فهرست مقالاتی که به صورت پوستر ارائه می شوند

سه شنبه ۱۰ آبان ۱۳۹۰ – ساعت ۱۰:۳۰ تا ۱۲:۰۰

#	کد مقاله	عنوان مقاله	ارائه کننده
1	11-F-CAP-1110	تشخيص جريان هجومي در حفاظت ديفرانسيل ترانسفورماتور قدرت با روش مبني بر تبديل موجك گسسته	معصومه رسول پور
2	11-E-CAP-1210	Novel Fault Location Algorithm Based on the Matching Between Transient Current Samples and Simulated Waveforms Using PSO	Esmaeel Niazi
3	11-F-CAP-1271	ريكلوزينگ اتوماتيك سرعت بالا در خط انتقال kV 765 عسلويه اصفهان با استفاده از مولفه هاي متقارن توان ظاهري با توجه به مدل قوس بازگشتي	حسن آبنيكي
4	11-F-CAP-1328	هماهنگي بهينه ركلوزر سكشنالايزر فيوز و رله جريان زياد با استفاده از الگوريتم ژنتيك	تقي ابراهيمي
5	11-F-CAP-1399	بازيابي هماهنگي سيستم حفاظتي شبكه توزيع بعد از نصب منابع توليد پراكنده	محمود سرلك
6	11-F-CAP-1510	جايابي بهينه محدودكننده جريان خطا و تحليل اثر آن بر پايداري حالت گذرا	فرزاد مليجي
7	11-F-CAP-1692	مدل سازي خطاي امپدانس بالا در شبكه هاي توزيع انرژي الكتريكي	سيدمحمدحسن حسيني
8	11-F-CAP-1828	ارائه الگوريتمي مبتني بر ماتريس امپدانس براي مكان يابي خطا در شبكه هاي توزيع چهار سيمه	اسماعيل ابراهيمي
9	11-F-CAP-2069	جايابي خطا در ميكروگريد با استفاده از تبديل S	احسان بهرامي سعادت آبادي
10	11-E-ELM-1051	Parameter Estimation of Induction Motor Using Shuffled Frog Leaping and Imperialistic Competitive Algorithms	Mansoor Ojaghi
11	11-E-ELM-1266	Direct Power Control of Grid and Rotor Side converters in DFIG Based Wind Turbine	Jafar Zandzadeh
12	11-E-ELM-1287	A New Hybrid Model for Doubly-Fed Induction Generator with Inter-Turn Stator Fault	Mohamad Yosefikiya
13	11-F-ELM-2102	روش كاهش ريپل گشتاور و نوسانات جريان راه‌اندازي در موتورهاي القائي	علي دقيق
14	11-F-ELM-2157	تحليل عملكرد نامتعادلي ماشينهاي القايي متقارن تحت شرايط نامتعادلي همزمان روتور و استاتور	مهدي رجائي
15	11-F-HVS-2228	مطالعه موردي اثرات نيروهاي مكانيكي ناشي از بروز خطاي اتصال كوتاه در يك پست انتقال	پژمان خزايي
16	11-F-MNG-1154	بررسي تاثير اشتغال بر كيفيت زندگي كاري كاركنان	محسن محمدنوربخش لنگرودي
17	11-F-MNG-1190	بررسي عوامل موثر بر سيستم پذيري مديران در حوزه هاي ستادي و عملياتي شركت توزيع نيروي برق تهران بزرگ	امير نويدي
18	11-F-MNG-1215	مديريت دانش و عملكرد در حوزه بهره برداري شركت توزيع برق شهر يزد ؛ تحليلي بر تأثير عوامل زمينه اي مديريت دانش با كاربرد مدل يابي معادلات ساختاري	فاطمه شاكري
19	11-F-MNG-1245	شناسايي عوامل تأخير در پروژه‌هاي برق منطقه‌اي تهران	وحيد قرباني
