TEST Engineering & Management

May-June 2020
ISSN: 0193-4120 Page No. 10632 - 10636

Performance Analysis of Advanced Load Frequency Control of an Isolated Micro Grid Using Artificial Intelligent Controller

Dr.V.Shanmugasundaram1, Mr.D.Kesavan2, Kousalya P3

Article Info
Volume 83
Page Number: 10632 - 10636
Publication Issue:
May - June 2020

Article History
Article Received: *19 November 2019*
Revised: *27 January 2020*
Accepted: *24 February 2020*
Publication: *18 May 2020*

Abstract:
This works presents a fuzzy based predictive approach for load frequency control of an isolated micro grid. A centralized model predictive control (MPC) is implemented in the micro grid. The parameter-driven MPC is made adaptable by adjusting its parameter using fuzzy controller. The proposed fuzzy MPC employs a rule-based fuzzy controller to fuzzify the tuning parameter. The closed loop system response obtained by the proposed fuzzy MPC has been found faster and adaptable for different scenarios in the system.

Keywords: *MPC, Micro Grid, Fuzzy controller.*

I.Introduction

The development in vastindustries due to technology development has raised the demand level of electricity. Hence, to meet out this demand, micro grid is the only solution which can provide electricity to rural areas.Thus the design of micro-grid of micro grid includes diesel generators RES and loads. The micro grid can be operated in both isolated/grid connected mode. If it is connected with grid, the loads to the microgrid is supplied by the connected electric system. In case of isolated mode, the load may vary according to the application where it is utilized.Recently, the development of V2G technology, the design of EV's are user friendly[1,2]. The power for the EV for operation can be supplied using micro-grid. The EV's connected to micro grid can provide an optimal solution to the load disturbance problem. It is proven that abort 95% of the wasremain idle in a day [3-5]. While applying V2G topology to these vehicles, they can acts as mobile storage units. This in turn will eliminate the load frequency control problem of a micro grid. Hence, this work focused on the design of damping controller for micro grid using EV.Hence, to overcome this problem, numerous research work has been carried out so far various controllers such asfuzzy [6,9], sliding mode controller [10,11]. Adaptive control [12,13] have been discussed so far. The hybrid combination of type 2 FL sets with modified harmony search algorithm is adapted to tune PI controller of LFC present in the MG it is easy to implement and it has the capability to handle uncertainties caused by system. But the selection of membership function plays a vital in the design of this system.A new LFC controller using multivariable predictive control (MGPC) was introduced. But due to large competition, it computations, the classical control [7,8] were not able to achieve the required satisfactory performance.Hence, to overcome these problems, this work proposed a fuzzy based controller scheme for LFC problem in micro grid which is connected with EVS. Thus the effectiveness of the proposed topology is confirmed by using MATLAB simulation.

II.METHODOLOGY

LFC model of MG with EV figure 1.depicts the block diagram representation of MG with DG, EV and load disturbances.

TEST Engineering & Management
May-June 2020
ISSN: 0193-4120 Page No. 10632 - 10636

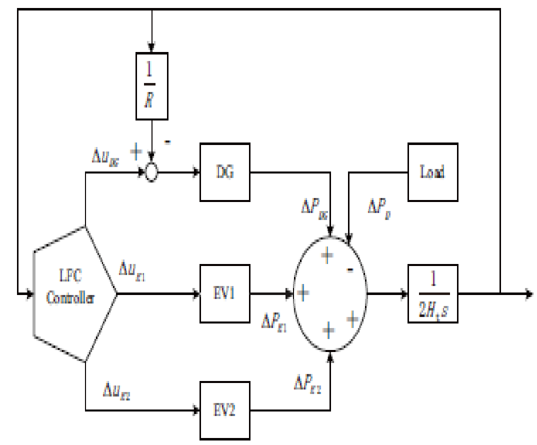

Figure 1.block diagram representation of MG

EV modeling

EVS play a vital role in the world. The equivalent model of EV for proposed controller is displayed in figure 2[14-16]. This can be used to charge /discharge the battery of EV.

