AN EFFECT OF PID CONTROLLER ON TWO AREA INTERCONNECTED POWER SYSTEM MODEL USING MATLAB SIMULINK

Deeksha Porwal[1], Ritu Jain[2]

[1]PG Student, [2]Assistant Professor
Department of Electrical Engineering
Gyan Vihar School of Engineering & Technology, SGVU Jaipur, Rajasthan, India

ABSTRACT: This paper presents the analysis of automatic generation control (AGC) of interconnected thermal-thermal power system each containing two units in the conventional environment. The improvement of AGC with the addition of a unit with a different type of controller in both the areas is studied. Time domain simulations are used to study the performance of the power system and control logic. Suitable method for controlling the thermal power system is described. The stability of the transfer functions 6 and14 used at the generator side is improved by the PID controller. Simulation studies carried out on a two-area interconnected power system each containing two units with and without considering PID controller, shows that the proposed PID controller is very effective for the stability of the system.

***Keywords*—Automatic Generation Control, Capacitive Energy Storage, Frequency Response, MATLAB/SIMULINK, PID Controller, Thermal-Thermal interconnected power system each consisting two units.**

I. INTRODUCTION

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankin cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy [1]. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil-fuel power stations produce a large part of man-made CO2emissions to the atmosphere, and efforts to reduce these are varied and widespread.

Almost all coal, nuclear, geothermal, solar thermal electric and waste incineration plants, as well as many natural gas power plants are thermal. Natural gas is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency. Power plants burning coal, fuel oil, or natural gas are often called fossil-fuel power plants. Some biomass-fueled thermal power plants have appeared also. Non-nuclear thermal power plants, particularly fossil-fueled plants, which do not use co-generation, are sometimes referred to as conventional power plants.

Commercial electric utility power stations are usually constructed on a large scale and designed for continuous operation. Electric power plants typically use phase electrical to produce alternating current (AC) electric power at a frequency of 50 Hz in India. Large companies or institutions may have their own power plants to supply heating or electricity to their facilities, especially if steam is created anyway for other purposes. Steam-driven power plants have been used in various large ships, but are now usually used in large naval ships. Shipboard power plants usually directly couple the turbine to the ship's propellers through gearboxes. Power plants in such ships also provide steam to smaller turbines driving electric generators to supply electricity. Shipboard steam power plants can be either fossil fuel or nuclear. Nuclear is, with few exceptions, used only in naval vessels. There have been perhaps about a dozen turbo-electric ships in which a steam-driven turbine drives an electric generator which powers an electric motor for propulsion.

Actually, all these create instability in the system frequency for interconnected power system. Also, the number of oscillation and settling time of frequency increases and consequently, system frequency decreases continuously in abrupt manner and this is not desirable in any manner in the power system. So, through this paper stability of power system frequency is achieved by the use of Proportional, Integral, Derivative (PID) controller for two area interconnected power system through Automatic Generation Control (AGC) . Hence, the system frequency settles down rapidly after giving the load disturbance of 0.01 per unit (pu).

II. AUTOMATIC GENERATION CONTROL

In an electric power system, Automatic Generation Control (AGC) is a system for adjusting the power output of multiple generators at different power plants, in response to changes in the load. Since a power grid requires that generation and load closely balance moment by moment, frequent adjustments to the output of generators are necessary. The balance can be judged by measuring the system frequency; if it is increasing, more power is being generated than used, and all the machines in the system are accelerating. If the system frequency is decreasing, more loads are on the system than the instantaneous generation can provide, and all generators are slowing down. Before the use of automatic generation control, one generating unit in a system would be designated as the regulating unit and would be manually adjusted to control the balance between generation and load to maintain system frequency at the desired value. The remaining units would be controlled with speed droop to share the load in proportion to their ratings. With automatic systems, many units in a system can participate in regulation, reducing wear on a single unit's controls and improving overall system efficiency, stability, and economy.

Where the grid has tie interconnections to adjacent control areas, automatic generation control helps maintain the power interchanges over the tie lines at the scheduled levels. With computer-based control systems and multiple inputs, an automatic generation control system can take into account such matters as the most economical units to adjust, the coordination of thermal, hydroelectric, and other generation types, and even constraints related to the stability of the system and capacity of interconnections to other power grids.

Maintaining power system frequency at constant value is very important for the health of the power generating equipment and the utilization equipment at the customer end. The job of automatic frequency regulation is achieved by governing systems of individual turbine-generators and Automatic Generation Control (AGC) or Load frequency control (LFC) system of the power system.