20	11-F-MNG-1278	تحليلي بر ميزان آمادگي شركت توزيع برق يزد جهت استقرار مديريت دانش با رويكرد چارچوب ارزيابي عمومي	فاطمه شاكري
21	11-F-MNG-1808	برنامه ريزي استراتژيك در شركت توزيع نيروي برق شيراز	صديقه پورعدل
22	11-F-MNG-1871	طراحي مدل ارزيابي عملكرد كاركنان براساس مدل شايستگي با رويكرد منطق فازي و AHP (مطالعه موردي پژوهشگاه نيرو)	كيميا ميركمالي
23	11-F-MNG-2301	سنجش بهره وري نيروي انساني در صنعت برق با استفاده از مدل ACHIEVE	حسين منصوري
24	11-F-MNG-2305	نيازسنجي آموزشي مديران در رابطه با مهارت هاي سه گانه مديريتي با رويكرد MCDM	حسين منصوري
25	11-F-MNG-2370	بررسي علل تأخير در انجام پروژه‌هاي طرح و توسعه(مطالعه موردي: شركت برق منطقه‌اي يزد)	حامد فلاح تفتي
26	11-F-PDS-1114	تاثير اتوماسيون و پاسخگويي بار در كاهش هزينه هاي قابليت اطمينان شركت هاي توزيع	حميدرضا آراسته
27	11-F-PDS-1256	توسعة ديناميك پست‌هاي فوق‌توزيع با استفاده از ماتريس احتمال برگرفته شده از شرايط توأم جغرافيايي و الكتريكي شبكة توزيع	سيدمهدي مظهري
28	11-F-PDS-1267	روش جديد آشكارسازي جزيره مزارع بادي بر اساس اندازه گيري زاويه فاز	مريم زادفلاح فرشمي
29	11-F-PDS-1307	مدل سازي شينه هاي كنترل ولتاژ در روش پخش بار پسرو-پيشرو	محمد جعفريان
30	11-F-PDS-1620	بازنگري و مطالعه موردي تلفات و ضريب تلفات در سيستم هاي سه فاز نامتعادل و غيرسينوسي	ميثم احمدي
31	11-F-PDS-1643	جايابي همزمان رگولاتور ولتاژ و خازن‌هاي ثابت و سوئيچ‌شونده در سيستم‌هاي توزيع با استفاده از الگوريتم بهينه‌سازي توسعه يافته و چندهدفه اجتماع ذرات	رضا ابولي
32	11-F-PDS-1695	مقايسه كاربردي(ANFIS) با (MLP) در تعيين محل عيب يابي كابل فشار متوسط	سلمان نصرالهي
33	11-F-PDS-1722	آسيب پذيري ترانسفورماتورهاي هوايي توزيع در برابر زلزله و راهكار بهسازي آنها	محمدعلي جعفري
34	11-F-PDS-1892	كاهش هزينه وافزايش پايداري خطوط هوايي شبكه توزيع با بهينه سازي فونداسيون و لحاظ نمودن ضريب اطمينان بهينه در طراحي مكانيكي پايه ها	فرامرز سپهري
35	11-F-PDS-2024	كليدزني بهينه شبكه هاي توزيع در جهت كاهش تلفات	علي عسگري
36	11-F-PDS-2027	متعادل‌سازي بار در شبكه‌هاي توزيع فشارمتوسط توسط جابجايي مشتركين تكفاز	اميد همايي
37	11-F-PDS-2125	طراحي و ساخت دستگاه تخلخل سنج بتن جهت ارزيابي سازه هاي بتني مورد استفاده در صنعت برق	سعيد عباچي زاده
38	11-F-PDS-2168	استفاده از الگوريتم دسته بندي فازي c-meanو شبكه عصبي جهت تجديد آرايش شبكه‌هاي توزيع به منظور كاهش تلفات	رحمان دشتي
39	11-F-PDS-2269	ارائه يك الگوريتم كاربردي براي جايابي سكسيونر در شبكه هاي فشار متوسط توزيع ايران	مرضيه كرمي
40	11-E-PQA-1056	A New Structure of Single Phase Multilevel Inverter with Reduced Number of Switches and Low Output Harmonics	Mohsen Ebadpoor

