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Simulation and Analysis of Two Area System Comprising Wind and Conventional Energy Sources

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***Abstract*—This paper explains the working of two area system and comprises wind power plant and conventional power plant. In this work the two area power system is further analyzed under load and wind speed perturbation. It is shown that when these perturbations are applied to the system then the system frequency is resorted after some time interval by de-loading the wind turbine. The whole system is designed and simulated in MATLAB software.**

***Index Terms*— Interconnected power systems, wind generation, Conventional Sources, load fluctuation, LFC and WT de-loading.**

I. INTRODUCTION

In an interconnected power system that consists of several control areas, as the system varies, the tie-line power will change and the frequency deviations will occur. The load–frequency control is a part of the AGC system. The objective of LFC is to damp the transient deviations in area frequency and tie-line power interchange. The control error signal in LFC is called ACE, which represents the real power imbalance between generation and load. The ACE is a linear combination of net tie-line power error and frequency error. This signal is used to regulate the generator output power based on network load demand. Different types of controllers have been proposed in literature for the load frequency control.
Large Scale Power Systems are normally divided into control areas based on the principle of coherency. Ref. [1] The coherent areas are interconnected through tie lines which are used for contractual energy exchange between areas and provide inter-area support during abnormal operations AGC and Ref. [3][2] Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. In large interconnected power system, generation of power is done by thermal, hydro, nuclear and gas power units. Nuclear units owing to their high efficiency are usually kept at base load close to their maximum output with no participation in system AGC. Gas plants are used to meet peak demands only. Thus the natural choice for AGC falls on either thermal or hydro units.
Ref. [4]In past, most of the earlier works in the area of LFC pertain to interconnected thermal systems and relatively lesser attention has been devoted to the AGC of interconnected hydro-thermal system involving thermal and hydro subsystem of widely different characteristics. Ref. [5] Concordia and Kirchmayer have studied the AGC of a hydro-thermal system considering non-reheat type thermal system neglecting

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generation rate constraints. Ref. [6] from the literature, it is observed that Nanda, Kothari and Satsangi are the first to present comprehensive analysis of AGC of an interconnected hydrothermal system in continuous-discrete mode with classical controllers. In the interconnected hydro-thermal system used by them, the thermal system uses reheat turbine and the hydro system uses a mechanical governor. Ref. [8][7] In the past decades, fuzzy logic controllers have been successfully developed for analysis and control of nonlinear systems. These methods provide good performances but the system transient responses are relatively oscillatory. Abbreviations - Automatic Generation Control (AGC), Area Control Error (ACE), De-loading Factor (DF), Doubly Fed Induction Generators (DFIG), Fuzzy Logic Controllers (FLCs), Load Frequency Control (LFC), Mega Volt Ampere(MVA), Proportional Integral Derivative (PID), Proportional Integral (PI), Rate of Change of Frequency (ROCOF), Wind Turbine (WT),

II. Power System Modelling And Problem Formulation

Usually, a large scale power system consists of a number of interconnected control areas, which are connected by tie-lines power as show in the flg 1. There are different complicated nonlinear models for large-scale power systems. However, for the design of LFC a simplified and linear zed model is usually used. The detailed power system modeling of two area system contains a wind turbines and one steam turbine in area one and two steam turbines in area two. These two areas are tied together through power lines.

In Area I, there is one wind turbine driven doubly fed induction generator (DFIG), rated 1.5 MW is connected. Apart from this generator, there is one steam turbine driven synchronous generator (900 MVA) is also connected to the power system. As the renewable energy sources, are intermittent in nature, so there will be fluctuations in voltage and frequency of the system.

The Area I comprise of one DFIG and one synchronous generator is connected to the Area II with the help of transformers and transmission network. In Area II there are conventional energy sources are used. Two steam turbine driven synchronous generators are used. Both the generators have 900 MVA capacities.

Power system loads and losses are sensitive to frequency. Data captured right after frequency disturbances indicate that their aggregate initial change is in the same direction as the frequency change. Once a generating unit is tripped or block of load is added to the system, the power mismatch is initially compensated by an extraction of kinetic energy from system inertial storage which causes a declining system frequency. As the frequency decreases, the power taken by loads also decreases. Equilibrium for large systems is often obtained when the frequency sensitive reduction of loads balances the output power of the tripped unit or that delivered to the added block of load at the resulting new frequency. If this effect halts the frequency decline it usually does so in less than 2 seconds. If the mismatch is large enough to cause the frequency to deviate beyond the governor dead band of generating units, their output will be increased by governor action. For such mismatches, equilibrium is obtained when the reduction in the power taken by loads plus the increased generation due to governor action compensates for the mismatch. Such equilibrium is normally obtained within a dozen seconds after the tripping of a unit or connection of the additional load.

