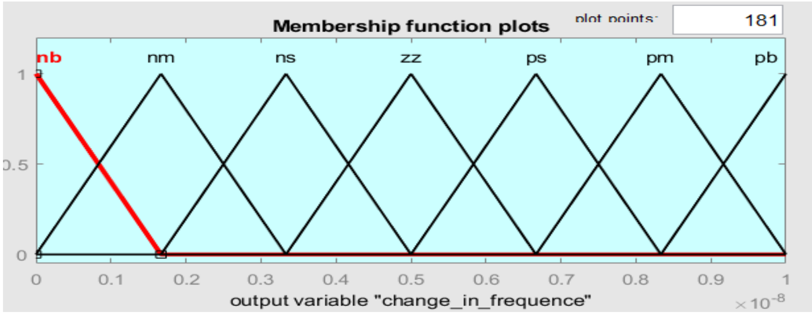

Figure 4.3: Output variable change in frequency

5. Simulation and Results

This section presents the simulation and discussion of various cases of load frequency control. The cases include the load and generation variation and parametric variation in the system. All the cases have been compared to the system response.

Case -1: Base case system response with all DERs, Solar cell perturbation 0.2pu, Load disturbance 0.2pu.

The load frequency control of a micro grid with all sources such as PV, Wind, fuel cell, diesel and battery storage is simulated in this case. This case presents the frequency deviation response of the system with a step load change of 0.02p.u and solar power change i.e. ΔPs taken as 0.2p.u. The comparison of system response is shown in Fig.5.1 The proposed controller gives better and faster response when compared to PID controller. The response of control inputs i.e. change in thermalis shown in Fig.5.2. The response of change in thermal, system, and microgrid power is shown in Fig.5.3.The simulation period and sampling time is taken as 10s and 0.01s respectively.

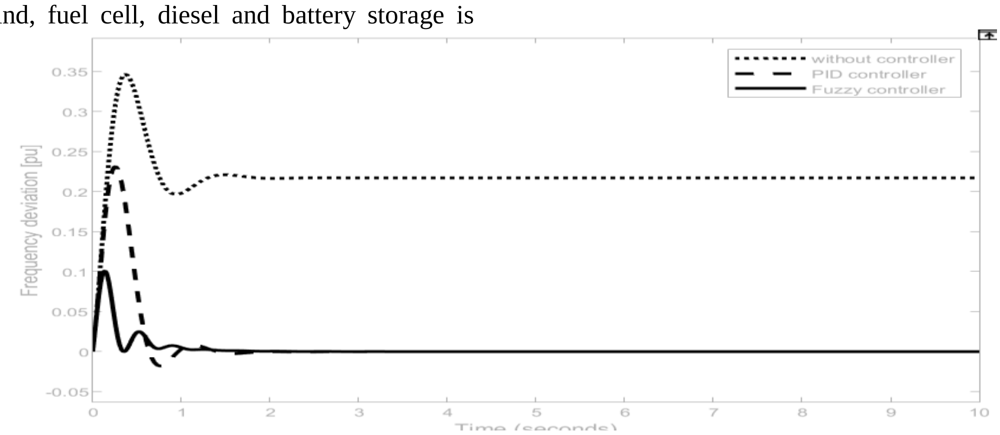

Figure 5.1: Comparison of system response

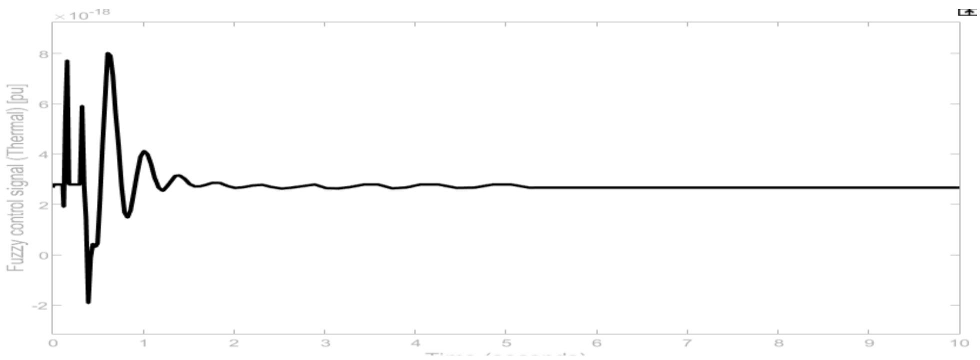

Figure 5.2: Response of control inputs in thermal unit.

