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Optimal Coordination of Over Current and Distance Relays

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***Abstract*- Over current and Distance relays are commonly used for protecting power systems. In many sub-transmission and transmission power systems , the main protection schemes use distance relays and directional over current relays are used as secondary protection. In the optimal methods, the operating times of the relays are minimized in the frame of the objective function, subject to coordination constraints, relay characteristic curves and the limits of the relay settings. In the project a new optimal method for the coordination of over current and Distance relay based on genetic algorithm has been developed. Various over current relays characteristics are considered and the best of them is selected by genetic algorithm to fulfill optimal coordination.**

Keywords- Power System Protection;Overcurrent Relay; Distance relay; Optimal Coordination; Relay characteristics; Genetic Algorithm

I. INTRODUCTION

In a power system some failure will occur somewhere in the system.When a failure occurs on any part of the powersystem, the relays detect the abnormal conditions and operates. The relays supply information to the circuit breaker which performs the function of circuit interruption. The circuit breaker isolate the defective element from the rest of the system.The main function of protection system is to isolate the minimum possible part of power system at a fault or an abnormal condition. When a fault occurs in a power system , it should always be detected by two different protection relays. The protection relays are normally designated Main and Backup protection.

Distance and overcurrent relays are mainly used for transmission and sub transmission protection system. To consider comprehensive coordination, a distance relay with distance one, an overcurrent relay with overcurrent and finally a distance relay with an overcurrent one when one of them is considered to be main relay and other as backup must be coordinated. In many transmission systems the main protection schemes use distance relays and the directional over current relays are used as a secondary protection.

When the main protection fails to operate, the first stage backup protection should operate. The determination of time delay for the operation of all backup relays is known as coordination of protection system. Several optimization methods are proposed for coordination of overcurrent relays. The optimal coordination of over current relays has been performed using linear programming techniques such as simplex [2];two phase simplex[3]; and dual simplex [4] methods. The optimal solution is made by constraints only in [6].The disadvantage in the above method is that an optimal solution is not obtained if the constrains are not fulfilled.

The optimal coordination by evolutionary algorithm [9] may have two problems; miscoordination and lack of a solution. This is because optimization techniques as based on an initial guess and can be trapped in local maximum or minimum values. The intelligent optimization method using Genetic Algorithm does not have this problem. For optimal coordination of relays the critical fault locations have to be determined. The discrimination time between backup and main relays are minimum at critical fault points. The coordination of relays is done based on the constraints derived from values of Δt for critical fault locations .

In all existing mathematical coordination methods, fixed characteristics is applied for all over current relays. To achieve optimal coordination the best characteristics for over current relay is required.In this paper the best characteristics of over current relay is selected by genetic algorithm for optimal oordination.In this method the constraints are included in the objective function.

II. REVIEW OF COORDINATION PROBLEM

A. Problem Statement :

The optimal coordination of relay can be considered as an optimization problem. The aim of the optimization problem is to minimize the objective function subject to constraints. The general form is

$$Obj = \min \sum_{1\leq i\leq n} t_i \qquad (1)$$

Subject to

$$T_b - T_m \geq CTI \qquad (2)$$

Where n is the number of relays and ti is the operating time of ith relay. Tb is the operating time of backup relay and Tm is the operating time of primary relay. CTI is the coordination time interval.

B. Relay characteristics:

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The relays used for protection are distance and overcurrent relays. The distance relays have fixed time of operation while we consider various characteristics for each overcurrent relay.The operating time of over current relay can be found out using the formula

$$t = TSM\left[\frac{k}{M^{\infty}} + L\right]$$

Where M is the ratio of short circuit current to pick up current of relay, t is the relay operating time, K,α,L are the scalar quantities.The value of K,α,L differ for each characteristics of overcurrent relay which is given in Table I The TSM of the relays are having discrete value ranging from 0 to 1 in steps of 0.05.

