Estimation of Transmission Network Fault Location Using Genetic Algorithm

تحديد مكان الأعطال فى شبكة النقل باستخدام خوارزم جينى

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ملخص:

تقدم هذه الورقة وسيلة لتحديد مكان الأعطال فى شبكات النقل و ذلك وفقا لتوافق أشكال الموجات. وقد تم الحصول على أشكال الموجات خلال حالة العطل من برنامج محاكاة للنظام المختبر و مقارنتها بالأشكال الناتجة من برنامج حساب دوائر القصر بعد تغذيته بالأماكن المقترحة للأعطال و مقاومة دائرة القصر. و قد تم استخدام خوارزم جينى لإيجاد الحل الأمثل مما يوفر نتائج أكثر دقة من الوسائل المعروفة.

ABSTRACT:

This paper presents an approach to determine the location of fault in transmission network based on the "waveform matching" algorithm. The during-fault waveforms resulted from a simulation program of the test system will be compared to the waveforms resulted from a short-circuit calculation program, fed with the suggested fault location and fault resistance, for matching. The search process to find the best waveform match is actually an optimization problem. The genetic algorithm (GA) is introduced to find the optimal solution. This method can offer more accurate results than other known techniques.

KEYWORDS:

Fault location – Waveform matching – Genetic Algorithm.

Accepted December 31, 2003.

1– INTRODUCTION:

Prompt and accurate location of faults in a large-scale transmission network is critical when system reliability is considered and actually is the first step in the system restoration. The accuracy of fault location estimation essentially depends on the information available. While there have been some successful algorithms for fault location utilizing one-end, two-end or three-end data, the satisfactory solutions are harder to formulate if only the local information or only the data at limited substation locations are available. The one-end algorithm is the simplest and does not require the communication of the data between the monitoring devices located at different buses. Its accuracy may be adversely affected by the fault resistance [1]. The two-end and three-end algorithms are essentially independent of the fault resistance and can yield quite accurate estimates [2,3]. Furthermore, synchronized sampling may obtain better results than non-synchronized sampling [4].

To improve the accuracy for fault location when only limited recorded data are available, the "waveform matching" based approach may be used. In this approach the model of the power system is utilized to carry out the simulation studies under the predetermined fault conditions and record the resulting waveforms. The matching is then made between the voltage and current waveforms recorded and the voltage and current waveforms generated from short-circuit calculation programs. The fault is searched through the system by utilizing an iterative searching process.

In this paper, the fault location estimation is mathematically formulated as an optimization problem of which the fault location and fault resistance are unknown variables. An efficient GA based searching scheme is developed for obtaining the solution that is globally optimal [5].

The rest of the paper is organized as follows. The problem statement is presented first where the concept of "waveform matching" is illustrated. The proposed genetic algorithm-based implementation approach is illustrated next. Finally, case studies of the proposed technique applied on 11-bus test system of an electric utility company are carried out.

2 – PROBLEM STATEMENT:

For improved accuracy of fault location by utilizing limited data, the waveform-matching based approach may be utilized. The process to determine the fault location is iterative because several lines in the system and variety of possible fault resistances should be searched to obtain the optimal matching. The searching process may consist of the following steps:

- An initial fault location is assumed.
- The short-circuit calculation program is set according to the specified fault.
- The short-circuit calculations corresponding to the specified fault are carried out.
- The required waveforms for matching are obtained.
- The recorded waveforms are compared with the generated ones by short-circuit calculation program and the matching degree are evaluated according to an appropriate criteria.
- The initial fault location is modified according to certain approach and then the process proceeds to the second step and continue the steps 3 through 6.

The above steps are iterated until the calculated waveforms that best match the recorded ones are produced. The fault location will be as the one specified in the short-circuit calculations when generating waveforms that best match the recorded waveforms.

To evaluate the matching degree of the calculated and recorded waveforms, two different criteria may be employed. The first one utilizes phasors for matching. The other one utilizes transients for matching. Only the phasor matching is investigated in this paper.

