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MODELING, ANALYZING AND SIMULATION OF POSSIBILITIES IN A SMART GRID TOPOLOGY

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Abstract- The main aim of this paper is to simulate a simulate a smart grid using Matlab simulation work space in order to analyze the power and frequency of a smart grid, that consist of synchronous generators, wind farms and a solar power plant. This analysis will make us able to calculate the maximum possible load that can be connected to the buses, and even give us the idea of correct way of connection between the power units in the discussed network. It is clear that, a smart grid is one the newest network all over the world, so that this type of network must have an extensive power delivery that have a two-way connection between the buses and the units. It means the all the units must sense each other in order to create a smart controlled network.

Keywords: Wind Farms, Solar Plant, Microgrid, Smartgrid, Active Power, Load Analysis.

I. INTRODUCTION

A smart grid as a next generation network consist of some low capacity renewable distributed generators as the distribution network and some high capacity central power generators (commonly thermal plants) that are linked to each other using a bi-directional connection, makes the network able to control the participation of costumers as the production unit (energy sources) or a load, so the demand will be smartly managed, so we will have real time information about the optimal operation and the performance of a smart network [1]. A smart grid in general is divided into three technical categories called Smart Infrastructure System, Smart Management System and Smart Protection System [2]. These categories also have subcategories and the simulation of this paper is based on one of the parts of the Smart Infrastructure System named Smart Power generation [3].

The main parameters of studying network stability are Frequency and Active power, this network may be a conventional power grid, microgrid or any virtual power plant [4]. The frequency control analysis has already done in Isolated Microgrids [5]. Micro grid is designed to operate in grid connected and isolated mode [6]. Storage elements are needed to control the frequency in isolated micro grid [7].

Because of controlling frequency on different rating of storage and integrating a lot of kinds of devices are used, so, very complex situation will be created [8]. for the realization of a virtual power plants, the active and reactive power control of the electronically interfaced DG Sources also been done [9].

In this research paper only the power flow analysis in virtual power plant having small capacity has been depicted. Now days, for reaching a highly stable network, smart grids are a technically combination of conventional and distributed generation. So, the active power can be controlled and the reliability of network will be increased.

In this paper, we try to synchronize this two types of power plant. Four thermal synchronous generators are used to building the conventional unit and a wind farm, including 6 units of wind power plant and a solar plant is used to forming the distributed generation unit, both units are sharing the maximum percentage of the power generation in their respective field. The distributed unit consist of wind farm and solar farm is connected to the major load and is treated as a smart grid. In order to build the simulation, model we use a synchronous generator machine for the thermal unit and a doubly fed induction generator (DFIG) for the wind farm [10].

Each thermal plant is to produce 900 MW of rating power and the wind power plants have 12 MW of rating power. Because the transmission voltage is 230 KV. So, the thermal power units generate 13.8 KV that is step-up to 230 KV and the generated voltage of wind power unit is 575 KV and again step-up to 230 KV. The model of simulation divided the conventional power plant into two systems each have two thermal units having 900 MW capacity and for each area we have a system control.

II. METHODS OF CONTROLLING ANALYSIS OF ACTIVE POWER AND FREQUENCY

Controlling and analysis of active power and frequency of the simulated power system, is explained by two methods, named as following:
(i)- By ALFC method, in this method we automatically control the load frequency of synchronous generators, and the active power values of each individual busbar is measuring.

(ii)- The second way is again using ALFC method to controlling frequency of DFIG unit and measuring active power values at each individual busbar.

A. Controlling the Frequency and Active Power of Synchronous Generators

The load fluctuations cause decreasing and increasing of frequency. So, we use ALFC method in both single and double area loop.