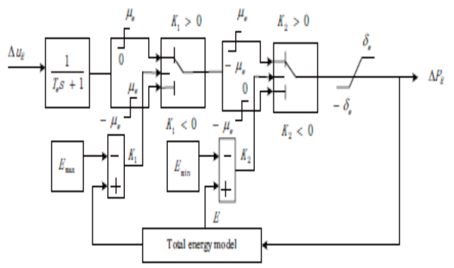

Figure 2. Equivalent model of EV

Thus the equivalent EV model can be denoted as

$$\Delta \dot{P}_E = \frac{1}{T_e}\Delta u_E - \frac{1}{T_e}\Delta P_E (1)$$

Subjected to constrains

$$-\mu_e \le \Delta P_E(t) \le \mu_e \quad (2a)$$

$$-\delta_{ej} \le \Delta \dot{P}_{Ej}(t) \le \delta_{ej}, j = 1,2 \ (2b)$$

Here,

$T_e -$ Time constant (EV)

$\Delta UE -$ LFC signal to EV

$\Delta PE -$charging/ discharging power

$\Delta PE = 0,$ EV- ideal state.

$\Delta PE > 0$ EV- discharging state

$\Delta PE < 0$ EV- charging state

DG modeling

ASDG exhibits faster starting and higher efficient, it was implemented in this work. When the demand fluctuates, the DG maintains the output by regulation its fuel[17].

Thus, the TF of the DG is represented in figure 3.

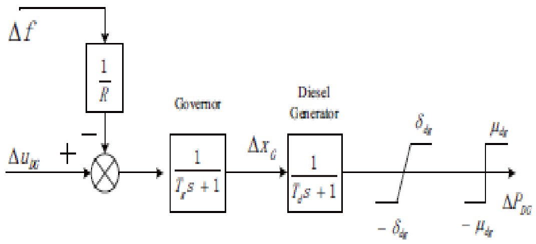

Figure 3. TF of the DG

$\Delta f -$ Deviation frequency

$\Delta UPG -$ LFC to DG

$T_g, T_d -$ Time constants

Thus, the modeling can also be expressed as

$$\Delta \dot{P}_{DG} = \frac{1}{T_d}\Delta X_G - \frac{1}{T_d}\Delta P_{DG} (3)$$

$$\Delta \dot{X}_G = \frac{1}{T_g}\Delta u_{DG} - \frac{1}{T_g}\Delta X_G - \frac{1}{RT_g}\Delta f (4)$$

Subjected to the constrains

$$-\mu_{dg} \le \Delta P_{DG}(t) \le \mu_{dg} \quad (5a)$$

$$-\delta_{dg} \le \Delta \dot{P}_{DG}(t) \le \delta_{dg} \quad (5b)$$

State space model of MG

The SS model of MG can be expressed as

$$\dot{x}(t) = A_c x(t) + B_{cu} u(t) + B_{cd} d(t) \ (6a)$$

$$y = C_c x(t) (6b)$$

$$A_c = \begin{bmatrix} 0 & \frac{1}{2H_t} & 0 & \frac{1}{2H_t} & \frac{1}{2H_t} \\ 0 & -\frac{1}{T_d} & \frac{1}{T_d} & 0 & 0 \\ -\frac{1}{RT_g} & 0 & -\frac{1}{T_g} & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{T_{e1}} & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{T_{e2}} \end{bmatrix} \quad (7)$$

$$B_{cu} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ \frac{1}{T_g} & 0 & 0 \\ 0 & \frac{1}{T_{e1}} & 0 \\ 0 & 0 & \frac{1}{T_{e2}} \end{bmatrix} \quad (8)$$

$$B_{cd} = \left[-\frac{1}{2H_t} \ 0 \ 0 \ 0 \ 0\right]^T \quad (9)$$

May-June 2020
ISSN: 0193-4120 Page No. 10632 - 10636

$C_c = [1\ \ 0\ \ 0\ \ 0\ \ 0]$(10)
$x = [\Delta f \Delta P_{DG} \Delta X_G \Delta P_{E1} \Delta P_{E2}$ (11)
$u = [\Delta u_{DG} \Delta u_{E1} \Delta u_{E2}]^T$(12)
$d = [\Delta P_D]$ (13)
$y = [\Delta f]$ (14)

Design of MPC

The frequency regulation can be attained by controlling the generator units. So diesel unit is taken as controlled variable in MPC formulation[18,19]. Thus, it is mathematically predicted as

