Article

Voltage and Frequency Stability in Restructured Power System with Demand Side Load Shift

Mahima Vijay[1], RK Gupta[2], Nagendra K Swarnkar[3]

Abstract

An advanced hybrid technique for reliability improvement of restructured power system using artificial intelligence algorithms and droop logic, demand side load management with hybrid renewable and grid power generation has been proposed. MATLAB along with GUIDE (Graphical User Interface Design Environment) has been used for implementing the model which represents the demand side management.

Keywords: AC induction motor, Dynamic breaking, Droop control, Field oriented control, Regenerative breaking

Introduction

The main objective of a power system is to provide reliable and continuous electricity for customers. In restructured power system, it is possible to design a suitable program generation for individual GENCOs which can reduce the effect of contingencies. Around the world, the shortage of transmission system capacities along with the need for reliable power supply is causing an increased interest in Distributed Generation. These units are of limited size (100MVA or less) and can be connected directly to the network or distribution on the customer side. Recent studies have predicted that by year 2010, DG will account for up to 25% of all new generation.[6]

Hence based on these predictions the DG devices can be strategically placed in power system to achieve well known technical benefits like grid reinforcement, reduction in power loss and on-peak operating costs, improvement in voltage profiles and load factoring, deferment of system upgrades, improvement of system integrity, reliability and efficiency, Security assessment of large scale, non-liner power grids.[2,4]

Indian Power Sector Scenario

There are some facts about the scenario of power sector in India.[5]

For decreasing or eliminating the supply demand gap some methods are already given, which included renovation and modernization of generation sector, development of national grid, strengthened role of renewable, Demand side management, restructured power system etc.[3,6-10].

Here in this article we have used droop control and artificial neural networks for the demand side management and have used MATLAB software including GUIDE (Graphical User Interface and Design Environment).[1]

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Droop Control

In transmission lines, the real (P) and reactive powers (Q) are designed as:-

$$P = (v_1 * v_2)/x * \sin\delta \quad (1)$$

$$Q = (v_1^2/x - v_1 * v_2/x) * \cos\delta \quad (2)$$

Droop control is a control strategy commonly applied to generators for primary frequency control (and occasionally voltage control) to allow parallel generator operation. In the above mention equations residence (R) is neglected for an overhead transmission lines as it is much lower than inductance (L). Also the power angle δ is lesser so:-

$$\Delta = (x * P)/(v_1 * v_2) \quad (3)$$

$$v - v_2 = x * Q/v_1 \quad (4)$$

Therefore sin δ = δ and cos δ=1

Hence from the above equation (3) and (4), it is clear that the power angle δ can be controlled by regulating real power P. Also the voltage v can be controlled through reactive power Q. Dynamically the frequency control leads to regulate the power angle and this in turn controls the real power flow.

Finally, the frequency and voltage amplitude of micro grid are manipulated by adjusting the real and reactive power autonomously. As a result, the frequency and voltage droop regulation can be determined as:[1]

$$f - f_0 = k_p(P - P_0) \quad (5)$$

$$v - v_0 = k_q(Q - Q_0) \quad (6)$$

Where f, v = the frequency and voltage at a new operating point. P, Q= Active and reactive power at a new operating point, f_0, v_0= base frequency and voltage, P_0, Q_0= temporary set points for the real and reactive power, Kp, Kq= droop constant. The block diagram of droop control can be given as:

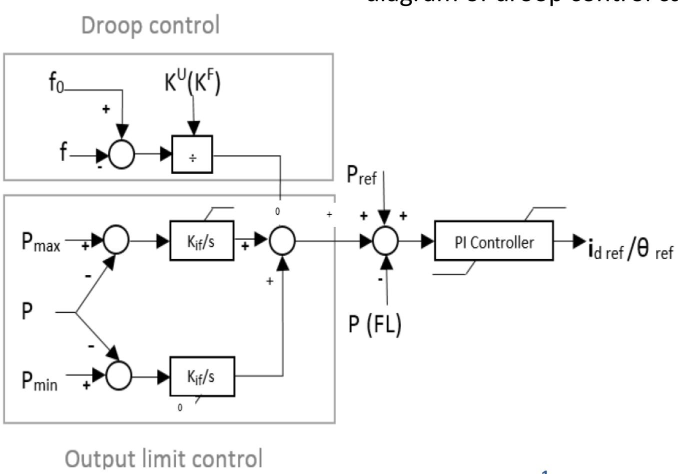

Figure 1.Droop Control Block Diagram[1]

The equation 5 and 6 are plotted in the characteristics as:

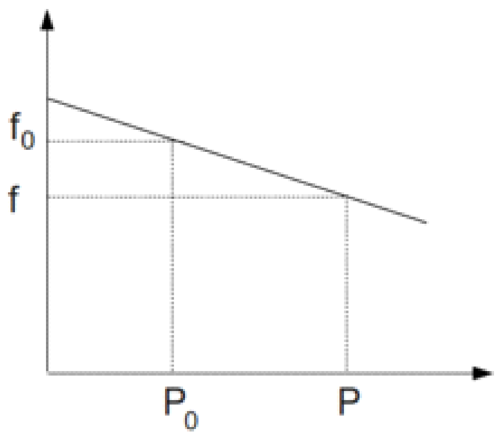

Figure 2.Frequency Droop Characteristics[1]

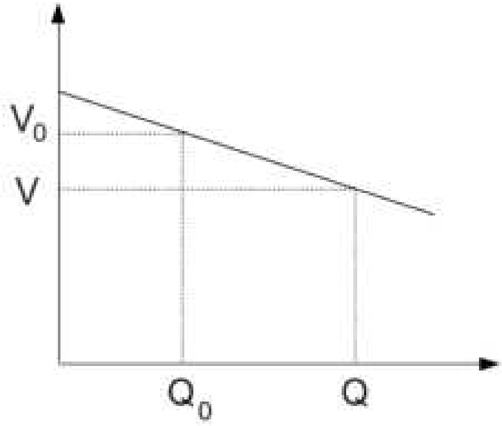

Figure 3.Voltage Droop Characteristics[1]

Work and Model Description

Here I am giving a simple explanation about how this modal works and what innovation I have done using this MATLAB simulating modal.

as shown in model, as a source of supply we have three options, these are given in left side of the modal in which two of them are renewable energy sources, solar and wind and the third one is grid energy, which is taken as a optional resource.

Now as loads we have three tier here, tire 1, tire 2, tire3 .Here each tire have 6 load so that number of loads would be 6*3=18 in the system. In each tire two loads are of 100W, two are of 500W, and the remaining two are of 1000W. If we make calculation of them the total load in one tier would be:-

(100*2) + (500*2) + (1000*2) = 3200W

As I have mentioned that we have 3 tire in the system so the total load would be 3200*3 = 9600W.

We have two renewable in the system solar and wind. Here the maximum power solar can deliver is 1KW and the maximum power wind can deliver is 2KW. So the total renewable power can be delivered would be 3KW. So if load require power up to 3KW this power would be sufficient to supply but as we know that total load is 9600W which is much more than the total power which can be delivered by the renewable.

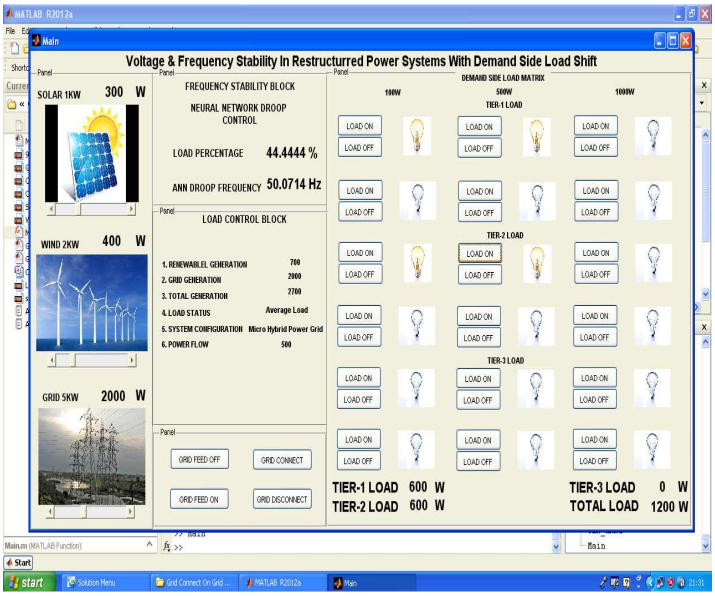

Figure 4.Main Model of Work

As the renewable generation is 3000, and grid generation is zero, so the total generation would be 3000 but if we add grid generation, then the total generation would be 3000 + (we take from grid as load demand).

In the modal above four buttons are given which are grid connect, grid disconnect, grid feed on and grid feed off. When we click on grid connect the grid would be connected and the supply can be given to the load and the supply a grid can give, shows by the range scale as shown in figure. Here the total power grid can supply is 5KW. Then if we click on grid disconnect, grid would be disconnected from the system. Then the only supply that the system can take would be from renewable. Here total load is 9600W and the total supply is 8000W including the grid power. These parameters are taken like that because we also have to show that when system is overloaded the load would automatically be disconnected priority wise.

