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PERFORMANCE OF PSO ALGORITHM IN COORDINATION OF DIRECTIONAL OVERCURRENT RELAYS CONSIDERING FAULT CURRENT DIRECTION

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Abstract- In an electric power network, from view point of many consumers, power generation, and transmission should become exactly without interruption. Because the distribution system relates directly to consumers so should have high reliability. Overcurrent relays are often used for primary protection of distribution lines and secondary protection of radial transmission lines. The main objective in protection systems is the rapid separation of minimum amount of equipment as much as possible and without operation interference. These should be done after error detection in the system. This paper proposes proper coordination of directional overcurrent relays (DOCR) based on Particle swarm optimization (PSO) algorithm with take into account of fault current direction restriction. The proposed algorithm has been tested in the standard IEEE 30 bus distribution system.

Keywords: Directional Overcurrent Relays, Fault Current Direction, Optimal Relay Setting, PSO Algorithm.

1. INTRODUCTION

Distribution systems because of their importance, should have high reliability. Although distribution networks are exposed to various errors such as short circuits. So, a measurement, monitoring and control system is an essential part of these systems. each network in which the error occurred and detected at the earliest possible time separate from the rest of the network and Until the error is not resolved, the entire network is at risk. Such a control and monitoring system, is named a protection system. Directional overcurrent relay is used in protection systems of mesh networks and specially for faults that are in its forward zone. analysis method investigated to select optimal pickup current and time dial setting to minimize operation time of relays [1].

Hybrid PSO algorithm is shown in coordination overcurrent relay in Variable Network Topologies [2]. performance of Artificial bee colony algorithm in selecting of relay setting has shown in [3]. Application of evolutionary algorithm for optimal Directional overcurrent relay coordination is shown in [4].

The performance of PSO algorithm about coordination of overcurrent and distance relays discussed in [5]. Coordination of overcurrent relays in interconnected networks using accurate analytical method and based on determination of fault critical point has been discussed in [6].

Also coordination of directional overcurrent relays considering fault current direction has been investigated in [7]. Location of faults influence on optimal coordination of directional overcurrent relay has been investigated in [9]. Coordination of directional overcurrent relays using seeker algorithm is shown in [10]. A new nonlinear directional overcurrent relay coordination technique, and banes and boons of near-end faults based approach is shown in [11]. Reviewing the impacts of distributed generation on distribution system protection discussed in [12]. Implementation of full adaptive technique to optimal coordination of overcurrent relays is shown in [13]. Optimum coordination of overcurrent relays in distribution system using genetic algorithm has shown in [14].

2. DIRECTIONAL OVERCURRENT RELAYS COORDINATION

Inverse time overcurrent relays that is used mainly in distribution systems, are an example of protective relays.in a normal power system, overcurrent relays should guarantee fast performance, reliability, and selectivity. In order to ensure coordination between relays, operation time of backup relay should be greater than operating time of main relay as coordination time interval (CTI). The objective function is taken to be the sum, T, of the coordination times of all the relays which needs to be minimized as follows:

$$T=\sum_{i=1}^{n}\sum_{j=1}^{m}(tp_{ij}+tb_{ij}) \tag{1}$$

Minimization of main and backup relays operating time is an essential problem by upon formulation and N indicates number of relays but M is as number of fault locations. The inverse time current characteristic of a directional overcurrent relay is formulated by Equation (2):

$$t = TDS \frac{A}{\left(\frac{I_{sc}}{I_p}\right)^B - 1} \quad (2)$$

Before substituting the relay operating time in the objective function in Equation (1), its direction should be checked using the following constraint:

$$\theta_{\min} \le \theta \le \theta_{\max} \quad (3)$$

where, $\theta_{\min}$ and $\theta_{\max}$ are as the relay angle limits which represent the forward operation zone of the relay and are taken as 135 and 45, respectively based on [8]. If this equation was attended, the relay time is added to the objective function and the primary/backup pair scheme is not modified otherwise the relay operating time is excluded and the relay primary/backup pair is modified taking into account the fault current direction. Parameters *A* and *B* for standard inverse overcurrent relay is 0.14 and 0.02, respectively. The *CTI* is as interval of coordination time and shows the minimum time difference between the primary and the backup relay and generally is between 0.2-0.5 s and it is chosen to be 0.3 s in this analysis. The minimum and maximum pick up current will depend on the system's rated load currents and system's short circuit levels. Parameter *TDS* could take between 0.1 and 0.3.

