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Online Diagnosis and Monitoring for Power Distribution System

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ABSTRACT

Recently, power distribution system is getting larger and more complex. It is very difficult even for the experts to diagnosis and monitoring to made best action. This motivated many researchers to investigate power systems in an effort to improve reliability by focusing on fault detection and classification. There have been many studies on problems but the results are not good enough for applying to real power system. In this paper, a new protective relaying framework to diagnosis and monitoring faults in an electrical power distribution system with. This work will extract fault signatures by using ellipse fit using least squares criterion during fault condition. By utilizing principal component analysis methods, this system will identify, classify and localize any fault instantaneously.

Keywords: Fault Detection and Classification; Protective Relaying; PCA; PSCAD

1. Introduction

Fault detection is a focal point in the research of power systems area since the establishment of electricity transmission and distribution systems. The objectives of a power system fault analysis is to provide enough information to understand the reasons that lead to an interruption and to, as soon as possible, restore the handover of power, and perhaps minimize future occurrences if possible at all [1]. Several techniques are adopted for pattern recognition of generating the high frequency signals Artificial Neural Network (ANN) and Wavelets among other powerful pattern recognition and classification tools. ANN based algorithms depend on indentifying the different patterns of system variables using impedance information ANN is that the resolution is not efficient since it can be a very sparse network with the need for large size training data adding an additional burden on its computational complexity [2-4]. Wavelet transform is adopted to discriminate the faults type from the magnetizing inrush current [5]. Others incorporated wavelet transform with other methods such as Probabilistic Neural Network (PNN), adaptive resonance theory, adaptive neural fuzzy inference system, and support vector machines [6-10]. Fuzzy logic was also combined with discrete Fourier transform, adaptive resonance theory, principles of estimation and independent component analysis to enhance performance [9]. Unfortunately, most of the available tools for fault detection and classification are not efficient and are not investigated for real time implementation there is a need for new algorithms that have high efficiency suitable for real time usage especially for power distribution system.

2. Fault Ellipse Signature

Least squares fitting of voltage and current ellipses. During healthy condition for power distribution system for each voltage and current data during one cycle the pure ellipse we can generated in this research we using least squares criterion to define the ellipse parameter. We will try to fit the best ellipse to the given measurements from the voltage and current signal during one cycle. The mathematical representation of use will be the CONIC Equation of the Ellipse which is:

Ellipse = a*x^2 + b*x*y + c*y^2 + d*x + e*y + f = 0

Also during the fault condition we using the same method to fit ellipse parameters, the fit method using least squares criterion is very reliable method to restore the voltage and current data during fault condition to ellipse as shown in **Figure 1** the fitting ellipse for prefault condition during fault single phase to ground (AG). In the first row the fitting ellipse for phase a, b and c respectively in healthily condition and in second row the we note the first fitted ellipse for phase a will be different than fitted ellipse for phase a in first row but the no difference between phase a and b so in this way we can easily visual detect and classify the fault type.

Principal Component Analysis (PCA) based Fault Detection, Classification and Localization Method. PCA has