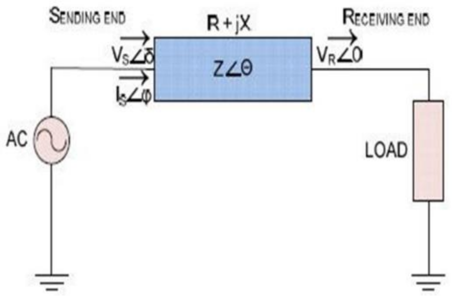

Figure 1. Theoretic model of synchronous generator

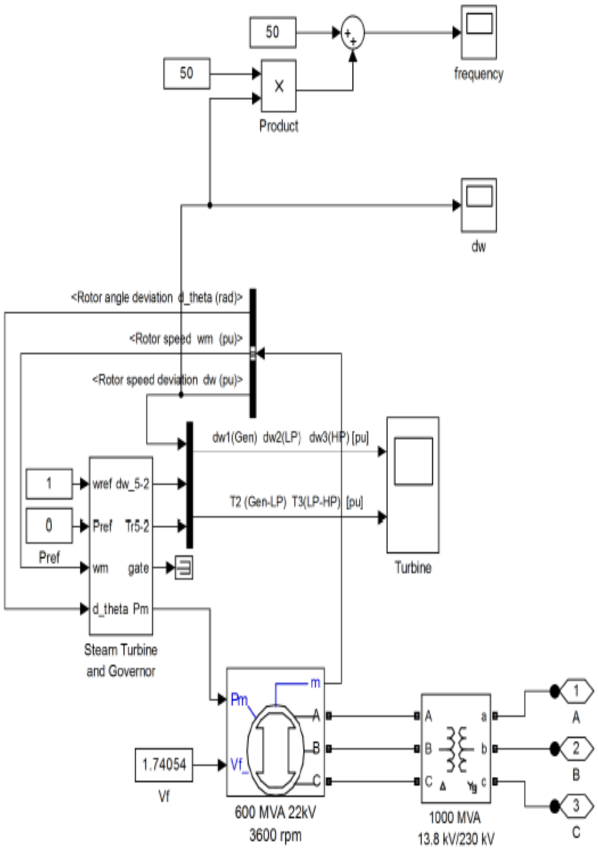

Figure 2. Simulink model of synchronous generator

The automatic frequency control loop is used to control the frequency, in thermal power plants, which includes loads, generators, governor and prime mover. During normal operation the real power transferred over the tie line, for a two area system, is given by

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} \sin\delta_{12} \tag{1}$$

where, $X_{12} = X_1 + X_{tie} + X_2$ and $\delta_{12} = \delta_1 - \delta_2$.

For a small fluctuation in the tie-line flow:

$$\Delta P_{12} = \left.\frac{dP_{12}}{d\delta_{12}}\right|_{\delta_{12}} \quad , \ \Delta\delta_{12} = P_{s12}\Delta\delta \tag{2}$$

$$\Delta P_{12s} = P\left(\Delta\delta_1 - \Delta\delta_2\right) \tag{3}$$

$$\frac{\Delta\Omega(s)}{-\Delta P_L} = \frac{\left(1+\tau_g s\right)\left(1+\tau_T s\right)}{\left(2Hs+D\right)\left(1+\tau_g s\right)\left(1+\tau_T s\right)+1/R} \tag{4}$$

The tie-line power fluctuation then takes in the form of Figure 3.

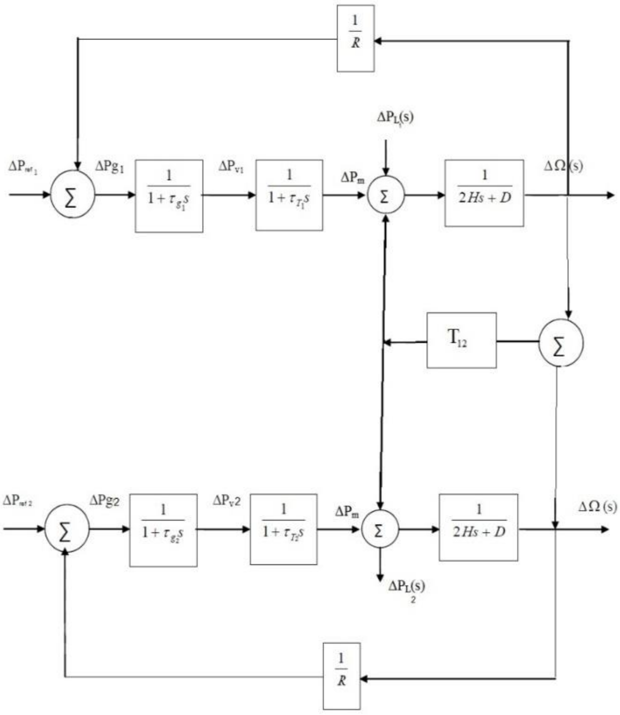

Figure 3. Tie-line power representation

B. Controlling Frequency on DFIG Side

DFIG is the short form of Doubly Fed Induction Generator, in this type of machines an AC current is injected into both the rotor and the stator windings. When a DFIG is used in wind turbines it means that, the amplitude and frequency of output voltage is not affected by the speed of turbine rotor, or in the other words the wind speed, this situation cause output always maintain at a constant value. This is the reason that we could directly connect the DFIG to the AC power network, and be sure that it will remain synchronized all over its generating time with the whole network.

