Academic Science

**International Journal of Electronics, Electrical and Computational System**
**IJEECS**
**ISSN 2348-117X**
**Volume 6, Issue 7**
**July 2017**

# Impact of Range of Time Multiplier Setting on Relay Coordination

**Miss.-Shubhangi B. Walke**
Department of Electrical Engineering,
K. K. Wagh I. E.E. & R., Nashik, Savitribai Phule University, Pune

**Prof. Nayana N. Jangle**
Assistant Professor
.Department of Electrical Engineering, K. K. Wagh I. E.E. & R., Nashik

## ABSTRACT

*The reliability and stability of the power system decreases with abnormal operatingcondition of the protective system which may be caused due to overvoltage, under-frequency, overload etc.andleads to interruption of the supply, and may damage equipment's connected to the system. To maintain system stability and reliability it is necessary to have a protective system which operates as quickly as possible, isolates smallest part of the system under fault. For this purpose it is necessary to have coordination between the protective devices to assure safe operation. Over-current relays especially Inverse Definite Minimum Time (IDMT) relays are most commonly used protective device in the distribution system. It is vital that during abnormalities or faults, the IDMT relays must be capable to isolate only the faulty part of power system from the healthy system. The operating time of IDMT relays can be reduced with proper coordination between primary and backup relays by selecting optimum settings. Heuristic-based optimization techniques are used to find the optimum solution for time multiplier setting (TMS) and plug setting (PS) of IDMT relays. In this paper, investigations are carried out to explore the impact of TMS range selected in the optimization problem on optimum settings of IDMT relays. The results of these investigations have shown that better results can be obtained with a minimum range of TMS.*

***Keywords-Over current Relay, Relay coordination,Time multi-plier setting ,Pick up Current, PSO, Distributed Generation***

## I) INTRODUCTION

The shunt faults in a power system give rise toa sudden increase of the current. Thismagnitude of fault current can be utilized foridentification of fault existence. Therefore, theover-current protection is most widely used forthe protection of power system. IDMT relaysare commonly used for the protection ofdistribution systems. In distribution system,they play a more prominent role as these relaysare used for primary as well as backupprotection. A relay must trip for a fault underits primary zone of protection. The back-up relay should be operated only if theprimary relay fails to operate and unable to clear the fault. Therefore operating time of backup relay should be more than the primary relay, if backup relays are not well coordinated, the relay may get maloperate. Therefore, relaycoordination have an importance in providing protection of powersystem. Each relay must becoordinated with the other relays in the powersystem operated as quickly as possible so as to disconnect unhealthy or faulty part of the system. Different relays are available in practice but the overcurrent relay is mainly used in distribution system which may be of different types like Instantaneous Overcurrent relay, Definite Time Overcurrent Relay, Inverse Definite Minimum Time Relay(IDMT), Directional Overcurrent Relay. The optimum coordination of overcurrent relay is a constrained optimization problem and can be solved by different optimization methods to determine optimum values of TMS and PS.

In this paper, the problem of finding the optimum values of TMS and PS is formulated as constrained non-linear optimization problem. The MATLAB toolbox is used to determine optimum values of TMS and PS

considering different ranges of TMS and fixed range of PS to maintain the selectivity. In this paper, a case study on a simple radial system is presented to determine the impact of TMS range on optimum coordination of overcurrent relays.

## II) THEOROTICAL CONCEPT

A) Concept of relay coordination

Overcurrent phase and earth fault relay coordination is necessary to have proper fault detection and fault clearance sequence. These relays must be able to distinguish between the normal operating currents including short time overcurrent that may appear due to certain equipment normal operation.

During fault conditions, these relays operate quickly isolating the faulted section of the network only therefore continued operation is maintained of the healthy circuits. In the event of failure of primary relays used for isolating the fault within its primary zone of protection, backup relays should operate after providing for sufficient time lag for the operation of primary relays. Hence, the operation of backup relays must be coordinated with those of the operation of the primary relays. Once the relays are coordinated, the discrimination in the operation of primary and backup relays and their coordination with the maximum possible load currents will be plotted on the time current characteristics (TCCs). Relay coordination needs to be calculated for maximum and minimum fault conditions and for various possible network configurations. Where a network has several levels of primary and backup relay levels, the source end relay operation can become quite delayed due to successive time discrimination at downstream load end coordination levels. In such cases it may be necessary to ensure isolation of fault at the earliest by possibly coordinating the source end relays with much faster dedicated equipment relays in the downstream.