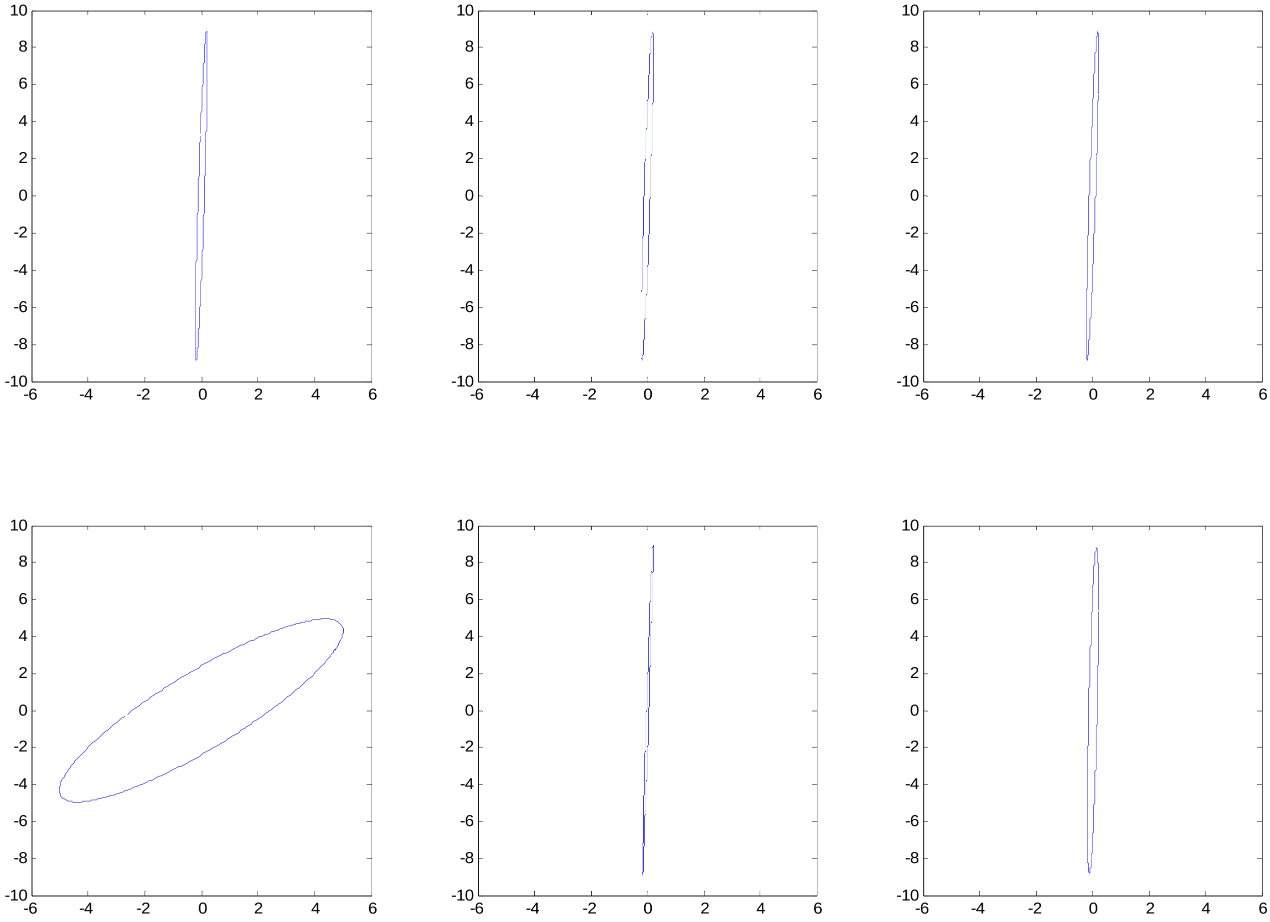

Figure 1. The fitting ellipse for prefault condition during fault single phase to ground (AG).

proven to achieve excellent results in feature extraction and data reduction in large datasets [9]. Typically PCA is utilized is to reduce the dimensionality of a dataset in which there is a large number of interrelated variables while the current variation in the dataset is maintained as much as possible [9]. The principal components (PCs) are calculated using the covariance matrix after a simple normalization procedure. After ellipse fitting we apply the PCA using following steps:

Step 1: Get data from fitting ellipse;

Step 2: Subtract the mean;

Step 3: Calculate the covariance matrix;

Step 4: Calculate the eigenvectors and eigenvalues of the covariance Matrix;

Step 5: Choosing components and forming a feature vector.

In fact, it turns out that the eigenvector with the highest eigenvalue is the principle component of the data in **Figure 2** after applying PCA in fitted ellipse during fault condition the eigenvector with the larges eigenvalue was the one that pointed down the middle of the data. It is the most significant relationship between the data dimensions.

We note the angle of principal component will be a unique and distinguished as shown in **Figure 3**.

The classification process of a fault is divided into two stages; the first is the prefault procedure using all signatures generated prior to testing, to enforce their projections onto the principal components space calculated the principle component healthy angle (PCHA). The second stages is the testing process during fault condition, are followed to project the test pattern onto PCA space followed by measuring of the Principle component fault angle (PCFA). This minimum distance will identify a match of a pattern to a fault or no fault at all. This method uses only current and voltage signals measured by relay agents at each bus of the network sections to identify the type of fault if it is a three lines to ground (3LG), single line to ground (LG), double line to ground (DLG) or a line to line (LL) fault. It also determines the phases included in fault and the bus or line at which the fault occurred.

An analysis of all possible types of fault in three phase system, *i.e.* LG faults (AG, BG, CG), LL faults (AB, BC, CA), DLG faults (ABG, BCG, CAG) and 3LG faults (ABCG), is carried out. In this paper, the proposed algo

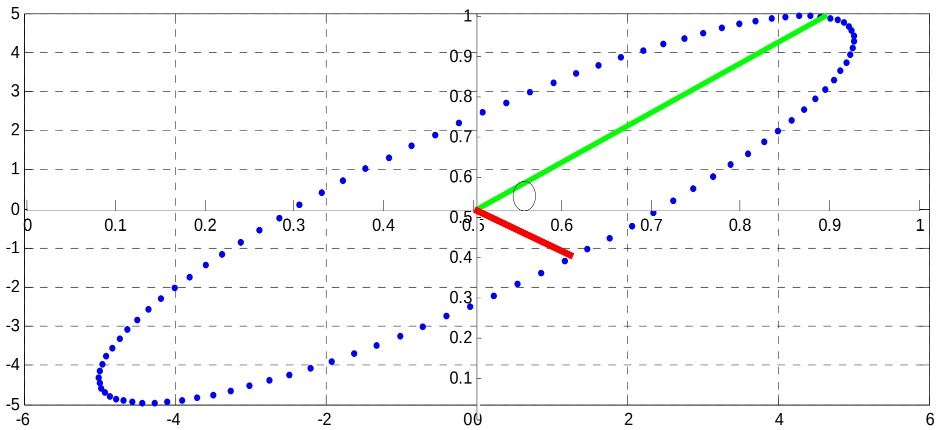

Figure 2. Fault ellipse signature.