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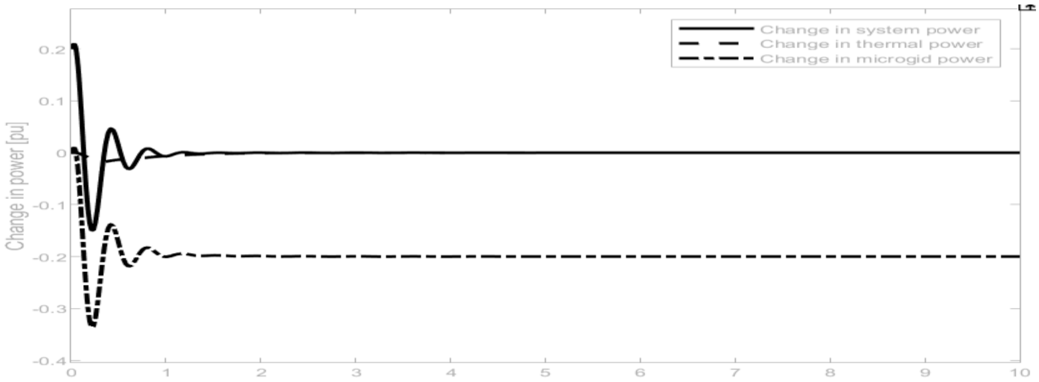

Figure 5.3: Response of change in thermal, overall system, and microgrid power

Case -2: System response with dispatchable DERs

This case studies the frequency regulation in the system when there are only dispatchable units such as diesel unit and battery in single area power system. The load change is 0.02p.u. The comparison of system response is shown in Fig. 5.4. Since there are only two dispatchable generation units in this case. The corresponding response of cost function and the change in control inputs are respectively shown in Fig.5.5 and Fig. 5.6. The simulation period and sampling time is taken as 10s and 0.01s respectively.