B) Types of Relay Coordination:

Relay is always essential since various additions deletion of feeders and equipment will occur after the initial commissioning of plants. As power can be received from generators of the captive power plant, the analysis becomes complex. Relay co-ordination can be done by selecting proper plug setting and time multiplier setting of the relay, operatingcharacteristics of this relay are usually expressed in the form of a curve with operatingcurrent of plug setting multiplier along the X axis and operating time along the Y axis. This is achieving by applying protective devices to a power system as primary and backup pairs. In this setup, primary protection is set to operate faster for faults in their primary protection zone while backup protection is set to operate with a predetermined time delay for faults in their backup protection zone. There are three types for coordination like coordination by time,coordination by current magnitude and coordination by time and current magnitude.

1) Coordination by Time:

In the coordination by time method, the adjacent protective devices which form primary and back-up protection pairs are arranged to operate in graded times. The protection device closest to the fault is arranged to trip in the shortest time, each adjacent breaker back to the source operates at longer times after a predetermined time delay. For a simple radial power system in Figure an overcurrent relay at A would

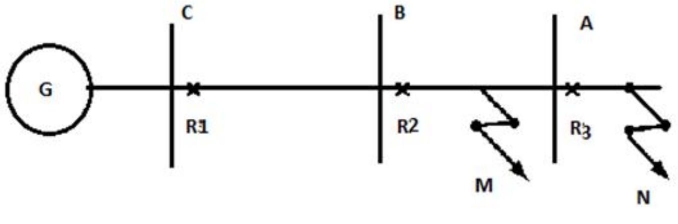


Figure 3.4: Simple Radial System

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

be set to operate faster for a fault close to A than a relay at B and C for a faultclose to A. An overcurrent relay at B is set to operate faster than an overcurrent relay at C for a fault at B, and so on close to A than a relay at B and C for a fault close toA. An overcurrent relay at B is set to operate faster than an overcurrent relay at C fora fault at B, and so on.

2) Coordination by current magnitude:

Due to the differing impedance between the source and the location of faults for different fault locations, the fault currents produced by faults in different locations of the power system will differ in magnitude. Therefore, current magnitudes are usefulto arrange for the relay nearer to the fault to operate first before upstream relays. The relay at C in figure can be arranged to trip line BC for a fault at B and relay at B can be arranged to trip line BA for a fault at A, and so on. Relays that use this method of coordination have known as instantaneous overcurrent relays.

3) Coordination by both current magnitude and time:

The disadvantage of coordination by time is onlythat protection devices are closer to the source. Where fault current levels are higher will operate in longer time delays. On the other hand, discrimination by current only has a disadvantage in the fact that in cases where the impedance between two fault locations on the power system does not change significantly, the magnitude of the fault current will also not change. It will, therefore, be difficult for the protection devices to distinguish between the in zone fault and the out of zone fault. Coordination by both current magnitude and time has been introducing. In this coordination method, protective devices applied at locations A, B and C in figure are designed to use inverse operating characteristics the higher the fault current, the faster the protective device operating time and the lower the fault current, the slower the device was operating time. For example, for a fault close to breaker A, the protective device at A will be typically set to operate in 0.2 seconds. But will operate in 0.8 seconds for a fault near breaker B. For a fault near breaker B, the protection device at B will operate faster than the protection device at A. Therefore, in this case Inverse Definite Minimum Time relay is used which has inverse characteristics i.e. as current increases the operating time of relay decreases.

The operating characteristics of IDMT relay is mathematically expressed by the equation:

$$T_{op} = \frac{\alpha (TMS)}{(PSM)^{\gamma} - 1}$$

Where,

*Top*= Operating time of relay.

*PSM*= Plug Setting Multiplier.

*TMS* =Time Multiplier Setting.

$\alpha$ and $\gamma$are constants for different relay characteristics

## III) GENETIC ALGORITHM THEORY

### A) Introduction

Genetic algorithm (GA) is a random search technique used for computing and to find exact or approximate solutions to optimization and search problems. [1] Genetic algorithms are categorized as global search heuristics.They are parts of evolutionary computing, a rapidly growing area of artificial intelligence.GAs have inspired by Darwin’s theory of evolution Survival of the fitness.