TABLE I

CHARACTERISTICS OF OVERCURRENT RELAYS

Number of characteristics	Type of characteristics	Standard	*K factor* (C1)	∞ **factor**	*L factor*
1	Short time inverse	AREVA	0.05	0.04	0
2	Standard inverse	IEC	0.14	0.02	0
3	Very inverse	IEC	13.5	1	0
4	Extremely inverse	IEC	80	2	0
5	Long time inverse	AREVA	120	1	0
6	Moderately inverse	ANSI/IEEE	0.0515	0.02	0.114
7	Very inverse	ANSI/IEEE	19.61	2	0.491
8	Extremely inverse	ANSI/IEEE	28.2	2	0.1217

C. Coordination constraints:

The coordination constraint is

$$T_b - T_m \geq CTI \qquad (4)$$

In the paper the protection scheme composed of over current and distance relays hence the constraint becomes

$$t_b(F) - t_{z`2} \geq CTI$$

Where $t_b(F)$ is the operating time of overcurrent relay at F, t_{z2} is the operating time of second zone of distance relay and *CTI* is the coordination time interval. $t_b(F)$ depend on the characteristic type of overcurrent relay.

III. APPLICATION OF GENETIC ALGORITHM TO RELAY COORDINATION

Genetic algorithm is one of the most powerful search methods for solving optimization problems. TSM and various characteristics of overcurrent relays are the unknown quantities in the optimization. Therefore these two parameters are considered as genomes of chromosomes in GA. Hence the initial value of TSM and characteristics set are randomly selected.

R1		R2		R3		…	Rn	
TSM 1	CHAR1	TSM2	CHAR2	TSM3	CHAR3	…	TSMn	CHARn

Fig 1 . Structure of chromosome

The Objective Function (OF) is used to evaluate the goodness of each. Chromosome with more effectiveness are used for producing new generation of chromosomes. The new offsprings are produced by genetic operation crossover or mutation.[4]. The new offsprings indicate the new TSM and characteristics of relays.

The process is terminated after a fixed number of generations. Better solutions are obtained if the number of generations are higher.obtained.The r number of generation depends on complexity of the system and population size.

IV. PROPOSED METHODOLOGY

The objective function formulated is

$$OF = \alpha_1 \times \sum_{i=1}^{N}(t_i)^2 + \beta_2 \times \sum_{k_1=1}^{P_1}\left(\Delta t_{mb|k_1|} - \left|\Delta t_{mb|k_1|}\right|\right)^2 + \beta_3 \times \sum_{k_2=1}^{P_2}\left(\Delta t_{mbDISOC|k_2|} - \left|\Delta t_{mbDISOC|k_2|}\right|\right)^2$$

Where *∞1, β2 and β3*, are weighing factors, *i* is the number of overcurrent relays(*i=1 to N*), k_1 is the number of main and backup overcurrent relays(k_1*=1 to* P_1), k_2 is the number of main distance and backup overcurrent relays (k_2*=1to*P_1), *Δ* t_{mbtil} is the discrimination time between main and backup over current relays.

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The second and third term in the objective function fulfill the requirement of coordination of over current and distance relays. If $\Delta t_{mbDISOCIk2I}$ is positive then the relative term is zero. If it is negative the term will have large values.Then based on selection and evaluation of GA , the Chromosomes with more optimal objective function values are selected for next generation.Therefore the TSM and characteristics set belongs to miscoordination which produces large OF is not chosen.

The flowchart of proposed method is shown in Fig 2.The network data are initially entered, then the impedance of first, second and third zone of distance relay is calculated. The short circuit current for fault close to circuit breaker of overcurrent relay is calculated. Time of operation of distance relay and overcurrent relay are calculated and initial values for population are entered. After that GA will start, the process will be continued for a fixed number of generation.

