ISSN Number: 2454-2024(Online)

International Journal of Technical Research & Science

DESIGN OF PID STRUCTURED TCSC CONTROLLER FOR SMALL SIGNAL STABILITY IMPROVEMENT USING GRAY WOLF OPTIMIZATION ALGORITHM

Geetanjali Meghwal, Shruti Bhadviya, Abhishek Sharma, Prakash Sundaram, Arvind Singh Rathore
E-Mail Id: genius1998.sy@gmail.com
Department of Electrical Engineering, Geetanjali Institute of Technical Studies, Udaipur, Rajasthan, India

Abstract- In power system stability plays a very important role and necessary to maintain the stability of system when different contingency applied. The Power system is very complex and interconnected this resulting into lower frequency oscillations due to variation in load which creates stability problems. Stability enhance by various controller and optimization technique. To eliminate the stability problems proposed PID structured TCSC controller used in SMIB system. Proposed work implements with MATLAB/ Simulink environment and the performance of the PID structured TCSC controller is compared for without and with GWO algorithm. Observations and results tested on different loading conditions as nominal, light and heavy loading. Different types of fault consider in different loading conditions and various types of graphs presented as speed deviation, power angle deviation etc. All contingencies tabulated and compare results without and with GWO algorithm. The system evaluation is done by time domain simulation using MATLAB/Simulink software. It is detected that the out of all algorithms GWO algorithm found more compatible for parameters reduces settling time and provide superior performance of the power system. Different simulation results are also obtained for various loading & fault conditions.

Keywords: GWO Algorithm, PID Controller, SMIB, TCSC.

1. INTRODUCTION

Dynamic oscillations conveyed beside a specific transmission strip in power-systems with the oscillation frequency ranges from 0.1 Hertz to few Hertz are regularly known as power-system low-frequency oscillation. Once begun, the oscillation may persevere for a minute and afterward die away, or rise continually and may bring about the breakdown of the power-system. So the power system required to continuous observation and analysis required. But there is no option maintain manually because this is very huge and complex. So minute to minute variation is required so if not proper arrangements of contingency then power system dies out. In this paper SMIB using a PID structured TCSC controller used. TCSC a FACTS devices & it is very effective in enhancing the capability of power transfer, increasing reliability & security plus it can compensate reactive power. The Impact of TCSC on power system stability is reasonably evaluated using MATLAB/SIMULINK. TCSC controller parameters are optimized by GWO, and to validate effectiveness of the proposed technique comparative result analysis is done [6]. This paper presented PID structured TCSC controller when optimized by GWO algorithm when power system stability is improved. System tested with different loading and fault conditions our system shows superior result for all cases[4].

2. OBJECTIVE FUNCTION

Here, J is the objective function formulated using integral time absolute error for speed deviation. It is shown in Equation 1 as objective function of the system.

$$\text{ITAE} = \int_0^{t_{sim}} t|\Delta w(t)|dt \tag{1}$$

Where
‘w’ =error signal(Δw)
t_{sim}=Simulation time range

The beyond impartial function should be minimized in order to obtain a better response from the structure with respect to stabilization time and overshoot. The limits of the problem are the limits of the limitations of the TCSC regulator.

3. PID STRUCTURE TCSC CONTROLLER

Fig. 3.1 shows PID structure TCSC controller is contained capacitor bank(C), bypass inductor (L) and bidirectional thyristor. TCSC reactance is varied by modifying its thyristor firing angle. Where α is firing angle [1] and

DOI Number: https://doi.org/10.30780/IJTRS.V08.I04.002

proportional gain (K_P), integral gain (K_I), and derivative gain (K_D) as part of a PID controller. The input and output signal of the proposed controller is the speed deviation ($\Delta\omega$) error &reactance ($X_{TCSC}(\alpha)$) respectively[5].

PID controller parameters (Kp, Ki, Kd) are optimized using speed error signal so that TCSC reactance modulate effectively to cancel some portions of line reactance and improves damping of power oscillations[7].

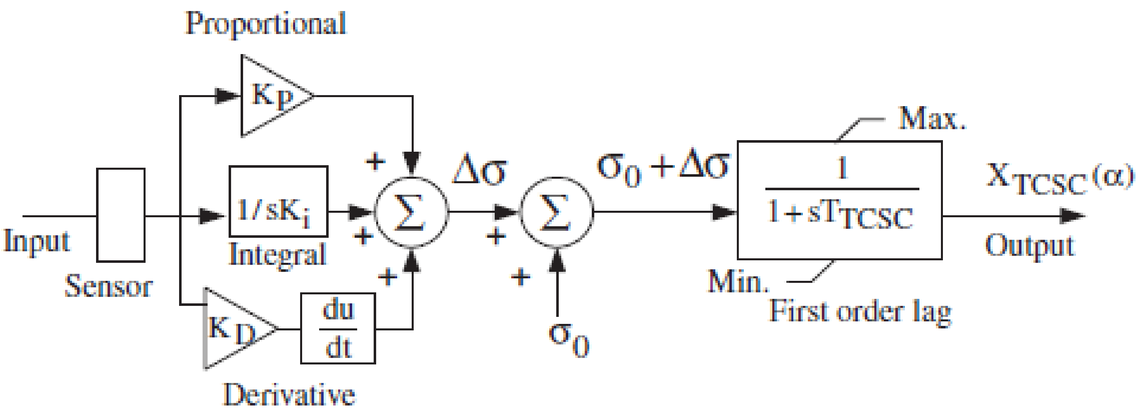

Fig. 3.1 PID structure of TCSC based controller[7]

4. GWO TUNED PID STRUCTURE TCSC CONTROLLER

4.1 Application of Soft-Computing Techniques

Meta-heuristic optimization algorithms are increasingly popular in technical presentations because: (i) they are based on concepts that are fairly simple and easy to realize; (ii) not require incline info; (iii) may by-pass local optima; (iv) it may stay used for a variety of difficulties that span different disciplines. Meta-heuristic algorithms inspired by nature resolve optimization difficulties by imitating biological or physical phenomena. It is divided as (see Fig. 4.1):