$x(k+1) = Ax(k) + B_u u(k) + B_d d(k)$(15a)
$y_c(k) = C_C x(k)$(15b)
$\underset{\Delta U(k)}{min} J(x(k), \Delta U(k), m, p)$ (16)
$-\mu_{dg} \le \Delta P_{DG}(t) \le \mu_{dg}$(17a)
$-\delta_{dg} T_s \le \Delta P_{DG}(t) - \Delta P_{DG}(t-1) \le \delta_{dg} T_s$ (17b)
$-\mu_{ej} \le \Delta P_{Ej}(t) \le \mu_{ej}, j = 1,2$(17c)
$-\delta_{ej} T_s \le \Delta P_{EJ}(t) - \Delta P_{Ej}(t-1) \le \delta_{e,j} T_s, j = 1,2$ (17d)
$L\Delta U \le V$ (18)

Design of FLC

In MPC, the parameters such asT_s , control horizon, input parameters (tuning) has to be selected thoroughly. Hence, in order to obtain maximum control over MPC, FLC is implemented. The fuzzy logic controller is characterized as follows

- Seven fuzzy sets (NB, NM, NS, ZE, PS, PM, PB) for each input and output variables.
- Triangular membership function represented by µ is used because of its simplicity and ease of implementation.
- Implication using Mamdani-type min-operator
- Defuzzification using the centroid method.

The conversion of fuzzy values is shown in Figure 4a, Figure 4b and Figure 4c by the membership functions.

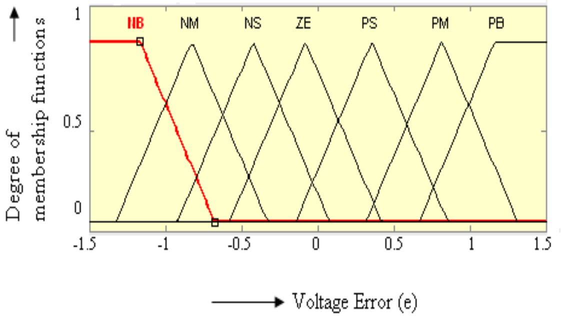

Figure 4a. Membership functions for *e*

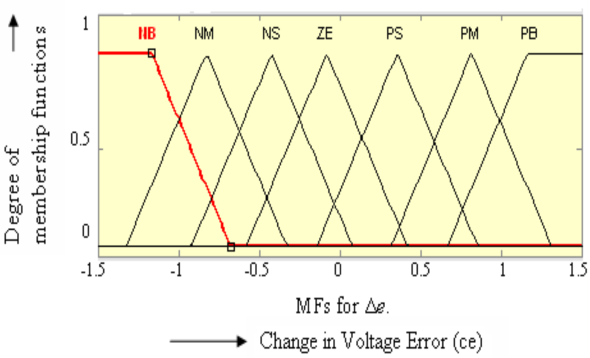

Figure 4b. Membership functions for Δ*e*

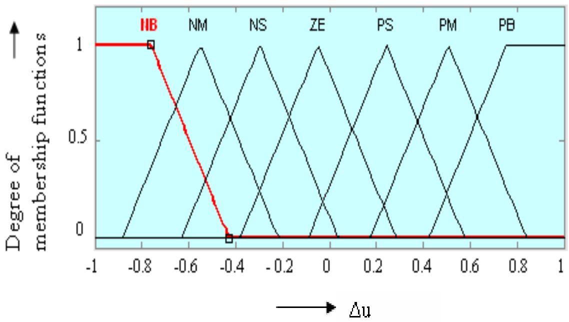

Figure 4c. Membership functions for Δu

The output of the system is computed with the rules formulated. The formulated rule table is shown in Table which contains 49 rules.

Table 1. Rule base of fuzzy controller

Δe/e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NM	NS	ZE	PS	PS	PM	PB

PM	NS	ZE	PS	PS	PM	PB	PB
PB	ZE	PS	PM	PM	PB	PB	PB

III.RESULTSAND ANALYSIS

The discussion of LFC in a typical MG is analyzed in this section. The FCM model developed using MATLAB is displayed in figure5.

