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Impact of Dg on Relay Coordination Using Genetic Algorithm

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Abstract: Distributed generation (DG) is commonly used to supply the local loads. The penetration of distributed generation leads to violating the relay coordination in the distribution network. The interconnection of DG affects miscoordination of distribution system protection, because of the generator ability to contribute large fault currents to the fault point. The impact of DG on relay coordination affect the operating time of relay. The CTI associated with primary and backup relay pairs is getting violated due to changes in fault current level. Thus, coordination between primary and backup relays fails in the presence of distributed Generation. Hence, the interconnection of DG in the distribution system causes an adverse impact on protection coordination. Relay coordination problem has many constraints due to coordination criteria. Heuristic based optimization techniques are used to solve the optimization problems. These techniques have a drawback of converging to the values that may not be optimum due to the wide range of design variables and difficulty in getting an initial feasible solution with a short range of design variables. This paper presents a new algorithm to overcome the problem of the initial feasible solution in determining the optimum settings of OCRs. In this context, the optimization problem is formulated as constrained non- linear optimization problem and is determining using Genetic Algorithm (GA). This algorithm is tested on two different networks that found suitable to give satisfactory results.
Keywords: Distributed Generation, Relay coordination, Genetic Algorithm, MATLAB Toolbox, Inverse Definite Minimum Time relays,

I. INTRODUCTION

Shunt faults in a power system give rise to sudden built up of current. This magnitude of fault current can be utilized for the indication of fault existence. The over-current protection is most widely used for the protection of power system. Directional overcurrent relays (DOCR) are commonly used for the protection of distribution systems and also as a secondary protection of the transmission system. In distribution feeders, they play a more prominent role and there it may be the only protection provided. A relay must trip for a fault under its primary zone of protection. Only if, the primary relay fails to clear the fault, the back-up relay should take over tripping. If backup relays are not well coordinated, the relay may get mal-operate. Therefore, relay coordination is a major concern for power system protection. Each relay in the power system must be coordinated with the other relays in the power system [1, 2]. Several heuristic-based optimization techniques were proposed for optimum coordination of OCRs [3]. The optimum settings for TMS and PS are obtained using different algorithms proposed by the researchers. In some cases, pickup currents are determined based on experience and only the value of TMS is optimized. Several non-linear programming (NLP) methods are used to optimize both TMS and PS. However, NLP methods are complex as well as time consuming. To avoid the complexity of the NLP methods, the OCR coordination to avoid the complexity of the NLP methods, the OCR coordination problem commonly formulated as a linear programming problem (LPP) [13]. Various LPP techniques are present by the researchers for OCR coordination [3-6]. In [7, 8], optimum coordination is achieved by considering different network topologies. In [9], a genetic algorithm is proposed to find the optimum solution for relay settings. In [10], GA is used to find the optimum relay settings. Injections of distributed generation (DG) in distribution system jeopardize the existing protection scheme. The impact depends on some DGs, size, type and location. Moreover, the position of DG in distribution network changes the configuration of the distribution system. The distribution system is radial in nature, and overcurrent based protection scheme are set for the uni-directional flow of current. But the injection of DG power causes meshed configuration of the distribution system and on few branches current flows in the both directional.14-15]. In this paper, the problem of determining the optimum values of TMS and PS of OC Relay had been formulating. The Genetic algorithm optimization method with proposed algorithm is used to determine optimum values of TMS and PS. Two case studies with a 3-bus system with 3 OCR relays and 3-bus system with 8 OCRrelays are presented to illustrate the proposed method.

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II. PROBLEM FORMULATION

Relay Coordination problem can be formulated as constrained optimization and solved by different optimization methods. To achieve relay coordination, the sum of all primary relay operating times should be minimized using the optimal relay settings [time multiple setting (TMS) and plug setting (PS)] [8-10]. This is present in equation 1.

$$\min z = \sum_{i=1}^{N} t_i \qquad (1)$$

Where

z- The objective function in zone k,

i-Index,

t_i - Operating time of the i^{th} primary relay for its near-end fault in k,

N - A total number of directional overcurrent relays.

