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Study the Effect of RES Integration with AGC&AVR Controlled Deregulated Power System

Shreedevi Rajaput[1], Nithya S[2], Vijaya laxmi Narayan[3], Keerty[4], M J Chandrashekar[5]

[1 2 3 4] Student, Electrical & Electronics Engineering, S J B Institute of Technology, Bengaluru, India

[5] Assoc. Professor, Electrical & Electronics Engineering, S J B Institute of Technology, Bengaluru, India

Abstract: **This paper proposes an Automatic Generation Control (AGC) scheme along with automatic voltage regulation under a deregulated system involving competing generation companies. The responses of the proposed system are studied with addition of different controllers. This paper mainly focuses on the study of the effect of the proposed system with the integration of RES. The simulation is done in MATLAB/SIMULINK R2013a. The simulation results of frequency and power responses in deregulated environment are presented. The model is designed in such a way that, the frequency deviation is controlled to a large extent, even for fluctuating load and with large disturbance in the system.**

Keywords: **Automatic generation control, automatic voltage regulator, load frequency control, deregulation, RES integration.**

I. INTRODUCTION

In an interconnected power system, it is required to maintain system frequency and tie-line power exchange fixed to their least possible values for efficient, economic and reliable operation of the power system. By controlling the real and reactive power generated by the different sources in the system, the mismatch in system frequency and tie-line power due to sudden change in load, is compensated. The two major controlling actions in the system are provided by the Automatic Voltage Regulator (AVR) loop and the Automatic Load Frequency Control (ALFC) loop. The reactive power of the system determines the magnitude of terminal voltage. The real power of the system determines the megawatt output and frequency of the synchronous generator [1].

The regulated power system is unreliable when used for a longer period of time. Hence, a need for a new system arises, which will increase the competition and customer participation in the electricity market. Such a new system is called a restructured power system. It is also called a deregulated one which consists of GENCOs, TRANSCOs and DISCOs replacing generation units, transmission units and distribution units. The AGC units act as GENCOS [2]. The frequency and the power responses of the same model when different controllers are used is also studied. The interconnection of AGC units with the AVR units in the deregulated environment is done and its effect on the system is studied.

The integration of renewable energy sources [RES] with deregulated power system is quite complex. So, only one DISCO is replaced with RES and its effects are studied. The static load at the DISCOs is replaced by dynamic load. Since both RES and dynamic load are fluctuating loads, our work is to control the fluctuations as much as possible and bring frequency and voltage references to steady state within a short time.

II. AGC & AVR

(i) Load Frequency Control [LFC]

Load frequency control (LFC) is a fundamental control problem in an interconnected power system. The frequency monitors loads and losses in a power system. When there is a sudden increase in the load on the system, the power mismatch is initially compensated. This is done by extracting the kinetic energy from system inertial storage. This causes a decline in the system frequency [3]. The power taken by the load decreases with the frequency. In large systems,

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equilibrium is obtained when there is a reduction in frequency sensitive load. This balances the output of the tripped generator. Sometimes, there is an increase in load at the new frequency. Equilibrium is reached within 2 s. Equilibrium is reached within 10-15 s when there is a large mismatch in the system.

(ii) Automatic generation control [AGC]

It is important to adjust the power output of multiple generators at different power plants, in response to the changes in load. Such a controlling action is done with the concept of automatic generation control (AGC) [4]. A large scale power system is divided into a number of control areas. A control area is a part of the power system to which a common generation control is applied. When a two-area system is modelled, two control areas are considered with one AGC unit in each area. A weak tie-line is used to connect these two units from two different control areas.

(iii) Automatic voltage regulator [AVR]

The AVR control loop consists of an amplifier, an exciter, a generator field, a sensor and a controller. The exciter unit excites the alternator field and controls its flux. During slow and steady changes in the load, the AVR maintains the generator terminal voltage constant [5].

III. DEREGULATED POWER SYSTEM

Competitiveness in the electricity market has increased in the restructured power system. The structure of traditional power system is changed with the concept of deregulation. Under the deregulated environment, the system is divided into a number of independent entities such as- generation companies [GENCOs], transmission companies [TRANSCOs], distribution companies [DISCOs] and independent system operators [ISO]. These entities compete in the power market. Due to this, consumers can choose the DISCOs as well as the GENCOs. There is also a provision to sell power to DISCOs at competitive prices [6]. Figure 1 represents the block diagram of two-area AGC system in restructured scenario.

