ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 12, December 2014

A Novel Approach for Fault Classification and Fault Phase Selection for Transmission Lines

K. Ravi narayana[1], Dr. V. Ganesh[2]

PG scholar, Dept. of EEE, JNTUA college of Engineering, Pulivendula, Kadapa(dt) A.P, India[1]

Associate Professor, Dept. of EEE, JNTUA college of Engineering, Pulivendula, Kadapa(dt) A.P, India [2]

Abstract: Transmission lines are used to transmit electric power for large distances in electrical power systems. The rapid growth of electrical power systems over the past few decades has resulted in a massive increase of the quantity of lines operative and their total length. These lines are exposed to faults as a result of lightning, short circuits, faulty equipment's &human errors. This paper presents a novel approach for fault classification and faulted phase selection for Transmission lines that is dispensed with sequential reactive power components. The proposed technique has been taking a look at about two cases and every case has eighteen test cases from each end. This technique identifies single line to ground fault, double line to ground fault & double line faults for given test case systems and this is implemented using Mat Lab software package.

Keywords: Transmission lines, lightning,s hort circuits, Sequential Reactive power components.

I. INTRODUCTION

Transmission lines are a vital a part of the electrical power system, as they give the path to transfer power between generation and load. The significant challenge to the transmission line protection lies in faithfully identifying and separating faults compromising the protection of the system. This paper presents fault classification and fault phase selection using sequential reactive power components. The Symmetrical components are measured on the each side, i.e. sending end and receiving end. The reactive power formed by positive and negative sequence components is employed to classify the faults and the lines involved.

BehnamMahamedi and JianGuo Zhu [1] proposed a fault classification and fault phase selection technique based on the symmetrical components of reactive power for single circuit transmission lines. It uses only two limits to judge the fault classification and faulted phase selection and the different fault cases are evaluated to reveal the capability of the proposed method.

Lin et al [2] put forward a faulted phase selection method based on super imposed positive and negative sequence currents combined with correlation theory, which was used to calculate the angle between two signals. It can be found out that the method is highly vulnerable to fault resistance.

Benmuoyal and Masheredjian [3] put forward an interesting method to determine the direction of faults and fault phase selection based on the ratio of differential super imposed voltage to differential superimposed current. It can be found out that thresholds required for the method is not an easy task.

Adu [4] presented an accurate fault classificationtechnique for power system monitoring devices based onthe phase angles between superimposed positive and negative sequence currents. The method also used the relative magnitudes of the zero and negative sequence currents with respect to the positive sequence current todifferentiate between the grounded and ungrounded faults. Move over the method failed for non- zero fault resistance.

Z. Q. BO et al [5] proposed a positional protection of transmission line using fault generated high frequency transient signals (by introducing the digital signal processing). These methods benefit from the specific transient patterns of electrical signal after fault inception. The success rate of these methods, however, highly depends on the sampling frequency [6].

K. M. Silva et al [7] presented an interesting method Haar Wavelet based method for fast fault classification in transmission lines was based on calculating the energy of detail coefficients of the phase currents. The performance of the method is jeopardized due to fault incident angle variations.

Xinzhou Dong et al [8] put forward a fault classification and faulted phase selection based on the initial current traveling wave. The characteristics of various faults were investigatedon the basis of the Karenbauer transform. The sampling frequency adopted for evaluation studies was chosen 400 KHZ which is much more than common sampling frequency used numerical relays[9]. Typically, high sampling frequency is the main dis advantages of transient based method.

II. PROPOSED METHOD

The proposed method is based on the symmetrical components of reactive power. It is well-defined as follows

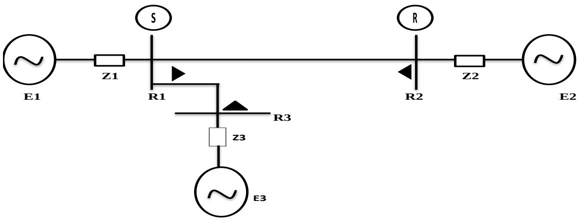

Fig. 1 Transmission line protected by the relays at the ends

Here E1 is sending end and E2, E3 are receiving ends.