Depending upon relay characteristics the above optimization problem has following constraints,

A. Relay Setting

Each relay has time multiple setting (TMS) and plug setting (PS). PS limit has chosen based on the maximum load current and the minimum fault current seen by the relay, and the available relay setting. The TMS limits are based on the available relay current-time characteristics.

$$PS_{imin} \leq PS_i \leq PS_{imax} \qquad (2)$$

$$TMS_{imin} \leq TMS_i \leq TMS_{imax} \qquad (3)$$

Where

$PS_{i,min}$- minimum value of PS ofrelay R_i

$PS_{i,max}$- maximum value of PS ofrelay R_i

$TMS_{i,min}$- minimum value of TMS ofrelay R_i

$TMS_{i,max}$ - maximum value of TMS ofrelay R_i

$TMS_{i,min}$and $TMSi_{,max}$ taken as 0.025 and 1.2, respectively.

B. Bounds on Relay Operating Time

The relay needs a certain minimum amount of time to operate. Also, a relay should not be allowed to take too long time for its operation. Has been mathematically stated as.

$$t_{imin} \leq t_i \leq t_{imax} \qquad (4)$$

Where,

t_{imin}- Minimum operating time of the relay for the fault at any point in the zone k,

t_{imax} -Maximum operating time of the relay for the fault at any point in the zone k,

C. Backup-Primary Relay Coordination Time Interval

The fault sensed by both primary as well as secondary relay simultaneously. The backup relay should take over the tripping action only after primary relay fails to operate, to avoid mal-operation. If R_i is the primary relay for fault at k, and R_j is backup relay for the same fault, then the coordination constraint can be stated as.

$$t_{j,k} - t_{i,k} \geq \Delta t \qquad (5)$$

Where,

ti,k -Operating time of the primary relay R_i , for the fault at k, tj,k -Operating time of the backup relay R_j , for the same fault at k,

Δt - Co-ordination time interval (CTI).

III. GENETIC ALGORITHM

A Genetic Algorithm Heuristic non-traditional optimization technique he has based on the, mimic the process of evolution, right. GA is advantages of converging to the global optimum. The genetic algorithm will be slow compared to conjugate gradient is disadvantages of GA.Distinguishing characteristics of GA compared to traditional methods are as follows:

GA works with the coding of the parameter set, not the parameter themselves.

GA's search for a population of the point, not a single point.

GA uses the objective function information & not the derivatives & second derivatives.

A. Important terms in Genetic Algorithm

1) Chromosome: a set of generation, a chromosome contains the solution in a form of generations.
2) Generation: a part of the chromosome, a generation contains a part of the solution. It determines the solution. e.g. 16743 is a chromosome and 1,6,7,4 and 3 are its generations.
3) Individual: same as a chromosome.
4) Population: number of individuals present with the same length of the chromosome.
5) Fitness: the value assigned to an individual based on how far or close an individual is from the solution.
6) Fitness function: a function that assigns fitness value to the individual. It is problem specific.
7) Crossover: taking two fit individuals and then intermingling there chromosome to create new two individuals.
8) Mutation: changing a random generation in an individual.
9) Selection: Selecting individuals for creating the next generation.

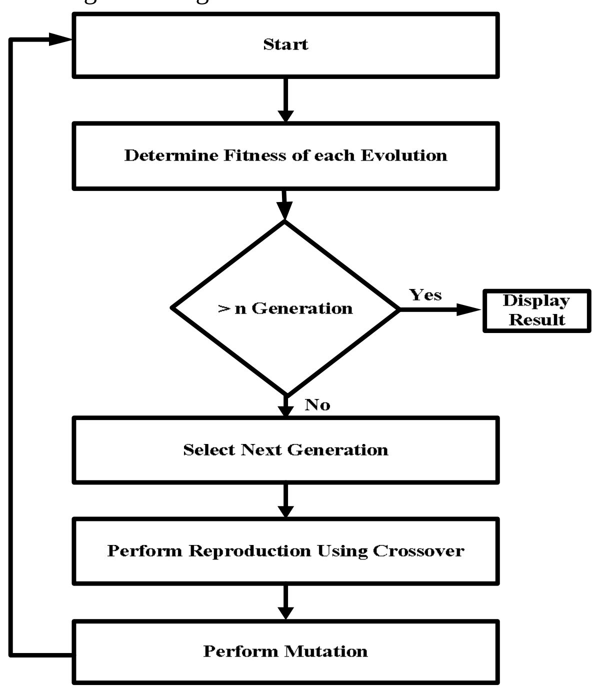

Fig 1. Flow chart of GA Algorithm

B. Coordination of Overcurrent Relay

Fault in the power system is sense by both primary as well as backup relays. The primary relay should operate first and if the primary relay fails to operate the backup relay should operate. So it is necessary to set the operating time of primary relay less than that of the backup relay. A simple radial feeder with three sections they are shown in Fig.2.

