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Optimization of Controller Parameters During Uncertain Conditions for a Renewable System

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Abstract

Demand of the energy is increasing day by day. In order to cope up with the ever-increasing demand, the new methods of obtaining energy from the renewable sources is encouraged. These sources of energy have a wide number of applications in the power system, especially in the remote areas. So, these sources of energy are incorporated with the existing power system. Since the output of these renewable sources of energy is highly unpredictable and fluctuating, this will result in the variation of output power and eventually leads to power quality issues. Wind power is a major source of renewable energy, and the world is in high demand. Nevertheless, due to large variations in power output, it is difficult to manage wind power. To mitigate these fluctuations, this paper proposes a method for suppressing frequency variability in wind power generation using battery storage systems which take into account charging status (SOC) and variations in response speed between generators and battery storage systems. Using this method, we model a load frequency control system that controls both internal variability due to the dynamics of the power system and external variation due to wind generators. If a large load is unexpectedly attached (or disconnected) to the network in multi-area electrical power systems, or if a generating unit is suddenly disconnected by the protective equipment, there will be a long-term imbalance in the power balance between that supplied by the turbines and that consumed by the loads. Originally, the kinetic energy of spinning turbine, generator and engine rotors covers this discrepancy, resulting in a shift in the frequency of the process. The Load Frequency Control (LFC) problem is therefore an important issue in the operation and control of the power system. The traditional PI type controllers were applied to LFC in functional systems. Several methods have been suggested in the literature to address the limitations of modern PI controllers. A PID form controller for the LFC problem is considered in this paper. The proposed PID controller's parameters were tuned using the Particle Swarm Optimization (PSO) approach.

Keywords— *vehicle-to-grid (V2G); electric vehicle (EV); load frequency control (LFC); isolated grid; diesel generator; PID controller.*

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I. INTRODUCTION

Power system is a one of the largest and complex electrical networks which usually consist of generation, transmission and distribution networks together with consumer load demands that are spread over a wide geographic area throughout the network [1]. The machine load in the power system always keeps on altering from period to period, depending on the consumer's needs. To uphold the trustworthiness of the powersystem and to ensure its stable operation, properly designed controllers are necessary to regulate system variations.

The industry's rapid growth has further contributed to the power system's increased complexity. Frequency is extremely reliant on active power, and reactive energy is highly hooked on voltage. Thus, the power system’s governor complexity can be alienated into two sections. The one section has to regulate the real power to control the frequencyand the other has to regulate reactive power to control the voltage [2]. The Automatic LoadFrequency Control (ALFC) is commonly known as the active power or load andthe frequencycontroller.The ALFCessentiallyused to control the generator's real power output yield and its frequency and/or (speed). ALFC gives the control command to prime mover with change in system frequency and the prime moverwill respond through or via the speed administrator to change the flow of steam (or hydro) to controlled the change in frequency to zero.

So, we are in need of the Automatic LoadFrequencyControl to primarily uphold the firmness when load deviations occur. This is completed by minimalizing, apart from the power exchange, transient frequency deviations and also by making the effort for steady state error to very nearly zero [3]. Inequality surrounding demand generation induces variations in frequency. If the frequency deviates and not upheld within the prescribedvalues, it can lead to lines tripping, and system collapse, and the blackouts [4].

This paper will demonstrate the effective means of controlling the frequency deviations by incorporating the electric vehicle with the existing system. The deviations are then optimized using a PID Controller. The remaining part of the paper is arranged as follows: The isolated MG model is described in Section 2. Section 3 addresses in depth a Particle Swarm Optimization Algorithm.In order to support the functionality of the proposed control scheme, a section 4 simulation example with a specific isolated MG system is formed with various disorders. Section 5 describes the proposed model for the Simulink environment. Results are formulated in the Section 6. Finally, Section 7 draws conclusions.

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II. MICRO – GRID ISOLATED MODE

A. Micro-Grid Model.

A general model of MGs has been described in Fig 1. with distributed loads and distributed energy resources like microturbines, WTs, PVs, EVs[5]. Distributed management system (DMS) administers the MG, and the Microgrid distributed system MGDS manages the operation of the MG. Number of PMUs along with the communication network have been used on this MG to measure real-time information of the isolators/disconnectors, distributed energy resources, EV(s) and loads[7].

