GENETIC ALGORITHM APPROACH INTO RELAY CO-ORDINATION

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ABSTRACT

The Over-Current (OC) relays are the major protection devices in a distribution system. The relays in the power system have to be coordinated so as to avoid mal-operation and hence to avoid unnecessary outage of healthy part of the system. Only if the primary protection does not clear the fault, the back-up protection should initiate tripping. This paper presents Genetic Algorithm (GA). GA is used to find optimal value of setting of OC relay. GA searches it globally. Systems with OC considered and real coded GA is used in software MATLAB.

Key words: over-current relay, relay co-ordination in radial systems, genetic algorithm.

1. INTRODUCTION

A power system consists of different equipments which are needed to be protected. They are divided into particular zones according to their specifications. This zone has protective system containing various relays acting as primary relay and backup relay. A protective relay is the device, which gives instruction to disconnect a faulty part of the system. This action ensures that the remaining system is still fed with power, and protects the system from further damage due to the fault. Relay co-ordination plays an important role in the protection of power system. For proper protection, co-ordination of relays with appropriate relay settings is to be done.

Relay coordination can be done for relays within the zone and for relays of different zones. However the review of Co-ordination is always essential since various additions / deletion of feeders and equipments will occur after the initial commissioning of plants. [1-3]
Relay co-ordination can be done by selecting proper plug setting and time multiplication setting of the relay, considering maximum fault current at the relay location. [1, 3]

Several methods have been proposed for the coordination of over-current relays. These methods can be classified into three classes: trial and error, topological analysis method, and optimization method.[10] However, the solutions found by the first two classes, are not optimal. In other words, relay time multiplier settings are relatively high. In the optimal methods, the operating times of the relays are minimized, subject to the so-called coordination constraints, relays characteristic curves and the limits of the relays settings. With optimization techniques linear and non linear methods the optimal values of setting are found out. [6, 10]

In this paper GA method is used to find optimal value of time multiplier setting. GA is global search method which is work on natural genetics concept. [2]

2. CO-ORDINATION OF OC RELAYS IN SYSTEM

A radial system has only one power source for a group of customers. A power failure, short-circuit, or a downed power line would interrupt power in the entire line which must be fixed before power can be restored.

As shown in figure 2.1 radial system has two directional relays as RA and RB and faults are F1 and F2. For fault F1 the RA will operate as primary and as fault is behind relay RB; it will not operate. Fault F2 will be seen by both RA and RB and RB is primary protection will operate in operating time decided according to PMS and TMS suppose it is 0.1sec. RA will act as back-up protection so if RB fails then RA operates. Operating time of RA will be operating time of RB plus operating time of Circuit Breaker (CB) plus overshoot time of RA. [1]

A loop/ ring-main system is loops through the service area and returns to the original point. The loop is usually tied into an alternate power source. By placing switches in strategic locations, the utility can supply power to the customer from either direction. If one source of power fails, switches are thrown (automatically or manually), and power can be fed to customers from the other source.

The loop/ring-main system provides better continuity of service than the radial system, with only short interruptions for switching.

Refer figure 2.2, all directional relays have their tripping direction away from the concerned bus. For coordination purpose the relays are operating in loops the given loops are considered in clockwise direction they can also operate in anti-clockwise direction.
1. \( R_8 \rightarrow R_{14} \rightarrow R_{12} \rightarrow R_{13} \)
2. \( R_9 \rightarrow R_{10} \rightarrow R_{11} \rightarrow R_7 \)
3. \( R_8 \rightarrow R_9 \rightarrow R_{10} \rightarrow R_{11} \rightarrow R_{12} \rightarrow R_{13} \)

Their operating time will also determine and arranged in same way. In first loop, \( R_{13} \) is primary and \( R_{12} \) will backup it. \( R_{14} \) will backup \( R_{12} \) and so on. [3]

As the size and complexity of the system goes on increasing it becomes more and more difficult to coordinate the relays.