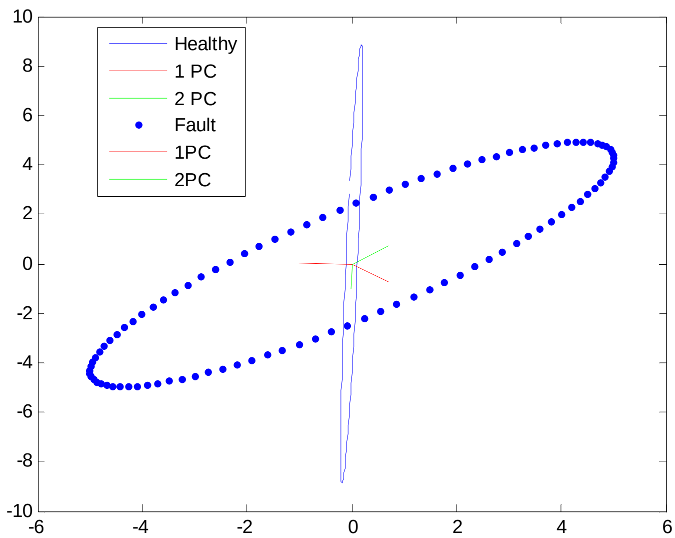

Figure 3. Fault ellipse signature.

rithm determines the type of fault first, and finally it determines the fault location.

To identify the fault type we note the PCFA with less than comparing with PCHA for example if we have Fault AG we note PCFA for phase a less than PCHA for phase a and PCFA for phase b and c are the same as PCHA for phase b and c, also for fault ACG the PCFA for phase a and c less than PCHA for phase a and c but PCFA for phase b is the same of PCHA for phase b, also for low impedance fault the difference between PCFA and PCHA is very high and will increased gradually at faulted buses then will be increased after faulted buses but in high impedance fault the difference between PCFA and PCHA is not high and will increased gradually for small change at faulted buses then PCFA will equal PCHA after faulted buses.

3. Experimental Results and Case Study

The radial network consists of 8 km length of 11 kV feeder as shown in **Figure 4**.

We need to verify that the proposed distribution system simulation model can operate in different modes and to analyze its performance and operational scenarios.

3.1. Fault Analysis

Case 1: Symmetrical fault

In this case a 3-phase symmetrical fault is applied on the bus 5. The fault occurs at t = 5 sec. and remains for 5 cycles in the system. The fault resistance is 0.1 ohm the bus voltage and fault current are shown in **Figure 5**.

Case 2: Single phase to ground

The bus voltage and fault current without renewable are shown in **Figure 6**.

Case 3: 2 phase to ground

The bus voltage and fault current without renewable are shown in **Figure 7**.

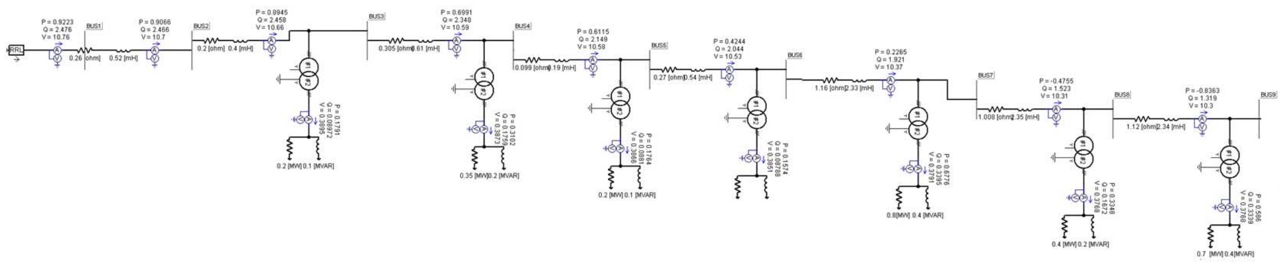

Figure 4. The radial network consists of 8 km length of 11 kV feeder.