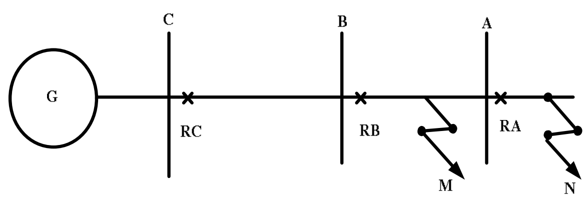

Fig 2. Radial Feeder System.

For a fault at point N, relay RA should operate first. Let the operating time of RA are set to 0.2 (sec). The same fault have been seen by relay RB as well as RC, but relay RB should wait for 0.2 (sec) plus, a time equal to the operating time of circuit breaker (CB) at bus A, plus the overshoot time of relay A, which is called as coordination time interval (CTI).Accordingly operating time for each relays should be set. This is necessary for maintaining the selectivity of relays at A, B and C. In the same way for the fault at point M

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operating time of relay C should be set as operating time of relay C plus CTI [7]. The selection of TMS and PS for settings of operating time with CTI is shown in fig.3.

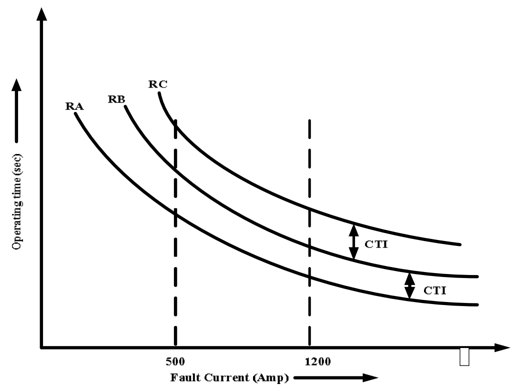

Fig 3. Coordination Time Interval

IV. RESULT

An MATLAB program is developed to find optimum values of TMS and PS for OC relay coordination problem. The program will test on different systems and were found to give satisfactory results in all the cases. Two case studies on the radial feeder as well as a multi-loop distribution system with DG and effect on relay coordination are presented here for demonstration. Detail procedure for the formulation of an objective function and constraints would be present. Also, application of GA for the objective function is explained. The obtained results are obtained using Genetic Algorithm (GA).

A. Iillustration-I

A radial distribution system, with three OC relays as shown in Fig. 2. is considered to test the algorithm, The maximum fault current just beyond bus A, bus B and bus C are 2500 (Amp), 3500 (Amp) and 4500 (Amp) respectively, the CT ratio for RA is 200:1, RB is 300:1 and for RC is 500:1. Minimum operating time for each relay is considered as 0.2 (sec), and the CTI is taken as 0.3 (sec). Current seen by each relay at different fault locations is given in Table 1.

Table I. Current Seen by Relay At Fault location

Fault Position	Relay		
	A	*B*	*C*
Just Beyond A	12.5	8.33	5
Just Beyond B	---	11.66	7
Just Beyond C	---	---	9

The characteristic equation of normal IDMT overcurrent relay is given by

$$T_{op} = \frac{0.14 * TMS}{\left(\frac{I_f}{ps}\right)^{0.02} - 1} \qquad (5)$$

Where
Top- Operating time of IDMT relay
TMS -Time multiple setting
PS- Plug setting
I_f - Fault current seen by relay

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Consider x1, x2 and x3 are the TMS and y1, y2 and y3 are the PS of relay RA, RB and RC respectively, then the optimization problem to minimize the total operating time formulated as-

$$\min z = \frac{0.14 * x1}{\left(\frac{12.5}{y1}\right)^{0.02} - 1} + \frac{0.14 * x2}{\left(\frac{11.66}{y2}\right)^{0.02} - 1} + \frac{0.14 * x3}{\left(\frac{9}{y1}\right)^{0.02} - 1} \quad (6)$$

