

Load Frequency Control of a Two Area Power System with Electric Vehicle and PI Controller

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ABSTRACT: This paper focuses the modelling and the simulation of Load Frequency Control (LFC) for a two area power system with EV and PI controller. The controlling of active power and frequency in a power system network is known as LFC. To maintain the frequency constant against the changing active power loads, which is also referred as unknown external disturbances is the important task of LFC. The intermittent power generation from wind causes a large frequency fluctuation when the LFC capacity is not enough to compensate the unbalance generation and load demand. Also in the future transport sector, the Plug-in Hybrid Electric Vehicle (PHEV) is widely expected from the customer side. Therefore, the Vehicle to Grid (V2G) power control can be applied to compensate for the inadequate LFC capacity. The simulation done using MATLAB/SIMULINK software shows the satisfactory behaviour of the interconnected power system with a load frequency controller.

KEYWORDS: Load frequency control, Plug in electric vehicle, Vehicle to grid control

I. INTRODUCTION

The entire interconnected system network is called the Grid. As the increasing environmental and energy security concerns, renewable energy from wind or solar as well as Electric Vehicles (EVs) will be widely deployed in the smart grid in the next decade. The large-scale integration of these new types of generation and load in power grids will have significant impact on grid operation, planning and stability control. The widespread penetration of large scale wind power has been increasing largely because of plentiful availability and reduced CO₂ emissions [1]–[3]. However, the wind power is intermittent in nature. This may cause an imbalance of supply and load demand and lead to a severe frequency oscillation problem [4]. Particularly, this problem may occur considerably when the capacity of LFC is insufficient during the night period [5].

On the other hand, in the future transportation system, the PHEVs are used extensively for driving in the customer side because of low-cost charging, reduced petroleum usages and reduced greenhouse emissions [6]–[8]. Reference [9] concentrates on the autonomous distributed V2G control considering the charging request and battery condition for suppressing the fluctuations of frequency and tie-line power flow in the two-area interconnected power system. Generally, the controller structures such as lead-lag compensator, and proportional integral (PI) etc., are preferred in practice because of their simple structure and low order. Simulation studies exhibits the coordinated control effects of a two area power system with and without EV and PI controller.

Paper is organized as follows. The modelling of a two area interconnected power system is described in Section II. Model validation is illustrated in Section III. Section IV explains the implementation of PI controller. Section V concludes the work.

II. SYSTEM MODELLING

The V2G based PHEVs is applied to compensate the unequal real power in each area when the LFC capacity is not enough. Here, a two-area interconnected power system with wind farm and PHEV is considered for the simulation study. Fig.1 shows the linearized model of a two area inter connected power system.

The operation objectives of the LFC are to maintain uniform frequency, to divide the load between generators and to control the tie line interchange schedules. The change in frequency and tie line power are sensed, which is the measure of the change in rotor angle δ . The error signal, Δf and ΔP_{tie} , are amplified, mixed and transformed into a real power command signal ΔP_v , which is sent to the prime mover to call for an increment in torque. The prime mover, therefore brings change in the generator output by an amount ΔP_g which will change the values of Δf and ΔP_{tie} within the specified tolerance.

