A Relative Analysis of Load Frequency Control With And Without Secondary Loop Control In Three Area Power System

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Abstract- *Frequency of electrical power supplied by the plant is an important aspect of the power quality. Since variation in frequency prominently affects the speed of motors at the production units in various industries. Also various domestic appliances have the rated frequency. So there is a need to maintain the frequency constant. This paper presents the three area network model for an interconnected power system in which the tie-line power is also maintained constant because there is certain contractual constraint among the different power companies or electricity boards. A comparative analysis is done with and without secondary control in Load Frequency Control. Simulations have been performed on MATLab.*

Keywords- Automatic Generation Control, Load Frequency Control, Area Control Error, Secondary Loop Control

I. INTRODUCTION

In the Electrical power system the load demand is continuously changing with time. In accordance with it the power quality output by the generating unit is altered, if there would be power mismatch in input and output. With the variation in load demand the active and reactive power changes and it adversely affects the voltage profile and load frequency. The voltage profile is compensated by excitation control which is having low time-constant elements but the control of frequency is achieved primarily through speed governor mechanism aided by supplementary means to precise control. The load frequency control is a slow acting process with a major time constant associated to turbine and generator moment of inertia, as compared to voltage control this time constant is much larger than that of the generator field time constant. The disturbance in load demand side in a certain area affects the frequency also power system stability in the other areas so that it is essential in modern power systems to design such a network which not only controls the frequency but also controls the tie line power to maintain the stability of interconnected networks.

Control area is an area in which all the generators constitute a coherent group and closely knit electrical area so that all the generators speed up and slow down together maintaining the frequency within a tolerable limit ($\pm$0.5 Hz) [1]. The boundaries of the control area would be the state electricity board or individual power company.

Many researchers have been working to resolve this problem in load frequency specially after the concept of multi area networks as there are lots of advantages of interconnected networks compared to isolated networks. There were several approaches proposed to optimize the gain constants with considering the uncertainties of the power system [2] i.e. generating rate constraints [5], valve speed limit to handle the nonlinearities in the power system. Decentralized PID controller based on Kharitonov's theorem and stability boundary locus [10] was proposed to take care of uncertainties in each control area. Laurent series expansion methods were suggested to tuning the controller parameters and with simulation achieves better damping for frequency and tie-line power flow deviations. Plotting the stability boundary locus in the $K_P - K_I$ plane and then computing the stabilizing values of the parameters of a P-I controller proposed in [8] and with the time delay in [11]. Internal model control method is proposed in [12] with the additional degree of freedom to cancel the effect of undesired poles of disturbances. This paper is to deal with the understanding the importance of secondary loop control for LFC following theoretical background in section II, MATLab/Simulink tools is used for modelling the three area network without secondary in section III and with secondary in section IV.

II. FREQUENCY CONTROL STAGES

The typical frequency control loops are simply represented in Fig.1 are described as

A. *Primary Control*

Under normal operation, small frequency deviations can be attenuated by the primary control. This type of control is endeavored locally to keep the balance involving generation along with demand within the network. It is apprehended by speed of turbine governors that adjusts the generators output as a response to the frequency divergence in the area. If there is a major disturbance then the primary control permits the balance of generated as well as utilized power at a frequency distinguishable from the set-point quantity in order to make the network stable.

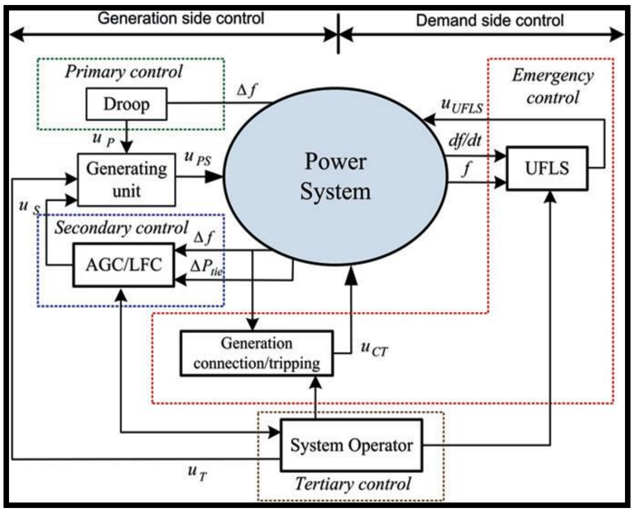

Fig. 1: Frequency Control Loops

B. Secondary Control

For larger frequency deviation (off-normal operation), according to the available amount of power reserve, the secondary control is responsible to restore system frequency. This type of control is exerted by means of an automatic centralized procedure in the control building block. It has two purposes:

1) It keeps the interchange power connecting the control block and its adjoining blocks according to the planned value.
2) In case of major frequency drop, it brings back the set point value of the frequency.