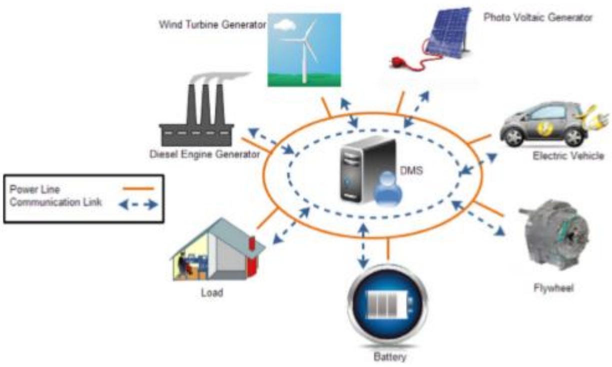

Fig. 1. Micro-Grid general Scheme[5]

B. Electric-Vehicle Model.

Modelling EVs can be carried out with equivalent EVs with different inverter capacity as each EV station has the different number of EV's as shown in Fig. 2 [7, 27]. This equivalent model shows the charging and discharging of EV's in controllable state [6]. As noted, the frequency deviation across the output of ALFC is limited by the controllable EVs by utilizing their storage capacity. The response of EV to the frequency deviation always remain within the energy capacity limits as per their specified SOC as given in Eq.1[7].

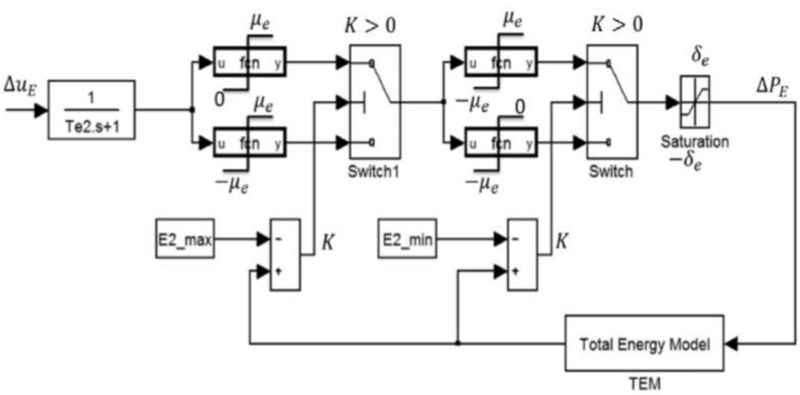

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Fig. 2. EV model for LFC [7, 27].

$$E2\_min \leq E_{control} \leq E2\_max \qquad (1)$$

Where,$E_{control}$ is the controllable EV's total energy whereas the lower and the higher energy limits are the $E2\_min$ controls and $E2\_max$ controls respectively.

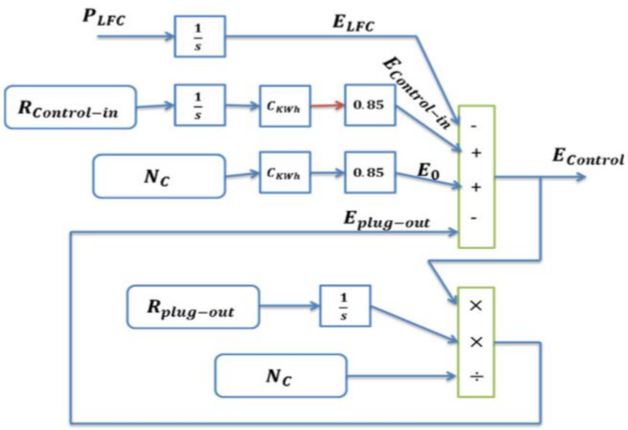

Fig. 3. Total Energy Model.

Fig. 3 shows as equivalent model to calculate the total energy generation as $E_{control}$ from all controllable EVs, where the Eq. 4 represents that relation in mathematical form.

$$E_{control} = -E_{LFC} + E_{control-in} + E_0 - E_{plug-out} \qquad (2)$$

Where,

E_{LFC} is the LFC signal energy

$E_{control\text{-}in}$ can be defined as the increase in energy due to the changing state of EVs

E_0 is the initial energy

$E_{plug\text{-}out}$ is the decrement in energy because of plug-out of EVs

$N_{control}$ is the total controllable EVs

$R_{control\text{-}in}$ is the rate of control.

