# POWERCON
2010 HANGZHOU

## 2010 International Conference on Power System Technology

### Technological Innovations Making Power Grid Smarter

**24-28 October, 2010 Hangzhou, China**

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# A New Hybrid Particle Swarm Optimization for Optimal Coordination of Over Current Relay

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*Abstract*—**Directional over current relays (DOCRs) coordination problem is a nonlinear and nonconvex problem which has many constraints. Optimal coordination of over current relays has been usually solved using linear and nonlinear programming. Also genetic algorithm and particle swarm optimization methods are used to fined the optimal solution of the problem. In this paper a new hybrid approach will be used for optimal coordination of over current relays. In this work, both time setting multiplier (TMS) and current setting ($I_P$) are taken into account in the optimization procedure. The former is consider as a continues parameter and the later is assumed to be discrete parameter. The novelty of this paper is that quantizing $I_P$ parameter is taken into account as a part of optimization producer in the particle swarm optimization iterations. After that, we can calculate the optimum TMS with linear programming at the end of each iteration of PSO optimization algorithm. To increase the accuracy of proposed algorithm, first particle positions of swarms was calculated with linear approaches. Both near-end and far-end faults are taken into account in the constraint of the optimal coordination problem and the results are compared with the other methods. The obtained results are quite encouraging and will be useful as an effective method for coordination of over current relays.**

*Index Terms*--: **Over current relay, hybrid PSO, linear programming, relay coordination**

## I. Introduction

THE problem of coordinating protective relays in electric power system consists of selecting their suitable settings such that their fundamental protective function is met under the requirements of sensitivity, selectivity, reliability and speed. The optimal settings of these types of relays play an important role in reducing the impact of the fault on the power system. The calculation of the TMS as a continues parameter and the $I_P$ as a discrete parameter, is the core of the coordination study. Several optimization techniques have been proposed for coordinating directional overcurrent relays. One of the simplest method is to use linear method like simplex two-phase. In [1], it is assumed that the $I_P$ are predetermined by choosing one of the available pickup current settings as the predetermined value, thus, the problem becomes a linear and can be solved by linear programming problem. The simplex two-phase method was proposed to determine the optimal TMS of the relays. However, there could be better $I_P$ for the relays, other than the predetermined one, that would provide a optimal solution for the coordination problem. In [2], both TMS and $I_P$ were assumed to be continuous and the generalized reduced gradient nonlinear optimization technique was proposed to calculate the optimal relays' settings. As the $I_P$ is a discrete value in such relays, the discrete $I_P$ solutions was obtained by rounding off the continuous $I_P$ solutions to its nearest discrete value. Unfortunately, rounding the $I_P$ value could lead to a solution that is outside the feasible region or not optimum setting. In [3], the coordination problem was proposed by considering the dynamic changes in the network topology but it used linear methods as [2]. Recently, the interest in applying artificial intelligence in optimization has grown rapidly. Genetic algorithm (GA) [4] and particle swarm optimization (PSO), are two powerful tools for solving the complex and nonlinear optimization problems like optimal coordination of overcurrent relays. In [5], the GA was applied to the coordination problem to reach the global optimum value with less computational time compared to conventional single point searching methods. In [6] a hybrid GA was used for solving optimal time coordination of over current relays considering different network topologies. A common feature between PSO and most EA is that it is initialized with a random population, but unlike all EA it does not rely on the famous Darwinian natural selection "survival of the fittest", but mainly depends on "constructive co-operation" among individuals (agents). Another important difference between PSO and EA is the ability of PSO to keep track of the position, and the change in position (velocity) of each particle (agent), while EA can only keep information regarding the position of the members of the population. As the conventional PSO capable of finding solution for unconstraint problems, a modified PSO is necessary to consider the constraints.

In this paper a new hybrid method is proposed to find the optimal coordination of over current relays. In this work we take into account both TMS as a continues parameter and $I_P$ as a discrete parameter in optimization procedure. The novelty of this paper is that quantizing $I_P$ parameter is consider as a part of optimization producer in particle swarm optimization iterations. After that, we can calculate the optimum TMS with linear programming at the end of each iteration of PSO optimization algorithm. To increase the accuracy of proposed algorithm, first particle positions of swarms are calculated with linear approaches. Both near-end and far-end faults are taken into account in the constraint of the optimal coordination

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problem and the results are compared with other methods. The obtained results are quite encouraging and will be useful as an effective method for coordination of over current relays.