C. Tertiary Control

Tertiary control is any automatic or manual change in the working points of generators or loads participating, in order to:

1) Guarantee the provision of an adequate secondary control reserve at the right time.
2) Distribute the secondary control power to the various generators in the best possible way, in terms of economic considerations.

Typically, operation of tertiary control (in succession or as a supplement to secondary control) is bound to the time-frame of scheduling, but has in principle the same impact on interconnected operation as secondary control. The power which can be connected automatically or manually under tertiary control, in order to provide/restore an adequate secondary control reserve, is known as the tertiary control reserve. This tertiary control reserve must be used in such a way that it will contribute to the restoration of the secondary control range when required.

D. Emergency Control

The direct measures for emergency conditions are based to a certain extent on the philosophy that in the event of a major disruption, selective restrictions in the energy supply are more acceptable than the consequences of an extended network breakdown resulting in a power cut lasting for several hours.

The system frequency as a global parameter is the main criterion that signalizes emergency situations in the system. Due to its equal value in the interconnected system, all partners are automatically participating in problem solving by the automatic action of the primary controllers. Local indicators that inform about possible emergency situations, are "overloading of the interconnecting tie-lines" that can result in action of automatic protection situation are also "decreasing of the transmission voltage" causing voltage collapse due to abnormally high flow of reactive power in the transmission system. Counteraction of the secondary controller and the measures for emergency conditions shall be avoided in a coordinated way.

Therefore, for a serious load-generation imbalance associated with rapid frequency changes following a significant fault, the LFC system may be unable to restore frequency. In this situation, another action must be applied using standby supplies, or emergency control and protection schemes (such as UFLS) as the last option to decrease the risk of cascade faults, additional generation events, load/network, and separation events.

In a power system, all four forms of frequency control are usually present. The demand side can also participate in frequency control through the action of frequency-sensitive relays, which disconnect some loads at given frequency thresholds or using self-regulating effects of frequency-sensitive loads, such as induction motors. The amount of required power reserve depends on several factors including the type and size of load/generation imbalance. Primary frequency control loop provides a local and an automatic frequency control by adjusting the speed governors in the time frame of seconds after a disturbance. The secondary frequency control loop initializes a centralized and an automatic control task using the assigned spinning reserve, which is activated in the time frame of a few seconds to minutes after a disturbance. The tertiary frequency control is usually known as a manual frequency control by changing the dispatching of generating units, in the timescale of tens of minutes up to hours after a disturbance.

In the conventional power grids, the primary control reserves maximum duration of 30 s, whereas in the modern power grids and micro grids with lower inertia, the time constants are much smaller.

III. ANALYSIS OF THREE AREA NETWORK WITHOUT SECONDARY CONTROL LOOP

By using simulation models we can obtain the performance characteristics of the system very easily and quickly for analysis purposes. Below are the various systems Simulink models with their respective responses plotted against time. Three area interconnected systems without using a secondary loop is given in Fig. 2. Fig. 4 presents the settling down of frequency to a finite value which is less than the actual frequency. Fig. 5 shows the power change due to tie-line on account of the deviation in the load. Here stability is improved with interconnection. We have taken the values of the different parameters as shown in table 1 for modeling the Simulink model and its successful operation to obtain the desired results.