### B) Overview of Genetic Algorithm

Genetic Algorithm (GA) is a random adaptive search algorithm which is based on the mechanisms of natural selection and natural genetics. The principle of survival of the fittest to search for optimal solutions is applied

by this algorithm. Solutions from one population, initialized randomly, are used to create a new population through genetic operators like selection, crossover, and mutation. This algorithm is different from traditional optimization system in the following aspects:

• They work with the coding of the parameter, not the parameter itself.

• They search for a population of points (parallel search), not a single point.

• GA uses the objective function for optimization, not the derivative or other auxiliary knowledge.

• They use probabilistic rules, not deterministic rules

**C) Terminologies Related To Genetic Algorithm**

1)Fitness Function- It is an objective function which describes the optimality of a solution (that is, a chromosome) in a genetic algorithm so that particular chromosome may be ranked against all the other chromosomes.

2)Chromosome- A chromosome is a set of parameters that define a proposed solution to the problem which the genetic algorithm is trying to solve. The chromosome is represented as a simple string although a wide variety of other data structures are also used.

3)Selection- Genetic Algorithm uses the rank-based selection method. The probability of selecting an individual solution is assigned based on the ranking of the individual solution when all other solutions were ranked according to the fitness. The fitness of the individual was determined by evaluating the value of the individual according to the objective function. The fittest or feasible individual will not dominate or control over selection because the probability has based on ranking not only the fitness. Individual solutions are selected through a fitness-based process, where fitter solutions are typically more mostly selected.

4)Reproduction–Reproduction is nothing but to generate a second generation population of solutions from the solutions which are selected through genetic operators like crossover and mutation. For each new solution which is to be produced, a pair of parent solutions is selected for producing offspring from the pool which is selected previously. By producing a child solution, a new solution is produced which typically shares many ofthe characteristics of its parents. New parents are selected for each new child, and theprocess continues until a new population of solutions of desired size is generated.

5)Crossover - In genetic algorithms, crossover is genetic operator used to change the programming of a chromosome or chromosomes from one generation to the next. It is similar to reproduction and biological crossover, upon which genetic algorithms are based.

6)Mutation -Mutation is a genetic operator which is used to maintain genetic variety from one generation of a population of algorithm chromosomes to the next generation. It is similar to biological mutation. The need of mutation in GAs is preserving and introducing the variety. Mutation avoids local minima by avoiding the population of chromosomes from becoming too similar from each other by slowing or even by stopping evolution.

## IV) PROBLEM FORMULATION

**A. Objective Function**

In the coordination problem, the purpose is to minimize the TDS and calculates Ip of each relay, so that the sum of the operating time of the primary relay, for near end fault, is to be minimized. [11] The objective function can be defined as follows

$$\min j = \sum_{i=1}^{n} W_i t_i \quad \text{.................................(4.1)}$$

Where;

*n*is the number of relays and

*ti*is the operating time of the i relay for near-end fault.

*Wi is* weight depends upon the probability of a given fault occurring in protection zone and usually set to one.

**B. Relay characteristics**

In this study all relays are assumed to be identical. [2] The characteristic equation [4] can be defined as follows in equation 2:

$$T_{op} = \frac{a\,(TMS)}{(PSM)^{¥} - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots(4.2)$$

**C. Coordination constraints**

1. Selectivity constraints for all relay pairs

Selectivity means that the faulted line is the only part to be disconnected which means that the primary time must be greater than the secondary time with certain delay as

$$T_{backup} - T_{primary} \geq CTI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

Where

$T_{backup}$is operating time of backup relay.

$T_{primary}$is the operating time of primary relay.

*CTI* is Coordination time Interval, is equal to 0.3 seconds.

2. Bounds on TDS

There setting boundaries must be fulfilled as described in equation4.

$$TDS_{i\min} \leq TDS_i \leq TDS_{i\max} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots(4.4)$$

Where

$TDS_{imin}$is the lower limit and

$TDS_{imax}$is upper limit of $TDS_i$.

These limits are 0.05 and l.l respectively.

**3. Limits on primary operation times**

This constraint imposes constraint on each term TDS of the objective function to lie between 0.05 and l.2.

**B) Proposed Algorithm:**

There are certain steps to carry out the total operating time of the relay.

1)Generate Primary backup relay pairs. The knowledge of primary backup relay pairsis essential in the formulation of the coordination constraints.

2)Find out the fault current of relays at different locations of fault.

3)The objective function and constraints are defined in MATLAB.

Academic Science

**International Journal of Electronics, Electrical and Computational System**
**IJEECS**
**ISSN 2348-117X**
**Volume 6, Issue 7**
**July 2017**

4)Minimization of objective function is carried out and the values of total operating time at different ranges of TMS are calculated using GA toolbox in MATLAB.