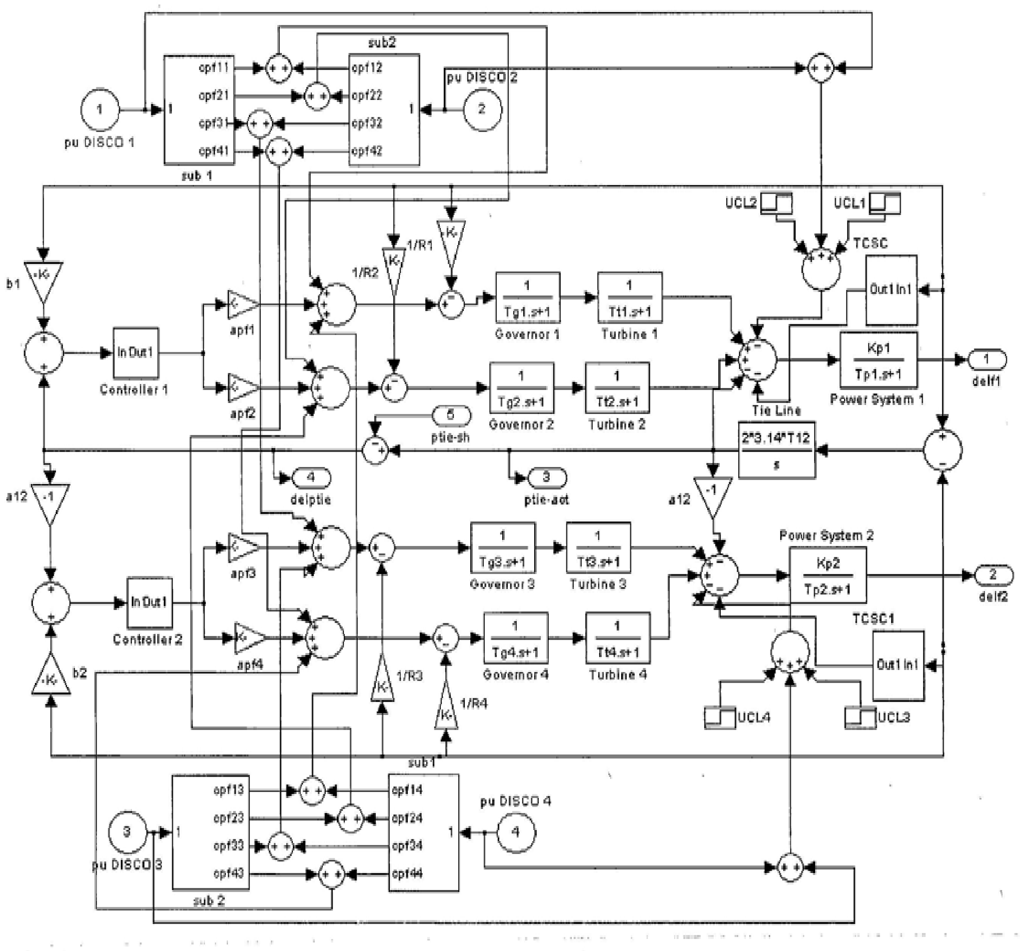

Fig-1: Block diagram of two-area AGC system in restructured scenario

IV. RES INTEGRATION

It is important to look for an alternate source, in order to reduce the burden on the GENCOs. RES integration to the system might provide a better solution for this problem. Presently, wind power and photo-voltaic (PV) systems are the most commonly used RES, which are under research. Transformation of the deregulated power system into a RES based one is not simple or easy. Variability in the generation obtained using most of the RES affects the stability and operation of the power system. Due to this, balancing of the power system becomes uneconomical.

V. DYNAMIC LOAD MODEL

The model has been simulated with static loads. The deviations in the power system will sustain for a short period before reaching steady state when static loads are used. Figure 2 represents the dynamic load model. Dynamic loads are usually unstable loads. When the power system is subjected to such a load, it experiences large disturbances. Here, the load keeps on varying w.r.t time. The model is designed in such a way that, steady state frequency response in different conditions is obtained inspite of continuous fluctuations in load. The response of the other parameters of the power system, when subjected to dynamic load is also studied.

