PSO Optimized PID Controller for Interconnected multi-area Power system with and without HVDC link under Open Market System

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Abstract – *This work presents Load Frequency Control (LFC) of multi -area interconnected thermal power systems incorporate with reheat turbine. Area 1, area 2 and area 3 are interconnected using normal HVAC tie line. In this investigation HVDC link is connected in parallel with HVAC tie line and performance of AC/DC tie line is compared with ordinary HVAC tie line. The dynamic performance of the system is observed with conventional PI controller. Optimal values of proportional and integral controller gain values are tuned using Particle Swarm Optimization technique. Time domain simulation is utilized to study the behavior of system with 1% of step load disturbance given in either area of the system. Finally, simulation result indicates that the system with HVDC link yield better controlled response in terms of settling time and overshoot*

Key Words: Three area power system, LFC, HVDC link, PSO, Open Market System,PID

I. Introduction

Energy is important, which is used in our day to day life from ancient days. Different kinds of energies used are mechanical, thermal, electrical etc. Out of all energies electrical energy is preferred due to various advantages. Because electrical energy can be easily transported from one place to another, easily converted into other forms of energy, easily controlled and regulated to match requirements and also the losses during transportation is mini-mum. Due to the advancement in technology the power consumption is increasing continuously and power demands on the power system are never steady and it varies continuously [9-11]. Change in active power affects the system frequency and variation in reactive power causes the changes in magnitude value of voltage. Therefore to maintain the steady state operation of power system is necessary to control both active and reactive power.

Load frequency control (LFC) method is used to control the frequency of large interconnection of power system [9-11]. This provides reliable electric power with good quality to consumers. Because quality and reliability of power is very much important for sensitive loads such as hospitals, processing plants (semiconductor, food, rayon and fabrics) and data processing. To produce more power, power systems are interconnected. Here thermal power plants are interconnected. Generally thermal plants respond to rapidly changing loads without difficulty and this plant, not only produces electric power, but also generates steam for different industrial purposes. It occupies less space compared to Hydro electric plants. Interconnection of power plants provides maximum advantages over individual power plant operation. The interconnection between power systems can highly improve the continuity, security and integrity of power supply, reduce the cost of energy per unit and improves the reliability of supply to the consumers. Due to increased size of power system, the complexity is increased. So the stability of the power system should be maintained. In this paper, stability of the power system is maintained by the conventional PI controller. In addition to the HVAC tie line HVDC link is connected in parallel. Due to this parallel HVAC tie line and HVDC link the settling time and oscillations are reduced and the system performance is improved [3-6].

The main objectives of the present work are:

- To model the simulink model of three area interconnected thermal power systems with re-heat turbine.
- To study the effects of HVDC link parallel with HVAC tie line in multi-area thermal power systems.
- To optimize the integral and proportional controller gains using integral time absolute error technique with and without HVDC link.

- To compare the dynamic performances of reheat thermal power systems with and without HVDC link

II. THREE AREA POWER SYSTEMS

The LFC investigated system consists of three generating units of equal size, area 1, 2 and 3 comprising a reheat thermal power system. Here conventional PI controller act as a supplementary controller. The block diagram representation of three area power systems with PI controller is shown in fig.1. [1-2,5-6]. MATLAB version 7.5(R2007b) has been used to obtain the frequency deviation in area1, area3, tie line power flow deviation in area 1, area 3 and area control error in area 3 with 1% of step load perturbation in area 1.

