Automatic generation control (AGC) in two area power system with integrated renewable energy source

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Abstract:

The automatic generation control (AGC) in two area power systems resulting in frequency regulation or load frequency control are simulated. A simulation model modern load frequency control model for the improvement of power system operation with the introduction of new energy resources (renewable energy resources) is presented. A two-area power system is presented for frequency and tie-line power deviation and changes. The simulation model is developed with a PID controller. Using a control scheme, the system is transferred from a primary state to the ultimate state without any change or oscillations in frequency and tie-line power of two area power system. Hence the final steady-state cure of the system is fetched to zero error. These results are compared with and without renewable sources to study the impact of modern energy in the power system control in case of load disturbance in both the area. For this application, MATLAB SIMULINK software is used for the simulation of two area models.

1. Introduction.

Electrical Power systems are quite large and complicated networks involving of generation system networks, transmission system networks, and distribution system networks along with loads. In the electrical power system, the load keeps changing in every period of time according to the needs of the load centres area. So the proposed controllers are mandatory for the regulation of the system deviations to maintain the stability of the power system and its reliable operation [1].. A flexible system is required for the automatic generation control to ensure and maintain the balance in the system between generation and consumers due to any disturbance in the system [2] , recently the new participant (renewable energy sources) has introduced in energy market worldwide Synchronous generators are used conveniently , which operate on transient faults condition happens in power system but in case of renewable energy sources integrated system there is a significant problem with the variability and uncertainty nature of renewable resources which RESs are nature dependent sources [3], we need to analyse typical response to real power needs are illustrated using the latest simulations tools MATLAB SIMULINK [4]. Since the requirement for the voltage regulation and reactive power and the influence on system stability of both excitation and speed control, with the use of suitable feedback signals are examined [5]. To keep the power system efficient, flexible, reliable and secure the frequency stability is the most essential the frequency of the system deviate from its defined value due to load change and other disturbance the system, the fluctuation of frequency beyond its defined limit casing loss of stability in the power system [6], to ensure this concerns additional units such as renewable energy resources (wind, solar, energy storage) and conventional type resource result to complexity and increase the size of the power system and adding challenge to the AGC, where automatic generation control is responsible to fluctuate the system frequency the prescribed set of value. [2] [1]. The main control loop responds to frequency variations through the speed governor and the steam flow is achieved accordingly to the real power generation to fairly fast load variations. Thus sustain a megawatt balance and this main loop performs a sequence speed or frequency control [7].

Solar energy is newly having a wide application in AGC control, a combination of green energy with the conventional energy lead to frequency deviation in frequency control system [7] [2], , the researcher has been analysed the stability of a two-area system integrating the PV unit by injecting variable solar power and also studied the influence of solar power to LFC in the two-area interconnected system and established the improved performance due to the PV unit [8].PID controller is widely used in the industrial control system as a control loop fed back [9]. It calculates an error between the measures process variable and the desired set point. PID parameters are tuned to ensure satisfactory closed-loop performance [10]. It is used to improve the dynamic performance and to reduce the steady-state error the value of gains (Kp, Ki, Kd) is automatically achieved by tuning in the Matlab simulation model. Kp is used to decrease the rise time. Kd is used to reduce overshoot and setting time. Ki is to eliminate the steady-state error [11]. The study indicates the following objectives.

- ✓ To simulate a test model of two area power system consisting of different conventional energy sources as well as renewable energy sources using MATLAB/SIMULINK.
- ✓ To design a proportional Integral Derivative (PID) controller to analyse the transient response of the proposed power system model.
- ✓ To optimize the impact of renewable energy resources in the load frequency control of two area power system.