Here two switches are also given, grid feed on and grid feed off. These are useful in the manner that whenever the grid supply is on and demand is less then supply the extra amount of power can be delivered to the grid. And to off this mode another switch is grid feed off.

Results

Artificial neural network works on the basic principle of biological neural network. Here we have used artificial neural networks to control inverter frequency to simulate droop, and allow frequency stability of system.

Table 1.Load and Frequency (Micro Islanding Mode)

S. No.	Load percentage	Frequency
1	0	51.2
2.	10	50.8
3.	20	50.6
4.	30	50.2
5.	40	50.1
6.	50	50.0
7.	60	50.0
8.	70	50.0
9.	80	50.0
10.	90	49.5
11.	100	49.1
12.	110	49.0
13.	120	48.8
14.	130	48.7
15.	140	48.6
16.	150	48.5

Table 2.Load and Frequency (Grid Tie Mode)

S. No.	Load percentage	Frequency
1.	0	50.8
2.	10	50.7
3.	20	50.6
4.	30	50.4
5.	40	50.1
6.	50	50.0
7.	60	50.0
8.	70	50.0
9.	80	49.9
10.	90	49.5
11.	100	49.3
12.	110	49.2
13.	120	49.1
14.	130	48.9
15.	140	48.8
16.	150	48.8

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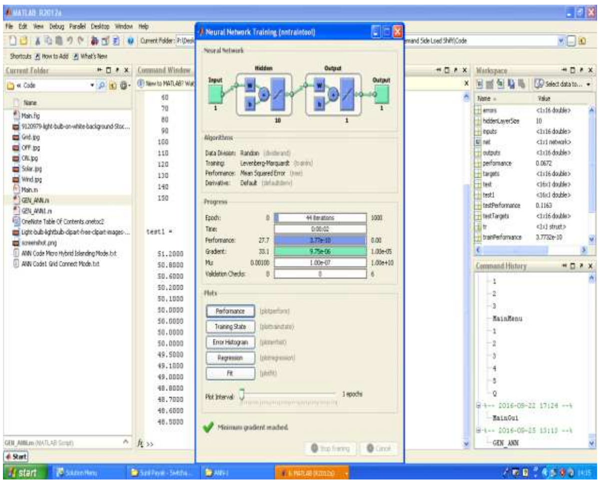

Figure 5.ANN Training Results of Hybrid Micro Islanding Mode Droop Control

Figure 5 shows the ANN training results in hybrid micro islanding mode, using the neural network training tool.

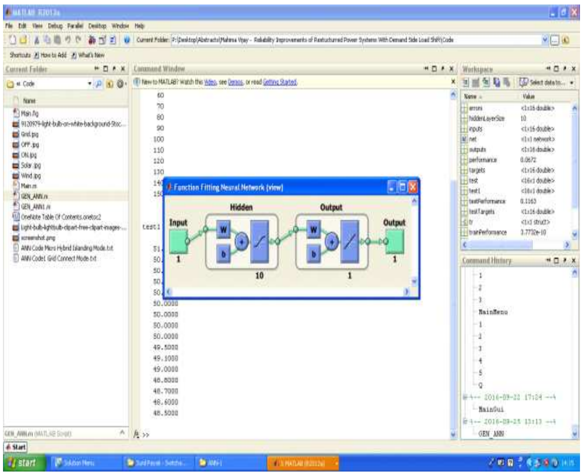

Figure 6.Function Fitting Neural Network

Figure 6 shows function fitting neural network, it has 1 input, 10 hidden layer and 1 output.

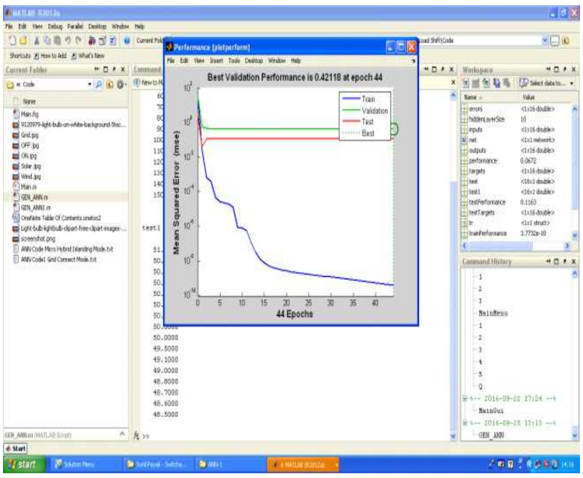

Figure 7.Prformance of ANN Training Results in Hybrid Micro Islanding Mode Droop Control

Figure 7 shows the performance of ANN training results in hybrid micro islanding mode droop control. It has train, validation and test. Time is 4 sec, validation 0.42118 sec and test in 0.2 sec.

