PID Controller Tuning for Microgrid

Swati Jain[1], Kaushal Sen[2]

[1]*Research Scholar,* [2]*Assistant Professor, Oriental college of Technology Bhopal*

Abstract - This paper presents an autonomous control of isolated microgrid. Due to extensive utility of distributed sources microgrid control is an important area of research. In this paper microgrid with conventional and non-conventional sources and storage has been taken into consideration. The variation in load affects the system frequency due to mismatch in power generation and load. In this perspective the tuning of PID controller is done through load disturbance rejection method which is then compared with conventional method. MATLAB/SIMULINK tool has been used to prove the efficacy of proposed method.

Keywords - Load disturbance rejection, fuel cell, diesel generator, battery energy storage system, fly wheel, PV.

I. INTRODUCTION

DGs are situated in nearness to the load focuses, accordingly keeping away from the long transmission and dispersion systems by and large. The microgrid may work in an independent mode or it can work in a matrix interconnected mode, chose by the working conditions. Since, the idea of microgrid includes numerous little limit generators, may likewise be with variable power yield, associated together requires exceptionally organized activity among the various units to keep up the framework security [1]. The accessibility of electric vitality simply doesn't serve the present necessity, yet the nature of electric vitality provided is additionally significant. The term nature of electric vitality has numerous features, significantly, the framework steadiness which is firmly combined with frameworks' working frequency. This must be accomplished through appropriate coordination among the DGs and burdens, and different substances of the framework. This coordination can be acknowledged by incorporating the correspondence advances with the vitality innovations, subsequently making the ways towards a more astute administration of the power framework and its segments. As previously mentioned, if the framework limit is little, it very well may be alluded as keen microgrid [2]-[3]. The DG incorporates non-regular/sustainable power sources like wind, PV, energy, biogas, micro hydro, smaller scale turbines just as diesel generators, consolidated warmth power (CHP), heat motors [3]. The DG innovation effectively coordinates the inexhaustible assets in the current power framework. In [4], the point of inexhaustible portfolio principles is to use the sustainable power support around 2-25% [5]-[7].

The microgrids are frequently characterized as a collection of DERs and partner stacks that work interconnected. They may likewise be disengaged loads that work interconnected with the principle framework. They may likewise be secluded and work independently [8]. The microgrids have discovered applications in various zones like industry, utility, machines, military, aviation, peak shaving, combined Heat and force (CHP) etc. [9]-[13]. Microgrid operates in either grid connected or isolated mode. During the isolated mode, there will be an adjustment in the power balance between the age and burden. The power yields from controllable smaller scale sources are to be managed appropriately to have a steady activity with respect to control equalization and frequency of activity. The arrangement is to have either a diesel generator/gas based alternator, energy unit, water electrolyzer and battery to overcome any barrier between the power delivered by the sustainable power sources and loads. In the customary Automatic Generation Control (AGC), it is entrenched that less the droop values, lesser will be the frequency deviations. Be that as it may, on the off chance that the more droop, at that point there is a prerequisite for frequency inclination term for AGC as an auxiliary regulator. In literature ziegler and Nichols technique has been proposed for the tuning of regular PID controller[15-17]. The regulator gains once tuned for a given working point are just reasonable for constrained working point changes. In this way, the utilization of the customary PID regulator doesn't meet the prerequisites of the strong presentation [18-19]. To tune the PID modified LDR technique is proposed in this paper [20-23]. A more practical demonstrating of a microgrid for the investigation of frequency guideline in microgrid:

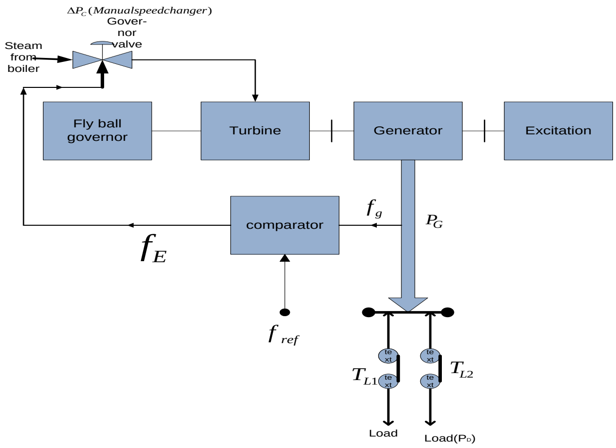
- Including the significant boundaries P-f droop attributes for various sources in microgrid.
- Calculation of p-f droop from bode plot stability rule.
- Systematic tuning of auxiliary regulators boundaries utilized with various microgrid sources by regular strategy.
- For frequency guideline, PID regulator structure by Load Disturbance Rejection strategy.

II. AUTOMATIC GENERATION CONTROL

The fundamental part of power framework is transmission lines and dissemination frameworks. Power systems are utilized to change over common vitality into electrical power. There are number of strategies accessible to create power. Conventional and non-conventional sources can be adopted. One of the principle challenges in power framework is that the measure of dynamic power expended in addition to misfortunes should consistently rise to the dynamic influence delivered. In the event that more power would be delivered than expended, the frequency would rise and the other way around. Indeed, even little deviation from the ostensible frequency worth would harm machine and different apparatuses. So it is important to control the controller with the goal that the generation and request will consistently in match. The Automatic generation control (AGC) assumes a significant job to adjust the power and load.

A. Speed Governing Control

At the point when the electrical burden is out of nowhere expanded then the electrical power surpasses the mechanical force input. Because of this the inadequacy of intensity in the load side is extricated from the pivoting vitality of the turbine. Because of this the motor vitality of the turbine for example the vitality put away in the machine is diminished and the lead representative imparts a sign to gracefully more volume of water or steams or gas to speed up the central player in order to repay speed lack.



$$f_E = f_g - f_{ref} = errorsignal$$

Figure.1: Model of Automatic Load Frequency Control

At first the framework is working ordinarily. With the unexpected difference in load there is change in frequency. This changed frequency is contrasted with our reference frequency with produce error in frequency (f_E). The opening of valve is constrained by this blunder frequency. The measure of steam (from evaporator) to be provided to the generator relies upon the opening of valve. The weight applied by the steam helps in changing the speed of generator and along these lines the typical recurrence is reestablished back. This is the way the framework appeared above progresses in the direction of accomplishing frequency control. In the event that the heap on the framework is expanded out of nowhere, at that point the turbine speed drops before the lead representative can alter the contribution of the steam to the new burden. As the adjustment in the estimation of speed reduces the error signal decreases and the situation of the lead representative and not of the fly balls comes to the matter required to keep up the steady speed. Approach to reestablish speed or frequency is to include an integrator the way. The integrator unit will screen the normal blunder over some stretch of time and will beat the balance. In this manner as the load of the framework changes constantly the generation is balanced naturally to reestablish the frequency to the ostensible worth. In an interconnected framework comprising of a few pools, the job of the AGC is to divide the load among the framework, stations and generators in order to accomplish most extreme economy and sensibly uniform frequency [25].

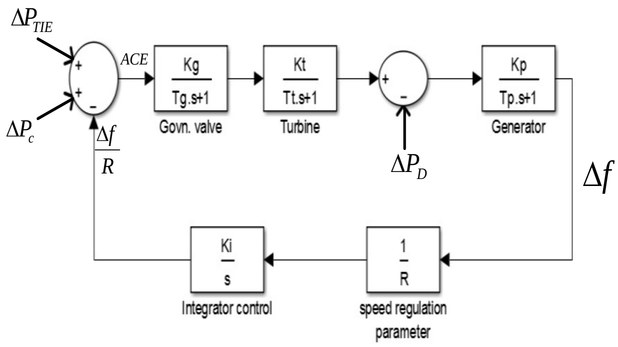


Figure.2: Block Diagram of Speed Governing Control with AGC

Where K_g, K_t, K_p are Gains of the governing valve, turbine and diesel generators, T_g, T_t, T_p are Time constant/delay of the governing valve, turbine and Diesel generator, ACE is Area control error, ΔP_c, ΔP_{Tie} is Change in Tie-line power, b is Frequency bias coefficient. Area control error (ACE) for each area consist of linear combination of frequency and tie line error, as given below

