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Power Analysis and Stabilization Techniques for Smart Grids

Md. Hadiul Islam*, Karthik Suresh*, and S. Senthilmurugan*,[1]

Abstract – *In recent years, there has been a plethora of research and development in the field of smart grids, especially on the power analysis and stabilization of the grids. This article aims to give intricate detail on the problems adhering to smart grids along with an analysis (case study), design and techniques for the power analysis and stabilization of smart grids. The smart grid is so designed that the reactive power losses are minimized and the synchronization losses between two adjacent buses are prevented to a negligible extent. Reactive power is one of the major components in a power system that add up to the major losses and thus the overall power loss [1]. Reducing the losses in reactive power will facilitate the reduction of overall power losses and hence is a major field of study among researchers. The article also gives intricate information on the two-way electric flow system of smart grids which create a widely automated and distributed network of power. All simulations and experimentation are carried out using the MATLAB/SIMULINK approach.*

Keywords – *active power, load analysis, MATLAB/SIMULINK, reactive power, real power, smart grids, stabilization.*

1. INTRODUCTION

Smart grids are interactive electrical system grids that automatically integrate, sense and harvest energy that is fed from various sources of generation plants such as the conventional and distributed power plants [2]. The conventional power plants can be considered as the thermal power plants whose generation depends on coal. The distributed power plants mainly consist of the input from generated electricity of solar and wind power plants. For the example in this article, a wind generation power plant is used whose rating is defined in later stages but can be used for any alternative energy source.

The smart grid integrates a flexible and operative approach to metering technology and is classified into three types which are the smart infrastructure, smart management and smart protection systems [3]. The article gives a comparative case study of active, real and reactive power for an efficient smart infrastructure system. The smart power generation system consists of several generators, distribution and storage micro grids. The storage micro-grids, for this particular experiment, are taken to be re-chargeable Lithium polymer batteries. These batteries are considered as they are comparatively cheap, have high energy density of the order 0.9-2.63 megaJoules/L [4]. Many different frequency stabilization modules are integrated in order to make the input to the main grid from the micro- grids more stable. After which, the voltage needs to be stepped up as micro-grids are of low voltage and high cost efficiency [5].

As explained in [6] and [7], the simulation of power systems and the analysis for smart grids is done using two types of energy/generation sources. One being the conventional while the other the distributed systems. The analysis is usually done for the active power and the reactive power. The reactive power is divided into two parts being the inductive and capacitive power consumption. But unlike many research studies conducted on the use of this approach, this article discusses a new approach towards the simulation profile. In this article, the real, reactive and active power are considered simultaneously for simulation and a more direct way to calculate the results.

2. METHODOLOGY

The simulation is done on the MATLAB/SIMULINK with some pre-defined and measured initial conditions. As mentioned earlier, the use of both conventional and distributed generators is implemented in a smart energy generation system. For the simulation profile, the conventional system is considered to be a thermal power plant of rating 900 mega Watt which produces 13.8 KV as an output which has to be stepped up to 230KV which is the ideal transmission voltage [8]. For the distributed system, a wind turbine is considered whose rating is 12 MW and produces an output of 575 volts. This is again stepped up to 230KV. The wind turbine uses a doubly-fed induction generator [9].

The basic power transmission line consists of sending-end power and receiving-end power which can be interpreted with more detail by the diagram:

A double-fed induction generator is one in which the voltage produced by a conventional generator (inside the wind turbine) is given as input to both the stator and the rotor, which has many advantages, one of them being a constant voltage output. This means that no matter what speed the wind turns the turbine, the output of the generator is always maintained constant.

The power equations can be given for the real, active and reactive power. The equations for both

*Department of Electrical and Electronics Engineering, SRM Institute of Science and Technology, Kattankulathur, India.

Email: sen.accet@gmail.com, hads320@gmail.com, karthik.ss@srmuniv,edu.in

sending-end and receiving-end power of the transmission line can be used to interrupt the transmission loses which can be considered as Bus loses. The amount of bus loss can be given by the loss angle. By decreasing the loss angle, the amount of power loss on the bus can be reduced effectively. The power equation can be related to the value delta by the given representation given in [10].

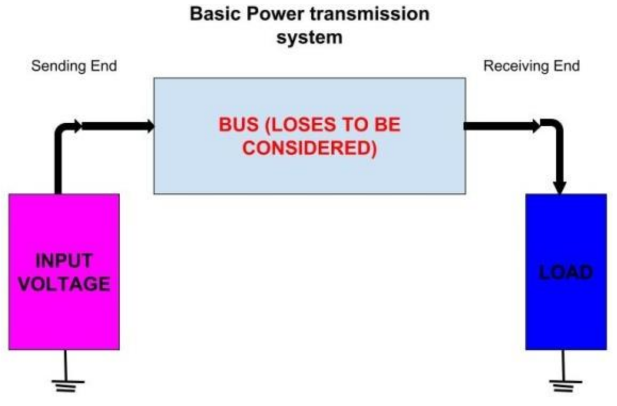


Fig. 1. The basic power transmission system.