Table 1: System Parameters for Three Area System without Using Secondary Control

Particular	Area 1	Area 2	Area 3
K_{sg} *(Gain of speed governor)*	1	1	1
T_{sg}(Time constant of speed governor in sec.)	0.80	0.20	0.30
K_t *(Gain of turbine tranfer function)*	1	1	1
T_t *(Time constant of turbine in sec.)*	0.30	0.50	0.60
H *(Inertia constant)*	10	5	4
D (pu MW/Hz)	1	0.60	0.80
1/R(Speed regulation)	15	20	16
ΔP_D *(Alteration in load Demand)*	1	0	0

IV. ANALYSIS OF THREE AREA NETWORK WITH SECONDARY CONROL LOOP

The model for the three area system including the secondary control is given away in Fig. 3. The results of the variation in frequency as well as tie line power output with

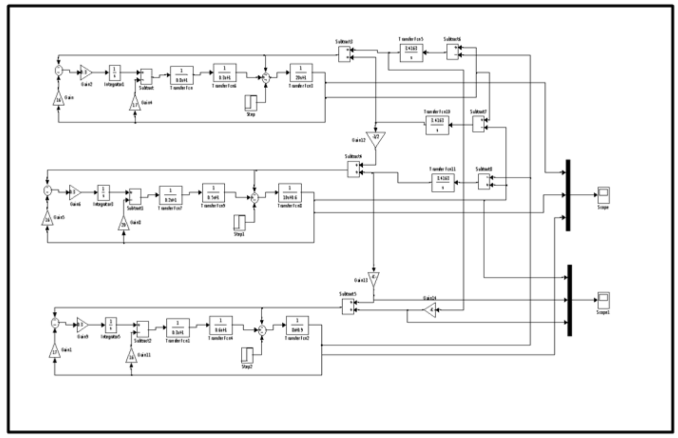

Fig.2: Simulink Model of Three Area System without Using Secondary Loop

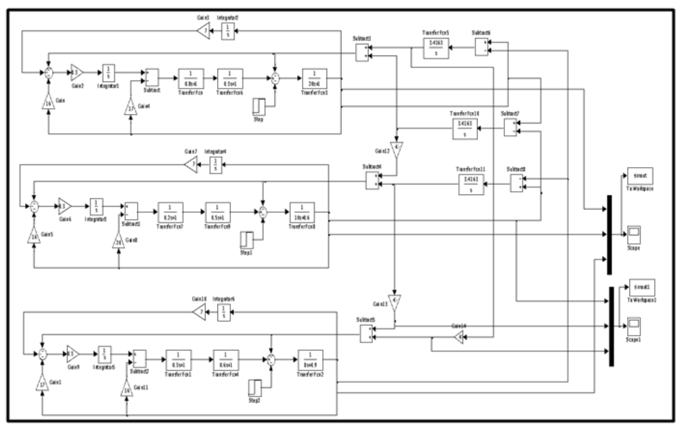

Fig. 3: Simulink Model of Three Area System with Using Secondary Loop

respect to time are being shown in Fig. 6 and Fig. 7. The system operates in a similar way to that of the two area system, taking into consideration the changes in the load. We have taken the values of the different parameters as shown in table 1 for modeling the Simulink model and its successful operation to obtain the desired results.