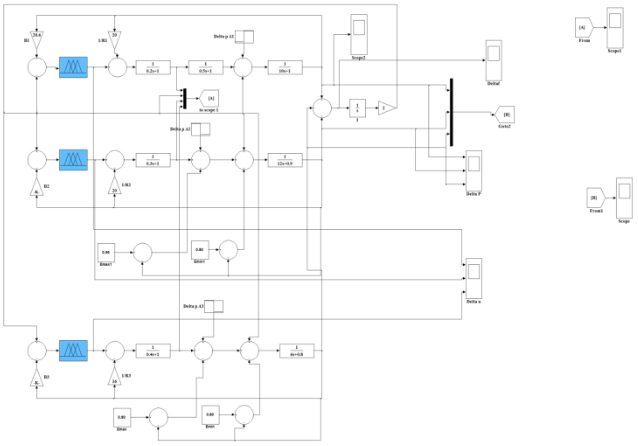

Figure 5. Simulation diagram of proposed topology

Figure 6shows the frequency deviation of MG with EVS.

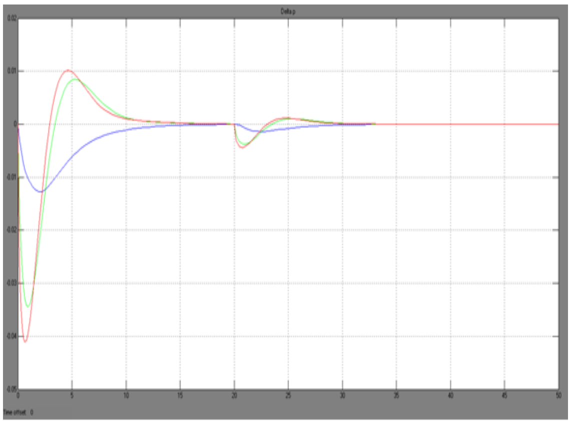

Figure 6.Frequency deviation of MG with EVs . (using fuzzy logic controller)

Figure 7shows the control input of the DG, EV1 and EV2.

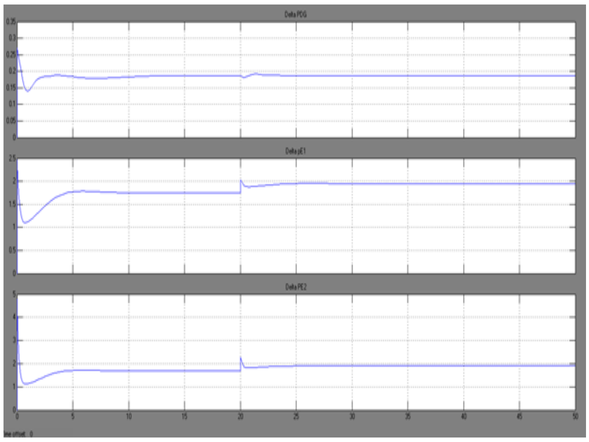

Figure 7. Control input to DG, EV1 and EV2.

Similarly, figure 8shows the power deviations occurred in DG, EV1 and EV2.

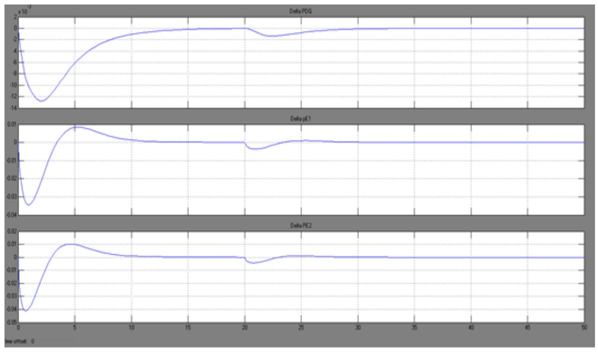

Figure 8. Power deviations occurred in DG, EV1 and EV2.

IV.CONCLUSION

This work proposed a new fuzzy MPC for effective LFC in a MG. FC is adopted with 49 rules. From the simulation results, it is confirmed that the proposed fuzzy MPC achieves faster response than the other controllers. Hence, it can be utilized for frequency regulation in smart grid applications.