$$t_{bij} - t_{pij} \ge CTI \quad (4)$$

$$I_{pj\min} < I_{pj} < I_{pj\max} \quad (5)$$

$$TDS_{\min} < TDS_j < TDS_{\max} \quad (6)$$

3. PARTICLE SWARM OPTIMIZATION

The main idea of particle algorithm, obtained sessions of collective fish and birds adapted. In order to model the mass movement of animals is considered two approaches, one dimension, the social interaction between the group members and other individual scores, which may possess that each member of the group, their past. In the next *Nvar* optimize a problem, a particle, an array element is a row with *Nvar*. The array is defined as follows:

$$particle = [P_1, P_2, \ldots, P_{Nvar}] \quad (7)$$

Particle that is the lowest cost as the best of the bunch is considered as a best experience, It should be noted that the initial velocity for each particle is formed randomly.

$$V = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_N \end{bmatrix} = \begin{bmatrix} v_{1,1} & v_{2,1} & \cdots & v_{Nvar,1} \\ v_{1,2} & v_{2,2} & \cdots & v_{Nvar,2} \\ \vdots & \vdots & \ddots & \vdots \\ v_{1,N} & v_{2,N} & \cdots & v_{Nvar,N} \end{bmatrix} \quad (8)$$

After producing the initial population (particles) and consider an initial velocity for each particle, the performance of each particle is calculated based on its position, of Each particle velocity based on the best response obtained in the group of particles (the best of the bunch) and it was the best place ever will change. At the same time changes the position of the particle quickly gathered, a new position of particle is obtained. Speed particles at each step is updated according to the following equation to calculate the position of the particle.

$$v_{k+1}^i = wv_k^i + c_1.r_1.\left(p_k^i - x_k^i\right) + c_2.r_2.\left(p_k^g - x_k^i\right) \quad (9)$$

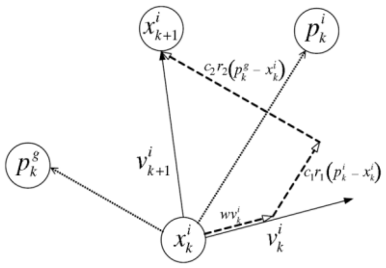

Figure 1. Updating velocity and position

The direction of particles to its new location is shown in Figure 2, each particle in PSO is consisted of two dimension (*TDS*, I_p).

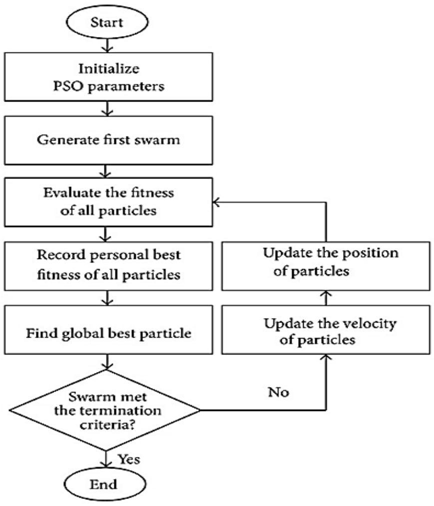

Figure 2. Flow chart of PSO

The test system is a distribution portion of the IEEE 30 bus which represents a portion of the American Electric Power System and its parameters are available in [15]. The mentioned system has been composed from three 33/132 kV distribution substations which have been connected to 15 feeders protected by 28 directional overcurrent relays. Fault nodes (F15-F30) have been investigated on feeders.

