OPTIMIZATION OF ELECTRICAL POWER TRANSMISSION SYSTEM USING PSO WITH SVC

Ritesh Soni[1], Hitesh Lade[2]
Satyam and Surbhi Group of Institutes, Bhopal

Abstract: This paper presents a Static VAR compensator (SVC) Model which is developed using SIMULINK. The block SVC consist of PI controller, the parameters (Kp,Ki) of which are being selected from optimizations made by PSO. The best output from PSO is selected and then feeded into the SVC parameters to get the optimized output of the same. A 800KM transmission line and SVC is modeled in the MATLAB. An algorithm has been developed for the same based on PSO. The best and optimized output from the algorithm is seen.. The outputs can be checked with optimized PSO and without PSO optimization. It is clearly seen that PSO optimized SVC gives better results as compared to non optimized SVC.
Keywords: Static VAR Compensator (SVC), PID Controller, AVR, TCR, Voltage regulation, MATLAB Simulink.

I. INTRODUCTION

The stability improvements is very essential for large scale power system. The AC power transmission system has numerous limits, classified as static limits and dynamic limits [2,3]. Traditionally, fixed or automatically switched shunt and series capacitors, reactors and synchronous generators were getting used to boost same varieties of stability augmentation [2]. For some reasons coveted execution was being not able accomplish successfully. A static volt-ampere compensator (SVC) is a gadget for giving quick acting receptive power remuneration on high voltage transmission systems and it will add to improve the voltage profiles inside the transient state. The SVC may be controlled externally by exploitation properly designed differing kinds of controllers which might improve voltage stability of a large scale power grid. Aadditionally, designed PI controller and system performances were investigated. With a view to improving performance PID controller has been designed for SVC to injects Vqref externally. The dynamic nature of the SVC lies within the use of SCR devices (e.g. GTO, IGCT) [4]. Therefore, SCR based mostly SVC with PID controllers are used to improve the performance of multi-machine power system.

II. CONTROL CONCEPT oF SVC

The SVC is a device that controlled shunt susceptance and injects reactive power into transmission line results in increasing the bus voltage reached to its equivalent desired voltage level. If bus voltage will increase, the SVC can inject less reactive power, and also the result are to attain the required bus voltage [Fig.1]. Here, +Qcap could be a fixed capacitance value, thus the magnitude of reactive power injected into the system, Qnet, is controlled by the magnitude of –Qind reactive power absorbed by the TCR. the premise of the thyristor-controlled reactor (TCR) that conduct on alternate half-cycles of the provision frequency. In the event that the thyristors are gated into conduction precisely at the pinnacles of the supply voltage, full conduction winds up in the reactor, and along these lines the current is that a similar like the thyristor controller were short circuited. SVC based for the most part framework is appeared in Fig.1 [2,8].

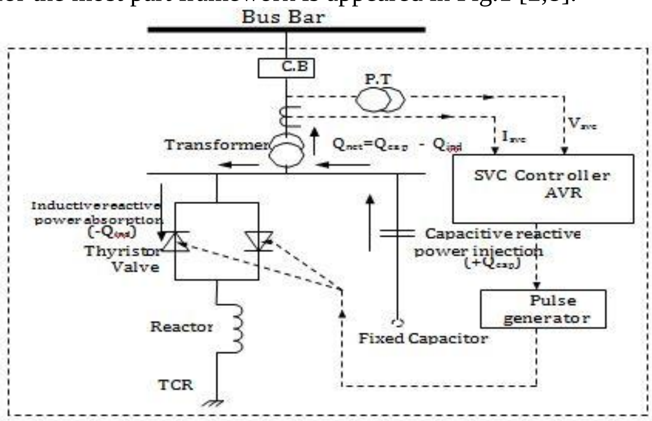

Fig.1 SVC based control system

III. PID CONTROLLER TUNING PROCESS

The piece graph of PID controller parameters and PID square are appeared in fig 2 and fig 3 individually. The way toward picking the controller parameters to fulfill given execution details is named PID tuning. Most PID controllers are balanced nearby, numerous option sorts of tuning principles are proposed inside the writing. Misuse those tuning rules, fragile and adjusting of PID controllers might be made nearby.

