# Analysis of ANN Based Enhanced Droop Technique for Appropriate Power Sharing of Parallel Connecting Inverters

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***Abstract :-*** **Microgrid has recently emerged as the most effective approach for deploying and controlling distributed generation (DGs) in a vast power system. In the microgrid, maintaining constant frequency and voltage for continuous load-sharing is difficult in island mode. Simultaneous inverter module processing is a solution for improving inverter stability, efficiency, and redundancy in microgrids. An autonomous microgrid's key aim is to keep the voltage level normal during a load shift. Island mode can understand the load sharing of equivalent DGs in Droop control and an Enhanced Droop control approach is also executed. And then, The simulation of two inverters in island mode was implemented in MATLAB/SIMULINK. Additionally, the findings show the feasibility and precision of the control scheme.**

***Keywords— Inverter parallel control, Droop control, ANN***

## I. INTRODUCTION

With the rapid growth in power technologies, a better control strategy is needed to regulate the frequency and voltage at the same time as the inverter is interconnected to ensure proper power-sharing of the inverter. Droop management is an approach to the proper sharing of active and reactive power to consumers [1]. Microgrid load is predominantly resistive to low voltage [2]. Microgrid has two grid-connected (GCM) and autonomous modes (AM). In GCM, the frequency can be stabilized by the utility system, the only issue being that when the grid is disconnected from the microgrid frequency, it is impossible to recover the nominal value [3].

Recently, The parallel approach to monitoring the operation of the Inverter typically uses the master-slave management method peer to peer method and droop management [4]. Master-Slave Management Method Needs interconnections for control that restrict distance between the distributed power source, and the noise is added, then its technology has a range of drawbacks. Various methods are presented to control voltage and frequency. In [5,6], a Virtual impedance loop by virtual transformation power frame and traditional droop regulation is used to restore frequency after a sudden change in load. In this approach the principle of bifurcation in the scheduling of the drooping characteristics intended for the frequency Regulation in isolated microgrids [6]. Derivative term and adaptive regulation method is used for fast response in dynamics and having better transient response. In this method, Static drooping features paired with an adaptive transient Droop function and 2-Degree of freedom controller is been proposed [7-9]. In literature, various power-sharing techniques have been proposed and implemented by the researchers as seen above.

The technique has several disadvantages such as large weak control of voltage, hard to select the right coefficient for integral-derivative, sharing of power in non-linear loads are not present, and sharing of reactive power is not seen. In this paper, the test system is shown in section II. The remainder of the paper is coordinated as follows: Comparison of Droop and FRL is presented in section III. Section IV is focused on the Simulink model. In section V simulation results are discussed. Finally, in section V, a conclusion on the obtained results and future work has been discussed.

## II. TEST SYSTEM

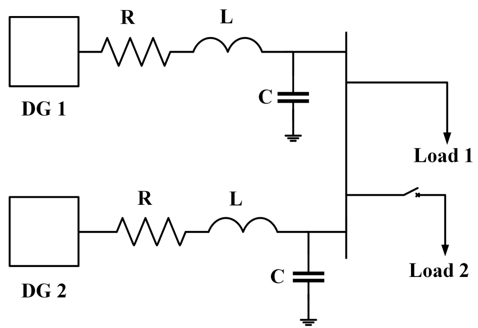



Fig. 1. General structure of test system

Consists of two DGs connected in parallel to serve the load. The droop control technique is used to share the power of the inverter connected in parallel having an LC filter connected with both the DGs. Both the VSCs are in PQ control mode, P-f and Q-E droops are applied. A PLL is used to obtain the PCC voltage as well as frequency.

## III. DROOP CONTROL

Droop control is used in the parallel operation of the inverter without contact between the system. It is advantageous if any inverter fails to operate, the system would not be disturbed. In an inverter, inertia is not present and frequency will decrease with an increase in load, the inertia is emulated by the technique called droop control.