. Whenever the integration of renewable will come play there is a big challenge with variability and uncertainty nature of wind and solar energy resources. Means it's very difficult to predict and set the output of renewable resources [12]. known that renewable resources are nature dependent resources where photovoltaic system is dependent on sunlight irradiances and wind energy on speed of wind [13]. Electrical Power systems usually convert natural energy (coal, oil, hydro, wind, solar) into electric energy. The transportations of electrical power to industries, houses, and load centres to fulfil all kinds of power needs [14] [15]. It is well well-known that three-phase alternating current (AC) is generally used to transport the electrical power from generation to distribution centres [16]. Throughout the transportation of electrical power, in cooperation the active power equilibrium as well as reactive power equilibrium of the system regarding to load change should be maintained between generation and utility the AC power [17]. Those two balances relate to two equilibrium points: frequency of the system and operating voltage. When each of the two balances is changed, the stability points in system operating mode will float. A desired quality which reserve the load of the electric power system requires both the system frequency and operating voltage to remain at standard values (HZ) during the operation of the system [12].

2. Proposed model for two area power system control

the recommended two area power system control model is represented in fig.1 which is consist of two different renewable energy sources and two conventional type of energy generation source distributed in two different areas, the both area are connected through tie-line in order deployed the power sharing between the area 1 power system and area 2 power system to maintain the load demand in the consumer side. Where in area 1 their area one hydro-thermal unit and two renewable sources (PV system and wind) and the same distribution area followed in area 2. The both area are connected by a common line in between which join the both area together known as tie-line. Whenever the load change is happening the one of the respected area the power system of respected is responsible to take care of the load change or in case the load change in one of the areas is not maintained by the power system of respected area the power follow in the tie-line is taking place which change in the tie-line power in need to be maintained

The proposed model for two area power system containing the secondary control loop is given in fig.1 The system operates under two area power system, taking into consideration of the change in load in each area.

The proposed mathematical model for generator is represented in equation 1 by applying swing formula for synchronous generator to the small perturb or change we get.

$$\frac{2Hd2\Delta s}{\omega dt2} = \Delta Pm - \Delta Pe$$

Whenever the small change is happing in power system the speed is given by.

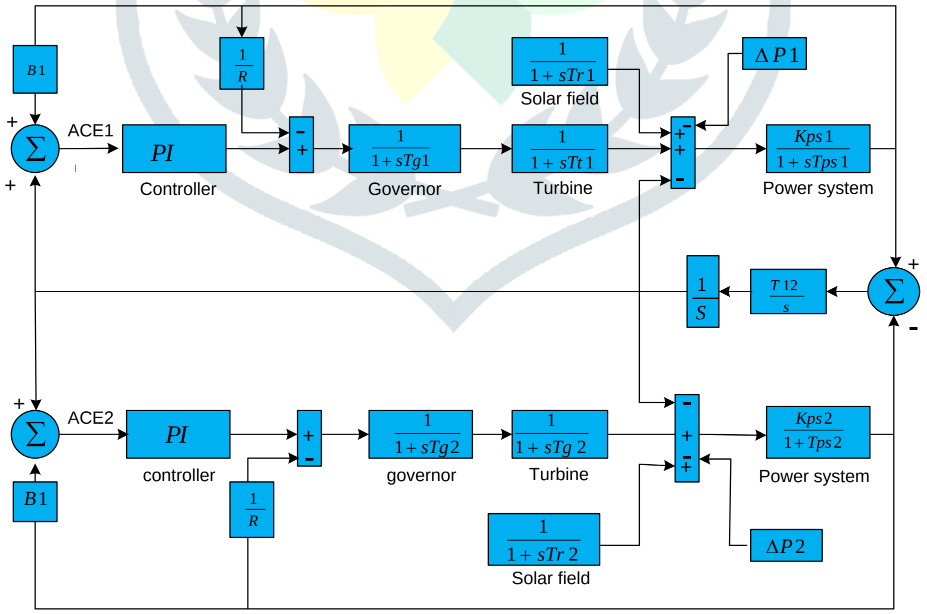


Fig. 1 model for two area power system containing renewable energy sources

$$\frac{\frac{d\Delta\omega}{\omega s}}{dt} = \frac{1}{2H}(\Delta Pm - \Delta Pe)$$

By Taking Laplace transform

$$\Delta\Omega(s) = \frac{1}{2Hs}[\Delta Pm(s) - \Delta Pe(s) \dots (1)$$

The load in system are mathematically represented where the power system area consists of different load types which can resistive and inductive load.

$$\Delta Pe = \Delta Pl + D\Delta\boldsymbol{\omega} \;\ldots\ldots\ldots(\mathbf{2})$$

The ΔPl is non frequency sensitive load distributions, D$\Delta\boldsymbol{\omega}$ is given as frequency of the sensitive load deviation and D is percent change in load by percent change in frequency.

