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Comparative study of transient voltage drop detection techniques in electric power distribution system under fault operation

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Abstract

This paper presents a comparative study of transient voltage drop detection techniques in electric power distribution system under four types of fault operation. There are four techniques for consideration such as Fourier transformation, Park's transformation, Symmetrical component and RMS. MATLAB/Simulink blocks used for simulation with IEEE 4 bus radial distribution test system and 4 bus loop distribution test system. This paper focus on the sensitivity of each technique for detection the transient voltage drop in term of time comparison. The simulation result shown that symmetrical component technique is the best technique which spends a shorter time for detecting transient voltage drops for both of two test systems while the load bus number four was fault.

Keywords: Transient Voltage, Detection Technique, Power Distribution, Fault

1. Introduction

Power distribution system is very important for supporting increasing user. Although the increasing user, this system have to operate for supplying with reliable and efficiency of supply voltage. The most common causes to fault in the power distribution system is short circuit which are classified into four types such as balance three phase fault (3ϕF), unbalance double line fault (LLF), unbalance double line to ground fault (DLGF) and unbalance single line to ground fault (SLGF) [1]. Each of these types effecting to the voltage quality to failure, resulting a lot of electrical loads which are connected to this system damaged. Detecting the cause of transient voltage drop in the power distribution system is necessary. However, choosing the correct technique for detecting with sensitivity and appropriate under fault conditions of power distribution system are considered. In this paper presents a comparative study of the detecting technique of transient voltage drop. This will be used to further develop and improve the power quality.

2. Transient Voltage Drop Detection Techniques

Detecting the transient voltage drop must be consider both of sensitivity and accurate properties to prevent the impact on the load [2]. The technique used to detect the voltage is numerous. Each technique has different detection sensitiveness. This paper presents four techniques of transient voltage drop detection such as Symmetrical Components, Root mean Square, Park's Transformation and Fourier Transformation

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2.1. Symmetrical Component Technique

Symmetric component analysis using the linear phase converters of three phase voltage of three phase power system (abc system) are used in the form of base-positive voltages in symmetrical component system (012 system) called symmetric components such as the positive phase sequence, the negative phase sequence and zero phase sequence can be written as a symmetric transformation matrix [3]. The voltage in 012 system calculated as follow (1).

$$\begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{1}$$

Where, $a = e^{j120^\circ}$

2.2. Root Mean Square Technique

Phasor of voltage calculations which is defined in form of voltage magnitude as the root mean square quantities and the phase angle [4]. However, an analysis have to require the data of the voltage signal in a period. Therefore, calculating the root mean square calculated as follows (2).

$$V_{rms} = \sqrt{\frac{1}{T}\sum_{t=0}^{t+T} V^2(t)\,dt} \tag{2}$$

2.3. Park's Transformation Technique

Park's Transformation converts vectors in the xyz reference frame to the direct-quadrature zero reference frame (0dq) [5]. The primary value of the Park transform is to rotate the reference frame of a vector at an arbitrary frequency. The Park transform shifts the frequency spectrum of the signal such that the arbitrary frequency now appears as dc and the old dc appears as the negative of the arbitrary frequency [6]. The Park transformation calculated as follows (3)

$$V_{0dq} = \mathrm{R}(\theta)\mathrm{P}(0)V_{abc} \tag{3}$$

where, $\theta = \omega t = 2\pi ft$

$$V_{abc} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$V_{0dq} = \begin{bmatrix} V_0 \\ V_d \\ V_q \end{bmatrix}$$

$$\mathrm{R}(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$\mathrm{P}(0) = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}$$

In (3) can be written in matrix form therefore, the voltage in 0dq transformation as (4)

$$\begin{bmatrix} V_0 \\ V_d \\ V_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ \cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ \sin\theta & \sin(\theta - 2\pi/3) & \sin(\theta + 2\pi/3) \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (4)$$

