Load Frequency Control of Photovoltaic-Gasifier for Interconnected Two-Area Power Systems

Sawat Yukhalang

Abstract: ***Load frequency control (LFC) in interconnected power system of small distribution generation (DG) for reliability in distribution system. The main objective is to performance evaluation load frequency control of hybrid for interconnected two-area power systems. The simulation consist of solar farm 10 MW and gasifier plant 300 kW two-area in tie line. This impact LFC can be address as a problem on how to effectively utilize the total tie-line power flow at small DG. To performance evaluation and improve that defect of LFC, the power flow of two-areas LFC system have been carefully studied, such that, the power flow and power stability is partially LFC of small DG of hybrid for interconnected two-areas power systems. Namely, the controller and structural properties of the multi-areas LFC system are similar to the properties of hybrid for interconnected two-area LFC system. Inspired by the above properties, the controller that is propose to design some proportional-integral-derivative (PID) control laws for the two-areas LFC system successfully works out the aforementioned problem. The power system of renewable of solar farm and gasifier plant in interconnected distribution power system of area in tie – line have simulation parameter by PID controller. Simulation results showed that 3 types of the controller have deviation frequency about 0.025 Hz when tie-line load changed 1 MW and large disturbance respectively. From interconnected power system the steady state time respond is 5.2 seconds for non-controller system, 4.3 seconds for automatic voltage regulator (AVR) and 1.4 seconds for under controlled system at 0.01 per unit (p.u.) with PID controller. Therefore, the PID control has the better efficiency non-controller 28 % and AVR 15 %. The result of simulation in research to be interconnected distribution power system substation of area in tie - line control for little generate storage for grid connected at better efficiency and optimization of renewable for hybrid. It can be conclude that this study can use for applying to the distribution power system to increase efficiency and power system stability of area in tie – line.***

Keywords **:** ***Load Frequency Control, Photovoltaic, Gasifier, Two-Area Power Systems.***

I. INTRODUCTION

The attractive renewable power generation technologies are solar and gasifier power generation. Some form of energy storage or additional generation for small DG substation such an integrations of various equipment results in hybrid power generation/energy storage system (PG/ESS) combining all available kinds of different renewable energy [1]. The model of a power network partitioned into control areas having optimal load frequency control for distributed [2]. Power flow at small DG to consider LFC because frequency is function of active power and voltage is a function of reactive power [3]. However, the control loop is active power-frequency (P-f) and reactive power-voltage (Q-V) control loop. For small load, they tackle the change in load demand without changing in frequency for load frequency control system with demand-side control through the smart meter [4-8]. But small DG with gasifier plant was found to be effective in automatic shaking mechanism reducing the tar [9], adaptive predictive control for adjustment of oxygen concentration in syngas [10], performance control are done when the gasifier is unstable, robust optimal control for shell gasifier in LFC power plants [11-16], and solar farm was found controls technique battery storage [17], energy management unit and integrated control of photovoltaic (PV) solar farm [18-20], and PV solar farms feed active power during day time and become inactive in the night time [21-22]. Both, LFC systems help to reduce the demand for transmission by overcoming local and tie-line stability when control design appropriate for interconnected power systems [23-24].

From the control system and frequency response of the tie line, the desired performance and suitability of the system and the controller. LFC of the power system connection of hybrid replicate the system from the actual parameters of both distributed power generators. As presented here.

II. II.CONTROL MODEL OF INTERCONNECTED TWO AREA POWER SYSTEM

A. Two Area Interconnected Control System

This paper studied and considered in LFC two-areas interconnected by using PID controller in Fig. (1) is automatic generator control (AGC).