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Novel Fault Location Algorithm Based on the Matching Between Transient Current Samples and Simulated Waveforms Using PSO

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Abstract

Relays installed to protect transmission lines have current inputs, which take phase currents via CTs. Almost all modern numerical relays are equipped with "Fault Recording" function to record the phase currents and/or voltages in the event of a power system fault. Recorded samples have valuable data about the fault location. This paper presents a novel fault location algorithm, which utilizes only current samples recorded by the relay in the one terminal. Recorded samples will be compared with the waveforms, which are generated by simulation of various conditions of the fault. Various conditions include different fault locations, fault resistances and equivalent models of the source. Using PSO algorithm, the best configuration that has the highest matching between sampled data and simulated waveforms is specified as the fault condition. As a result, the fault location is determined with nearly no computational error. Extensive simulations carried out in SimPowerSystem toolbox of MATALB software confirm capability and accuracy of proposed method.

1. Introduction

Accurate fault location reduces time and costs related to the dispatched crews searching to find the fault location [1]. Also, provides customers and consumers feeding with minimal interruption and improves the performance of the power system [2]. In most papers, fault location methods, which are used in the transmission lines, are based on two different methodologies [3]: first group is related to methods, which use fundamental component of voltage and current in order to calculate impedance from the fault locator to the fault point. These methods are well known as impedance methods [4]. Second category is related to the algorithms, which utilize traveling wave theorem and analyze high frequency voltage and/or current traveling waves generated by fault occurrence [5, 6]. However, some other innovative algorithms are presented in papers, which use different methods to find the location of fault. For example in [7] it is suggested to combine travelling wave method and impedance measurements. Algorithm presented in [8] proposes the application of support vector machine in combination with frequencycharacteristics of the measured voltage and current transient signals. Artificial neural networks are used in [9, 10] to calculate the location of fault.

Matching between sampled data and simulated results is presented in some papers. In [11] it is proposed to calculate fault location by matching voltage sags in multiple busses of the system with the simulated systems. Algorithm presented in [12] suggests matching between during fault voltage and current phasors in feeder in addition to voltage sag measurement in the remote terminal with the simulated networks. Similarly, in [13] it is suggested to match the during fault current and voltage phasors, with simulated waveforms to determine fault location.

This paper presents an innovative algorithm based on matching between simulated transient waveforms and sampled data. Current samples taken in just one terminal with low sampling rate of 12 or 16 samples per cycle are sufficient. Almost all modern numerical relays have fault recorders to record current and voltage samples taken from transmission lines via CTs and VTs. The recording function is used to record the phase currents and/or voltages in the event of a power system fault, up to several seconds [14].

Current samples, which are taken by CTs and recorded by the relay, are compared to the waveforms generated by simulation of different conditions of the fault. By iteratively posing faults in the system, running simulation, and comparing the simulated waveforms with the recorded current samples, optimal estimation of the fault location is obtained. PSO algorithm is applied to find optimal estimation. Proposed method uses transient waveforms instead of phasors. Because of using current samples taken via CTs and recorded in relay in just one terminal, no additional sampling and recording equipments are required and it is avoided from data synchronization and communication systems, hence, low cost is achieved. Fault resistance, fault distance and the type of the fault have no effect on the accuracy of the algorithm. Both the fault location and fault resistance are calculated as the results of the algorithm. To evaluate operation of the proposed method, a typical 132 kV single ended transmission line is simulated using SimPowerSystem toolbox of MATLAB. Simulation results confirm capability and accuracy of proposed method.

2. Particle Swarm Optimization [15]

Particle Swarm Optimization (PSO) is one of the population-based evolutionary computation techniques. PSO algorithm was first introduced by Kennedy and Eberhart in 1995 [16] and has been used to solve a broad range of optimization problems. Starting with a randomly initialized population, each particle in PSO flies through the searching space with a dynamically adjusted velocity. The velocity adjustment is based upon the historical behaviors of the particles themselves as well as their companions. In this way, the particles tend to fly towards better and better searching areas over the searching process. The searching procedure based on this concept can be described as:

$$v_i^{k+1} = w_i v_i^k + c_1 r_1 \times \left(pbest_i - x_i^k\right) + c_2 r_2 \times \left(gbest - x_i^k\right) \tag{1}$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{2}$$

where, c_1 and c_2 are constants defined as acceleration coefficients; w_i is the inertia weight factor; r_1 and r_2 are random coefficients between zero and 1, x_i and $pbest_i$ represent the ith particle and the best previous position of x_i, respectively; $gbest$ is the best particle among the entire population; v_i velocity for particle x_i. Every particle's position is then evolved according to (2), which produces a better position in the solution space. Fig. 1 shows an illustration of this searching process. The optimization process begins with a random value. For each generation of particles, the fitness is evaluated to find the local best (*pbest*) and the global best (*gbest*). The particles' new velocities and positions are calculated according to (1) and (2). The process is repeated until reaching desired fitness value corresponding to certain generation number.