III. CAPACITIVE ENERGY STORAGE

To realize the full potential of Electro-chemical Capacitors (ECs) as Electrical Energy Storage (EES) devices, new materials and chemical processes are needed to improve their charge storage capabilities by increasing both their energy and their power densities. Incremental changes in existing technologies will not produce the breakthroughs needed to realize these improvements. Rather, a fundamental understanding of the physical and chemical processes that take place in the EC—including the electrodes, the electrolytes, and especially their interfaces—is needed to design revolutionary concepts. For example, new strategies in which EC materials simultaneously exploit multiple charge storage mechanisms need to be identified. Charge storage mechanisms need to be understood to enable the design of new materials for pseudo capacitors and hybrid devices. There is a need for new electrolytes that have high ionic conductivity in combination with wide electrochemical, chemical, and thermal stability; are non-toxic, biodegradable, and/or renewable; can be immobilized; and can be produced from sustainable sources. New continuum, atomistic, and quantum mechanical models are needed to understand solvents and ions in pores, predict new material chemistries and architectures, and discover new physical phenomena at the electrochemical interfaces. From fundamental science, novel energy storage mechanisms can be designed into new materials.

ECs include two general types, electric double layer capacitors (EDLCs, also known as super capacitors or ultra capacitors) and pseudo capacitors. ECs differ from conventional dielectric and electrolytic capacitors in that they store far more energy. As EES devices, ECs have a number of potentially high-impact characteristics, such as fast charging (within seconds), reliability, large number of charge-discharge cycles (hundreds of thousands), and wide operating temperatures. Because of their very fast charging rate, ECs may be able to recover the energy from many repetitive processes (e.g., braking in cars or descending elevators) that is currently being wasted. Large-scale ECs can perform functions of a different kind, such as power quality regulation of the electrical grid, which can avoid the costly shutdown of industrial operations as a result of intermittent outages and power fluctuations. While ECs are related to batteries, they use a different energy storage mechanism. Batteries move charged chemical species (ions) from one electrode via an electrolyte to the second electrode, where they interact chemically. Thus batteries store chemical energy (see Chemical energy storage panel report). EDLCs store electrical charge physically, without chemical reactions taking place. Because the charge is stored physically, with no chemical or phase changes taking place, the process is highly reversible and the discharge-charge cycle can be repeated virtually without limit. Typically, an EDLC stores electrical charge in an electrical double layer in an electrode-electrolyte interface of high surface area (see sidebar “Electrochemical Capacitor”). Because of the high surface area and the extremely low thickness of the double layer, these devices can have extraordinarily high specific and volumetric capacitances. A striking dissimilarity between batteries and ECs is the number of 17 charge-discharge cycles each can undergo before failure. The dimensional and phase changes occurring in battery electrodes represent one of the key limitations in attaining longer charge discharge cycling. In contrast, no inherent physical or chemical changes occur in EC electrodes during cycling because the charge is stored electro statically. As a result, ECs exhibit cycle lifetimes ranging from a few hundred thousand to over one million cycles. Most notably, however, ECs have the ability to deliver an order of magnitude more power than batteries. However, at present, their energy densities are generally lower than those of batteries. As the energy densities of ECs have increased, applications using ECs as EES devices—from vehicles, cell phones, and photocopiers to larger industrial drive systems— have increased1 and in some cases have displaced batteries.

IV. CONVENTIONAL DESIGN MODEL

The load demand is continuously changing in a day so it becomes very difficult to keep the system frequency at desired value. So here comes the role of “AGC” .The main objective of the AGC is to keep the system frequency at desired value for slow and normal load changes. AGC cannot be used to keep the system frequency at desired value for large load changes in that case one has to use emergency control. The other objective of AGC is to manage in parallel the customer load requirements and maintain the schedule power interchange in tie line. As the load increases the system frequency drops, through AGC we bring back the system frequency back to its normal value.

The problems regarding control of AGC has been already studied with Super Magnetic Energy Storage (SMES) [2],[3],[4] and Battery Energy Storage (BES) [5],[6]. To improve the dynamic performances CES unit is considered in the system. CES has several benefits compared to SMES [10] and BES systems and its is also less maintenance compared to the predefined units [7],[8]. CES device is a DC current device that stores energy in the electrostatic field. Several others technologies are there like: (1) Compressed air (2) Batteries (3) Underground Pumped Hydro. But capacitive energy storage element with a converter unit, both are highly efficient as there is no conversion of energy from one form to another as in pumped hydro, for example, where electrical energy is converted to mechanical energy and then back again. The application of capacitors as an energy storage device is one of the latest technology [9]. The low energy density and the dielectric losses of capacitors make it less attractive as a bulk energy storage device. However, a small rating CES can effectively damp out the power frequency and tie-line power oscillations caused by small perturbations to the load. CES units are practically maintenance free and do not impose any environmental problems unlike magnetic energy storage units. CES can be upgraded by adding extra capacitor modules to increase its capacity [1, 13].