By observing the figure one it can be derived as

$$Q_1 = \text{imag}\{V_1 \times I_1{}^*\} \quad (1)$$

$$Q_2 = \text{imag}\{V_2 \times I_2{}^*\} \quad (2)$$

$$Q_0 = \text{imag}\{V_0 \times I_0{}^*\} \quad (3)$$

Where Q_1, Q_2 and Q_0 are respectively positive sequence reactive power, negative sequence reactive power and zero sequence reactive power. Similarly V_1, V_2, V_0, I_1, I_2 and I_0 are respectively positive, negative, zero sequence components of voltage and current measured at relay points (either receiving or sending end). In this paper Q_0, Q_1 and Q_2 are used to evaluate the proposed method.

II.I Technique for single line to ground fault.

Assume that the single line to ground fault at some 'm' distance in the transmission line from relay point R_1 as shown in the Fig. 1. All sequence components of voltages and currents are measured from both the sending end and receiving end relays then calculate the zero and negative sequence reactive powers of both ends.

The ratio of the zero sequence reactive power to the negative sequence reactive power for both the ends are calculated then both or any one of the ends Q_0/Q_2 ratio is greater than 1 then it is a single line to ground fault.

$$\frac{Q_{0S}}{Q_{2S}} > 1 \quad (4)$$

In the equation four subscript S is represented to tell that it is obtained from the sending end measurements.

$$\frac{Q_{0R}}{Q_{2R}} > 1 \quad (5)$$

In the equation five subscript R is represented to tell that it is obtained from the receiving end measurements.

$$Q_{20} = \text{image}\{(V_2 + V_0) \times (I_2 + I_0)^*\} \quad (6)$$

From the above equations 4, 5 & 6 it is clear that it is a single line to ground fault and another task is identifying the faulted line by checking on which phase Q_{20} is the maximum that is the faulted line.

II.II Technique for double line to ground fault.

Assume that the double line to ground fault at some 'm' distance in the transmission linefrom relay point R_1 as shown in Fig. 1. All sequence components of voltages and currents are measured from both the sending end and receiving end relays then calculate the zero and negative sequence reactive powers of both ends.

The ratio of zero sequence reactive power to the negative sequence reactive power for both the ends are calculated then both of the ends Q_0/Q_2 ratio is in between 0 and 1 then it is a double phase to earth fault.

$$0 < \frac{Q_{0S}}{Q_{2S}} < 1 \quad (7)$$

$$0 < \frac{Q_{0R}}{Q_{2R}} < 1 \quad (8)$$

$$Q_{20} = \text{imag}\{(V_2 + V_0) \times (I_2 + I_0)^*\} \quad (9)$$

From the above equations 7, 8 & 9 it is clear that it is a double phase to earth fault and another task is identifying the faulted phases by checking on which phases the Q_{20} is minimum those phases are affected phases.

II.III Technique for line to line fault.

Assume that the phase to phase fault at some 'm' distance in the transmission line from relay point $R_1$of Fig. 1. All sequence components of voltages and currents are measured before the fault and after the fault. Calculate the Q_{12} as below

$$Q_{12} = \text{imag}\{(V_1 + V_2) \times (I_1 + I_2)^*\} \quad (10)$$

Q_{12} is the reactive power measured by the relay on the each phase and after the fault there is no change in the current of healthy phase. If the ΔQ_{12} is equal to zero, then it is healthy phase and ΔQ_{12} is not equal to zero then it is faulted phase. Therefore, from this the phase to phase fault is determined by checking the ΔQ_{12}. Another task is identifying the faulted phases, it is simply done by the same procedure as ΔQ_{12} is zero on the phase it is healthy phase and another two phases are not healthy phases.

II.IV Algorithm for Proposed method

Step 1:
Sample the parameters of three phase voltage and current from the relay points.

Step 2:
Calculate the symmetrical components of the voltage and current.

Step 3:
Sequential reactive powersQ_0, Q_1& Q_2 are calculated from the symmetrical components.

Step 4:
After the fault is injected, first check the phase to phase fault by $\Delta Q_{12}$is not zero on the any one of the phase then it is a line to line fault and find out the faulted phases.

Step 5:
If it is equal to zero on all lines, then it's not a line to line fault, then, check for the double line to ground fault by the ratio Q_0/Q_2 is in between zero and one for both relays then, it'll be declared as a double line to ground fault and find out the faulted lines with the ground.

Step 6:
If the ratio is larger than one it'll be declared as single line to ground fault and find out the faulted phase with the ground. These steps are for both cases 1 & 2 and also for its test cases.