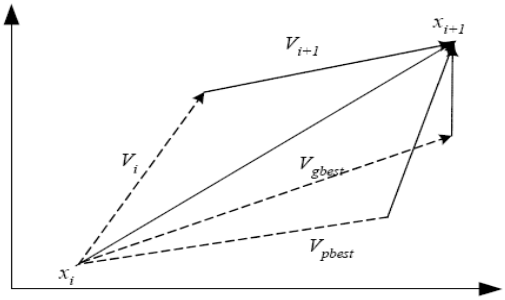

Fig. 1. Illustration of PSO searching process [15]

3. Transient Waveform-Matching Fault Location Algorithm

In the event of a power system fault, transient current and voltage waveforms are produced. Proposed algorithm on this paper, applies a transient waveform-matching algorithm to find accurate location of fault using samples taken from current transient waveforms. When the fault is detected, fault recording function of the relay is activated to record the samples taken from current waveforms via CTs.

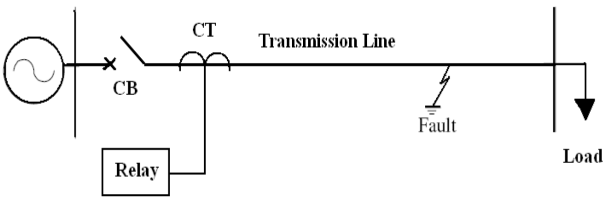

Fig. 2. Transmission line with relay and CT

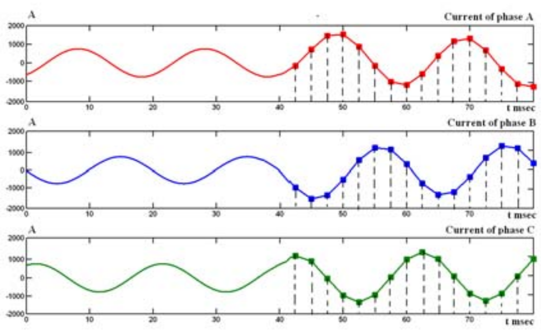

Fig. 3. Three phase transient currents for fault at t =40 msec and recorded samples in the relay

A typical transmission line, which is equipped with CTs and such relay is shown in Fig. 2. Three phase transient currents caused by symmetrical three-phase fault at t = 40 msec and sampling process are presented typically in Fig. 3. Because of using low sampling rate 12 or 16 samples per cycle, the algorithm is not affected by the core saturation of CTs and related high frequency filtering problem. So, conventional CTs, which are installed in the substations, can be used for this purpose.

Using recorded current samples, it is possible to determine fault location. Various conditions of the system including different fault location, fault resistance and different thevenin equivalent models of the source are simulated. Every configuration has its own transient current waveforms. Current samples are taken from simulated networks and then are compared to the real sampled data. The best configuration that has the highest matching between sampled data and simulated waveforms is specified as the fault condition. Thereupon, the fault location, fault resistance and thevenin equivalent model of the source are determined, simultaneously. PSO algorithm is used to find the best configuration, which is more similar to the real fault condition. Fig 4. represents the flowchart of proposed algorithm.

Matching between simulated data and current samples, which are recorded in the relay, is checked by the fitness function:

$$f_i(x_i,R_i,V_i,\theta_i)=\sum_{k=1}^{N}\{|I_{ks}-I_{kr}|\} \quad (3)$$

where, x_i and R_i are fault location and fault resistance in ith iteration, respectively. V_i and θ_i are amplitude and angle of the source voltage, respectively. I_{ks} and I_{kr} are simulated and real data samples. N is the number of data samples taken from the network and recorded in the recorder. Computational error for the distance calculated as fault location can be obtained by:

$$\%error=\frac{x_{calculated}-x_{actual}}{L_{Line}}\times 100 \quad (4)$$

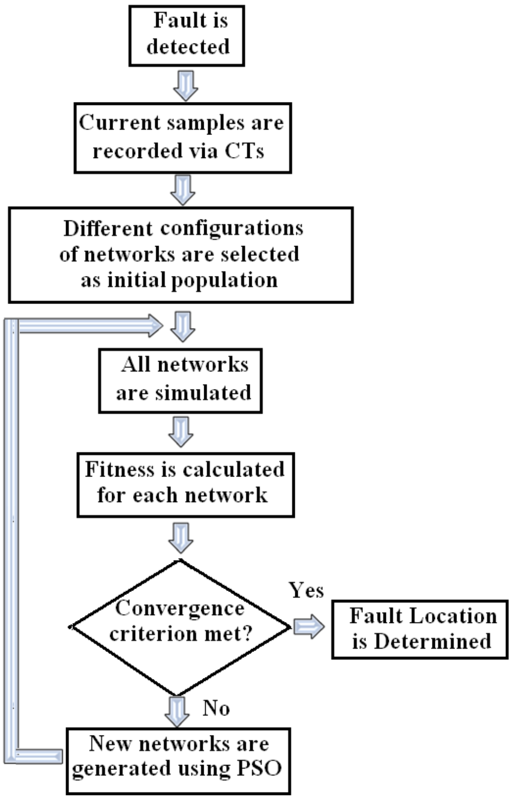

Fig .4. Representation of proposed algorithm

4. Evaluation of Proposed Algorithm

To evaluate capability and accuracy of the proposed algorithm, a 132 kV and 50 Hz three-phase transmission line with the length of 123 km is simulated using SimPowerSystems toolbox of MATLAB software. Fig. 5 shows schematic diagram of the studied system in the SimPowerSystems toolbox of MATLAB software.

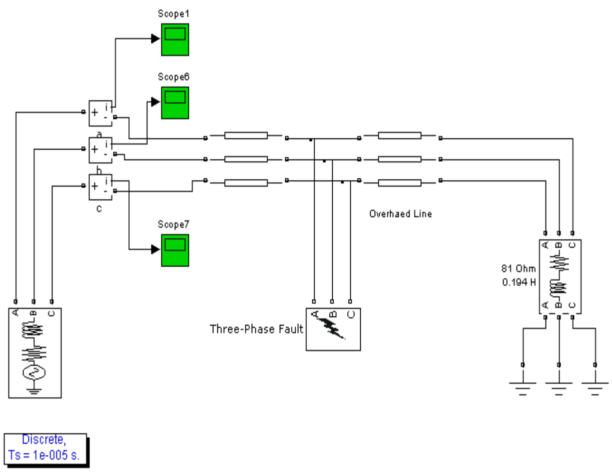

Fig. 5. Schematic diagram of the studied system in the SimPowerSystems

The transmission line parameters, which are used in the simulations, are R = 0.3317 Ω/km, L = 1.326 mH/km and C = 8.688 nF/km. The equivalent model used for the voltage source includes an ideal voltage source with the amplitude of 132 kV in series with the resistance of R = 13.6 Ω and the inductance of L = 0.35 H as the source impedance.
Various configurations of system for single-, double- and three-phase to ground faults, as well as for two and three phase faults have been simulated. Fault resistances between zero and 100 Ω and different fault locations are applied and for each configuration, fault location is calculated using proposed algorithm. For example if a single phase to ground fault occurs in distance 31 km from terminal, with 19 Ω fault resistance in t = 40 msec, the three phase currents and recorded samples are as shown in the Fig. 6.

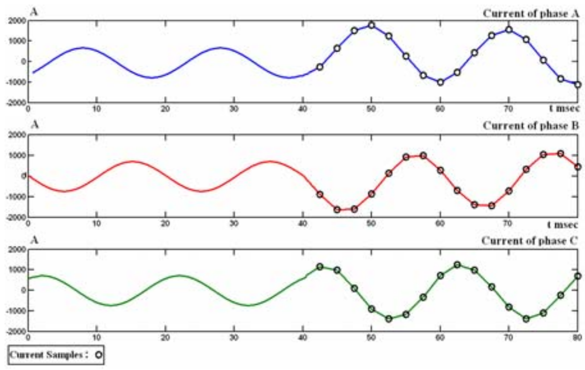

Fig. 6. Three phase currents and the samples for single phase to ground fault in 31 km with 19 Ω fault resistance

After that samples are taken from the transient current waveforms, the algorithm is started. Specified number of systems with random configuration including random fault location, fault resistance and source parameters are simulated as initial population. Fitness function (3) is computed for each random configuration and the algorithm will be repeated until the fitness is minimized and reach to the desired accuracy. Fitness function calculated in successive iterations for mentioned fault condition is shown in Fig. 7. It is clear From Fig. 7 that the fitness function is minimized near the fault location of 31 km and fault resistance of 19 Ω. After 100 iterations, fault location and resistance are determined 30.993 km and 19.3492 Ω, respectively. Where determined fault location has 0.006 % computational error.