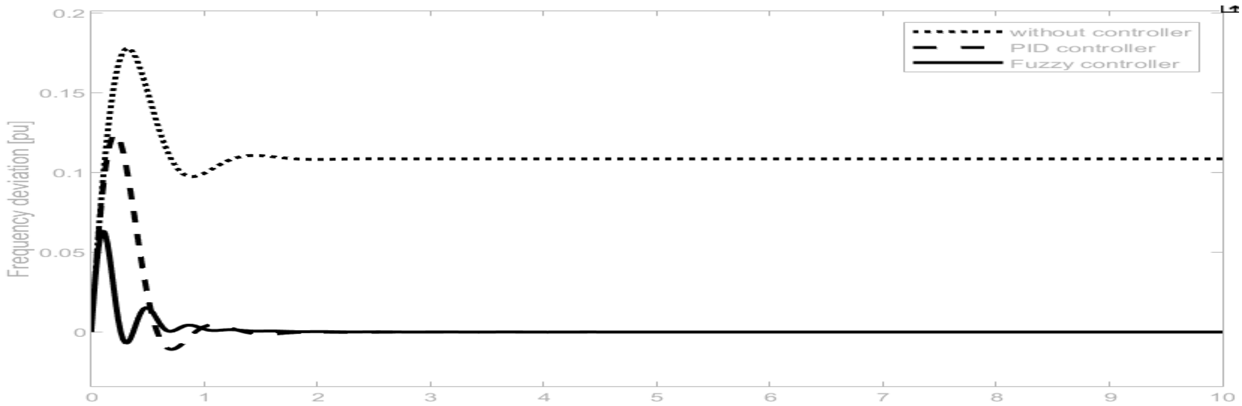

Figure 5.4: Comparison of system response

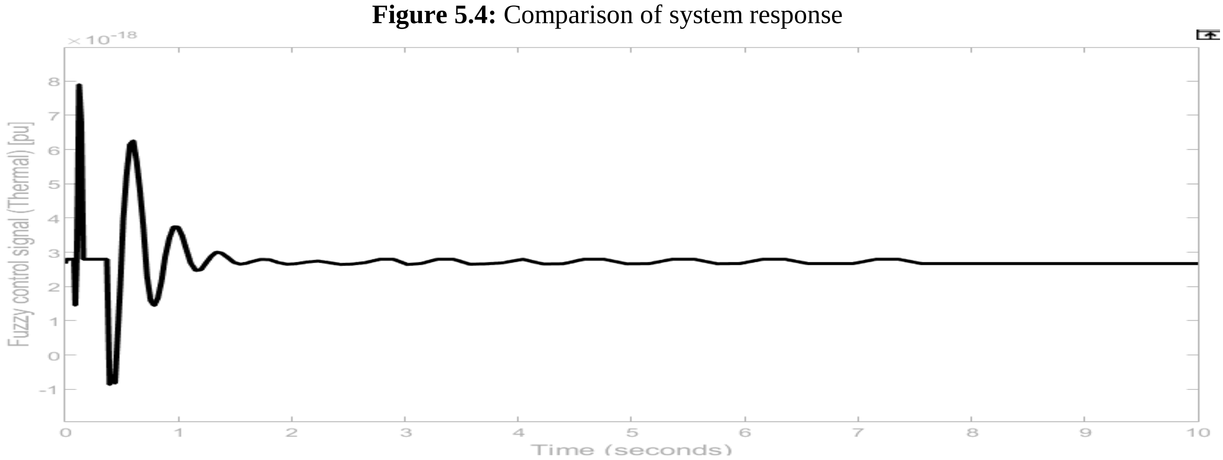

Figure 5.5: Response of control inputs in thermal unit

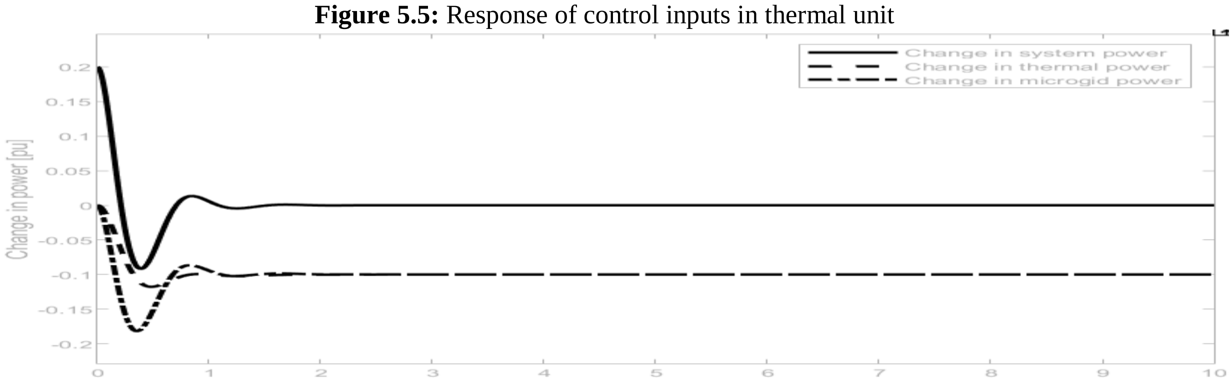

Figure 5.6: Response of change in thermal, overall system, and microgrid power

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Case 3: System response with series of step variation in load and solar power

This case evaluates the system response of the micro grid with series step changes in the load and solar power. The load and solar power changes are implemented with increase and decrease in value of ΔPL and ΔPS. The system response for this case is shown in Fig.5.7, Fig.5.8 shows the response of cost function and control inputs respectively for the series of step load variation in the system. The control inputs are accordingly varied by fuzzy and PID controller to meet the load changes for minimum frequency deviation in the system. The response with virtual inertia is shown in fig. 5.9. which shows that injection of virtual inertia control improves the response.

