Modeling the Input Variables and Setting on the Static System Model at Using the Genetic Algorithm for Fault Location in the Power Transmission Grid

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Abstract. In the paper is presented a method for fault location in the power grid through waveform matching of the recorded wave from failure with simulation from the static system model wave failure. The basis of the approach is comparing of the phase of the waves. The search process to find the best waveform match is actually an optimization problem. The genetic algorithm is used to find the optimal solution. The proposed method is suitable in cases where data from digital fault recorders are scarce. In these circumstances, the proposed approach provides more accurate results compared to the other known techniques. But for the correct operation of this method for fault locating in the system exercise influence both the form of the acquired form from digital fault recorders input data thus the correlation between the power transmission system and the static system model. Namely these issues are the subject of this paper.

Keywords: Genetic Algorithm, Fault Location, Digital Fault Recorders, Simulation.

1 Introduction

Rapid and accurate identification of the site of accident in the transmission system is crucial for its reliability and is the first step towards rapid recovery system. The accuracy of evaluating of the fault essentially depends on the available information. While there are some successful algorithms for the fault location, using data from two or three substations, it is difficult to achieve satisfactory results if the information is from a limited number of substations [1, 2].

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, simulation studies are carried out to obtain simulated waveforms under specified fault conditions. The simulated waveforms are then compared with the recorded ones. By iteratively posing faults in the system, running simulations, and comparing the simulated waveforms with the recorded ones, an optimal estimate of the fault location may be obtained. It may be determined as the one specified in the simulation studies that allows simulating the waveforms that best match the recorded ones. The matching is made at the phasor level presently.

In this research, the fault location estimation is mathematically formulated as an optimization problem of which the fault location and fault resistances are unknown variables. An efficient genetic algorithm (GA) based searching scheme is developed for obtaining the solution that is globally optimal [3].

The article explains the key concepts of "sparse data" and "waveform matching". Below are presented the requirements towards the input data to the GA and an algorithm for tuning the static model of the system. The algorithm is tested and the results of before and after tuning the Static System Model are presented in tabular form.

2 Contributions to Internet of Things

The paper presents a method for fault location in the power grid through waveform matching of the recorded wave from failure based on simulation by using a static system model. For solving this optimization problem used genetic algorithm. The accuracy of the proposed method depends on the actuality of static system model with actual power grid in the moment. The contribution of this publication is to develop an algorithm for setting the static model of the system. The proposed method is suitable in cases where data from digital recorders are scarce.

3 Motivating Problem

The proposed approach uses the method "waveform matching". There are presented two key concepts, namely "sparse data" and "waveform matching" as follows.

3.1 Sparse Data

Sparse data, in the work, is referred to the data obtained from recording devices sparsely located at various substation locations. The recording devices may include digital fault recorders (DFRs), digital relays, or other intelligent electronic devices (IED). The data captured by the recording devices may include analog quantities such as voltage and current waveforms and digital quantities such as breaker status and relay operation status. The both analog and digital quantities may be useful for locating the fault.

If only sparse data are available for fault location, in many cases, none of the one-end, two-end and three-end algorithms may be applicable for locating the faults with satisfactory accuracy [1-2]. To solve the fault location problem utilizing sparse data, the “waveform matching” based approach may be used as illustrated next.

3.2 Waveform Matching

In the "waveform matching" approach, a power system model is used to carry out simulation study. To simulate the waves in the model need to ask fault. Then are compare the simulated and recorded waves and on the degree of match is determined the fault. Theoretically, the simulated fault waveform will match completely with the recorded fault waveform if the assumed fault location and fault resistance correspond to the real fault condition.

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. When searching for the appropriate fault resistance first selects the most probable locations of the accident. Changing the fault resistance according to a specific increment, fault locations are searched thoroughly. The process will proceed until the selected sections in power system and possible fault resistance range are exhausted.

After completing the search, the fault is determined based on the optimal matching scheme. There are two possible schemes - phasor matching and transient matching. In the test is used the phasor for matching. The degree of similarity can be expressed by the following criterion:

$$f_c\left(x, R_f\right) = \sum_{k=1}^{N_V} r_{kV} \left|V_{ks} - V_{kr}\right| + \sum_{k=1}^{N_i} r_{ki} \left|I_{ks} - Ikr\right| \tag{1}$$

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.; r_{kv}, r_{ki} – weights for the errors of the voltages and currents respectively.; $V_{ks}, V_{k\gamma}$ – the during-fault voltage phasors obtained from the short-circuit studies and from recorded waveforms respectively.; $I_{ks}, I_{k\gamma}$ – the during-fault current phasors obtained from the short-circuit studies and from recorded waveforms respectively.; N_v, N_i – the number of the selected voltage and current phasors respectively.; k – the index of the voltage or current phasors.;

The best estimate of the fault will be achieved when the value of the function is the smallest. Therefore, the problem of assessing the fault actually is optimization problem.

