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Integration of renewable energy generation for frequency support of HVAC interconnected systems under deregulated area

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Abstract ---This paper proposes a modified model for active power/ frequency support of multi-area power system analysis that takes into account the effects of AC systems under deregulated environment of the power market. The AC part of studied system is comprised of conventional generators and HVAC lines. Simulations performed by Matlab software demonstrate how renewable power plants can serve as conventional generators in AGC control loops under constraints determined by the market rules. This scenery is considered one of the most promising evolutions of the future electrical power systems.

Keywords -*Automatic Generation Control, Deregulated power system, Load frequency control*

INTRODUCTION

Frequency control is one of the most profitable ancillary services though the large scale power system analysis. Until now, a lot of studies have been made in this concept [1-6] but new concepts related to high penetration of renewable resource. Conventional power system has changed and experienced a rapid revolution through deregulation, power market, integration of high penetrate renewable energies like PV and distributed generation with energy storage technologies. Modern future power system will be a mixed of hybrid AC/DC grids or parallel AC/DC transmission lines and high penetration of renewable energy sources (RES) like wind and PV power plants. These changes made our system more complex. Most of renewable resources have stochastic behaviours which eventually will have various impacts on the grid. Those are dependent on weather conditions and geographic location and as results their stochastic behaviour can significantly influence power systems performance. These effects will be more relevant in case of large-scale penetration of RES. Therefore, modern power plants based on RES should both deliver power as conventional generators and contribute to the support the grid services by providing ancillary services and in this way applications of advanced technology are very important to reach this goal [7].

The models and control schemes currently used in conventional power systems have several difficulties and limitations to be extended toward modern system, which makes necessary to look for modification. In order to smoothing the operation and increasing the stability of the network, new installations and technologies are needed, e.g., advanced power electronics, FACTS equipment. For example, in a large scale power system, interconnections between neighbouring areas will be important to improve the stability issue of the large system and interconnection of asynchronous areas or in case of very large distance . Also in case of power market and liberalization of power system, we need secure corridors to transfer power for a very long distance. So HVDC technology will be a very good candidate to face up with these problems. HVDC and FACTS equipment considering advanced control methods can essentially improve the reliability of complex interconnected systems [8-10]. Based on this brief introduction, a generalized model for Automatic Generation Control (AGC) considering renewable generation and parallel AC/DC transmission links for frequency control ancillary services is proposed. Due to the lack of research in this field, especially considering power market operations, a generalized formulation for modified AGC with RES is presented adding market scenario signals. By means of proposed model, the manner of interaction for different type of generations with AC/DC interconnections under power market scenario is presented. Difference characteristics of these plants could be added considering this generalized formulation in AGC model. A two-area power system model is used for validating the proposed model in Matlab simulations.

CONVENTIONAL MODEL OF AGC

In multi area interconnected system, each area will consists of a group of generators and loads and AGC system in an interconnected power system should control the area frequency as well as the transmitted power between areas. A typical system for this type of analysis is a normal two area interconnected system [1]. Two generation companies (GENCO) and two distribution companies (DISCO) have been considered in each area. As shown in Fig. 1, areas are connected by parallel HVAC line

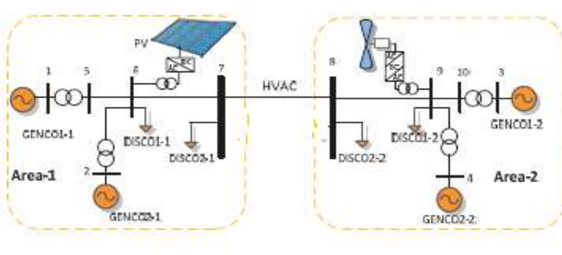

Figure 1: Two- area power system

Conceptually, the relationships between power deviations and frequency deviation are as follows [1]:

$$\Delta P_m(s) - \Delta P_L(s) = 2H_S \Delta f(s) + D\Delta f(s)$$

Where Δf is the frequency deviation of the system, $\Delta P_{m\_}$ is generated power deviation, $\Delta P_{L\_}$ is load change, _H is the inertia constant of the system, and D_ is the load damping coefficient. For modelling the interconnections between *N* areas, the tie-line power change between areas *I* and the rest of area could be presented as:

$$\Delta P_{tie,ij} = \sum_{\substack{j=1 \\ j\neq 1}}^{N} \Delta P_{tie,ij} = \frac{2\Pi}{s}[\sum_{\substack{j=1 \\ j\neq 1}}^{N} T_{ij}\, \Delta f_i - \sum_{\substack{j=1 \\ j\neq 1}}^{N} T_{ij}\, \Delta f_j] \quad (2)$$