So far, the "waveform matching" based approach for fault location has been employed manually by some engineers. The matching is made at the phasor level. There may be certain difficulties involved in the manual matching based method. First, it may be time consuming and even difficult to manually pose faults, run short-circuit calculation and compare the calculated and recorded phasors. Second, there is no accepted approach for guiding the searching process. The engineers usually have difficulty in knowing where to pose faults in the next iterative step, and may have to pose faults randomly. Third, since the fault resistance is unknown, a zero fault resistance has to be assumed in manual methods when posing faults. This may introduce undesirable errors.

3 – PROPOSED GA BASED IMPLEMENTATION APPROACH:

To effectively guide the searching process, a genetic algorithm (GA) based searching approach based on " phasor matching" is proposed. In the following sections the fault location is first formulated as an optimization problem, and then the application of GA for fault location estimation is illustrated.

A- Formulation of The Fault Location Searching Process as an Optimization Problem:

In the fault location problem discussed so far, there may be two possible unknown parameters, namely the fault location and the fault resistance. The matching degree can be presented by a value obtained from the following criteria [2]:

$$f_c(x, R_f) = \sum_{k=1}^{N_V} r_{kv} \left| V_{ks} - V_{kr} \right| + \sum_{k=1}^{N_I} r_{ki} \left| I_{ks} - I_{kr} \right| \qquad (1)$$

where,

$f_c(x,R_f)$: the cost function using phasors for matching, it is a non-negative number.

x, R_f : the fault location and fault resistance, respectively.

r_{kv}, r_{ki} : weights for errors of the voltage and currents, respectively.

V_{ks}, V_{kr} : the during-fault voltage phasors obtained from the short-circuit studies and from the recorded waveforms, respectively.

I_{ks}, I_{kr} : the during-fault current phasors obtained from the short-circuit studies and from the recorded waveforms, respectively.

N_V, N_I : the number of the selected voltage and current phasors, respectively.

k : the index of voltage or current phasors.

The cost function will be zero when the phasors obtained from the short-circuit studies exactly match those obtained from the recorded waveforms. The best fault location estimation will be achieved when the cost function is at minimum. Therefore, the problem of fault location estimation is actually an optimization problem.

B- Proposed Genetic Algorithm Based Searching Problem:

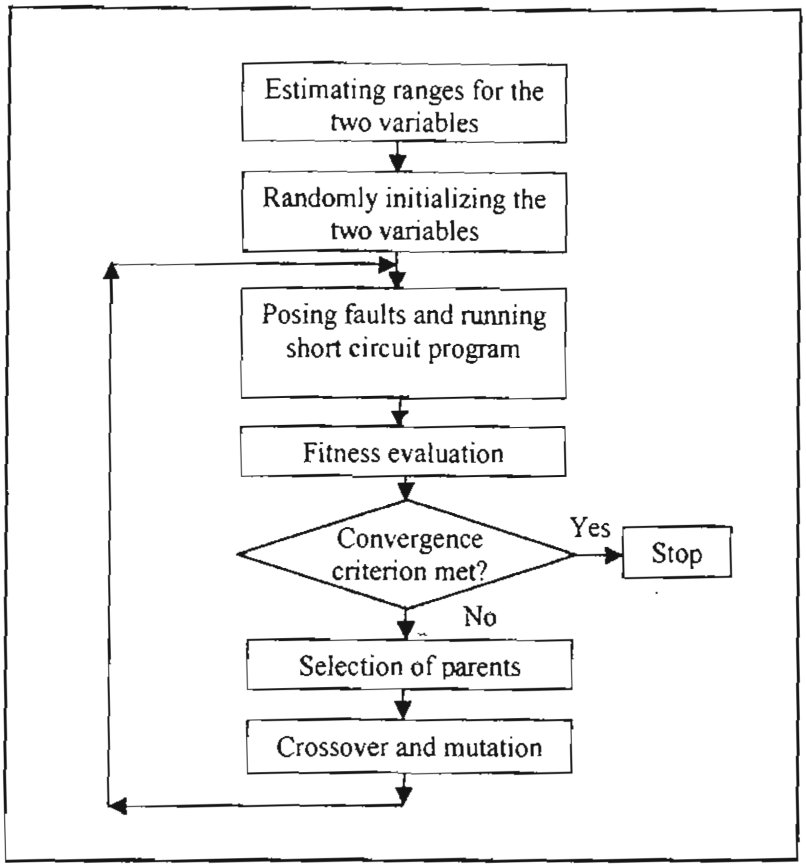

Fig. (1): The Flowchart For The GA Based Fault Location Estimation.