The main objective of this paper is to demonstrate the effect of CES unit on AGC with PID controller and without PID controller, and the performance of the system has been analyzed with above mentioned controller. The figures 6 and 7 will show the performance analysis of the system such as deviation, no. of oscillations before coming to steady state.

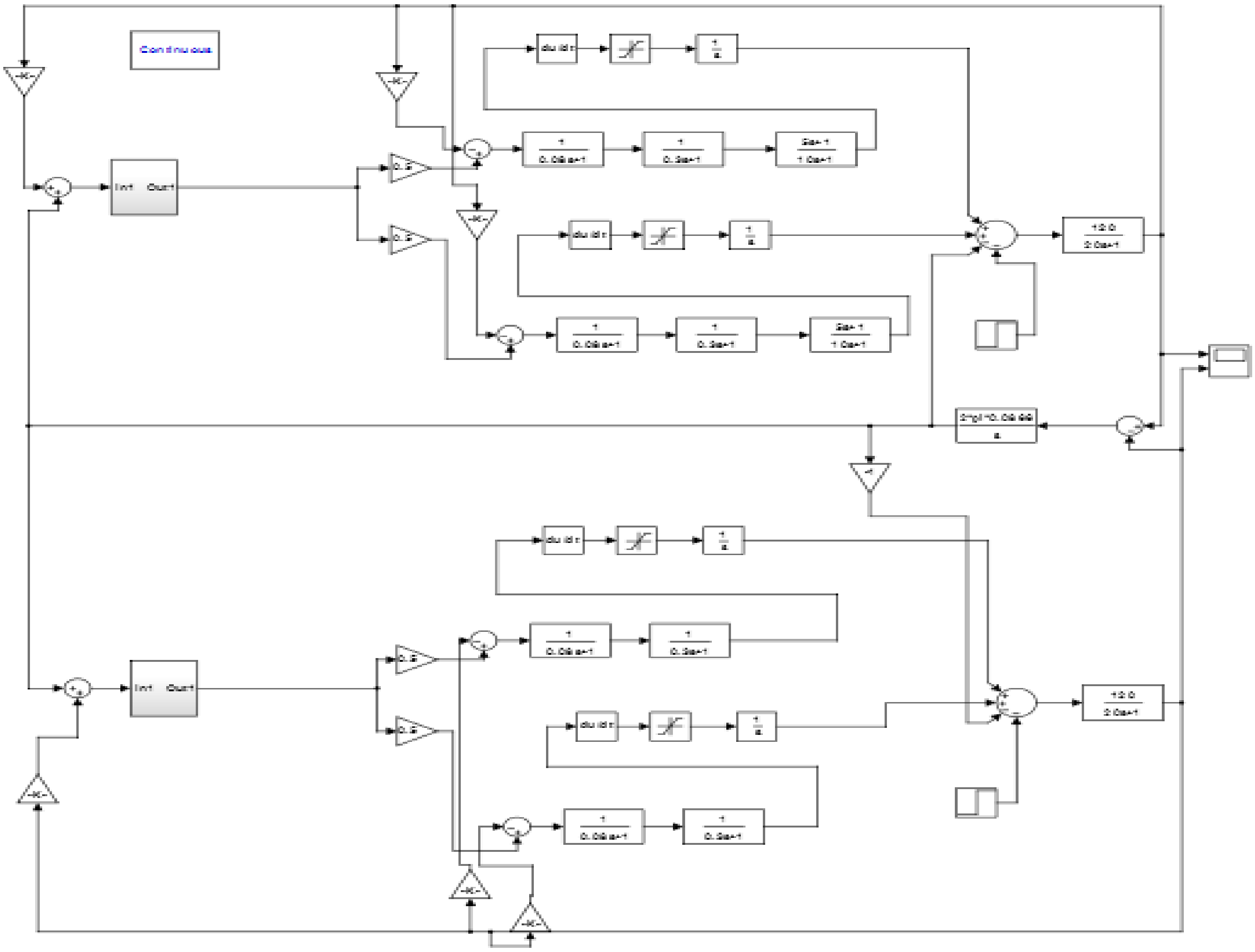

Figure 1:- Two Area Power System Model with CES Unit

A two area power system model is shown in the figure.1 where area 1 is a reheat system unit and area 2 is a non reheat system unit, each having a generation rate constraint of 3% and 10% per minute respectively. In power system a generation of power is kept under a maximum limit. In this case by controlling the steam governing system the generation rate of the power plant can be controlled. So typical value of Generation Rate Constraint (GRC) is taken as 3% per minute.