III. SIMULATION MODEL

Because of analyzing frequency and power in smart gird we need to simulate a smart grid, there for we start a step by step simulating method to simulate a semi complete smart grid. First step is to simulate a traditional grid fed by synchronous generators, then we will add a wind power plant and a solar power plant finally gather this power unit together and analyses the possibility of the connection. Analyzing connection of wind and solar power plant separately and together check the possibility of the connection in following figures.

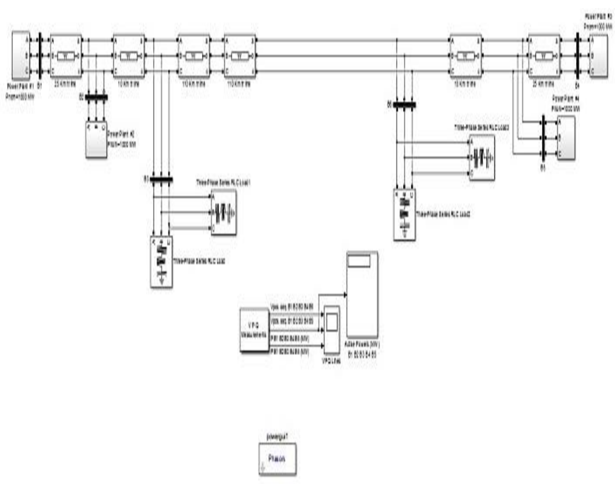

Figure 4. Model of a traditional network system

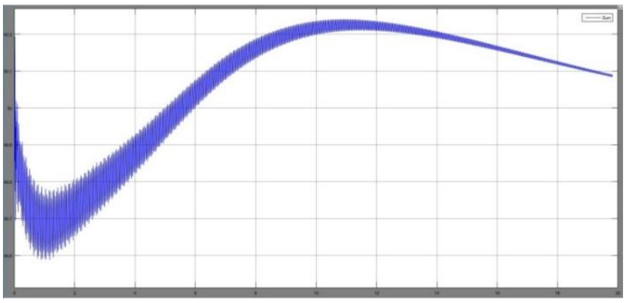

Figure 5. Frequency of synchronous generators

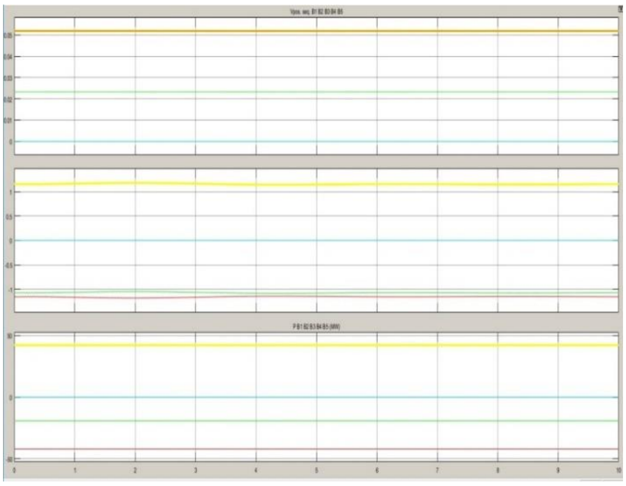

Figure 6. Voltage, reactive power and active power results for buses 1 to 5 of control units