III. RESULTS

III.I Case –I, when a fault occurs between E_1& E_2

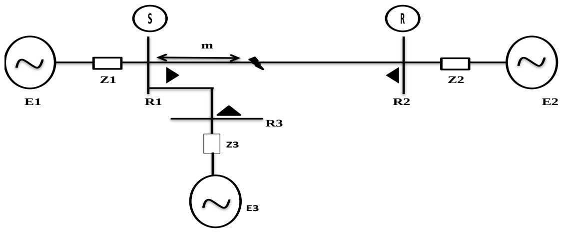

FIG. 3 SIMULATED SYSTEM CASE 1

The simulated system details in fig. 3 are E_1=400KV, 50Hz and E_2=380KV, 50Hz and transmission line length is 200 Kilo meters.

Source impedances:

$$Z_{11}=Z_{2S}=0.32+j6.56\ \Omega$$
$$Z_{01}=1.76+j9.28\ \Omega$$
$$Z_{13}=Z_{2R}=0.48+j8.8\Omega$$
$$Z_{03}=1.76+j11.68\Omega$$

Transmission line parameters :(distributed model)

$$Z_{1L}=Z_{2L}=0.021+j.278\Omega/km$$
$$Z_{0L}=0.302+j0.905\ \Omega/km$$
$$C_{1L}=13.170\ nF/km$$
$$C_{0L}=8.396\ nF/km$$

Table. 1 Different fault cases for evaluation of simulated system cases 1 & 2 are shown.

Cases	**Fault type**	**Fault distance (Kilo meters)**	**Fault resistance (Ω)**
1	AG	100	10
2	AG	190	10
3	BG	100	50
4	BG	190	50
5	CG	100	100
6	CG	190	100
7	ABG	100	10
8	ABG	190	10
9	BCG	100	50
10	BCG	190	50
11	CAG	100	100
12	CAG	190	100
13	AB	100	10
14	AB	190	10
15	BC	100	50
16	BC	190	50
17	CA	100	100
18	CA	190	100

Table. 2 Sequential reactive power components and ratio of zero sequence reactive power to the negative sequence reactive power from the sending end relay point is shown.

Case	**Q_0/Q_2**	**$\lvert Q_{20}\rvert$**		
		$\lvert Q_{20}\rvert_A$	**$\lvert Q_{20}\rvert_B$**	**$\lvert Q_{20}\rvert_C$**
1	0.9970	$4.3720*10^7$	$1.0566*10^7$	$1.1221*10^7$
2	0.3067	$3.4283*10^7$	$1.2161*10^7$	$0.9299*10^7$
3	0.9950	$0.3704*10^7$	$1.4258*10^7$	$0.3401*10^7$
4	0.3059	$1.8668*10^6$	$6.8480*10^6$	$2.4218*10^6$
5	0.9957	$0.9416*10^6$	$1.0180*10^6$	$3.9325*10^6$
6	0.3059	$0.6728*10^6$	$0.5165*10^6$	$1.8986*10^6$
7	0.0855	$4.8767*10^7$	$3.0582*10^7$	$7.9582*10^7$
8	0.0583	$4.7002*10^7$	$2.3729*10^7$	$5.6266*10^7$
9	0.0264	$5.4312*10^7$	$4.5842*10^7$	$3.0651*10^7$
10	0.0081	$3.2757*10^7$	$3.1059*10^7$	$2.4152*10^7$
11	0.0190	$1.0779*10^7$	$1.7165*10^7$	$1.3223*10^7$
12	0.0046	$1.2389*10^7$	$1.5703*10^7$	$1.4202*10^7$

Table. 3 Sequential reactive power components and ratio of zero sequence reactive power to the negative sequence reactive power from the receiving end relay point are shown.