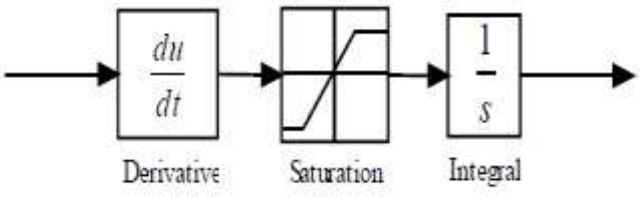

Figure 2:- Generation Rate Constraint Block Diagram

The small perturbation power system model considered can be represented by the standard state space model as
$\dot{X}=AX+BU+\Gamma ps$ [1]
Where X, U and p are the state, control and disturbance vectors respectively and A, B and Γ are constant matrices of compatible dimensions associated with them. The state variables chosen are as shown in the power system model. The effect on AGC of interconnected power systems is examined by fitting CES of similar rating to both the areas simultaneously [1],[12].

This block diagram is used in MATLAB Simulation as CES sub system. In the both the areas control of CES unit can be observed.

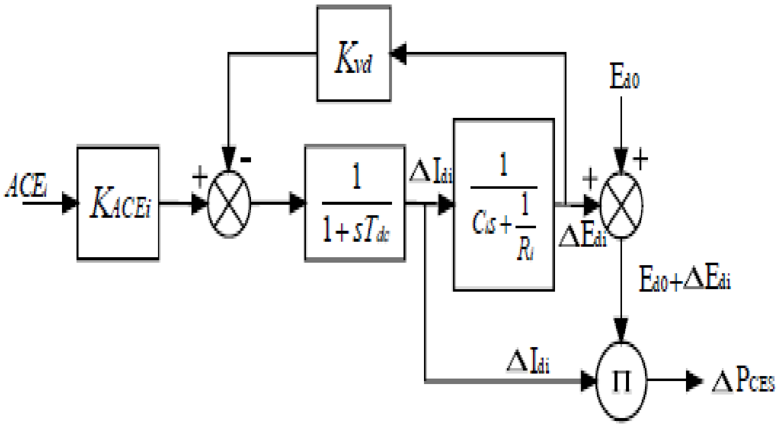

Figure 3:- CES Block Diagram with Capacitor Voltage Deviation Feedback

In this simulation, by using PID controller block from the MATLAB SIMULINK Library, to compare the responses of the system with CES unit without PID controller and with PID controller. The responses are taken in the time range of 50 seconds. The responses are shown below and the comparison of system frequency is furnished for clear the idea regarding the system performances.

V. PROBLEM STATEMENT

The transfer functions numbered 6 and 14 in the SIMULINK model which are the heart of this paper is now ready to stabilize with the use of PID controller. Without any controller the transfer function of the system is not stable as the graph or Fig.4 is showing the frequencies of the system are continuously decreasing.