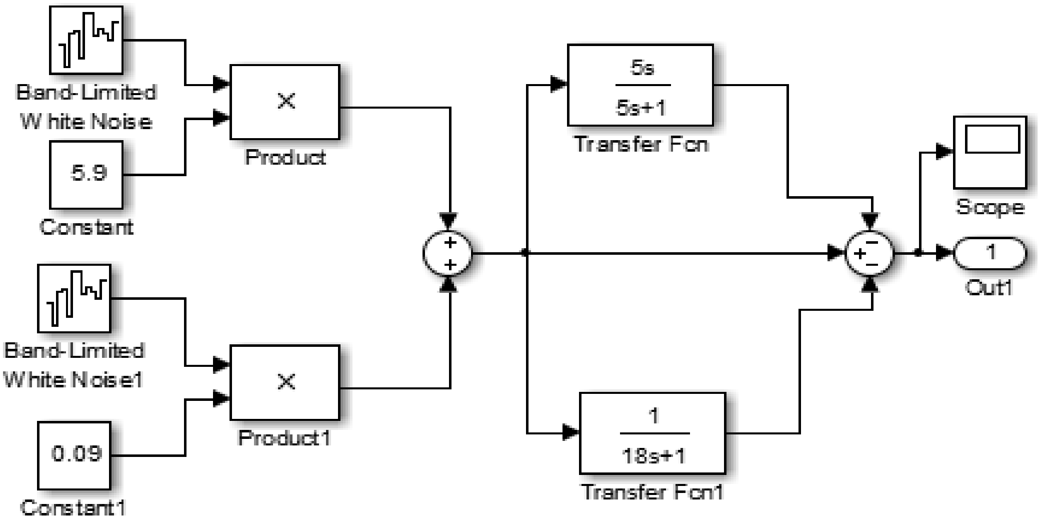

Fig-2: Dynamic load model

VI. SIMULATION RESULTS

Case-(i): AGC and AVR controlled deregulated power system

The two-area AGC and AVR controlled deregulated power system with identical areas can be made best use of w.r.t parameters of the system to obtain the best response.