$$\omega = \omega_{ref} - M(P - P_n) \quad (1)$$

$$U = U_{ref} - N(Q - Q_n) \quad (2)$$

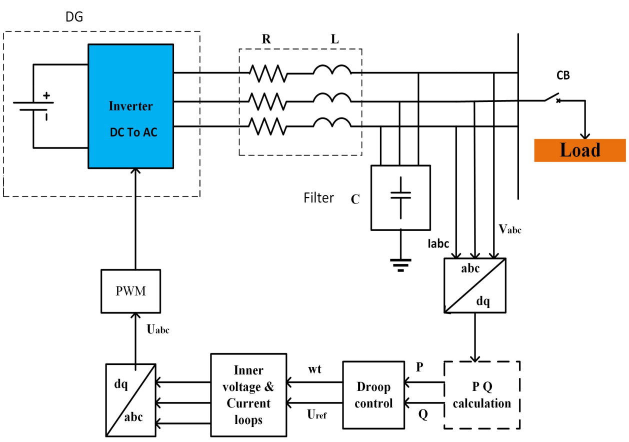


Fig. 2. Droop control technique

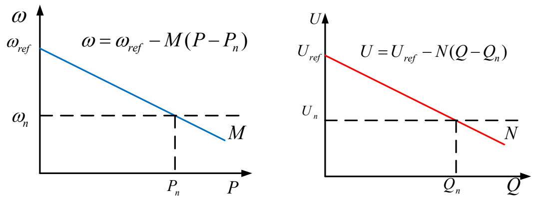
Droop control is simple to implement and a more reliable shown in Fig.2. Droop control frequency is related to active power and voltage is related to reactive power shown in equations (1) and (2).

Where ω and U are frequency and output voltage amplitude and are the references active and reactive power and M and N are the droop coefficients. Droop is based on P/f and Q/E control. If load demand is increased at the consumer's side then there is a change in frequency and voltage to make the system stabilize droop control technique is used by setting the droop coefficients. Power must be calculated by equation (2). According to equations, the Droop control technique for a parallel-connected inverter is shown in Fig.3. If multiple inverters are linked, the same will apply to another inverter. Droop Characteristics are shown in fig.1 (a) and (b). Apparent power delivers to PCC from both the inverters equation (3).

$$S_{total} = P_{inv} + Q_{inv} \quad (3)$$

$$P = \frac{3}{2}(V_d * I_d + V_q * I_q) \quad (4)$$

$$Q = \frac{3}{2}(-V_d * I_q - V_q * I_d) \quad (5)$$



(a) (b)

Fig.3 (a) P-F characteristics (b) Q-V characteristics

Active and reactive power transferred to the load by DGs is calculated by equations (4) and (5). If there is a steady state then (4) and (5) can be rewritten as (6) and (7)

$$P = \frac{3}{2}(V_q * I_q) \quad (6)$$

$$Q = -\frac{3}{2}(V_d * I_q) \quad (7)$$

### A. *Droop control with FRL (Enhanced)*

Droop control using the FRL approach is used to make the system more robust if there is a sudden shift in load it is applicable on all forms of loads linear (resistive) and non-linear (inductive). To measure frequency and voltage error, an External loop is added with a low pass filter and fed to the controller to minimize the error and send it to the droop controller shown in fig. 4. For pure resistive load output impedance Zo = Ro and for inductive and resistive both Zo = Ro + jXo, on basis of output impedance power is supplied to the load. FRL gives better results for both types of load.

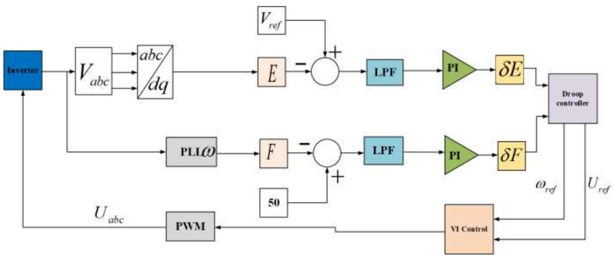


Fig. 4 Droop control with FRL

### B. *Enhanced Droop control with ANN*

Artificial neural networks (ANN), fuzzy logic, and a various algorithms have recently become popular for solving industrial problems and it helps in various other problems mainly in optimization, price forecasting, and system modeling, in replacement of PI controller for better performance of the system and in many others. One of the most important intelligent approaches in microgrid system and control is artificial neural networks (ANN) which is widely using in now a days [10,11]. The ANN has three layers: an input layer, a hidden layer, and an output layer. The assigned input signal is routed layer by layer through the network. Each node's relations are weighted. The input and hidden layers weights are represented by $W^{ih}$, while the hidden and output layers' weights are represented by $w^{ho}$. These weights are adjusted in the training period. The output of the secret layer neurons is arithmetically expressed by equation (8).