The most important and key element in power generation is take care by prime mover, and the prime mover can be of any type for example in hydro-electric power generation we have hydraulic turbine at waterfall and steam turbine for steam power plant. So the mathematical model can be represented as

$$Gt = \frac{\Delta Pm(s)}{\Delta Pv(s)} = \frac{1}{1+\tau ts} \ldots\ldots\ldots(3)$$

Where $\boldsymbol{\tau}$t is turbine constant in rang of 0.2 to 2,0 sec

In power system the load increasing or decreasing which taken decided by the consumer side, whenever the increase or decrease in load is happening it required to increase or decrease the input in the turbine to fulfill the need and to avoid extra energy generation, so the governor is taken the right to send the signal to the generation side to moderate the fuel/ waterfall to the furnace/penstock. Commonly the governor compensates the speed deficiency in the power system.

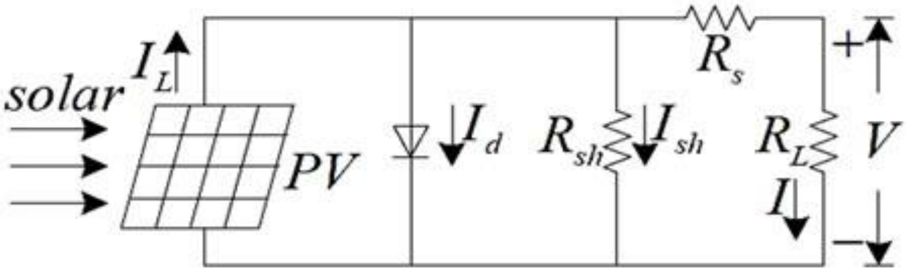
$$\Delta Pg = \Delta Pref - \frac{1}{R}\Delta F \ldots\ldots\ldots\ldots(4)$$

In (s) domain we get

$$\Delta Pg = \Delta Pref - \frac{1}{R}\Delta\Omega(s) \ldots\ldots\ldots(5)$$

2.1 Solar photovoltaic system

Photovoltaic system is converting the solar energy to electrical when the incident sunlight falling on the surface of the collectors and it generate the photovoltaic current (Ig) and when the system in open circuit mode the potential difference will arise and when it's short circuited the generated currant (Ig) is flow throughout the circuit path, the PN junction equivalent circuit is represented in the fig.2



Fug.2 Equivalent circuit of PV photovoltaic panel

According to fig.2 the Rsh is the manufactured process resistance and Rs is the between the junction of the two composite metal silicon and semiconductor of the photovoltaic panel.

A 12 volts' solar photovoltaic module has 36 series solar cells in arrangement. And the combination of cell arranges a PV module and as modules make PV array. These arrays create solar farm which is connected together by the DC to DC converters, inverters for grid connection to convert DC to AC, And DC tie voltage control.

$$Io = Ig - Iset\left(\exp\left(\frac{Vo}{AKT}\right) - 1\right) \ldots\ldots(1)$$

$$Ig = \frac{S(Isc + IT(T+25))}{1000} \ldots\ldots\ldots(2)$$

From the equation above the Io and Vo are the solar cell output. The incremental change in the PV array system power output is in labelled [1]. η as the conversion efficiency of system cell in rang of 9% to 12%.

$$Ppv = \eta SA\left[1 - \frac{T-25}{200}\right] \;\ldots\ldots(3)$$

25ºC is taken as the temperature T and Ppv is power output from the PV system which linearized as ΔPpv =GpvΔS [1].and the Gpv is the transfer function for the PV system.

$$Gpv = \frac{Kpv}{1+sTpv} \ldots\ldots\ldots\;(4)$$

In the formula (4) the Kpv is the gain and the Tpv is the time constant.