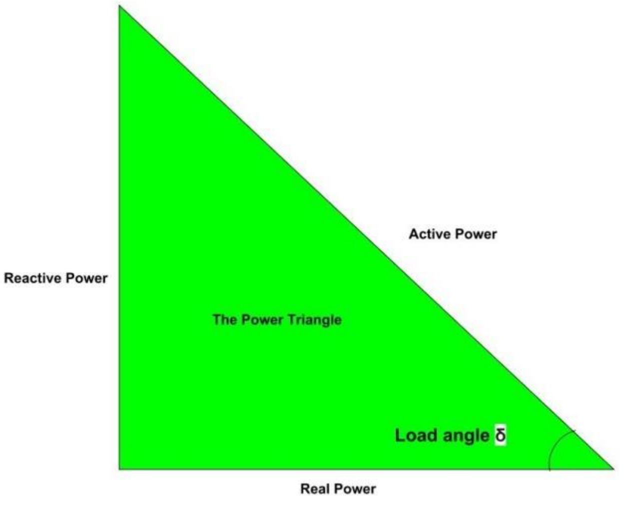


Fig. 2. The power triangle.

The active power is a unit of both reactive and real power and can be interpreted in the power triangle.

$$P_A = V\,I$$
$$P_R = VI\cos\delta \qquad (1)$$
$$P_X = VI\sin\delta$$

Where PR, PA and PX are the real, active and reactive power respectively. The load angle is given by the difference between the sending-end load angle and receiving end load angle which is

$$\delta = \delta_S - \delta_R \qquad (2)$$

Where R and S are the receiving-end and sending-end load angles respectively. The relation between the real, active and reactive power can be given by

$$Active\ Power = \sqrt{((Real\ Power)^2 + (Reactive\ Power)^2} \qquad (3)$$

$$P_R{}^2 + P_X{}^2 = P_A{}^2$$

For effective simulation, there are six busses which are considered in the whole system. Bus B3 and B6 are connected to consumer level RLC loads. To have ease in calculation and to provide stable outputs, we analyse and interpret the capacitive loads to be completely constant [11] throughout the consumption period and calculate the varying power with respect to the RL loads.

B3 and B6 give an output toward the total power consumption of the domestic load. Using this data, the load consumption on the individual loads is interpreted. This data is hence used to study the stability of the Smart grid on changing loads. A more detailed description is given in the next section showing the simulation results.

3. SIMULATION AND RESULTS

The parameters that are mentioned and calculated at the junction for each bus are the voltages, the active current values and ultimately the active and reactive power values which are measured using the voltage sensor and current sensor values at the end of each bus or junction. The simulation results are shown with the help of Figure 3 and Figure 4 which are the simulation credentials of the total system.

Table 1. Power simulation table for load bus 3.

	Load Bus 3	
S. No.	Active Power (MW)	Reactive Power (MVAR)
1	1200	350
2	1040	380
3	1300	390
4	1150	330
5	1100	320
6	1060	300

Table 2. Power simulation table for load bus 6.

	Load Bus 6	
S. No.	Active Power (MW)	Reactive Power (MVAR)
1	2000	470
2	2050	540
3	2200	560
4	1950	490
5	1900	470
6	1860	450

Table 3. Frequency simulation data.

Frequency(Hz)	
Minimum Frequency (Hz)	Maximum Frequency (Hz)
49.9	50.292
49.7	50.105
49.81	50.06
49.87	50.03
49.96	51.23
49.78	50.24

4. RESULTS AND DISCUSSION

Initial load values are taken from the problem of [12]. The corresponding active power values and the reactive power values are taken from the above simulation table itself for the discussion and tabulation of each of the following cases.