5)The differences in total operating time at different ranges of TMS are observed.

**C) Impact of Range of TMS:**

To protect the power system, relay should operate for minimum fault current and relay should not operate for maximum load current, which is achieved by proper relay settings. The minimum current to start the relay operation is set with the help of PS and TMS decides the total operating time of the relay. Relay coordination problem becomes more complicated with an increase in relay numbers. The number of constraints increases with an increase in primary and backup relay pairs. The heuristic base optimization techniques are used to solve the optimization problem. These techniques randomly generate a set of possible solutions (population) to get a feasible initial solution. This solution is converted to the optimum solution using an iterative process. During the iterative process, the solution for the objective function is improved by modifying the possible solutions of design variables. The new solution is accepted if it gives a better solution than the previous one. With a wide range of TMS, the number of worst solutions is generated in the population. This leads to a non-optimum solution.

Figure 4.1 shows the three areas, A, B, and C with fixed range of PS and different range

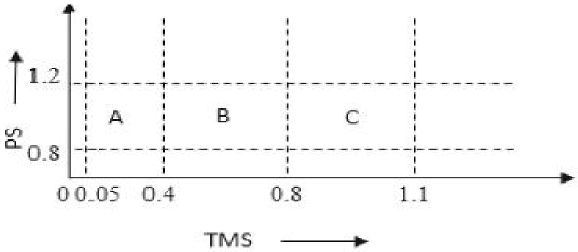


**Figure4.1 Possible areas of solution for TMS and PS**

of TMS. The range of TMS is considered 0.05 onward to satisfy the constraints ofminimum operating time. With the maximum range of TMS (i.e. 0.05 to 1.1), the Figure 5.1: Possible areas for solution of TMS and PSsolution is available in all the three areas, but the solution available from the area Band C contains the higher value of TMS. This increases the operating time of the relay.Similarly for medium range of TMS (0.05 to 0.8), the solution is available in the area A and B, where area B gives a non-optimum solution. With minimum range of TMS,the solution is available from area A, which gives the optimum solution with a smallervalue of TMS.

## V) SIMULATION RESULTS AND DISCUSSIONS

Fault in the power system has sensed by both primary as well as backup relays. Theprimary relay should operate first and if the primary relay fails to operate the backuprelayshould operate. So it is necessary to set the operating time of primary relayless than that of the backup relay. A simple radial feeder with three sectionsshownin figure 5.1. For a fault at point N, relay R1 should operate first. Let the operating time

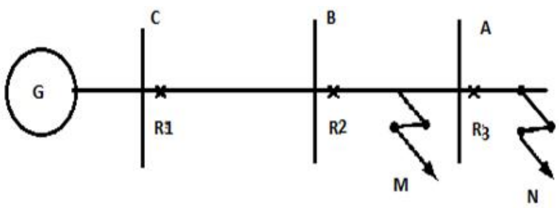


Figure 5.1: Simple Radial System

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

of R1 has set to 0.2 sec. The same fault will have seen by relay R2 as well asR3, but relay R2 should wait for 0.2 sec plus, a time equal to the operating time ofcircuit breaker (CB) at bus A, plus the overshoot time of relay 1, which is called as Coordination time interval (CTI).

A radial distribution system, with three OC relays as shown in figure.6.1 is considered to test the algorithm, The maximum fault currentjust beyond bus A, bus B, and bus C are 500 A, 800 A and 1100 A respectively, CT ratio for R1 is 200:1, R2 is 300:1 and for R3 is 500:1.

**Table 5.1: Fault Currents at different locations**

| Fault Position | Relay | | |
|---|---|---|---|
| | A | B | C |
| Just beyond A | 2.5 | 1.666 | 1 |
| Just beyond B | | 2.666 | 1.6 |
| Just beyond C | - | - | 2.2 |

Minimum operating time for each relay has considered as 0.2 sec, and the CTI hastaken as 0.3 sec.The operating characteristics of IDMT relay is mathematically expressed by the equation:

$$T_{op} = \frac{0.14(TMS)}{(PSM)^{0.02} - 1}$$

Where,

$T_{op}$= Operating time of relay.

$PSM$= Relay Plug Setting Multiplier.

$TMS$ = Relay time multiplier setting.