2.2 Proportional Integral Derivative (PID) controller

PID controller is usually used in the industrial applications control system as a control loop feedback. Because of its simplicity as the gain for the Kp, Ki, Kd is easy to calculate. It calculates an error between the procedures process variable and the wanted set point. PID controller parameters are modified to ensure satisfactory closed-loop performance. Used to improve the dynamic performance and to minimize the steady-state error. The value of gains Kp, Ki, Kd is automatically achieved by a correction in the Matlab simulation model. Kp is used to decrease the rise time. Kd is used to decrease the overshoot and settling time. Ki is to remove the steady-state error. The theory of area control error related to the PID control system is as follows.

Proportional term, Pout = K_p e (t)

Integral term, Iout = Ki $\int_0^t e(t)\ dt$

Derivative term Dout = Kd d/dt e(t)

Where Kp = proportional gain, Ki = Integral gain, Kd = Derivative gain

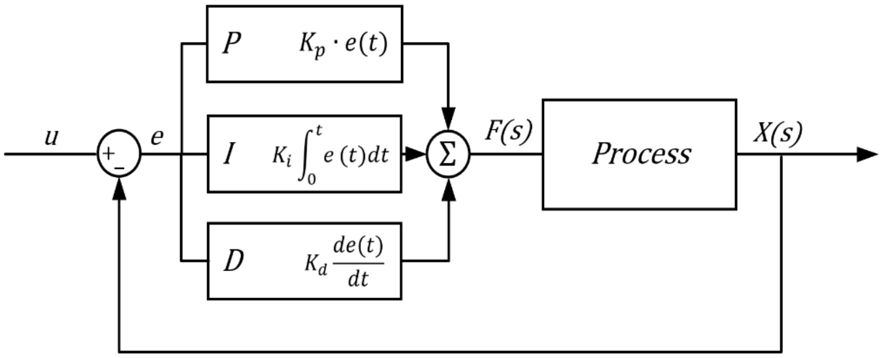
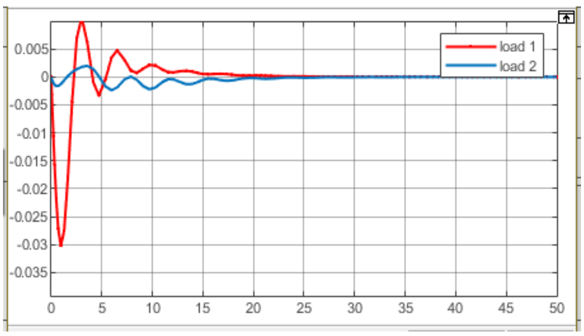


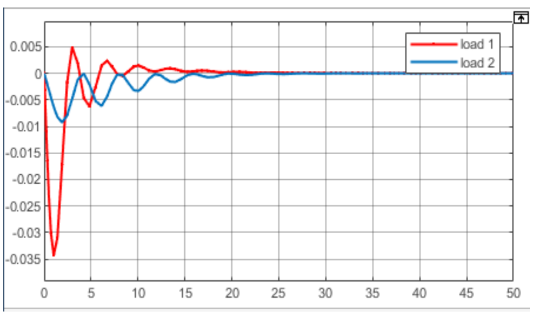
Fig.3 PID controller

3. Simulation model and result Discussion.

A 5000MWA power system is simulated using MATLAB/SIMULINK with the interconnected solar field the plant the system is running under the steady-state condition and the output frequency of the system is regulated at 50Hz as India standard operating frequency. The system consists of two areas having a separate generator for both areas A and area B a photovoltaic systems area integrated with both areas A as well as area B to support the system, and these two areas are connected through a common line which is called tie-line, the power shared between the two areas are transferred through the tie-line, hence for controlling the power follow through the tie-line between both area the integrator controller are attached along the tie-line of system. Whenever the sudden increase in the load is happening in one of the systems the controller will send a signal to prime through a feedback loop to increase the input in a waterfall on the hydro turbine or foul input to the steam turbine to increase the output power to feed the increased load to the system and accordingly if this increased power is supplied by one of the generators the for its respected area. But when the increased power is supplied by both generators the power shared between the generators are following through the tie line of the system. After a load change of 100MWA in area A and 50MWA in area two, the system can fulfil the unexpected load change in both areas of the system, where the frequency curve for both systems after a transient change in the both has to reach the nominal frequency (50Hz).