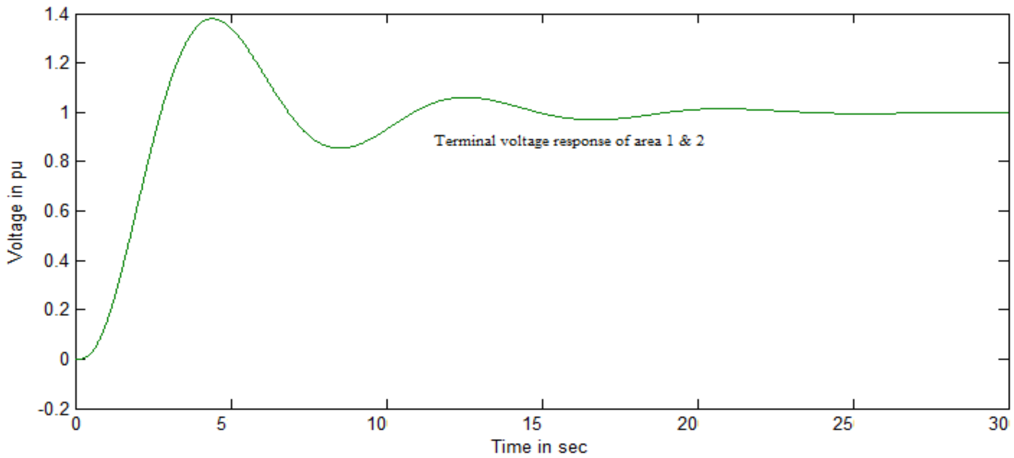

Fig-3(a) Voltage response of AVR in deregulated system

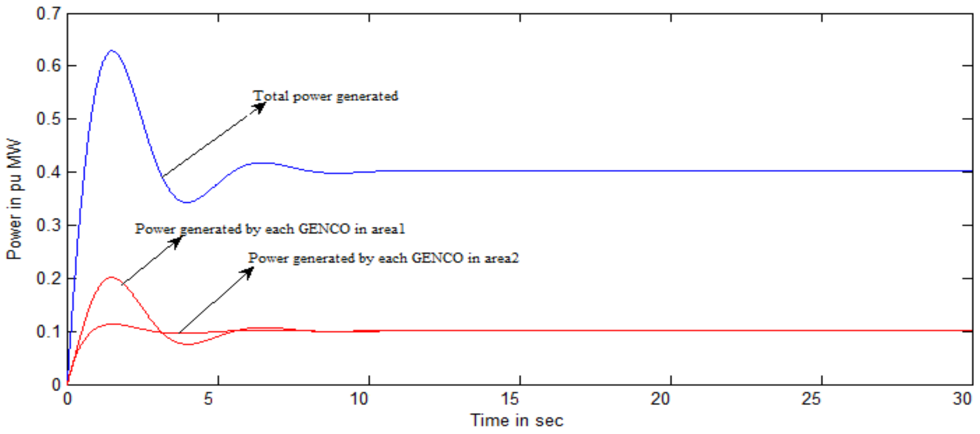

Fig-3 (b) Power generated in AGC controlled system

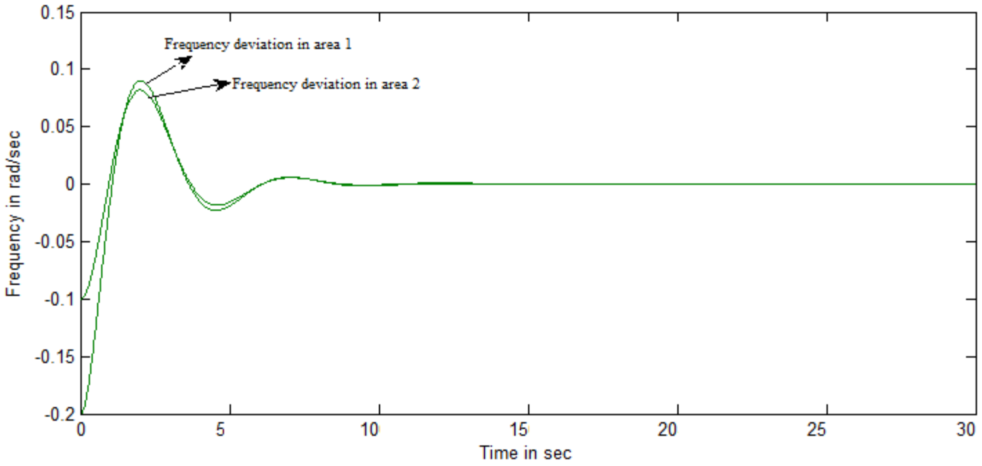

Fig-3 (c) Frequency deviation of AGC in deregulated system

Figure 3(a) shows the terminal voltage response of the system. It is observed that terminal voltage response of area 1 and area 2 is same. The terminal voltage is regulated to nominal value within 20-22 secs. Figure 3(b) shows the power generated in the system. Initially, the load demand to the system is 0.4 p u MW. The power generated by each GENCO in each area is 0.1 p u MW. The total power generated in the system sums upto 0.4 p u MW. Figure 3(c) shows the frequency deviation in the system. The frequency of both the areas reaches steady state stability within 10-12 secs.