- Evolution based
- Physics based
- Swarm based methods.
- Human Based Methods

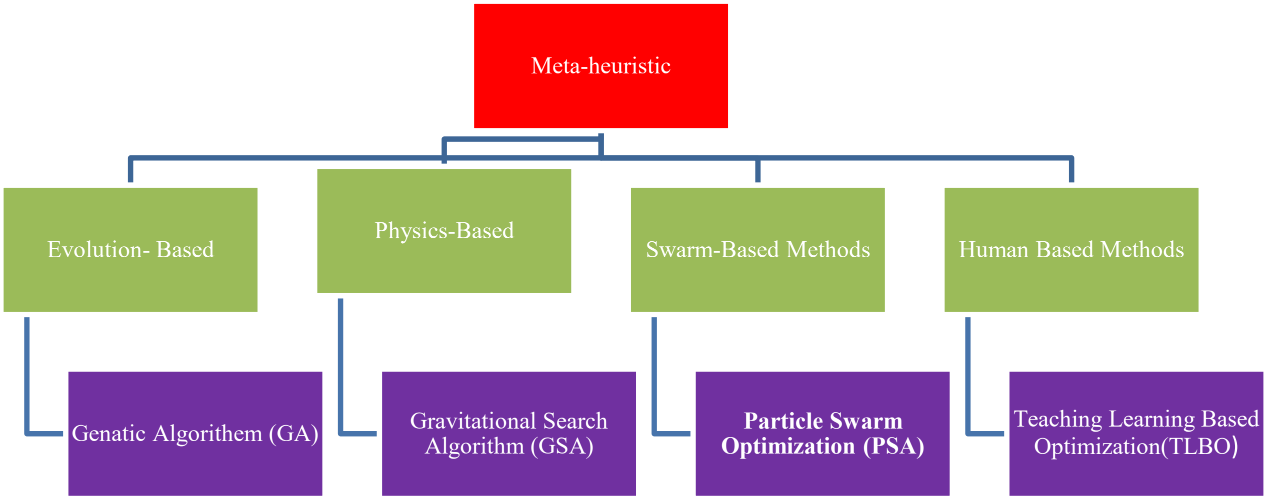

Fig. 4.1 Classification of Meta-heuristic Approach

The techniques falling under above groups are mostly nature inspire, these either mimics some biological phenomenon or physical phenomenon.

The first group (Evolution based) is based on evolution which mainly follows lows of evolutions in nature. It always starts with random solution and generates best individual solutions to form the next level of generation. One very good example of it is Darwinian evolution based GA. Others falling into the group are Evolution Strategy (ES), Probability Based Incremental Learning (PBIL), Genetic Programming (GP) and Biogeography-Based Optimizer (BBO).

The Physics based method uses universal physical laws. Gravitational Local Search (GLS) and GSA some of the many techniques in it.

The Next group (Swarm based) follows the performance of animals living in groups. The most common method in it is PSO which is based on group of flying birds. Another technique comes into to the same group is ant colony optimization.

The last but not the least group is inspired from the human nature. Some of the common example falling under it is TLBO, HS, TS etc.

In the search methods based on population, there are two stages, namely the investigation and utilization. In the first stage of investigation, the movements of the operators must be randomized to the extent which is possible in the search space. This stage is followed by exploitation stage, in it the most promising local region in the search space is investigated in detail. The two stages must have a proper balance between them for the successful execution of Meta heuristic algorithm.

4.2 Gray Wolf Optimization Algorithm (GWO)

To solve complex engineering problems and real application, GWO results prove that the proposed algorithm is more suitable for challenging tasks with unknown search space. GWO results found more competitive and challenging then optimization techniques like PSO, GSA, DE, ES and EP. So we choose GWO technique for TCSC based structured PID controller. In GWO technique wolves live pack is basically belongs to Canidae family having a leader Alpha(α) who indicates their strict social dominance hierarchy and most of the decision for the group is also taken by him. Hence leader's decision is followed by other members of the group. Some common decisions consist hunting area, waking time, sleeping place etc. α is not the strongest member of group but it manages entire group activity which shows that discipline and organization in the pack are found prior towards strength. [3].

It is a population based metahuristic optimization algorithm which shares a general characteristic regardless of their nature. Search process ID categorized into exploration and exploitation phase. Optimization process includes operators to globally explore the search space. Using phase perturbation method design variables is randomized. Exploitation is defined as "Process of investigation in detail with respect to promising area(s) of the search space". To meet exact balance between exploitation and exploration the most compatible task in the algorithm development[4]. The various steps follow by GWO algorithm as Social Hierarchy, Prey Encircling, Hunting, Attacking, Prey Searching[3]

4.2.1 GWO Algorithm Pseudo Code

```
Pseudo codes for GWO technique are[2]:
Grey wolves population is created initially let it be $X_i$ (i=1,2, . . . ., n)
α, A &C is initialized.
Search agent fitness is calculated,
$X_\alpha$= best search agent
$X_\beta$= second best search agent
$X_\delta$= third best search agent
while (t< maximum iteration count)
    for each search agent
        Current search agent position is updated by
        $\vec{X}(t+1) = \frac{\vec{X}_1+\vec{X}_2+\vec{X}_3}{3}$
    end for
    α, A& C are updated
    all search agents are fitness are calculated
    $X_\alpha$, $X_\beta$ & $X_\delta$ are updated
    t=t-1
end while
return $X_\alpha$
```

5. SYSTEM MODEL

5.1 MATLAB/Simulink Implement of SMIB System with PID Structured TCSC Controller

Fig. 5.1 shows a matlab model of the PID structured TCSC controller. The various blocks are present in this model and various components are connected in design manner. The name of various blocks are TCSC, exciter, generator, stator, PID structure with TCSC, measurement blocks etc. The SMIB system develops with the PID structure TCSC controller. The PID controller parameters tuned by GWO technique. Performance is evaluated while compared with the system without controller and with GWO algorithm.