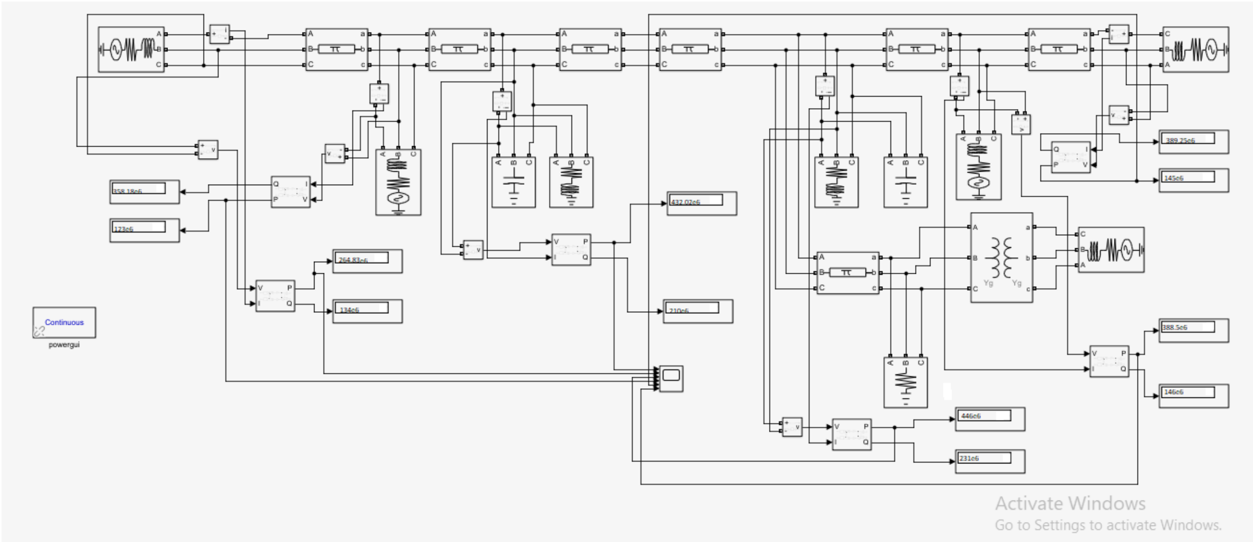


Fig. 3. Simulation model (with initial parameters).

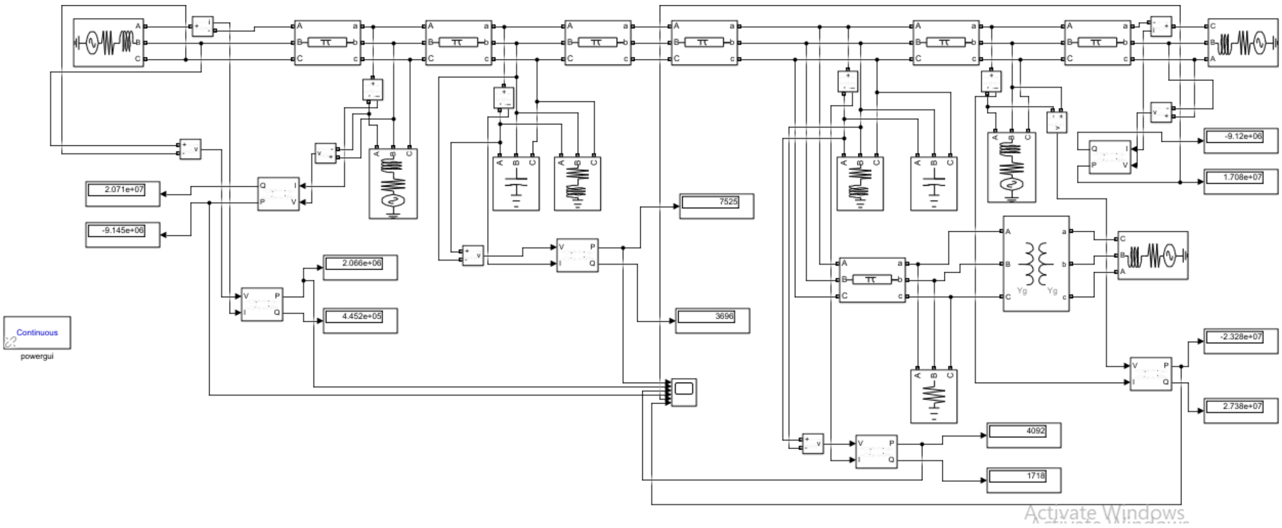


Fig. 4. Simulation model (with secondary parameters)

Note that each case comprises of a tabulation of considered values and a simulated graph which shows the values of output for load tension on each bus (considered near all load and generation sites). Each case has its own set of primitive and derived values which is depicted and plotted to show accurate simulation results.

A. Case 1

Thus we can observe and conclude from the graph for case 1 and as also shown in simulation model 1 that the active power values are 620.4 MW for supply bus-1, 458.7 MW for supply bus -2, 748.3 MW for load bus-1, 674.2 MW and 673.5 MW for supply buses- 3 and 4.

The data for each bus is divided into two different tables, each from the specific consumer level load tension buses.

