WIND FARM CONDUSED PRIMARY LOAD FREQUENCY CONTROL FOR MULTI-AREA POWER SYSTEM WITH ETHERIZING LOAD FREQUENCY

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Abstract— *Electrical energy concurrent which cannot be stored so must be utilized as soon as it is generated. Therefore it requires an effective balance of power flow within multi area power system. This paper studies about a two area system [Hydro power plant & PMSG based Wind energy conversion system] which is connected through a tie line. Due to the rapid fluctuation in the wind power it causes disturbance in frequency which affects the active power of the system. To overcome this problem tie line must be stabilized using load frequency control in both the areas of power system. The simulation results for proving the efficiency of PLFC are illustrated. This is achieved by embedding PLFC in PMSG control system for both the area of power system.*

Keywords— ***hydro power plant, wind farm, multi- area power system, primary load frequency control***

1. INTRODUCTION

In real situations, the power systems consist of conventional forms of electrical power generations like, thermal, hydro, and nuclear as a major share of electrical power. The configuration of today's integrated power system becomes more complex due to these power plants with widely varying dynamic characteristics. Nuclear units owing to their high efficiency are usually kept at base load close to their maximum output with no participation in system automatic generation control (AGC) Gas power generation is ideal for meeting varying load demand. However, such plants do not play very significant role in AGC of a large power system, since these plants form a very small percentage of total system generation. Gas plants are used to meet peak demands only. Thus the natural choice for AGC falls on either thermal or hydro units. Here we consider the hydro power plant. Wind energy records the fastest growth rate in the world. Increasing penetration of large scale wind farm into the power system has given rise to stability problem due to their output power fluctuations [2][3]&[15]. Wind farm output power fluctuations can be smoothed by additional devices such as flywheel energy storage system (FESS)[4]&[7], Superconducting Magnetic Energy Storage (SMES) [8], Battery Energy Storage System (BESS) or STATCOM [11] because they have high response speed and high efficiency. However their installation is still doubtful from a practical.

A multi area interconnection is comprised of region, or areas, that are interconnected by tie-line. Tie-lines have the benefit of providing inter area support for abnormal condition as overall as the transmission parts for contractual energy exchanges between the areas. Which consists of inter-connected control areas, load frequency then it is important to keep the frequency and inter area tie power near to the scheduled values. Changes in the power system load affects mainly the system frequency, while the reactive power is less sensitive to changes in frequency and is mainly dependent on fluctuations of voltage magnitude. So the control of the real and reactive power in the power system is dealt separately. The load frequency control mainly deals with the control of the system frequency and real power whereas the automatic voltage regulator loop regulates the changes in the reactive power and voltage magnitude. Organization of this paper, Modelling the components of two area system Control of energy source Frequency fluctuation on each area and power fluctuation on tie line can be decreased.

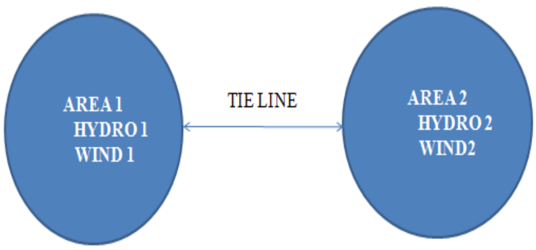

Fig 1:Two Area Power System

II.TWO AREA SYSTEM

Power system model used in this study is shown in Fig 1, which consists of two areas (Area 1 and Area 2) connected through a tie line Each of Area 1 and Area 2 consists of conventional synchronous generators (SGs) and wind farms (WFs) operated under Automatic Generation Control wind farms composed of PMSG equipped with cooperated PLFC, Classical two area power system model representation can be found in the literatures [10, 12].

A) Hydro power plant model

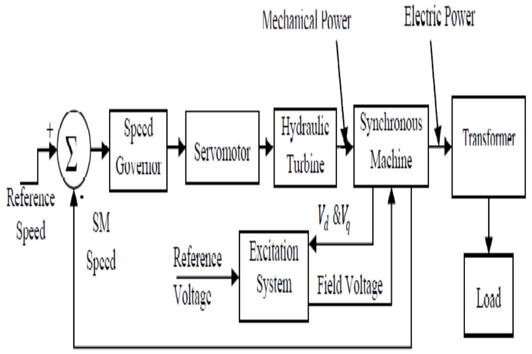

Fig 2: Block Diagram of Hydro Power Plant

In designed model PID is used as turbine governor because this control has simple structure, stability, strong robustness and non steady state error. In this block diagram shown in the Fig 2, the measured synchronous machine speed is fed back to compare with the reference speed signal [13].

