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# Dynamic PSO based 2 DOF-PID controller Tuning for Load Frequency Control

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***Abstract*: : The present work is about the load frequency control of a practical power system under certain operating conditions. The primary goal of the load frequency control is to reduce the area control error to zero when the system is experienced to abrupt load change. Real power is mainly affected by frequency change. To ensure satisfactory operation of the load quality of power delivered to load must be good so a load frequency controller is needed to ensure system frequency within the permissible limits. PID control is widely used in industry and accepted universally because they give robust performance under various operating conditions at least time compared to intelligent controllers. In this paper, dynamic PSO based Two-Degree- of Freedom Proportional-integral-Derivative (2- DOF PID) controller is used to tune the gains of the PID controller. Simulation results shows the advantage of this approach with respect to a PID controller.***

***Key Words*: Load frequency control, PID control, PSO algorithm, Two-area power system.**

## I. INTRODUCTION

Electrical power system is a huge network consisting of many areas, each area consisting of one or more generators. These areas are coupled by using tie lines for emergency power exchange. In a practical scenario, the load on the system is never constant due to various operating conditions. Sudden load change on the system makes frequency to vary from its nominal value. To have a satisfactory operation of the load the frequency must be with in permissible limits. Although the speed governor action is present, there will be some error present in steady state. so, a secondary control is requisite to keep the frequency limits at the stated value. To have a reliable and safe operation of power system LFC is required. In steady state operation the system frequency is maintained constant. An increase in the load causes the frequency to decrease and vice-versa

A controller used in LFC will cope with the changes occurring on the system to balance the generation and load demand. To achieve this control parameters of PID controller are tuned by using optimization algorithms

From the literature survey various control techniques have been proposed to LFC for better execution of the system. In 1970 the concept of two area connected power system was given by Elgerd and Fosha [1]. LFC has achieved a massive importance in Power system because the deviation in frequency from nominal value cause instability problems in power system. LFC provides real power balance in the system by maintaining frequency constant. Authors have studied LFC with Fuzzy logic control (FLC) and various optimization techniques. In [2] authors have used Fuzzy logic-based controller for interconnected power system. Ali and Abd-Elazim[3] have discussed a secondary controller PI using BFOA in interconnected power system

Neural network model is used in LFC in which the network is trained to get required output[4]. In [5], TLBO algorithm is used for tuning gains of Fuzzy-PID controller in multi-area system.[6] deals with Fractional order PID(FOPID) controller which uses genetic algorithm (GA) to determine control parameters. comparison of various secondary controllers which are used in LFC have been discussed in [7]. Rabindra kumar sahu and others have proposed a 2 -DOF PID controller to compare the performance with other controllers [8]. LFC is also studied with artificial neural networks in deregulated power system and is discussed in [9]. In this paper Dynamic-PSO based 2-DOF PID controller is used in comparison with PID controller. The simulation results are carried out by using MATLAB Simulink.

## II. MODEL OF THE SYSTEM

A Simple system comprising of Governor and Turbine is taken here. controllers are provided in each area to account for the disturbances occurring due to changing load demands. The equation describing the system is

$$X = A\,\mathrm{x} + B\,\mathrm{u} + L\,\mathrm{d}$$
$$y = \mathrm{C}\,\mathrm{x}$$

where $A$ is the system matrix, $B$ is the input matrix, $L$ is the disturbance matrix, and $x(t)$ , $u(t)$ are state control vectors, $d(t)$ is the load disturbance vectors