$$ACE = \Delta P_c + \Delta P_{Tie} - \frac{\Delta f}{R} \quad (1)$$

$$ACE = \Delta P_{Tie} - \frac{\Delta f}{R} \quad (2)$$

$$ACE = \Delta P_{Tie} + b.\Delta f\,(b = -\frac{1}{R}) \quad (3)$$

In the fig. 2 using governing valve, Turbine and generator(whose transfer function is known) a system is designed which is operating at normal condition. With the

ISSN: 2395-2946

adjustment in load request, the speed of generator and intensity of produced changes. So as to control this progressions speed guideline parameter(R) or droop and vital regulator is utilized. The speed guideline boundary goes about as programmed speed transformer in view of which the overseeing speed is consequently controlled.

B. Conventional PI controller for AGC

Conventional PI controllers are included as supplementary controller in the above transfer function block diagram model of the hybrid system for LFC. The speed lead representative directs the frequency of the framework when mismatch between load and generation. To achieve this we should control speed transformer by load frequency regulator as per some reasonable control technique and the framework frequency change might be considered as the feedback signal. The objective of this work is to investigate the problem of frequency control of an isolated hybrid power system using LDR technique and their performance is compared with classical PID controller.

It is described to tune the integral controller with an optimum gain value KI. A performance index PI is selected using integral square error (ISE) which should be minimized with the help of gain KI. The performance index (PI) which has to be minimized is given by

$$PI = \int_0^{\infty} (\Delta f^2 + P_{tie}^2)dt \quad (4)$$

The graph shown in fig.3 indicates the results obtained from the system with and without controller. In the system using controller the magnitude of error is less.

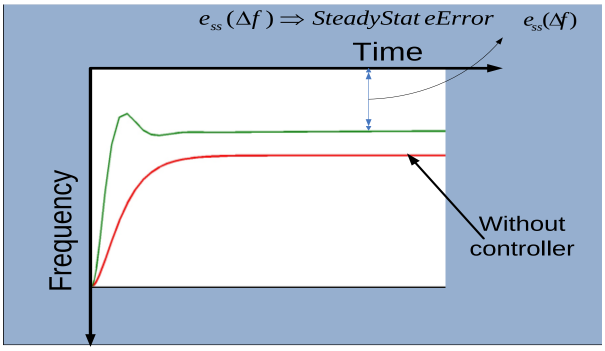


Figure.3: Representing Error Reduction in system using Integral Controller

III. PROPOSED METHOD

Objective of the controllers is to regulate the power output of secondary sources, to minimize the frequency deviation by generating appropriate control signals and hence to enhance the performance of the microgrid. In the presence of many secondary sources there is a chance of adverse interaction between their regulators which leads to deterioration of frequency stability of the microgrid. So far there is no single definition for best tuning that applies to all loops. Therefore, to avoid the adverse interaction there is a need of appropriate tuning of the individual PID controller [13]. In this paper SISO toolbox is used for PID tuning (PID controller is used because there is a need to improve both transient and steady state response).To generate this compensator Ziegler-Nichols open loop is used as a tuning algorithm with LDR as tuning preference. This method uses the Chien-Hrones-Resnick (CHR) setting with 20% overshoot. It is worth mentioning here that Ziegler-Nichols closed loop can not be applied to first-order or second-order systems with time delay. If Ziegler-Nichols closed loop is selected for these cases, the tuning algorithm will automatically be switched to Ziegler-Nichols open loop[20]. From the compensator "C" the Values of gains are calculated using

$$C = K_p + \frac{K_i}{S} + K_d S \quad (5)$$

The Frequency bias is selected at which ITSE (Integral time square error) is minimum [13] and given by

$$ITSE = \int_0^t t|\Delta f|^2 dt \quad (5)$$

The results obtained from the LDR method are compared with classical method and it is found that proposed method gives the better response over the classical method as mentioned in Table-I and table-II