Subjected to

$$\frac{0.14 * x3}{\left(\frac{5.00}{y1}\right)^{0.02} - 1} - \frac{0.14 * x1}{\left(\frac{12.5}{y2}\right)^{0.02} - 1} \geq 0.3 \quad (7)$$

$$\frac{0.14 * x2}{\left(\frac{8.33}{y2}\right)^{0.02} - 1} - \frac{0.14 * x1}{\left(\frac{11.66}{y1}\right)^{0.02} - 1} \geq 0.3 \quad (8)$$

$$\frac{0.14 * x3}{\left(\frac{7.00}{y3}\right)^{0.02} - 1} - \frac{0.14 * x1}{\left(\frac{11.66}{y1}\right)^{0.02} - 1} \geq 0.3 \quad (9)$$

$$\frac{0.14 * x1}{\left(\frac{12.5}{y1}\right)^{0.02} - 1} \geq 0.20 \quad (10)$$

$$\frac{0.14 * x2}{\left(\frac{11.66}{y2}\right)^{0.02} - 1} \geq 0.20 \quad (11)$$

$$\frac{0.14 * x3}{\left(\frac{9.00}{y3}\right)^{0.02} - 1} \geq 0.20 \quad (12)$$

Minimum operating time for each relay is set to be 0.20. The lower bound on the values of TMS and PS are taken as 0.05 and 0.8 respectively. The upper limit of TMS and PS for the entire relay is taking as 1.1 and 1.2. MATLAB toolbox used to solve the above optimization problem using GA. Table II shows the result obtained using GA.

Table II. Result for Illustration-I

Relay Number	GA	
	TMS	*PS*
R_A	0.083	0.811
R_B	0.159	0.943
R_C	0.223	0.874
Total operating time (sec)	1.2861	

B. Iillustration-II

Due to the presence of DG in distribution system, the original relay coordination is lost. The original relay coordination is restored by disconnecting all DGs during the fault conditions. This will lead to the loss of DG power as well as it will create resynchronization problems for connecting DGs after clearing the fault.

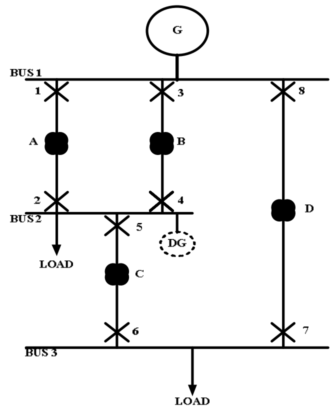

Fig: 1. 3- Bus system with 8 directional OCRs.

The 3-bus distribution system shown in Fig. I. is considered for the illustration. This system consists of 3 buses, 3 lines and one generator. A 1 MVA synchronous DG is connected at bus; 2 to supply the local loads and both loads consider as 10 MW. The system data is given in Table I. All lines are protected by directional overcurrent relays with normal inverse characteristic. Four different fault points (A to D at the middle of each line) are considered. Relay primary backup relationship and fault current data without considering DG and with DG is given in table - II. The minimum operating time as well as CTI is considered as 0.2 sec. The GA method is used to find optimum relay settings without considering DG. The optimum relay settings are presented in table – III.

Table I. System Data

Sr.No.	Particulars	Ratings
1	Generator	25MVA, 11KV, Xd' = 0.25 pu
2	Line	0+j0.25 pu
3	DG	1MVA,11KV,Xd' = 0.30 pu

Table II. Fault Currnt Data

Fault Point	Relay		Fault current(Amp) With 1- DG			
			With DG		Without DG	
	Primary	Back up	Primary	Back up	Primary	Back up
A	1	--	--	--	--	--
	2	6	4677	4769	3453	1480
B	3	--	--	--	--	--
	4	6	4677	4769	3453	1480
C	5	1	6174	875	2801	1400
	5	3	6174	875	2801	1400
	6	8	2613	6191	2801	1867
D	8	--	--	--	--	--
	7	5	6191	2613	2801	1867

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Table III. Optimum Values For TMS and PS

Relay Number	TMS & PS obtained using With DG		TMS & PS obtained using Without DG	
	TMS	PS	TMS	PS
1	0.1039	0.8493	0.1684	0.8296
2	0.0817	0.8007	0.1663	0.8972
3	0.1056	0.8319	0.1357	0.8412
4	0.0783	0.8916	0.1387	0.9068
5	0.1910	0.8170	0.2361	0.8159
6	0.1604	0.8980	0.3914	1.0001
7	0.0789	0.8320	0.1331	0.8779
8	0.2535	0.8350	0.5718	0.8256
Total operating Time(Sec)	2.2388		4.9080	

V. CONCLUSION

In this paper, the interconnection of DG affectSs miscoordination of distribution system protection, because of the generator ability to contribute large fault currents to the fault point. Thus, coordination between primary and backup relays fails in the presence of distributed Generation. The CTI associated with primary and backup relay pairs is getting violated due to changes in fault current level. Hence, the interconnection of DG in the distribution system causes an adverse impact on protection co ordination. The optimum relay coordination problem is formulating as constrained optimization problem considering minimum operating time for each relay is considered as 0.2 (sec), and CTI is taking as 0.2 (sec). The optimum values for TMS are obtained using GA. The algorithm was testing for various system configurations, including multi-loop systems, and was found to give satisfactory results in all cases.