(a)

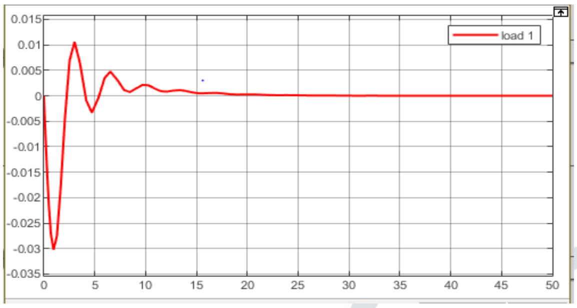


(b)

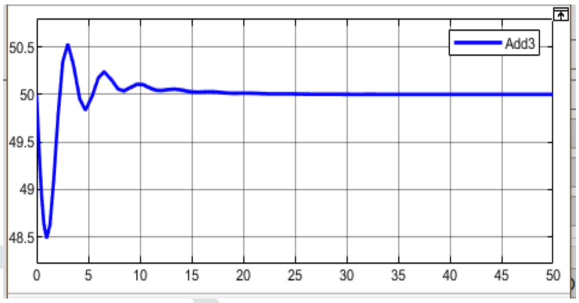
Fig.4 (a.) system response without renewable sources, & (b). system response with renewable sources

The study indicates that impact of renewable energy sources in the automatic generation control where the solar photovoltaic PV act as an ancillary source to the power system as the system is set to maximum concentrate on renewable and less to main grid power and during the shortage of power in the system the renewable sources will act as ancillary to fulfil the load demand in the power system, the step response of the both area with and without renewable is presented in the fig.4 where the system operating with solar system give a better response and the frequency deviations are taking lesser time to reach the steady state condition.

The 1000MWA load change is accruing in area A which result in an underdamped in stop response of area A where after a transient response, the change in the output frequencies are deviating in range of (-0.035-0.015) where the after a transient response the change in the frequency are decreasing to zero.



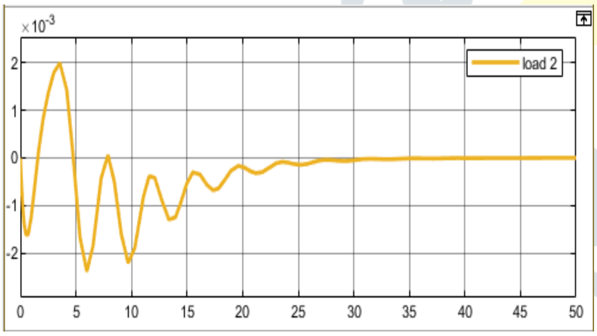
(a)



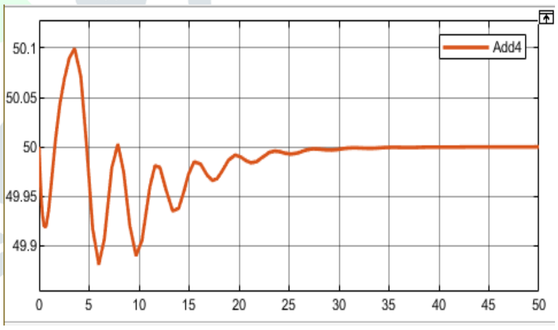
(b)

Fig.5 a. frequency response of area A, & b. the change with references to 50HZ of area A

Frequency deviation is reaching the zero change which shows after a transient change in the output frequency the cure shows an underdamped output with offset time given to the system the output curve in reaching the steady-state and the added load to system area fulfilled successfully. Hence its show in fig.5 which shows the change concerning the nominal frequency which 50Hz.where the 100MW load increment is accruing in the system.



