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Gravitational Search Algorithm for the Coordination of over current Relay

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Abstract: *The over current relays are the major protection devices in a distribution system. This paper presents Gravitational Search Algorithm (GSA) method for coordination of overcurrent relays Nowadays, various programming optimization techniques are frequently used to find optimal relay settings of overcurrentrelays. The overcurrent relay coordination in radial distribution networks is a highly constrained optimization problem. The purpose is to find an optimum relay setting to minimize the time of operation of relays and at the same time, to avoid the mal-operation of relays. This paper presents Gravitational Search Algorithm (GSA) for the coordination of overcurrent relay. Andthe comparison of results obtained from GSA with Particle Swarm Optimization (PSO). A proper combination of primary and backup relay is selected to avoid mal operation of relays. A four bus radial system is simulated in MATLAB SIMULINK platform and programming is done using MATLAB software.*

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I. Introduction

The most visible effect of fault is a sudden build-up of current. So naturally the magnitude of current can be employed as positive indicator for existence of a fault. Thus, overcurrent relaying is the most natural principle of relaying. Therefore the over-current protection is the most widely used form of protection. Overcurrent (OC) relay is usually employed as backup protection. But in some situations it may be the only protection provided.

A relay must get sufficient chance to protect the zone under its primary protection. Only if the primary protection does not clear the fault, the back-up protection should initiate tripping. A typical power system may consist of hundreds of equipment and even more protection relays to protect the system. Each relay in the system needs to be coordinated with the relay protecting the adjacent equipment. If backup protections are not well coordinated, mal-operation can occur and, therefore, OC relay coordination is a major concern of power system protection. Each protection relay in the power system needs to be coordinated with the relays protecting the adjacent equipment. The overall protection coordination is thus verycomplicated.

The main function of the power system protective devices is to detect and remove the faulty parts as fast as possible. Nowadays, various programming optimization techniques are frequently used to find optimal relay settings of overcurrent (OC) relays. In the present study two cases with and without DG can be taken. A latest optimization technique Gravitational Search algorithm (GSA) can be applied to find the relay settings for both the cases.

This paper discusses the relay coordination in radial distribution system. The Gravitational Search Algorithm (GSA) a latest optimization techniquehas been applied to find the relay settings and the results of this method are compared with particle swarm optimization (PSO) technique. A four bus radial system is taken under consideration and the problem adopted here is a constrained optimization problem[1].

II. Coordination of OC Relay

As soon as the fault takes place it is sensed by both primary and backup protection. The primary protection is the first to operate as its operating time being less that that of the backuprelay. The two basic protection schemes used in radial system are primary and backup protection. The two attributes of a relay that are of utmost importance for reliability and stability of any power system are sensitivity and selectivity. When fault occurs on a system both primary and backup relay sense it but primary relay is first to issue the trip signal because it's operating time is less in comparison to that of the backup relay. That means there is certain amount of delay in operating time of primary and backup relay known as coordination time interval (CTI).

The coordination time interval (CTI) between the backup and the primary relay depends on various parameters such as operating time of primary relay, operating time of circuit breaker associated with the primary relay, overshoot time of backup relay, and signal travelling time.

III. Design Issues

The relay coordination problem of OC relays can be formulated as constrained optimization problem. The objective function of the problem is total operating time of all the relays present in the system. The function is to be minimized so that each relay operates in minimum time and reliability of the system is maintained. The formulated objective function which is denoted as „S" here is

$$\min s = \sum_{i=1}^{n} t_{i,k} \qquad (1)$$

where n is the number of relays, $t_{i,k}$ is operating time of ith relay for fault in k_{th} zone. The constraints to solve this optimization problem are divided in three sections.