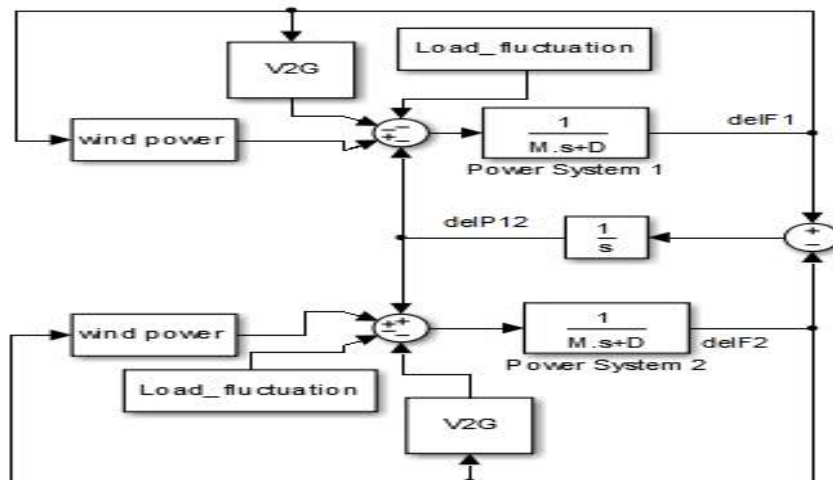


Fig.1. Linearized model of a two area interconnected system

1. GENERATOR MODEL

Applying the swing equation of a synchronous machine to small perturbation, we have

$$\frac{2H}{\omega_s} \frac{d^2 \Delta \delta}{dt^2} = \Delta P_m - \Delta P_g \quad (1)$$

Or in terms of small deviation in speed,

$$\frac{d \Delta \omega}{dt} = \frac{1}{2H} (\Delta P_m - \Delta P_g) \quad (2)$$

With speed expressed in per unit, without explicit per unit notation, we have,

$$\frac{d \Delta \omega}{dt} = \frac{1}{2H} (\Delta P_m - \Delta P_g) \quad (3)$$

Taking Laplace transform of (3), we obtain,

$$\Delta \Omega(s) = \frac{1}{2Hs} [\Delta P_m(s) - \Delta P_g(s)] \quad (4)$$

2. LOAD MODEL

Power system consists of many types of electrical loads. For resistive loads such as lighting and heating loads, the electrical power is independent of frequency. Motor loads are sensitive to changes in frequency. Sensitivity to the frequency depends on the composite of the speed-load characteristics of all the driven devices. The speed-load characteristic of a composite load can be approximated as,

$$\Delta P_g = \Delta P_L + D \Delta \omega \quad (5)$$

Where ΔP_L the non-frequency sensitive load is change, and $D\Delta\omega$ is the frequency sensitive load change.

3. PRIME MOVER MODEL

The source of mechanical power, commonly known as the prime mover, may be hydraulic turbines, steam turbines, wind turbines, gas turbines etc. the model for the turbine relates change in mechanical power output ΔP_m to changes in valve position ΔP_V .

$$G_T(s) = \frac{\Delta P_m(s)}{\Delta P_V(s)} = \frac{1}{1 + \tau_T s} \quad (6)$$

4. GOVERNOR MODEL

When the generator electrical load is suddenly increased, the electrical power exceeds the mechanical power input. This power deficiency is supplied by the kinetic energy stored in the rotating system. The reduction the kinetic energy causes the turbine speed and consequently the frequency to fall. The change in speed is sensed by the turbine governor which acts to adjust the turbine input valve to change the mechanical power output to bring the speed to a new steady state.

The speed governor mechanism acts as a comparator whose output ΔP_g is the difference between the reference set power ΔP_{ref} and the power $\frac{1}{R}\Delta\omega$ as given from the governor speed characteristics, i.e.,

$$\Delta P_g = \Delta P_{ref} - \frac{1}{R}\Delta\omega \quad (7)$$

or in s-domain,

$$\Delta P_g(s) = \Delta P_{ref}(s) - \frac{1}{R}\Delta\Omega(s) \quad (8)$$

The command ΔP_g is transformed through the amplifier to the valve position command ΔP_V .