TABLE I - Tuning Of PID Controller Gains According To Classical Method

Microgrid Components	Frequency Regulation K_f	K_p	K_i	K_d
Diesel Generator	4	0.0397	0.0756	3.3084
Aqua Electrolyzer	0.2	0.35	0.03	0.07
Fuel Cell	2	0.1220	0.2154	3.1608
Battery	0.1	0.4188	0.01666	0.01
Fly wheel	0.1	0.3654	0.01666	0.01

TABLE II-Tuning Of PID Controller Gains According To LDR Method

Microgrid Components	Frequency Regulation K_f	Modified K_p	Modified K_i	Modified K_d

 ISSN: 2395-2946

Diesel Generator	4	0.1025	0.0073	0.3013
Aqua Electrolyzer	0.2	1.498	4.5399	0.1044
Fuel Cell	2	0.1858	0.0464	0.156
Battery	0.1	3.380	0.1251	0.098
Fly wheel	0.1	3.380	0.1251	0.098

IV. RESULTS AND DISCUSSIONS

The Detailed block diagram of the microgrid is shown in Fig. 4. using MATLAB/SIMULINK. The system was put under power variation in load as well as in sources. Before creating disturbance in all the cases, constant wind power supply of approximately 0.3 p.u., solar power supply of 0.3 p.u. and a load demand of 0.6 p.u. are considered. The time period shown in some plots is the different from the simulation time since in those cases the system is settling before the simulation time.

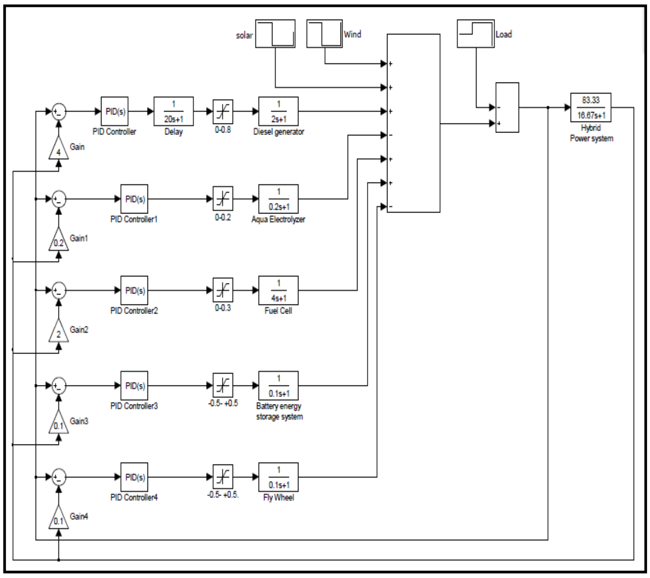


Figure.4: SIMULINK Diagram of the microgrid.

To observe the efficacy of proposed method wind power decreases from 0.3 p.u. to 0.25 p.u. and again increases from 0.25 p.u. to 0.28 p.u. & solar power is decreased from 0.3 p.u. to 0.25 p.u. and again decreases to 0.20 p.u. similarly load demand is first decreased from 0.6 p.u to 0.55 p.u and then increased to 0.70 p.u. for a time period of 50 sec. and 100 sec. respectively.

Time	T=0 sec	T=50 sec	T=100 sec
Wind power	0.3 p.u.	0.25 p.u.	0.28 p.u.
Solar power	0.3 p.u.	0.25 p.u.	0.20 p.u.
Load demand	0.6 p.u.	0.55 p.u.	0.70 p.u.