## II. Relay Coordination Problem

In the coordination problem of DOCRs, the goal is to determine the time multiplier setting and pickup current setting of each relay, so that the overall operating time of the primary relays is minimized [6]. Therefore, the objective function can be defined as follows:

$$\min J = \sum_{i=1}^{n} W_i t_i \tag{1}$$

where n is the number of relays and $t_i$ is the operating time of the *i*th relay for near-end fault. In Fig. 1, the near-end fault and the far-end fault for *i*th relay are shown as $F_1$ and $F_2$ , respectively. The weight $W_i$ depends upon the probability of a given fault occurring in each protection zone and is usually set to one [6].

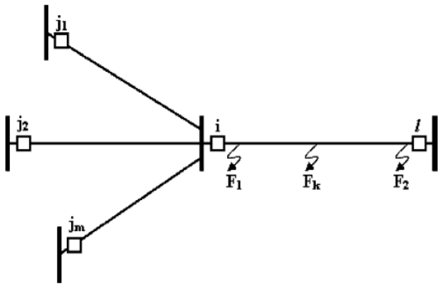


Fig. 1. Primary and backup relays

### A. Relay Characteristic

All relays were assumed identical and with characteristic functions approximated by the following equation [1]

$$T_i = \frac{0.14 \times TMS_i}{\left(\frac{I_i}{I_{set_i}}\right)^{0.14} - 1} \quad \text{and} \quad \left(\frac{I_i}{I_{set_i}}\right) = \text{PSM}_i \tag{2}$$

where $TMS_i$ and $I_{set_i}$ are the time multiplier setting and pickup current setting of the *i*th relay, respectively and $I_i$ is the fault current passing through *i*th relay. It can be seen from (2) that the nonlinearity in relay characteristics function is related to pickup current variable. If the parameter $I_{set}$ is assumed to be determined prior, then the relay characteristics will be a linear function of TMS variable. In this case, the coordination problem can be formulated as a linear programming problem.

### B. Bounds on the Relay Settings

The limits on the relay parameters can be presented as follows:

$$TMS_i^{\min} < TMS_i < TMS_i^{\max} \tag{3}$$

$$\max(\alpha . I_{load_i}^{\max}, I_{set_i}^{\min}) < I_{set_i} < \min(\beta . I_{fault_i}^{\min}, I_{set_i}^{\max}) \tag{4}$$

The minimum pickup current setting of the relay is the maximum value between the minimum available tap settings ( $I_{set}^{\min}$ ) on the relay and maximum load current ( $I_{load}^{\max}$ ) passes through it. In similar, the maximum pickup current setting is chosen less than the minimum value between the maximum available tap settings ( $I_{set}^{\max}$ ) on the relay and minimum fault current ( $I_{fault}^{\min}$ ) which passes through it.

### C. Primary-Backup Relay Constraint

The coordination constraints between the primary relay and its/their backup relay(s) for the near-end and the far-end faults are: (see Fig. 1)

$$t_j^{F_1} - t_i^{F_1} \geq CTI \tag{5}$$

$$t_j^{F_2} - t_i^{F_2} \geq CTI \tag{6}$$

where $t_i^{F_1}$ and $t_i^{F_2}$ are the operating time of *i*th primary relay for the near-end and far-end faults, respectively. Also, $t_j^{F_1}$ and $t_j^{F_2}$ are defined in the same way as the *j*th backup relay. The Coordination Time Interval (CTI) is the minimum interval that permits the backup relay to clear a fault in its operating zone. In other words, the CTI is the time lag in operation between the primary and its backup relay. It includes many factors, such as the breaker operating time, relay overtravel time and a safety margin. The value of CTI is usually selected between 0.2 and 0.5 s.