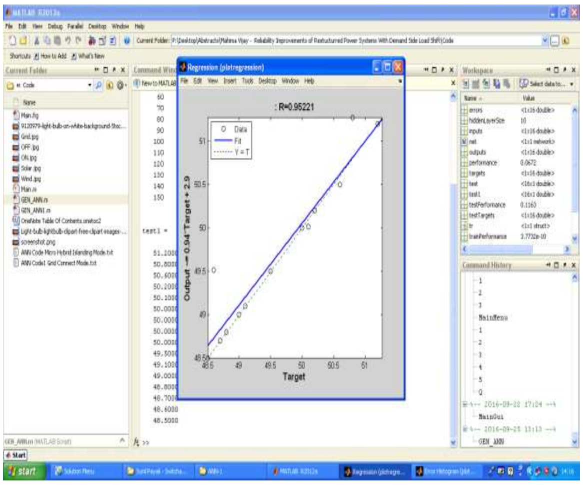

Figure 8.Regression of ANN Training Results in Hybrid Micro Islanding Mode Droop Control

Figure 8 shows the regression of ANN training results in hybrid micro islanding mode droop control. Target output is 51.5.

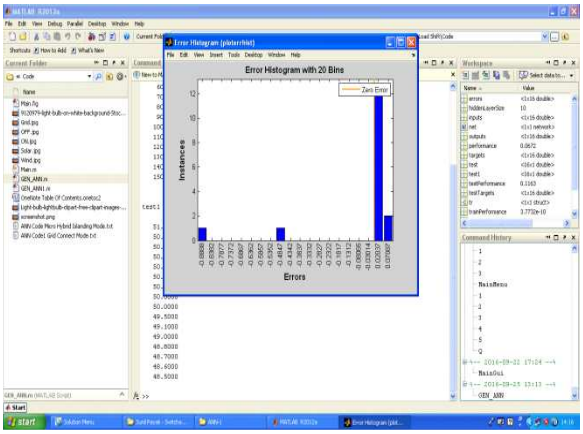

Figure 9.Error Histogram

Figure 9 shows the error histogram, and the graph is plotted between error and instances. At error -0.8888, instances is 1. At error -0.02037, instances is 13.

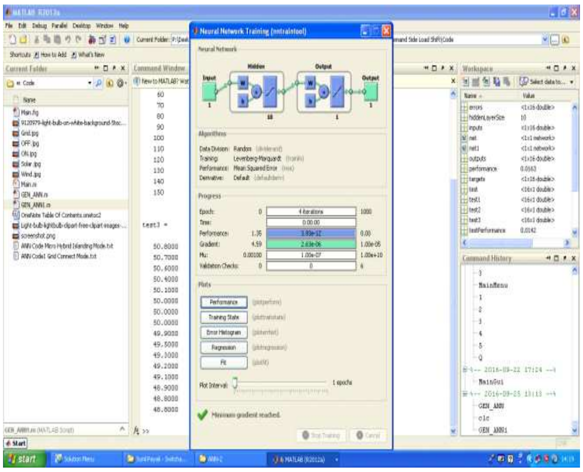

Figure 10.Consolidated Parameters of ANN Training in Grid Tie Mode

Figure 10 shows the consolidated parameters of ANN training in grid tie mode, using the neural network training tool.

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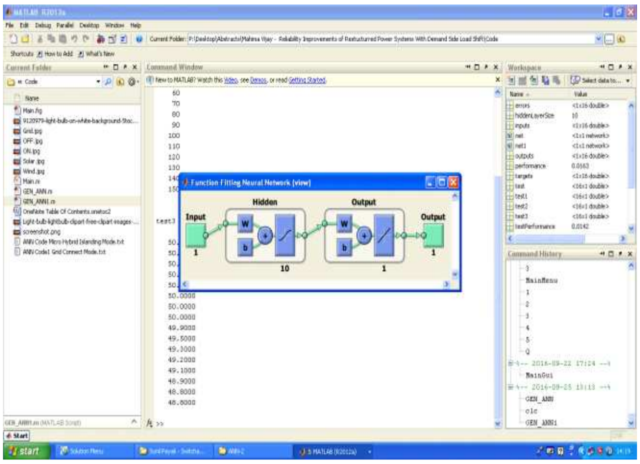

Figure 11.Function Fitting Neural Network

Figure 11 shows the function fitting neural network, has 1 input; 10 hidden layers, 1 output layer and 1 output.