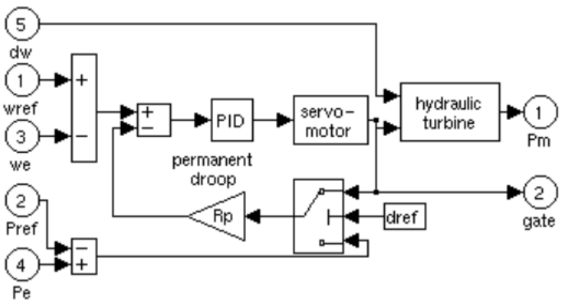

Fig 3: Typical model of hydro power plant

The Fig 3 explicates the speed deviation produced by comparing reference and synchronous generator speed is used as a input for PID based speed governor. The governor produces the control signal, causing a change in the gate opening. The turbine then produces the torque, driving the synchronous machine generating the electrical power output. The speed governor continuously checks speed deviation to take action.

For the simulation model Excitation System Block is taken from Power System Block set of MATLAB. Excitation System maintains the generator terminal output voltage at constant level. In the developed model the effect of load variation on i) generator excitation system, ii) governor and iii) the synchronous generator is studied.

B) Wind turbine model

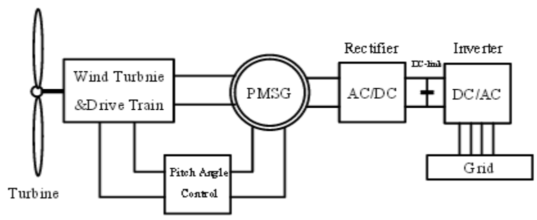

Fig 4:PMSG based WECS

The Fig 4 consists of wind turbine, drive train, converter, resonance circuit.

The below equation represents the power output of the wind turbine [1]:

pwt = Turbine(vw,pitchangle) (1)
bi = (1/((8.1-(0.08*pitchangle)) (2)
(0.035/(pitchangle^3+1))));
Cp = 0.5176*((116/bi)-(0.4*pitchangle)-5)* (3)
10^(- 21/bi)+(0.0068*8.1);
pwt =0.5*0.07*pi*(37^2)*(vw^3)*cp; (4)

where Pwt is the captured wind power (W), ρ is the air density (Kg/m3), R is the radius of rotor blade (m), Vw is wind speed (m/s), and Cp is the power coefficient. The value of Cp is dependent on tip speed ratio (λ) and blade pitch angle (β).

In order to limit the aerodynamic power above the rated wind speed, wind turbine is equipped with pitch angle controller system.

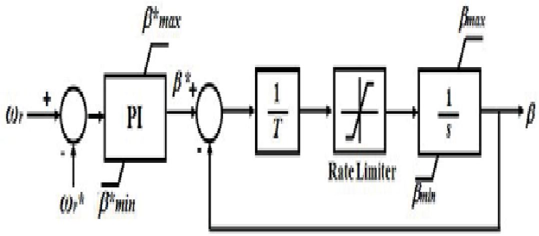

Fig 5: Pitch Control Model

The control loop of the pitch actuator is represented by a first-order transfer function with the pitch rate limiter. A PI controller is used to manage tracking error and set pitch angle reference. This is shown in fig 5.

C) PMSG: Primary Load Frequency Control

Frequency control maintains the frequency of a power system tightly around its nominal value when demand or supply fluctuates. The primary control can rebalance power and stabilize the frequency but does not in itself restore the nominal frequency. the mechanical power input to a generator based on the local frequency deviation. It is called the droop control and is completely decentralized.

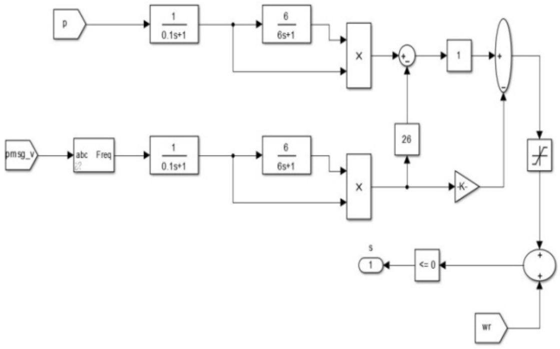

Fig 6: PMSG Embedded on PLFC

The Fig 6 consists of measurement filters, washout filters, a permanent speed droop (1/Rp) and an integral controller with gain Ki. In order to smooth the power output of wind turbine generator the low pass filter (LPF) is considered[1]. The permanent speed droop is used to controlled the frequency fluctuation, and the tie line power deviation is controlled by using proportional controller with gain K.