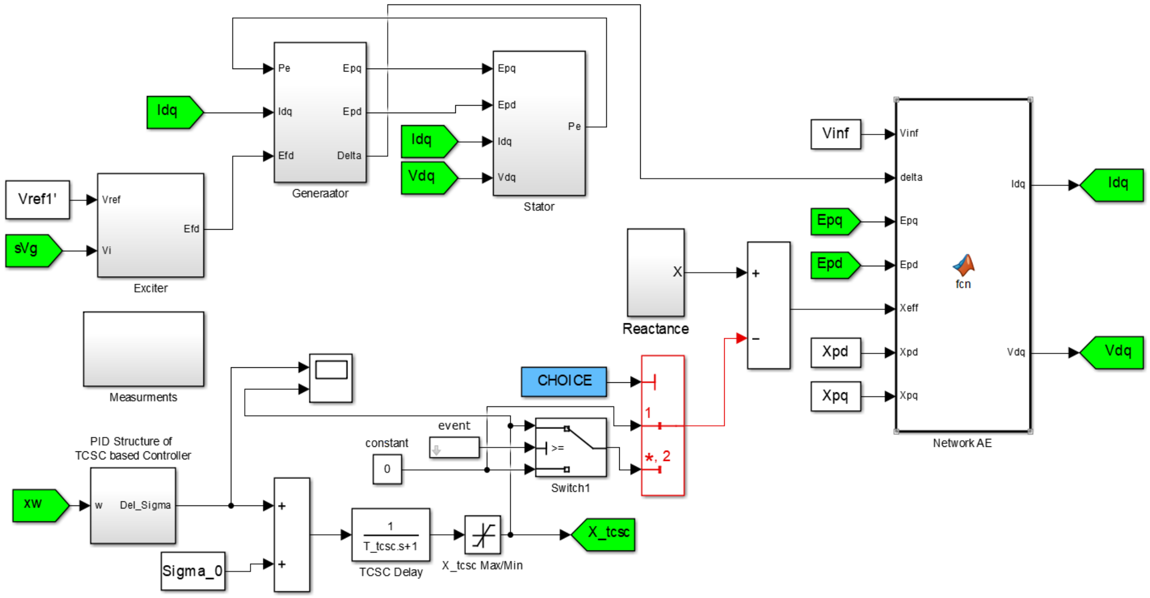

Fig. 5.1 MATLAB model of SMIB using PID structure TCSC controller

6. RESULT AND DISCUSSIONS

The Proposed system is designed without PID structured TCSC controller a with GWO algorithm. The system is tested on various types of loading conditions as nominal, light and heavy loading. The various faults applied at various fault conditions and various graphs presented in a proposed system as speed deviation, power angle deviation, variation in TCSC reactance, electrical power deviation, at without a controller, with GWO technique. The various comparisons a table presented in this paper. Fig. 6.1 shows a best cost v/s iteration graph of GWO algorithm. Table-6.2 shows PID structure TCSC controller parameters.

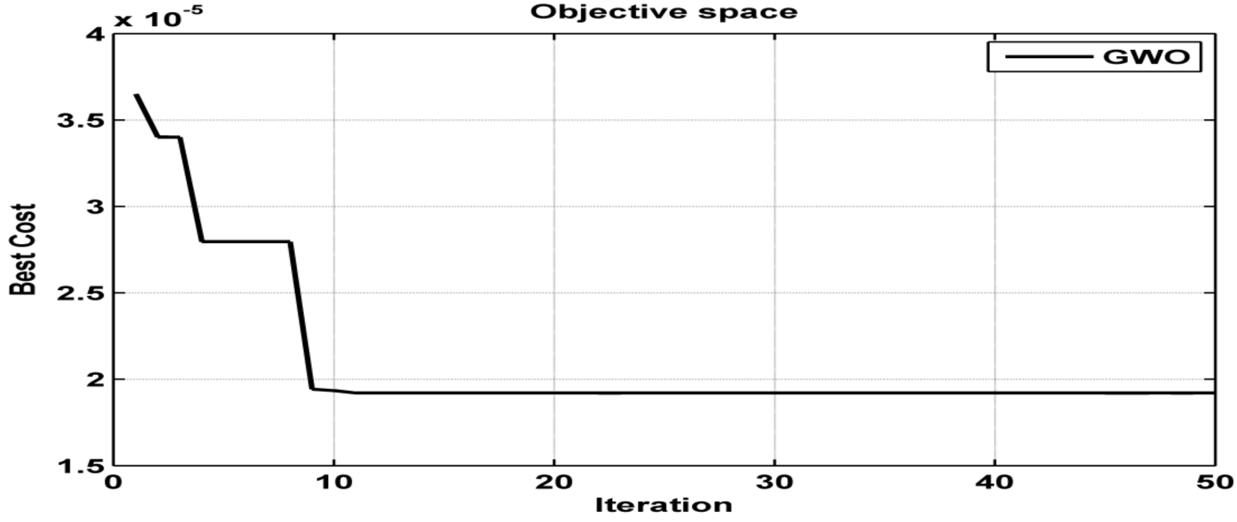

Fig. 6.1 Best Cost V/s Iteration Graph of GWO Algorithm

Table-6.1 PID Tuned TCSC Based Controller Parameters

Optimized Algorithm	PID Tuned TCSC Based Controller Parameters			ITAE Fitness Values
	K_P	K_I	K_D	
GWO[7]	500	2.177×10^{-4}	8.1260	1.9201×10^{-05}

Table-6.2 Types of Different Fault applied in Proposed System

Types of Fault	Conditions
ftype-1	10% Step Increase in References Voltage Setting
ftype-2	Symmetrical Three Phase Faults
ftype-3	10% Step Decrease In Mechanical Torque Input
ftype-4	Permanent Line Outage Disturbance

6.1 Case-1 Nominal Loading Conditions

Fig. 6.2 to 6.5 shows various graph as speed deviation, power angle response, variation of TCSC reactance, electrical power response at various types of fault conditions as mention on the table-2. Each graph response shows as without and with GWO algorithm. When the proposed system without controller shows the high oscillatory response, but when system tuned with GWO algorithm that time, the high oscillatory response damp out very fast and improve the stability of the system. Every fault condition system shows superior response and table-6.3 shows a comparison table of various conditions.