Case-(ii): System subjected to dynamic load

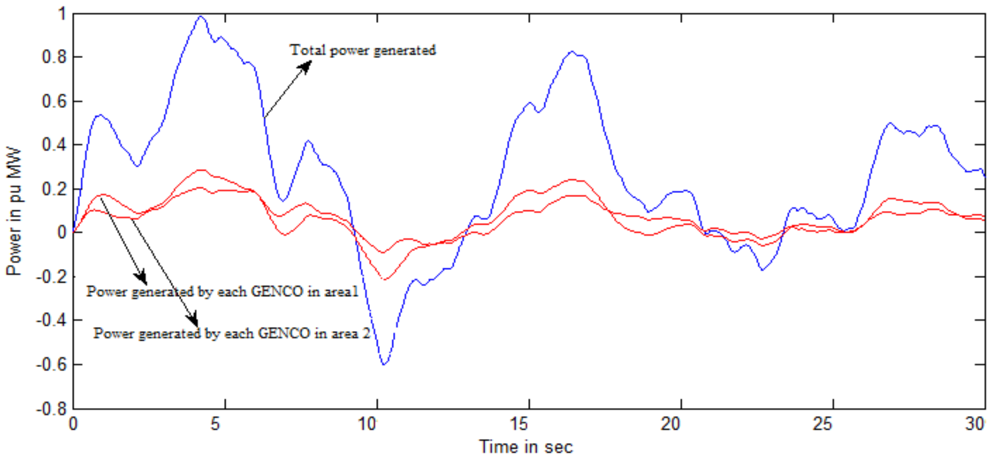

Fig-4 (a) Power gernerated in response to dynamic load

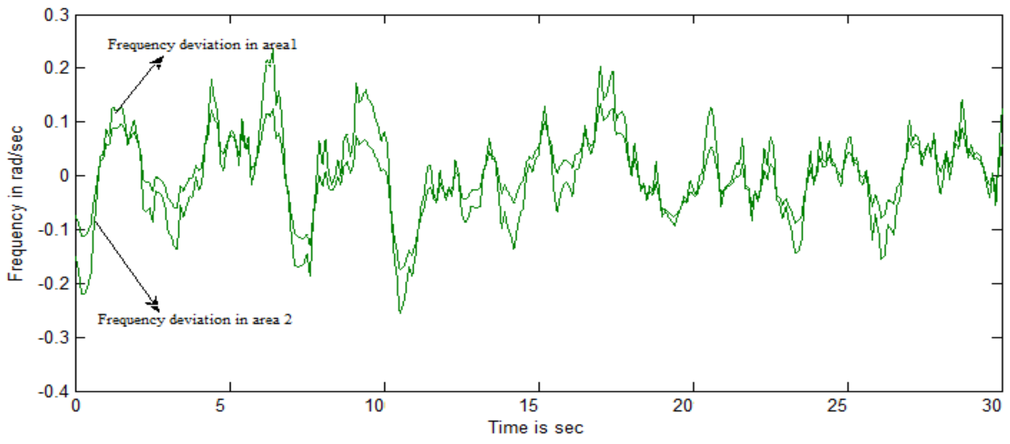

Fig-4(b) Frequency response to dynamic load

Figure 4(a) shows the power generated in response to dynamic load. It is observed that the total power and the power generated in each area in response to the dynamic load have lot of disturbances. Since the load is fluctuating, power is generated accordingly. The model is designed in such a way that, the disturbances in the generated power are reduced to some extent. Figure 4(b) shows the frequency response to dynamic load. The frequency deviation in both the areas is fluctuating w.r.t time. Steady state stability cannot be reached when the system is subjected to dynamic load.