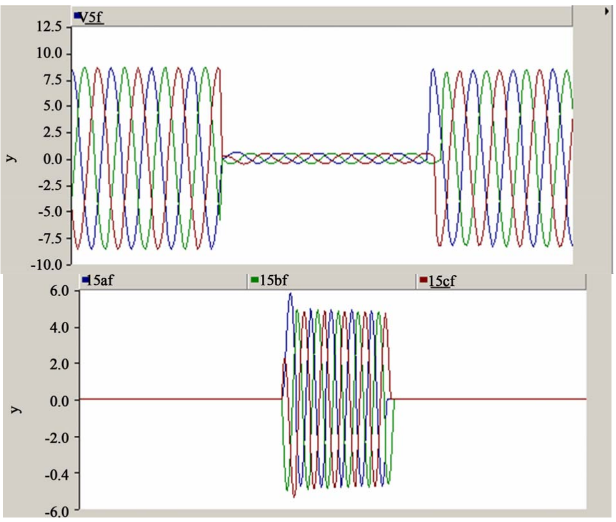

Figure 5. Symmetrical fault.

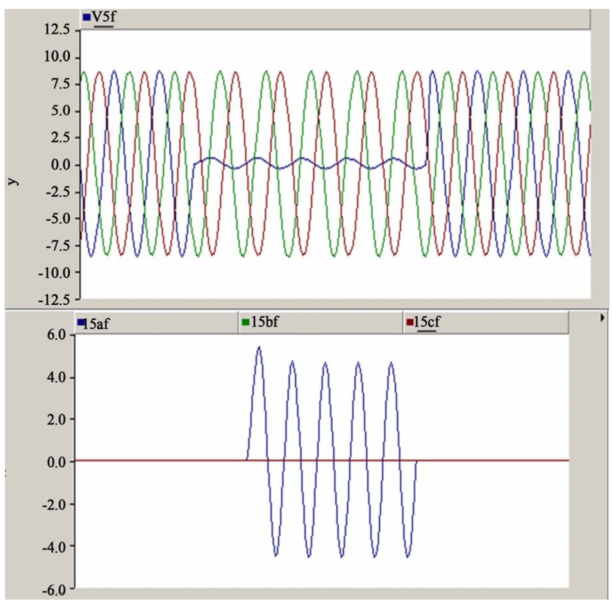

Figure 6. Single phase to ground fault.

3.2. Diagnosis and Monitoring

The first stage is using fitted ellipse generated for all phases from the prefault condition also fitted ellipse generated during fault condition as shown in the following

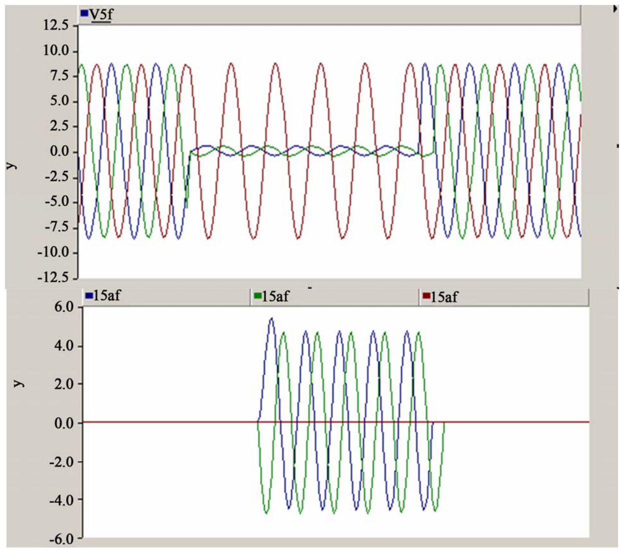

Figure 7. Double phase to ground fault.

Figures 8 and **9** for AG, ABG and ABCG.

After applying fault detection, classification and localization algorithm using PCA, for AG fault at bus 4 we note in the second stage after apply the PCA to identify the principal component fault angle, in **Table 1** shown the result for Fault AG at bus 4 the PCFA for phase a less than PCHA for phase a and PCFA for phase b and c are the same as PCHA for phase b and c so it is easily to detect the type of fault also at low impedance fault the difference between PCFA and PCHA is very high and will increased gradually at faulted buses then will be increased after faulted buses but in high impedance fault the difference between PCFA and PCHA is not high and will increased gradually for small change at faulted buses then PCFA will equal PCHA after faulted buses also the location of the fault we can note easily as shown in **Figures 10** and **11**.