Case	**Q_0/Q_2**	**$\lvert Q_{20}\rvert$**		
		$\lvert Q_{20}\rvert_A$	**$\lvert Q_{20}\rvert_B$**	**$\lvert Q_{20}\rvert_C$**
1	1.1825	$3.8984*10^{10}$	$0.9601*10^{10}$	$0.996*10^{10}$
2	1.4864	$1.3182*10^{12}$	$0.3243*10^{12}$	$0.3545*10^{12}$
3	1.1835	$0.5130*10^{10}$	$2.0006*10^{10}$	$0.4928*10^{10}$
4	1.4873	$0.6640*10^{11}$	$2.4711*10^{11}$	$0.6084*10^{11}$
5	1.1818	$1.2485*10^9$	$1.3014*10^9$	$5.0727*10^9$
6	1.4863	$1.5334*10^{10}$	$1.6765*10^{10}$	$6.2341*10^{10}$
7	0.1016	$0.6147*10^{11}$	$0.3619*10^{11}$	$1.0244*10^{11}$
8	0.2814	$1.5114*10^{12}$	$0.3325*10^{12}$	$2.3013*10^{12}$
9	0.0314	$5.8584*10^{10}$	$4.9015*10^{10}$	$3.1406*10^{10}$
10	0.0398	$8.0558*10^{11}$	$6.7396*10^{11}$	$3.9809*10^{11}$
11	0.0225	$1.168*10^{10}$	$1.9363*10^{10}$	$1.4686*10^{10}$
12	0.0226	$2.3739*10^{11}$	$3.9704*10^{11}$	$3.0664*10^{11}$

From the tables 2 & 3 it is clear that the ratio of Q_0/Q_2 is greater than one on any one of the relay points, then it is line to ground fault and the maximum Q_{20} is represents the faulted line. The ratio of Q_0/Q_2 is less than one on both ends of relay point, then it is line to line ground fault and the minimum Q_{20} on the line represents the faulted lines.

Therefore, as tabulated in the tables 2 & 3 this confirmed a line to ground faults and double line to ground faults in simulated system case 1.

Table. 4 ΔQ_{12}Sequential reactive power components in line A, line B and line C from the sending end relay point are shown.

Case	ΔQ_{12}		
	ΔQ_{12A}	ΔQ_{12B}	ΔQ_{12C}
13	$-2.4425*10^8$	$-6.6953*10^8$	0
14	$-2.5875*10^8$	$-6.6953*10^8$	0
15	0	$-6.6658*10^7$	$-3.1365*10^8$
16	0	$-5.2376*10^7$	$-2.5146*10^8$
17	$-1.4195*10^8$	0	$-7.6177*10^7$
18	$-1.1252*10^8$	0	$-5.9031*10^7$

Table. 5 ΔQ_{12} Sequential reactive power components in line A, line B and line C from the receiving end relay point are shown.

Case	ΔQ_{12}		
	ΔQ_{12A}	ΔQ_{12B}	ΔQ_{12C}
13	$-7.2105*10^9$	$-3.1582*10^{11}$	0
14	$-6.1905*10^{11}$	$-1.6690*10^{12}$	0
15	0	$-4.0706*10^{10}$	$-1.0574*10^{11}$
16	0	$-7.5076*10^{11}$	$-7.7461*10^{11}$
17	$2.4189*10^{10}$	0	$-2.9516*10^{10}$
18	$-2.3925*10^{11}$	0	$-4.7790*10^{11}$

As tabulated in the tables 4 & 5, ΔQ_{12} is zero on the healthy lines while they were not zero on the faulted lines this confirmed a line to line faults for case 1.

From the tables 2, 3, 4 & 5 it is clear that the single line to ground, double line to ground and double line faults are effectively identified by the proposed method in the case 1 and also lines which are affected.

III.II Case – II, when a fault occurs between E_2& E_3

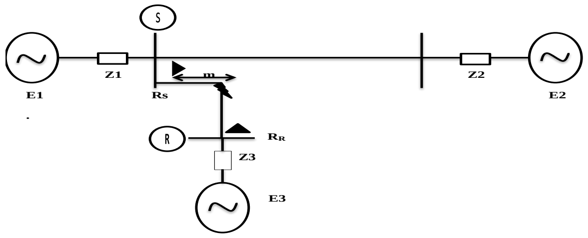

Fig.4 Simulated System Case 2

The simulated system details in fig. 3 are E_1=400KV, 50Hz and E_3=380KV, 50Hz and transmission line length is 200 Kilo meters.
Source impedances:

$$Z_{11}=Z_{2S}=0.32+j6.56\ \Omega$$
$$Z_{01}=1.76+j9.28\ \Omega$$
$$Z_{13}=Z_{2R}=0.48+j8.8\Omega$$
$$Z_{03}=1.76+j11.68\Omega$$

Transmission line parameters :(distributed model)

$$Z_{1L}=Z_{2L}=0.021+j.278\Omega/km$$
$$Z_{0L}=0.302+j0.905\ \Omega/km$$
$$C_{1L}=13.170\ nF/km$$
$$C_{0L}=8.396\ nF/km$$

Table. 6 Sequential reactive power components and ratio of zero sequence reactive power to the negative sequence reactive power from the sending end relay point are shown.