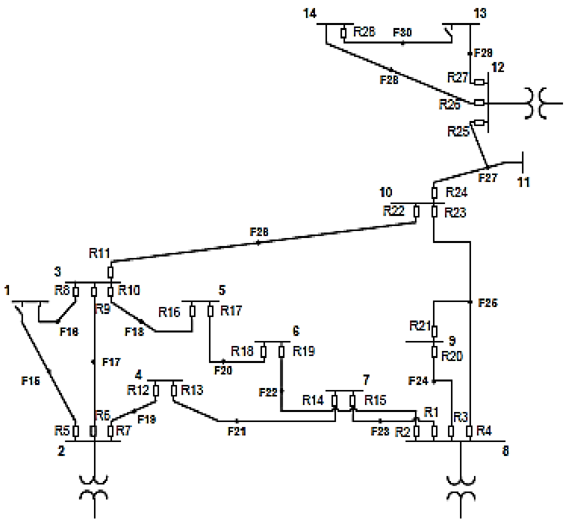

Figure 3. Distribution portion of the IEEE 30-bus system

4. LOAD FLOW ANALYSIS

The Newton-Raphson method for load flow is used for IEEE 30 bus system and the result in showed Figure 5. voltage deviation from the amount of content for distribution networks according to standards is 10%.

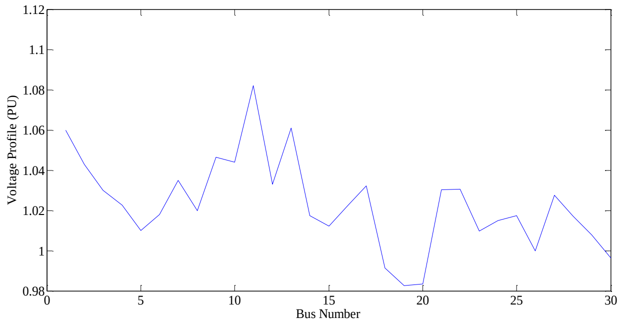

Figure 4. Voltage profile of distribution portion of IEEE 30-bus system

5. COORDINATION OF DIRECTIONAL OVERCURRENT RELAYS USING PSO WITHOUT CHECKING OF FAULT CURRENT DIRECTION

In this section, particle swarm optimization is used to determine optimal settings (TDS, I_p) of 28 directional overcurrent relays in IEEE 30 bus system without checking of constraint (3) and total relay operating time in this section is 59.23 s. The result of parameters is determined by the algorithm and showed by following:

Table 1. Optimal setting of relay (TDS, I_p) for the mentioned system using PSO without checking of fault current direction

Relay	TDS (s)	I_p (A)	Relay	TDS (s)	I_p (A)
1	0.1618	204.08	15	0.2414	227.26
2	0.1323	907.641	16	0.1290	480.7
3	0.1946	1712.3	17	0.1269	510.315
4	0.2243	221.831	18	0.1302	122.6
5	0.1671	258.08	19	0.1285	276.56
6	0.1062	426.41	20	0.1080	766.3
7	0.1011	171.5	21	0.1099	207.35
8	0.2704	41.79	22	0.1608	78.83
9	0.2123	389.44	23	0.1221	310.77
10	0.1383	1156.7	24	0.1345	161.98
11	0.1363	498.88	25	0.1436	112.16
12	0.2672	245.89	26	0.2014	462.13
13	0.1288	209.44	27	0.2181	883
14	0.2247	108	28	0.1333	453.4

Table 2. Optimal operating time of the primary and backup relays using PSO without checking of fault current direction

Fault location	Operation	Time of	Relays	in sec
	P	B1	B2	B3
F22	R2	R15	R21	R23
	0.1323	1.049	0.7576	0.8125
	R19	R17	......	......
	0.1515	0.7538	......	......
F23	R1	R19	R21	R23
	0.1618	1.090	0.6394	0.8125
	R15	R13	......	......
	0.2954	1.2645	......	......
F24	R3	R15	R19	R21
	0.1946	1.2847	1.2847	1.2847
	R20	R4	R23	......
	0.1515	0.8556	0.8531	......
F25	R4	R15	R19	R20
	0.2305	1.049	1.090	0.8780
	R21	R3	R25	......
	0.2393	1.044	0.5752	......
	R23	R11	......	......
	0.1972	0.6297	......	......