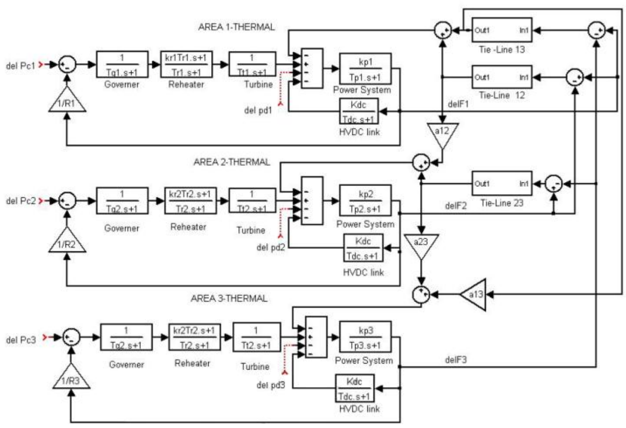

Figure1. Three Area interconnected Power system with HVDC link

a). HVDC link

HVDC link is used to transmit electric power for long distance. With HVDC system the elimination of the effect of line reactance and no charging current makes it possible to have stability without any consideration of the line length [5]. HVDC is also preferred for underground and submarine cable transmission over long distance at high voltage. In case of AC cable the temperature rises due to charging current forms a limit for loading. That is beyond certain limit AC cable cannot be used due to thermal limit and the HVAC interconnection between the power systems produces many problems particularly in case of long distance transmission [3, 7-8]. By the use of HVAC lines, large oscillations are produced which make frequent tripping and increases fault current level. These problems reduce the overall system dynamic performance.

When the HVDC link is used in parallel with the HVAC line, the above problems are reduced and the dynamic performance of the system is also improved. The important features of HVDC transmission lines are fast controllability of line power and improvement of transient stability in HVAC lines. HVDC system has three basic parts such as AC to DC converter station, transmission line and DC to AC converter station. Converters used in both ends are much expensive and HVDC transmission system is economical for long distances and also converters produce a lot of harmonics which may cause interference with communication lines requiring filters which increase the cost. The transfer function model of HVDC link is given by

$$\frac{\Delta P_{dc}}{U_{dc}} = \frac{K_{dc}}{1 + sT_{dc}}$$

Where

K_{dc} - Gain associated with DC link

T_{dc} -Time constant of DC link

b). OPEN MARKET SYSTEM

In the Open Market system there are several GENCOS and DISCOS, a Disco has the freedom to have a contract with any Genco for transaction of power. A Disco may have a contract with a Genco in another control area. Such transactions are called "bilateral transactions." All the transactions have to be cleared through an impartial entity called an independent system operator (ISO). The ISO has to control a number of so-called "ancillary services", one of which is AGC.

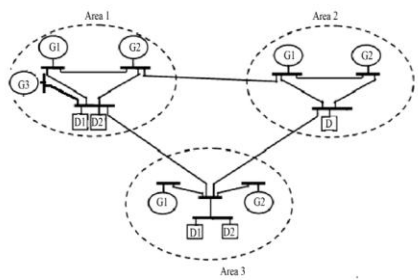

Figure2: Block Diagram of Three area Open Market System

Figure 2, shows the Three area Open market system where G1, G2, G3 represents the GENCOS in the control area and D1, D2 represents the corresponding DISCOS. Area1 comprises of three

GENCOs with thermal power system of reheat and hydro turbine combinations and two DISCOs, Area2 comprises of two GENCOs with hydro and thermal (reheat turbine) combination and one DISCO, Area3 consists of two GENCOs with hydro and thermal (reheat turbine) combination and two DISCOs.

c). Open Market System with HVDC link

In the open market environment the vertically integrated utility (VIU) power system no longer exists. Deregulated system consists of GENCOs, DISCOs, transmission companies and independent system operators (ISO). However the common goal is to keep frequency constant. The deregulated system contains two areas. Each area contains two generators and also two discos as shown in fig.3.

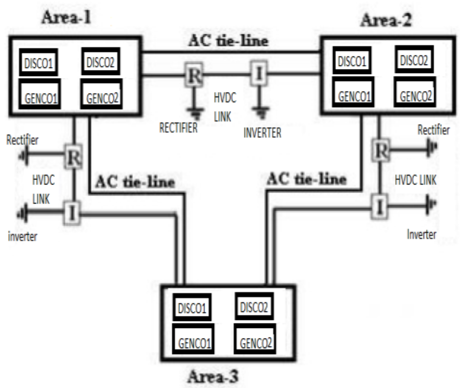

Figure 3: Configuration of Three-Area Power system With HVDC link.