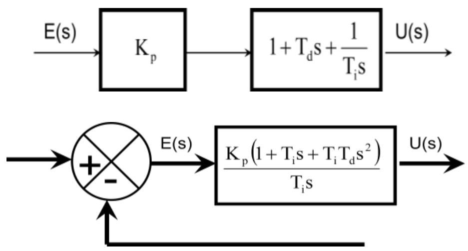

Fig.2 Block diagram of PID controller parameters

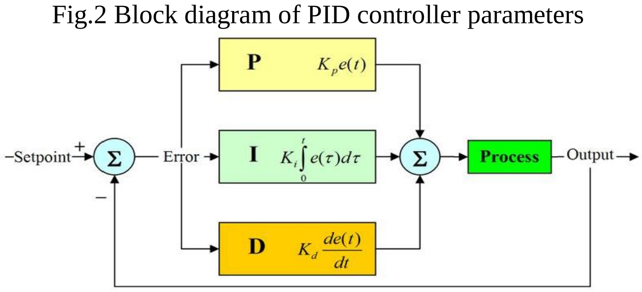

Fig. 3 PID BLOCK

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Performance of PID depends on the system gain. So it required to adjust them. Different methods are used:
Open loop Method
Closed loop Method

OPEN LOOP METHOD
Here, this are applying steps to the method and get the response like as shown in the graph and get the dead time, reaction rate and process gain.

- Put the controller in manual mode
- Wait till the method value (Y) is stable and not dynamical
- Step the output of the pid controller - The step should be large enough to check a major amendment within the method value. A rule of thumb is that the signal to noise magnitude relation should be larger than five.
- Collect information and plot as shown below.
- Repeat creating the step within the other way.
- K = the method gain=change in method value /change in manipulated value

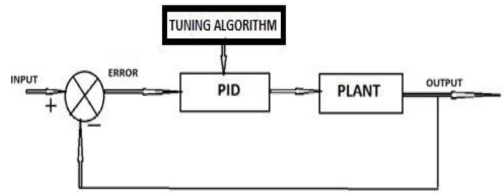
Close loop method
Another tuning technique is formally called the ziegler Nichols technique, by John G. Ziegler and Nathaniel B. Nichols within the 1944 [6]. As within the technique on top of, the Ki and Kd gains are first set to zero. The P gain is raised till it reaches the ultimate gain, Ku, at that the output of the loop starts to oscillate. The most advantage of the closed-loop tuning technique is that it considers the dynamics of all system elements and thus provides correct results at the load wherever the test is performed. Another advantage is that the readings of ku and Pu are simple to read and also the period of oscillation may be accurately read though the measurement is noisy. The disadvantages of the closed-loop tuning methodology are that once tuning unknown processes, the amplitudes of undamped oscillations will become excessive (unsafe) and also the test will take an extended time to perform. One will see that once tuning a slow method (period of oscillation of over an hour), it will take an extended time before a state of sustained, undamped oscillation is achieved through this trial-and-error technique. For these reasons, different tuning techniques have conjointly been developed and a few of them are represented below. First, it's basically trial-and-error methods, since many values of gain should be tested before the ultimate gain. Second, whereas one loop is being tested during this manner, its output might have an effect on many alternative loops, so presumably upsetting an entire unit.

IV. PROBLEM STATEMENT

The project is objected to design a PID controller for a low damping plant. The low damping plants are the higher request plants which displays slow conduct. This implies the plant has expansive settling time, vast pinnacle overshoot which are undesirable for better execution. Here we have chosen a model exchange capacity of a low damping crude plant as takes after:-

T(s) = (25.2*S^2 +21.2*S +3)/(S^5 + 16.58*S^4 + 25.41*S^3 +17.18*S^2+11.70*S+1)

For the plant model the transfer function is as follows:-
T1=([25.2 21.2 3],[1 16.58 25.41 17.18 11.70 1])
The parameters can be obtained as follows:-
S=Stepinfo{T1,'RiseTimelimits',[0.1, 0.9]}
The above command returns:-
S = RiseTime : 2.1972 sec
Settling Time : 33.513 sec
Overshoot : 7.1023
Peak : 3.2131
Peak Time : 4.1789 sec
The plant model can be figured as :-