$$\psi_h = \frac{2}{1+\exp(-2*(W^{ih}*x_i+b^{ih}))}-1 \quad (8)$$

For i=1,2 and h=1,2,..10

Mathematically representation of networks output is shown by equation (9)

$$Y_1 = w^{ho}*\psi_h + b^o \quad (9)$$

## IV. Simulation Model

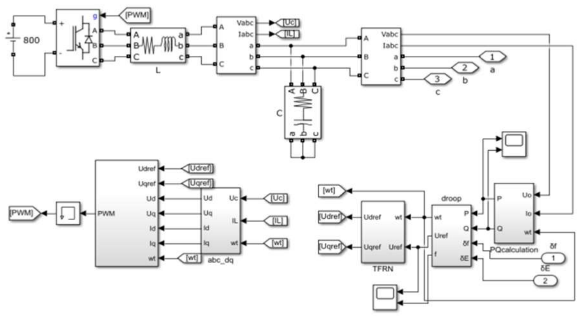



Fig. 5. Simulink model of DG with controlling

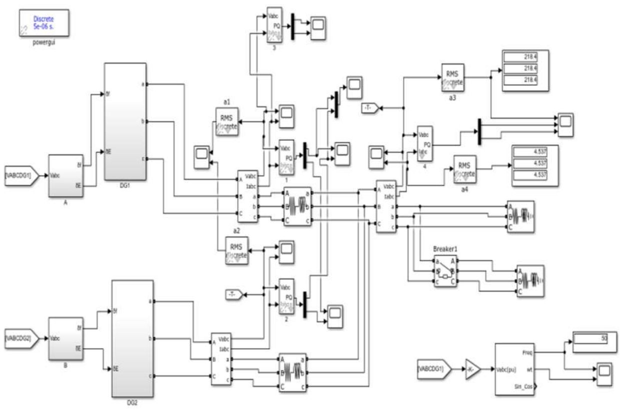


Fig. 6. Simulink model of a test system

As seen in Figure 1, the DG is connected to an LC filter and has inverter control. First, the $V_{abc}$ and $I_{abc}$ frames are convert to DQ frames, then the active and reactive power of the system is measured after that droop control is performed, and then finally modulated signal is sent to the inverter via PWM.

The tested system as shown in fig. 6 is been used to take simulation results, two DGs connected parallel two serve a single load.

## V. Simulation Results

Both methods have been verified on the test system as two inverters connected parallel with a single load and after 2sec 5kw load is added then results are taken. Both Inverters are of equal ratings having input Dc voltage 800V and both the inverter shares equal power to load. Initially, 5kw load is applied after 2sec load is switch to 10kw and results are taken.

All the parameters of the line, inverter are shown in Table I.

Fig. 7–8 gives the information of regression and performance plot. The training phase is depicted as a graph. As seen in Fig.7, there is the mean square error for each variable is gradually decreasing. The mean square error eventually hit At the 13th epoch, the minimum value was 0.00000022997. With the regression plot as shown in Fig.8. With the help of correlation coefficient value (R), the ANN has been properly trained for the task at handsets of data Validation and final evaluation. The network's success is also considered to be satisfactory (If R=1, it means there is no correlation at all.)

Active power shares by both the DGs/inverter in conventional droop are shown in Fig. 9. DG1 shares more active power in comparison to DG2 but droops coefficients for both the DGs are the same they must share equal power. Active power shares by Both the DGs/inverter in enhanced droop technique is shown in Fig 10, before 2-sec both the shares equal active power but after 2-sec both the DGs not shares power equally they are full fill the requirement of load but not sharing an equal amount of power. As seen from fig 11 active power before 2-sec and after 2-sec both the DGs shares an equal amount of active power after 2-sec initially it is taking time to share equal power but after 3-sec share approximately equal power.

Table I. System Parameters

| Parameters | Inverter 1 | Inverter 2 |
|---|---|---|
| DC source | 800V | 800V |
| Carrier Frequency | 10kHz | 10kHz |
| Droop coefficients | M=0.0001 N=0.002 | M=0.0001 N=0.002 |
| Ref. Frequency | 50Hz | 50Hz |

Active and reactive power at the point of common coupling (pcc) is also improved as we have seen in Fig.12 and Fig.13, not actual proper power we are getting at pcc in conventional droop but it is improved in enhanced and enhanced with ANN.

Proper frequency must be maintained at PCC as we have seen from results FRL frequency restores exactly to 50Hz compare to the conventional droop technique. Frequency is also seen in Fig 14 restores to 50Hz in case of enhanced and enhanced with ANN.