References

1. D. Tran, Energy Management for Lifetime Extension of Energy Storage System in Micro-Grid Applications, IEEE Transactions on Smart Grid, 4(3): 1289–1296, 2013.
2. M. S. Mahmoud, N. M. Alyazidi, and M. I. Abouheaf, Adaptive intelligent techniques for microgrid control systems: A survey, International Journal of Electrical Power & Energy Systems, 90: 292–305, 2017.

May-June 2020
ISSN: 0193-4120 Page No. 10632 - 10636

3. H. Y. Guo, F. Liu, R. Yu, R. Yu, Z. P. Sun, and H. Chen, Regional path moving horizon tracking controller design for autonomous ground vehicles, Science China(Information Sciences), 60(1): 013201, 2017.
4. M. S. Elnozahy, and M. M. A. Salama, Studying the feasibility of charging plug-in hybrid electrical vehicles using photovoltaic electricity in residential distribution systems, Electric Power Systems Research, 110(110): 133–143, 2014.
5. L. E. Bremermann, M. Matos, J. A. P. Lopes and M. Rosa, Electric vehicle models for evaluating the security of supply, Electric Power Systems Research, 111(6): 32–39, 2014.
6. M. Singh, P. Kumar, and I. Kar, Implementation of Vehicle to Grid Infrastructure Using Fuzzy Logic Controller, IEEE Transactions on Smart Grid, 3(1): 565–577, 2012.
7. M. H. Khooban, T. Niknam, F. Blaabjerg and T. Dragicevic, A new load frequency control strategy for micro-grids with considering electrical vehicles, Electric Power Systems Research,
143: 585–598, 2017.
8. S. Pati,K. B. Mohanty, S. K. Kar, and S. Mishra, Voltage and frequency control of a micro-grid using a fuzzy logic controller based STATCOM equiped with battery energy storage system, inInternational Conference on Circuit, Power and Computing Technologies, pp. 1–7, 2016.
9. S. Leonori, E. D. Santis, A. Rizzi and F. M. F. Mascioli, Multi objective optimization of a fuzzy logic controller for energy management in microgrids, in Evolutionary Computation, pp. 319–326, 2016.
10. S. Pati, S. K. Kar, K. B. Mohanty, and S. Mishra, A sliding mode controller based STATCOM with battery storage for voltage and frequency stabilization in a micro-grid, in International Conference on Circuit, Power and Computing Technologies, pp. 1–7, 2016.
11. C. Mu, Y. Tang, and H.He, Observer-based sliding mode frequency control for micro-grid with photovoltaic energy integration, in Power and Energy Society General Meeting, 2016.
12. H. T. Zhang, Z. H. Chen, Y. J.Wang, M. Li, and T. Qin, Adaptive predictive control algorithm based on Laguerre Functional Model, International Journal of Adaptive Control & Signal Processing, 20(2): 53-76, 2006.
13. M. H. Khooban, T. Niknam, F. Blaabjerg, P. Davari and T. Dragicevic, A robust adaptive load frequency control for micro-grids, Isa Transactions, 65: 220, 2016.
14. X. J. Liu, L. X. Niu, and J. Z. Liu, Nonlinear multivariable supervisory predictive control, pp. 2779–2784, 2009.
15. P. S. V. Sagar, and K. S. Swarup, Load frequency control in isolated micro-grids using centralized model predictive control, in Power Electronics, Drives and Energy Systems (PEDES), 2016 IEEE International Conference on, pp. 3–16, 2016.
16. J. Yang, Z. Zeng,Y. Tang,J. Yan,H. He, and Y. Wu, Load frequency control in isolated micro-grids with electrical vehicles based on multivariable generalized predictive theory, Energies, 8(3): 2145–2164, 2015.
17. Z. M. Cheng, H. T. Zhang, M. C. Fan, and G. R. Chen, Distributed Consensus of Multi-Agent Systems With Input Constraints: A Model Predictive Control Approach, IEEE Transactions on Circuits & Systems I Regular Papers, 62(3): 825–834, 2015.
18. E. F. Camacho, and C. B. Alba, Model predictive control, Springer Science Business Media, 2013.
19. J. Yang, L. He, and S. Fu, An improved PSO-based charging strategy of electric vehicles in electrical distribution grid, Applied Energy, 128(3): 82–92, 2014.