## III. Conventional Particle Swarm Optimization

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Eberhart and Kennedy in 1995 [7], [8]. PSO is inspired from the swarming behavior of animals and human social behavior. PSO shares many similarities with evolutionary computation techniques such as GA. The problem is initialized with a population of feasible random solutions; however, PSO has no evolution operators such as crossover and mutation. In PSO, the feasible solutions, called particles, fly through the problem space by following the current optimum particles. The particle adjusts its position according to its own experience and the experience of the neighboring particles. Let *x* and *v* denote the particle's position and its velocity in the search space. Thus, the position of the *n*th particle in a *D*-dimensional space is represented as (7).

$$x_n = [x_{n1}, x_{n2}, x_{n3}, \ldots, x_{nd}] \tag{7}$$

The best previous position explored by the *n*th particle is recorded and denoted as $pbest_n$. Another value that is recorded by the particle swarm optimizer is the best value obtained so far by any particle in the population. This best value is a global best and is known as gbest. Each particle tries to modify its position using the current velocity and its distance from pbest and gbest. The modification can be represented by the concept of velocity and can be calculated as shown in the following formulas:

$$v_{nd}^{i+1} = \omega.v_{nd}^{i} + c_1.rand().(p_{best_{nd}} - x_{nd}^{i}) + c_2.rand().(g_{best} - x_{nd}^{i}) \quad (8)$$

$$x_{nd}^{i+1} = x_{nd}^{i} + v_{nd}^{i+1} \quad (9)$$

$$\left|v_{nd}^{i+1}\right| \le kV_{\max} \quad (10)$$

The first term in (8) represents the inertia of the particle, while the second and third terms represent the memory and the cooperation between particles, respectively. The parameter $V_{max}$ represents the resolution with which regions within the feasible search space are to be searched. Choosing a high number for $V_{max}$, can make the particles fly past the optimal solutions. On the contrary, by setting small value for $V_{max}$, particles may not explore sufficiently and the particle becomes trapped in a local optimal solution. The constants $c_1$ and $c_2$ represent the learning rate or the acceleration term that pulls each particle towards $p_{best}$ and $g_{best}$ positions. High values of $c_1$ and $c_2$ could cause the particle to move past the optimal solution. While low values could cause the particle to get trapped in a feasible solution before being pulled toward to the optimal solution. The inertia weight $\omega$ governs how much of the previous velocity should be retained from the previous time step. In this work a linearly decreasing inertia weight is used, as follows:

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{itr_{\max}} \times itr \quad (11)$$

where $\omega_{\max}$ and $\omega_{\min}$ are the maximum and minimum weight values that are constant and $itr$ is the iteration number. This setting allows the particles to explore a large area at the start of the simulation (when the inertia weight is large), and to refine the search later by using a small inertia weight. In addition, damping the oscillations of the particles around $g_{best}$ is another advantage gained by using a decreasing inertia weight. These oscillations are recorded when a large constant inertial weight is used. Accordingly, damping such oscillations assists the particles of the swarm to converge to the global optimal solution. In (10), k is a coefficient for controlling the velocity of particle and is defined in $0.1 \le k \le 1$ [12]. Updating procedure is shown in Fig. 2 [10].

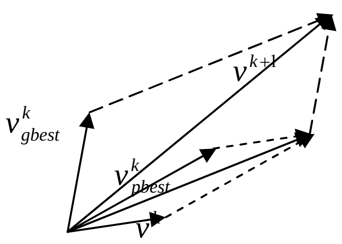


Fig. 2. Updating process in conventional PSO [12]

## IV. PROPOSED HYBRID PSO AND LP METHOD

In most published literature, the standard PSO algorithm is used for unconstrained optimization tasks. PSO in its standard form is not capable of dealing with the coordination of DOCR, which is a constrained optimization problem. Different approaches were presented to modified conventional PSO. In [9], a penalty factor is used for updating process. In this way the speed of convergence to optimal solution is very low. In [10], constraints were satisfied by using a fitness function. In [11], the problem was formulated as a mixed-integer and in updating process by controlling the speed, the constraint were satisfied.

In this paper a very simple method base on hybrid of PSO and linear programming is presented. At the beginning for creating the first population, a random set of $I_{set}$ which one available in the relays are selected and then for improving the convergence of PSO the TMS are computed with linear programming. Then the position of each particle ($I_{set}$) is updated with (8) and then the constraints should be checked. If the constraints are not satisfied, then updating process are done with (12). again the constraints are checked. If again the constraints are not satisfied, updating is done by (13). Thus we have:

If the constraints are not satisfied for the first time:

$$\begin{cases} v_{nd}^{i+1} = c_2.rand().(g_{best_{nd}} - x_{nd}^{i}) \\ x_{set}^{i+1} = x_{set}^{i} + v_{nd}^{i+1} \end{cases} \quad (12)$$

If the constraints are not satisfied for the second time:

$$\begin{cases} v_{nd}^{i+1} = 0 \\ x_{set}^{i+1} = p_{best_{nd}} \end{cases} \quad (13)$$

After updating the $I_{set}$ is finished and quantizing to available setting, the TMS can be calculated with linear method at the end of each iteration of PSO method. Both near-end and far end faults are taken into account in the constraint of the optimal coordination problem. To show the accuracy of the proposed method the result are compared with linear programing and GA methods.

