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A SOLUTION OF OVER CURRENT RELAY CO-ORDINATION PROBLEM WITH DIFFERENT TEST SYSTEMS USING MOTH FLAME OPTIMIZATION ALGORITHM

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Abstract* — Relay coordination is essential to ensure quick operation of relays in order to avoid the excessive damage to the equipments and end users consumers. As the probability of shunt fault occurring in the network is higher comparatively so protection is done accordingly. Relay coordination means coordination of proper relaying operation with certain insight between primary and back-up relays pair connected in the network. The proper operation of overcurrent relays used in the network governs mainly by two parameters, i.e. Plug Setting Multiplier (PSM) and Time Multiplier Setting (TMS). The method which inspire by Nature Meta-heuristic Moth flame Optimization (MFO) Algorithm is used to find out the optimal relay setting.

I. INTRODUCTION

Coordination of protective relays is defined as the "process of choosing settings or time delayed characteristics of the protective devices", such that the operation of the devices will occur in a predefined order to minimize customer service interruption and power system isolation due to a power system disturbance. Inverse Definite Minimum Time (IDMT) over-current relays are the most widely used protective relays to detect and isolate faults on the power system. This type of relays is often used as main protection or backup protection in radial and interconnected power system networks. For IDMT overcurrent relays [8], the task of performing relay coordination involves the setting of pick up current and time multiplier parameters. The most important parameter for overcurrent relay coordination is the time multiplier which has a direct influence on the operating time of an overcurrent relay. An increase in the time multiplier results in an increase in the operating time of the overcurrent relay and vice versa. The pick-up current is set to be stable for maximum load current the equipment can carry continuously but should also be sensitive enough to detect minimum fault at the end of intended reach.

A comprehensive review of different optimal coordination methods like seekers algorithm[13], fire fly algorithm[2,8], hybrid genetic algorithm[3],hybrid PSO[14], artificial bees colony[4],flower polliation[7],CMA-ES[10]algorithm,GAN-LP[15] for mitigate the relay problem.

The objective of the research is to extend the previously performed task and include new algorithms, namely Linear Programming techniques, Genetic Algorithm, and meta heuristic nature inspired algorithm namely Moth Flame Optimization (MFO)[6].

Linear Programming [1] technique has been applied extensively on the problem of relay coordination reporting satisfactory results. To apply the selected evolutionary algorithms on a typical power system network and compare results with the other techniques.

To study the application of heuristic algorithms and compared the results with the other techniques. To find out the optimal relay coordination time for the efficient operation of system, when fault occurs it should initiate the trip command and isolate the faulty part.

II. PRINCIPAL OF RELAY COORDINATION

Coordination of relays is classically defined as "the process of choosing settings or time delay characteristics of protective relays, such that the operation of the relay will occur in a specified order to minimize customer service interruption and power system isolation due to an abnormal operation of power systems (power system disturbances)". To minimize the extent of the power system disconnected during a fault, the protection system is arranged to operate in zones which are generally overlapped and decided by the positions of the Current Transformer [11].

There are two types of systems namely, Unit Protection and Non unit protection. In Unit protection scheme the relay will operate for the defined zone according to the reach. Where as in non-unit protection system, the protection devices do not have defined zone and can reach into the protection zone of adjusting the devices. Therefore, these devices have to be coordinated with adjacent protective devices in order to carry out selective clearing of faults on power system for its efficient operation.

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This is achieved by applying protective relays to a power system as primary and backup pairs. In this set up, Primary protection is set to operate faster for the in zone fault while backup protection[16] is set to operate with predetermined time delay for the faults in their backup protection zone. The predetermined time delay is known as minimum coordination time (MCT) or minimum coordination interval (MCI). Overcurrent relays are the most widely used relay in non-unit protection system on the power system[11,16].

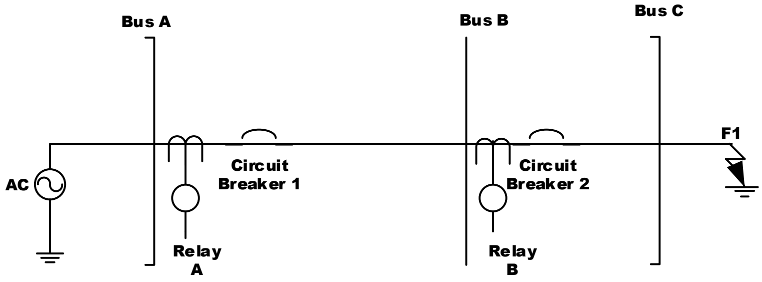

Figure 1.Radial Feeder system

A simple radial feeder with two sections is shown in Fig. 1. For fault at point F, relay RB is first to operate. Let the operating time of RB is set to 0.1 s. The relay RA should wait for 0.1 s plus, a time equal to the operating time of circuit breaker (CB) at bus B, plus the overshoot time of relay a [1]. This is necessary for maintaining the selectivity of relays at A and B [2,8].