In **Table 2** shown the result for Fault ABCG at bus 4 the PCFA for phase a, b and c less than PCHA for phase a, b and c, so it is easily to detect the type of fault also at low impedance fault the difference between PCFA and PCHA is very high and will increased gradually at faulted buses then will be increased after faulted buses but in high impedance fault the difference between

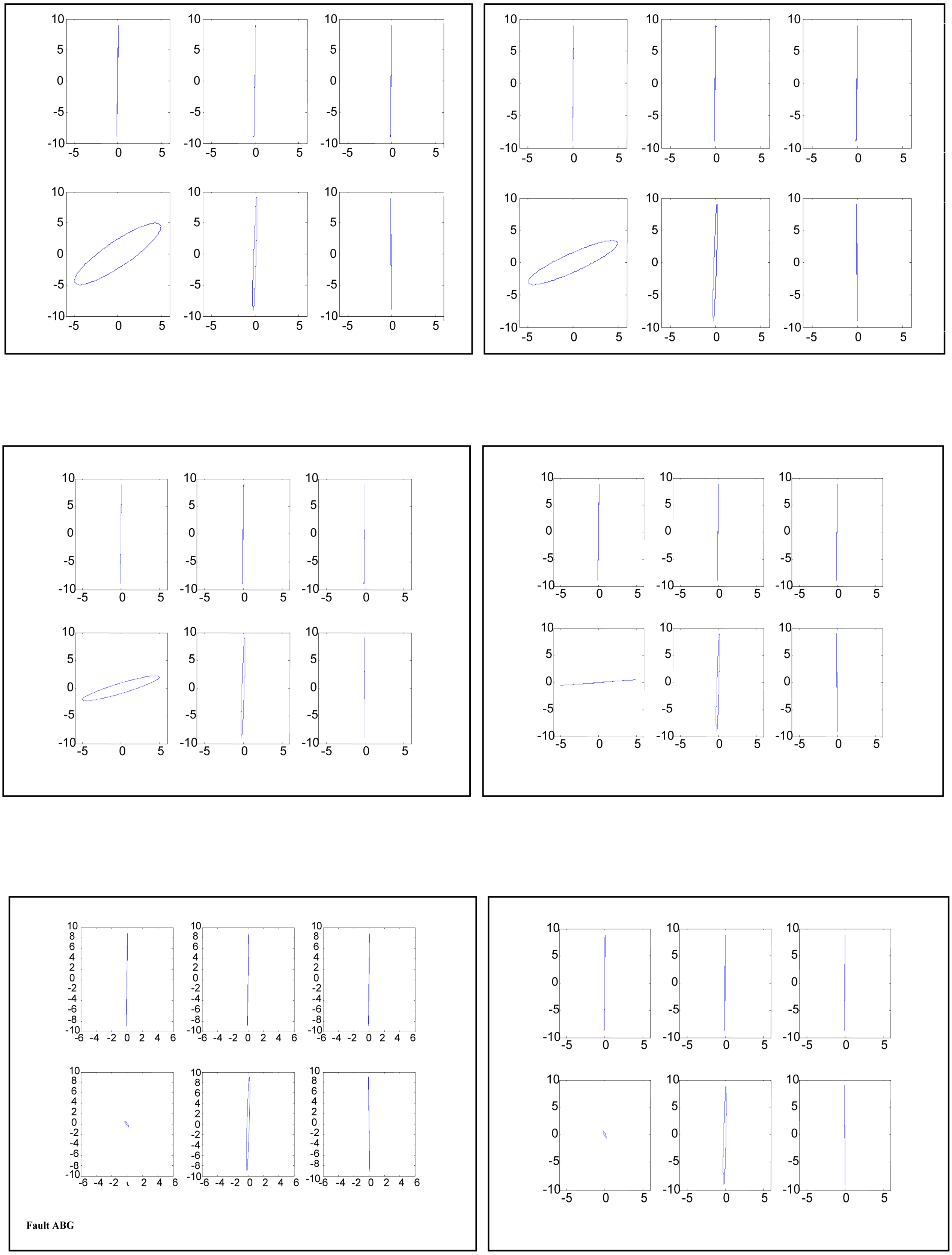

Figure 8. Fault AG at bus 4.