$$\Delta P_V = \frac{1}{1 + \tau_g s} \Delta P_g(s) \quad (9)$$

The overall system can be represented in a block diagram as in Fig.2

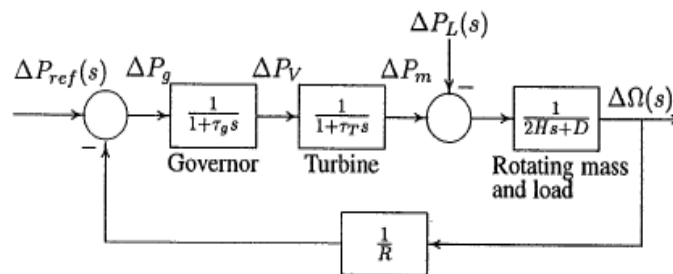


Fig.2. Block diagram of a wind based generating system

III. MODEL VALIDATION

From practical point of view of view, the problems of frequency control of interconnected areas, or power pools are more important than those of isolated areas. Many advantages can be derived from the pool operation. Under the normal operating conditions, each pool member or control area, should strive to carry its own load, except such scheduled portions of the other members load as have been mutually agreed upon. Also, each control area must agree upon adopting regulating and control strategies and equipment that are mutually beneficial under both normal and abnormal situations. The advantages of belonging to a pool are particularly evident under abnormal conditions.

Since peak demands occur at various hours of the day in various areas, the ratio between peak and average load for a large pool is smaller than that of the individual systems. It is obvious that all the pool members can benefit from a reduced need of reserve capacity by a scheduled arrangement of energy interchange. Fig. 3 represents the SIMULINK

model of the overall system without PI controller. Also the active power and frequency deviation is shown in Fig. 4a and Fig. 4b.

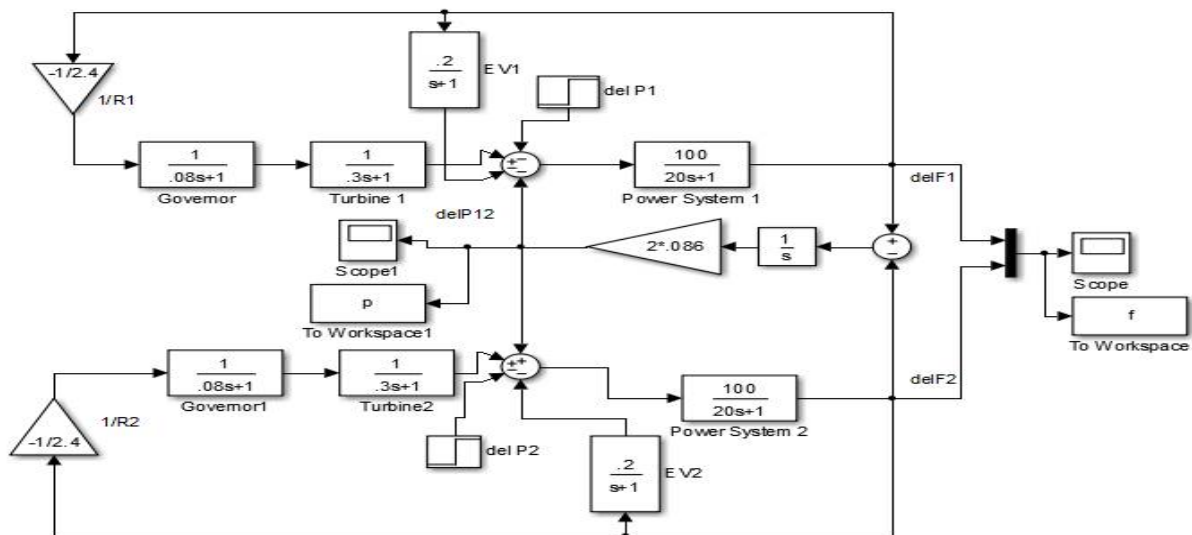


Fig. 3. SIMULINK model of the overall system.