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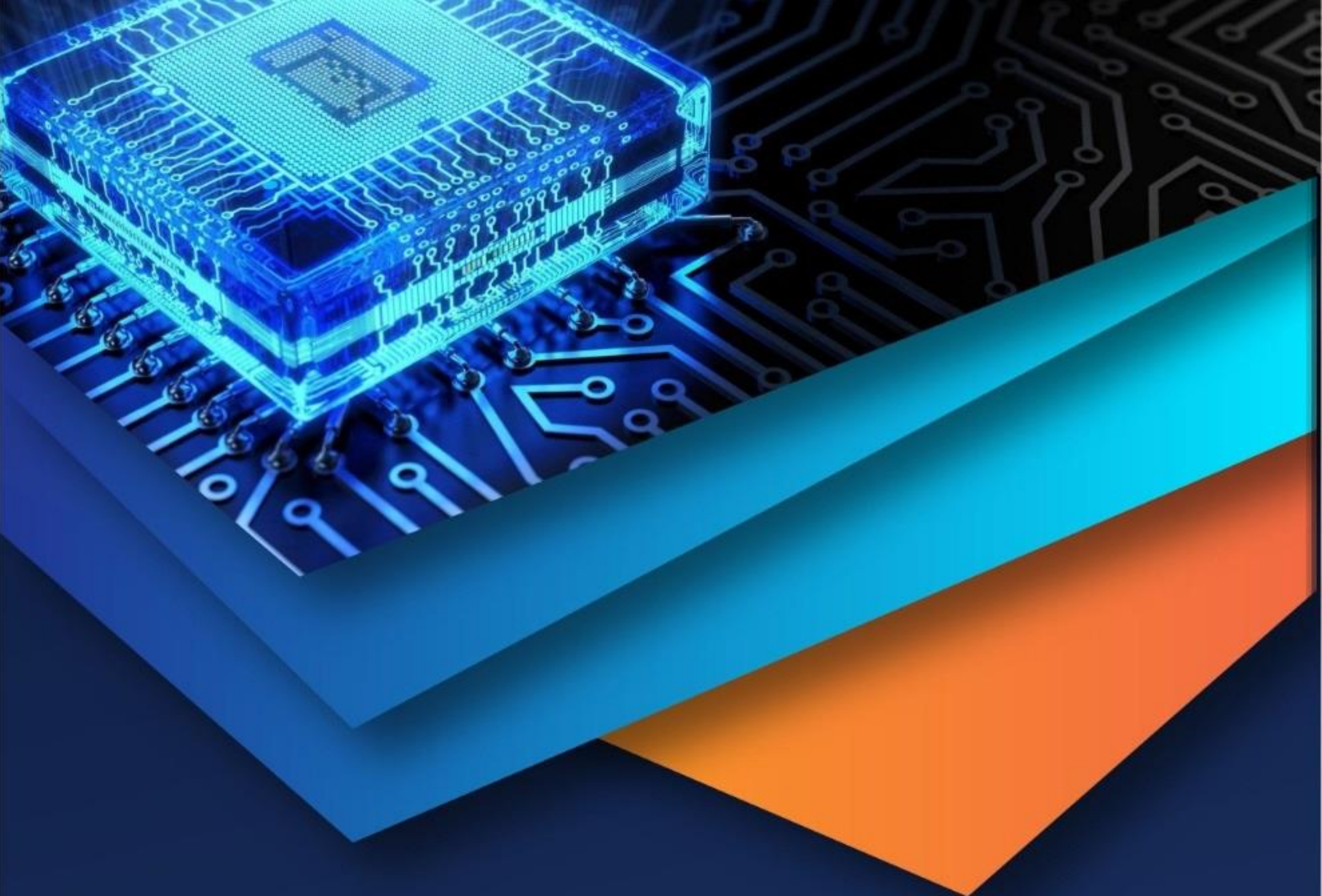

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