Since there may be several local minimum and maximum points in the cost function, it is difficult to use the gradient-based method to find the global minimum. The genetic algorithm based optimization approach is a good choice to search for the global optimum solution. We have to convert the minimization problem to maximization one in order to utilize GA. That requires us to convert the cost function to a fitness function of GA. The simplest conversion is to multiply the cost function by (-1). We have to add a constant to make the corresponding fitness function positive. The fitness function is as follows:

$$f(x,R_f) = C_{max} - f_c(x,R_f) \tag{2}$$

where,

$f(x,R_f)$ is the fitness function.

C_{max} is the maximum fitness value in the current population.

In equation (2), fault location and fault resistance are selected as two variables. They are represented as binary strings in GA. Three GA operators are generally used: selection, crossover, and mutation. The selection operator mimics the process of natural selection of strings to create a new generation, where the fittest members reproduce most often. The crossover, applied with probability, acts on a pair of selected members providing the exchange of data carried by binary strings. The mutation, applied with probability, randomly affects the single bit in a member. The GA search process is as follows: at the beginning, the initial population is generated randomly. Then posing the fault according to the initial population, the short-circuit study is carried out to obtain the calculated during-fault phasors and further calculate the fitness value for each individual. The next generation is produced by applying the three steps as described above. The process is repeated until the best match is found.

4 - CASE STUDY:

This section presents results of the application of the proposed method on an 11-bus test system of an electric utility company shown in Fig.(2). The system description is listed in [6]. The GA uses the following parameters:

Population size : 30

Number of generations: 100

Crossover probability : 0.9

Mutation probability : 0.001

The coding binary string length for fault location and fault resistance is 6 bits. Fault location ranges from 0 to (4 x number of system lines). Fault resistance ranges from 0 to 0.4 pu.

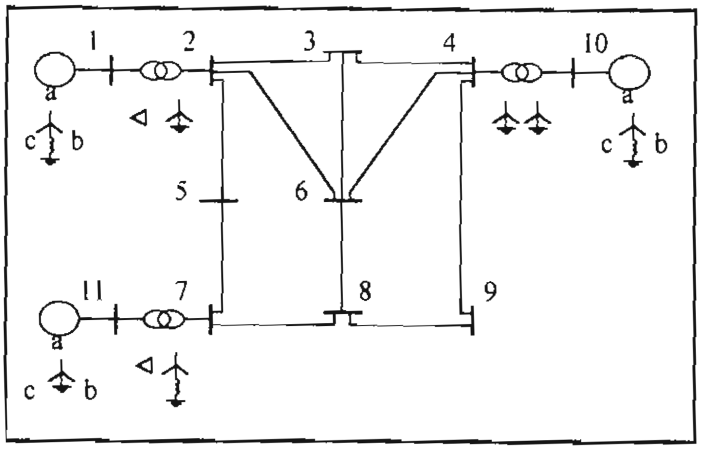

Fig. (2): 11-Bus Test System.

The recorded phasors that are used for matching were measured at bus (2). The phasors are as follows:

Vab: the line voltage between phase (a) and phase (b).

Vbc: the line voltage between phase (b) and phase (c).

Vca: the line voltage between phase (c) and phase (a).

I23 : the line current of line (2-3).

I25 : the line current of line (2-5).

I26 : the line current of line (2-6).

(i) Case 1:

The predetermined fault that is posed to the simulation program is between bus (6) and bus (8). The fault is located in the middle of the line, i.e. 50% of the line measured from bus (6). The fault resistance is selected to be 0.3 pu. The fault type is a line-to-line fault between phase (b) and phase (c).