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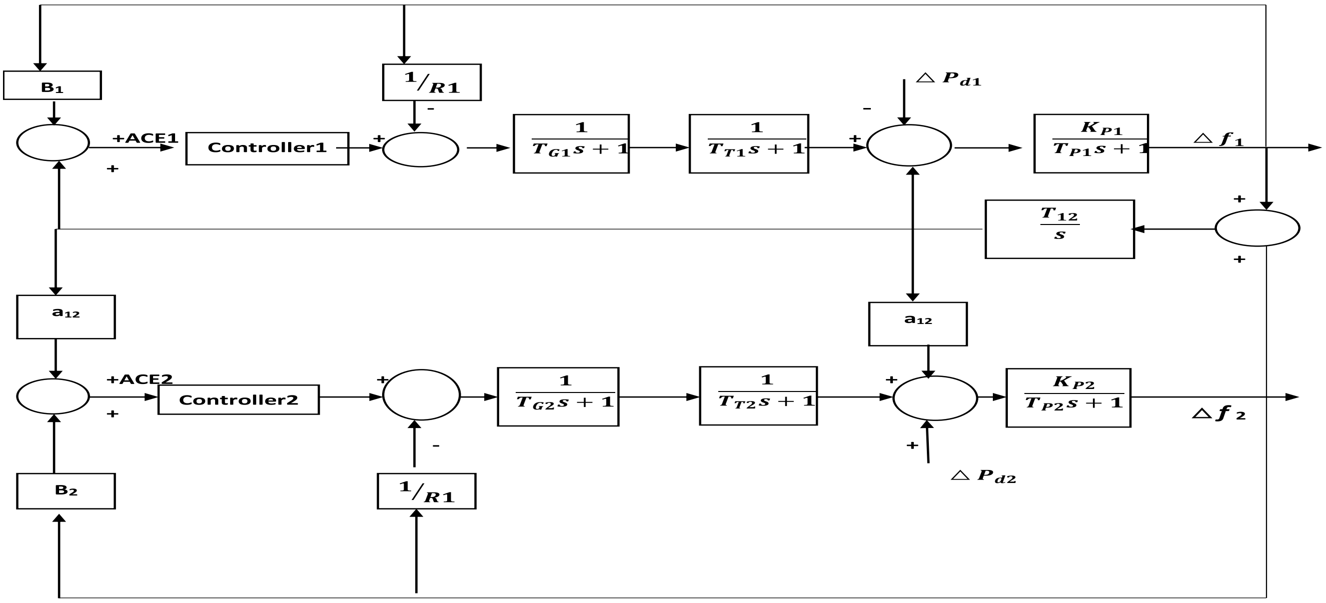


Fig. 1 Simple system comprising of Governor and Turbine

$$A = \begin{bmatrix} \frac{1}{Tp1} & \frac{Kp1}{Tp1} & 0 & 0 & 0 & 0 & \frac{-Kp1}{Tp1} & 0 & 0 \\ 0 & \frac{-1}{Tt1} & \frac{1}{Tt1} & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{R1Tg1} & 0 & \frac{-1}{Tg1} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{-1}{Tp2} & \frac{Kp2}{Tp2} & 0 & \frac{-Kp2}{Tp2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{-1}{Tt2} & \frac{1}{Tt2} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R2Tg2} & 0 & \frac{-1}{Tg2} & 0 & 0 & 0 \\ T_{12} & 0 & 0 & -T_{12} & 0 & 0 & 0 & 0 & 0 \\ -B_1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -B_2 & 0 & 0 & -a_{12} & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \frac{1}{Tg1} & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & \frac{1}{Tg2} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \qquad d(t) = \begin{bmatrix} \frac{-Kp1}{Tp1} & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & \frac{-Kp2}{Tp2} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \qquad x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \end{bmatrix}$$

$u=[u_1 \quad u_2]^T$ , $y=[y_1 \quad y_2]^T=[ACE_1 \ \ ACE_2]^T$
Where

$T_{12}$ = the synchronizing constant between the area 1 and area 2
$T_t$= turbine time constant
$T_g$= governor time constant
$B$=the bias constant for each area.
$R$=the regulation constant for each area.
$K_p$=gain for each area power system.
$T_p$=time constant for each area power system

### A. Area Control Error (ACE)

$$ACE=\Delta P_{tie}+B_f\Delta f \ =(P_{tie}-P_{tie,sched})+B_f(f-f_s)$$

Where $\Delta P_{tie}$ is the tie line power variation, $B_f$ is called frequency bias constant, $\Delta f$ is the deviation in frequency, $P_{tie,sched}$ is the scheduled tie line power, $f_s$ is the nominal value of frequency. $P_{tie}$ is the new tie line value. $f$ is the new frequency value when the power system is subjected to disturbance

The objective function taken here is integral square error (ISE) and is given by

$$ISE= J =\int_0^{tsim} (\Delta f1^2+\Delta f2^2+\Delta ptieline^2)dt$$

Where B1and B2 are frequency bias,
Δptie is change in tie line power,
ΔF1 and ΔF2 are changes frequency,
tsim is range of time of simulation
The motive here is to minimize the integral square error (ISE) based on optimization technique.