Case-(ii): PV system integrated power system

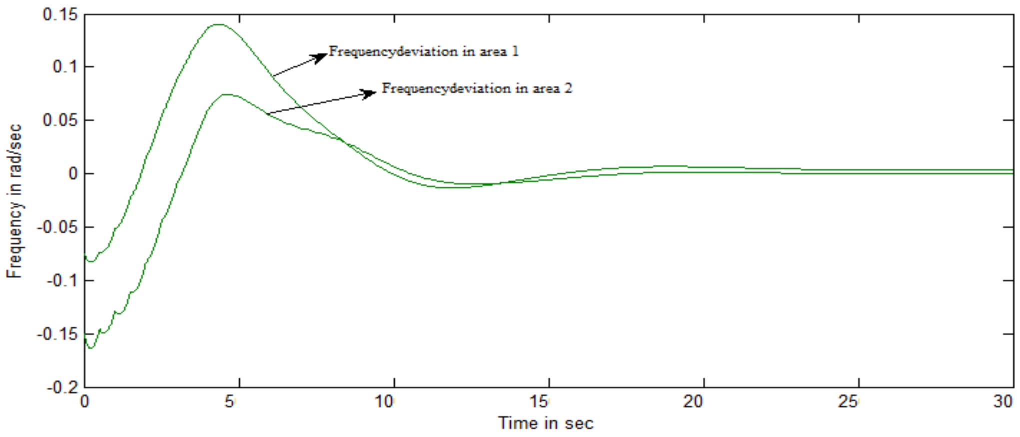

Fig-5 (a): Frequency deviation in PV integrated system

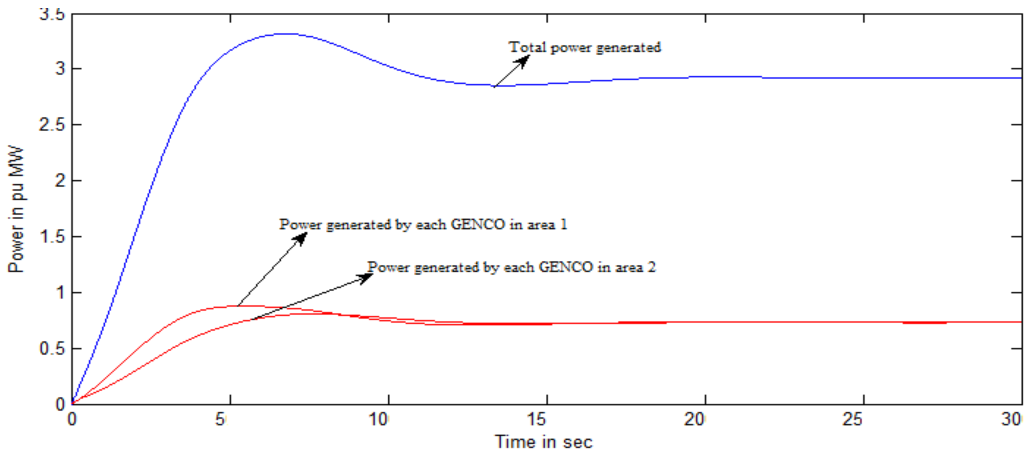

Fig-5(b): Power generated in PV integrated system

Figure 5(a) shows the frequency deviation in PV integrated power system. It is observed that steady state stability is reached within 15-18 secs. Figure 5(b) shows the power generated in PV integrated system. The load supplied by the PV system is 2.5 p u MW. The total load demand of the system is 2.8 p u MW. It is observed that the power generated by each GENCO in each area is 0.7 p u MW. The total power generated in the system sums up to be 2.8 p u MW, meeting the load demand.

Case-(iii): Wind Turbine integrated power system

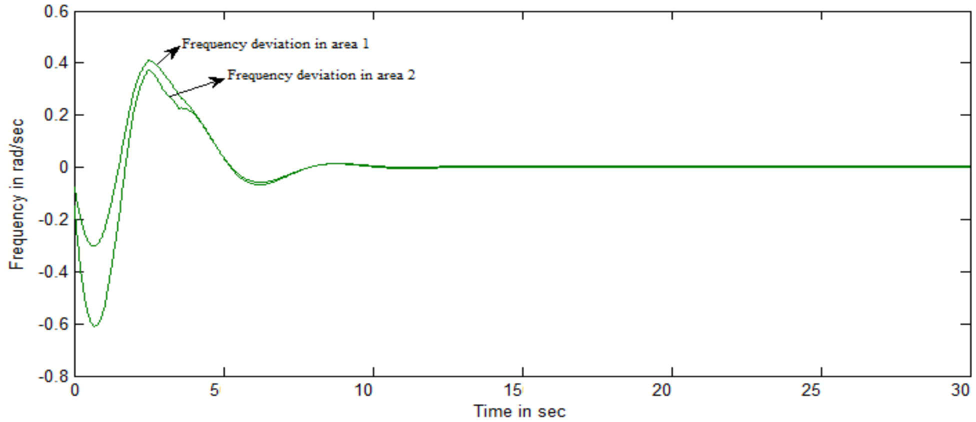

Fig-6(a): Frequency response of wind turbine integrated power system

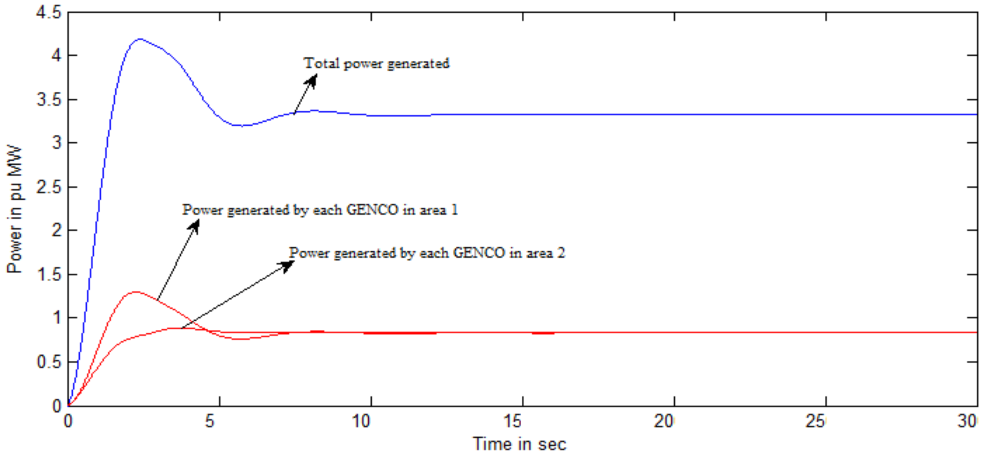

Fig-6(b): Power generated in wind turbine integrated power system

Figure 6(a) shows the frequency deviation in WT integrated power system. It is observed that steady state stability is reached within 10-12 secs. Figure 6(b) shows the power generated in WT integrated power system. The load supplied by the WT system is 3 p u MW. The total load demand of the system is 3.3 p u MW. It is observed that the power generated by each GENCO in each area is 0.825 p u MW. The total power generated in the system sums up to be 3.3 p u MW, meeting the load demand.