A. Coordinationcriteria

$$t_{bi,k} - t_{i,k} \geq \Delta t \quad (2)$$

where, $t_{i,k}$ is the operating time of primary relay at i for fault in zone k and $t_{bi,k}$ is the operating time of backup relay for fault in same zone and Δt is the coordination time interval (CTI)

B. Bounds on relay operatingtime

$$t_{i,kmin} \leq t_{i,k} \leq t_{i,kmax} \quad (3)$$

where, $t_{i,kmin}$ is the minimum operating time of relay at i for fault in zone k and ti,k max is the maximum operating time of relay at i for fault in zone k. So bound on time multiplier settings (TMS) will be

$$TMS_{i,k\ min} \leq TMS_{i,k} \leq TMS_{i,k\ max} \quad (4)$$

C. Bounds on Pickupcurrent

The minimum value of pickup current is determined by maximum load current seen by each relay. The maximum pickup current is determined by minimum fault current seen by each relay. This will impose bound on relay plug setting (PS) also which is given belowas:

$$I_{p\ min} \leq I_p \leq I_{p\ max}$$

$$PS_{min} \leq PS \leq PS_{max} \qquad (5)$$

D. Relay characteristics

All relays are identical and assumed to have IDMT characteristic as [3], [4]:

$$t_{op} = \frac{\lambda(TMS)}{(PSM)^{\gamma}-1} \quad (6)$$

$$t_{op} = \frac{\lambda(TMS)}{(I_{relay}\ /PS*CT_{\sec\ rated}\ )^{\gamma}-1} \qquad (7)$$

Where, top is relay operating time, PS is plug setting. TMS is time multiplier setting, PSM is plug multiplier setting, I_{relay} is fault current seen by relay and CT sec rated is rated current of CT secondary. For normal IDMT characteristic relay, γ is 0.02 and λ is 0.14. Hence we have two parameters, TMS and PS to be determined using GSA.

Gravitational Search Algorithm (GSA):

Gravitational Search Algorithm is a population based heuristic algorithm based on gravitational and Newton"s law of motion. Agents are regarded to be bodies having variable masses. Gravitational force between masses guides the movement of the agents. Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of distance between them. Four parameters quantify each body in GSA: Position of the mass in d^{th} dimension, inertia mass, active gravitational mass, passive gravitational mass. The velocity of a body in a dimension is controlled by the gravitational and inertial masses. Moreover, the fitness value obtained through the application of this algorithm gives the value of these parameters. The basic flowchart of GSA is given in Fig.1.

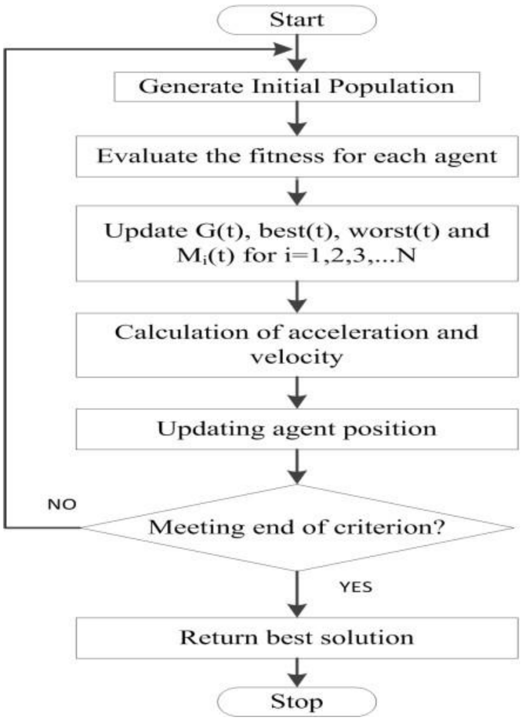

Fig.1. Flowchart of GSA

IV. Results

A 4 bus radial system is taken, in which the grid is of 25 MVA and standard line data"s are taken. Two cases are taken here, utility only mode, grid connected mode with 20 % penetration of DG. In all cases GSA technique is applied to find the optimum value of TMS and PS of six relays present in each feeder. This optimization is achieved in MATLAB platform.