In general the coordination of directional over-current relays in power systems can be stated as an optimization problem, where the sum of operating times of the relays of the system, for near end fault is to be minimized

Minimize:

$$\min s = \sum_{i=1}^{n} t_I \quad (1)$$

Where n is numbers of relays, t_i is operating time of i^{th} relay.

A. Coordination constrain:

The relays in the system have to be coordinated by the criterion,

$$t_{2,k} - t_{1,k} \geq MCT \quad (2)$$

Where $t_{1,k}$ is the time of operating of the main relay at k, for in zone fault and $t_{2,k}$ is the time lag of the back-up relay, for the fault considered. MCT is Minimum Coordination Time. In this paper it has been taken as 0.25

B. Bound on the relay operating time

Constraint imposed because of restriction on the operating time of relays can be mathematically stated as:

$$t_{i,min} \leq t_{i,k} \leq t_{i,max} \quad (3)$$

where, ti,min is the minimum operating time of relay at i for fault at any point, ti,max is the maximum operating time of relay at i for fault at any point.

C. Relay Characteristics

Distance and overcurrent relays are commonly used in the protection of Transmission line. Distance relays have fixed operating time based on impedance while there are various characteristics for an over-current relay. The operating time of relay considered in the network can be calculated using the formula:

$$T_{op} = \frac{a}{(PSM)^{b} - 1} * TMS + C \quad (4)$$

Where, PSM = Plug Setting Multiplier and it is the ratio of current at short circuit to pick up current of relay. A, B, C are constants specified in the table given below.

TMS = Time Multiplier Setting of the relays are having distinct step values in a range from 0 to 1 in step value of 0.1.

TABLE I

VARIOUS CHARACTERISTICS OF OVER-CURRENT RELAYS [16]

Numbers of characterises	Types of characteristics	Standard	Constant A	Constant B	Constant C
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	0.1212

D. Relay Coordination Characteristics

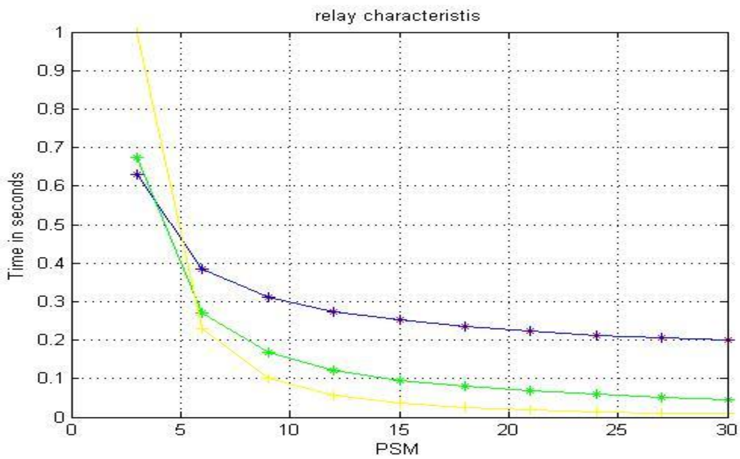

Figure 2.relay Characteristics

III. Linear Programming Method

Linear programming method (LP)[5]; also called as a linear optimization) method to derived the best results (such as maximum benefit or lowest cost) in a mathematical model whose requirements are represented by linear relationships. Linear programming is a special case of mathematical programming (mathematical optimization).

LP method is the most frequently used one of the method for the optimization of any problem. In this, the constraints are handled as a linear function and hence the formulation of the optimization problem is taken as a linear mixed integer problem.

In this study, we consider the plug setting (PS) of the relay as fixed and the time of operation is considered as a linear function of relay Time Dial Setting only.

$$K=\frac{a}{(PSM)^b-1} \quad (5)$$

Hence the relay coordination objective function is now reduced as

$$T_{op} = K*TDS \quad (6)$$

In this method, the constraints are handled with either of the following:

$A_{eq}*x = B_{eq}$; Linear Equality Constraints (7)

$A*x \leq B$; Linear Inequality Constraints (8)

$B_{lower} \leq x \leq B_{upper}$; Bounded Constraints (9)

The relay coordination problem is considered as bounded constraint optimization problem.

$$T_{op(min)} \geq T_{op} \geq T_{op(max)} \quad (10)$$

This method is easy conventional and most powerful method and implementation of this is the simplest and easy to understand. It is readily available in MATLAB toolbox.