Transfer function 6 and 14 is

$G(S) = \frac{120}{20s+1}$,

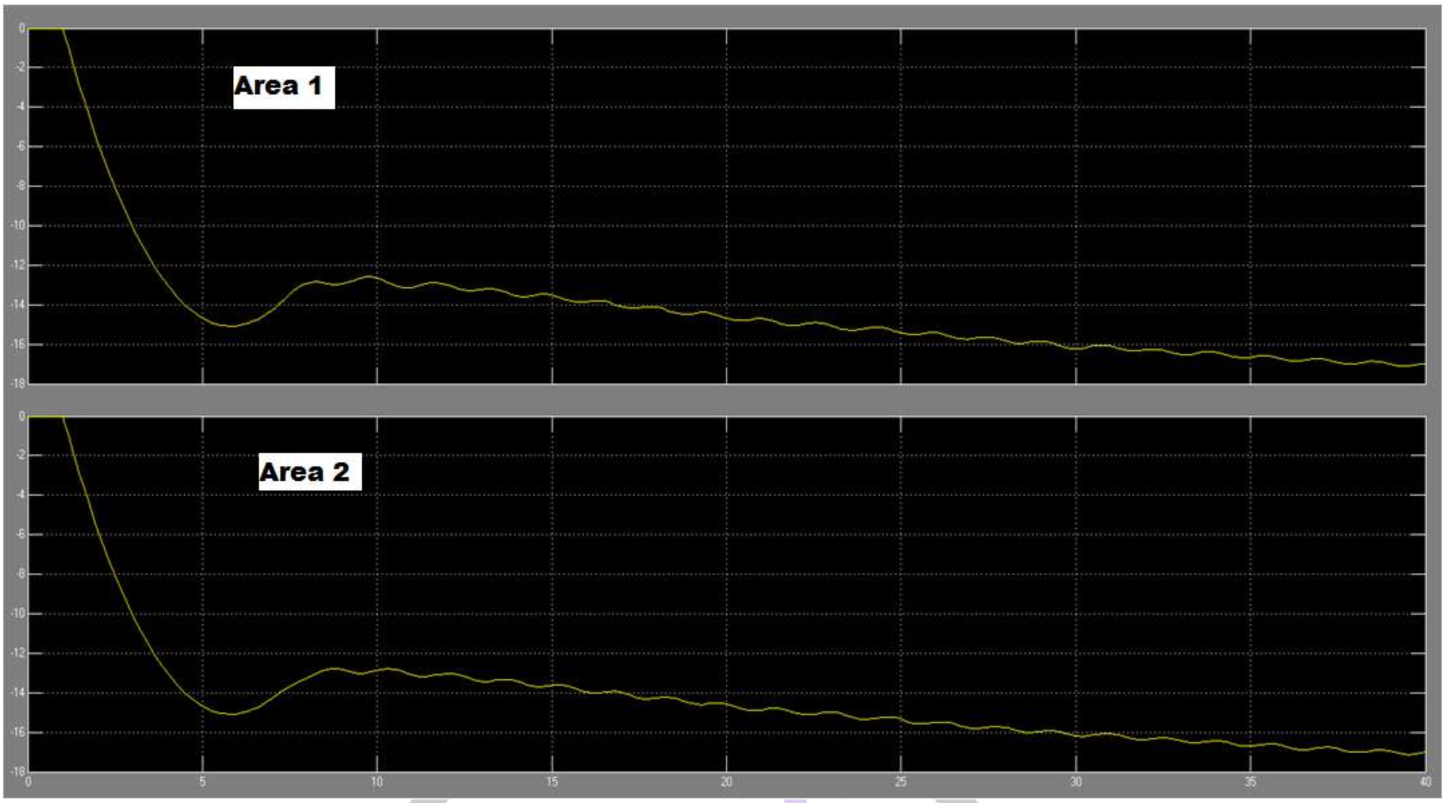

Figure 4:- Frequency waveforms of two interconnected area without any controller.

VI. PROPOSED METHODLOGY

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change [1]. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element. For a discrete time case, the term PSD, for proportional-summation-derivative, is often used.

A PID controller relies only on the measured process variable, not on knowledge of the underlying process, making it a broadly useful controller. By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set-point, and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

Some applications may require using only one or two terms to provide the appropriate system control. This is achieved by setting the other parameters to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value due to the control action.

If the PID controller parameters (the gains of the proportional, integral and derivative terms) are chosen incorrectly, the controlled process input can be unstable, i.e., its output diverges, with or without oscillation, and is limited only by saturation or mechanical breakage. Instability is caused by excess gain, particularly in the presence of significant lag.

Generally, stabilization of response is required and the process must not oscillate for any combination of process conditions and set points, though sometimes marginal stability (bounded oscillation) is acceptable or desired. The stability of the transfer functions 6 and 14 is stabilizing by the PID controller which is clearly seen in the figure 7.