Table 4. Load distribution data for case 1, load bus 3.

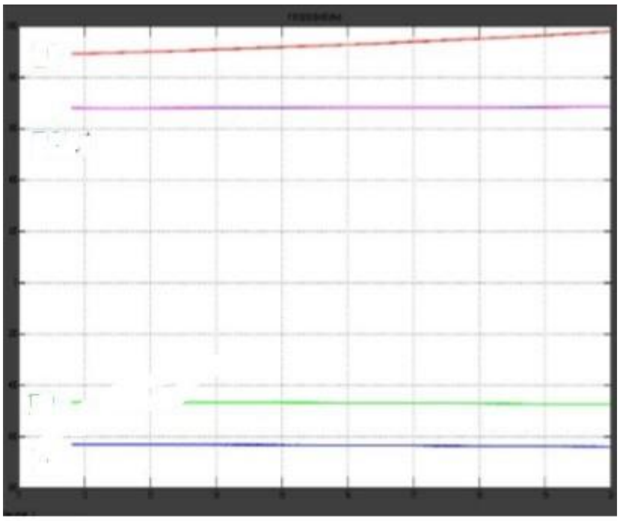
Load Bus 3	
Active Power (MW)	Reactive Power (MVAR)
1200	350

Table 5. Load distribution data for case 1, load bus 6.

Load Bus 6	
Active Power (MW)	Reactive Power (MVAR)
2000	470

B. Case 2

Thus we can observe and conclude from the graph for case 2 and as also shown in simulation model 2 that the active power values are 639.2MW for supply bus-1, 473.2 MW for supply bus-2, 976.9 MW for load bus-1, 654.8 MW and 684.3 MW for supply buses- 3 and 4.



Case 1:i) Load Bus-1 ii) Supply Buses iii)Load Bus-2 iv) Supply Bus

Fig. 5. Active power (MW) vs time (s): Case 1: i) load bus-1 ii) supply buses-3 and 4 iii) load bus-2 iv) supply bus.

Table 6. Load distribution data for case 2, load bus 3.

Load Bus 3	
Active Power (MW)	Reactive Power (MVAR)
1040	380

Table 7. Load distribution data for case 2, load bus 6.

Load Bus 6	
Active Power (MW)	Reactive Power (MVAR)
2050	540

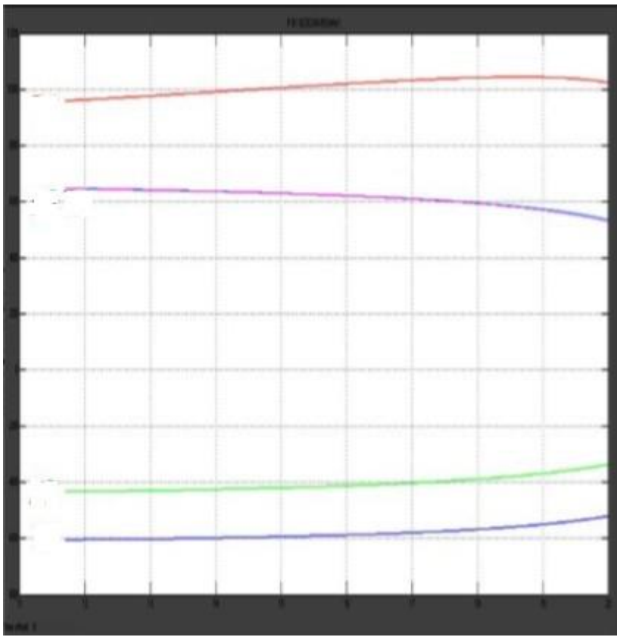


Fig. 6. Active power (MW) vs time (s): case 2: i) load bus-1 ii) supply buses-3 and 4 iii) load bus-2 iv) supply bus.

C. Case 3

Thus we can observe and conclude from the graph for case 3 and as also shown in simulation model 3 that the active power values are 489.7 MW for supply bus-1, 213.2 MW for supply bus-2,887.9 MW for load bus-1,527.2 MW and 568.5 MW for supply buses- 3 and 4.

In the analysis of the loads in the above simulation models, the inductive and the resistive loads are varied in the RL series branch whereas the capacitive load is taken as constant in the parallel C branch as shown in simulation models 1 and 2.

We can observe the unique change of power values with respect to the table. The data is systematically arranged so as to have a better understanding of the different cases considered with reference to [12] and the values are set accordingly.

Table 8. Load distribution data for case 3, load bus 3.

Load Bus 3	
Active Power (MW)	Reactive Power (MVAR)
1300	390

Table 9. Load distribution data for case 3, load bus 6.