The power system is assumed to contain a hydro and a thermal unit in all the three areas therefore each area includes two GENCOs and also two DISCOs as shown in Fig. 3

III.PARTICLE SWARM OPTIMIZATION

PSO is a stochastic heuristic population based optimization method, which is based on swarm intelligence. It is originated by idea comes from the research on the bird and fish flock movement behaviour. PSO algorithm is first given by Kennedy and Eberhart in 1995 [12-13]. This algorithm is widely used for so many applications because of its easy implementation and only few parameters need to be tuned.

Basic idea of PSO is while the birds in search of food from one place to another, there will always a bird that is moving close to food very well or having information of good food. Then birds will eventually flock to the place where food can be found, their movement is inspired by their best known position as well as flock best known position. As far as PSO algorithm is concerned, each bird position is compared to the best known position of swam as well as their best known position, and the birds' next move from one place to another root for development of the solution, good position is equal to most optimist solution [13].

$$v_i^m(iter+1) = w * v_i^m(iter) + c_1 * R_1(0,1) * \left(pbest_i^m(iter) - x_i^m(iter)\right) + c_2 * R_2(0,1) * (gbest^m(iter) - x_i^m(iter))$$

$$x_i^m(iter+1) = x_i^m(iter) + v_i^m(iter+1)$$

Where , *iter* = iteration number
i=particle index, *m* = Dimension, v_i^m Velocity of ith particle in mth dimensions, x_i^m ith particle in mth dimensions, $gbest_i^d$ Swarm Global best position of ith particle in m^{th} dimension, $pbest_i^d$ Particle best position of ith particle in m^{th} dimension, w Momentum, c_1, c_2 Acceleration constants R_1, R_2 Random numbers with uniform distribution [0, 1]

a) Tuning of PID controller using PSO

In this work, tuning or optimization of PID controller is done through PSO optimization. After 10 runs the best values of found by PSO optimization for PID tuning. The acceleration constants C1, C2 and w values selected for present algorithm is 1.2, 0.12 and 0.9 respectively.

IV. Results and Experimentation

***a) Comparison of Three-Area interconnected power system under open market system with and without HVDC Link using PSO-PID controller*:**

For the open market system, a restructured system is designed with two GENCO's, two DISCO's. Here in figure 4 each area has two generators and two turbine. And the subsystem DPM is the complete implementation of the Disco partition matrix, which gives the details of the participation of DISCO's in contract with GENCO's.

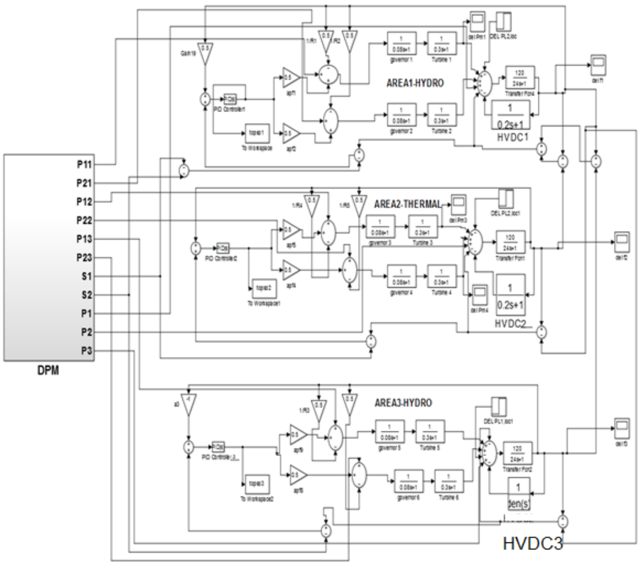

Fig 4: SIMULINK model of Three–Area Interconnected power system with HVDC link using PSO-PID under open market system.

Table1: Settling Time comparison using PSO-PID controller with and without HVDC link under open market system

Configuration	***Area 1(sec)***	***Area 2 (Sec)***	***Area 3(sec)***
With EHVAC link only	*7*	*7*	*7*
With EHVAC/HVDC link	*5.5*	*5.5*	*5.5*

Table 2: Deviation comparison of Change in frequency (Δf) using PSO-PID controller with and without HVDC link under open market system

Configuration	***Area 1(p.u.)***	***Area 2 (p.u.)***	***Area 3(p.u.)***
With EHVAC link only	*0.007*	*0.007*	*0.008*
With EHVAC/HVDC link	*0.004*	*0.004*	*0.004*

Table 1 and 2 shows the comparison between with and without HVDC link under open market system simulation results on the basis of settling time and overshoot. Here from tables it can be seen that the settling time in case of HVDC link is very less around 5.5 seconds where as in case of only EHVAC it is 7 seconds.