C. Diesel – Generator Model.

Diesel generator (DG) has the characteristics of fast starting speed, long service [9] life and high efficiency as a small electricity generator. Within short intervals, DG can track

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variations in demand via power control mechanisms [10]. The DG will change its output through fuel control when demand fluctuates. The DG model for LFC is shown in Fig. 4. The time transfer function model. This model represents the relationship between LFC signal and DG's output power. This model is composed of a governor and a generator, which are referred to respectively by the first-order inertia plants [11].

D-G is a limited power generating system with structures of fast opening speed, toughness and high effectiveness. In short intervals of time [12], DG may obey changes in load demand through mechanisms for power control. The DG adjusts performance via the fuel control when the demand for energy fluctuates. Figure shows the DG template for LFC's continuous time transfer feature. The figure shows the association [13] amongst the LFC signal and the D-G output yield power.

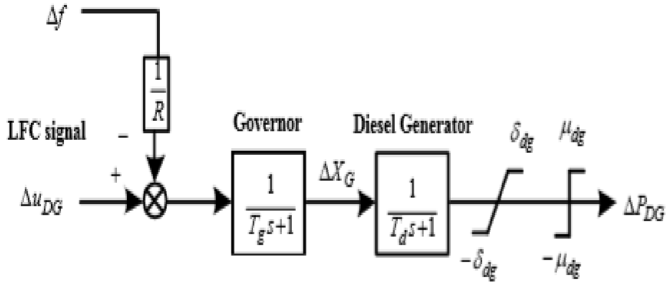

Fig. 4. D-G Transfer - Function Model.

Where,

Δf is the system's change in frequency.

ΔU_{DG}represents the change in inputsignal to DG from LFC.

$\Delta X_G$is the change inoutput of the governor represent the valve position.

T_g is the governor's time constant

$T_d$is the DG's time constant

R is the DG's speed regulation constant

$\pm\delta_{dg}$ are the power ramp rate limits

$\pm u_{dg}$ are the power increment limits

ΔP_{DG} is the power increment output of DG.

As shown in Fig. 4,ΔP_{DG} represents the output power state of the DG. It set to zero only when there is no imbalance between the generation and demand and at such condition the frequency deviation across the system is also zero, i.e. $\Delta f=0$[14-15]. Eventually, the power balance of the grid decides this certain power level [16-20]. The reference to DG indicates

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that the power generated by DG is greater that needed, and the opposite indicates that the power generated by DG is lower than the actual power required.[7].

D. Micro – Grid Scheme along with PID based LFC Controller

In the Fig. 5,PID based LFC and the isolated MG proposed, consisting of a generic DGand EVs are illustrated. Power electronic interfaces are required for synchronization of DG sources, and for reversing dc voltage from the EVs and energy storage devices for making the proper interconnection with the MG.[5,11].

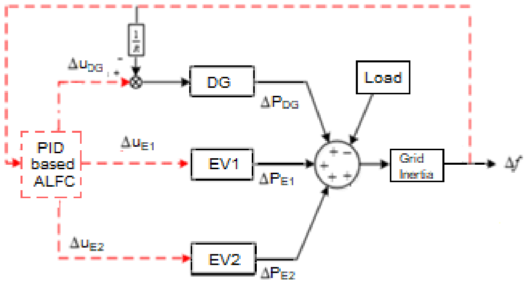

Fig. 5. LFC with control model of micro-grid

Each micro source has a circuit breaker that is designed for the disconnection of the network and for main purposes avoids the effects of severe disturbances through the MG. The DG produced compulsory power for the secondary frequency control a certain amount that is considered to be the spin reservoir. [20-24]

III. OPTIMIZATION TECHNIQUE USED

PID controllers are widely used as part of the framework for process control. PID controller tuning is very important for optimum control. Ziegler - Nicols method and Cohen - Coon methods are the most common methods. The parameters of the system change in the physical system as the operating conditions fluctuate. Many controllers are typically designed to one operating state. The controller therefore shows meagre presentation when it is made to function under different conditions of operation.

Therefore, the controllers should be regularly replaced. In order to achieve better performance, many new fine-tuning approaches were proposed. A robust approach based on Particle Swarm Optimization (PSO) is used to avoid the retuning of the PID controller. PSO is using information from swarms. The approach was inspired by the social interaction, animal behaviors seen among birds and fish.