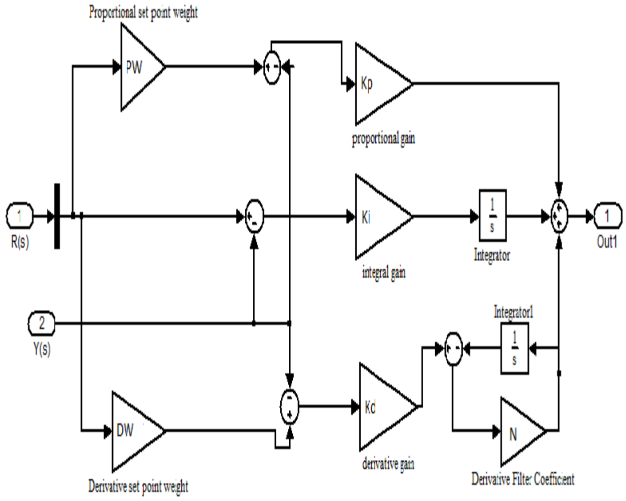
## III.PROPOSED CONTROLLER

### A. PID Control

It produces an output which combines of the outputs of proportional integral and derivative controllers. In PID controller proportional part mainly minimize the error due to disturbance, the integral part reduces the steady state error and the derivative part enhances the transient response and stability of the system. PID controller gives combined effect of proportional integral and derivative actions when used in a closed loop system.

### B. 2-DOF PID Control

In a two degree of freedom control the no of closed loop transfer functions that can be tuned independently is two. The Block diagram representation of a 2-DOF PID is shown in Fig.2



Where R(s) is the reference signal , Y(s) is the feedback from output and U(s) is the output signal .Kp is the proportional gain Ki is the integral gain and Kd is the derivative gain and N is the filter coefficient for derivative controller.
A controller structure of 2-DOF PID is shown in Fig. 3

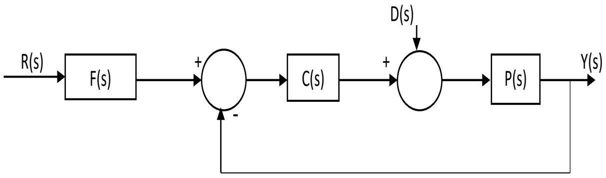


Fig.3. Two degree of freedom controller structure

## IV.PROPOSED ALGORITHM

### A. Particle Swarm Optimization (Pso)

Particle swarm optimization (PSO) is the oldest optimization technique based on swarm intelligence. It was proposed in 1995 by James Kennedy and Russ Eberhart [10]. It is influenced by the communal behavior of bird amass or sea shoaling. A family of birds (Particle) move around a search space for location of food (best solution). Since they don't have any idea about the location of the food, they track the bird which is proximate to the food. An individual gains knowledge from other members in the swarm. It is assumed that the bird flying has a certain position and velocity v at a time t. while searching food, the bird changes its locale by altering velocity. Here each solution is considered as a bird, particle. Fitness function of all the particles is calculated using objective function. Particles update their position and velocities until best solution is found.

Velocity is updated
$V_{i+1}=\omega V_i+C_1{*}\text{rand}()*(PB_i-X_i)+C_2{*}\text{rand}()*(GB_i-X_i)$
Position is updated
$X_{i+1}=X_i+V_{i+1}$
$C_1$ and $C_2$ are the learning factor ω is the inertia weight
rand () is any random number between (0 1)
$PB_i$ Personal best performance
$GB_i$ Best performance of the group

### B. Dynamic Particle Swarm Optimization(Dpso)

To overcome the drawbacks in standard PSO we go for Dynamic PSO. In standard PSO algorithm, it is difficult to establish initial design parameters and while solving complex problems, particles move into undesirable states and easily falls into local minima. Due to this disadvantage, early convergence takes place which affects the whole evolution process. At every step, velocities of (accelerating) each particle is modified towards its $PB_i$ and $GB_i$ locations until optimum values are found, the particle revises its position and velocity with the following equation