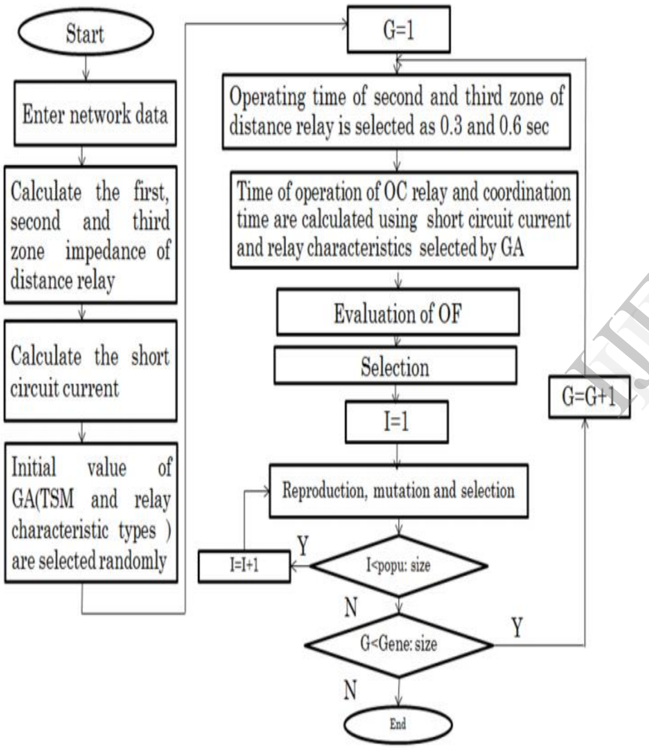

Fig 2. Flowchart of proposed method

V. Test Case

A.Network Information

The proposed method is applied to a sample power network which consists of 6 buses, 7 lines, 2 transformers and 2 generators. The R (pu) and X (pu) are based on100MVA and 150kV. All the lines are protected by both overcurrent and distance relays.

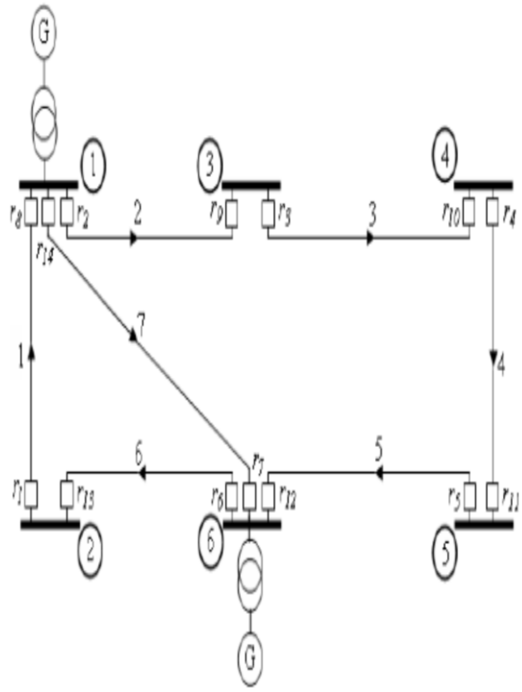

Fig 3. Sample network

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The network information is given in Table II, III and Table IV.

TABLE II
LINE INFORMATION OF SAMPLE NETWORK

Line	R(pu)	X(pu)	V(kv)
1	.0018	.0222	150
2	.0018	.0222	150
3	.0018	.02	150
4	.0022	.02	150
5	.0022	.02	150
6	.0018	.02	150
7	.0022	.0222	150

TABLE III
GENERATOR INFORMATION OF SAMPLE NETWORK

Generator	X(pu)	V(kV)
	0.1	10

TABLE IV

TRANSFORMERS' INFORMATION OF SAMPLE NETWORK

Transformer	X (pu)
	0.026666

The primary and backup relay pair is identified by using graph theory and it is given in table V.

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TABLE V.
LIST OF PRIMARY/BACKUP RELAY PAIRS

Pair no.	Primary relay	Backup relay	Pair no.	Primary relay	Backup relay
1	2	1	11	13	8
2	14	1	12	8	9
3	3	2	13	14	9
4	4	3	14	9	10
5	5	4	15	10	11
6	6	5	16	11	12
7	7	5	17	7	13
8	1	6	18	12	13
9	2	7	19	6	14
10	8	7	20	12	14

The short circuit current for the back up over current relays is listed in Table VI.

TABLE VI
SHORT CIRCUIT CURRENT DATA

Relay No.	Short circuit current
1	828
2	816
3	3505
4	1769
5	1103
6	340
7	337
8	2682
9	1571
10	1563
11	2492
12	340
13	337
14	1174

The pick up current settings of the relays is listed in Table VII.