Case	Q_0/Q_2	$\lvert Q_{20}\rvert$		
		$\lvert Q_{20}\rvert_A$	$\lvert Q_{20}\rvert_B$	$\lvert Q_{20}\rvert_C$
1	0.9980	$6.5353*10^7$	$1.5810*10^7$	$1.6756*10^7$
2	0.3065	$3.0682*10^7$	$1.0891*10^7$	$0.8321*10^7$
3	0.9958	$0.5245*10^7$	$2.0310*10^7$	$0.4875*10^7$
4	0.3060	$1.6970*10^6$	$6.2340*10^6$	$2.2073*10^6$
5	0.9970	$1.5704*10^6$	$1.6736*10^6$	$6.5102*10^6$
6	0.3065	$0.6332*10^6$	$0.4844*10^6$	$1.7851*10^6$
7	0.1004	$0.7941*10^8$	$0.4281*10^8$	$1.250*10^8$
8	0.0581	$4.2094*10^7$	$2.1324*10^7$	$5.0483*10^7$
9	0.0265	$8.2514*10^7$	$6.9270*10^7$	$4.6534*10^7$
10	0.0081	$2.9024*10^7$	$2.7510*10^7$	$2.1406*10^7$
11	0.0167	$2.0498*10^7$	$3.1842*10^7$	$2.5220*10^7$
12	0.0046	$1.1235*10^7$	$1.4236*10^7$	$1.2873*10^7$

Table. 7 Sequential reactive power components and ratio of zero sequence reactive power to the negative sequence reactive power from the receiving end relay point are shown.

Case	**Q_0/Q_2**	**$\|Q_{20}\|$**		
		$\|Q_{20}\|_A$	**$\|Q_{20}\|_B$**	**$\|Q_{20}\|_C$**
1	1.1835	$9.9691*10^{10}$	$2.4533*10^{10}$	$2.5583*10^{10}$
2	1.4867	$1.3002*10^{12}$	$0.3198*10^{12}$	$0.3497*10^{12}$
3	1.1847	$1.0806*10^{10}$	$4.2076*10^{10}$	$1.0348*10^{10}$
4	1.4868	$0.6811*10^{11}$	$2.5347*10^{11}$	$0.6240*10^{11}$
5	1.1838	$0.3143*10^{10}$	$0.3283*10^{10}$	$1.2782*10^{10}$
6	1.4864	$1.7998*10^{10}$	$1.9676*10^{10}$	$7.3168*10^{10}$
7	0.1193	$1.8334*10^{11}$	$0.9192*10^{11}$	$2.9473*10^{11}$
8	0.2797	$1.3366*10^{12}$	$0.3062*10^{12}$	$2.0694*10^{12}$
9	0.0314	$1.5864*10^{11}$	$1.3190*10^{11}$	$0.8504*10^{11}$
10	0.0396	$7.7137*10^{11}$	$6.4754*10^{11}$	$3.8187*10^{11}$
11	0.0198	$3.5999*10^{10}$	$5.8109*10^{10}$	$4.5331*10^{10}$
12	0.0226	$2.2634*10^{11}$	$3.7828*10^{11}$	$2.9235*10^{11}$

From the tables 6 & 7 it is clear that the ratio of Q_0/Q_2 is greater than one on any one of the relay points, then it is line to ground fault and the maximum Q_{20} is represents the faulted line. The ratio of Q_0/Q_2 is less than one on both ends of relay point, then it is line to line ground fault and the minimum Q_{20} on the line represents the faulted lines. Therefore, as tabulated in the tables 6 & 7 this confirmed a line to ground faults and double line to ground faults in simulated system case 2.

Table. 8 ΔQ_{12}Sequential reactive power components in phase A, phase B and phase C from the sending end relay point are shown.