In wind turbine driven induction generator, the output power P_a, developed by wind turbine with blade radius ‘r’ can be expressed as under:

$$P_a = \frac{1}{2}\rho\pi r^2 C_p(\lambda, \beta) V_w^3 \qquad (1)$$

where, πr^2 is the rotor swept area, C_p is the power co-efficient, λ is the tip speed ratio, β is the pitch angle while V_w being the wind speed. The tip speed ratio λ can be described as:

$$\lambda = \frac{r\Omega}{V_w} \qquad (2)$$

Where, Ω is the turbine rotor speed. The relevant wind turbine characteristics are depicted in Fig. 2.As from the above equations it is found that the frequency of the system is dependent on the wind speed. So for regulating this frequency deviation frequency controller has to be designed. The x-axis is representing the turbine speed in run per minutes and y- axis is representing the power in KW. The output mechanical power is different w.r.t turbine speed. When the wind speed is 5 m/s than the mechanical power is generated a small value, but increase the turbine speed of generator than the mechanical power is generated with increasing rate as show in the flg. If the wind speed is 10 m/s than the mechanical power is generated 0.5 KW at 1000 rpm of the turbine speed of generator and mechanical power is increase with the turbine speed of generator. The mechanical power is increasing up to 1500 rpm and after this mechanical power is saturated up to 2000 rpm.

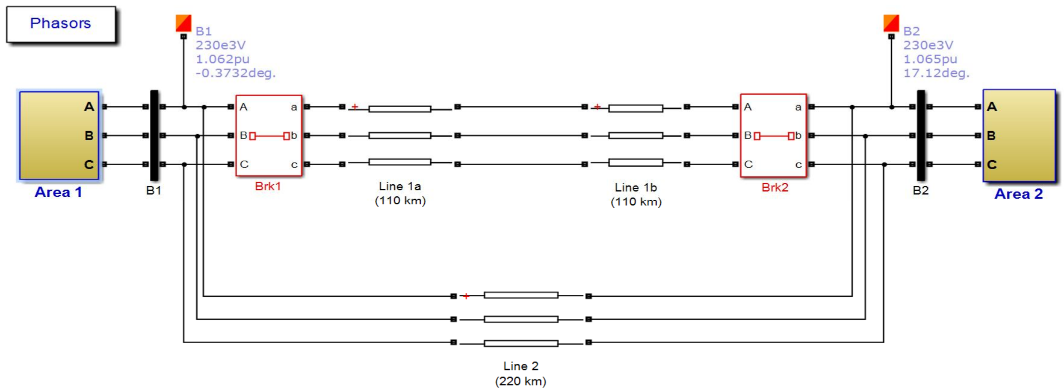


Fig.1 Two area system connected through transmission network

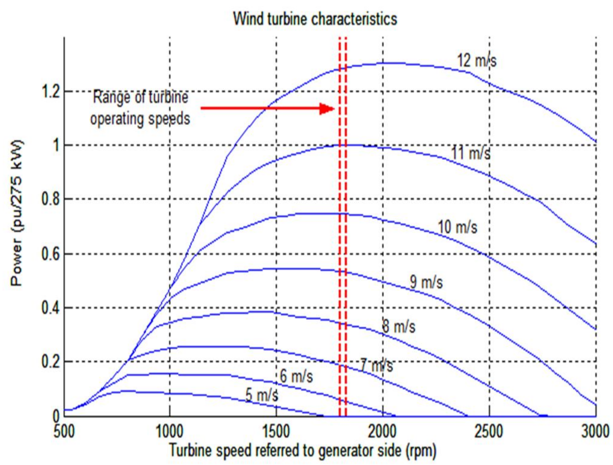


Fig.1. Mechanical power versus turbine speed characteristics

But after this the mechanical power is decrease with turbine speed increase as show in the fig. In Similar way the mechanical power is change w.r.t turbine speed at the different wind speed.