3. PROBLEM STATEMENT

The general relay coordination problem can be stated as a parametric optimization problem. The coordination problem of directional OC relays in interconnected power systems, can be stated as an optimization problem, where the sum of the operating times of the relays of the system, for near end fault, is to be minimized with considering primary and back-up relays. That is, [2]

\[
min Z = \sum_{i=1}^{m} t_{i,i} \\
\text{...2.1}
\]

Where, \( t_{i,i} \) indicates the operating time of the primary relay at \( i \), for near end fault. There are some important criteria as follows: [2, 8]
1. Coordination criteria

\[ t_{bi,i} - t_{i,i} \geq \Delta t \quad \ldots 2.2 \]

where \( t_{i,i} \) is the operating time of the primary relay at \( i \), for near end fault \( t_{bi,i} \), is the operating time for the backup relay, for the same near end fault and \( \Delta t \) is the coordination time interval (CTI)

2. Bounds on the relay operating time

\[ t_{i,i \text{min}} \leq t_{i,i} \leq t_{i,i \text{max}} \quad \ldots 2.3 \]

where \( t_{i,i \text{min}} \) is the minimum operating time of relay at \( i \) for near end fault (fault at \( i \)) \( t_{i,i \text{max}} \) is the maximum operating time of relay at \( i \) for near end fault (fault at \( i \))

3. Relay characteristics –
All relays are assumed to be identical and are assumed to have normal IDMT characteristic as

\[ t_{op} = \lambda \ast (TMS) \div [(PMS)^{\alpha} - 1] \quad \ldots 2.4 \]

Where \( t_{op} \) is relay operating time, \( TMS \) is time multiplier setting, and \( PMS \) is plug multiplier setting. For normal IDMT relay \( \alpha \) is 0.02 and \( \lambda \) is 0.14(refer table.1). As the pickup currents of the relays are pre determined from the system requirements, equation (2.4) becomes

\[ t_{op} = a \ast (TMS) \quad \ldots 2.5 \]

Where,

\[ a = \lambda \div [(PMS)^{\alpha} - 1] \quad \ldots 2.6 \]

Making substitution from equation (2.5) in equation (2.1), the objective function becomes

\[ \min Z = \sum_{i=1}^{m} ai(TMS)i \quad \ldots 2.7 \]

Thus the relay characteristic constraint is incorporated in the objective function itself. The values of \( i \alpha \) for \( i_{th} \) relay for different fault locations are predetermined.

<table>
<thead>
<tr>
<th>Types of Curves</th>
<th>( \alpha )</th>
<th>( \Lambda )</th>
<th>( B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normally inverse</td>
<td>0.02</td>
<td>0.14</td>
<td>2.97</td>
</tr>
<tr>
<td>Very Inverse</td>
<td>1.0</td>
<td>13.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Extremely Inverse</td>
<td>2.0</td>
<td>80.0</td>
<td>0.808</td>
</tr>
<tr>
<td>Long time Inverse</td>
<td>1.0</td>
<td>120.0</td>
<td>13.33</td>
</tr>
</tbody>
</table>

Table.1 Values of characteristics
4. GENETIC ALGORITHM

Genetic Algorithms based on the principles of natural genetics and natural selection. The basic elements of natural genetics are, reproduction, cross-over, mutation are used for genetic procedure. GA is inspired by Darwin's theory about evolution. In nature, the individual that has better survival traits will survive for a longer period of time. Therefore, after a long period of time, the entire population will consist of lots of genes from the superior individuals and less from the inferior individuals. In a sense, the fittest survived and the unfit died out. This force of nature is called natural selection. Genetic algorithm can find out global minima from different local points. [2,9]

Operators of Genetic Algorithm

1. Crossover: In genetic algorithms, crossover is genetic operator used to vary the programming of a chromosome or chromosomes from one generation to the next. It is analogous to reproduction and biological crossover, upon which genetic algorithms are based. Types of crossover, single point, two point, uniform, arithmetic crossover.

2. Mutation: In genetic algorithms of computing, mutation is a genetic operator used to maintain genetic diversity from one generation of a population of algorithm chromosomes to the next. It is analogous to biological mutation. It is done by adding or subtracted a small number from selected number (for real coded GA).