## V. SIMULATION

In order to evaluate the performance of the proposed method, it is applied to a 8-bus, 7-branch, 14-overcurrent relay network sketched in Fig. 3. All relays have inverse characteristic as shown in (2) and the aim is to find an optimal setting for network relays in order to minimize the final operating time and in such a way that all constraints are satisfied. The system data for lines, transformers, generators and loads are presented in table I, II, III, IV. TMS is a continues parameter which can set in [0.1 1.1], while the $I_{set}$ is a discrete value which can set in specified numbers (0.5, 0.6, 0.8, 1, 1.5, 2.5). The ratios of the current transformers (CTs) are indicated in Table V, and CTI is assumed to be 0.3 seconds. In order to solve the relay coordination problem first, it need to determine the primary and backup relay pairs.

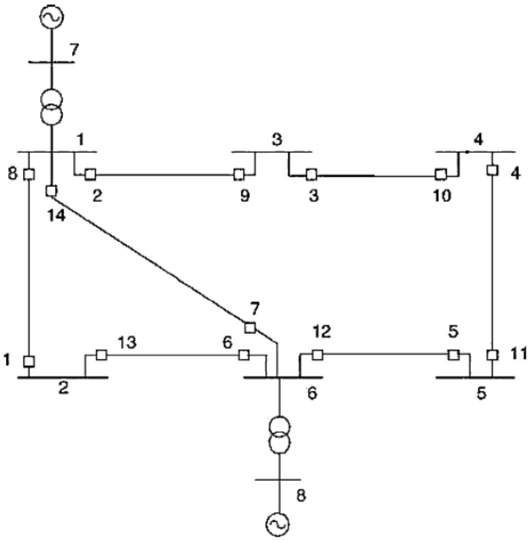


Fig. 3. Single line diagram of 8-bus system

TABLE I
LINE CHARACTRISTICS

| *Nodes* | $R(\Omega / km)$ | $X(\Omega / km)$ | *Length (km)* |
|---|---|---|---|
| 1-2 | 0.004 | 0.05 | 100 |
| 1-3 | 0.0057 | 0.0714 | 70 |
| 3-4 | 0.005 | 0.0563 | 80 |
| 4-5 | 0.005 | 0.045 | 100 |
| 5-6 | 0.0045 | 0.0409 | 110 |
| 2-6 | 0.0044 | 0.05 | 90 |
| 1-6 | 0.005 | 0.05 | 100 |

TABLE II
TRNSFORMER DATA

| *Node* | $S_n(MVA)$ | $V_p(kV)$ | $V_s(kV)$ | *X%* |
|---|---|---|---|---|
| 7-1 | 150 | 10 | 150 | 4 |
| 8-6 | 150 | 10 | 150 | 4 |

TABLE III
GENERATOR DATA

| *Node* | $S_n(MVA)$ | $V_p(kV)$ | $V_s(kV)$ |
|---|---|---|---|
| 7 | 150 | 10 | 150 |
| 8 | 150 | 10 | 150 |

TABLE IV
LOAD DATA

| *Nodes* | *P(MW)* | *Q(MVAR)* |
|---|---|---|
| 2 | 40 | 20 |
| 3 | 60 | 40 |
| 4 | 70 | 40 |
| 5 | 70 | 50 |

For determining the primary and backup relay pairs, first select a relay then determine the relays which install in the far bus of the selected relay, then omitting the relay which is in the same line with selected relay. Now, it can say that the selected relays are the backup relays for the primary relay. Table VI shows the primary and backup relays pairs.