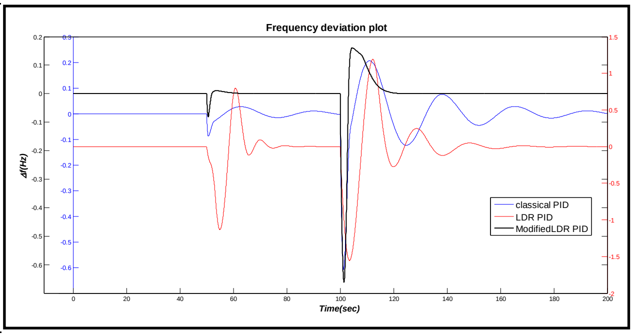


Figure.5: Frequency Deviation of Microgrid

From fig. 4, the following observation can be observed

1. For classical method, the first transient is not eliminated and second transient is eliminated in 160 sec.
2. For LDR method, the first transient is eliminated in 35 sec second transient is eliminated in 100 sec.
3. For Modified LDR method, the first transient is eliminated in 12 sec the second transient is eliminated in 22 sec. for frequency regulation.

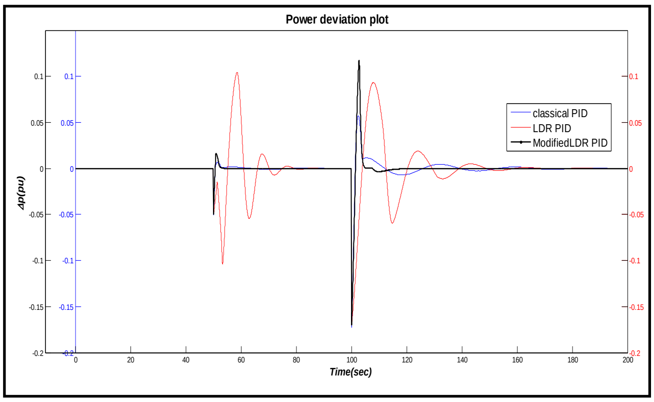


Figure 6: Power Deviation of Microgrid

From fig.6 the following observation can be observed

1. For classical method, the first transient is 40 sec. and the second transient is eliminated in 130 sec.
2. For LDR method, the first transient is eliminated in 35 sec and second transient is eliminated in 90 sec.
3. For Modified LDR method, the first transient is eliminated in 12 sec the second transient is eliminated in 22 sec. for regulation of power.

 ISSN: 2395-2946

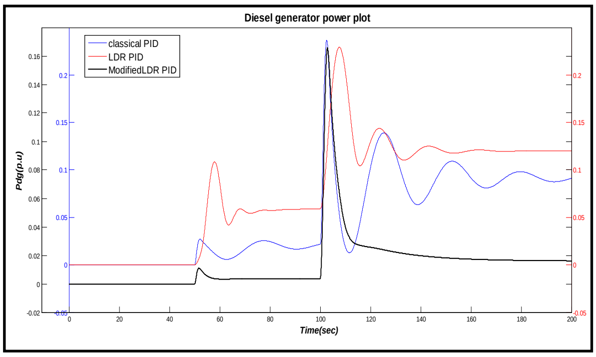


Figure.7.: Diesel generator power

At steady state period, contribution from diesel generator is 0.1 p.u at 150 sec, 0.12 p.u at 80 sec and 0.02 p.u at 75 sec for Classical, LDR and Modified LDR method respectively to compensate the difference in load power of 0.22 p.u. This has been shown in fig.7.

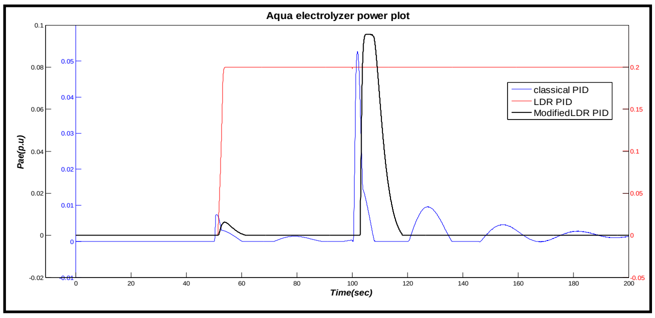


Figure.8: Aqua Electrolyzer power

The contribution of Aqua electrolyzer is negligible, it is used to generate Hydrogen for fuel cell only. This has been shown in figure.8.