III.SIMULATION MODEL AND RESULT

Hydro power plant as shown in Fig 7 implements an IEEE type 1 synchronous machine voltage regulator combined to an exciter which describes the generate the mechanical power that drives the synchronous generator. In addition, an excitation system block is used to generate the excitation voltage that supplies the synchronous generator. Feedback systems are used through PID controllers to regulate both the generated excitation voltage as well as the mechanical power produced by the turbine.

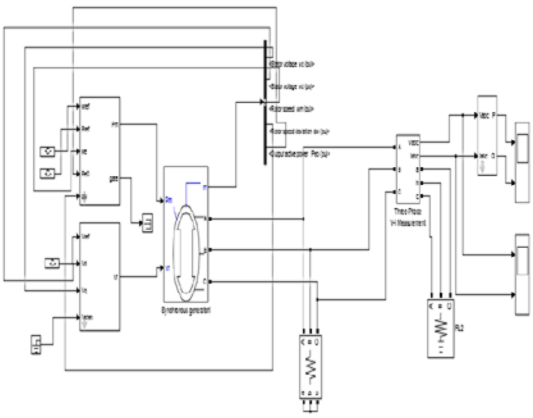

Fig 7: General model of Hydropower plant under Matlab software

Parameters of the permanent magnet synchronous generator
Number of phases :3
Back EMF : Sinusoidal
Rotor Type :Round
Mechanical Input :Speed(ω)
The model is made of a 250 MVA.

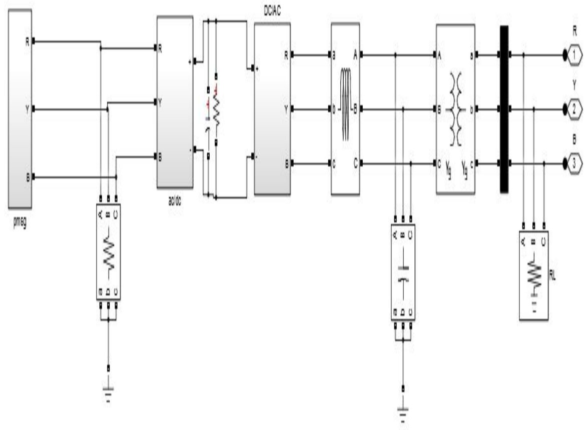

Fig 8: Simulation model of WECS

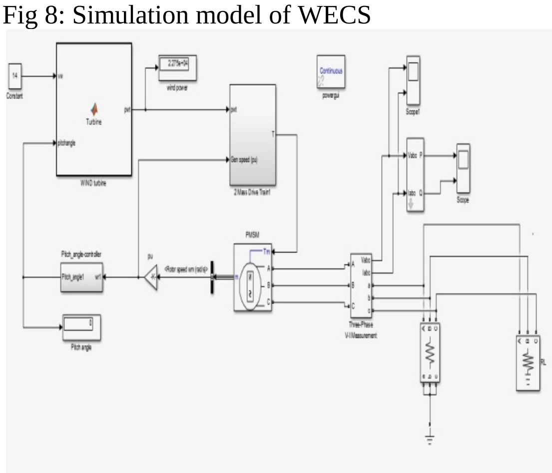

Fig 9: Simulation model of PMSG

When the huge wind farms with large power output fluctuations are connected to the power system, capability of the conventional power plant to damp the frequency fluctuation is not sufficient. Therefore, control strategies to smooth output power of wind farms become very important.