Case	**ΔQ_{12}**		
	ΔQ_{12A}	**ΔQ_{12B}**	**ΔQ_{12C}**
13	$-2.8838*10^{8}$	$-7.8930*10^{8}$	0
14	$-2.3027*10^{8}$	$-5.8193*10^{8}$	0
15	0	-8.7703	$-3.6782*10^{8}$
16	0	-4.8756	$-2.2907*10^{8}$
17	$-1.6350*10^{8}$	0	$-8.9753*10^{7}$
18	$-1.0388*10^{8}$	0	$-5.4138*10^{7}$

Table. 9 ΔQ_{12} Sequential reactive power components in phase A, phase B and phase C from the receiving end relay point are shown.

Case	**ΔQ_{12}**		
	ΔQ_{12A}	**ΔQ_{12B}**	**ΔQ_{12C}**
13	$-5.9917*10^{10}$	$-7.0667*10^{11}$	0
14	$-7.4061*10^{11}$	$-2.0210*10^{12}$	0
15	0	$-1.3420*10^{11}$	$-2.5761*10^{11}$
16	0	$-1.0937*10^{12}$	$-1.1049*10^{12}$
17	$7.3128*10^{9}$	0	$-8.9869*10^{10}$
18	$-3.8151*10^{11}$	0	$-7.5817*10^{11}$

As tabulated in the tables 8 & 9, ΔQ_{12} is zero on the healthy lines while they were not zero on the faulted lines this confirmed a line to line faults for simulated system case 2and from the tables 6, 7, 8 & 9 it is clear that the single line to ground, double line to ground and double line faults are effectively identified by the proposed method in the case 2 and also lines which are affected. Sequential reactive power components in all the tables are in VAR.

IV. CONCLUSIONS

This paper gives a novel approach for fault classification and fault phase selection for transmission lines with the positive, negative and zero sequential reactive power components. This method is easily implementedfor new transmission lines with protection technology using pilot scheme. The main advantage of this method is it works with constant thresholds, i.e. 1 and 0.The another advantage of proposed method can identify high resistance faults where existing methods fails such as current based methods. This method identifies faults such LG, LLG and LL for two test cases.

REFERENCES

[1] BehnamMahamedi and JianoGuo Zhu, senior member, IEEE. ”Fault classification and faulted phase selection based on the symmetrical components of Reactivepower forsingle-circuit transmission lines,” IEEE transactions on power delivery, vol. 28, no. 4, October 2013.

[2] X. N. Lin, M. Zhao, K. Alymann, and P. Liu, “Novel design of a fast phase selector using correlation analysis,” IEEE Trans. Power Del., vol. 20, no. 2, pt. 2, pp. 1283–1290, Apr. 2005.

[3] G.Benmouyal and J. Mahseredjian, “A combined directional and faulted phase selector element based on incremental quantities,”IEEE Trans. Power Del., vol. 16, no. 4, pp. 478–484, Oct. 2001.

[4] T. Adu, “An accurate fault classification technique for power system monitoring devices,” IEEE Trans. Power Del., vol. 17, no. 3, pp. 684–690, Jul. 2002.

[5] Z. Q. Bo, M. A. Redfern, and G. C. Weller, “Positional protection of transmission line using fault generated high frequency transient signals,”IEEE Trans. Power Del., vol.15,no.3,pp. 888–894,Jul.2000.

[6] W. L. A. Neves, N. S. D. Brito, B. A. Souza, and A. V. Fontes, “Sampling rate of digital fault recorders influence on fault diagnosis,” in Proc. Transm. Distrib. Conf. Exp., Latin America, Nov. 2004, pp. 406–411.

[7] K.M.Silva,K. M.C. Dantas, B.A. Souza, N.S.D. Brito, F.B. Costa, and J.A.C.B.Silva, “Haar wavelet based method for fast fault

classification in transmission lines," in Proc. IEEE/Power Eng. Soc. Transm. Distrib. Conf. Exp., Latin America, Aug. 2006, pp. 1–5.
[8] X.Dong, W.Kong, and T.Cui, "Fault classification and faulted-phase selection based on the initial current traveling wave," IEEE Trans. Power Del., vol. 24, no. 2, pp. 552–559, Apr. 2009.
[9] I.Zamora, A.J.Mazón, V. Valverde, E.Torres, and A.Dysko, "Power quality and digital protection relays,"presented at the Int. Conf. Renew. Energies Power Qual., Barcelona, Spain, 2004.
[10] H. Saadat, Power SystemAnalysis, 2nded.NewYork: McGraw-Hill, 2002.