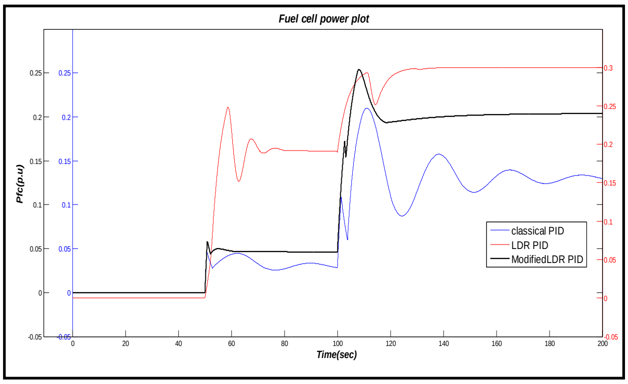


Figure.9: Contribution of Fuel Cell Power in Microgrid

From figure.9, the fuel cell is contributing 0.12 p.u. power in 200 sec for classical method whereas 0.30 p.u. in 30 sec and 0.2 in 70 sec for LDR method and Modified LDR method respectively to compensate the difference in load power of 0.22 p.u. for frequency regulation.

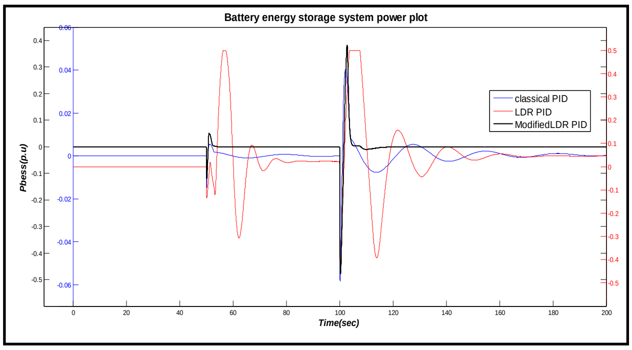


Figure.10: Contribution of BESS Power in Microgrid

Figure.: Contribution of D

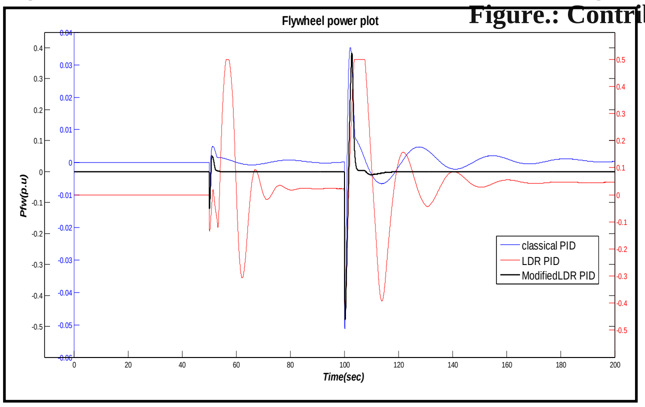


Figure.11: Contribution of Fly Wheel Power in Microgrid

It is evident from above results that the proposed method works effectively and achieves better response than conventional method.

Figure.6.32: Contribution

V. CONCLUSION

This paper presents a new approach to reduce frequency deviation using LDR based PID Controller. The results obtained by this method are promising and are much more superior than the classical method. By using LDR method there is less transient period in comparison to classical method. So the proposed method is more effective for microgrid control.

REFERENCES

[1] Chowdhury, S.P., Crossley, P., Chowdhury, S., Clarke, E.: ‘Microgrids and active distribution networks’ (Institution of Engineering and Technology, London, 2009)

[2] N. Hatziargyriou, M. Ddonnelly, S. Papathanassiou, J.A. Pecas-Lopes, J. Usaola, R. Lasseter, A. Efthymiadis, K. Karoui, S. Arabi, M.Takasaki, and H.chao, “Modeling new forms of generation and storage,” *Electra*, no. 195, pp. 54-63, Apr. 2001.