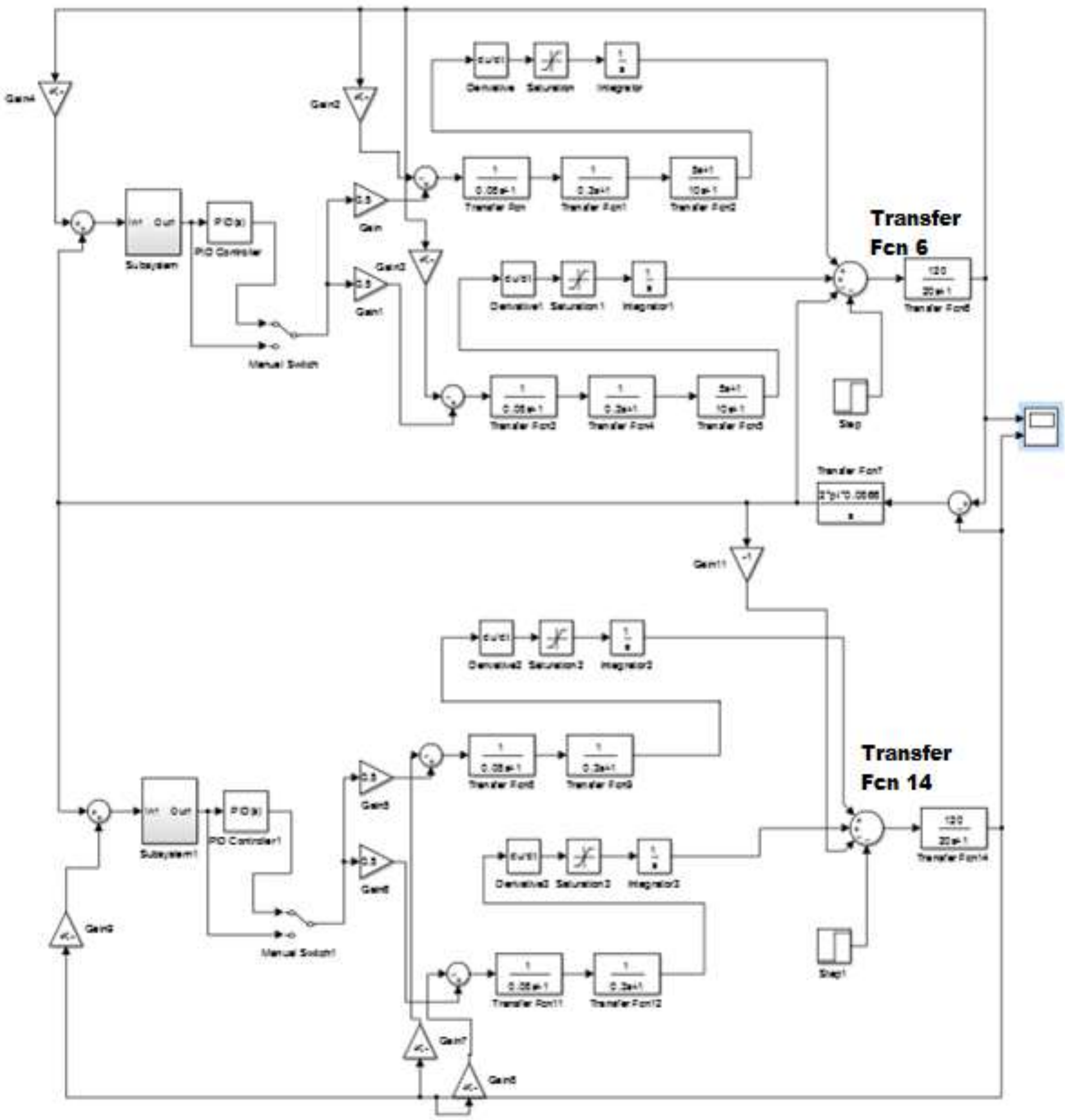

Figure 5:- Proposed Design Model

For the stability of the transfer function 6 and 14, PID controller is using as shown in image. Manual switch is using to change the position of the controller i.e. 'ON' and 'OFF'.