Where T_{ij} is the synchronizing coefficient between areas. For two area system with two generation units the frequency deviation in area 1 (ΔF_1) and in area 2 (ΔF_2) the s-domain could be like this:

$$\Delta F_1(S) = \frac{1}{D_{sys,1} + sM_{sys,1}} (\Delta P_{m1} + \Delta P_{m2} - \Delta P_{d1} - \Delta P_{tie.12}) \quad (3)$$

$$\Delta F_2(S) = \frac{1}{D_{sys,2} + sM_{sys,2}} (\Delta P_{m3} + \Delta P_{m4} - \Delta P_{d2} + \Delta P_{tie.12}) \quad (4)$$

Where M_{sys} is the inertia coefficient of the system ($M_{sys} = 2H$),D_{sys} is the damping of the system,ΔP_m is deviation of generated power by each unit and ΔP_d is any local load change as distrubance. Relationship between output power devation and frequency could be as follows:

$$\Delta P_{m1}(s)=\frac{1}{1+sT_{T-G,1}}[apf_1 K_{I1} \int ACE_1 - \frac{1}{R_1}\Delta F_1(s)] \quad (5)$$

$$\Delta P_{m2}(s)=\frac{1}{1+sT_{T-G,2}}[apf_2 K_{I1} \int ACE_1 - \frac{1}{R_2}\Delta F_1(s)] \quad (6)$$

$$\Delta P_{m3}(s)=\frac{1}{1+sT_{T-G,3}}[apf_3 K_{I2} \int ACE_2 - \frac{1}{R_3}\Delta F_1(s)] \quad (7)$$

$$\Delta P_{m4}(s)=\frac{1}{1+sT_{T-G,4}}[apf_4 K_{I2} \int ACE_2 - \frac{1}{4}\Delta F_2(s)] \quad (8)$$

While ACE is the area control error which will present the imbalance of generated power and load demands within the control area and K_1 is the integrator gain constant for each ACE. By means of ACE, any power/frequency mismatched though the system will be checked. ACE could be a linear combination of frequency deviation and net interchange [11]

$$ACE_i=\Delta P_{tie,ij}+\beta_i \quad (9)$$

Where ΔP_{ij}deviation of transmitted power between areas and β_i is the frequency bias of each area. Frequency bias could be calculated as follows:

$$\beta_i = \frac{1}{R_i} + D_i \quad (10)$$

While R_i is the droop characteristic of generation units and D_i is the load-damping constant and as explained before, the transmitted power deviation for two-area power system example will be like this:

$$\Delta P_{tie,12}(s) = \frac{T_{12}}{s}[\Delta F_1(s) - \Delta F_2(s)] \quad (11)$$

FAULTS IMPLEMENTED IN SYSTEM

A power system failure across the town that happened due to a storm breakout or an internal equipment fault that disrupted your local power supply – these are all essentially the cases of faults in electrical systems. An electrical system fault can be defined as a condition in the electrical system that causes failure of the electrical equipment in the circuit.

i. Triple line to ground fault

A short circuit fault occurs when there is an insulation failure between phase conductors or between phase conductor(s) and earth or both. An insulation failure results into formation of a short-circuit path that triggers a short-circuit conditions in the circuit.

ii. Line to ground fault

In this, one of the three phases get short-circuited with ground, causing an unbalanced fault condition in the system

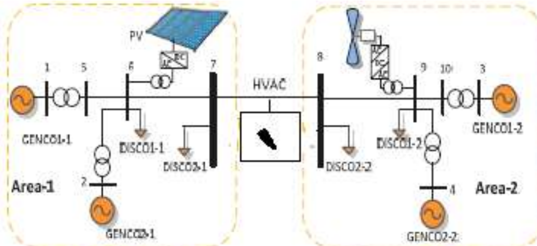

Fig 2: Fault occurred in power system

SIMULATION RESULTS

In this section to illustrate the performance of modified model with renewable source under power market scenario, a general simulation for two-area power system shown in Fig. 1, based on bilateral contracts of market is performed. Simulations are done in MATLAB platform and power system parameters are given in[11]