The open loop transfer function of the model :-
T(s) = (25.2*S2 + 21.2*S +3)/(S5+16.58*S4 +25.41*S3 +17.18*S2 +11.70*S+1)
Contribution of PID:-
PID(S) =(kD*S2 +kI +kp*S)/S
So, the overall transfer function of the controlled model:-
C(S)/R(S) = PID(S)*T(S)/(1+PID(S)*T(S)) =

(25.2*kD*S4)+(21.2*kD+21.5*kP)*S3+(25.2*kI+21.2*kp+ 3*kD)*S2+ (21.2*kI +3*kp)*S +3*KI

S6+16.5*S5 +(25.41 +25.2*kD)*S4+ (17.18 +21.2*kD +25.2*kP)*S3+ (11.70 + 25.2*kI +21.2*kP + 3*kD)*S2 + (21.2*kI +3*kp +1)*S + 3*kI

V. CONCEPT OF FITNESS FUNCTION FOR THE DESIGN

For our case of design, it had to tune all the three parameters of PID such that it gives the best output results or in other words it have to optimize all the parameters of the PID for best results. Here, it characterize a three dimensional pursuit space in which all the three measurements speak to three unique parameters of the PID. Every particular reason inside the hunt territory speak to a chose blend of [KP KI KD] that a chose reaction is gotten The execution of the reason or the mix of PID parameters is set by a wellness work or the esteem work. This wellness work comprises of numerous component capacities that are the execution list of the plan. The point inside the hunt zone is that the best point that the wellness work achieves an ideal esteem. For the instance of our plan, it have taken four component capacities to characterize wellness work. The wellness capacity might be an element of relentless state mistake, top overshoot, rise time and settling time. in any case, the commitment of those component capacities towards the underlying wellness capacity is set by a multiplier element that relies on the choice of the architect. For this outline the best reason for existing is that the reason wherever the wellness work has the slightest esteem. The chosen fitness function is:-

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F = (1-exp(-β)) (MP +ESS) + (exp(-β))(TS - Tr)
Where F:- Fitness function
MP :- Peak Overshoot
TS :- Settling Time
β:-Scaling Factor (Depends upon the selection of designer)
For present study case of design we have taken the scaling factor β = 1.

From the matlab library it have delineated a wellness capacity that has PID parameters as information qualities and it gives back the wellness estimation of the PID based for the most part controlled model as its yield. It has the format:-
Function [F] = fitness (KD KP KI)

```
function F= tightnes(kd,kp,ki)

T1=tf([25.2*kd 21.2*kd+25.2*kp

25.2*ki+21.2*kp+3*kd21.2*ki+3*kp 3*ki],[1 16.58 25.41+25.2*kd

17.18+21.2*kd+25.2*kp 11.70+25.2*ki+21.2*kp+3*kd .

21.2*ki+3*kp+1 3*ki]);

S=stepinfo(T1,'RiseTimeLimits',[0.1 0.9]);

tr=S.RiseTime;

ts=S.SettlingTime;

Mp=S.Overshoot;

Ess=1/(1+dcgain(T1));

F=(1-exp(-0.5))*(Mp+Ess)+exp(-0.5)*(ts-tr);
```

It have used this fitness function for the performance analysis of various combination of PID parameters reflected by the points within the three dimensional search area.

VI. PARTICLE SWARM OPTIMIZATION

James Kennedy and Russell C. Eberhart enhanced a substitution developmental system method named as Particle Swarm streamlining in 1995 [7]. The approach is suitable for taking care of nonlinear issue. The approach depends on the swarm conduct like winged creatures discovering sustenance by running. A basic variant of the PSO algorithmic rule works by having a population (called a swarm) of candidate solution (called particles). These particles are affected around within the search-space in step with some easy formulae. The movements of the particles are guided by their own best better-known position within the search-space yet because the entire swarm's best better-known position. When improved positions are being discovered these can then return to guide the movements of the swarm. the method is continual and by doing thus it's hoped, however not secured, that a satisfactory solution can eventually be discovered. Here during this technique a set of particles are place in d-dimensional search area with arbitrarily selecting rate and position. The initial position of the particle is taken because the best position for the beginning then the rate of the particle is updated supported the expertise of alternative particles of the swarming population.