The genetic algorithm (GA) based on the optimization approach is a good choice to search for the global optimal solution. To use GA has to convert the minimization problem to maximization problem in order to utilize the GA. That requires us to convert the cost function to a fitness function of GA. The fitness function is as follows:

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

where:
$f(x,R_f)$ – is fitness function
C_{max} – is the maximum fitness value in the current population.

In equation (2), the location of the short circuit and resistance were selected as two variables. They are represented as binary lines in GA. Usually in GA are used three operators: selection, crossover and mutation. The process of searching through GA 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 simulated 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 Implementation of the Algorithm for Setting Parameters of the Static System

4.1 Data Requirement

The data inputted by the user includes necessary information for the fault, matching options and selected fault data. The necessary information for the fault refers to the estimated fault type and faulted circuit that can help limit the GA range search. The matching options are used for specifying currents through the circuits or voltages at buses used for waveform matching. Selected fault data refers to a choice in the use of different DFR combinations under the situation where multiple DFRs are triggered.

The static system model refers to the saved case of PSS/E. It should contain the raw data for power flow, data for sequence impedance and system topology. The model is static since it may not reflect the prevailing system conditions. This may affect the accuracy of the algorithm and some measures overcoming the shortcoming should be taken.

The fault data refers for the data captured through Digital Fault Recorders (DFRs). The current software reads fault data provided in COMTRADE format [6]. The COMTRADE file should include two files: COMTRADE configuration file, which contains information for interpreting the data file, and COMTRADE data file, which contains analog (current and voltage) and digital values (breaker contacts and relay status) for all input channels for a specific substation.

The substation interpretation data contains information that relates to the channel numbers to the monitored signals. It also represents the correspondence between the designations used in the DFR files and those used in the PSS/E file. Each substation should have one interpretation file and the interpretation file needs to be modified to reflect the DFR configuration or the system model changes. The information should be provided by the user in advance.

The data inputted by the user includes necessary information for the fault, matching options and selected fault data. The necessary information for the fault refers to the estimated fault type and faulted circuit that can help limit the GA range search. The matching options are used for specifying currents through the circuits or voltages at buses used for waveform matching. Selected fault data refers to a choice in the use of different DFR combinations under the situation where multiple DFRs are triggered.

4.2 Synchronizing the Phasors from DFR Recordings

By applying Fourier algorithm using equation (2) are calculate the fitness values the voltage and currents phasor for different substations. The DFR data from different channels in the same substation or in different substation may lack synchronization. In order to reduce the error of matching, the phasor calculated from DFR must be synchronized. Fig. 1 shows the relationship between the phasors obtained from the load flow study and from the recorded waveforms. S_{na}, S_{nb}, S_{nc} represent pre-fault phasor of phases A, B, C respectively are obtained by the load flow study. R_{na}, R_{nb}, R_{nc} represent pre-fault phasors of phases A, B, C respectively are obtained from the recorded waveform. R_{fa}, R_{fb}, R_{fc} represent during-fault phasors of phases A, B, C respectively are obtained from the recorded waveform. α is the angle difference between the pre-fault phasor obtained by the load flow study and the pre-fault phasor obtained from the recorded waveform.

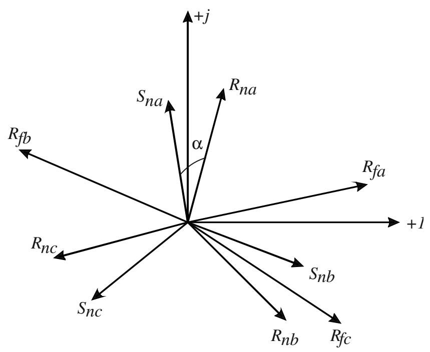

Fig.1 The relationship between the phasors obtained by load flow study and by recorded waveform.

The synchronization is done by rotating counterclockwise the pre-fault phasors R_{na}, R_{nb}, R_{nc} by an angle of α. Consider that the angle difference between pre-fault phasor and during fault phasor for a specific phase and current (voltage) is fixed; during-fault phasor R_{fa}, R_{fb}, R_{fc} is also rotated by an angle of α.