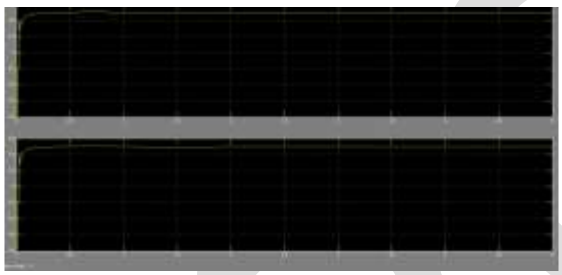

Fig 3: Power change in area 1(generators)

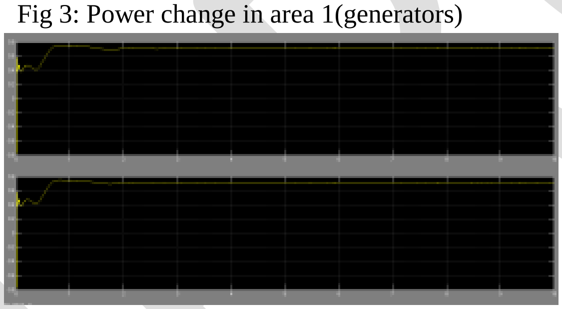

Fig 4: Power change in area 1(RES)

Fig 5: Power change in area 2(generators)

Fig 6: Power change in area 2(RES)