VII. RESULTS

WITHOUT ANY CONTROLLER

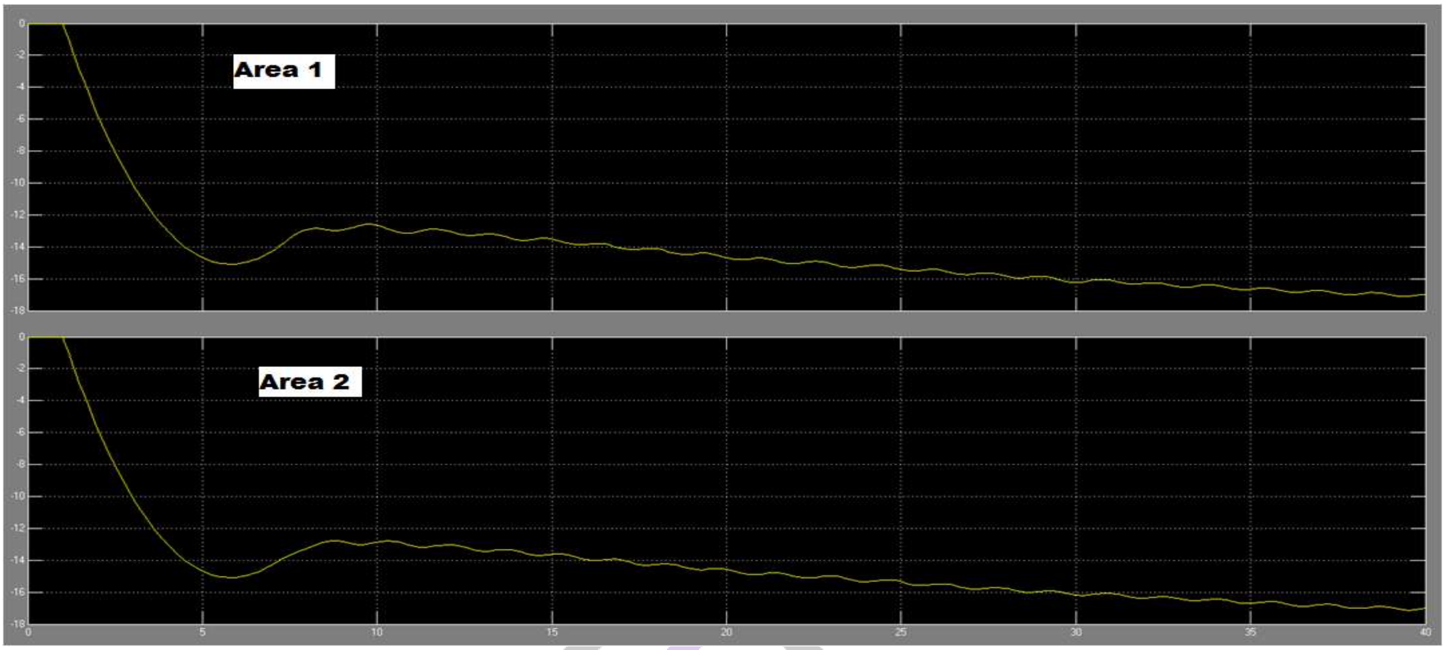

Figure 6:- Results of Two Area interconnected power system frequency without PID controller.

The frequencies of the transfer function 6 and 14 are decreasing continuously as shown in the figure 6. It means the stability of the system is continuously decreasing. Also the number of oscillations and settling time are more in the above scenario.

WITH PID CONTROLLER

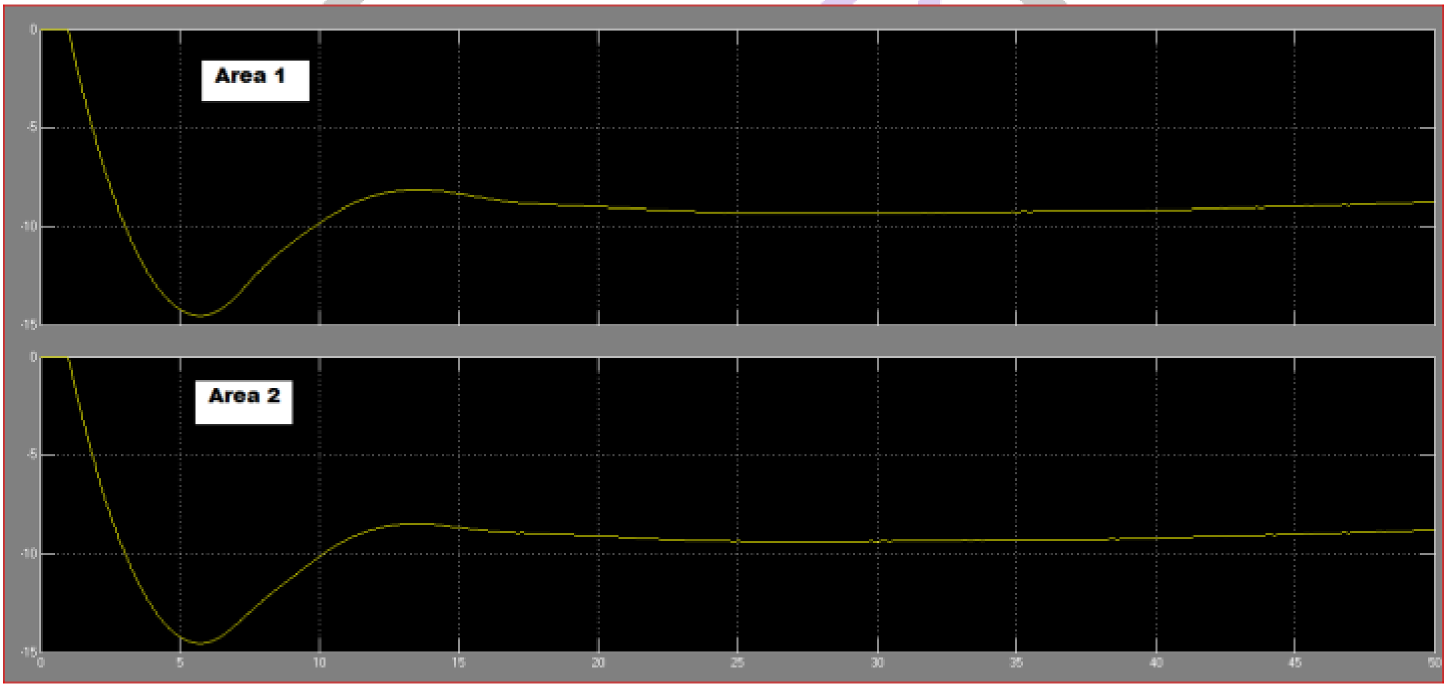

Figure 7:- Results of Two Area interconnected power system frequency by PID controller.