III. Frequency Control Using Deloading Method

WT is operated such that $P_{optimum}$ is less than the optimum available power all the time. Thus, the deficit between the actual output power and the optimum one is considered as a strategic reserve to support the system during frequency deviations. As mentioned in the first section; de-loading could be applied by two methods:

- If wind speed is considered constant and the pitch angle does not change, a requested amount of deloading is achieved at two alternative operating points. Compared to the MPT, the left point is of decreased and the right point of increased rotor speed. In it is explained why de-loading via under-speeding results to detrimental behaviour of the WG regarding the LFC problem and how it also threatens the balance of the mechanical system.
- Activating pitch control at all WSs so that $P_{optimum}$ is reduced based on the implied pitch angle. This technique is applicable for any WT equipped with pitch angle controls. However, pitching is a slow alternative due to mechanical response of servo motors controlling blades feathering. Wind turbine is designed much like governor control of synchronous machine in this part to make the wind power plant have a long-term frequency regulation capability.

In both methods a predefined DF is selected according to their required contribution of WFs in frequency drops mitigation. DF numerical value is adjusted based on several givens including the level of WFs penetration in system and the history of frequency excursions in the system. Moreover, it is not necessary that all WFs have the same DF, but it counts on the number and the nameplate ratings of WTs inside each WF. In this paper, it is assumed that DF equals 15 %, and the minor differences between the two methods are ignored.

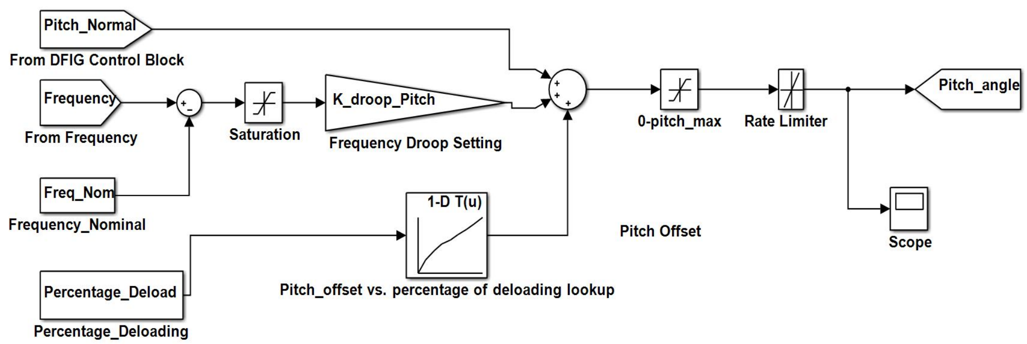


Fig.3. De-loading control of wind turbine

The rate of change of frequency modal is show in the below flg.4

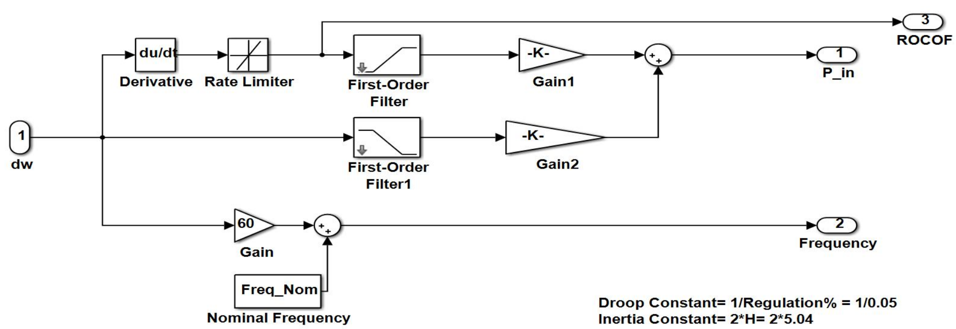


Fig.4.Rate of change of frequency

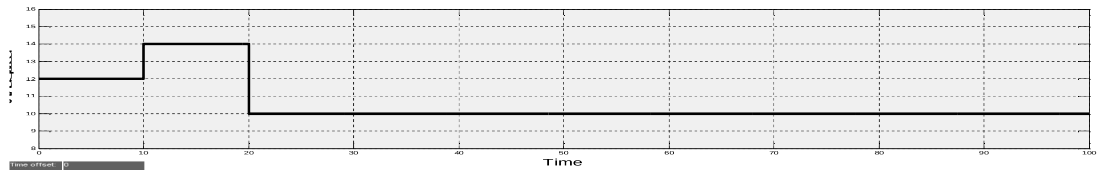
The frequency is changed w.r.t the load. If the load is not changed than the ROCOF is zero. If the load is changed than ROCOF occurs. So the ROCOF is directly proportional to the load variations. And other the rate of change of frequency is depending upon the percentage of deloading. If the percentage of deloading is higher than the rate of change of frequency is more.

IV. Simulation And Result

The system is subjected to the two perturbations, i.e. load change and wind speed variations. Means the frequency is changed w.r.t change in the load change as well as wind speed.