4.3 Tuning the Static System Model

As mentioned before, the given static system model, used in the simulation studies, may not reflect the prevailing operation conditions of the system when the fault occurs. The generator power output and load power may not always keep the same value and may vary with time. To match exactly the phasor extracted from DFRs and those obtained from simulation studies, it may be beneficial that the system model used in simulation studies is updated by utilizing the information captured close to the moment before the fault occurs. The process of updating the system is called “tuning of the static system model”.

Tuning the static system model includes two aspects [5]: tuning the topology of the system model and tuning the static parameters such as generator and load data.

The updating of the system topology relates to updating the service status of the circuits in the system. The pre-fault status of breaker in the circuit or the current through the circuit is used to update the system topology. There are two possible situations: 1) In the first situation, where both the circuit's breaker status and currents (or only the currents) are monitored by DFR, the current magnitude will be utilized to update the service status of the circuit. If the current magnitude is smaller than a pre-specified threshold, the circuit will be designated as being out of service. Otherwise, the circuit will be designated as being in service. 2) In the second situation, where only the breaker status of the circuits is monitored, the pre-fault breaker status will be utilized to determine the service status of the circuit. If the pre-fault status breaker indicates an open circuit, then the circuit will be determined as out of service. Otherwise, the circuit will be determined as being in service.

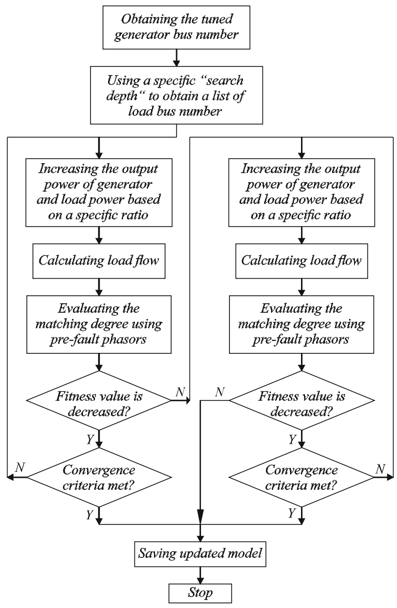

Fig.2 Block diagram of the static parameter settings.

The goal of updating the generator output power and the power load is to bring the static system model closer to the real life system. To reach the purpose, again is utilized the waveform-matching. The matching is made between the voltage and current waveforms obtained by DFRs and those generated by load flow studies. The equation (1) is applied as the objective function to evaluate the matching degree of the simulated and recorded waveforms. Here, the corresponding V_{ks}, V_{kr} and I_{ks}, I_{kr} have different meaning. They are the pre-fault voltage or current phasors obtained from the load flow study and recorded waveforms respectively. The static parameters that provide the best match are the ones that minimize the objective function. The flowchart for tuning the static system parameters is shown in Fig. 2.

5 Test Algorithms

The fault case is selected for which two DFRs located in substations Granitovo and Podves locations respectively, were triggered. Table 1 shows the effect of tuning the static parameters. The first column represents the different combinations of DFR data. The second column shows the fitness value calculated using the pre-fault phasor. The fitness value decreases significantly after tuning the system based on the strategy mentioned above. The updated fitness value is shown in the third column. These results prove the tuning strategy is effective. The more accurate tuning depends on the region of tuning and more real life data.

Table 1 The change of fitness value using pre-fault phasor before and after tuning

DFR UTILIZED	FITNESS VALUE USING PRE-FAULT PHASOR BEFORE MODEL TUNING	FITNESS VALUE USING PRE-FAULT PHASOR AFTER MODEL TUNING	QUANTITIES MATCHED
Granitovo	14,8	8,87	All monitored currents
Granitovo Podves	6,21	0,62	Currents on affected Ckt.25
Granitovo Podves	37,26	27,75	All currents
Granitovo Podves	7,45	0,92	Currents on affected Ckt.25, Ckt.27
Granitovo	17,21	19,41	All currents and voltages
Granitovo Podves	37,45	27,97	All currents and voltages

6 Conclusion

After tuning up of the system based on the strategy mentioned above, compatible values decreases significantly. These results demonstrate that the strategy is effective. The more accurate tuning depends on the region of tuning and more real life data.

The paper offers requirements toward input data for GA and tuning the static system model. The results presented in Table 1 are been used to test the GA [3].

The biggest advantage is using limited data to find the fault and using data from other digital recording devices. It is suitable for situations where conventional algorithms cannot be applied. The approach does not refer to a specific section or line; it is based on a system view. However, the known system model including the static parameters and topology is assumed.

The algorithm has been tested on four emergencies [3]. The test results show that the approach is very promising.

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