TABLE V
CT RATIOS

| *Relay no.* | *CT ratio* |
|---|---|
| 1 | 240 |
| 2 | 240 |
| 3 | 240 |
| 4 | 240 |
| 5 | 240 |
| 6 | 240 |
| 7 | 160 |
| 8 | 240 |
| 9 | 160 |
| 10 | 240 |
| 11 | 240 |
| 12 | 240 |
| 13 | 240 |
| 14 | 160 |

TABLE VI
PRIMARY AND BACKUP REALYS

| *Pairs no.* | *primary* | *backup* | *Pairs no* | *primary* | *backup* |
|---|---|---|---|---|---|
| 1 | 1 | 6 | 11 | 14 | 9 |
| 2 | 7 | 13 | 12 | 8 | 9 |
| 3 | 12 | 13 | 13 | 5 | 4 |
| 4 | 2 | 7 | 14 | 9 | 10 |
| 5 | 8 | 7 | 15 | 4 | 3 |
| 6 | 6 | 14 | 16 | 3 | 2 |
| 7 | 12 | 14 | 17 | 10 | 11 |
| 8 | 13 | 8 | 18 | 2 | 1 |
| 9 | 6 | 5 | 19 | 14 | 1 |
| 10 | 7 | 5 | 20 | 11 | 12 |

In this simulation the coefficients $\alpha .and. \beta$ are selected 1.3 and 0.6 to guarantee that relays work selective and have no conflict with load current.

The PSO parameters are determined in trial and error process and shown in Table VII.

TABLE VII
PSO COEFFICIENTS

| *coefficient* | *value* | *coefficients* | *value* |
|---|---|---|---|
| $c_1$ | 2 | $\omega_{\max}$ | 2 |
| $c_2$ | 1.5 | $\omega_{\min}$ | 0.1 |
| iteration | 30 | k | 0.5 |
| population | 15 | CTI | 0.3 |

Fig. 4. shows the convergence of the proposed method and it can be concluded that the algorithm converge to the global solution in 12 iterations. The solution of the proposed method

is shown in Table VIII. In order to demonstrate the effectiveness and performance of the proposed method, the results are compared with linear method and genetic algorithm method.

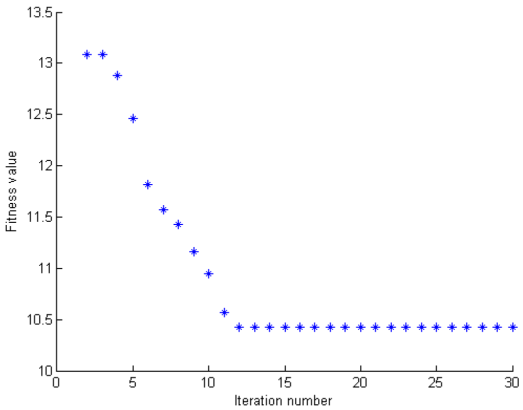


Fig. 4. Convergence of the proposed method

TABLE VIII
THE RESULTE OF METHODES

| *Relay no.* | *LP* | | *GA* | | *Proposed Hybrid PSO* | |
|---|---|---|---|---|---|---|
| | TMS | $I_{set}$ | TMS | $I_{set}$ | TMS | $I_{set}$ |
| 1 | 0.2378 | 2.5 | 0.3043 | 1 | 0.3069 | 1 |
| 2 | 0.2173 | 2.5 | 0.2917 | 2.5 | 0.1451 | 2.5 |
| 3 | 0.148 | 2.5 | 0.2543 | 2.5 | 0.1 | 2.5 |
| 4 | 0.1 | 2.5 | 0.1851 | 2.5 | 0.1 | 2.5 |
| 5 | 0.106 | 2.5 | 0.17 | 1.5 | 0.1 | 0.8 |
| 6 | 0.4031 | 2.5 | 0.2711 | 2.5 | 0.2028 | 2.5 |
| 7 | 0.2356 | 2.5 | 0.5316 | 0.5 | 0.2292 | 2.5 |
| 8 | 0.1661 | 2.5 | 0.2387 | 2.5 | 0.121 | 2.5 |
| 9 | 0.2613 | 1.5 | 0.1865 | 2 | 0.317 | 1 |
| 10 | 0.1777 | 2.5 | 0.1895 | 2.5 | 0.1835 | 1.5 |
| 11 | 0.2258 | 2.5 | 0.2014 | 2.5 | 0.1287 | 2.5 |
| 12 | 0.3975 | 2.5 | 0.289 | 2.5 | 0.28 | 2.5 |
| 13 | 0.1021 | 2.5 | 0.2207 | 1.5 | 0.1614 | 1 |
| 14 | 0.3164 | 2.5 | 0.5278 | 0.5 | 0.1828 | 2.5 |
| Obj-Fun | 11.1443 | | 10.9499 | | 10.4267 | |

In Table VIII the first column is the solution of optimization problem with linear programing method and the second shown the solution by GA and the third column is the solution with proposed hybrid PSO. In the last row, the optimal objective function values for three method are presented. It can be seen that the presented method achieve the best results.