$$\dot{x}(t) = Ax(t) + Bu(t) + \Gamma P(t) \tag{1}$$

$$\begin{aligned} x(t) &= \left[x_1\ x_2\ \dots\ x_7\right]^T \\ &= \left[\Delta f_1\ \ \Delta f_2\ \ \Delta p_{g1}\ \ \Delta p_{g2}\ \ \Delta X_{E1}\ \Delta X_{E2}\ \ \Delta P_{tie}\right]^T \end{aligned} \tag{2}$$

$$u(t) = \left[\Delta P_{C1}\ \ \Delta P_{C2}\right]^T \tag{3}$$

$$P(t) = \left[\Delta P_{d1}\ \ \Delta P_{d2}\right]^T \tag{4}$$

When,

A is the system matrix, B is the input distribution matrix; Γ

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is the disturbance distribution matrix, x (t) is the plant state vector, u(t) is the incremental change in the speed changer position, P(t) is the disturbance vector of load change. The frequency f and the tie-line power exchange, P_{tie} are the variables of interest in LFC. The two-area interconnected power system control is stability of frequency and power for interconnected in area control error (ACE):

$$ACE_i = \sum_{j=1}^{\infty} \Delta P_{tie,ij} + b_i \Delta f_i \quad (5)$$

$$ACE_1 = \Delta P_{12} + B_1 \Delta \omega_1 \quad (6)$$

$$ACE_2 = \Delta P_{21} + B_2 \Delta \omega_2 \quad (7)$$

So that,

ΔP_{12} = Deviation power flow area 1 – area 2

ΔP_{21} = Deviation power flow area 2 – area 1

$\Delta \omega$ = Electrical angular velocity frequency

B_1 = Frequency bias factors area 1

B_2 = Frequency bias factors area 2

Δf_i = Frequency deviation area

ΔP_{tie} = Tie-line power deviation

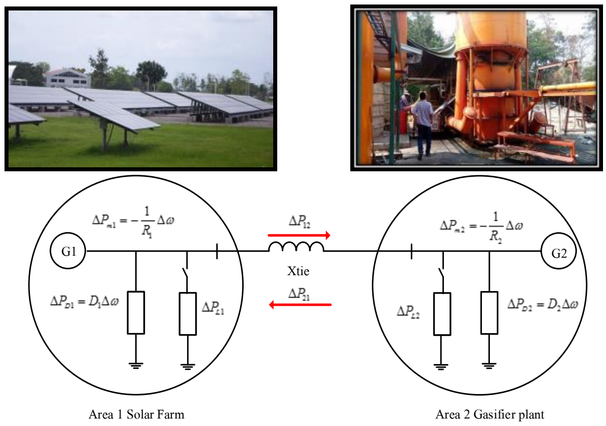

Fig. 1: Diagram two-area interconnected power system.

Consider in tie-line power system, consisting of two-area with a reactance (X_{tie}) between interconnect for performance, load frequency and frequency response the equivalent equation of the system to tie line between two-areas. The increase in the load power flow in a particular area will result in a decrease in the load in another area. It depends on the flow direction, which indicates the change in phase angle. Show in equation (8)

$$\Delta P_{12} = -\frac{\left(\frac{1}{R_2}+D_2\right)\Delta P_{L1}}{\left(\frac{1}{R_1}+D_1\right)\left(\frac{1}{R_2}+D_2\right)} = \frac{B_2}{B_1+B_2}\left(-\Delta P_{L1}\right) \quad (8)$$

When,

ΔP_{L1} = Deviation load area 1

R_1 = Speed regulation area 1

R_2 = Speed regulation area 2

D_1 = Constance load frequency area 1

D_2 = Constance load frequency area 2

B. PID-Controller

When Kp is Constance and the simulation power in two areas interconnected by PID to concept of decentralized direct tie-line power flow control. Show in equation (9)

$$U_i = -K_i K_d \int_0^t \left(ACE_i\right) dt = K_i K_d \int_0^t \left(\Delta P_{tie,i} + b_i \Delta f_i\right) dt \quad (9)$$

Including controllers is show in Fig. 2

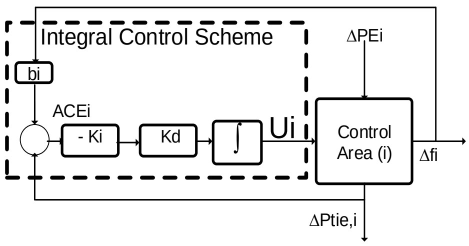

Fig. 2: Conventional of PID-Controllers.