IV. MOTH FLAME OPTIMIZATION

The Moth flame optimization (MFO)[6] was developed by Seyedali Mirjalili in 2015 and is inspired from the behavior of Moths. As it is population based multi agent optimization as well as using initial randomization can be categorized as Metaheuristic.

Idealized rules for relay coordination analogy

- All moths are travel towards moon/artificial flames of their behavior, **analogous** to that all relays which are going to be coordinated have same characteristic.
- Travelling is proportional to brightness of moon/artificial flames & inversely proportional to distance, **analogous** to that Time of Operation is inversely proportional to fault magnitude & proportional to the time setting.
- Travelling distance is determined by its objective function **analogous** to that time of operation is determined by relay setting parameters.

MFO algorithm is three tuple that approximate the global optimal of the optimization problem and defined as follow.

$$MFO = (I, P, T) \quad (11)$$

Where the I function that generate random population of moths and corresponding fitness value.

$$I : \emptyset - > \{M, OM\} \quad (12)$$

Where p function is main function moves the moths around the search space

$$P : M- > M \quad (13)$$

Where the t function returns true if the termination criterion is satisfied and false if termination criterion is not satisfied

$$T : M- > \{true, false\} \quad (14)$$

After the initialization, the p function is iteratively run until the t function returns true. Where the p moves around search spaces.

In mathematically,

$$M_i = S(M_i, F_j) \quad (15)$$

Where M_i indicate the I^{th} moth, F_j indicate the j^{th} flame, and S indicate the spiral function

- **Distance:**

The distance between moth and flame i & j respectively, can be found in Cartesian distance as follows:

$D_i = |F_j - M_i|$ (16)

D_i indicate the distance of I^{th} Moth for the J^{th} Flame.

- **Movement:**

The movement of a Moths "I" is travel to flame "J" is determined by following equation

$S(M_i, F_j) = D_i * e^{bt} * \cos(2pt) + F_j$ (17)

Where D_i indicate the distance of I^{th} Moth for the J^{th} Flame, b is a constant for defining the shape of the logarithm spiral, and t is a random number in [-1,1]

V. Implementation Part

To test the algorithm, initially the simple radial system shown in Fig.1 was considered. The maximum fault current just beyond bus A and bus B are 4000A and 3000A respectively, the plug settings of the relays are taken as 1, the CT ratios at bus A and bus B are taken as 300:1 and 100:1 respectively. Minimum operating time for each relay is considered as 0.2s and STI is taken as 0.57 s. Calculation of value of ap is done by using equation (1) and is as shown in Table II.

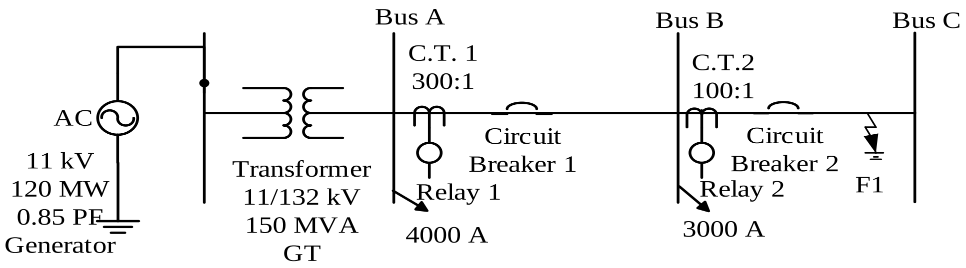

TABLE II

CALCULATION OF CONSTANT FOR RELAY

Sr. No.	Fault Location	Relay R_A	Relay R_B
1	Just Beyond Bus A	2.63	----
2	Just Beyond Bus B	2.97	2

'---' indicates that the fault is not seen by that relay

These lead to the following optimization equations: Objective Function:

S=2.63*x(1)+2*x(2) (18)

Subject to the coordination constraint

$2.63*x(1) - 2*x(2) \geq 0.5$ (19)

And the lower bounds on the relay decided by the minimum time for the relay to operate. (This time is taken as 0.2 sec.)

$2.63\ x(1) \geq 0.2$ (20)

$2\ x(2) \geq 0.2$ (21)

The upper limit is taken at 1.2.

'x' denotes the TMS. The subscript is for relay number. This problem is of three dimensional ('d'=2). The optimization equations were solved using MFO Algorithm in the MATLAB. The search agent no 40 and the number of iterations was 100.

The results obtained for the TMS is shown in Table III. The values are only for IDMT relay characteristics and for other relays we can find out using the same. The results for other characteristics are tabulated for the verification purpose that we can find out optimal setting for the same after references. The results are compared with Linear Programming. The linear Programming tool is available in MATLAB optimization toolbox. The total optimal time of operation is found out using following techniques mentioned in Table IV.