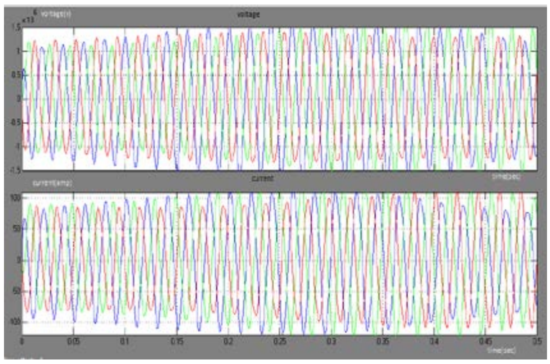

Fig 10(a): Output voltage and current without PLFC

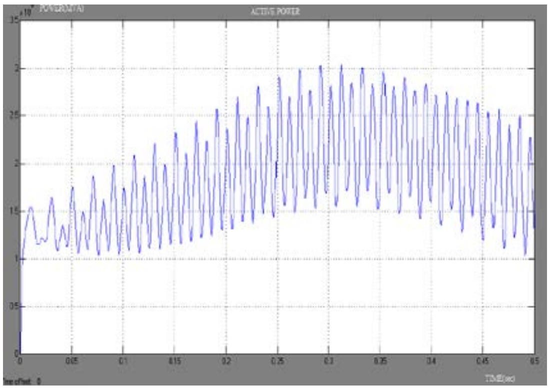

Fig 10(b): Output active power without PLFC

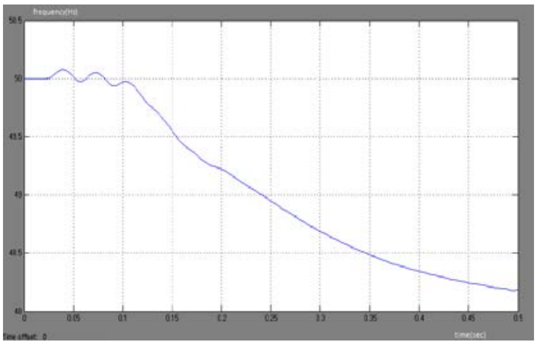

Fig 10(c): Output frequency without PLFC

The voltage and frequency fluctuation happens when the wind farm added to conventional power plant so both the area active power flows in tie line also fluctuates. This is shown in the above Figs 10(a)-10(c).when the two area system is integrated with the proposed PLFC the output waveforms were improved as shown below Figs 12(a)-12(c).

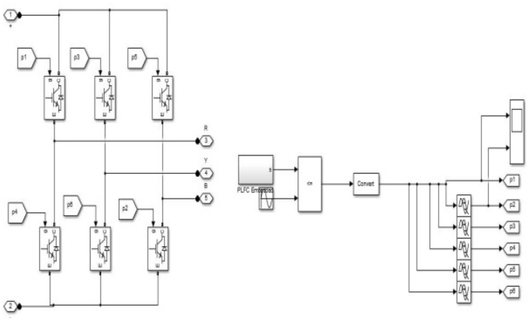

Fig 11: Converter Controller

TABLE 1
CONTROL PARAMETERS OF PLFC OF PMSG

Area	**1**	**2**
Speed droop permanent (R_P)	0.04	0.05
Bias Factor (B_P)	26	21
Proportional Gain (K)	1	1

The speed droop permanent (Rp) and the weighting bias factor (Bp) are selected in accordance with the speed droop permanent and the weighting bias factor of conventional power plants in each area.

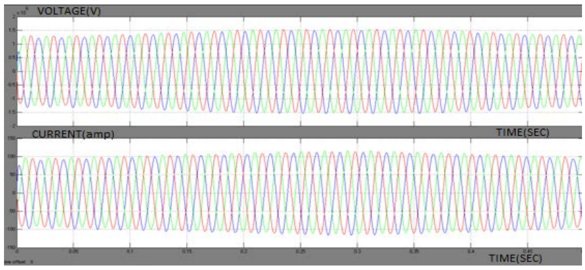

Fig 12(a): output voltage and current with PLFC

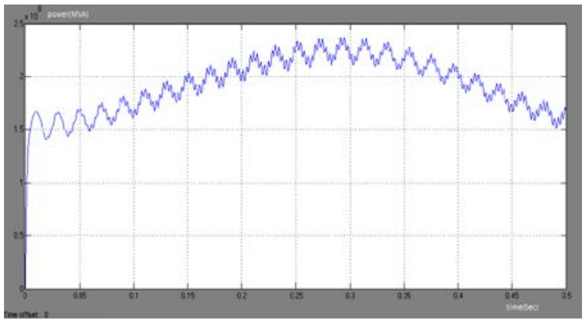

Fig 12(b): output active power with PLFC

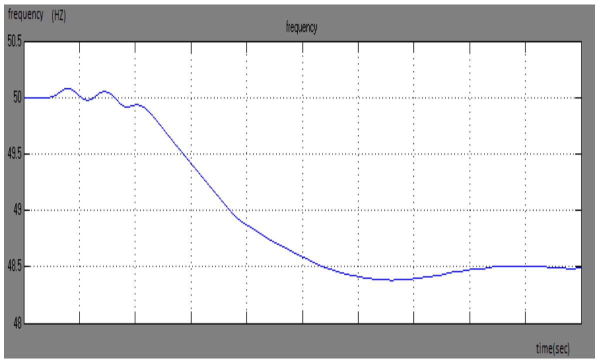

Fig 12(c): Output frequency with PLFC

IV.CONCLUSION

The proposed system consists of a primary load frequency control of PMSG based wind farm in multi-area power system. From the above discussions, it can be concluded that by smoothening the power output of the wind farm using the proposed primary load frequency control, the load frequency fluctuations on each area can be damped, and also tie line power transfer fluctuation can be decreased effectively.

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