2.4. Fourier Transformation Technique

Fourier transforms were used to analyse the signal separation of the power system under different voltage conditions. The Fourier series equations used for analysis the input signal voltage to detect the signal which deformed [7]. The Fourier series calculated as follows (5)

$$f(t) = \frac{a_0}{3} + \sum_{n=1}^{\infty} a_n \cos(n\omega t) + b_n \sin(n\omega t) \quad (5)$$

Where,
$$a_n = \frac{2}{T} + \int_{t=T}^{t} f(t)\cos(n\omega t)dt$$

$$b_n = \frac{2}{T} + \int_{t=T}^{t} f(t)\sin(n\omega t)dt$$

Therefore, the maximum voltage and phase angle defined as follows (6) and (7) respectively.

$$|H_n| = \sqrt{a_n^2 + b_n^2} \quad (6)$$

$$\angle H_n = \tan^{-1}\left(\frac{a_n}{b_n}\right) \quad (7)$$

3. Test system Parameters and Simulation Results

The test system considered in this paper has two systems, the IEEE 4 bus with radial power distribution system and the 4 bus with loop power distribution test system. In addition, the transmission line parameter transformer data and load data of IEEE 4 bus with radial power distribution system also shown in Table 1, Table 2 and Table 3 respectively [8].

Table 1. Transformer data

Three phase transformer					
Connection	VH (kV)	VL (kV)	S (kVA)	%R	%X
Step down	12.47	4.16	6000	1.0	6.0
Step up	12.47	4.16	6000	1.0	6.0

Table 2. Line parameters

Line	Types	GMR (ft)	R (Ω/mile)	Diameter (inch)
Conductors	ACSR	0.0244	0.306)	0.721
Neutral	ACSR	0.00814	0.592	0.563
Sequence	Positive (Ω/mile)		0.3061+j0.627	
Impedance	Zero (Ω/mile)		0.7735+j1.9373	

Table 3. Closed connection load data

Phase	Phase A		Phase B		Phase C	
Load status	P (kW)	pf (lag)	P (kW)	pf (lag)	P (kW)	pf (lag)
balanced	1800	0.9	1800	0.9	1800	0.9
unbalanced	1275	0.85	1800	0.9	2375	0.95

Therefore, can be written in the single line diagram of IEEE 4 bus with radial distribution test system as follow Fig. 1

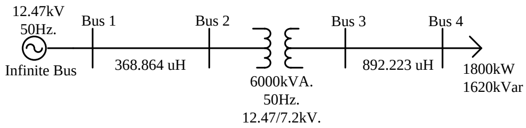

Fig 1. IEEE 4 Bus with radial distribution power system

On the other hand, there are the bus data line data and transformer data of the 4 bus with loop distribution test system in per unit to compare with the IEEE 4 bus with radial system also shown in Table 4 and Table 5 respectively

Table 4. Bus data

Bus No.	Type of bus	Generator		Load	
		|v| (pu)	deg	P (pu)	Q(pu)
1	Slack	1.02	0	0	0
2	PV	1.00	-	0.8	0.6
3	PQ	-	-	0.4	0.2
4	PQ	-	-	0.5	0.5

Table 5. Line data and transformer data

From bus	To bus	R	X
1	2	0.025	0.075
1	3	0.01	0.03
2	4	0.01	0.03
3	4	Transformer connected %X = 0.02	

Therefore, can be written in the single line diagram of 4 bus with loop distribution test system as follow Fig. 2

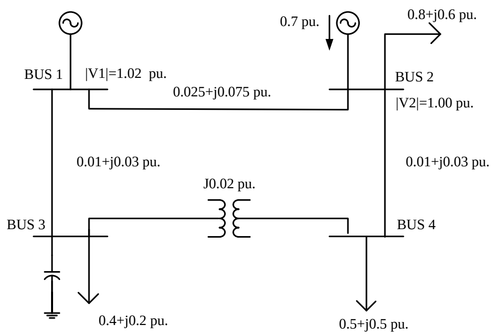

Fig. 2. The 4 Bus with loop distribution power test system

Simulation conditions using the Simulink blocks in the MATLAB program. In addition, four types of fault, SLGF, LLF, DLGF and 3ϕF start at 0.1 second on bus number 4 were simulated. The results of numerical simulations both of The IEEE 4 bus with radial distribution power system and The 4 bus with loop distribution power system compared in term of the time detection and detection techniques when fault on bus number 4 with four types of fault are shown in Table 6 and 7 respectively.