Considering x1, x2 and x3 are the TMS and x4, x5 and x6 are the PS of relay R1, R2and R3 respectively, then the optimization problem to minimize the total operatingtime can be formulated as,

.

$$\min j = \frac{0.14TMS_1}{\left(\frac{2.2}{PS_1}\right)^{0.02} - 1} + \frac{0.14TMS_1}{\left(\frac{2.666}{PS_1}\right)^{0.02} - 1} + \frac{0.14TMS_1}{\left(\frac{2.5}{PS_1}\right)^{0.02} - 1}$$

……………..(5.1)

Subjected to the constraints,

$$\frac{0.14TMS_1}{\left(\frac{2.2}{PS_1}\right)^{0.02} - 1} \geq 0.2$$

$$\frac{0.14TMS_2}{\left(\frac{2.666}{PS_2}\right)^{0.02} - 1} \geq 0.2$$

$$\frac{0.14TMS_3}{\left(\frac{2.5}{PS_3}\right)^{0.02} - 1} \geq 0.2$$

……………………….(5.2)

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

$$\frac{0.14TMS_2}{\left(\frac{1.666}{PS_2}\right)^{0.02}-1}-\frac{0.14TMS_3}{\left(\frac{2.5}{PS_3}\right)^{0.02}-1}\geq 0.3$$

$$\frac{0.14TMS_1}{\left(\frac{1.6}{PS_1}\right)^{0.02}-1}-\frac{0.14TMS_2}{\left(\frac{2.666}{PS_2}\right)^{0.02}-1}\geq 0.3 \quad \text{..........................(5.3)}$$

**Table 5.2:Operating Time of Relay at different TMS ranges**

| **TMS Range** | **0.05-1.20** | | **0.05-0.90** | | **0.05-0.60** | | **0.05-0.40** | |
|---|---|---|---|---|---|---|---|---|
| **Relay** | **TMS** | **PS** | **TMS** | **PS** | **TMS** | **PS** | **TMS** | **PS** |
| 1 | 0.052 | 0.936 | 0.051 | 0.95 | 0.056 | 0.877 | 0.05 | 0.966 |
| 2 | 0.064 | 0.802 | 0.05 | 1.048 | 0.057 | 0.872 | 0.05 | 0.972 |
| 3 | 0.05 | 0.807 | 0.05 | 0.8 | 0.05 | 0.806 | 0.05 | 0.8 |
| Total Operating Time | 1.10355 | | 1.097563 | | 1.082854 | | 1.068852 | |

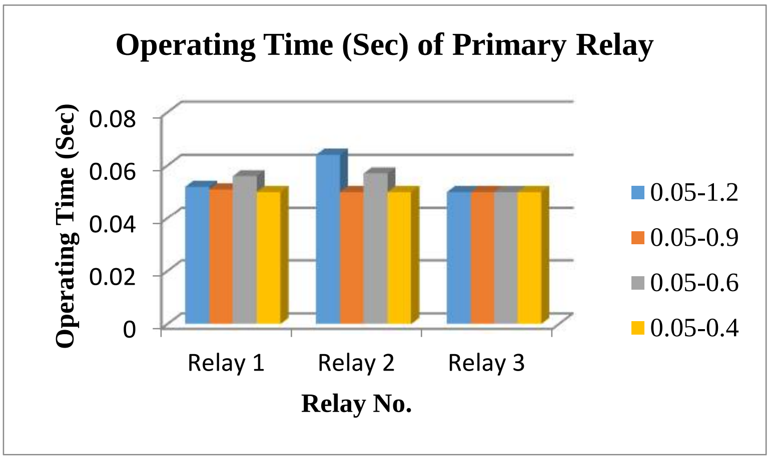


**Figure 5.2 Operating Time of Primary Relays with different Ranges of TMS**

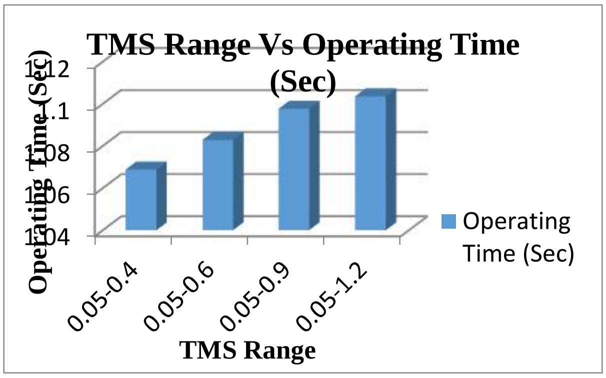


**Figure 5.2 Operating Time of Primary RelaysVs different Ranges of TMS**

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

## VI) CONCLUSION

This paper represents the impact of TMS range on operating time of relay. The problem is formulated as constrained non-linear optimization problem. The fix range of PS is considered to maintain the selectivity. The results are obtained by considering simple Radial system using GA optimization toolbox. The obtained results show that the optimum settings are obtained with smaller range of TMS as small value of TMS makes relay faster.