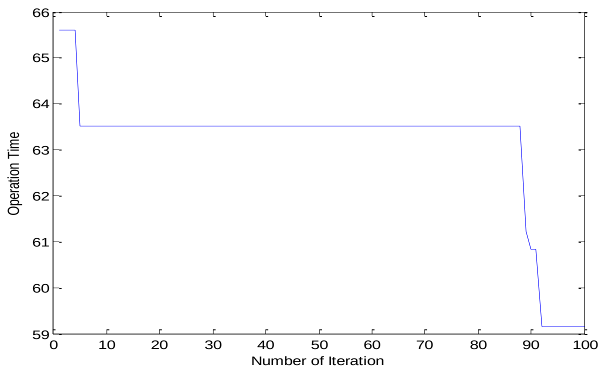

Figure 5. The total relay operating time using PSO without checking of fault current direction

6. COORDINATION OF DIRECTIONAL OVERCURRENT RELAYS USING PSO WITH CHECKING OF FAULT CURRENT DIRECTION

By adding Constraint (3), primary / backup scheme has changed, and in this case, the scheme should be modified and error detection relay is dependent on the direction of current and fault location. Analysis results of the short circuit by attention to the relay direction for the mentioned test system investigate that there are a few backup relays in which the short circuit current pass in opposite direction of the expected relay attended to the backup scheme.

This problem will cause misoperation of some relays. Table 4 represents the optimal relay setting (TDS, I_p) using the proposed formulation. The total operating relay time is 47.69 s. This means formulation of section 6 presents wrong results in regarding the optimal settings, optimal operating times of the relay totally. Table 1 summarizes misoperation of relays due to reverse direction for midpoint faults.

Table 3. Relay maleoperation because of reverse direction

Fault position	Relay with wrong performance
F22	R21
F23	R21
F24	R21
F25	R21

Table 4. Optimal relay setting (TDS, I_p) for IEEE 30-bus system using PSO with checking of fault current direction

Relay	TDS (s)	I_p (A)	Relay	TDS (s)	I_p (A)
1	0.149	156.26	15	0.121	183.062
2	0.110	410.85	16	0.190	148.13
3	0.167	639.64	17	0.151	497.24
4	0.100	217.10	18	0.103	227.23
5	0.165	214.69	19	0.1673	158.55
6	0.186	438.95	20	0.103	483.94
7	0.1041	171.46	21	0.133	178.79
8	0.152	102.41	22	0.214	51.83
9	0.109	410.06	23	0.221	174.32
10	0.122	1071.82	24	0.112	135.65
11	0.127	1033.85	25	0.109	219.00
12	0.239	228.72	26	0.126	127.10
13	0.141	176.36	27	0.236	759.34
14	0.114	99.39	28	0.174	173.12

Table 5. Optimal primary and backup relay operating times using PSO with checking of fault current direction

Fault location	Operating	Time of	Relays	in sec
	P	B1	B2	B3
F22	R2	R15	R23	......
	0.161	0.571	0.942	......
	R19	R17	......	......
	0.167	0.693	......	......
F23	R1	R19	R23	......
	0.149	0.840	0.942	......
	R15	R13	......	......
	0.206	0.966	......	......
F24	R3	R15	R19	......
	0.184	0.788	0.84	......
	R20	R4	R23	......
	0.395	0.721	0.5546	......
F25	R4	R15	R19	......
	0.211	0.496	0.840	......
	R21	R3	R25	......
	0.229	0.636	0.711	......
	R23	R11	......	......
	0.221	0.84	......	......