A 4 bus radial distribution system is modelled in MATLAB platform as given in Fig.2. The grid rating is 25 MVA, 161 kV and the transformer step downs the voltage to 11 kV. This system consists of six relays. The CT ratios of each relays are given in Table I. Faults are created at near end of each relays. Fault inception time is 1s and it is a sustained fault for 2s as shown in Fig.3.The objective function is derived using the equations given in section III.

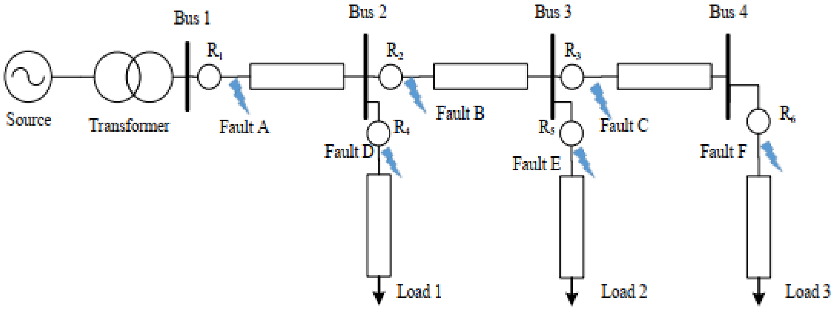

Fig. 2. Single source 4 bus radial system

TABLE I: C.T RATIOS OF EACH RELAYS

Relay No.	CT Ratio
1	1000/1
2	800/1
3	600/1
4	600/1
5	600/1
6	600/1

Here the twelve variables are there, six TMS and six PS of each relays. There are five constraints due to coordination time interval between primary and backup relays. The CTI is set as 0.3s. First six variables, x_1-x_6 represents the TMS and x_7-x_{12} represents PS.