Velocity is updated

$V_{i+1}$=ω$V_i$+ $C_1$*rand () *($PB_i$- $X_i$)+ $C_2$* rand ()*($GB_i$ - $X_i$)

Position is updated

$X_{i+1}$= $X_i$+ $V_{i+1}$

$C_1$ and $C_2$ are the learning factor ω is the inertia weight

rand () is any random number between (0 1)

$PB_i$ Personal best performance

$GB_i$ Best performance of the group

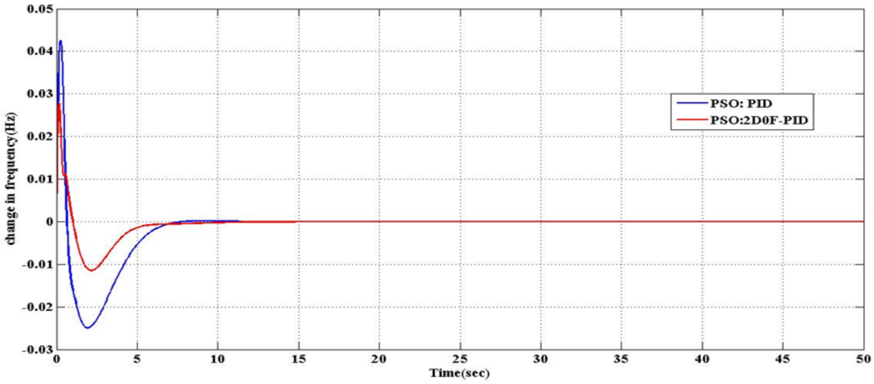
## V.SIMULATION RESULTS AND DISCUSSION

The results of the simulated system are discussed in the below section. A step load change of 10% in area-1 and -5% in area-2 is considered here. Simulations are carried out in MATLAB version R2009a.

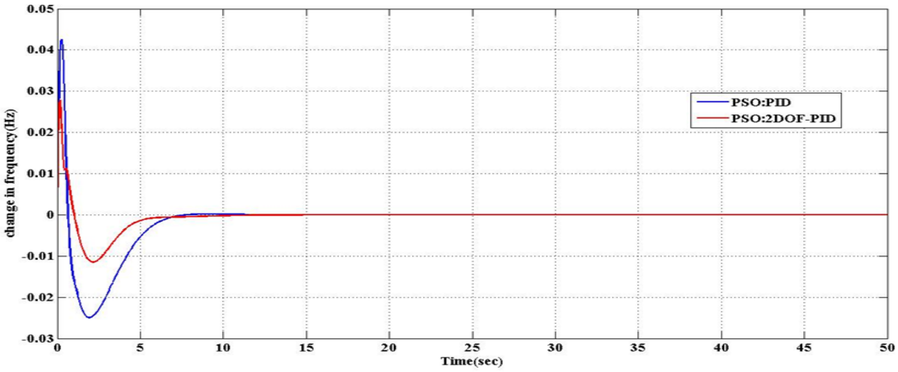
**TABLE 1** Values of the simulated system:

| | |
|---|---|
| $B_1$=$B_2$ = 0.4 MW/Hz | $T_{t1}$=$T_{t2}$ = 0.3sec |
| $T_{g1}$=$T_{g2}$= 0.08sec | $R_1$=$R_2$= 2.4Hz/pu MW |
| $T_{12}$= 0.545 pu MW | $T_{p1}$=$T_{p2}$= 20sec |
| $K_{p1}$=$K_{p2}$= 120 | $a_{12}$ = -1 |