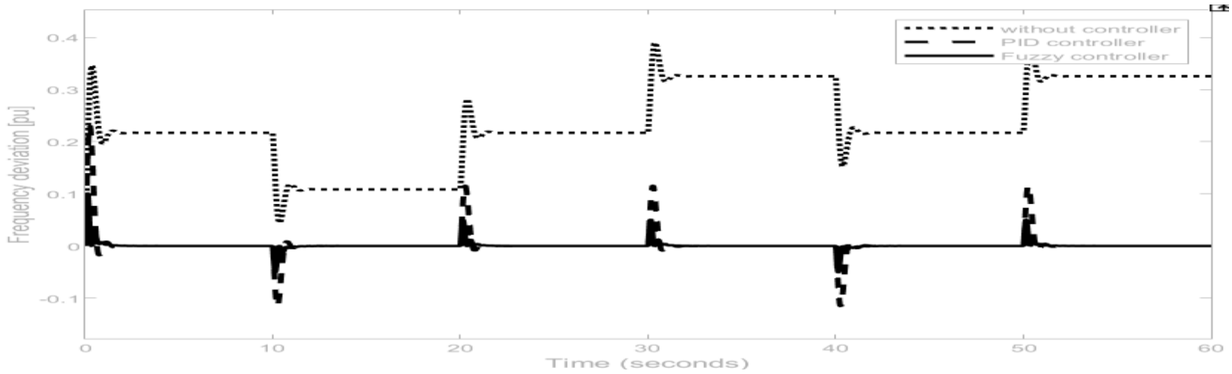

Figure 5.4: Comparison of system response

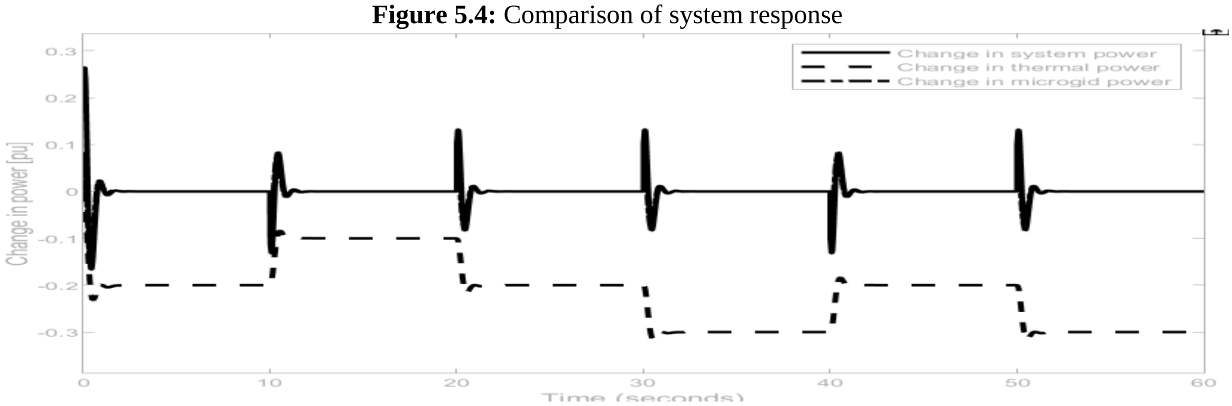

Figure 5.6: Response of change in thermal, overall system, and microgrid power

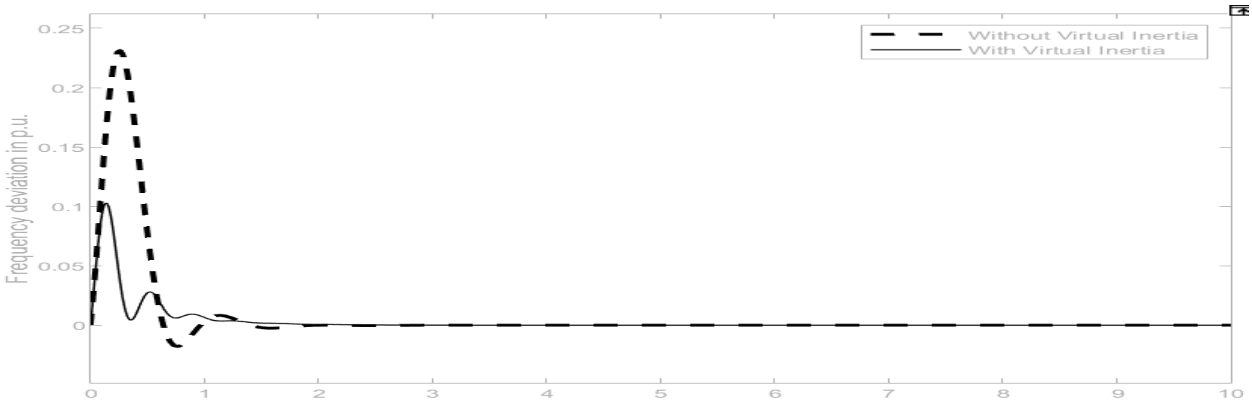

Figure 5.9: Response with virtual inertia

Table 1: Comparison of performance index

Cases	Without Controller	PI Controller	Fuzzy Controller
Case-1 (ITSE)	0.4873	0.01433	0.001522
Case-2 (ITSE)	0.1227	0.003923	0.0005119
Case-3 (ITSE)	3.686	0.3225	0.003426

6. Conclusion

This paper proposed a Fuzzy controller for effective and fast LFC of single area power system with microgrid. The Integral Time Squared Error (ITSE) value is demonstrated of each case. The membership functions of the gains are changed. The number of rules for the inference mechanisms is increased from two or five to seven. Therefore, the controller performance has been increased by developing a new rule table. It has been shown that the proposed control algorithm is effective and provides significant improvement in system performance.

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