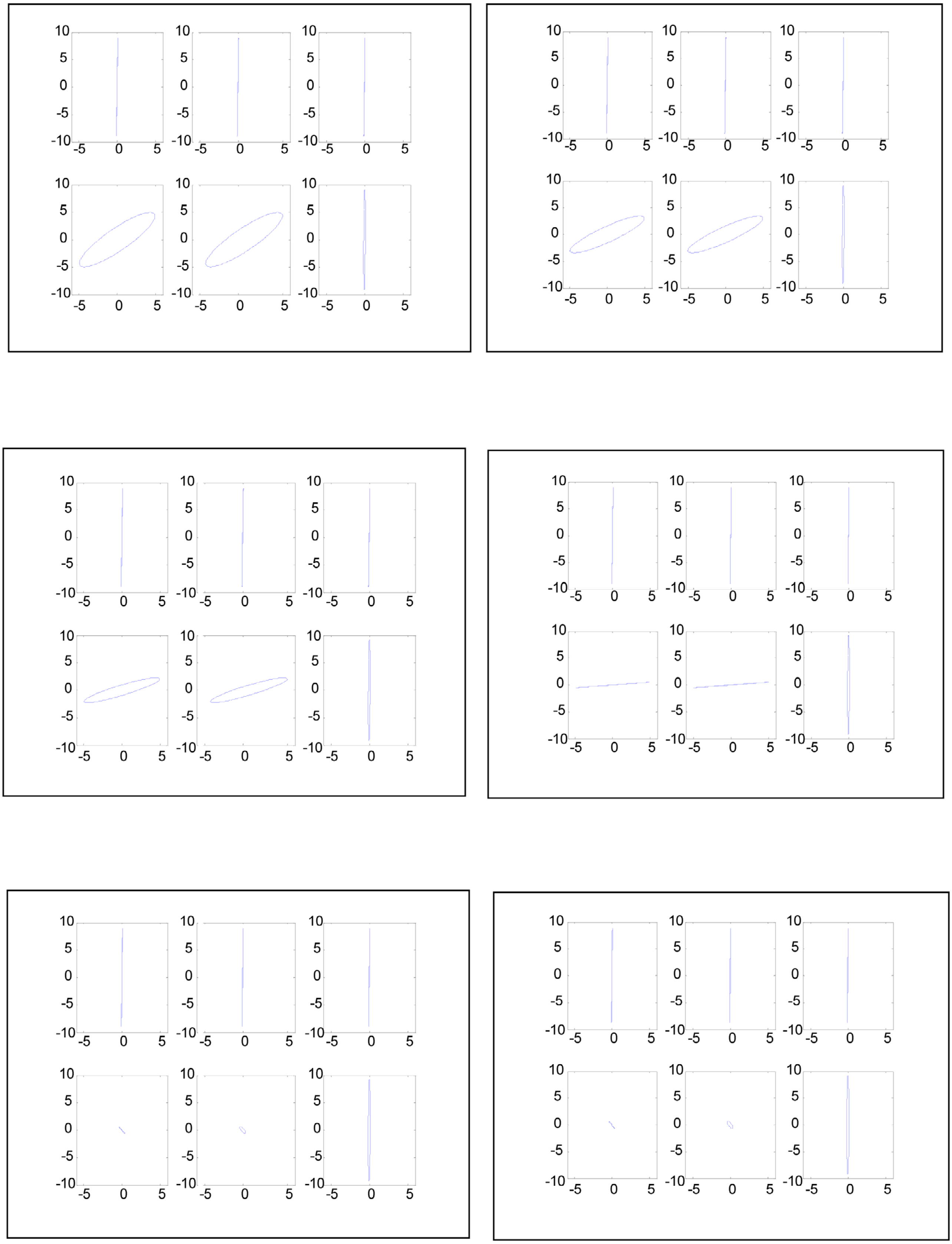

Figure 9. Fault ABG at bus 4.