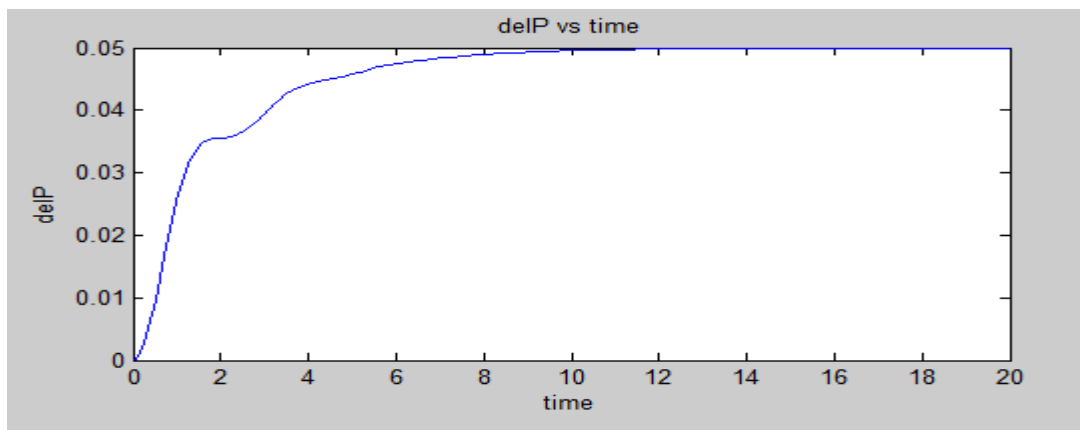


Fig. 4a. Graphical representation of delP vs time

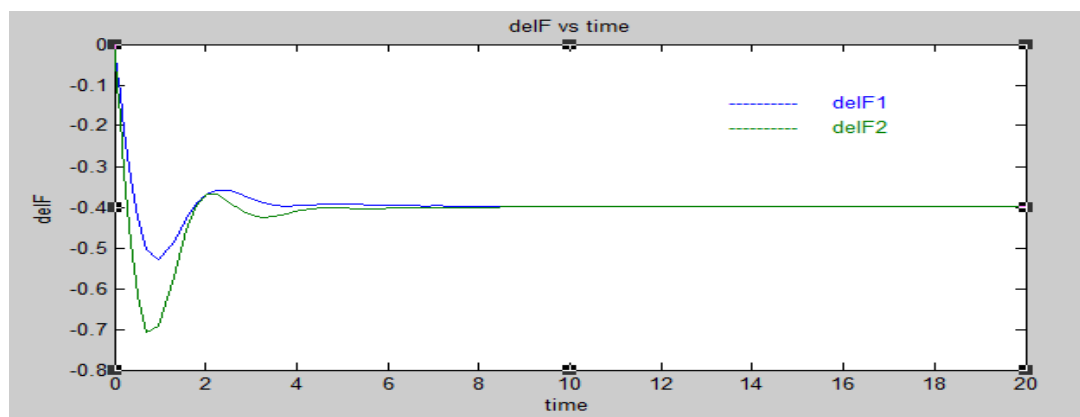


Fig. 4b. Graphical representation of delF vs time

IV. PI CONTROLLER

It is necessary to achieve better frequency consistency than is obtained by the speed governor. The control strategy has to satisfy certain specifications. The control loop must be characterised by a sufficient degree of stability. And, following a step load change, the frequency error should return to zero. In addition, it is required that the steady state tie line power variation, following a step load change must be zero. Suitable PI (Proportional-Integral) controller is used to improve both the steady state and transient response of the system. The SIMULINK model of the two area interconnected power system with PI controller is shown in Fig.5. The change in active power and frequency deviation with the implementation of PI controller is shown in Fig. 4a and Fig. 4b.