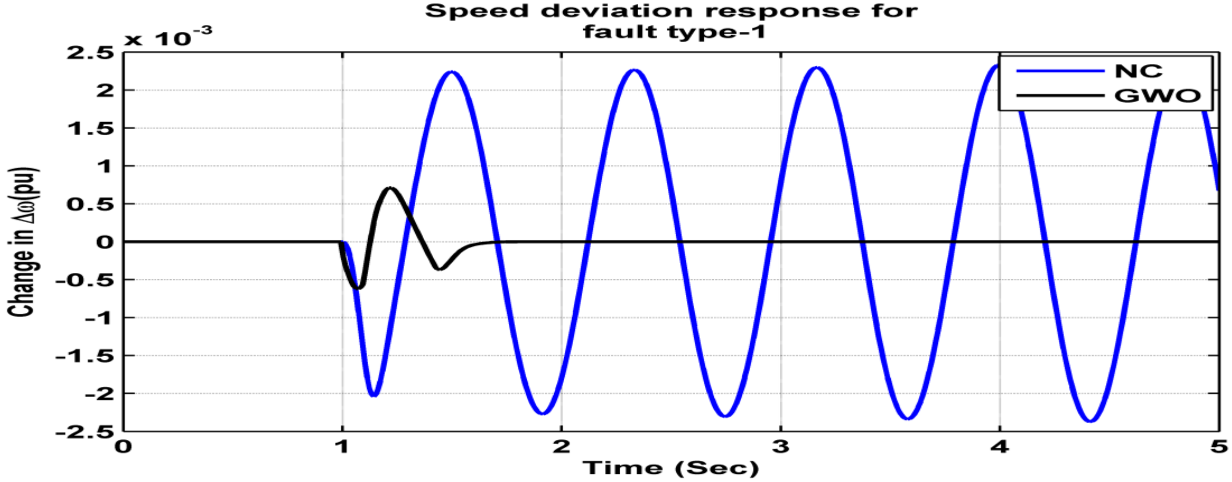

Fig. 6.2 Speed Deviation Response for Fault Type-1

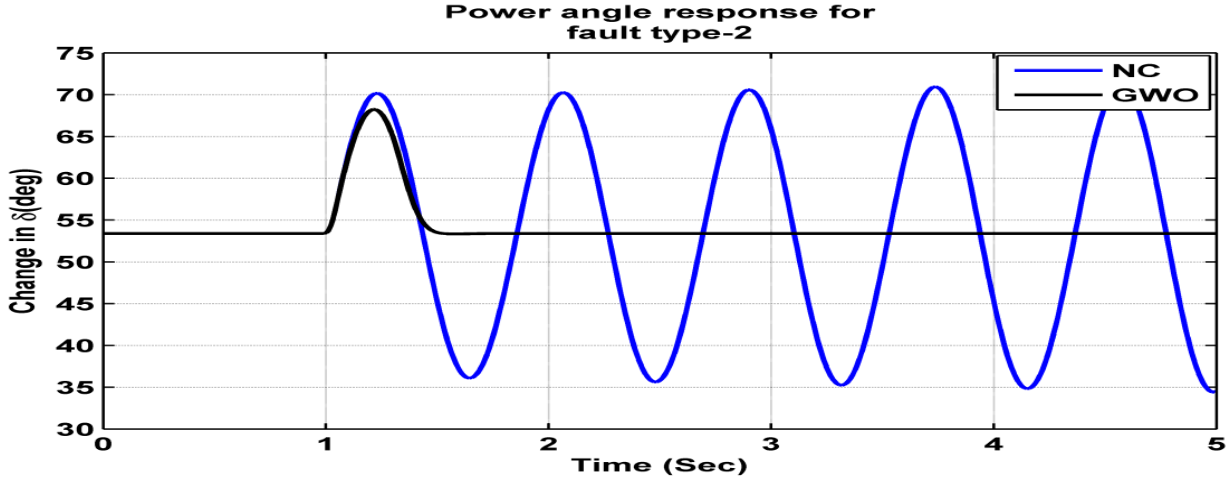

Fig. 6.3 Power Angle Response for Fault Type-2

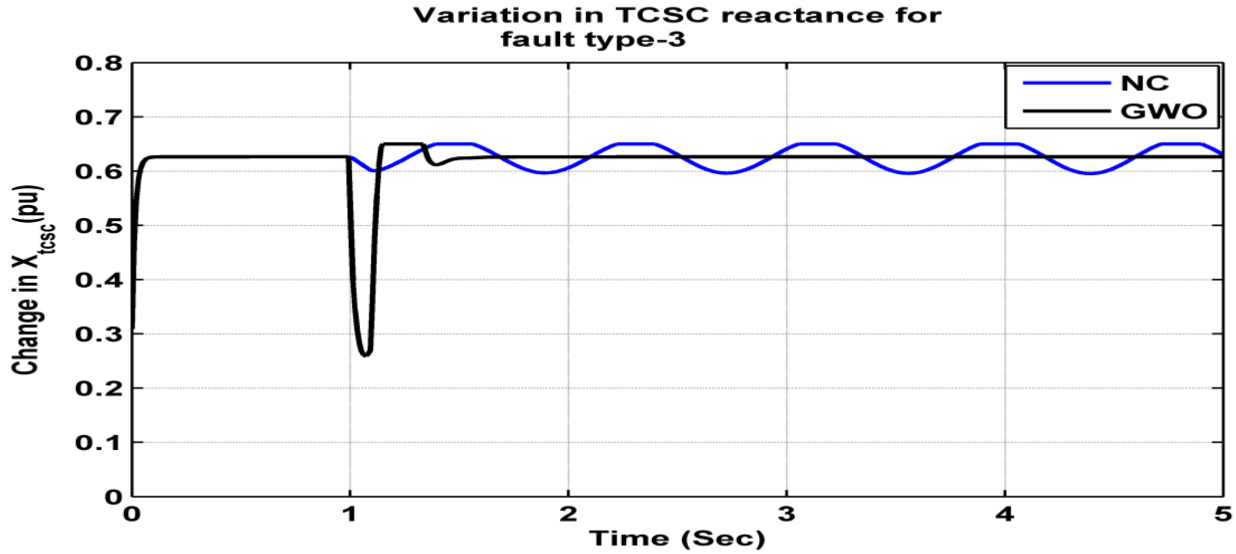

Fig. 6.4 Variations in TCSC Reactance for Fault Type-3

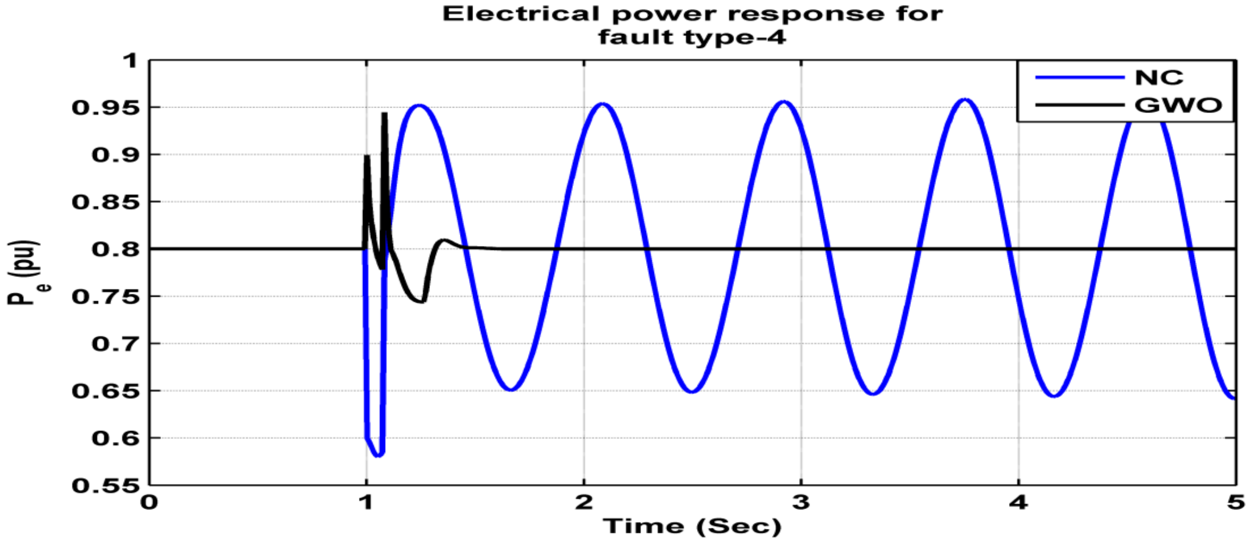

Fig. 6.5 Electrical Power Response for Fault Type-4

Table-6.3 SMIB System at Without Controller and with GWO Tuned PID Structured TCSC Controller at Nominal Loading

Types of Deviation	Without Controller (Settling Time) Seconds	With GWO Tuned PID Structured TCSC Controller (Settling Time) Seconds
Speed Deviation at ftype-1	Highly Oscillatory	1.6586
Power Angle Response at ftype-2	Highly Oscillatory	1.4811
Variations in TCSC Reactance at ftype-3	Highly Oscillatory	1.4475
Electrical Power Response at ftype-4	Highly Oscillatory	1.4251

6.2 Case-2 Light Loading Conditions

Fig. 6.6 to 6.9 shows various graphs as speed deviation, power angle response, variation of TCSC reactance, electrical power response at various types of fault conditions as mention on the table-2. Each graph response shows as without and with GWO algorithm. When the proposed system without controller shows high oscillatory response but, when system tuned with GWO algorithm that time the high oscillatory response damp out very fast and improve the stability of the system. Every fault condition system shows superior response and table-6.4 shows a comparison table of various conditions.