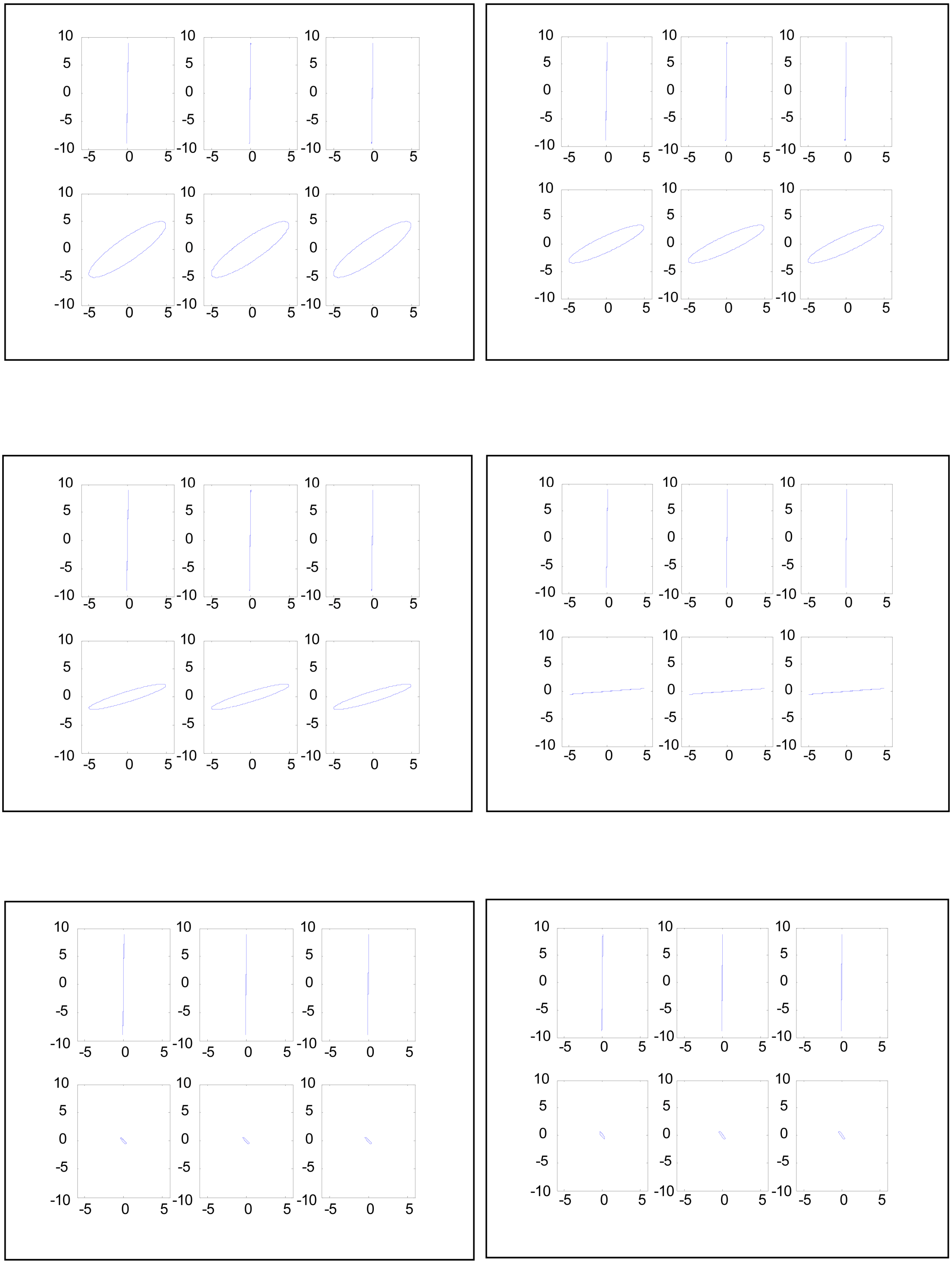

Figure 10. Fault AG at bus 4.

Table 1. Fault ABG at bus 4.

	Bus #1			Bus #2			Bus #3				
	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Rf	
PCHA	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677		
PCFA	44.9335	44.8228	89.8879	33.4652	33.3734	89.8907	23.0880	23.0317	89.8928	0.1	ABG
	62.5945	62.2000	89.8065	58.2303	57.8390	89.8075	54.1689	53.8227	89.8083	1	ABG
	84.4776	84.4295	89.4804	84.3265	84.2848	89.4791	84.2063	84.1705	89.4781	10	ABG
	88.3387	88.3339	89.4035	88.3253	88.3210	89.4017	88.3149	88.3110	89.4003	50	ABG
	88.8579	88.8547	89.3929	88.8515	88.8485	89.3911	88.8466	88.8436	89.3896	100	ABG
	Bus #4			Bus #5			Bus #6				
	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Rf	
PCHA	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677		
PCFA	6.1512	6.1058	89.9609	57.929	56.939	89.9350	61.630	62.749	89.9985	0.1	ABG
	46.7955	46.6012	89.8800	86.748	87.012	89.8841	86.665	86.979	89.9518	1	ABG
	84.1182	84.0880	89.5637	89.8712	89.8442	89.8442	89.9669	89.9359	89.7028	10	ABG
	88.3922	88.3880	89.4886	89.5984	89.5928	89.5503	89.6898	89.6834	89.6396	50	ABG
	88.9313	88.9281	89.4782	89.5648	89.5622	89.5411	89.6557	89.6526	89.6309	100	ABG

Table 2. Fault ABG at bus 4.

	Bus #1			Bus #2			Bus #3				
	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Rf	
PCHA	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677		
PCFA	44.9293	44.9275	44.9269	33.4916	33.4897	33.4889	23.1467	23.1447	23.1438	0.1	ABCG
	62.5519	62.5484	62.5486	58.2462	58.2422	58.2420	54.2657	54.2612	54.2605	1	ABCG
	84.4987	84.4986	84.5009	84.3537	84.3534	84.3559	84.2388	84.2385	84.2411	10	ABCG
	88.3464	88.3468	88.3462	88.3334	88.3339	88.3332	88.3233	88.3238	88.3232	50	ABCG
	88.8627	88.8621	88.8615	88.8564	88.8558	88.8553	88.8516	88.8510	88.8504	100	ABCG
	Bus #4			Bus #5			Bus #6				
	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Phase a	Phase b	Phase c	Rf	
PCHA	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677	89.3648	89.3656	89.3677		
PCFA	6.2217	6.2196	6.2190	54.795	54.845	54.870	60.330	60.372	60.388	0.1	ABCG
	47.0726	47.0677	47.0656	86.307	86.309	86.310	86.306	86.307	86.309	1	ABCG
	84.1552	84.1548	84.1576	89.9071	89.9065	89.9060	89.9980	89.9974	89.9969	10	ABCG
	88.4004	88.4008	88.4002	89.6053	89.6050	89.6052	89.6958	89.6955	89.6957	50	ABCG
	88.9361	88.9354	88.9349	89.5681	89.5681	89.5683	89.6585	89.6585	89.6587	100	ABCG