3. Reproduction: It generates a second generation population of solutions from those selected through genetic operator crossover. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated.

Important terminologies for GA

1. Fitness Function--A fitness function is a particular type of objective function that prescribes 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-- In genetic algorithms, a chromosome is a set of parameters which define a proposed solution to the problem that the genetic algorithm is trying to solve. The chromosome is often represented as a simple string, although a wide variety of other data structures are also used are ‘chromosomes’. GA starts with chromosomes called ‘population’.

3. Selection--During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions are typically more likely to be selected.

5. RESULTS

As relay coordination is optimized problem, a simple radial system is taken as first case, Consider same figure 1, data is available. One source/machine system with two buses A and B. each bus and corresponding line is protected with protective relays namely R_A and R_B both directional. According to figure faults F_1 and F_2 occurred. The line data is CT ratios are at R_A is 300:1 and at R_B is 100:1. The maximum fault current at bus A is 4000A and at bus B is 3000A. Plug setting for both relays is 100% that is 1.
Formulation of problem

**Step1.** Using equations 2.4 and 2.6, firstly calculate value of ‘a’ using information of primary-backup relay pairs for particular fault.

- For fault F₁ only Rₐ will operate as primary and no backup is present.
- For fault F₂ near bus B, it will sensed by Rₐ and Rₐ both. Relay Rₐ will be primary and Rₐ will backup.

**Step2.** Calculation of PMS value, for both fault position

\[
PMS = \text{Maximum fault current at relay CT ratio X Plug setting}
\]

Using equation 5.1 calculate value of PMSₐ for fault F₁ and PMSₐ (as primary) for fault F₂, to calculate PMSₐ for fault F₂ data of bus B will be considered.

**Step3.** Defining calculated values in optimization form:

Both TMS are unknown so variable ‘x’ will assign to it. TMSₐ and TMSₐ will be ‘x₁’ and ‘x₂’ respectively. By table-1 and equation 2.7;

<table>
<thead>
<tr>
<th>Fault</th>
<th>Rₐ</th>
<th>Rₐ</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₁</td>
<td>0.14</td>
<td>(13.33)₀.₀²⁻¹</td>
</tr>
<tr>
<td>F₂</td>
<td>0.14</td>
<td>(10)₀.₀₀²⁻¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 2: Value of ‘a’ for F₁ and F₂

[2] By equations 2.2 and 2.3 we can get constraints to the problem. Thus the problem according to equation 2.7 will be,

\[
\text{Min } f(z) = 2.63x₁+2x₂
\]

Subject to,

\[
2.97x₁-2x₂ \geq 0.57
\]

\[
2.63x₁ \geq 0.2
\]

\[
2x₂ \geq 0.2
\]

Proposed Algorithm [11]

01. Start.
02. Define fitness function
03. Set stopping criteria as number of generations.
04. Initialize GA parameters.
05. Create initial population.
06. Set iteration count = 1.
07. Evaluate the fitness of each chromosome in the population.
08. Sort the fitness and associated parameters.
09. If stopping criteria is satisfied
Then go to step 15.
else go to step 10.
10. Select pairs for mating (i.e. perform reproduction).
11. Perform crossover.
12. Mutate the population.
13. Increment iteration count.
14. Go to step 08.
15. Display results.
16. Stop
GA parameters are:
Population size: 200
Selection size (number of generations): 300
Crossover rate: 0.5
Mutation rate: 0.15
After solving the problem in MATLAB values of

<table>
<thead>
<tr>
<th>Fitness Function</th>
<th>TMS_A</th>
<th>TMS_B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.881852</td>
<td>0.259259</td>
<td>0.100000</td>
</tr>
</tbody>
</table>

Table 3 Results of Radial System

6. CONCLUSION

A schematic procedure is discussed to convert coordination problem as optimization problem. The program can be used for optimum time coordination of relays in a system with any number of relays and any number of primary–back-up relationships. The algorithm was successfully tested for various systems. Thus, the proposed approach proves to be a promising step toward automating the job of relay settings.

REFERENCES


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