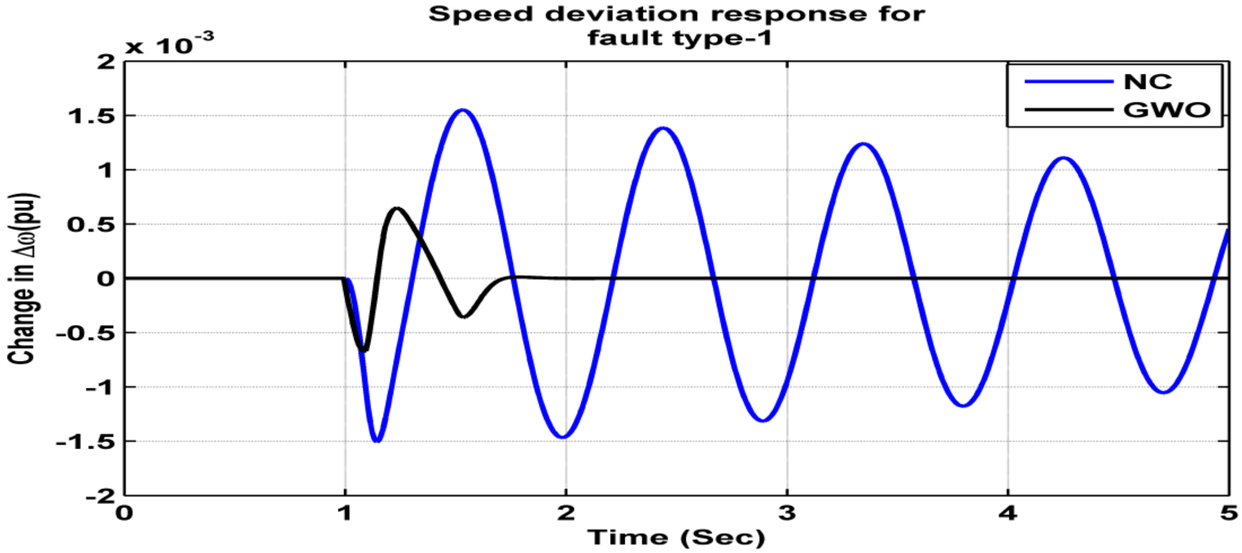

Fig. 6.6 Speed Deviation Response for Fault Type-1

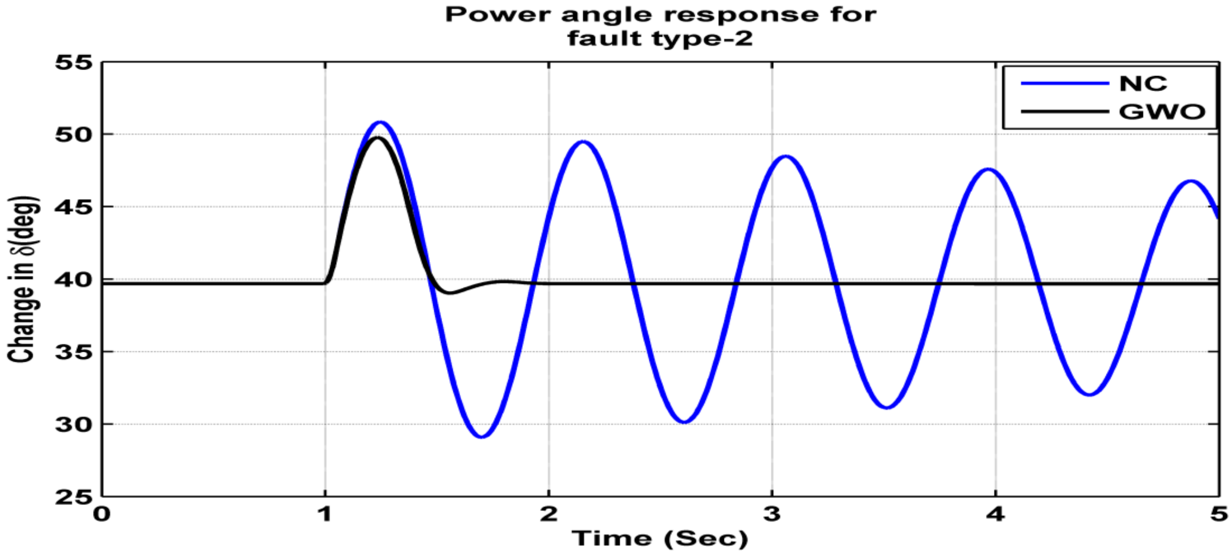

Fig. 6.7 Power Angle Response for Fault Type-2

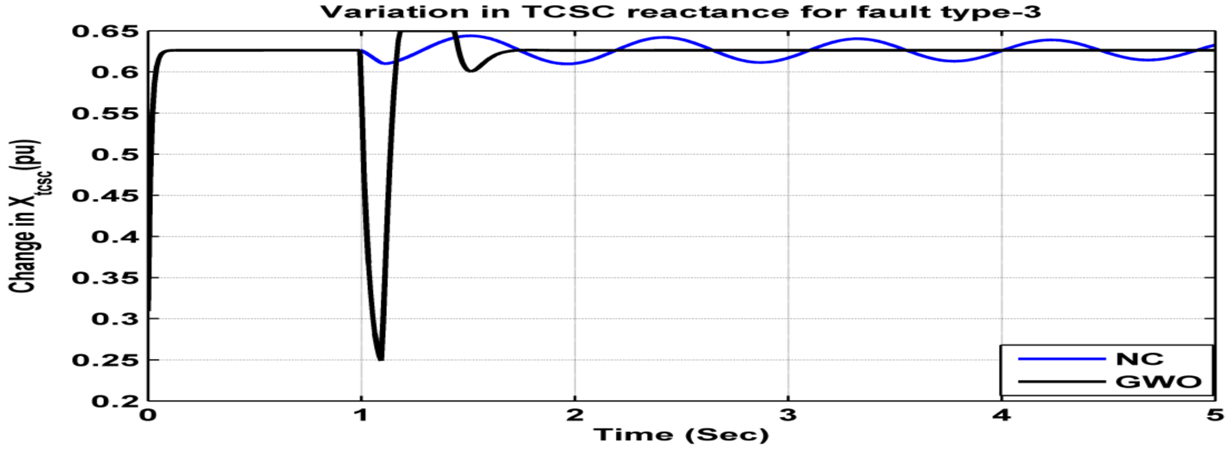

Fig. 6.8 Variations in TCSC Reactance for Fault Type-3

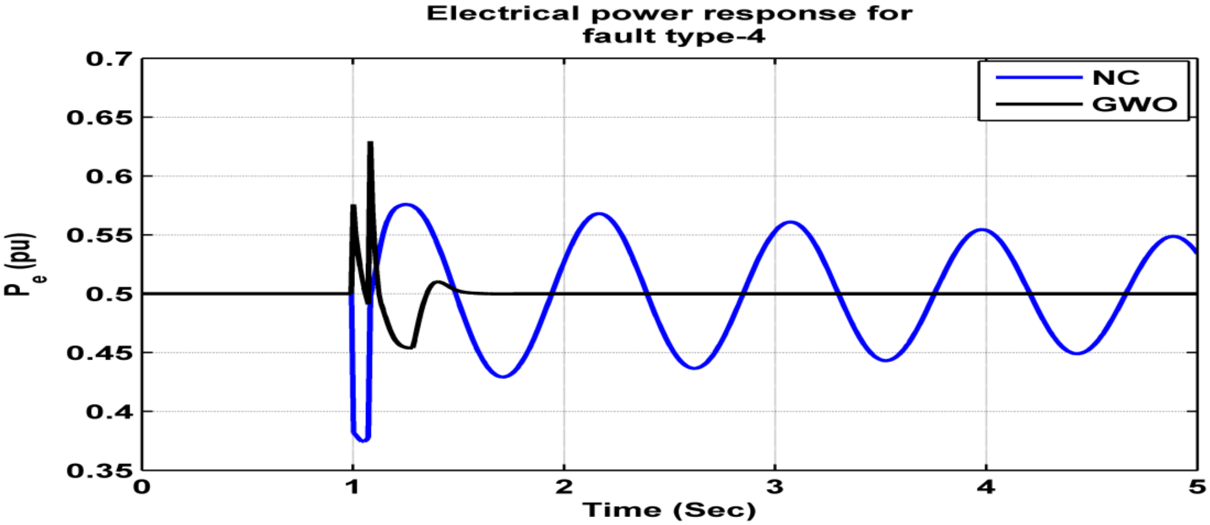

Fig. 6.9 Electrical Power Response for Fault Type-4

Table-6.4 SMIB System at Without Controller and with GWO Tuned PID Structured TCSC Controller at Light Loading

Types of Deviation	**Without Controller (Settling Time) Seconds**	**With GWO Tuned PID Structured TCSC Controller (Settling Time) Seconds**
Speed Deviation at ftype-1	Highly Oscillatory	1.7016
Power Angle Response at ftype-2	Highly Oscillatory	1.6609
Variations in TCSC Reactance at ftype-3	Highly Oscillatory	1.6141
Electrical Power Response at ftype-4	Highly Oscillatory	1.4958

6.3 Case-3 Heavy Loading Conditions

Fig. 6.10 to 6.13 shows various graphs as speed deviation, power angle response, variation of TCSC reactance, electrical power response at various types of fault conditions as mention on the table- 6.5. Each graph response shows as without and with GWO algorithm. When the proposed system without controller shows high oscillatory response but, when the system tuned with GWO algorithm that time high oscillatory response damp out very fast and improve the stability of the system. Every fault condition system shows superior response and table-5 shows a comparison table of various conditions.