Case-(iv): RES integrated power system with dynamic load

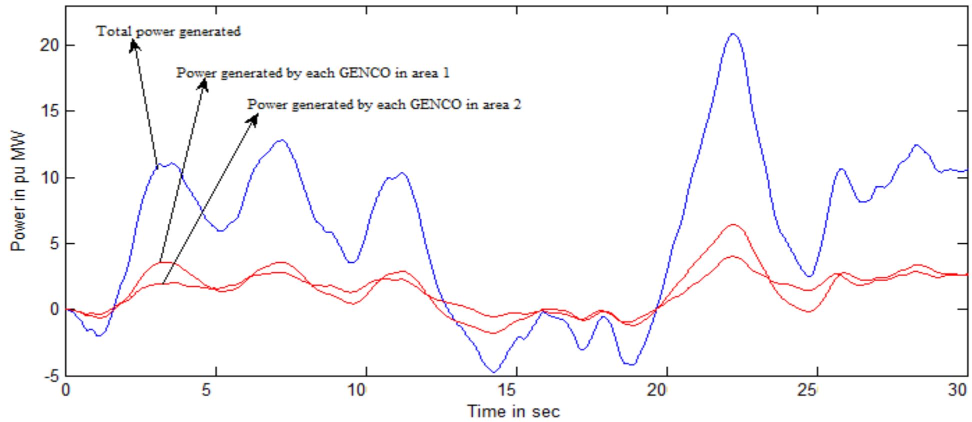

Fig-7(a): Power generated in RES integrated power system with dynamic load.

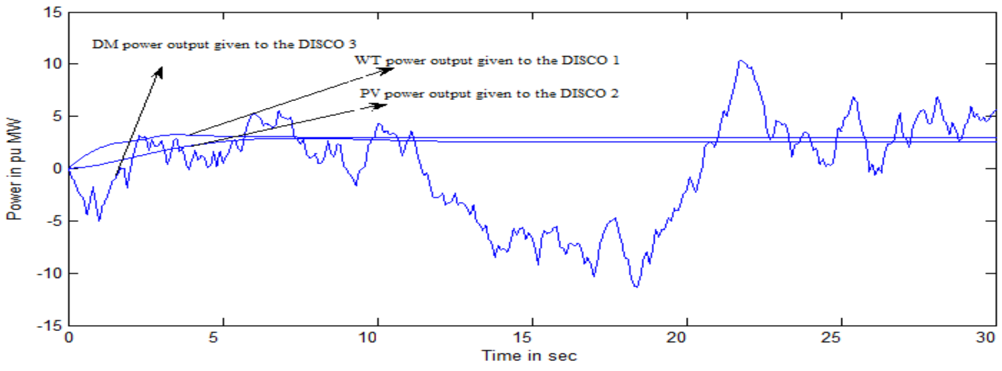

Fig-7(b): Power generated individually in RES integrated power system with dynamic load.

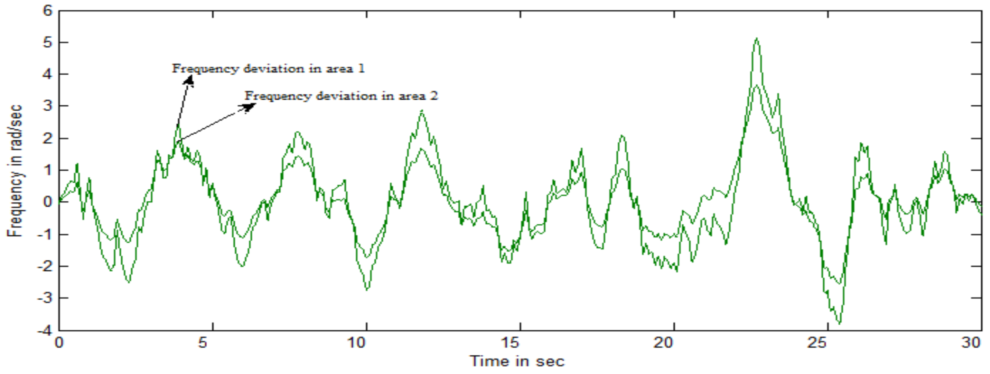

Fig-7(c): Frequency deviation in RES integrated power system with dynamic load

Figure 7(a) shows the power generated in RES integrated power system with dynamic load. The total power generated is within (+,-) 15 p u MW. The power generated follows the fluctuating load. Figure 7(b) shows the power generated individually by PV and WT system with dynamic load. It is observed that the power output of dynamic model is fluctuating upto a large extent when compared to the power output of RES. Figure 7(c) shows the frequency deviation in RES integrated power system with dynamic load. Since the load is fluctuating, the frequency will never reach steady state stability.