C. Parameter Design for Controller

This paper uses LFC with PID controllers. From systems, that non-automatic controls. By choosing the ratio of the integration to the performance index (J) using the Integral of The Error (ISE) method. Errors of the quadratic function of this integrator. The value increases over time regardless of whether the error value is positive or negative. The system will give a very low rate of delay which is β_1 = 0.517, J = 0.055 at K_i =0.21, K_p =0.88 and K_d = 0.59,

Where,
T_{h2}=0.08s, T_{Tt2}=0.3s, T_{p2}=20s, a_{12}=-1, ΔP_{d1}=0.01pu. , ΔP_{d2}=0.01pu. , R_1=R_2=2.0pu. MW/Hz., K_{P1}=K_{P2}=120Hz./pu.MW.,T_{12}=0.545.,B_1=B_2=0.420 pu.MW/Hz., K_{r2}=0.5Hz./pu.MW., K_{i1}=K_{i2}=0.2 Hz./pu.MW.,T_{r2}=10s.,

Nomenclature,

T_h = hydraulic valve actuator time constant, sec.
T_r = reheat time constant, sec.
T_t = main inlet volume and heat chest time constant, sec.
K_r = fraction of total gasifier turbine power generated gain constant, Hz/pu.MW.

K_P = power system gain constant, Hz/pu.MW.
T_P = power system time constant, sec.
R = speed regulation parameter, Hz/pu.MW.
ΔP_d = change in load, pu.
ΔP_{tie} = tie-line power deviation, pu.MW.
ΔP_c = change in speed changer position.
Δf = frequency deviation, Hz.
B = area frequency bias setting, pu.MW/Hz.
T_{12} = tie-line coefficient.

The block diagram as shown in Fig. (3) and Fig. (4).

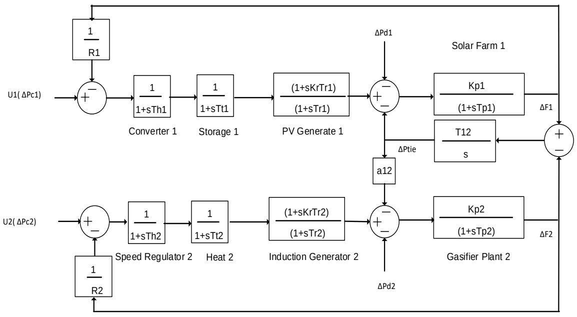

Fig. 3: Diagram of control two-area power system

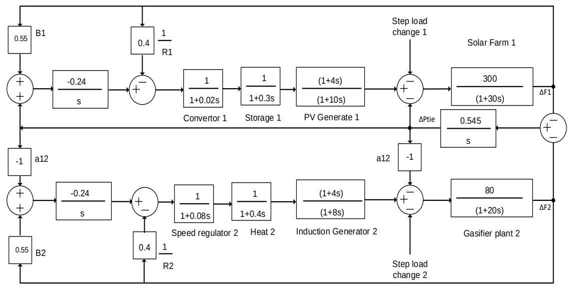

Fig. 4: Diagram of LFC by AVR controller

III. SIMULATION OF CONTROL SYSTEMS

The LFC of interconnected two-area power flow to tie-line balance, maintain the frequency constant and to make control area zero at the base of 12 MVA. The power generation from hybrid sources, solar farm and gasifier plant. Load variation (ΔP_{L1}) is 0.01 per unit (Step Load). At area 1, the speed of the power system is 10 percent and the area 2 is 4 percent.

At fixed frequency variation (Δf) of 0.025 Hz, the response to the change in load frequency in area 1 (ΔP_{D1}) was 0.022 MW, and the response to the change in load frequency in area 2 (ΔP_{D2}) was 0.010 MW, ΔP_{G1} = -0.788 MW and ΔP_{G2} =-0.275 MW. At value of new load area 1 = 8.105 MW of power flow 9.313 MW and new load area 2 = 0.001 MW of power flow 0.002 MW. The power flow in tie-line area 1 to area 2 = 0.655 MW at new frequency 50.025 Hz.

The simulation in paper using Matlab/Simulink show the effect of interconnected and frequency response. When the load change is instantaneous, 0.01 p.u. from the tie-line in the area 1, 2 of both hybrid power at non-controlled, AVR and PID controller types as shown in Fig. (5).