Table 6. Time (ms) detection of each technique of The IEEE 4 buses with radial distribution system

Techniques	Fault Types			
	3ϕF	SLGF	LLF	DLGF
Fourier Transform	2.700	2.800	2.400	2.800
Park’s Transform	1.010	2.000	1.500	1.350
Symmetrical Component	0.001	0.280	0.001	0.001
RMS	3.900	3.500	3.700	3.400

Table VI, can be seen that the time taken for transient voltage drop detection by the symmetrical component analysis technique is the fastest at all types of faults

Table 7. Time (ms) detection of each technique of 4 buses with loop distribution system

Techniques	Fault Types			
	3ϕF	SLGF	LLF	DLGF
Fourier Transform	2.800	2.800	2.400	2.800
Park's Transform	1.300	2.400	1.600	2.400
Symmetrical Component	0.001	0.520	0.001	0.540
RMS	3.400	3.500	3.800	3.400

In term of comparison, this paper presents the comparison result of each technique as bar plotting both of the IEEE 4 bus system and 4 bus test system are shown in Fig. 3 and Fig. 4 respectively.

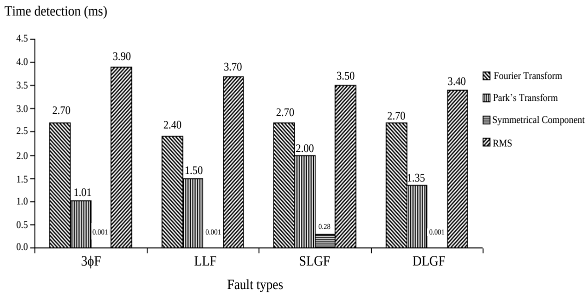

Fig. 3. Comparison of time detection of each detection techniques when 4 fault types on bus 4 with IEEE 4 Bus radial distribution system

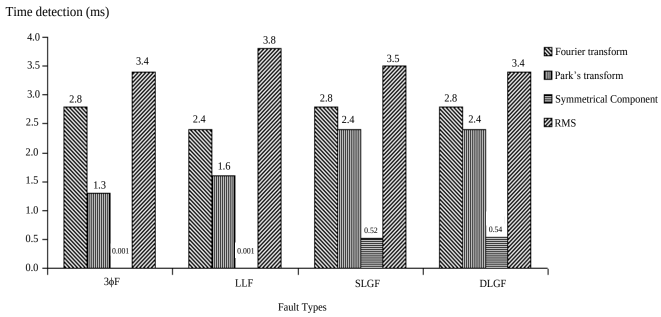

Fig. 4. Comparison of time detection of each detection techniques when 4 fault types on bus 4 with the 4 Bus loop distribution test system

4. Conclusion

This paper presents a technique for detection the transient voltage drop of power distribution system under operating on four types of fault such as SLGF, LLF, DLGF and 3ϕF by using MATLAB/Simulink blocks with both of IEEE 4 bus radial distribution test system and IEEE 4 bus loop distribution test system. The simulation results shown that in case of IEEE 4 bus radial distribution test system symmetrical component technique is the fastest and most effective technique which spent the time sensitivity for detection of SLGF, LLF, DLGF and 3ϕF is 0.28ms, 0.001ms, 0.001ms and 0.001ms respectively. Moreover, the 4 bus loop distribution test system symmetrical component technique is the fastest and most effective technique which spent the time is 0.52ms, 0.001ms, 0.54ms and 0.001ms respectively. Due to the technique of detecting transient voltage drop by symmetrical component technique, it is the technique that helps to detect the voltage the fastest and most effective. It would be useful to use as an alternative to voltage-sensing tools for various power compensation devices

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