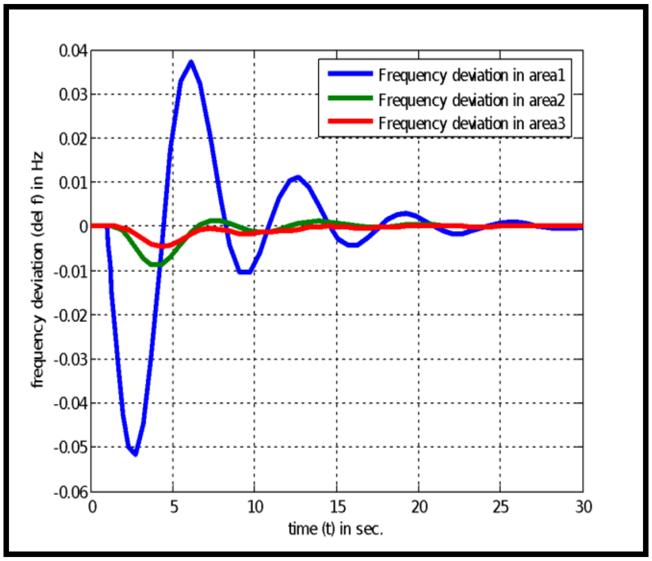

Fig.4: Frequency Deviation vs. Time for Three Area System without Secondary Loop

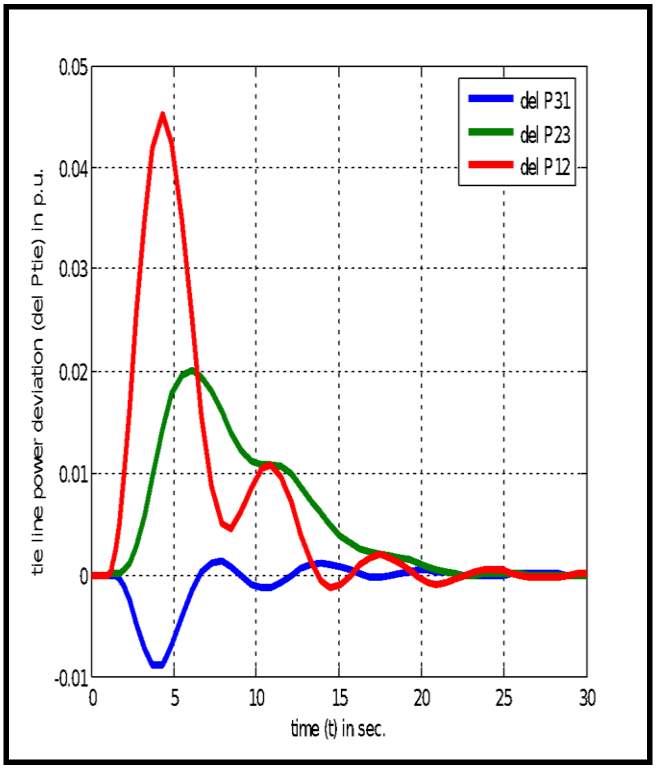

Fig. 5: Tie Line Power Deviation vs. Time for Three Area System without Secondary Loop

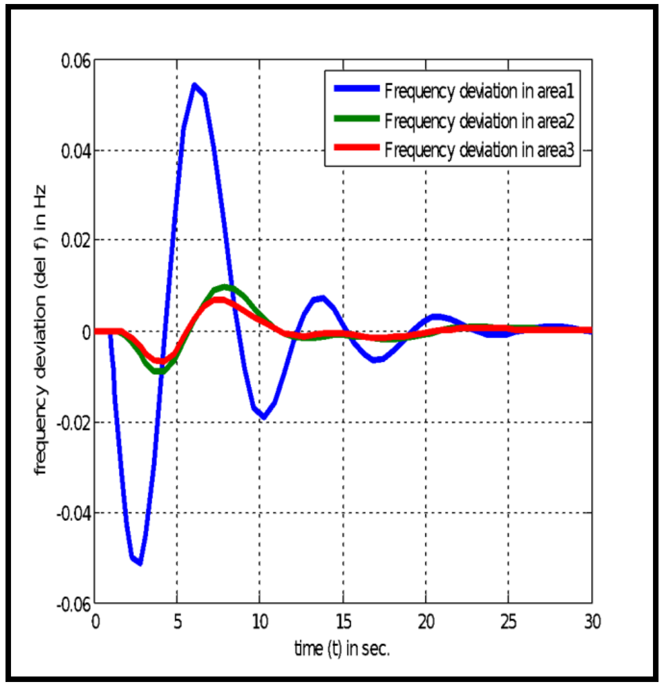

Fig.6: Frequency Deviation vs. Time for Three Area System by Using Secondary Loop

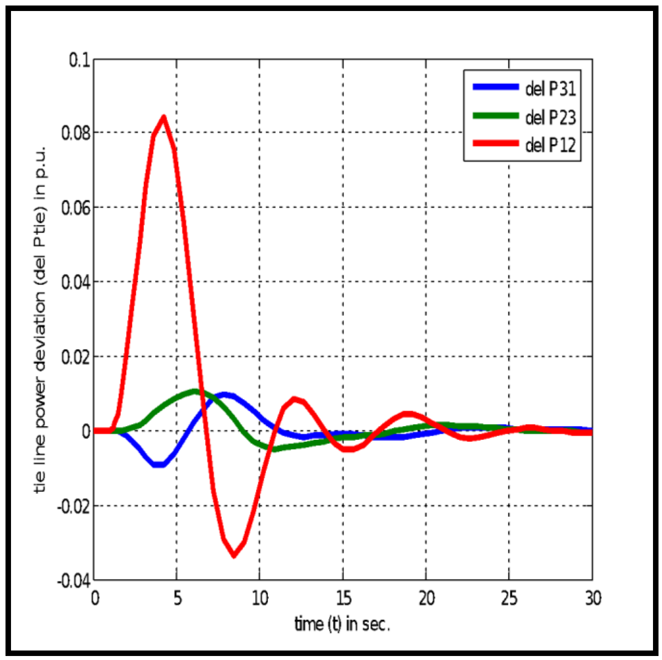

Fig.7: Tie Line Power Deviation vs. Time for Three Area System with Secondary Loop