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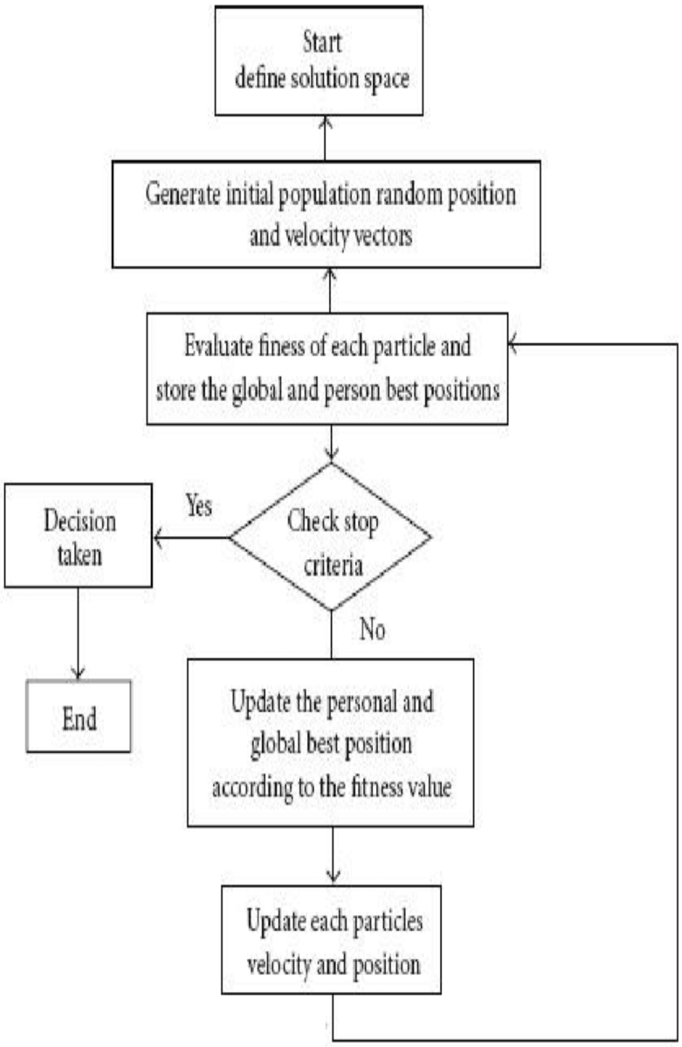

Fig. 6. Flowchart of PSO Algorithm.

The swarm intelligence (SI) is based on the PSO algorithm. The approach was inspired by studying social interaction, animal behaviors seen between birds, fish, etc. PSO follows the process found in fish, where by competing and cooperating with each other they seek food. The swarm has so-called elements in which each unit represents different possible collection of unknown constraints that should be optimized. Typically, a' swarm' is prepared by a random solution population. Particles travel in a randomly multi-dimensional search area in this process. It continues to change its location to its own understanding and also to understand its neighboring particle's experience. May particle's aim is to look for a solution to

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accomplish this very effectively. The elements swarm and move to the finest function called fitting - function. Then it congregates to a solution of one min or so.

A function is used to evaluate swarm performance, so we can find out if the best solution has been achieved.

IV. PROPOSED METHODOLOGY AND ITS APPLICATIONS

In power systems, it is very difficult to maintain the frequency deviation due to the load disruption and uncertain renewable generation, within the acceptable limits using the reserve energy from the conventional power sources. However, electricvehicles (EV's) can behave as the mobile and great energy storage units using the vehicle-to-grid (V2G) technique, which could be an isolated grid solution for load frequency control (LFC). In this proposed work, a model of LFC is established. Apart from the independent micro-grid controller, EV's and diesel generator (DG) are synchronized to achieve a satisfactory load frequency output.

To validate the effectiveness of the projected method, a reference scheduled micro-grid with EV's and DG, is demonstrated in the software Matlab / Simulink context. Results of simulation show that the energy deposited in EVs can be judiciously controlled. It increases the reliability of the process frequency with dynamic operating conditions like intermittent renewable - energy resources and constant load instabilities.There are also some limitations in the LFC systems, including power constraints and limitations in the speed of generation, which are difficult to consider in the design of the controller.

V. SIMULATION STUDIES

In order to inspect the presentation a well-tuned PID controller/supervisor have been premeditated in the simulation software. The classical system constraints are provided and the parameters of controllers are presented.