## REFERENCES

[1] D. K. Singh and S. Gupta, “Use of genetic algorithms (GA) for optimal coordination of directional over current relays,” in Engineering and Systems (SCES), 2012Students Conference on, March 2012, pp. 1–5.
[2] M. Bashir, M. Taghizadeh, J. Sadeh, and H. R. Mashhadi, “A new hybrid particle swarm optimization for optimal coordination of over current relay,” pp. 1–6, Oct 2010.
[3] S. Niyomphant, U. Leeton, Kulworawanichpong, and N. Chomnawang, “Application of linear programming for optimal coordination of directional over-current relays,” in Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2012 9th International Conference on, May 2012, pp. 1–4.
[4] P. P. Bedekar, S. R. Bhide, and V. S. Kale, “Optimum coordination of overcurrent relays in distribution system using genetic algorithm,” in Power Systems, 2009. ICPS ’09. International Conference on, Dec 2009, pp. 1–6.
[5] H. H. Zeineldin, E. F. El-saadany, and M. M. A. Salama, “Protective relay coordination for micro-grid operation using particle swarm optimization,” in 2006 Large Engineering Systems Conference on Power Engineering, July 2006, pp. 152–157.
[6] M. R. Asadi and S. M. Kouhsari, “Optimal overcurrent relays coordination using particle-swarm-optimization algorithm,” in Power Systems Conference and Exposition, 2009. PSCE ’09. IEEE/PES
[7] Y. Damchi, H. R. Mashhadi, J. Sadeh, and M. Bashir, “Optimal coordination of directional overcurrent relays in a microgrid system using a hybrid particle swarm optimization,” in Advanced Power System Automation and Protection (APAP),2011 International Conference on, vol. 2, Oct 2011, pp. 1135–1138.
[8] D. Vijayakumar and R. K. Nema, “Superiority of pso relay coordination algorithm over non-linear programming: A comparison, review and verification,” in Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008. Joint International Conference on, Oct 2008, pp. 1–6.
[9] Adhishree, J. M. Tripathi, S. R. Mohanty, and N. Kishor, “A simulation based comparative study of optimization techniques for relay coordination with distributed generation,” in Engineering and Systems (SCES), 2014 Students Conferenceon, May 2014, pp. 1–6.
[10] A. H. Reza, “New method on the relays protective coordination due to presence of distributed generation,” in Power Engineering and Automation Conference (PEAM), 2012 IEEE, Sept 2012, pp. 1–4.
[11] R. A. Swief, A. Y. Abdelaziz, and A. Nagy, “Optimail strategy for over current relay coordination using genetic algorithm,” in Engineering and Technology (ICET), 2014 International Conference on, April 2014, pp. 1–5.
[12] F. Motabarian, M. A. Golkar, and S. Hajiaghasi, “Surveying the effect of distributed generation (dg) on over current protection in radial distribution systems,” in Electrical Power Distribution Networks (EPDC), 2013 18th Conference on, April 2013, pp. 1–6.
[13] M. M. Mijalili, A. R. Sedighi, and M. R. Haghifam, “Impact of dg location on protection coordination in distribution systems,” in Electrical Power Distribution Networks (EPDC), 2012 Proceedings of 17th Conference on, May 2012, pp.
[14] A. S. Noghabi, H. R. Mashhadi, and J. Sadeh, “Optimal coordination of directional overcurrent relays considering different network topologies using interval linear programming,” IEEE Transactions on Power Delivery, vol. 25
[15] H. A. Abyaneh, M. Al-Dabbagh, H. K. Karegar, S. H. H. Sadeghi, and R. A. J. Khan, “A new optimal approach for coordination of overcurrent relays in interconnected power systems,” IEEE Transactions on Power Delivery
[16]Huchel and H. H. Zeineldin, “Planning the coordination of directional overcurrent relays for distribution systems considering dg,” IEEE Transactions on Smart Grid, vol. 7, no. 3, pp. 1642–1649, May 2016.