The results of the GA based fault location estimation program were as follows:

Fault type : line-to-line fault.

Faulted line : line (6-8).

Fault position : 73% of the line measured from bus (6).

Fault resistance: 0.23 pu

The simulation time on a Pentium III PC, 950 MHz processor was 90 seconds.

The maximum fitness value through the generations is shown in Fig.(3).

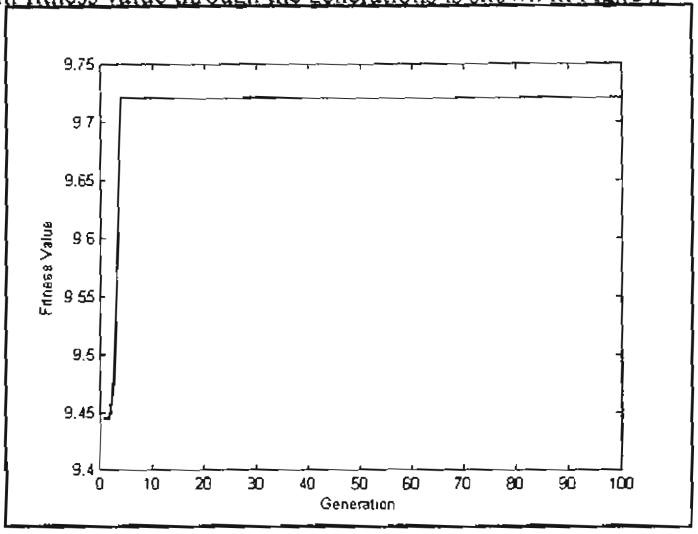

Fig. (3): Maximum Fitness Value of Case 1.

(ii) Case 2:

The predetermined fault that is posed to the simulation program is between bus (4) and bus (6). The fault is located 60% of the line measured from bus (4). The fault resistance is selected to be 0.2 pu. The fault type is a line-to-ground fault at phase (a). The results of the GA based fault location estimation program were as follows:

Fault type : line-to-ground fault.

Faulted line : line (4-6).

Fault position : 60% of the line measured from bus (4).

Fault resistance: 0.203 pu

The simulation time on a Pentium III PC, 950 MHz processor was 90 seconds.

The maximum fitness value through the generations is shown in Fig.(4).

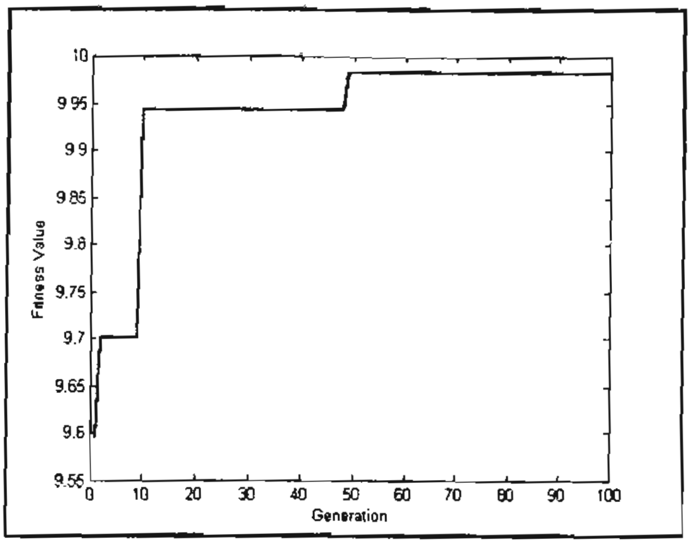

Fig. (4): Maximum Fitness Value of Case 2.

5 - CONCLUSION:

To improve the accuracy for fault location estimation when only limited data are available, the "waveform matching" concept may be used. The paper presented a fault location approach using "waveform matching" based on GA. The biggest advantage is to utilize the limited data available to locate fault without a need for additional devices or more monitored data. It is suitable for the situation in which conventional algorithms cannot be applied. The proposed software has been tested using an 11-bus system of an electric utility company. The test results show that the approach is quite promising where the fault location and fault resistance were accurately determined as shown from the test results.

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