When wind speed is varied but load is constant:

Frequency response of interconnected power system is show in flg 6 and wind speed variations in flg 5. The x-axis is representing the time and y- axis is representing the frequency in flg 6. The x-axis is representing the time and y- axis is representing the wind speed in flg 5. When the initial wind speed is 12, after 10 second the wind speed is 14 than the frequency is increase as show in th flg. After 20 second the wind speed is 10 than the frequency is decreases, and after this the frequence is in the saturated mode in flg 6.



Flg 5 Wind speed change w.r.t time

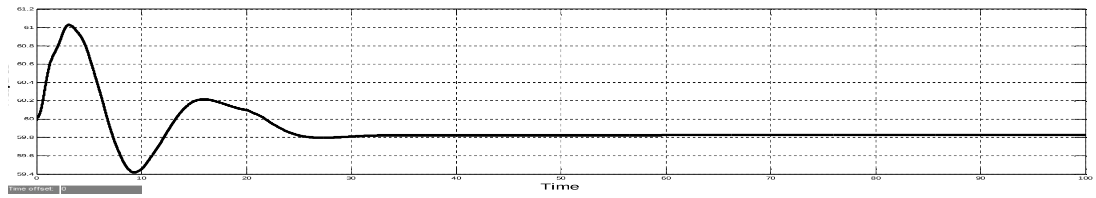


Fig. 6 Frequency response of interconnected power system

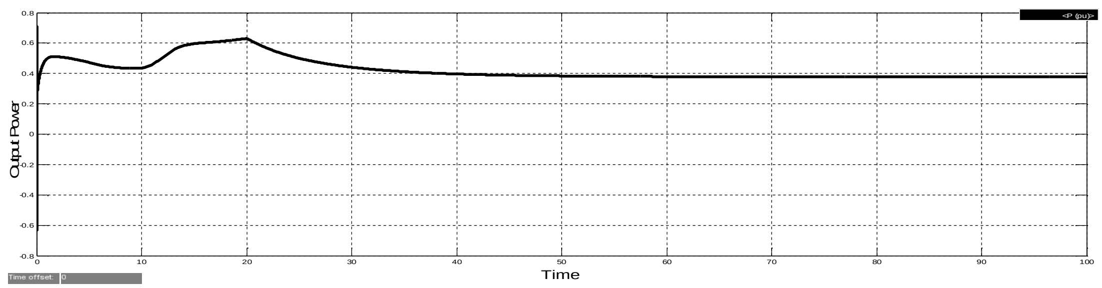
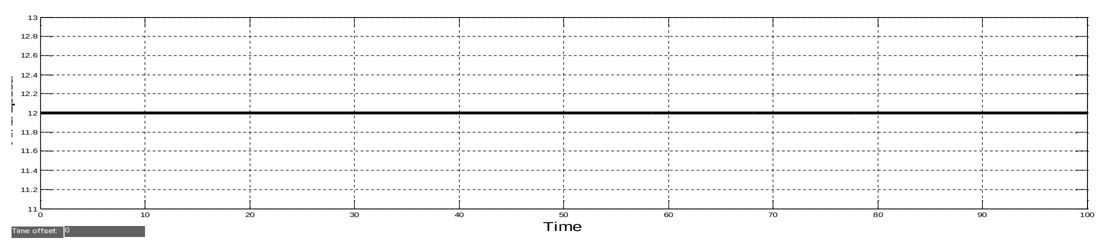


Fig. 7 Deviation in generator output

Output power generated by wind generator is show in the flg 7and wind speed variations in flg 5. The x-axis is representing the time and y- axis is representing the output power in flg 7. When the initial wind speed is 12, after 10 second the wind speed is 14 than the output power is increase as show in th flg. After 20 second the wind speed is 10 than the output power is decreases, and after this the output power is in the saturated mode in flg 7.

When load variations but wind speed constant:

Frequency response of interconnected power system is show in the flg 9 and wind speed constant in flg 8. The x-axis is represent the time and y- axis is represent the frequency in flg 9 and. The x-axis is representing the time and y- axis is representing the wind speed in flg 8. The load is change at the 50 sec. During this period the frequency is dropped with high rate as Show in flg .in 9. After some time the frequency is maintained by the deloading technique.



Flg 8 Wind speed constant w.r.t time

Output power generated by wind generator is show in the flg 10 and wind speed constant in flg 8. The x-axis is representing the time and y- axis is representing the output power in flg 10. The output power is no more affected by the load variation. The output power is produced by the generator is almost constant as show in the flg. 10.