V. OBSERVATION

By considering the above-stated simulation results it could be analyzed that the system experiences deviation in the frequency subjecting a sudden variation in the load and it is primarily because of the vanishing of equilibrium with the electrical load as well as the mechanical input which is given by the generator prime mover/ steam turbine. Fluctuations in the system are more in the single area system than two area systems for the reason that all the variations in the load are to be handled by one area only.

Moreover variation in frequency is made to be zero by using a secondary loop in both single area networks in addition to two area networks. We also see that the three area system also operates in a similar manner like that of two area systems and flowing power in a tie line which drifts from their contractual constraints between various areas are back to normal in steady state within a few seconds.

VI. CONCLUSION

In this paper we see that developing models in MATLab/Simulink of an interconnected three area system with transmission lines. In the case of single area load change then drifts in frequency is settled down near to a limited value following oscillation and so the new working frequency is less as compared to the supposed value which adversely affects the product quality in industries. This undesired situation was overcome by integral loop i.e. secondary control, frequency drift is made zero. Also developed the models for two and three area networks and found that there is stability improvement with interconnection. From the preceding analysis that the two area system, just as in the case of single area system in the uncontrolled mode, has steady state error but to a lesser extent and the tie line power deviation and frequency deviation exhibit oscillations that damped out later. Thus the advantage of interconnection is understood and we see that the dynamic response is chiefly administered by means of the secondary loop.

REFERENCES

[1] D. P. Kothari and I. J. Nagrath, Modern Power Sysem Analysis, 3rd edn., Tata McGraw-Hill Education Private Limited, New Delhi 2003

[2] M. Stankovic, G. Tadmor and T. A. Sakharuk, "On robust control analysis and design for load frequency regulation," in IEEE Transactions on Power Systems, vol. 13, no. 2, pp. 449-455, May 1998.

[3] Ravi Kumar, G. Ashok and B. Siva Prasad “Tuning PID Controller Parameters for Load Frequency Control Considering System Uncertainties,” Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, vol. 5, part -4, Issue 5, pp.42-47, May 2015.

[4] G. Padhan and S. Majhi, “A new control scheme for PID load frequency controller of single area and multi area power systems,” ISA Transactions, vol.52, pp.242-251, Nov. 2013

[5] J. Sharma, Y. V. Hote, and R. Prasad, “Robust PID Load Frequency Controller Design with Specific Gain and Phase Margin for Multi-area Power Systems,” IFAC-Papers Online, vol. 51, no. 4, pp. 627–632, 2018.

[6] L. Hari, M. L. Kothari and J. Nanda, "Optimum selection of speed regulation parameters for automatic generation control in discrete mode considering generation rate constraints," in IEE Proceedings Generation, Transmission and Distribution, vol. 138, no. 5, pp. 401-406, Sept. 1991.

[7] MATLAB 7.0.0.19920 (R14), The MathWorks Inc., May 2004. www.mathworks.com

[8] N. Tan, “Computation of stabilizing PI and PID controllers for processes with time delay,” ISA Transactions, vol. 44, no.-2, pp. 213–223, April 2005.

[9] P. Kundur, Power System Stability and Control, McGraw-Hill Education (India) Private Limited, New Delhi, 2014.

[10] S. Saxena and Y. V. Hote, "Load Frequency Control in Power Systems via Internal Model Control Scheme and Model-Order Reduction," in IEEE Transactions on Power Systems, vol. 28, no. 3, pp. 2749-2757, Aug. 2013.

[11] S. Sönmez and S. Ayasun, "Stability Region in the Parameter Space of PI Controller for a Single-Area Load Frequency Control System With Time Delay," in IEEE Transactions on Power Systems, vol. 31, no. 1, pp. 829-830, Jan. 2016.

[12] W. Tan, "Unified Tuning of PID Load Frequency Controller for Power Systems via IMC," in IEEE Transactions on Power Systems, vol. 25, no. 1, pp. 341-350, Feb. 2010.