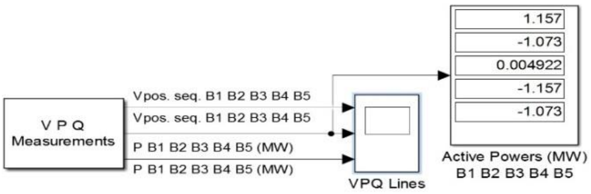

Figure 7. Numerical result of active power

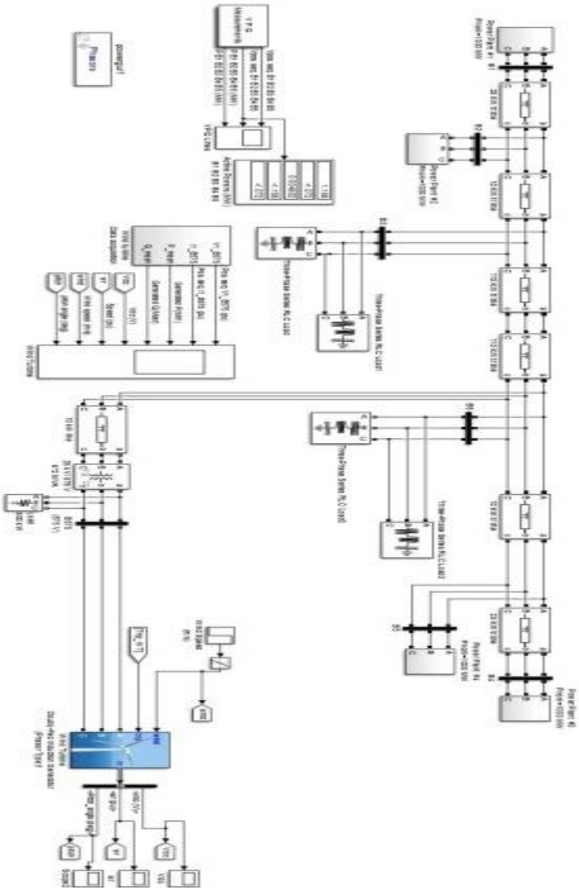

Figure 8. Wind farm connected to a traditional network

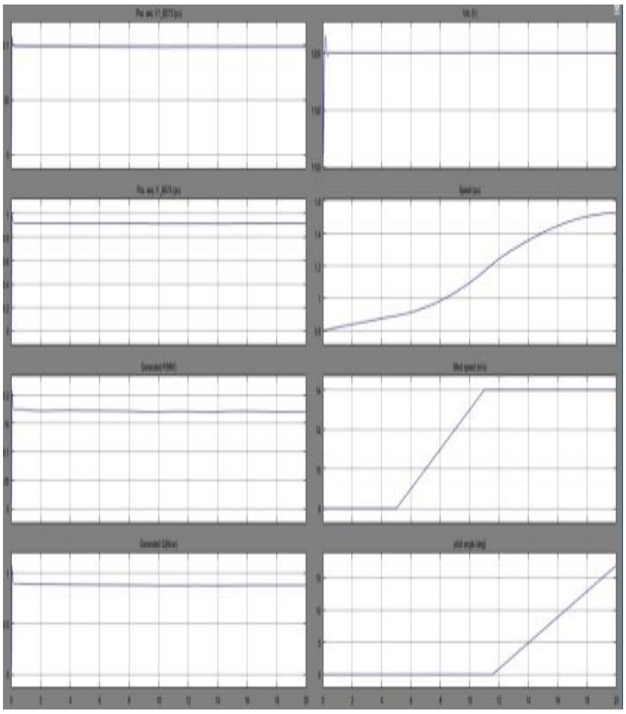

Figure 9. Results of bus 575 connected to the wind farm

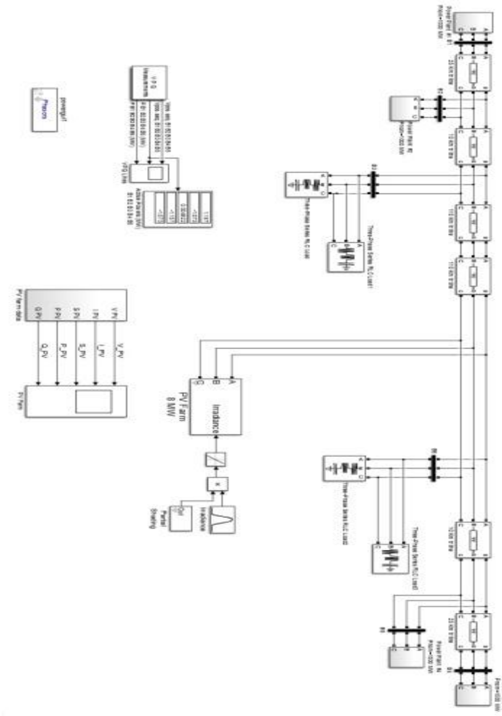

Figure 10. Solar farm connected to a traditional network

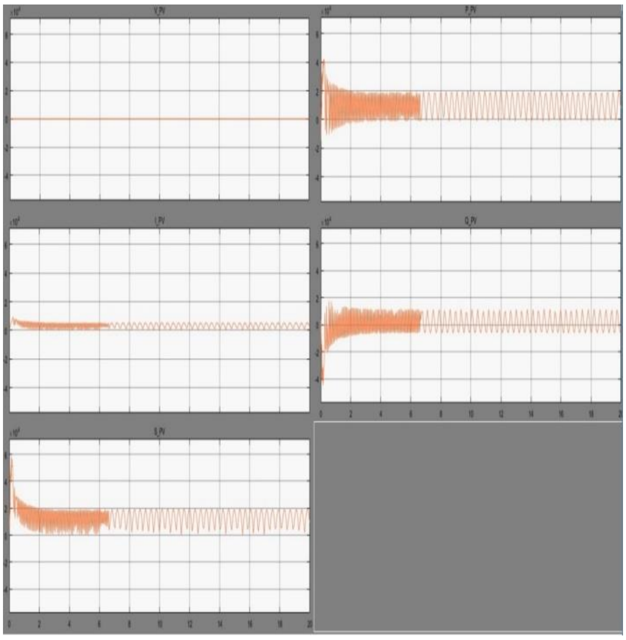

Figure 11. Voltage, current, *S*, active and reactive power results of a photovoltaic power farm