TABLE VII

PICKUP CURRENT SETTINGS DATA

Relay No.	Pick up current
1	125
2	200
3	150
4	200
5	137
6	137
7	162
8	137
9	135
10	137
11	162
12	137
13	150
14	200

GA Information

The GA control parameters are given in Table VIII, the parameters are found out by trial and error procedure.

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TABLE VIII

GA Parameters

GA parameters	value
No. of generation	100
Size of population	20
Initial population	random
Mutation	1

C. *Results and discussion*

The proposed GA is applied to the sample network.Optimum TSM and over current relay characteristics are obtained. The operating time of second and third zone of distance relay is selected as 0.3(sec) and 0.6(sec). The TSMs obtained are in a valid range (0.05-1.0) and the operating times are lower than that obtained using fixed characteristics. Best overcurrent relay characteristics selected by GA for each relay position is given in column 2. The operating time of relay considering fixed characteristics (characteristic 2) are shown in the column 4 and the operating time obtained considering TSM and characteristics selected by GA are listed in table IX and X. From the result obtained it is clear that operating time selected by GA is less than that obtained with fixed characteristics .

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TABLE IX

Operating time of over current relay with fixed characteristics

Relay No.	TSM	No. of chara selected	Operating time
1	.05	2	.1652
2	.1	2	.2236
3	.15	2	.3858
4	.2	2	.7584
5	.05	2	.3577
6	.1	2	.2147
7	.15	2	.4261
8	.2	2	.4335
9	.05	2	.3272
10	.1	2	.2887
11	.15	2	.3457
12	.2	2	.3979
13	.05	2	.1831
14	.1	2	.3050

TABLE X

Operating time obtained by GA

Relay No.	TSM(GA)	No. of chara selected (GA)	Operating time
1	.05	4	.0932
2	.35	4	.0914
3	.05	5	.5559
4	.05	1	.0353
5	.05	4	.7753
6	.05	5	.3229
7	.05	4	.0434
8	.05	5	.3490
9	.05	1	.0664
10	.05	4	.0552
11	.15	2	.3684
12	.05	5	.2336
13	.3	1	.2139
14	.4	1	.2331

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TABLE XI

Comparison of output with and without GA

Relay No.	TSM(selected by GA)	No.of chara selected by GA	Operating time in sec selected by GA	Operating time (sec)(fixed chara)
1	.05	4	.0932	.1652
2	.35	4	.0914	.7790
3	.05	5	.5559	.1286
4	.05	1	.0353	.1896
5	.05	4	.0753	.3577
6	.05	5	.3229	.4074
7	.05	4	.0434	.1420
8	.05	5	.3490	.3584
9	.05	1	.0664	.3272
10	.05	4	.0552	.1444
11	.15	2	.3684	.3984
12	.05	5	.2336	.9995
13	.3	1	.2139	1.0985
14	.4	1	.2331 7	1.2202

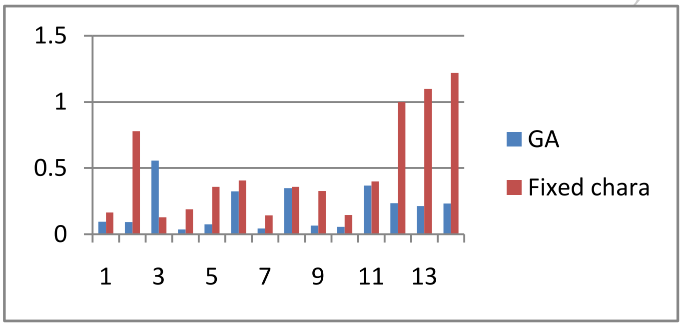

Fig. Comparison of output with and without GA

VI. CONCLUSION

Transmission lines are a vital part of the electrical distribution system, the line protection schemes are composed of distance relays and directional overcurrent relays. Protective relays coordination is very important in protection of the system. A method to automatically determine the optimum setting of overcurrent relays considering both distance and overcurrent relays has been presented.Separate relay computation would lead to loss of selectivity.Various relay characteristics are considered for each over current relay and best of them is selected by Genetic Algorithm for optimal relay coordination. The method has been tested on a sample six bus power network and from the results obtained it has been shown that the method is accurate and efficient.

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