Figure 5, 6 and 7 illustrates the comparison of frequency deviations of all the three areas with and without HVDC link under open market system where on x-axis it's the simulation time and on y-axis it is the Δf (frequency deviation).

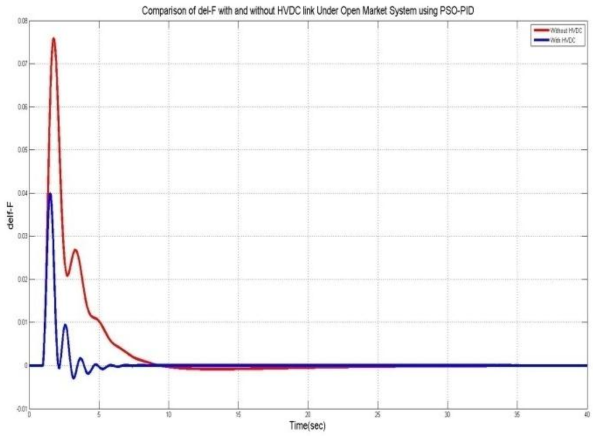

Fig 5: With and Without HVDC Link Area1 delta-F using PSO-PID under open market system.

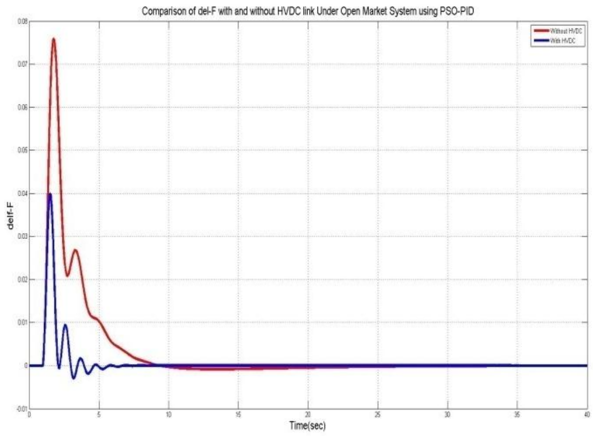

Fig 6: With and Without HVDC Link Area2 delta F using PSO-PID under open market system.

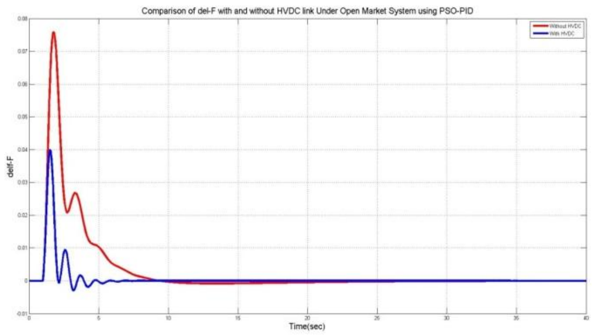

Fig 7: With and Without HVDC Link Area3 delta F using PSO-PID under open market system.

Figure 5, 6 and 7 displays the graph of the analysis under open market system using PSO-PID controller. The overshoot in case of HVDC link is quite less in open market case as well. And the settling time is also 1.5 seconds less when it is compared with the without HVDC link output plot. The addition of HVDC link in the open market system also where we have two GENCO's and two DISCO's in each areas have immensely improved the quality of the system dynamics.

V. CONCLUSIONS

The following summaries are the noteworthy contribution of this work:

- In this work simulink model of three area inter connected power system under open market system is modelled and performance of system is obtained with 1% of step load disturbance given in area 1.
- The proposed model of HVDC link is implemented in the interconnected Hydro-thermal-Hydro power systems.
- The optimal conventional controller gain values are obtained by using Particle Swam Optimisation with and without considering HVDC link in open market system.
- Investigation reveals that, the system yields more controlled and fast settled response when HVDC link is taken into an account.

VI. REFERENCES

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