TABLE III

TMS OBTAINED USING MFO AND LP METHOD

Relay	TMS	LP	MFO
R_A	x(1)	0.2891	0.27
R_B	x(2)	0.11	0.1

TABLE IV

'S' OBTAINED USING MFO AND LP METHOD

Total Operating Time	LP	MFO
S	0.399	0.38

As seen MFO gives total operating time 's' =0.38 s which is least compared to that obtained by and Linear programming method.

VI. CONCLUSION

The Time of Operation for the relay coordination is found out using both the techniques and the results are far better than the conventional one and near about optimal. The results using Moth Flame Algorithm in some cases are same as linear programming method but overall result is better than Linear Programming. We can further improve the result by modifying the constant or by changing constraint handling method.

REFERENCES

[1] S. Niyomphant, U. Leeton, T. Kulworawanichpong, and N. Chomnawang, "Application of linear programming for optimal coordination of directional over-current relays," *2012 9th Int. Conf. Electr. Eng. Comput. Telecommun. Inf. Technol. ECTI-CON 2012*, pp. 1–4, 2012.
[2] S. S. Gokhale and V. S. Kale, "Application of the firefly algorithm to optimal over-current relay coordination," *2014 Int. Conf. Optim. Electr. Electron. Equipment, OPTIM 2014*, no. 2, pp. 150–154, 2014.
[3] D. K. Singh and S. Gupta, "Optimal coordination of directional overcurrent relays: A genetic algorithm approach," *2012 IEEE Students' Conf. Electr. Electron. Comput. Sci. Innov. Humanit. SCEECS 2012*, pp. 1–4, 2012.
[4] D. Uthitsunthorn, P. Pao-la-or, and T. Kulworawanichpong, "Application of artificial bees colony algorithm for optimal overcurrent relay coordination problems," *Trans. Electr. Eng. Electron. Commun.*, vol. 10, no. 1, pp. 98–107, 2012.
[5] M. Bashir, M. Taghizadeh, J. Sadeh, and H. R. Mashhadi, "A new hybrid particle swarm optimization for optimal coordination of over current relay," *2010 Int. Conf. Power Syst. Technol. Technol. Innov. Mak. Power Grid Smarter, POWERCON2010*, pp. 1–6, 2010.
[6] S. Mirjalili, "Moth-flame optimization algorithm: A novel nature-inspired heuristic paradigm," *Knowledge-Based Syst.*, vol. 89, no. July, pp. 228–249, 2015.
[7] I. N. Trivedi, S. V. Purani, and P. K. Jangir, "Optimized over-current relay coordination using Flower Pollination Algorithm," *Souvenir 2015 IEEE Int. Adv. Comput. Conf. IACC 2015*, pp. 72–77, 2015.
[8] S. V Purani, "Optimal Over current relay co-ordination using Firefly Algorithm in Electrical Network : A nature inspired approach," 2016.
[9] L. Bianchi, M. Dorigo, L. M. Gambardella, and W. J. Gutjahr, "A survey on metaheuristics for stochastic combinatorial optimization," *Nat. Comput.*, vol. 8, no. 2, pp. 239–287, 2009.
[10] M. Singh, B. K. Panigrahi, and R. Mukherjee, "Optimum Coordination of overcurrent relays using CMA-ES algorithm," *PEDES 2012 - IEEE Int. Conf. Power Electron. Drives Energy Syst.*, pp. 1–6, 2012.
[11] Stanley H. Horowitz, Arun G. Phadke, Power System Relaying, third edison, John Wiley & Sons Ltd., Research Studies Press Limited 2008

[12] H. Zeineldin, E. F. El-Sadany, M. A. Salama, "Optimal Coordination of Directional Overcurrent Relay Coordination", Power Engineering Society general meeting, IEEE, pp. 1101-1106, vol. 2, June 2005.

[13] A. Turaj, "Coordination of Directional Overcurrent Relays Using Seeker Algorithm", IEEE Transactions on Power Delivery, pp. 1415-1422, 2012.

[14] C. Castillo, A. Conade, "Coordination of Overcurrent Relays Using Genetic Algorithms and Unconventional Curves", IEEE Latin America Transactions, Vol. 12, No. 8, December 2014.

[15] P. P. Bedkar, S. R. Bhide, "Optimal Coordination of Directional Overcurrent Relay Using the Hybrid GA-NLP Approach", IEEE Transactions on Power Delivery, vol. 20, No.1, January 2011.

[16] Bhalja, Maheshwari, Chothani, Protection and Switchgear, Oxford University Press, New Delhi, 2011.