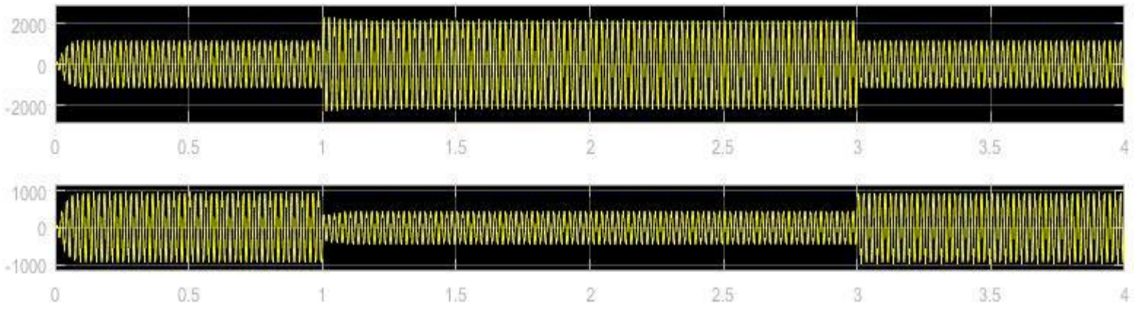

Fig.3 Fault current at point A in Primary side of CT for relay 1 and 2

A bar graph for both TMS and PS for GSA is shown below

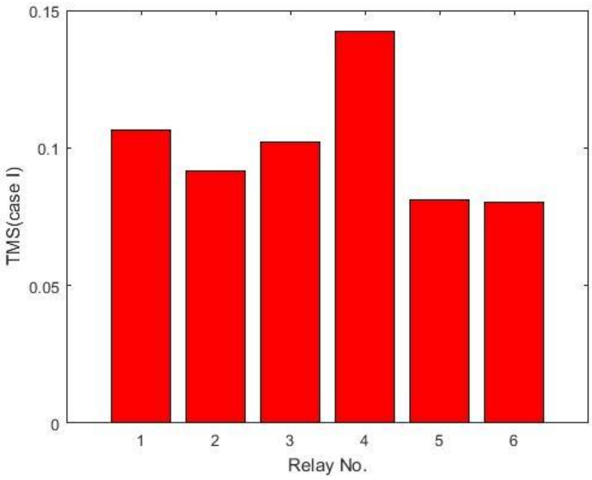

Fig. 4 TMS obtained from GSA

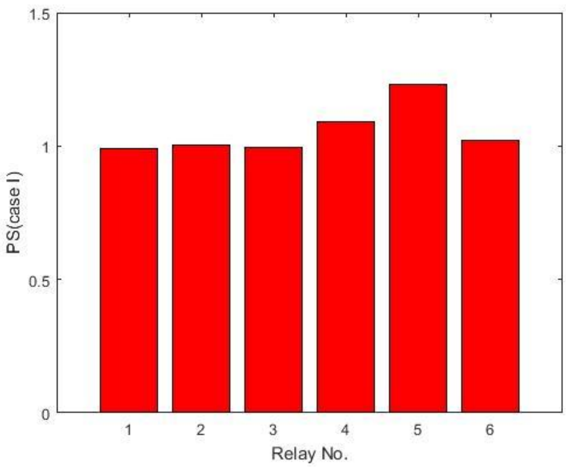

Fig. 5 PS obtained from GSA

The convergence graph is given in Fig.6. The values of TMS and PS obtained by GSA ensure that relay will operate in minimum possible time for fault at any location and coordination will be achieved.

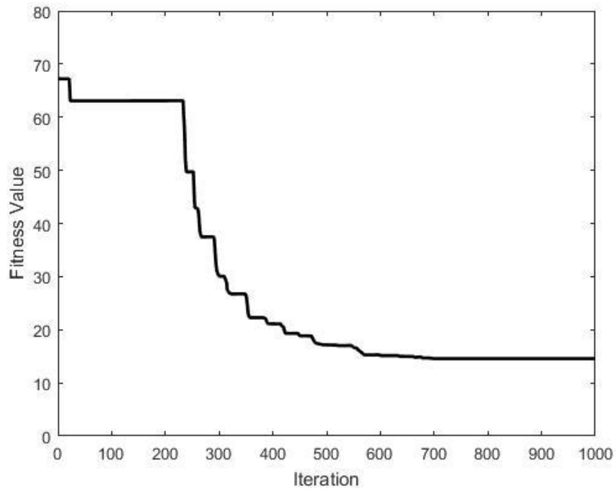

Fig. 6 Convergence graph for GSA

The TMS and PS values of each iteration for PSO are given below;