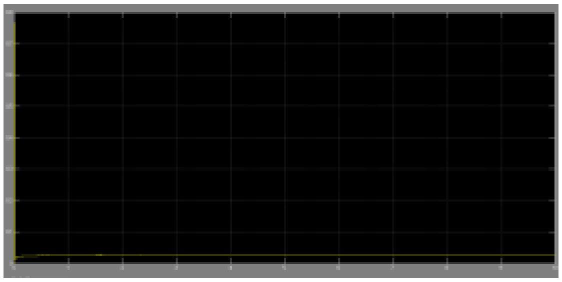

Fig 7: Output power of PV power plant in area 1

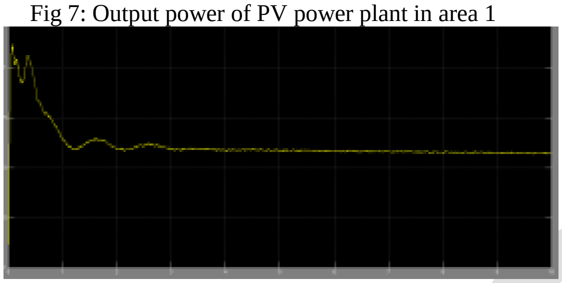

Fig 8: Output power of wind pant in area 2

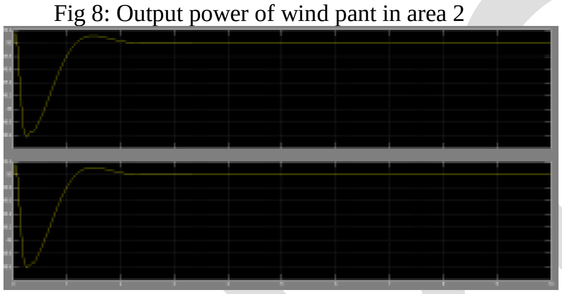

Fig 9: Frequency deviation in area 1

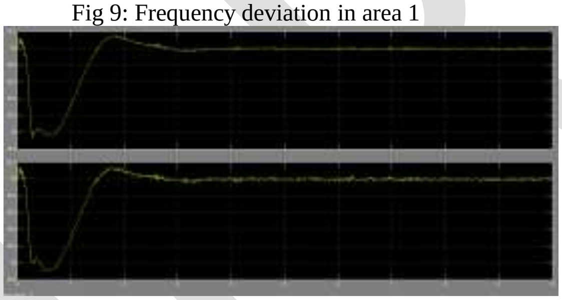

Fig 10: Frequency deviation in area 2

I. Line to ground fault applied in area 2 system:

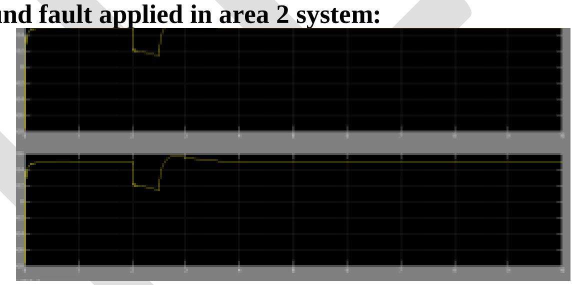

Fig 11: Power change in (generators) area 1

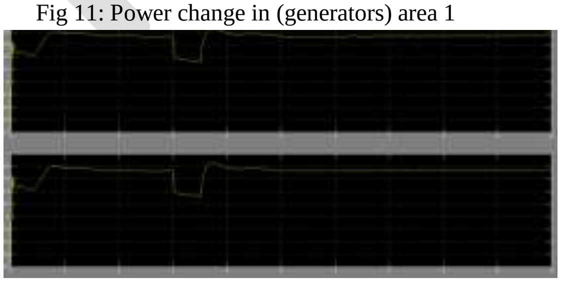

Fig 12: Power change in area 1(RES)

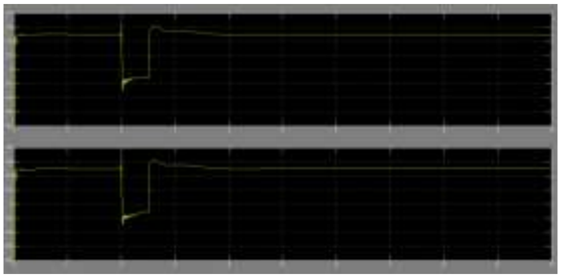

Fig 13: Power change in area 2

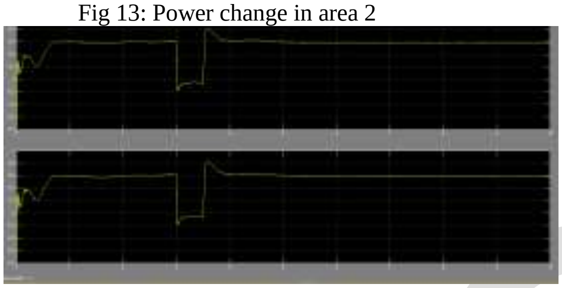

Fig 14: power change in area 2(RES)