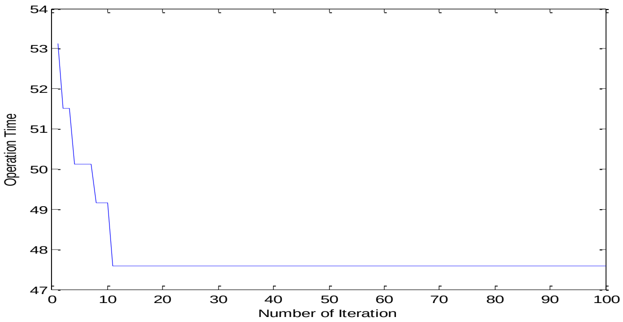

Figure 6. The total relay operating time using PSO with checking of fault current direction

7. CONCLUSION

Based on the result of the optimization algorithm. This paper investigates the impact of short circuit current direction when carrying out directional overcurrent relays coordination mainly by enlargement of complication in power system. The proposed approach examined on the IEEE 30-bus distribution system. Simulation results validate the proposed approach and investigate importance of short circuit currents direction controlling in directional overcurrent relays coordination.

REFERENCES

[1] A. Mahari, H. Seyedi, "An Analytic Approach for Optimal Coordination of Overcurrent Relays", IET Journal of Generation, Transmission & Distribution, Vol. 7, pp. 674-680, Feb. 2013.

[2] M. Ta Yang, A. Liu, "Applying Hybrid PSO to Optimize Directional Overcurrent Relay Coordination in Variable Network Topologies", Hindawi Publishing Corporation Journal of Applied Mathematics, Vol. 2013, pp. 1-9, January 2013.

[3] M.H. Hussain, "Solving Directional Overcurrent Relay Coordination Problem Using Artificial Bees Colony", International Journal of Electrical, Electronic Science and Engineering, Vol. 8, pp. 705-710, May 2014.

[4] N.M. Stenane, K.A. Folly, "Application of Evolutionary Algorithm for Optimal Directional Overcurrent Relay Coordination", Journal of Computer and Communications, Vol. 2, pp. 103-111, May 2014.

[5] A.A. Motie Birjandi, M. Pourfallah, "Optimal Coordination of Overcurrent and Distance Relays by a New Particle Swarm Optimization Method", International Journal of Engineering and Advanced Technology (IJEAT), Vol. 1, pp. 93-98, December 2011.

[6] D.S. Alkaran, M.R. Vatani, "Overcurrent Relays Coordination in Interconnected Networks Using Accurate Analytical Method and Based on Determination of Fault Critical Point", IEEE Transactions on Power Delivery, Vol. 30, pp. 870-877, April 2015.

[7] H.M. Sharaf, H.H. Zeineldin, D.K. Ibrahim "Protection Coordination of Directional Overcurrent Relays Considering Fault Current Direction", 5th IEEE Innovative Smart Grid Technologies Conference (ISGT Europe), pp. 1-5, 2015.

[8] J. Horak, W. Babic, "Directional Overcurrent Relaying (67) Concepts", 59th IEEE Annual Conference for Protective Relay Engineers, pp. 1-8, 2006.

[9] C. Aggarwal, H.A. Mangalvedekar, H.B. Chaudhari, "Effect of Fault Location on Optimal Coordination of Directional Over Current Relay", IEEE Conference of TENCON, pp. 1-5, 2008.

[10] T. Amraee, "Coordination of Directional Overcurrent Relays Using Seeker Algorithm", IEEE Transactions on Power Delivery, Vol. 27, pp. 1415-1422, April 2012.

[11] D. Birla, R. Prakash Maheshwari, H.O. Gupta, "A New Nonlinear Directional Overcurrent Relay Coordination Technique, and Banes and Boons of Near-End Faults Based Approach", IEEE Transactions on Power Delivery, Vol. 21, pp. 1176-1182, June 2006.

[12] M.T. Doyle, "Reviewing the Impacts of Distributed Generation on Distribution System Protection", IEEE Power Engineering Society Summer Meeting, pp. 103-105, 2002.

[13] M. Ojaghi, Z. Sudi, J. Faiz, "Implementation of Full Adaptive Technique to Optimal Coordination of Overcurrent Relays", IEEE transactions on power delivery, Vol. 28, pp. 235-244, January 2013.

[14] P.P. Bedekar, "Optimum Coordination of Overcurrent Relays in Distribution System Using Genetic Algorithm", International Conference on power system, pp. 1-6, 2009.

[15] Univ. Washington, Power Systems Test Case Archive, www.ee.washington.edu.

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