VII. ALGORITHM FOR PSO

Particle swarm optimization may be a population based mostly random optimization methodology. This algorithmic program was impressed from the social activity pattern of organisms, like Bird flocks, fish faculties, and sheep herds wherever aggregate behaviors are met, producing powerful, collision-free, synchronized moves. In such frameworks, the conduct of each swarm part depends on simple innate reactions, however their aggregate result is extremely entangled from an expansive perspective. For instance, the flight of a flying creature rush will be reenacted with relative precision by only keeping up an objective separation between each winged animal and its quick neighbors. This separation could rely on its size and captivating conduct. The swarms may likewise respond to the predator by rapidly dynamical their kind, breaking into littler swarms and re-joining together, representing an intriguing capacity to answer mutually to outer jolts to protect individual respectability.
The PSO algorithm consists of variety of particles that conjointly move through the search area of the problem so as to search out the global optima. every particle is characterized by its position and fitness. subsequently, the PSO algorithm updates rate vector for every particle then adds that velocity to the particle position. The speed updates are impacted by each the least complex worldwide arrangement identified with the absolute best wellness at any point found inside the entire swarm, and furthermore the best local arrangement identified with the absolute best wellness inside the present populace [7,9].
Proposed PSO-PID
The implementation of SVC controller within the SMIB system can enhance the system stability through choosing the optimum PID controller parameters of SVC exploitation PSO-PID tuning methodology. Fig.4 shows the block diagram of projected PSO/MPSO-PID controller for the SMIB system with SVC. In the projected PSO/MPSO-PID controlling technique every particle contains three members Kp , Ki ,&Kd . In alternative words the problem search area has three dimensions and every particle within the population should fly during a three dimensional area. Fig. 5 illustrates the flow diagram of implementing auto-tuning technique for PID controller exploitation PSO/MPSO algorithmic program to tune the PID Controller and collect the best parameters values. The initial values for rate vector and position vector within the 1st iteration will be taken as follows:

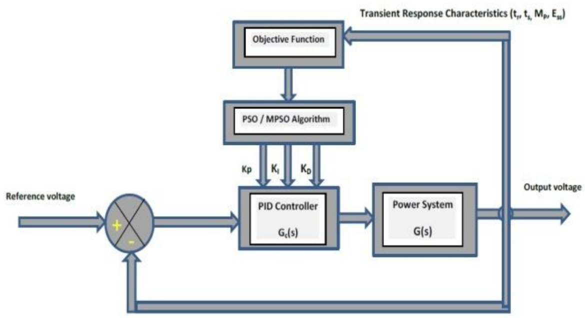

Fig 4. Block diagram of proposed PSO/MPSO-PID controller

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$$\left.\begin{aligned} x_{i,1}^{0} &= K_p^{min} + \left(K_p^{max} - K_p^{min}\right) * rand_{i,1}(0,1) \\ x_{i,2}^{0} &= K_i^{min} + \left(K_i^{max} - K_i^{min}\right) * rand_{i,2}(0,1) \\ x_{i,3}^{0} &= K_d^{min} + \left(K_d^{max} - K_d^{min}\right) * rand_{i,3}(0,1) \end{aligned}\right\}$$

$$\left.\begin{aligned} v_{i,1}^{0} &= \frac{x_{i,1}^{0}}{2} \\ v_{i,2}^{0} &= \frac{x_{i,2}^{0}}{2} \\ v_{i,3}^{0} &= \frac{x_{i,3}^{0}}{2} \end{aligned}\right\}$$

PSO PROGRAM

Initially it fixed the values of PSO algorithm constants as:
Inertia weight factor W = 0.3
Acceleration constants C1 , C2 = 1.5

As it have to optimize three parameters, namely KP ,KD ,KI of the controller, it have to search for their optimum value within the three dimensional search area, thus its tend to arbitrarily initialized a swarm of population "100" within the three dimensional search area with [Xi,1 Xi,2 Xi,3] and [Vi1 Vi2 Vi3] as initial position and velocity. Calculated the initial fitness function of each point and the point with minimum fitness function is displayed as gbest (initial value of global best optima) and the optimal fitness function as fbest1(Initial best fitness function). Runned the program with the PSO algorithm with thousands (or even more numbers) of iterations and the program returned final optimal value of fitness function as "fbest" and final global optimal point as "Gbest"[12].