A. SIMULINK MODEL

The MATLAB Simulink model for the proposed work is shown in Fig. 7, where an Electric Vehicle is integrated with an existing system. The load disturbance is applied in terms of the step input. The results for the change in the frequency and power are analyzed for different cases as shown below.

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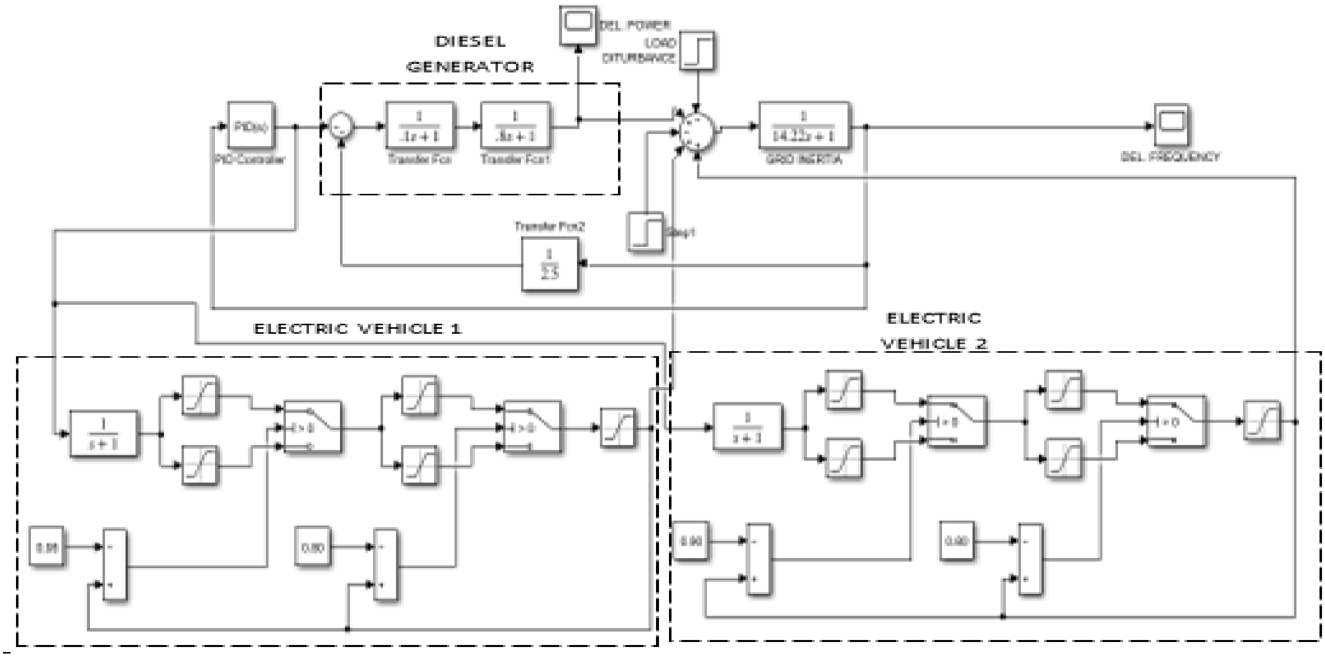

Fig. 7. MATLAB Simulink Model.

VI. RESULTS/OBSERVATIONS

The MG unit as shown in Fig. 7 is simulated in MATLAB/ Simulink environment to monitor the performance of the LFC controller on the MG. As compared performance of LFC controller with or without PID has been shown in Fig. 8. In order to represent a fair comparison, PSO optimization technique has been used to optimized the PID's controller parameters. The optimized PID parameters are given as:

Proportional - Gain = 4

Integral - Gain = 1.18

Derivative - Gain = 0.5

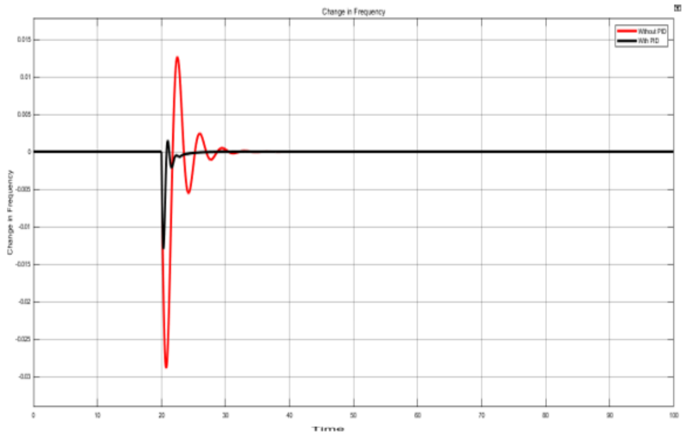

Fig. 8. Frequency Deviation response to load disturbance

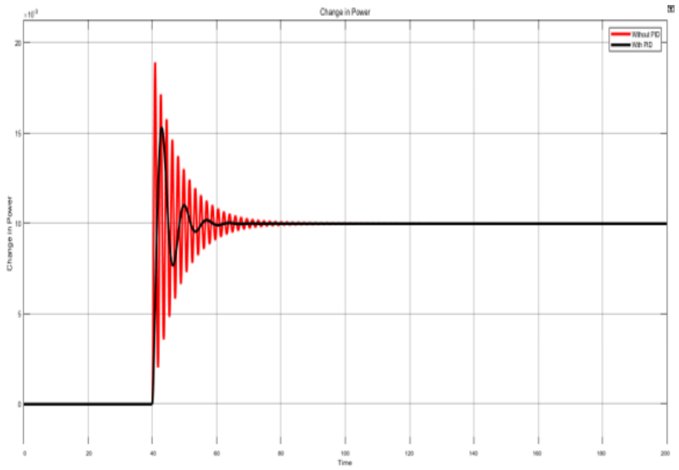

Fig. 9. Change in the power.

As seen from the Fig. 9, when the load disturbance is applied at t = 20, the change in the frequency is analyzed. Above graph shows the comparison of change in the frequency of the system between PID controlled and without PID controlled. The graph clearly shows that change in the frequency or frequency deviation is more in case of without PID and subsequently these deviations are reduced and brought to its normal value much quicker and efficiently by the use of PID Controller.

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REFERENCES

[1] Y. Zhang, L. Dong and Z. Gao, "Load frequency control for multiple-area power systems," 2009 American Control Conference, St. Louis, MO, pp. 2773-2778, 10-12 June 2009.

[2] I. J Nagrath and D. P Kothari,"Modern power system analysis," 3rd ed., TMH, New Delhi, 1993.

[3] O.I. Elgerd, "Electric energy systems theory- an introduction," 2nd ed., TMH, New Delhi, 2000.

[4] G. Turner, J. P. Kelley, C. L. Storm, D. A. Wetz and W. Lee, "Design and Active Control of a Microgrid Testbed," IEEE T Smart Grid, vol. 6, no. 1, pp. 73-81, Jan. 2015.

[5] M. R. Khalghani, M. H. Khooban,E. Mahboubi- Moghaddam, N. Vafamand and M. Goodarzi,"A self-tuning load frequency control strategy for microgrids: human brain emotional learning," Int J Elect Power,vol. 75, pp. 311–319, Feb. 2016.

[6] E. Mojica-Nava, C. A. Macana and N. Quijano, "Dynamic Population Games for Optimal Dispatch on Hierarchical Microgrid Control," IEEE T Syst Man Cy-S, IEEE Trans, vol. 44, no. 3, pp. 306-317, March 2014

[7] J. Yang, Z. Zhili, T. Yufei, Y. Jun, H. Haibo and W. Yunliang,"Load frequency control in isolated micro-grids with electrical vehicles based on multivariable generalized predictive theory," Energies,vol.8, no. 3, pp. 2145–64, March 2015.

[8] Zheng S, Tang X, Song B, Lu S, Ye B,"Stable adaptive PI control for permanent magnet synchronous motor drive based on improved JITL technique," ISA Trans.,vol. 52, no. 4, pp. 539–49, July 2013.

[9] H. Bevrani, F. Habibi, P. Babahajyani, M. Watanabe and Y. Mitani, "Intelligent Frequency Control in an AC Microgrid: Online PSO-Based Fuzzy Tuning Approach," in IEEE T Smart Grid, vol. 3, no. 4, pp. 1935-1944, Dec. 2012.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

[10] Shiqi Zheng, Tang Xiaoqi, Song Bao, Lu Shaowu, Ye Bosheng. Stable adaptive PI control for permanent magnet synchronous motor drive based on improved JITL technique. ISA Trans 2013;52(4):539–49.

[11] E. Yesil,“Interval type-2 fuzzy PID load frequency controller using Big Bang–Big Crunch optimization,” Appl Soft Computing, vol. 15, pp. 100–112, Feb 2014.