[3] Senjyo, T., Nakaji, T., Uezato, K., Funabashi, T.: ‘A hybrid power system using alternative energy facilities in isolated island’, IEEE Trans. Energy Convers., 2005, 20, (2), pp. 406–414

[4] D. J. Hall and R. G. Colclaser,“Transient modeling and simulation of a tubular solid oxide fuel cell,” IEEE Trans. Energy Convers., vol. 14, no. 3, pp. 749-753, Sep. 1999.

[5] M. D. Lukas, K. Y. Lee, and H. Ghezel-Ayagh, "Development of a stack simulation model for control study on direct reforming molten carbonate fuel cell power plant," IEEE Trans. Energy Convers., vol. 14, no. 4, pp.1651-1657, Dec. 1999.

[6] P. S. Dokopoulos, A. C. Saramourtsis, and A. G. Bakirtzis, "Prediction and evaluation of the performance of wind-diesel energy systems," IEEE Trans. Energy Convers., vol. 11, no. 2, pp. 385-393, Jun. 1996.

[7] N. Kodama, T. Matsuzaka, and N. Inomata, "The power variation control of a wind generator by using probabilistic optimal control," Trans. Inst. Elect. Eng. Jpn, vol. 121-B, no. 1, pp. 22-30, 2001.

[8] R. B. Chedid, S. H. Karaki, and C. El-Chamali, "Adaptive fuzzy control for wind-diesel weak power systems," IEEE Trans. Energy Convers., vol. 15, no. 1, pp. 71-78, Mar. 2000.

[9] Lee, D., Wang, L.: "Small signal stability analysis of an autonomous hybrid renewable energy power generation/energy storage system time domain simulations", IEEE Trans. Energy Convers., 2008, 23, (1), pp. 311–320.

[10] S. Mishra, G. Mallesham, and A. N. Jha, "Design of controller and communication for frequency regulation of a smart microgrid," IET Renew. Power Gener., vol. 6, no. 4, pp. 248–258, Jul. 2012

[11] J. Nagarath, M. Gopal, Control Systems Engineering, 3rd Edition. New Age International: 2001.

[12] M. Gopal, Control Systems Principles and Design, 3rd Edition. Tata Mc Graw Hill 2008.

[13] Mallesham, G., Mishra, S., Jha, A.N.: 'Ziegler- Nichols based controller parameter tuning for load frequency control in a microgrid'. Proc. Int. Energy, Automation, and Signal (ICEAS), 2011 International Conference on, 2011,pp. 1–8

[14] Kroposki, R. Lasseter, T. Ise, S. Morozumi, S. Papathanassiou and N. Hatziargyriou, "Making microgrid work," IEEE Power and Energy Magazine, vol. 6, no. 3, pp. 40-53, May-June 2008.

[15] R.H. Lasseter, "Microgrids," Proc. IEEE Power Eng. Soc. Winter Meeting, Jan. 2002, vol. 1, pp. 305-308.

[16] P. Agrawal, "Overview of DOE Microgrid Activities," Symposium on Microgrid, Montreal, June 23, 2006.

[17] O. I. Elgerd, Electric energy system theory: an introduction(2nd ed.), McGrawHill, New York(1982).

[18] P. Kundur, Power system stability and control, Tata McGraw Hill, New York,1994.

[19] Dulal ch. Das, A.K.Roy, N.Sinha, "Genetic Algorithm Based PI controller for frequency control of an autonomous hybrid generation system", IMECS hong cong. vol 2,march 16-18, 2011

[20] MATLAB 7.10.0 (R2010a).

A. Jeya. Veronika, N.S. Kumar, " Internal Model based Load frequency Controller Design for Hybrid Microgrid System", Energy Procedia, vol. 117 1032–1039, 2017.

[21] S. Khosravi, M.T. H. Beheshti, H. Rastegar, "Robust Control of Islanded Microgrid Frequency Using Fractional-Order PID", Iranian Journal of Science and Technology, Transactions of Electrical Engineering, 2020, https://doi.org/10.1007/s40998-019-00303-6