Now, we have the results for a traditional network and a wind farm connected or a photovoltaic unit connected micro gird. So, it's the time to merge all the units together and built a smart grid. The only problem is the topology of the network and the way that how these units could be connected. In the following we introduce a wrong way of connection then correct it to understand the reason that why we could not connect the units any way.

However, connecting a solar wind farm and a photovoltaic unit does not make any error in simulation but because of the simulation time contact we couldn't connect them directly.

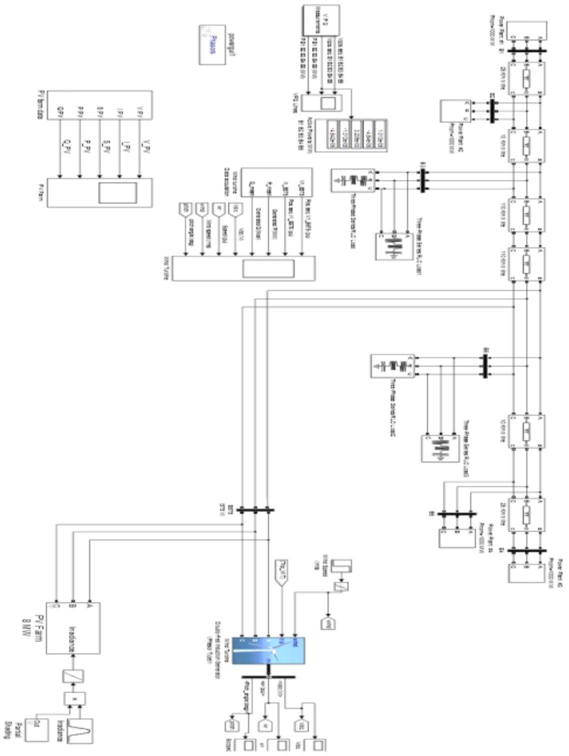

Figure 12. The wrong connection of units in a smart grid

A solar system effected by the angle of sun radiation and partial shading caused by the clouds must be simulated over the 24 hours but the wind farm tht have been stabilized show the result over a short period of time like 20 seconds.

So, we must connect them indirectly as shown in Figure 13. This figure indicates the final design of the topology of a smart grid consist of a traditional network, a wind farm, photovoltaic and control units and consumers and will analyze the effect of load changes on the grid.

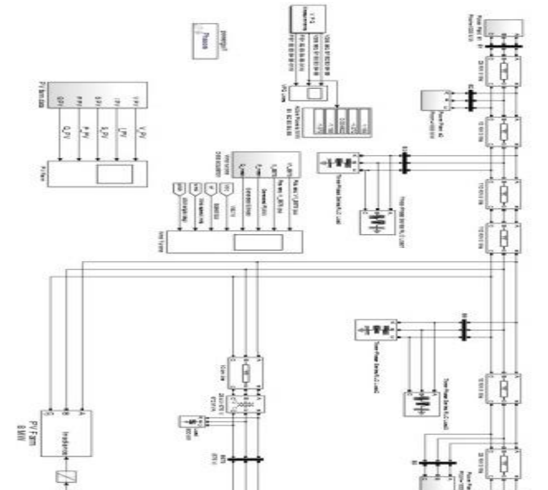

Figure 13. Topology of a smart grid

IV. RESULT AND DISCUSSION

Initial load values are taken from problem of [11] and simulation has been done. Some of the results are discussed here with their graph data are as:

A. Case I

The graph of frequency obtained from this Simulink model has shown in Figure 14. Hence this is observed from frequency graph that f_{max}=50.29 Hz and f_{min}=49.9 Hz. This is a stable working region of a power system network. The active power values are B1-586 MW, B2-424.8 MW, B3-754.1 MW, B4-637.3 MW, B5-638.9 MW.