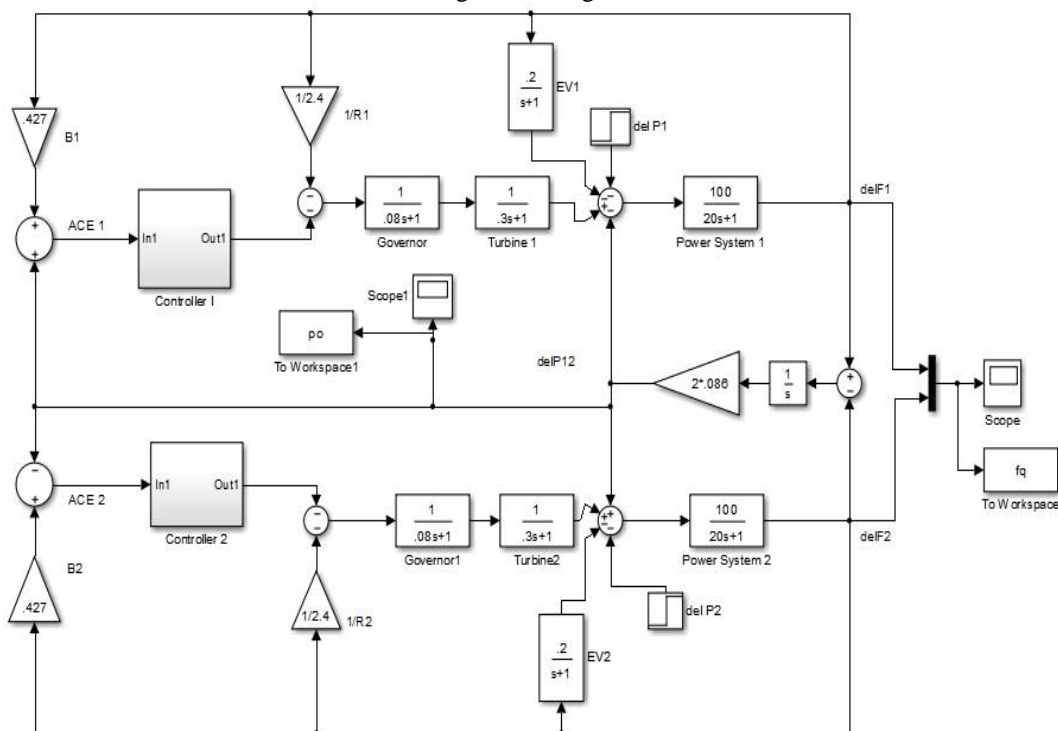


Fig. 5. SIMULINK model of the two area power system with PI controller

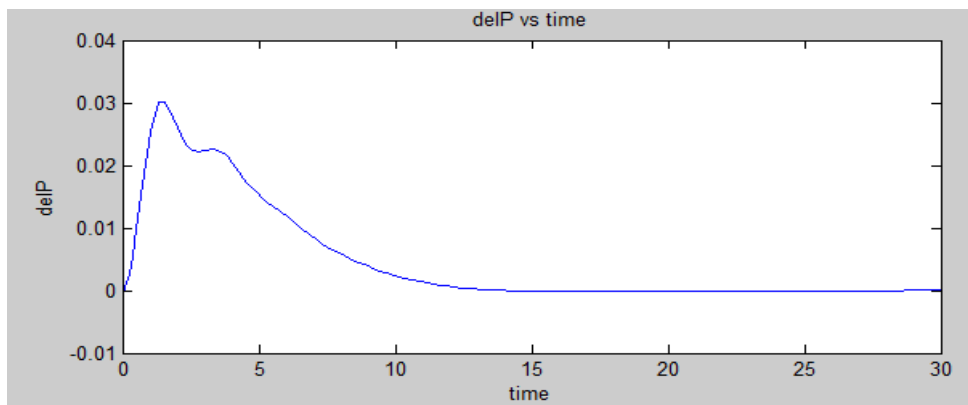


Fig. 5a. Graphical representation of delP vs time

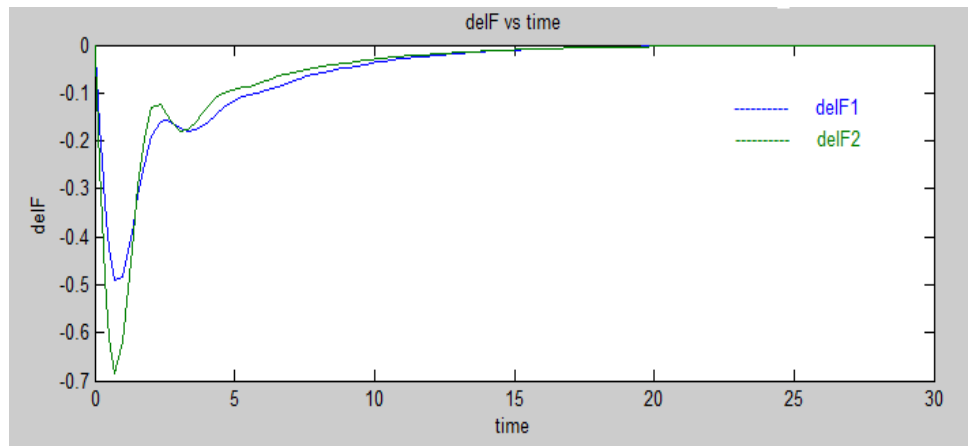


Fig. 5b. Graphical representation of delF vs time

V. CONCLUSION

The coordinated V2G control and frequency controller for LFC with wind power penetration has been described in this paper. It can be seen that the frequency deviation and the active power variation is controlled using an electric vehicle and PI controller. The frequency error and the steady state tie line power, following a step load change returns to zero. The simulation results shows the adequate response of an interconnected two area power system with the implementation of a load frequency controller. The parameter tuning of the PI controller can be done using PSO algorithm to ensure the robustness of the system.

REFERENCES

- [1] M. E. Khodayar, L. Wu, and M. Shahidehpour, "Hourly coordination of electric vehicle operation and volatile wind power generation in SCUC," *IEEE Trans. Smart Grid*, vol. 3, no. 3, pp. 1271–1279, Sep. 2012.
- [2] K. Moslehi and R. Kumar, "A reliability perspective of the smart grid," *IEEE Trans. Smart Grid*, vol. 1, no. 1, pp. 57–64, Jun. 2010.
- [3] R. Podmore and M. R. Robinson, "The role of simulators for smart grid development," *IEEE Trans. SmartGrid*, vol. 1, no. 2, pp. 205–212, Sep. 2010.