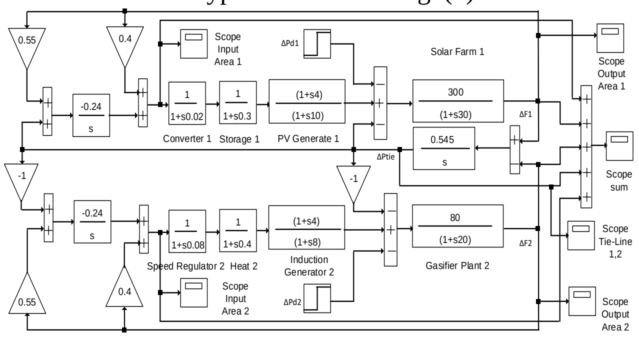

Fig. 5: Diagram of LFC by PID controller with Matlab/Simulink

IV. SIMULATION RESULTS

The simulation results of a two-area interconnected power system non-controlled, AVR and PID controller. As a control, the total value of the input signal between the area and the output side is shown in Figure (6, 7, 8).

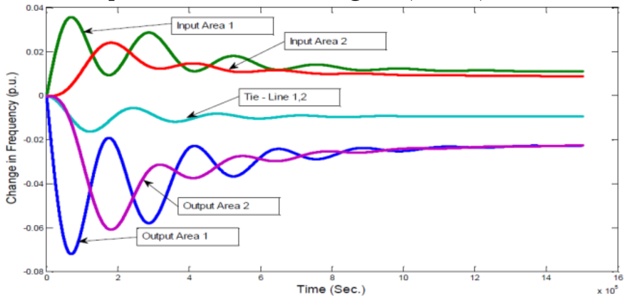

Fig. 6: Output frequency deviation non-controlled two-area

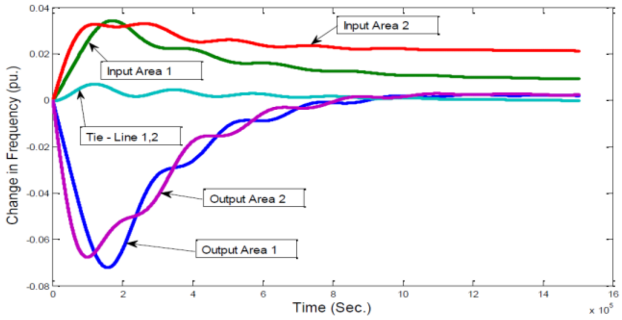

Fig. 7: Output frequency deviation AVR control two-area

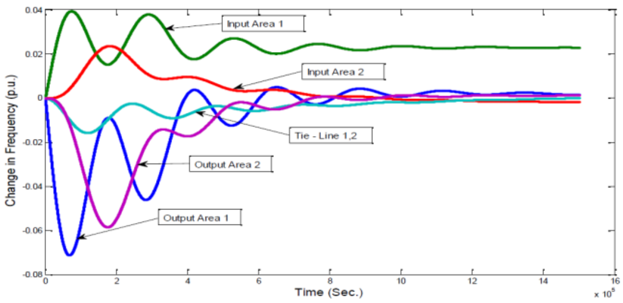

Fig. 8: Output frequency deviation PID control two-area

From Figure (6, 7, 8), the simulation output interconnected results of a two-area tie line with hybrid system at non-controlled, AVR and PID controller types. The controller combines the signal valuesobtained from the input side of the interface between the area and the output side. The values shown in Table (I, II, III) show the effect of the interconnected and frequency response. When the load change is instantaneous, 0.01 p.u. from the tie-line in the area 1, 2. Estimated time delay at steady state was 5.2, 4.3, 1.4 seconds, and maximum waveform values were -6.71, -0.012, -0.006, respectively.

In addition, the effects are also considered in the following simulation output tie line from Fig. (9), output frequency deviation area 1 from Fig. (10) and output frequency deviation area 2 from Fig. (11) as the response on table (1, 2, 3).