Load Bus 6	
Active Power (MW)	Reactive Power (MVAR)
2200	560

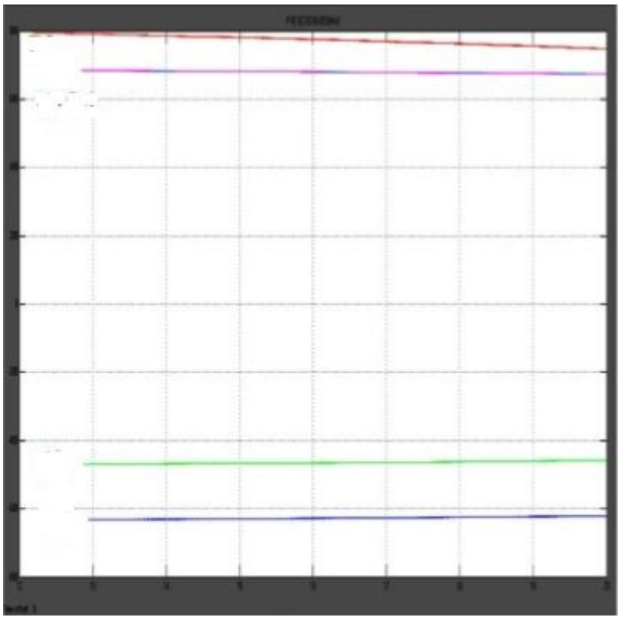


Fig. 7. Active power (MW) vs time (s): case 3: i) load bus-1 ii) supply buses-3 and 4 iii) load bus-2 iv) supply bus.

5. CONCLUSION

This article gives a detailed view on the power analysis of smart grids which helps in effectively designing and interpreting smart grid systems using both, the conventional and distributed energy generation systems. By using the proposed simulation profile which implements the use of real, active and reactive power, the overall power system efficiency for an accustomed power grid/distribution system can be calculated and further implementations can be executed accordingly. The stability analysis in this article describes the variation of the stability criterion with the reactive power (inductive and capacitive power). A further load analysis estimates the overall tension on each bus, which ranges from the load tension on the generation ends and the domestic/industrial consumption ends.

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REFERENCES

[1] Barot H. and K. Bhattacharya. 2007. Optimal reactive power planning and compensation effects on transmission line components. In *2007 IEEE Power Engineering Society General Meeting*. pp.1–7.

[2] Fang X., Misra S., Xue G., and Yang D., 2011. Smart grid–The new and improved power grid: A survey. *IEEE Trans. Smart Grid*.

[3] Rahimi F. and A. Ipakchi. 2010. Demand response as a market resource under the smart grid paradigm. *IEEE Transactions on .Smart Grid* 1(1): 82–88.

[4] Chu M.Y., De. Jonghe L., Visco S., employees, PolyPlusbattery co., 1996. High Specific Power, rechargeable Lithium Polymer Batteries. *IEEE.*

[5] Andersen P.B., Poulsen B., Decker M., Træholt C., and Ostergaard J., 2008. Evaluation of a generic virtual power plant framework using service oriented architecture. In *2008 IEEE 2nd International Power and Energy Conference*. pp 1212–1217.

[6] Kumar V. and P. Rai. 2014. Active power analysis of smart grids–using MATLAB/SIMULINK approach. *International Journal of Innovative Research in Advanced Engineering (IJIRAE)* 1(8).

[7] Kumar V. and P. Rai. 2014. Active power analysis of smart grids–using MATLAB/SIMULINK approach. *International Journal of Research in Engineering and Technology* 3(9).

[8] Xiang X., Qi L., and Cui X., 2010. Electromagnetic transient characteristics of 1000KV half–wavelength AC transmission lines. In *2010 5th International Conference on Critical Infrastructure (CRIS).*

[9] Doolla S. and J. Priolkar. 2011. Analysis of frequency control in isolated microgrids. *IEEE PES Innovative Smart Grid Technologies India*.

[10] Han X., Yang X., Song J., and Du X., 2007. Impact of dynamic loads on stability of Shanxi power grid. In *2007 International Power Engineering Conference (IPEC 2007).* pp. 559–563.

[11] Benzagmout A., Martire T., Beaufils G., Fruchier O., Talbert T., and Gachon D., 2018. Measurement of the i (v) characteristics of photovoltaic arrays by capacitive load method for fault detection. In *2018 IEEE International Conference on Industrial Technology (ICIT)*. pp. 1031–1036.

[12] Kundur P., 2017. *Power System Stability and Control: Power System Engineering Series.* USA: McGraw Hill Education Publications.