The Program for the Simulation Plot

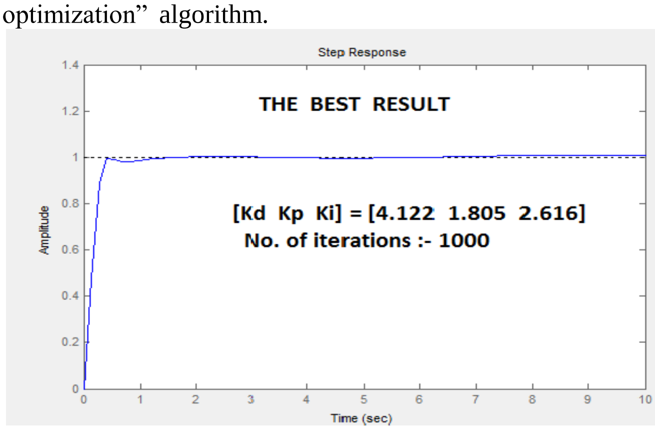
```
clc
close all
kd=input('enter the value of kd');
kp=input('enter the value of kp');
ki=input('enter the value of ki');
T1=tf([25.2*kd 21.2*kd+25.2*kp 25.2*ki+21.2*kp+3*kd 21.2*ki+3*KP
3*ki],[1 16.58 25.41+25.2*kd 17.18+21.2*kd+25.2*kp
11.70+25.2*ki+21.2*kp+3*kd 21.2*ki+3*kp+1 3*ki]);
ltiview
```

VIII. PROGRAM FOR PSO

```
clc
close all
c1=1.5;
c2=1.5;
for i=1:50
for j=1:3
X(i,j)=i*rand;
V(i,j)=i*rand;
Pbest(i,j)=X(i,j);

end
end
for i=50:100
for j=1:3
X(i,j)=0.5*i*rand;
V(i,j)=0.5*i*rand;
Pbest(i,j)=X(i,j);
end
end

for i=1:100
kd=X(i,1);
kp=X(i,2);
ki=X(i,3);
F(i,1)=tightnes(kd,kp,ki);
end
k=1;
m=1;

fbest=F(1,1);
while m<100
if fbest>F(m,1)
fbest=F(m,1);
k=m;
end
m=m+1;
end
k1=k;
fbest1=fbest;

Gbest=[X(k,1) X(k,2) X(k,3)]
gbest=Gbest;
k1
fbest1
```

```
gbest
for M=1:50

for i=1:100
for j=1:3
V(i,j)=0.5*(100-i)*V(i,j)+c1*rand*(Pbest(i,j)-
X(i,j))+c2*rand*(Gbest(1,j)-X(i,j));
X(i,j)=X(i,j)+V(i,j);
end
kd1=X(i,1);
kp1=X(i,2);
ki1=X(i,3);
kd=Pbest(i,1);

kp=Pbest(i,2);
ki=Pbest(i,3);
L=tightnes(kd,kp,ki);
P=tightnes(kd1,kp1,ki1);
if P<L
Pbest(i,1)=X(i,1);
Pbest(i,2)=X(i,2);
Pbest(i,3)=X(i,3);
end
end
for i=1:100

kd=Pbest(i,1);
kp=Pbest(i,2);
ki=Pbest(i,3);
F(i,1)=tightnes(kd,kp,ki);

end
m=1;
k=1;
while m<100
if fbest>F(m,1)
fbest=F(m,1);
k=m;
end
m=m+1;

end
Gbest=[Pbest(k,1) Pbest(k,2) Pbest(k,3)];
end
```

In our simulations using PSO algorithm, it have varied the number of iterations and kept the population of the swarm constant at 200. This study present a comparative study of the initial global best position out of randomly initialized swarm particles to the final global best position which comes after the application of "particle swarm optimization" algorithm.



So the optimum value of [Kd Kp Ki] will be 4.122, 1.805 & 2.616 which we are going to utilize in SVC to get the optimal output.