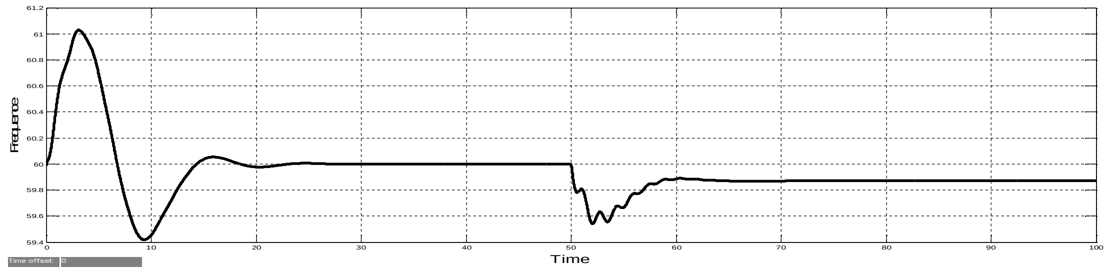


Fig. 9Frequency response of interconnected power system

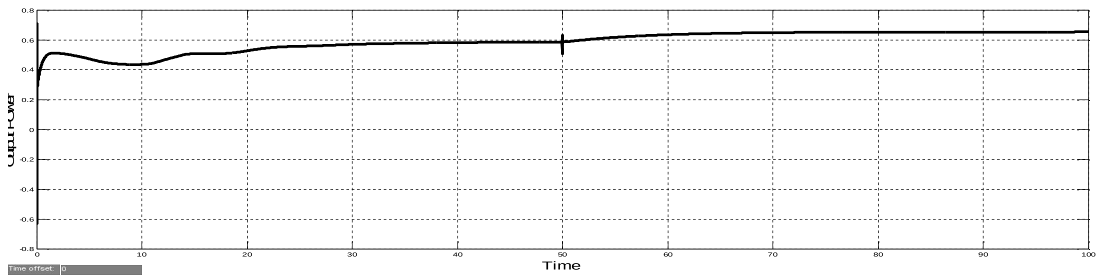


Fig. 10 Deviation in generator output

V. Conclusions And Future Scope

In this paper, frequency regulation of the two area system comprises of renewable (wind) and conventional energy sources performed under different perturbations. WT de-loading technique is performed for the better frequency regulation. With this technique, the frequency of the whole system i.e. area I and area II is better regulated and the frequency regulator is responded to the required pitch angle for the WT.

For the future work, the gain of the frequency controller can be optimized by some artificial intelligence technique. Also inertial response of the steam turbines used in the system can be utilized for frequency regulation.

References

[1] J. Nanda, J. *S*. Sakkaram, et al. Automatic generation control with fuzzy logic controller considering generation rate constraint, Proceedings of thc 6th International Confcrrnce on Advances in Power System Control, Operation and Management, APSCOM2003, Hong Kong, November 2003.

[2] Chaturvedi, D.K., Satsangi, P.S. & Kalra, P.K, et al. "Load Frequency Control: A generalized Neural Network Approach", Int. Journal on Electric Power and Energy Systems, Elsevier Science, Vol.21: 405-415, 99.

[3] Gayadhar Panda, Sidhartha Panda and C. Ardil, et al. "Hybrid Neuro Fuzzy Approach for Automatic Generation Control of Two–Area Interconnected Power System",International Journal of Computational Intelligence, Vol. 5, No. 1, pp. 80-84, 2014.

[4] M.L.Kothari, B.L.Kaul and J.Nanda, et al. "Automatic Generation Control of Hydro-Thermal system", journal of Institute of Engineers(India), vo1.61, Pt EL2, Oct 1980, pp 85-91

[5] C. Concordia and L.K.Kirchmayer, "et al." "Tie-Line Power and Frequency Control of Electric Power System - Part It", AIEE Transaction, vol. 73, Part- 111-A, April 1954, pp.133-146.

[6] J.Nanda, M.L.Kothari, P.S.Satsangi, et al. "Automatic Generation Control of an Interconnected hydrothermal system in Continuous and Discrete modes considcring Generation Rate Constraints", IEE Proc., vol. 130, pt D, No. I , Jan. 1983, pp 455-460.

[7] J. Talaq and F. Al-Basri, et al. "Adaptive fuzzy gain scheduling for load frequency control," IEEE Trans. Power Systems, vol. 14, Feb. 2012, pp. 145-150.

[8] E. Yesil, M. Guzelkaya and 1. Eksin, et al."Self tuning fuzzy PID type load and frequency controller,"Energy Conversion and Mmagement, vol. 45, 2013, pp. 377-390.