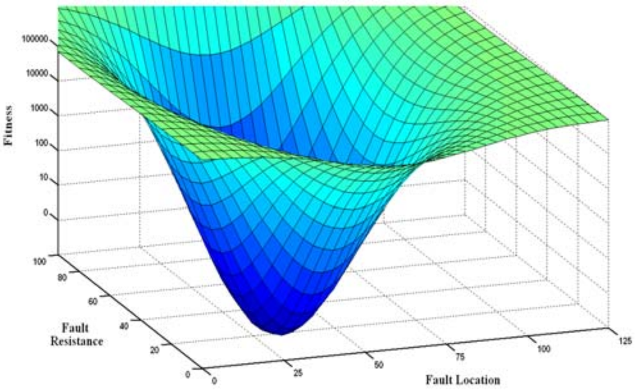

Fig. 7. Fitness function for fault occured in 77 km with fault resistance of 62 Ω

For another example if three-phase to ground fault occurs in distance 3 km with fault resistance of 2 Ω, fault location is calculated 3.011km which has less than 0.009 % error and fault resistance is calculated 2.159 Ω.

To demonstrate the effect of different parameters on the accuracy of proposed algorithm, following subsections discuss about the influence of fault resistance, fault inception angle, fault location and fault type on the algorithm.

4.1. Influence of fault resistance

About 80% of the faults occurred in transmission lines are single phase to ground case [17] which the line is short-circuited to the earth without or via a fault resistance. Majority of the fault location algorithms take effect from fault resistance. To evaluate the influence of the fault resistance, simulation results for single and double-phase to ground faults occurred in distance 87 km of transmission line with different fault resistances are presented in Table 1. It is clear from results presented in Table 1, that the fault resistance has no significant effect on the accuracy of the proposed algorithm.

4.2. Effect of fault distance

To investigate the effect of fault distance on the accuracy of proposed method, results for single-, double- and three-phase to ground faults occurred in different distances on the transmission line with zero fault resistance are shown in Table 2.

Table 1. Influence of fault resistance on the accuracy of the proposed method for faults occurred in 87 km

Fault type	Fault Resistance	Calculated distance	Error %
Single phase to ground	0	87.000	0.000
	30	86.993	-0.006
	90	87.012	0.010
Double phase to ground	0	86.895	-0.012
	30	86.973	-0.021
	90	86.975	-0.020
Three phase to ground	0	87.007	0.006
	30	87.015	0.012
	90	86.997	-0.002

Table 2. Effect of fault distance on the accuracy of proposed method

Fault type	Actual fault distance	Calculated distance	Error %
Single phase to ground	5	4.969	-0.025
	50	49.990	-0.008
	100	100.009	0.007
Double phase to ground	5	5.017	0.014
	50	50.001	0.000
	100	100.011	0.009
Three phase to ground	5	5.000	0.000
	50	49.985	-0.012
	100	100.980	0.017

4.3. Effect of fault type

The proposed algorithm in this paper is capable to find location of various types of faults occurred in transmission lines. To understand the effect of fault type on the accuracy of the proposed method, simulation results for single, double- and three-phase to ground faults and double and three-phase faults occurred with 12 Ω fault resistance are presented in Table 3.

Results in Table 3 confirm that the accuracy of the proposed algorithm is similar for different types of faults in the transmission line.

Table 3. Effect of fault type on the accuracy of proposed method

Fault type	Actual fault distance	Calculated distance	Error %
Single phase to ground	15	15.005	0.004
	75	75.022	0.018
	115	115.011	0.009
Double phase to ground	15	15.017	0.014
	75	74.997	-0.002
	115	115.005	0.004
Three phase to ground	15	15.015	0.012
	75	74.990	-0.008
	115	114.982	-0.015
Double-phase fault	15	15.024	0.020
	75	75.022	0.018
	115	114.988	-0.009
Three-phases fault	15	14.985	-0.012
	75	75.000	0.000
	115	115.007	0.006

5. Conclusion

This paper presents a new PSO-based fault location algorithm, which is based on the matching between transient current samples and simulated waveforms. Proposed algorithm determines accurate location of the fault using current samples recorded by the "recorder function" of protection relay. Various configurations of network including fault location, resistance and source model are simulated. Then, recorded samples are compared to the simulated waveforms. Applying PSO algorithm, the best configuration, which has highest matching between simulated waveforms and sampled data is recognized as the fault condition. Because of using current samples taken via CTs and recorded by relay in just one terminal, in addition to simple structure, no additional sampling and recording devices are required. Lower price is achieved and no communication systems and data synchronization is required. Simulation results confirm capability and high accuracy of the proposed algorithm.

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