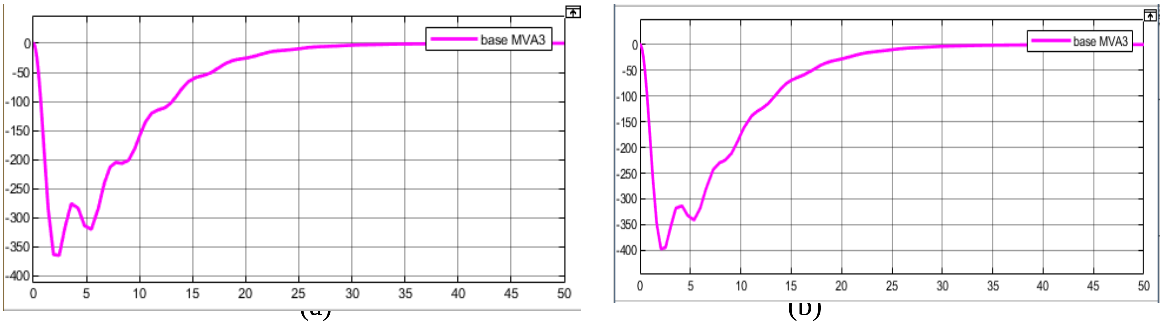
(a)



(b)

Fig.6 a. frequency response of area B, & b. the change with references to 50HZ of area B

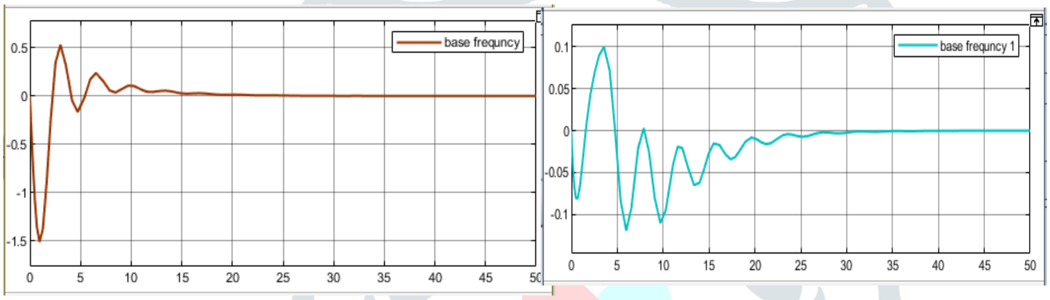
Fig.6 show the response for the area B which the 50MW change in load increment in the area B is accruing and the system have to feed the increased amount of 50MWand bring the system back to the normal operating mode and the system come to steady-state condition after some transient response



(a) (b)

Fig.7, (a). power deviation through the tie line with renewable sources, & (b). power deviation through the tie line without renewable sources

Whenever the operating frequency recovered to 50Hz which generation is equal to load demand means the system is successfully recovered the load change. According to the curves in the fig.7 in both case with and without renewable interface the tie-line power is reaching the zero. Means the power transmitted through the tie-line between both the area are keep to nominal state so the change in power follow through the tie line is reaching zero. And the system successfully recovered the load change happen in the both area.



(a) (b)

Fig.8, (a). base frequency deviation in Area A, & (b). base frequency deviation in area B

In order to check the change in frequency for the both area A&B frequency area keep in zero change after the fluctuations in starting time where the system has taken action against the sudden change in the system the change in frequency for the both area kept to zero.

Conclusion

The simulation outcome is exposed that the control system gives smooth performance and is appropriate in load frequency control. PID controller has been gain is set by hidden trial method as the ACE for the both area reaching almost the zero value and the frequency reaching to its nominal value and to control the planned reference power of a generating unit in two area system. The frequency variations and tie-line power deviation for two areas are defined in the base MVA curves. The performances of tie-line flow in each area during load change are also presented as a simulation result. PID controller lead the system to a stable power system with zero steady-state error. Accordingly, the PV system has an impact of an ancillary source to the power system. And the system is showing a successful behaviour under the load change conditions in both areas of the system.

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