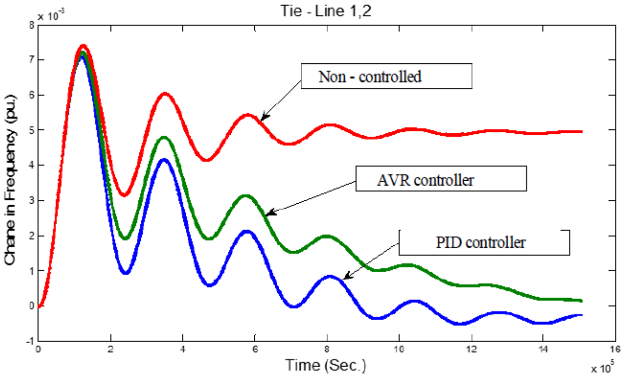

Fig. 9: Output frequency deviation tie - line area 1, 2

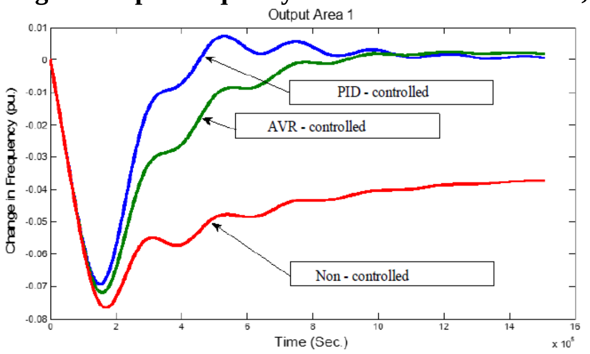

Fig. 10: Output frequency deviation area 1

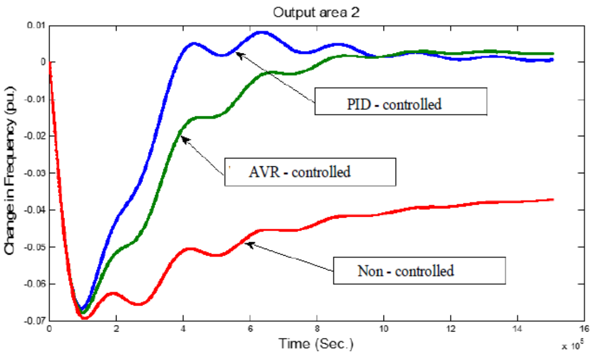

Fig. 11: Output frequency deviation area 2

From Figure (9, 10, 11), the simulation results of a two-area output frequency deviation tie line, output frequency deviation area 1 and output frequency deviation area 2 with hybrid system at non-controlled, AVR and PID controller types. The controller combines the signal setting time and overshoots response to be zero.

TABLE 1: OUTPUT FREQUENCY DEVIATION TIE - LINE 1, 2

Tie-Line Area 1, 2 (Steady State Error = 0 p.u.)	Setting Time (Sec.)	Maximum Overshoots
Non-controller	5.2	6.71
AVR	4.3	0.012
PID	1.4	0.006

TABLE 2: OUTPUT FREQUENCY DEVIATION CONTROL AREA 1

Tie-Line Area 1, 2 (Steady State Error = 0 p.u.)	Setting Time (Sec.)	Maximum Overshoots
Non-controller	7.9	4.73
AVR	4.8	0.035
PID	2.0	0.027

TABLE 3: OUTPUT FREQUENCY DEVIATION CONTROL AREA 2

Tie-Line Area 1, 2 (Steady State Error = 0 p.u.)	Setting Time (Sec.)	Maximum Overshoots
Non-controller	9.6	2.65
AVR	5.1	0.048
PID	3.9	0.044

From the table (1, 2, 3), the results show that the two-area frequency deviation output is non-controlled, AVR and PID controller. For output frequency deviation tie line, output frequency deviation area 1 and output frequency deviation area 2. Time delay values of steady state were 5.2, 7.9, 9.6 seconds with maximum values of -6.71, -4.73, -2.65, and 4.3, 4.8, 5.1 seconds with maximum values of -0.012, -0.035, -0.048, and 1.4, 2.0, 3.9 seconds with maximum values of -0.006, -0.027, -0.044, respectively.

V. CONCLUSION

In this paper, experimental results of photovoltaic-gasifier interconnected two-area power systems by program simulation Matlab/Simulink of the 10 MW and 0.003 MW solar power plants and gasifier plant, at 1 MW the load changes with a frequency of 0.025 Hz and when the large disturbance, respectively. Comparison of the steady-state response, the non-controlled, AVR and PID controller types. Using PID as control, the better performance was achieved non-controlled 34% and better AVR 14 % of load changes step load.

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