- [4] I. D. Margaris, S. A. Papathanassiou, N. D. Hatziargyriou, A. D. Hansen, and P. Sørensen, "Frequency control in autonomous power systems with high wind power penetration," *IEEE Trans. Sustainable Energy*, vol. 3, no. 2, pp. 189–199, Apr. 2012.
- [5] Y. Ota, H. Taniguchi, T. Nakajima, K. M. Liyanage, K. Shimizu, T. Masuta, J. Baba, and A. Yokoyama, "Effect of autonomous distributed vehicle-to-grid (V2G) on power system frequency control," in *Proc. 2001 IEEE Ind. Inf. Syst. Conf.*, pp. 481–485, Jun. 2010.
- [6] C. Pang, P. Dutta, and M. Kezunovic, "BEVs/PHEVs as dispersed energy storage for V2B uses in the smart grid," *IEEE Trans. Smart Grid*, vol. 3, no. 1, pp. 473–482, Mar. 2012.
- [7] Z. Fan, "A distributed demand response algorithm and its application to PHEV charging in smart grids," *IEEE Trans. Smart Grid*, vol. 3, no. 3, pp. 1280–1290, Sep. 2012.
- [8] E. Sortomme, M. M. Hindi, S. D. James MacPherson, and S. S. Venkata, "Coordinated charging of plug-in hybrid electric vehicles to minimize distribution system losses," *IEEE Trans. Smart Grid*, vol. 2, no. 1, pp. 198–205, Mar. 2011.
- [9] Y. Ota, H. Taniguchi, T. Nakajima, K. M. Liyanage, J. Baba, and A. Yokoyama, "Autonomous distributed V2G (vehicle-to-grid) considering charging request and battery condition," in *Proc. 2010 IEEE Innov. Smart Grid Technol. Conf.*, pp. 1–6, Jun. 2010.