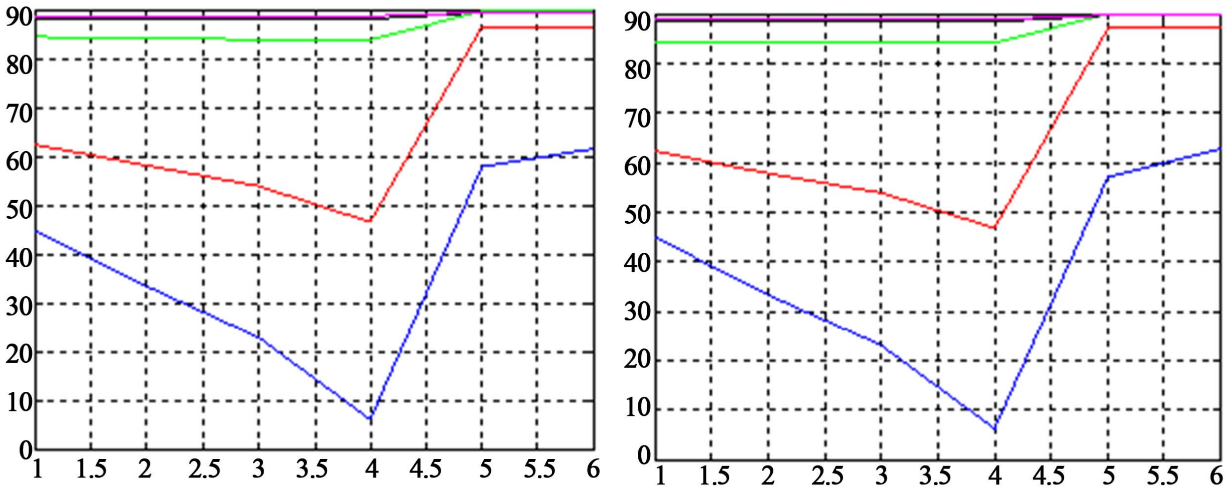

Figure 11. PCFA and PCHA value for fault AG at bus 4.

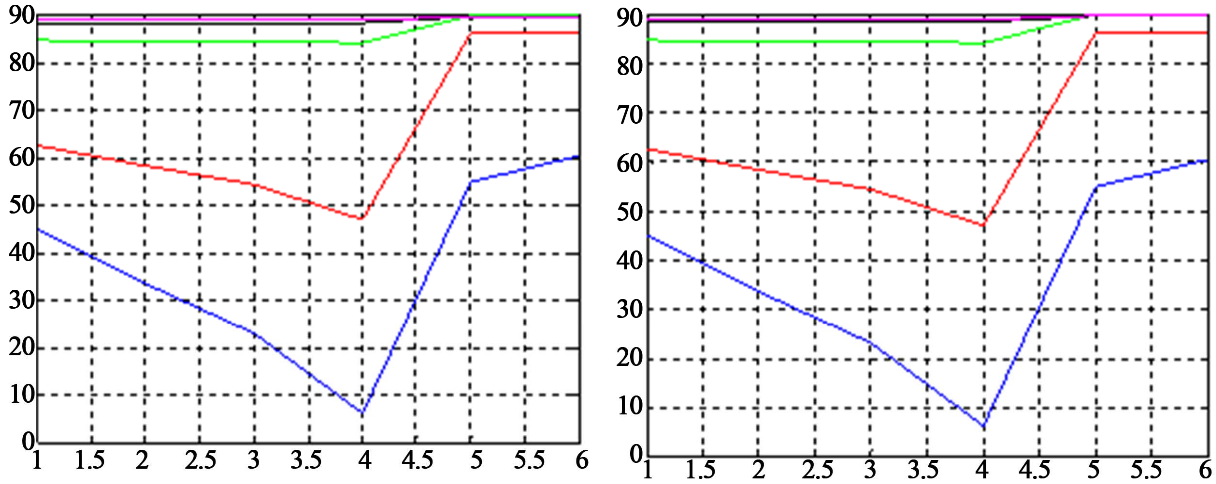

Figure 12. PCFA and PCHA value for fault ABG at bus.

PCFA and PCHA is not high and will increased gradually for small change at faulted buses then PCFA will equal PCHA after faulted buses also the location of the fault we can note easily in **Figure 12**.

3. Conclusion

This paper presented a new electrical protective relaying system framework to diagnosis and monitoring any fault type in electrical power system using principal component analysis fitting of voltage and current ellipses. Fault signatures were projected into the PC space and then based on ellipse parameter the diagnosis and monitoring will be take action on the system. This proposed work is computationally simple, efficient, and can be used in real-time applications.

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