Table 1. The first state of loads on buses 3 and 6

Load at bus 3		
Inductive	Active	Capacitive
150 MVAR	1100 MW	200 MVAR
Load at bus 6		
Inductive	Active	Capacitive
120 MVAR	1900 MW	350 MVAR

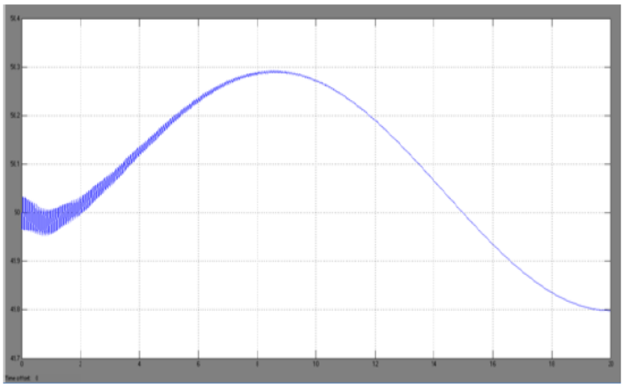

Figure 14. Graph of frequency in case I

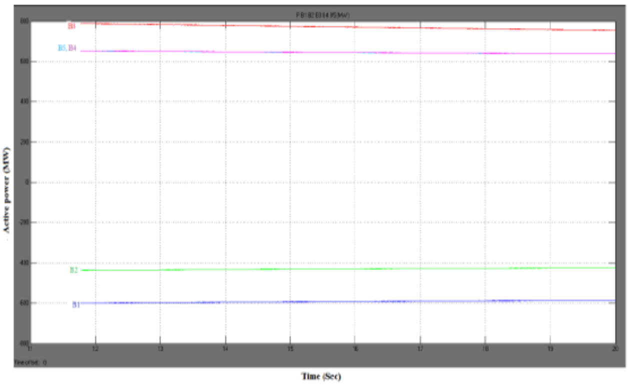

Figure 15. Graph of active power in case I

B. Case II

The graph of frequency obtained from this Simulink model has shown in Figure 16. Hence this is observed from above frequency graph that the f_{max}=50.06 Hz and f_{min}=49.81 Hz. This is a stable working region of a power system network. The active power values at different buses are B1-628.4 MW, B2-466.6 MW, B3-824.7 MW, B4-680.7 MW, B5-680.1 MW.

Table 2. The second state of loads on buses 3 and 6

Load at bus 3		
Inductive	Active	Capacitive
190 MVAR	1200 MW	200 MVAR
Load at bus 6		
Inductive	Active	Capacitive
210 MVAR	2100 MW	350 MVAR

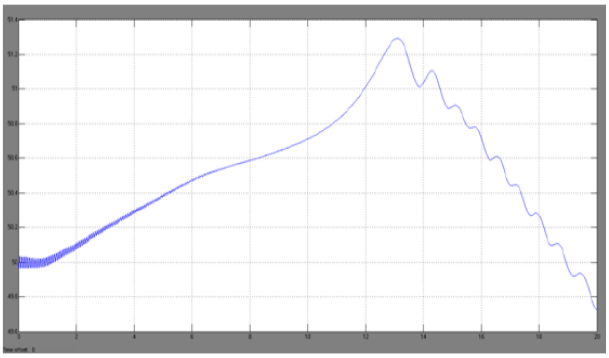

Figure 16. Graph of frequency in case II

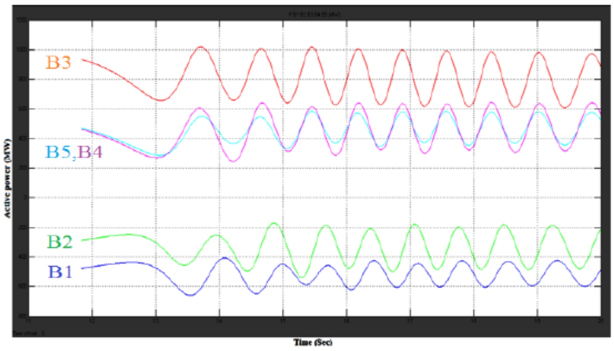

Figure 17. Graph of active powers in case II

C. Case III

The graph of frequency obtained from this Simulink model has shown in Figure 18. Hence this is observed from above frequency graph that the f_{max}=51.23 Hz and f_{min}=49.78 Hz. This is a stable working region of a power system network. The active power values are B-489.7 MW, B2-213.2 MW, B3-887.9 MW, B4-527.1 MW, B5-568.1 MW.