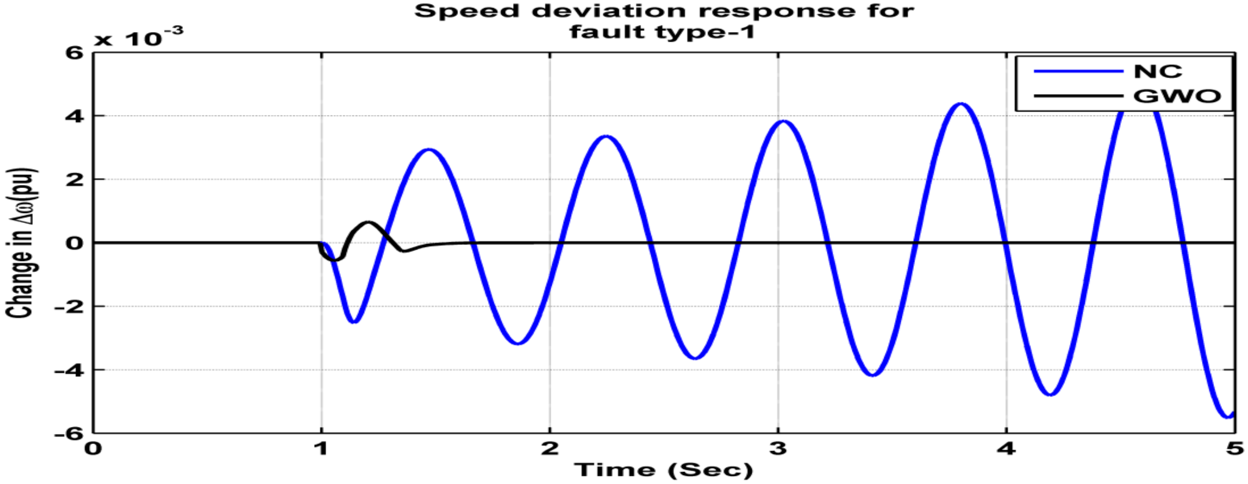

Fig. 6.10 Speed Deviation Response for Fault Type-1

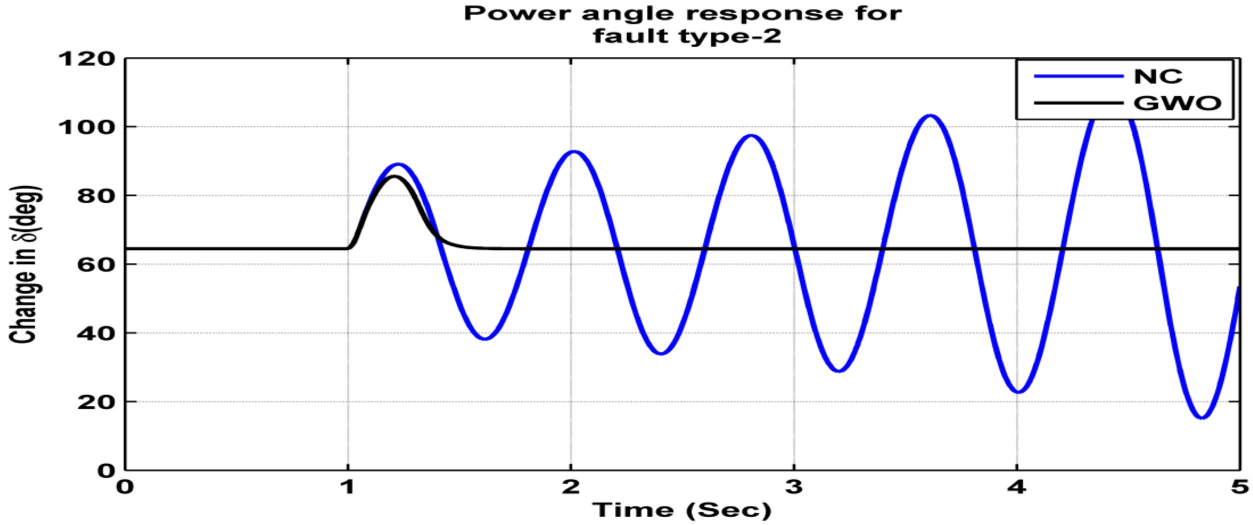

Fig. 6.11 Power Angle Response for Fault Type-2

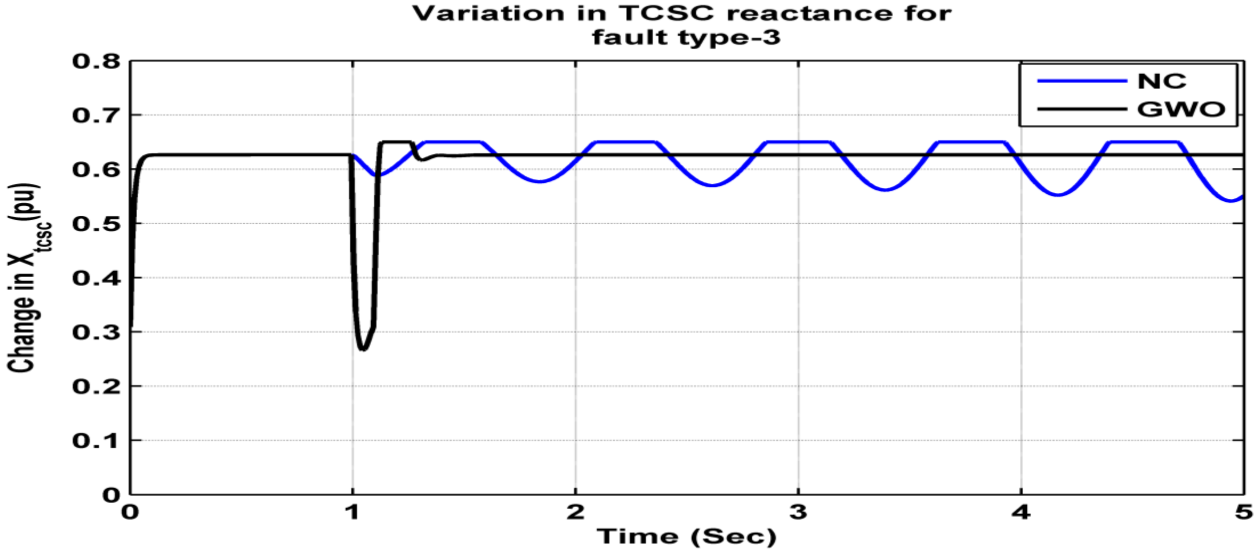

Fig. 6.12 Variations in TCSC Reactance for Fault Type-3

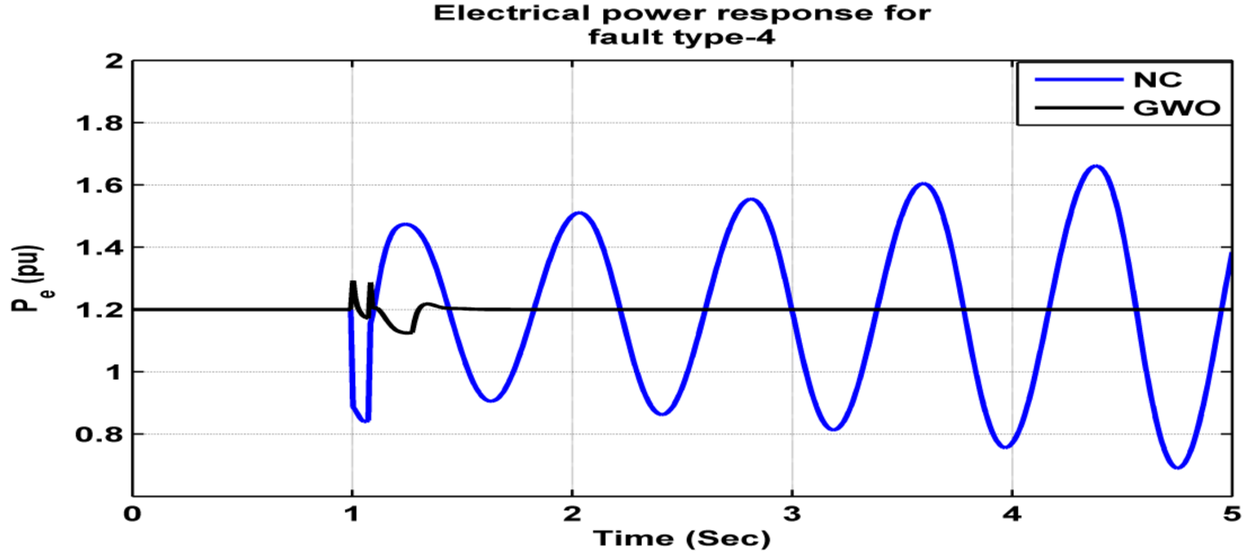

Fig. 6.13 Electrical Power Response for Fault Type-4

Table-6.5 SMIB System at Without Controller and with GWO Tuned PID Structured TCSC Controller at Light Loading

Types of Deviation	Without Controller (Settling Time) Seconds	With GWO Tuned PID Structured TCSC Controller (Settling Time) Seconds
Speed Deviation at ftype-1	Highly Oscillatory	1.5930
Power Angle Response at ftype-2	Highly Oscillatory	1.5346
Variations in TCSC Reactance at ftype-3	Highly Oscillatory	1.3322
Electrical Power Response at ftype-4	Highly Oscillatory	1.5268

CONCLUSIONS

Using GWO with PID structure TCSC controller system parameters are optimized and system performance is compared without and with GWO algorithm based PID controller for the same power system.Proposed system performance is analysed using various loading conditions and fault conditions. All the conditions of GWO tuned PID structure TCSC based system show the best performance and improves the stability of the power system. Finally GWO algorithm based results show very good performance and settling time also reduces quickly.

REFERENCES

[1] Zhang, Xiao-Ping, Christian Rehtanz, and Bikash Pal. Flexible AC transmission systems: modelling and control. Springer Science & Business Media, 2012.

[2] Mirjalili, Seyedali, Seyed Mohammad Mirjalili, and Andrew Lewis. "Grey wolf optimizer." Advances in engineering software 69 (2014): 46-61.