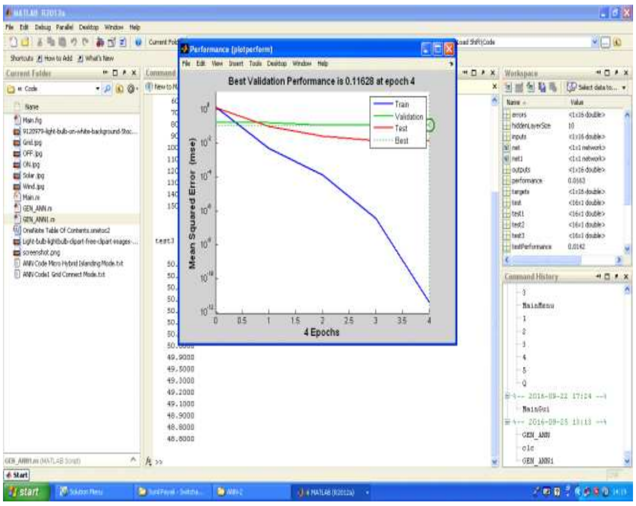

Figure 12.Performance of ANN Training Results in Grid Tie Mode Droop Control

Figure 12 shows the performance of ANN training results in grid tie mode droop control. It has train, validation and test. Time is 4 sec, validation 0.11628 sec and test in 0.7 sec.

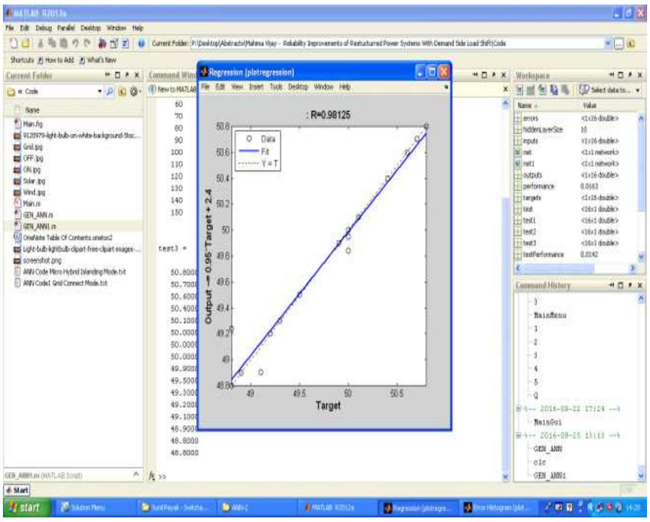

Figure 13.Regression of ANN Training Results in Grid Tie Mode Droop Control

Figure 13 shows regression of ANN training results in grid tie mode droop control.

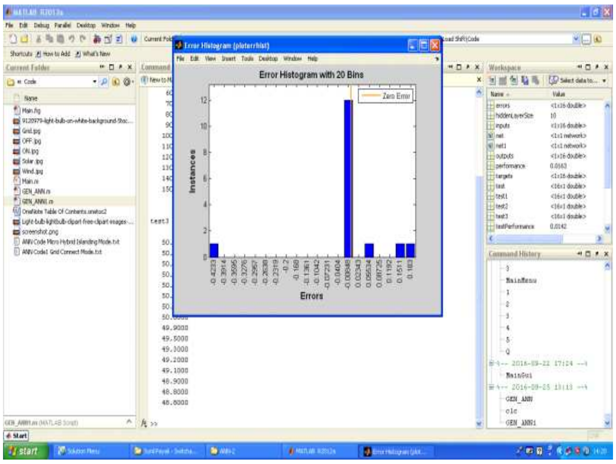

Figure 14.Error Histogram

Figure 14 shows the error histogram and the graph is plotted between errors and instances. At error -0.4223, instances is 1. At error -0.00848, instances is 12.

The condition of average load, under load and overload can be found by switching on and switch off the load of tiers and by the process given in project description.

Conclusion

In this article we have provided a new and unique algorithm for demand side load management problems along with integration of various modes of operation like Hybrid micro grid islanding mode, grid tie mode with grid feed and without grid feed. Also the proposed scheme provides for priority of local consumption of renewable energy and grid. As per high proliferation of grid feed inverter, the frequency load balance has been deterring recently, thus we have proposed a highly reliable artificial neural network droop control to simulate droop control by varying inverter frequency according to load. We have also taken care for training of artificial neural network in different modes as hybrid micro grid islanding mode and grid tie mode, because both of them exhibit different load frequency behaviours.

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