Table 3. The third state of loads in buses 3 and 6

Load at bus 3		
Inductive	Active	Capacitive
100 MVAR	960 MW	200 MVAR
Load at bus 6		
Inductive	Active	Capacitive
100 MVAR	1760 MW	350 MVAR

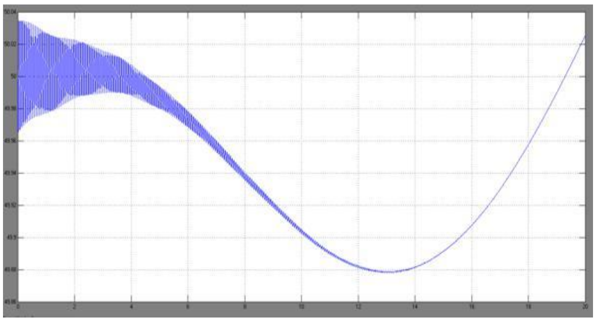

Figure 18. Graph of Frequency in case III

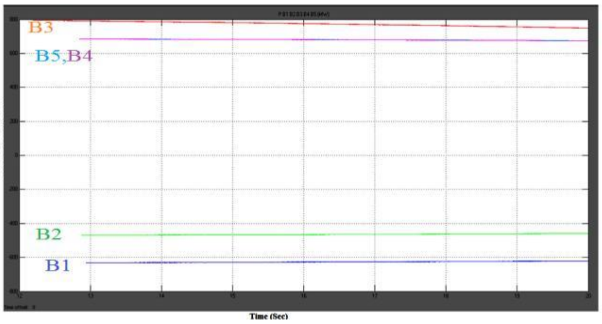

Figure 19. Graph of active powers in case III

D. Case IV

The graph of frequency obtained from this Simulink model has shown in Figure 20. Hence this is observed from above frequency graph that the $f_{\max}$=50.80 Hz and $f_{\min}$=49.2 Hz. This is a stable working region of a power system network. The active power values are B1-586.9 MW, B2-414.4 MW, B3-505.6 MW, B4-646.8 MW, B5-641.9 MW.

Table 4. The fourth state of loads on buses 3 and 6

Load at bus 3		
Inductive	Active	Capacitive
50 MVAR	650 MW	200 MVAR
Load at bus 6		
Inductive	Active	Capacitive
40 MVAR	1400 MW	350 MVAR

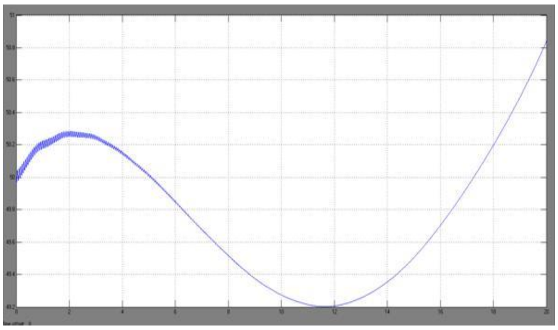

Figure 20. Graph of frequency in case IV

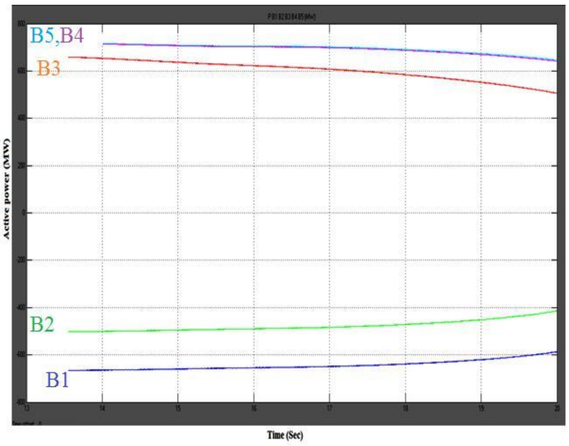

Figure 21. Graph of active powers in case IV

For the purpose of load analysis, as it is clear from simulation inductive and active loads are simulated as a series RL load. When capacitive load with its initial value used in series load.

At busbar B3, the capacitive load has the value of 200 MVAr whereas at busbar B6 its value is 350 MVAr. Initial values of active loads and inductive loads assumed as 1100 MW and 150 MVAr at B3, and those of B6 is taken as 1900 MW and 120 MVAr. The frequency measured at these loads are respectively 50.29 HZ and 49.90 HZ. the calculated negative and positive frequency deviation is 0.20% and 0.584% respectively. Defined variation for frequency deviation is 3%. So, as both positive and negative values of frequency deviation is under the defined value, the simulated smart grid is stable on these loads. Values at different bus bars are B1-586 MW, B2-424.8 MW, B3-754.1 MW, B4-637.3 MW, B5-638.9 MW, and also active power values also has been noted down.