[3] Faris, Hossam, Ibrahim Aljarah, Mohammed Azmi Al-Betar, and Seyedali Mirjalili. "Grey wolf optimizer: a review of recent variants and applications." Neural computing and applications 30 (2018): 413-435.

[4] Panda, Sidhartha, and Narayana Prasad Padhy. "MATLAB/SIMULINK based model of single-machine infinite-bus with TCSC for stability studies and tuning employing GA." International Journal of Energy and Power Engineering 1, no. 3 (2007): 560-569.

[5] Ganthia, Bibhu Prasad, Prashanta Kumar Rana, Tapas Patra, Rosalin Pradhan, and Rajashree Sahu. "Design and analysis of gravitational search algorithm based TCSC controller in power system." Materials Today: Proceedings 5, no. 1 (2018): 841-847.

[6] Kar, Priyanka, P. C. Panda, S. C. Swain, and Akshay Kumar. "Dynamic stability performance improvement of SMIB power system using TCSC and SVC." In 2015 IEEE Power, Communication and Information Technology Conference (PCITC), pp. 517-521. IEEE, 2015.

[7] Nanda J, Kaul B, 1978. Automatic generation control of an interconnected power system. Proc. Inst. Electr. Eng. 125, 385–390.

[8] Abdel-Magid, Y. L., and M. A. Abido. "Robust coordinated design of excitation and TCSC-based stabilizers using genetic algorithms." Electric Power Systems Research 69, no. 2-3 (2004): 129-141.

[9] Panda, Sidhartha. "Multi-objective non-dominated shorting genetic algorithm-II for excitation and TCSC-based controller design." journal of Electrical Engineering 60, no. 2 (2009): 86-93.

[10] Abido, M. A., and Y. L. Abdel-Magid. "Coordinated design of robust excitation and TCSC-based damping controllers." In 2003 IEEE Power Engineering Society General Meeting (IEEE Cat. No. 03CH37491), vol. 3, pp. 1726-1731. IEEE, 2003.