**(a)**



**(b)**



**(c)**

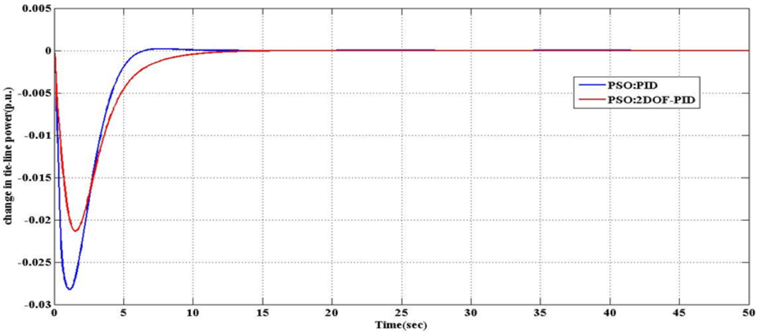


Fig.4. Results of the simulated system with PSO (a) frequency fluctuation in area-1 (b) frequency fluctuation in area-2 (c) tie-line power variation

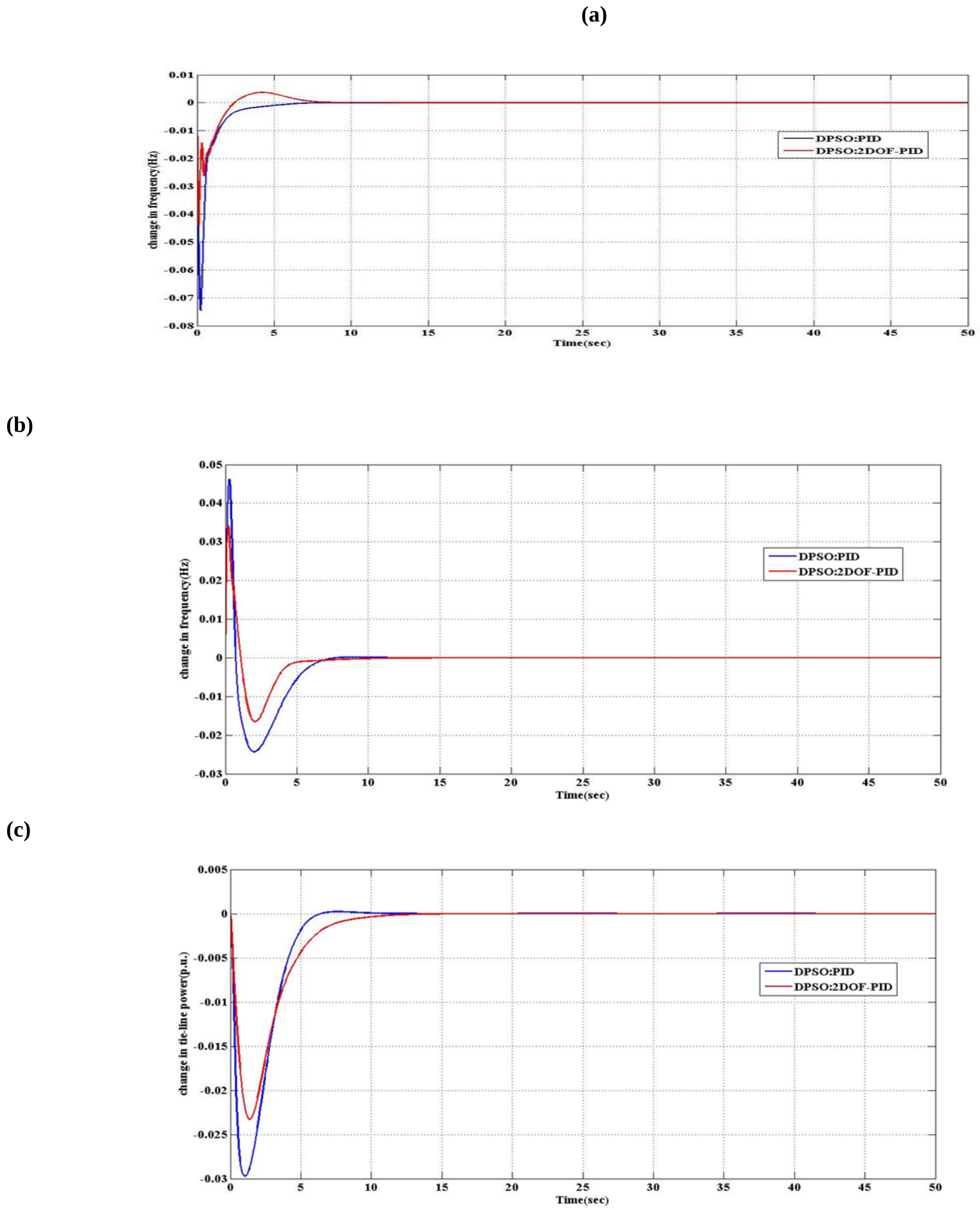


Fig.5. Results of the simulated system with DPSO (a) frequency fluctuation in area-1 (b) frequency fluctuation in area-2 (c) tie-line power variation