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IX. SVC MODEL SIMULATION & RESULT ANALYSIS

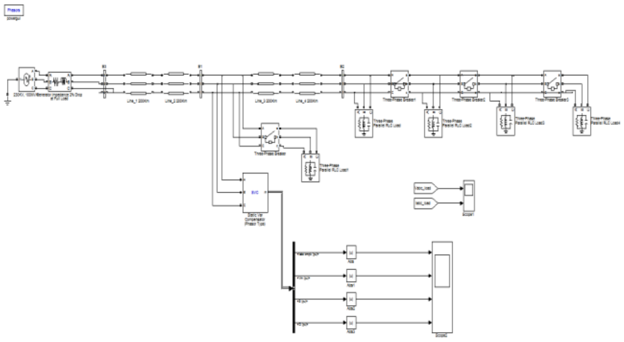

Fig 5. Proposed SVC Model

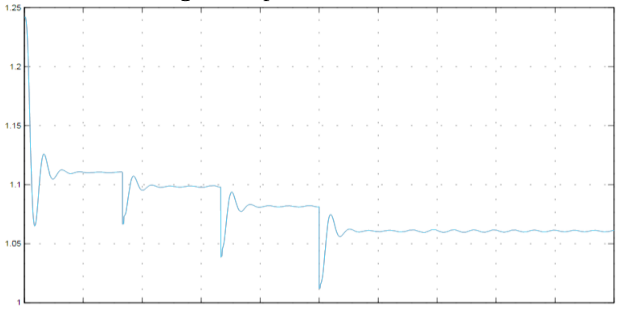

Fig 6. Voltage Waveform without tuning

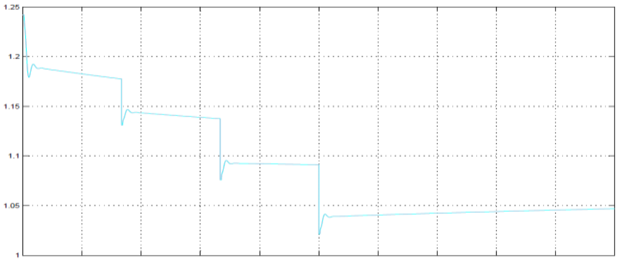

Fig 7. Voltage waveform after Tuning

- It can be clearly seen in fig 6 and fig 7 that the proposed scheme gives smooth voltage waveform in the long transmission line with reduced sub transient peak voltage. It seen that on the use of value obtained by PSO algorithm for PID constants a sub transient free response is seen.
- It improves the total harmonic distortion of the SVC model and hence the optimized value has increased the overall power factor if the system
- The latch jumps are rectified in the current waveform also termed as Gibson jumps and it shows a high level of filtration in the current waveforms as can be seen in fig 8 and 9. This reduces the current harmonics.

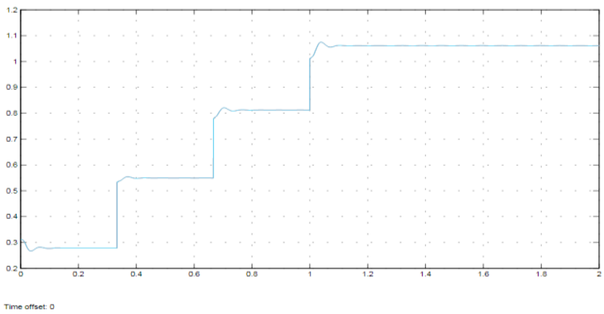

Fig 8. Current waveform without tuning

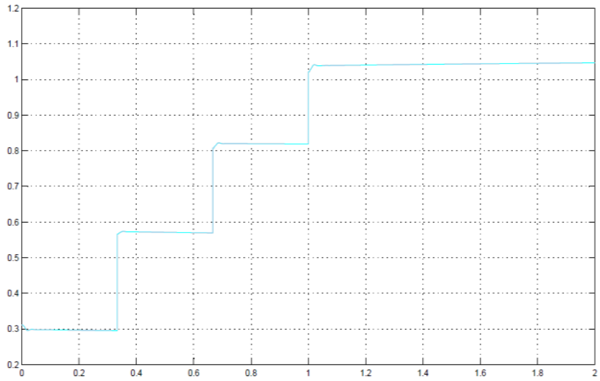

Fig 9. Current waveform after tuning

X. CONCLUSION

This paper presents the modified PSO algorithm for tuning of SVC which intern improves the receptive power remuneration ability of SVC and along these lines gives better outcomes. The examination paper issue is encircled as a streamlining issue as far as PID controller parameters, and the MPSO calculation is utilized to discover the ideal parameters values. The adequacy of the proposed procedure is analyzed under various stacking conditions, and the outcomes are contrasted and the established form of PSO and ZN tuning techniques. Thus we get the optimal output from our study.

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