## VI. CONCLUSION

In this paper a new hybrid method for optimal coordination of over current relays is proposed. In this work it takes into account both TMS as a continues parameter and $I_{set}$ as a discrete parameter in optimization procedure. The novelty of this paper is that quantizing $I_{set}$ parameter is considered as a part of optimization producer in particle swarm optimization iterations. After that it can calculate the optimum TMS setting with linear programming at the end of each iteration of PSO optimization algorithm. To increase the accuracy of proposed algorithm, first particle positions of swarms are calculated with linear approaches. Both near-end and far-end faults are taken into account in the constraint of the optimal coordination problem and the results are compared with linear programming and GA. The benefits of the proposed method are the way to meet the discrete value in optimization problem and its simplicity. The obtained results show that the proposed method is succeeded in finding a better solution with less iteration compared the LP and GA methods.

## VII. REFERENCES


[1] B. Chattopadhyay, M. S. Sachdev and T.S. Sidhu, "An On-Line Relay Coordination Algorithm for Adaptive Protection Using Linear Programming Technique," IEEE Trans. Power Del., Vol. 11, No. 1, PP. 165-173, Jan. 1996.

[2] A.J. Urdaneta, R. Nadira and L.G. Perez Jimenez, "Optimal Coordination of Directional Overcurrent Relays in Interconnected Power Systems," IEEE Trans. Power Del., Vol. 3, No. 3, PP. 903-911, July. 1988.

[3] A. J. Urdaneta, L. G. Perez and H. Restrepo, "Optimal Coordination of Directional Overcurrent Relays Considering Dynamic Changes in the Network Topology," IEEE Trans. Power Del., Vol. 12, No. 4, PP. 1458-1464, Oct. 1997.

[4] C. W. So, K. K. Li, K. T. Lai and K. Y. Fung, "Application of Genetic Algorithm for Overcurrent Relay Coordination ," Developments in Power System Protection, PP. 66-69, Mar. 1997.

[5] C. W. So, K. K. Li, K. T. Lai and K. Y. Fung, "Application of Genetic Algorithm to Overcurrent Relay Grading Coordination," APSCO. 97, Vol. 1, PP. 283-287 , Nov. 1997.

[6] A.S. Noghabi, J. Sadeh and H. R. Mashhadi, "Considering Different Network Topologies in Optimal Overcurrent Relay Coordination Using a Hybrid GA," IEEE Trans. Power Del., Vol. 24, No. 4, PP. 1857-1863, Oct. 2009.

[7] J. Kennedy and R. Eberhart, "Particle Swarm Optimization," Neural Networks. 1995, Vol. 4, PP. 1942-1948, Nov/Dec. 1995.

[8] J. Kennedy and R. Eberhart, "A New Optimizer Using Particle Swarm Theory," Micro Machine and Human Science. 1995, PP. 39-43, Oct. 1995.

[9] H. H. Zeineldin, E. F. El-Saadany, and M. M. A. Salama, "Optimal Coordination of Overcurrent Relays Using a Modified Particle Swarm Optimization," Elect. Power Syst. Res., Vol. 76, PP. 988–995, 2006.

[10] M. R. Asadi and S. M. Kouhsari, "Optimal Overcurrent Relays Coordination Using Particle-Swarm-Optimization Algorithm," PSCE '09, PP. 1-7, March. 2009.

[11] M. M. Mansour, S. F. Mekhamer and N. E. S. El-Kharbawe, "A Modified Particle Swarm Optimizer for the Coordination of Directional Overcurrent Relays," IEEE Trans. Power Del., Vol. 22, No. 3, PP. 1400-1410, July. 2007.

[12] F. V. D. Bergh, "An Analysis of Particle Swarm Optimizer," Ph.D. dissertation, Univ. Pretoria,Pretoria, South Africa, 2001 [Online]. Available: http://www.cs.up.ac.za/ cs/ fvdbergh/publications.php


## VIII. BIOGRAPHIES

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