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TABLE 2 COMPARISON OF PEAK UNDERSHOOT WITH PSO-PID AND PSO:2DOF PID

| Peak Undershoot(p.u.) | | | |
|---|---|---|---|
| **Controller/Technique** | $\Delta f_1$ | $\Delta f_2$ | $\Delta$ptie |
| **PSO - PID** | 0.0745 | 0.025 | 0.0282 |
| **PSO – 2DOF** | 0.0458 | 0.0115 | 0.0213 |

TABLE 3 COMPARISON OF PEAK UNDERSHOOT WITH DPSO-PID AND DPSO:2DOF PID

| Peak Undershoot(p.u.) | | | |
|---|---|---|---|
| **Controller/Technique** | $\Delta f_1$ | $\Delta f_2$ | $\Delta$ptie |
| **DPSO – PID** | 0.0744 | 0.0243 | 0.0297 |
| **DPSO – 2DOF** | 0.0438 | 0.0165 | 0.0233 |

TABLE 4 COMPARISON OF SETTLING TIMES OF VARIOUS CONTROLLERS AND TECHNIQUE

| Settling Time (sec) | | | |
|---|---|---|---|
| | $\Delta f_1$ | $\Delta f_2$ | $\Delta$ptie |
| **PSO - PID** | 5.4 | 6.7 | 6.1 |
| **DPSO – PID** | 5.8 | 6.8 | 6.0 |
| **PSO – 2DOF** | 7.4 | 6.0 | 8.7 |
| **DPSO – 2DOF** | 7.39 | 8.0 | 10.5 |

TABLE 5 VARIOUS CONTROL PARAMETERS OF PID CONTROL

| **PID Control** | **Area – 1** | | | **Area -2** | | |
|---|---|---|---|---|---|---|
| | $K_p$ | $K_i$ | $K_d$ | $K_p$ | $K_i$ | $K_d$ |
| **PSO** | 1 | 1 | 1 | 0.5212 | 0.9554 | 0.6179 |
| **DPSO** | 0.999 | 1 | 1 | 0.3664 | 0.8818 | 0.5165 |

TABLE 6 VARIOUS CONTROL PARAMETERS OF 2-DOF PID CONTROL

| **2DOF – PID Control** | **PSO** | | **DPSO** | |
|---|---|---|---|---|
| | **Area -1** | **Area -2** | **Area -1** | **Area -2** |
| $K_p$ | 0.9974 | 0.8681 | 0.9997 | 0.6290 |
| $K_i$ | 1 | 1 | 1 | 0.9968 |
| $K_d$ | 0.9930 | 0.5803 | 0.9997 | 0.4941 |
| **N** | 49.61 | 69.21 | 66.82 | 69.62 |
| **PW** | 0.9982 | 0.8960 | 0.9996 | 0.5311 |
| **DW** | 0.9936 | 0.8645 | 0.9979 | 0.2437 |

TABLE 7 COMPARISON OF INTEGRAL SQUARE ERROR FOR VARIOUS CONTROLLER/TECHNIQUES

| Controller/Technique | Integral Square Error(ISE) |
|---|---|
| PSO-PID | 0.2079 |
| DPSO-PID | 0.2068 |
| PSO-2DOF | 0.1062 |
| DPSO-2DOF | 0.1056 |

## VI. CONCLUSION

In this paper dynamic PSO based 2-DOF controller design using optimization has been proposed. Simulation and MATLAB code are executed in MATLAB R2009a.By observing the simulation results the peak undershoot is greatly reduced with this proposed approach than with a conventional PID controller

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