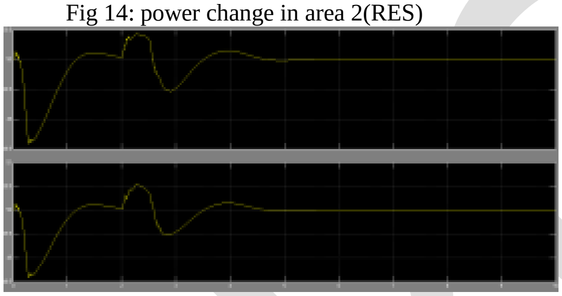

Fig 15: Frequency deviation in generators

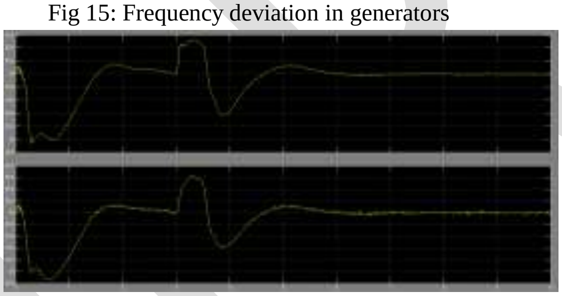

Fig 16: Frequency deviation in RES

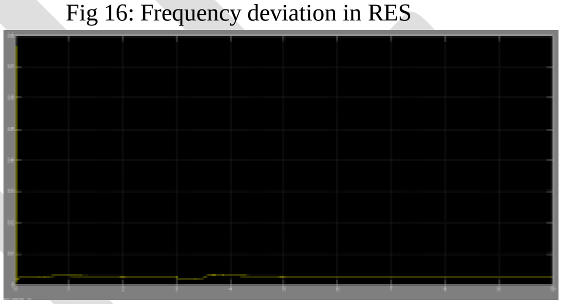

Fig 17: output power PV power plant in area 1

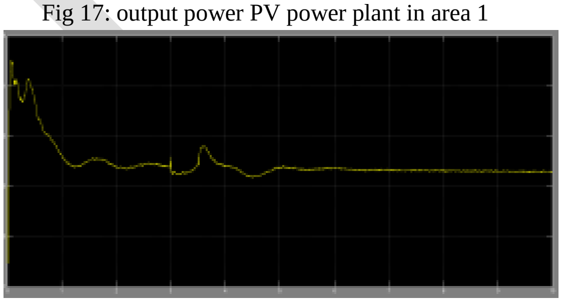

Fig 18: Output power of wind power plant in area 2

II. LLLG fault applied to system in area 2

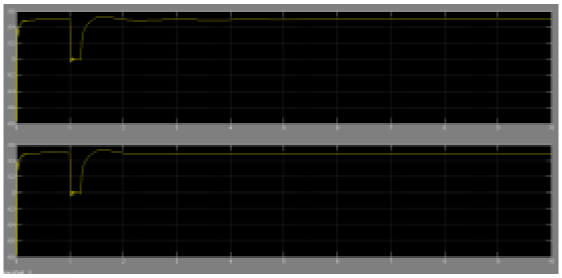

Fig 19: power change in area 1(generators)

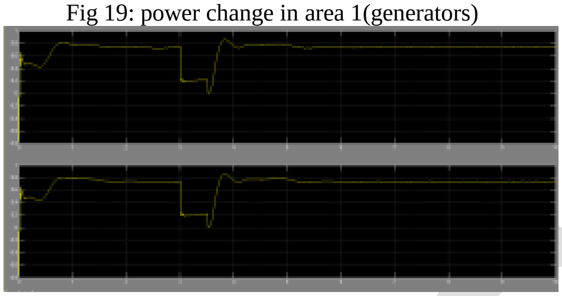

Fig 20: Power change in area 1(RES)

Fig 21: Power change in area 2(generator)

Fig 22: power change in area 2(RES)

Fig 23: Frequency deviation in generator

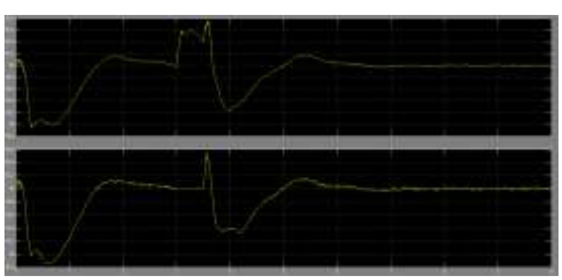

Fig 25: Frequency deviation in RES

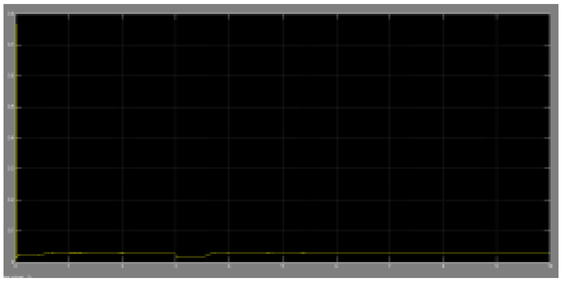

Fig 26: Output power of PV power plant

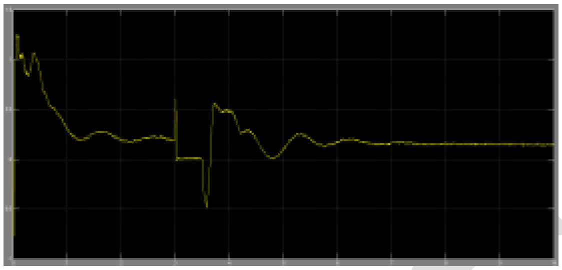

Fig 27: Output power of wind power plan

CONCLUTION

A generalized model for the AGC analysis in deregulated power systems is proposed. In this paper, modelling of renewable type of generation under bilateral contracts of power market are explained and illustrated. The proposed model is tested on two-area power system considering possible market scenarios. The results of simulation are also comparing the situations with and without renewable sources. There will be great possibility for future research considering HVDC lines for long distance, for fault reduction different scenarios, bigger test system with mode details of modeling.

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