In case II the values of inductive and active loads increased at both busbars B3 and B6. In spite of the fact that, measured frequency at busbars B3 and B6, are within the stable range, the results of measured active power at all buses B1, B2, B3, B4 and B6 don't have constant values and it is varying time to time, so, the load value of 190 MVAr and 1200 MW for B3 and 210 MVAr and 2100 MW for B6 are taken as an undesirable value of loads this network from the point of stable power system analysis. The minimum frequency measured is 49.81 HZ and maximum value is 50.06 HZ. The positive and negative deviation is 0.21% and 0.38%, respectively, that is within the ±3%. In order to reach the maximums possible limits of the simulated smart grid network, the maximum values of load have been taken, the result is that, however frequency is under the stable range but nature of active power is not compatible for taken loads.

In another case, the values of loads have decreased on both busbars to reach the authorized amounts of loads, that the power system in its stable operation range. Therefore, at busbar B6, the value of inductive load is decreased to 40 MVAr from its initial amount of 120 MVAr, and the value of active load decreased to 1400 MW from its initial amount of 1900 MW, thus, at B3 the value of inductive load decreased from 150 MVAr to 50 MVAr, and the active loads from 1100 MW to 650 MW. Achieved result from simulation shows that maximum and minimum frequency deviation (1.61%) is under stable range of ±3%, but studying the history of smart grids and their worst blackouts, shows that, on July 2013 in India one of the worst blackouts have been occurred on a similar situation like it. So, the final range of active loads for simulated smart grid is, from 650 MW to 1200 MW, also, the final possible amount for inductive loads is between the range of 50 MVAr to 190 MVAr on busbar B3, the similar ranges for busbar B6 is 1400 MW to 2100 MW, and, 40 MVAr to 210 MVAr.

V. CONCLUSIONS

The main aim of this paper was to make load analysis to check frequency deviation for reaching a stable smart grid, and to analyze the possibilities of connecting distributed generator to each other and to main network consist of thermal generators. The standard range for frequency deviation is defined ±3%, with this authorized range of the deviation, active and inductive loads taken as 1900 MW and 120 MVAr at B6, and 1100 MW and 15 MVAr at B3 respectively.

The maximum and minimum frequency values of named loads obtained as 50.29 HZ and 49.90 HZ respectively. The calculated positive and negative frequency deviation from these amounts of loads are 0.20% and 0.584% respectively, as it is clear, these amounts are under defined authorized frequency deviation (±3%.). Other different values have been taken between this range of loads and the results show that the proposed model for a smart grid is sufficient to sustain the active and inductive load variation.

REFERENCES

[1] X. Fang, G. Xue, D. Yang, “Smart Grid - The New and Improved Power Grid: A Survey”, IEEE Trans. Smart Grid, 2011.

[2] F. Rahimi, A. Ipakchi, “Demand Response as a Market Resource under the Smart Grid Paradigm”, IEEE Trans. Smart Grid, Vol. 1, No. 1, pp. 82-88, 2010.

[3] P.B. Andersen, B. Poulsen, M. Decker, C. Traeholt, J. Ostergaard, “Evaluation of a Generic Virtual Power Plant Framework Using Service Oriented Architecture”, IEEE PECon’08, pp. 1212-1217, 2008.

[4] C. Marinescu, “Analysis of Frequency Stability in a Residential Autonomous Microgrid Based on the Wind Turbine and Microhydel Power Plant”, Optimization of Electrical and Electronic Equipment, Vol. 50, pp. 1186-1191, 2010.

[5] P. Piagi, “Microgrid Control”, Ph.D. Dissertation, Electrical Engineering Department, University of Wisconsin, Madison, August 2005.

[6] P. Piagi, R. Lasseter, “Autonomous Control of Microgrids”, IEEE Power Engineering Society General Meeting, 2006.

[7] G. Lalor, “Frequency Control on an Isolated Power System with Evolving Plant Mix”, Ph.D. Dissertation, School of Electrical and Mechanical Engineering, University College Dublin, September 2005.

[8] H.A. Khan, H.C. Iu, V. Sreeram, “Active and Reactive Power Control of the Electronically Interfaced DG Sources for the Realization of a Virtual Power Plant”, 37th Annual Conference on IEEE Industrial Electronics Society (IECON’2011), Melbourne, VIC, Australia, 03 January 2012.

[9] R. Doherty, et al., “System Operation with a Significant Wind Power Penetration”, IEEE Power Engineering Society General Meeting, Vol. 1, pp. 1002-1007, 2004.

[10] P. Kundur, “Power System Stability and Control”, McGraw-Hill Inc., 1994.

BIOGRAPHIES

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