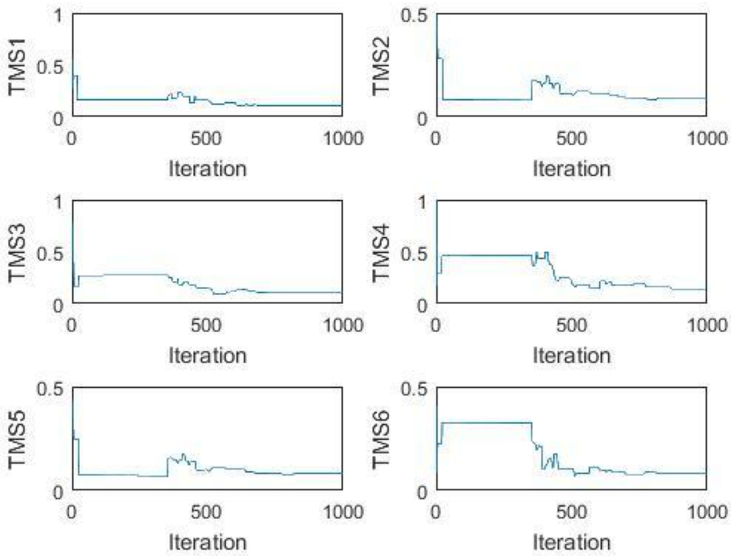

Fig.7. TMS value in each iteration for GSA

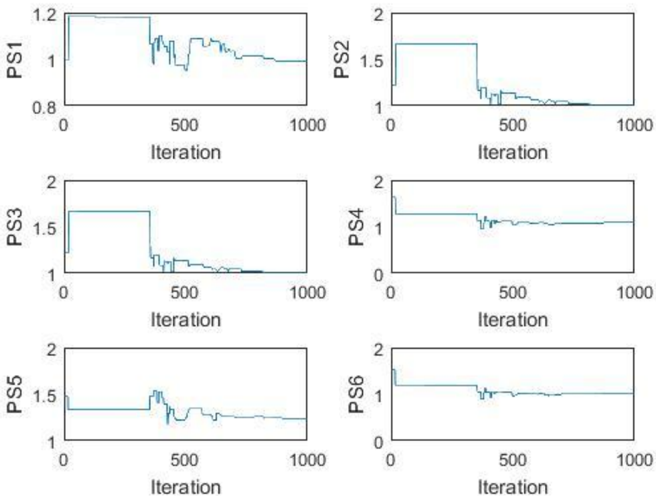

Fig.8. PS value in each iteration for GSA

TABLEIII.OBTAINED TSM AND PS OF RELAYS USING PSO

Relay No.	PSO	
	TMS	PS
1	0.0840	0.9985
2	0.0800	1.0742
3	0.0800	1.2461
4	0.0803	1.1453
5	0.0919	1.1011
6	0.0801	1.0427
Total operating time (sec)	**15.002**	

A bar graph for both TMS and PS for PSO is shown below;

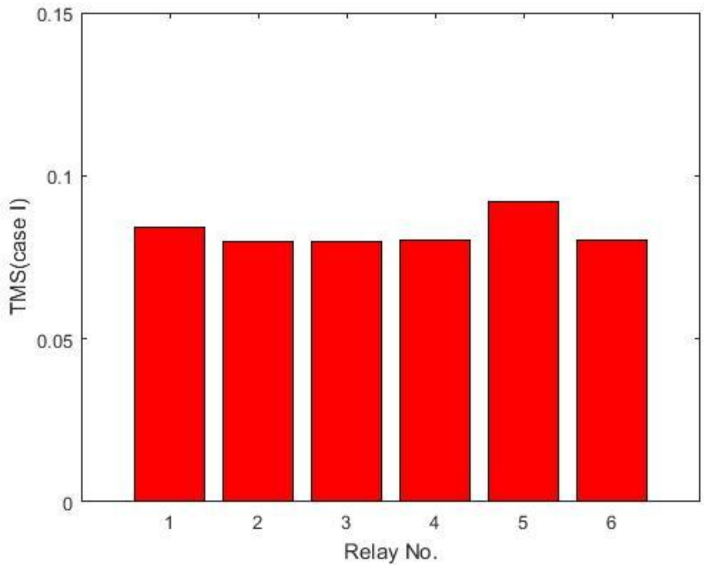

Fig.9. TMS obtained from PSO

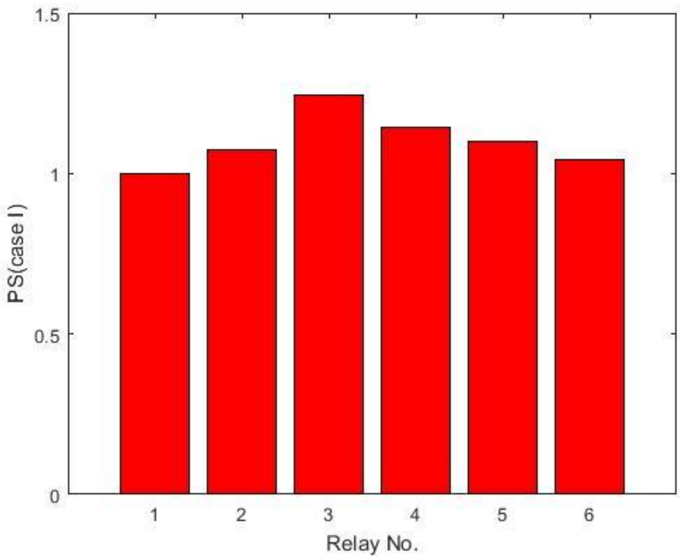

Fig.10. PS obtained from PSO

The TMS and PS values of each iteration for PSO are given below;