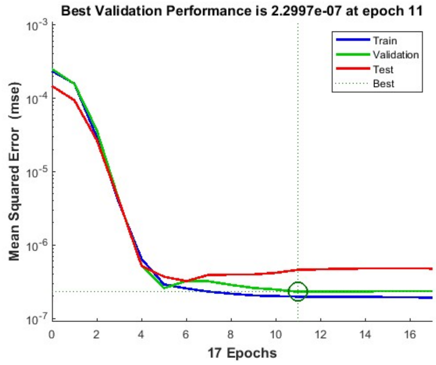



Fig. 7. Regression Plot

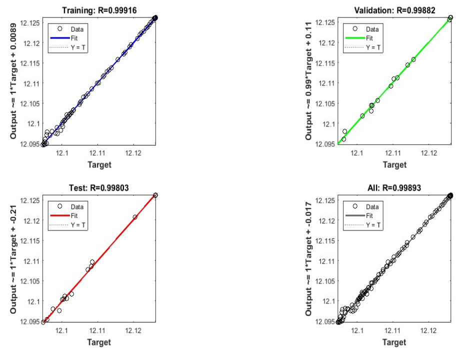



Fig. 8. Performance Plot

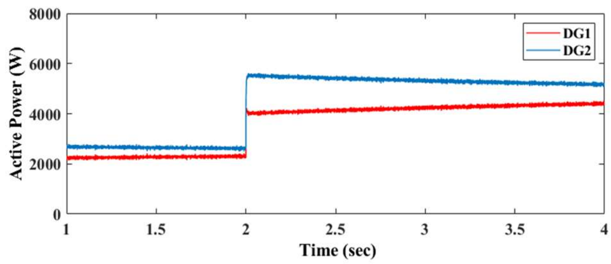



Fig. 9. Active power share by both the DGs in conventional droop

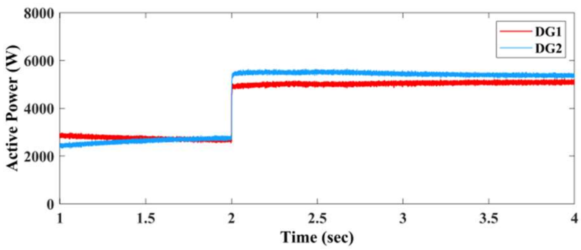



Fig. 10. Active power share by both the DGs in enhanced droop

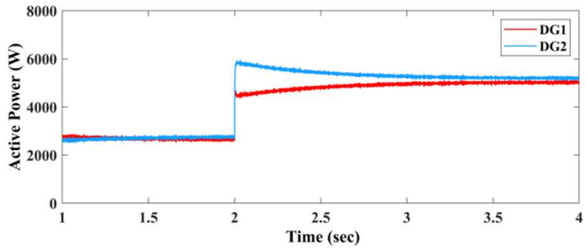



Fig. 11. Active power share by both the DGs in enhanced with ANN

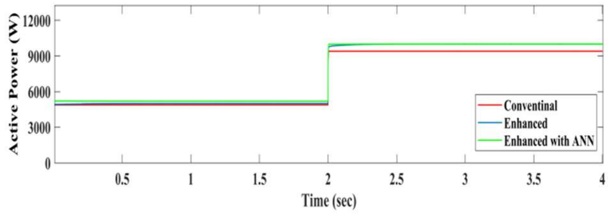



Fig. 12. Active power at pcc

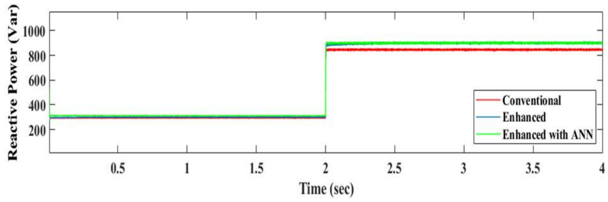



Fig. 13. Reactive power at pcc

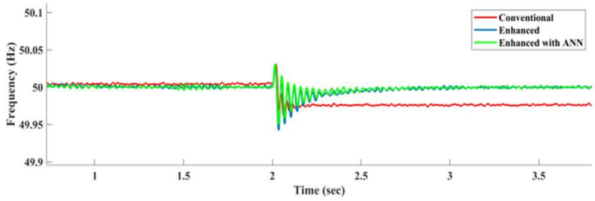



Fig. 14. Frequency of the system

## VI. Conclusion and Future Work

For autonomous microgrids, a distinction between droop control and droop with the FRL approach is presented in this paper. The findings of the simulation show that the frequency in FRL is improved than with the conventional droop control technique, after the load shift 2-sec frequency is restored to 50Hz for resistive load. Moreover, sharing of active power and reactive power is also improved at PCC. The outcomes of the simulation are obtained using MATLAB/Simulink. There are so many options are available for future research for this study. The approach used here can also be applied to other complex networks.

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