The frequencies of the transfer function after applying the PID controller get stable as well as increase as shown in the figure 7. It means the system transfer function is stable after applying the PID controller and as a result it has a good effect on the transient performance of the system and damp out the oscillation of the system. The most important aspect behind selecting the PID controller here rather than other composite industrial controllers is that PID controller has the benefit of all the three controllers i.e. Proportional, Integral, Derivative. The Integral controller reduces the offset error and the Derivative controller improves the transient response. Being an author the experiment has done by using different industrial controllers such as PI, PD and PID with different-different gain values but finally stuck the pointer of the clock to the most efficient PID controller.

VIII. CONCLUSION AND FUTURE SCOPE

In this work the effect of two area interconnected power system is examined and PID controllers are used to observe the performance of the system responses. The above mentioned system responses and observational data clears that the units with PID controller together have a good effect on the transient performance of the system and damp out the oscillation of the system.

Further work can be done to optimize the values of PID controller and effect of making variation in the value of the capacitance in the unit and observe the system responses of the system.

REFERENCES

[1] Rajesh Joseph Abraham, D.Das & Amit Patra, "Effect of Capacitive Energy Storage on Automatic Generation Control,"IEEE Power Engineering Conference, pp1070 - 1074 Vol. 2, 2005

[2] S. C. Tripathy & K. P. Juengst, "Sampled Data Automatic Generation Control with Superconducting Magnetic Energy Storage in Power Systems," IEEE Trans. Energy Conversion, vol. , no. , pp. 87-192, June 1997.

[3] S. Banerjee, J. K. Chatterjee & S. C. Tripathy, "Application of magnetic Energy Storage unit as Load Frequency Stabilizer," IEEE Trans. Energy Conversion, vol. 5, no. 1, pp. 46-51, Mar. 1990.

[4] R. Mikkonen, "Highlights of SC Power Applications in Europe," IEEE Trans. Applied Superconductivity, vol. 12, no. 1, pp. 782-787, Mar. 2002.

[5] H.J. Kunisch, K. G.Kramer & H. Dominik, "Battery Energy Storage-Another option for Load Frequency Control and instantaneous reserve," IEEE Trans. Energy Conversion, vol. EC-1, no. 3, pp. 41-46, Sep. 1986.

[6] A. Pivec, B. Bradford, M. Radimer & E. A. Hyman, "Utility Operation of Battery Energy Storage at the BEST facility," IEEE Trans. Energy Conversion, vol. EC-1, no. 3, pp. 47-54, Sep. 1986.

[7] Kwa-Sur Tam & A. Yarali, "Operation Principle and Applications of Multiterminal Superconductive Magnetic Energy Storage Systems," IEEE Trans. Energy Conversion, vol. 8, no. 1, pp. 54-62, Mar. 1993.

[8] T. Nitta, Y. Shirai & T. Okada, "Power Charging and Discharging Characteristics of SMES connected to Artificial Transmission Line," IEEE Trans. Magnetics, vol. MAG-21, no. 2, pp. 1111-1114, Mar. 1985.

[9] P. F. Ribeiro,B. K. Johnson, M. L. Crow, A. Arsoy & Y. Liu, "Energy Storage Systems for Advanced Power Applications," IEEE Proc. C, vol. 89, no. 12, pp. 1744-1756, Dec. 2001.

[10] Ellery Schempp & William D. Jackson, "Systems Considerations in Capacitive Energy Storage," Conf. IEEE, Energy Conversion Engineering Conference, vol. 2, pp. 666-671, 1996.

[11] E. W. Kimbark, Direct Current Transmission, vol. 1. New York: JohnWiley, 1971, p. 107.

[12] S.R. Khuntia & S. Panda, "Comparative Study of Different Controllers for Automatic Generation Control of an Interconnected Hydro-Thermal System with Generation Rate Constraints," International Conf. IEEE, Industrial Electronics, Control & Robotics(ICER), vol. 2, pp. 243-246, 2010.

[13] S. C. Tripathy, R. Balasubramanian & P. S. Chandramohanan Nair, "Small rating Capacitive Energy Storage for dynamic performance improvement of Automatic Generation Control," Proc. IEE, vol. 138, no. 1, pp. 103-111, Jan. 1991.