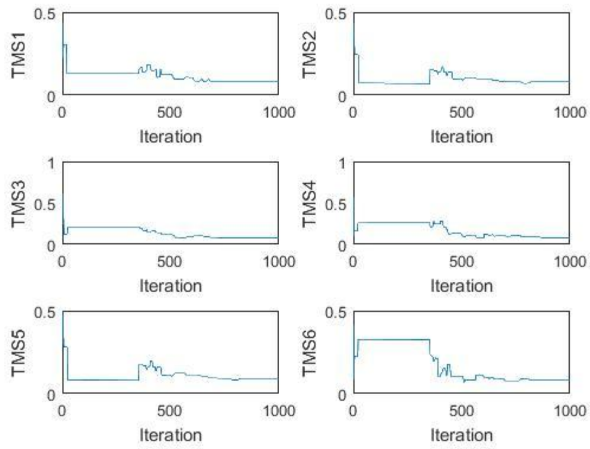

Fig.11. TMS value for each iteration using PSO

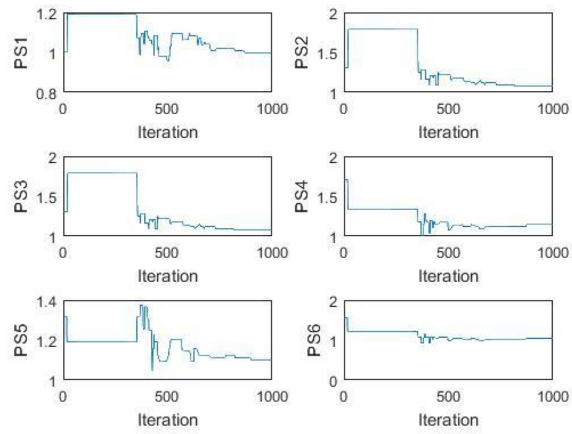

Fig.12. TMS value for each iteration using PSO

Here TMS given by PSO is lesser than GSA for most relays while PS given by GSA is lesser than PSO. This is even relevant because after overall calculation, the total operating time from GSA is coming less and thus relays will operate fast.

The convergence graphs of PSOis given in Fig. 13. The values of TMS and PS obtained by GSA ensure that relay will operate in minimum possible time for fault at any location and coordination will be achieved.

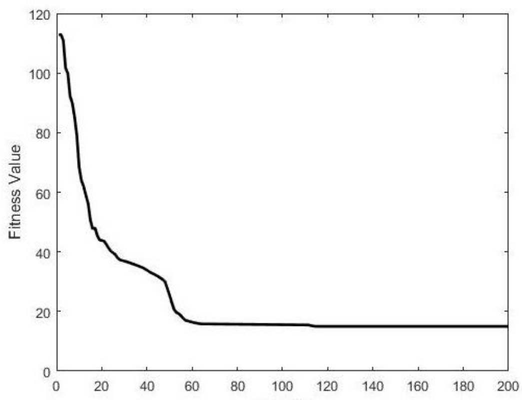

Fig.13. Convergence graph of PSO

TABLEIV.OPERATING TIME OF RELAYS FOR DIFFERENT FAULT POINTS

Fault Point	Primary Relay Unit		Backup Relay Unit		CTI (s)
	Relay No.	Operating Time (s)	Relay No.	Operating Time (s)	
A	1	1.34	-	-	-
B	2	0.68	1	1.63	0.95
C	3	0.96	2	1.62	0.54
D	4	1.33	1	1.64	0.31
E	5	1.32	2	1.63	0.31
F	6	1.88	3	2.20	0.32