Table-1: Comparison of Dynamic response of AGC & AVR controlled Deregulated model with integral, PI, PID controllers.

Controllers	**Frequency peak overshoot**	**Settling time (sec)**	**Power peak overshoot**	**Settling time (sec)**	**Voltage peak overshoot**	**Settling time (sec)**
Integral control	-0.85	20	-0.9	20	-0.75	20
PI	-0.85	20	-0.9	20	-0.75	20
PID	-0.625	8	-0.95	8	-0.75	8

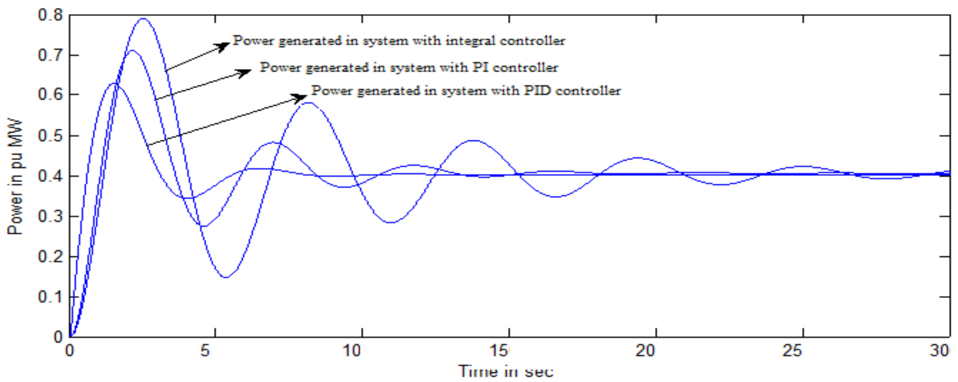

Fig-8(a): Power generated in the system modelled with different controllers

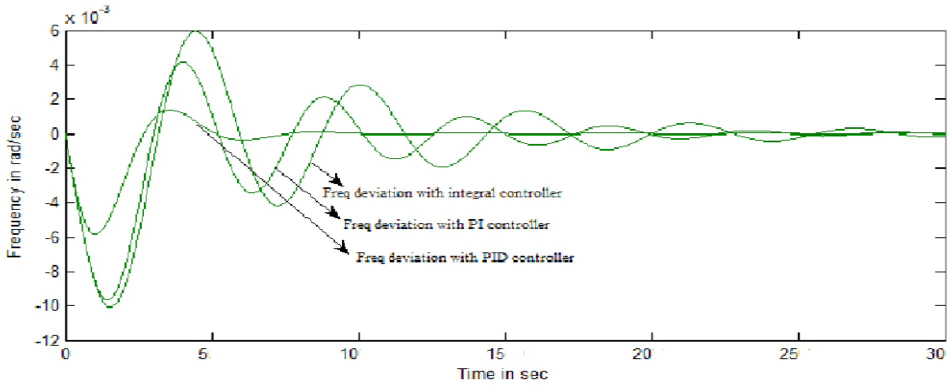

Fig-8(b): Frequency deviation in the system modelled with different controllers

The deregulated power system is modelled with different controllers and their effect on the system is compared. Figure 8(a) shows the power generated in the system modelled with different controllers. It has been observed that, with the use of PID controller in the system, quality power is generated and at a faster rate [10]. Figure 8(b) shows the frequency deviation in the system modelled with different controllers. It has been observed that, with the use of PID controller in the system, the frequency deviation is reduced to a large extent. Steady state stability is reached earlier compared to other controllers.

VII. CONCLUSION

In this paper, the effect of RES integration with AGC and AVR controlled deregulated power system on the frequency and power deviations has been represented. The response of the deregulated system, when integrated with RES and dynamic load is studied. Performance of the system is checked for different load deviations. It has been observed from table-1 that PID controller improves the responses of the system when compared to the conventional ones [12]. The model is designed in such a way that, the frequency deviation is controlled to a large extent, even for fluctuating load and with large disturbances in the system.

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