[12] J. Pahasa and I. Ngamroo, "Coordinated Control of Wind Turbine Blade Pitch Angle and PHEVs Using MPCs for Load Frequency Control of Microgrid," IEEE Syst J, vol. 10, no. 1, pp. 97-105, March 2016.

[13] M. Tarkeshwar and V. Mukherjee, "Quasi-oppositional harmony search algorithm and fuzzy logic controller for load frequency stabilisation of an isolated hybrid power system," in IET Genr TransmDis, vol. 9, no. 5, pp. 427-444, Apr. 2015.

[14] V. P. Singh, S. R. Mohanty, K. Nand andP. K. Ray, “Robust H- infinity load frequency control in hybrid distributed generation system,”Int J Elect Power, vol. 46, pp.294–305, Mar. 2013.

[15] D. Lee and L. Wang, "Small-Signal Stability Analysis of an Autonomous Hybrid Renewable Energy Power Generation/Energy Storage System Part I: Time-Domain Simulations," in IEEE T Energy Conver, vol. 23, no. 1, pp. 311-320, March 2008.

[16] S. Coupland and R. John, "Geometric Type-1 and Type-2 Fuzzy Logic Systems," IEEE T Fuzzy Syst, vol. 15, no. 1, pp. 3-15, Feb. 2007.

[17] M. Ghaemi, S. K. Hosseini-Sani and M. H. Khooban, "Direct adaptive general type-2 fuzzy control for a class of uncertain non-linear systems," IET Sci Meas Technol, vol. 8, no. 6, pp. 518-527, Nov. 2014.

[18] M. H. Khooban, T. Niknam, M. Sha-Sadeghi,“A time- varying general type-II fuzzy sliding mode controller for a class of nonlinear power systems,” J Intell. Fuzzy Syst., vol.30, no. 5, pp. 2927-2937, Apr. 2016.

[19] T. Niknam Taher, M. H. Khooban, A. Kavousifard, M. R. Soltanpour, “An optimal type II fuzzy sliding mode control design for a class of nonlinear systems,” Nonlinear Dynam, vol. 75, no. 1-2, pp. 73–83, Jan. 2014.

[20] M. H. Khooban, A. Alfi and D. N. M. Abadi, "Control of a class of non-linear uncertain chaotic systems via an optimal Type-2 fuzzy proportional integral derivative controller," IET Sci Meas Technol, vol. 7, no. 1, pp. 50-58, January 2013.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

[21] L.A. Zadeh,“The concept of a linguistic variable and its application to approximate reasoning – I,” Inform Sciences, vol. 8, no. 3, pp. 199–249,1975.

[22] F. Liu,“An efficient centroid type-reduction strategy for general type-2 fuzzy logic system,” Inform Sciences, vol. 178, no.9, pp. 2224-2236, May 2008.

[23] N. N. Karnik, and J. M. Mendel,“Centroid of a type-2 fuzzy set,” Inform Sciences,vol. 132,no.1- 4,pp.195–220, Feb.2001.

[24] S. Coupland and R. John, "A Fast Geometric Method for Defuzzification of Type-2 Fuzzy Sets," IEEE T Fuzzy Syst, vol. 16, no. 4, pp. 929-941, Aug. 2008

[25] Hongwei Wu and J. M. Mendel, "Introduction to uncertainty bounds and their use in the design of interval type-2 fuzzy logic systems," 10th IEEE International Conference on Fuzzy Systems. (Cat. No.01CH37297), Melbourne, Victoria, Australia, pp. 662-665 vol.3, 2-5 Dec. 2001

[26] J. M. Mendel, "Comments on α- Plane Representation for Type-2 Fuzzy Sets: Theory and Applications," IEEE T Fuzzy Syst, vol. 18, no. 1, pp. 229-230, Feb. 2010.

[27] T. Masuta and A. Yokoyama, "Supplementary Load Frequency Control by Use of a Number of Both Electric Vehicles and Heat Pump Water Heaters," IEEE T Smart Grid, vol. 3, no. 3, pp. 1253-1262, Sept. 2012.

[28] M. Datta and T. Senjyu, "Fuzzy Control of Distributed PV Inverters/Energy Storage Systems/Electric Vehicles for Frequency Regulation in a Large Power System," IEEE T Smart Grid, vol. 4, no. 1, pp. 479-488, March 2013.