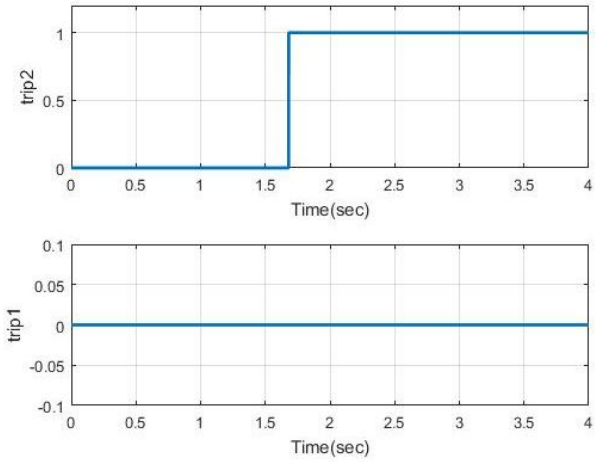

Fig.15. Trip signal of primary relay 2 and backup relay 1 for fault at point B

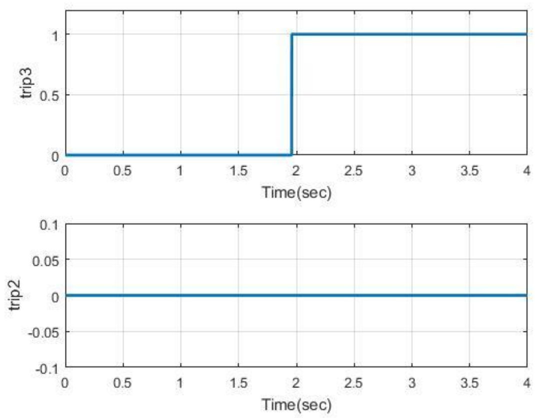

Fig.16. Trip signal of primary relay 3 and backup relay 2 for fault at point C

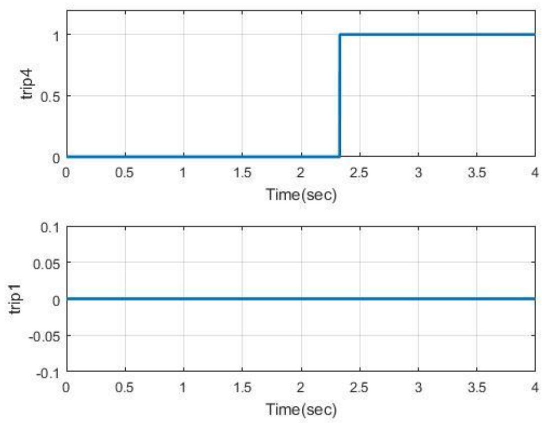

Fig.17. Trip signal of primary relay 4 and backup relay 1 for fault at point D

V. Conclusion

The optimization technique used in this paper in order to find the optimal time multiplier setting (TMS) and Plug setting (PS) of six relays so that their total operating time can be minimized. The simulated fault current retrieved in MATLAB-SIMULINK is subsequently processed in MATLAB. The objective function is framed for two cases i.e. with and without DG. Further, it is minimized by maintaining the range of TMS of each relay as 0.08 to 1 and coordination time interval as 0.3s.The range of PS, determined for each relay is based on maximum load current and minimum fault current.The range of PS determined for each relay is based on maximum load current and minimum fault current. The result is cited in a tabular form in order to reflect the superiority of GSA over PSO in the context of relay coordination objective. Coordination is achieved in every case. The mal operation of relays due to presence of DG is thoroughly discussed and a comparative assessment of results is done. This represents that GSA is a potential optimization technique which can be applied for relay coordination task. Once the relays are set as per settings given by GSA it will work for all types of asymmetrical faults that occur frequently in asystem.

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