Implementation of Characterization Algorithm for Voltage Sag

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ABSTRACT: The Dynamic Voltage Restorer (DVR) topologies in which the compensation schemes are sag type specific, the conventional characterization techniques cannot provide the informations required. Characterization algorithm that can identify the phase(s) affected and can provide information on sag magnitude and phase angle jump are hence needed. In this paper, instantaneous symmetrical component theory based algorithm is used for detection and characterization of voltage sags. The simulation study of the algorithm has been carried out in MATLAB/SIMULINK and the results are presented.

KEYWORDS: Dynamic Voltage Restorer, Phase angle jump, Symmetrical Component Theory, Sag magnitude, Voltage Sag.

I. INTRODUCTION

According to the IEEE 1959–1995 standard, voltage sag is the decrease of 0.1 to 0.9 p.u. in the rms voltage level at system frequency and with the duration of half a cycle to 1 min. Short circuits, starting large motors, sudden changes of load, and energization of trans-formers are the main causes of voltage sags. Since sags are largely due to faults in power system, they are classified into different types depending on the nature of fault which cause it. The four basic types A, B, C and D are shown in Fig.1. A single phase fault causes voltage sag in one phase (type B) at the terminals of a star connected load and in two phases (type C) at the terminals of a delta connected load. A phase-phase fault causes voltage type C sag at the terminals of a star connected load and type D sag at the terminals of a delta connected load. The sag types get transformed as it get propagated in power system, due to the transformers. Type B sag has zero sequence component which gets eliminated as it propagates in the power system through delta-delta or star-delta transformers and gets converted into type C or D respectively.

The sag inception is defined as instant when rms voltage of supply goes below 0.9 p.u. The sag detection time is the time taken by the algorithm to detect sag.

II. CHARACTERIZATION ALGORITHM

The instantaneous symmetrical component theory and Fourier transform can be combined to obtain fundamental symmetrical components. Instantaneous symmetrical components gives the instantaneous changes in voltages. It can hence be used to detect disturbances in a system. The sequence components are calculated as follows:

$$\begin{bmatrix} v_{a0} \\ v_{a1} \\ v_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

where $a = 1 < 120°$; v_{a0}, v_{a1} and v_{a2} and are the instantaneous zero-, positive-, and negative sequence components, respectively; v_{a1} and v_{a2} are complex and time varying quantities; v_a, v_b and v_c are instantaneous three-phase voltages at the PCC. Fourier transform is applied on the instantaneous symmetrical components of the voltage so that it can work even in presence of harmonics and distortions .

The fundamental symmetrical component (V_{ak}) is calculated from its corresponding instantaneous values (v_{ak}) as follows:

$$V_{ak} = \frac{\sqrt{2}}{\frac{T_s}{2}} \int_0^{T_s/2} v_{ak(t)}\, e^{-j(\omega t - \pi/2)}\, dt$$

where k= 0, 1 and 2 represent zero, positive, and negative sequence, respectively; ω is the fundamental frequency in radians per second and T_s is the system time period in seconds.

The fundamental symmetrical components characterize sag by the symmetrical component algorithm (SCA). The SCA characterizes voltage sag using sag-type indicator T_y, characteristic voltage V_{ch} which is a single complex voltage , and duration of sag.

Type of Sag

Based on the type of faults, sags are classified into four basic types namely A, B, C and D. A single phase fault causes sag of type B, while symmetrical fault causes sag of type A. Phase to phase fault causes sag of type C at star connected load and type D at delta connected load terminals. The fig. 1 represents the four sag types in phasor. In the figure, the presag voltages are given by $\overline{V_j}$ and $\overline{V_j}'$ where j= a, b and c respectively.
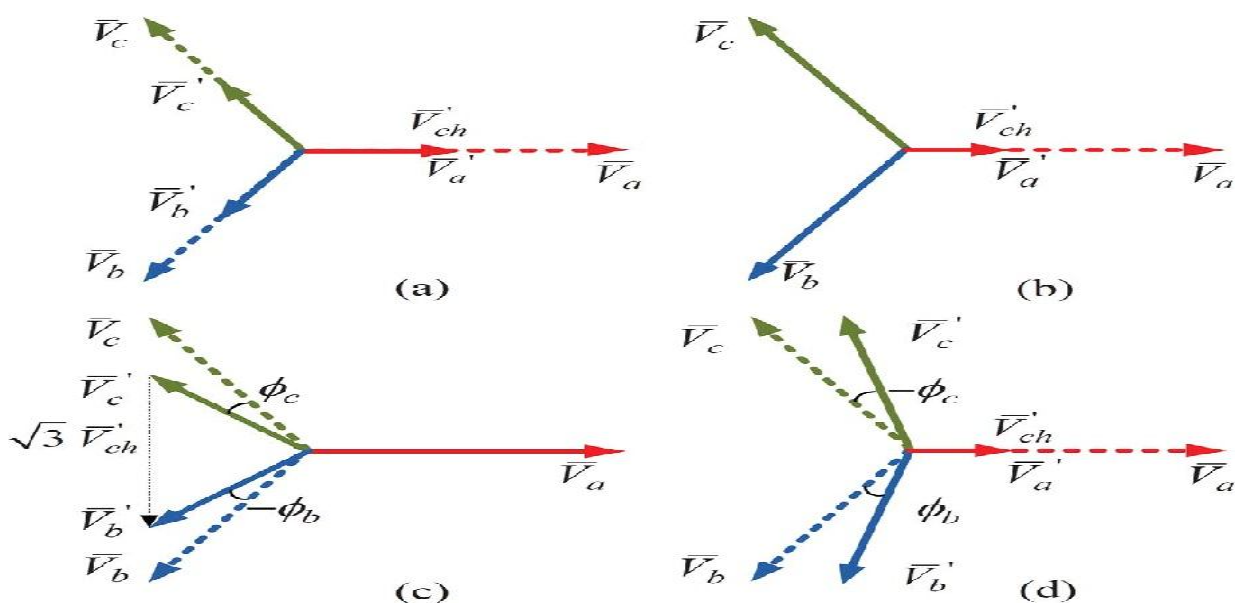

Fig. 1. Phasor voltages of sag types (a) type A (b) type B (c) type C (d) type D

The sag type indicator T_y is calculated by,

$$T_y = \frac{\angle V_{a2} - \angle V_{a1}}{60°}$$

Each sag type is further classified into three subtypes depending on the phases affected. For example, sag type D_b has phase-b affected and sag type C_a has phases b and c affected and phase-a healthy.

Type indicator (T_y)	0	1	2	3	4	5	7
Sag type	C_a	D_c	C_b	D_a	C_c	D_b	A

Table. 1. Numerizing type of sag

III.CHARACTERISTIC VOLTAGE

The characteristic voltage gives the three phase voltage sag. For sag-type C due to a phase-to-phase fault, characteristic voltage is along the affected line voltage; for other sag types, it is the affected phase voltage (sag types A, B, and D have the affected phase voltage $\overline{V_a}$ as their characteristic voltage), as shown in Fig. 3. The characteristic voltage can be calculated from the sequence components and the sag-type indicator (T_y) using

$$\overline{V_{ch}}' = \overline{V_{a1}}' - b^{(6-T_y)}\overline{V_{a2}}' + a^{(6-T_y)}\overline{V_{a0}}'$$

where a=1∠120° ;b= -a²=1∠60°; and $\overline{V_{a1}}'$, $\overline{V_{a2}}'$, and $\overline{V_{a0}}'$ are the complex positive-, negative-, and zero-sequence components, respectively.
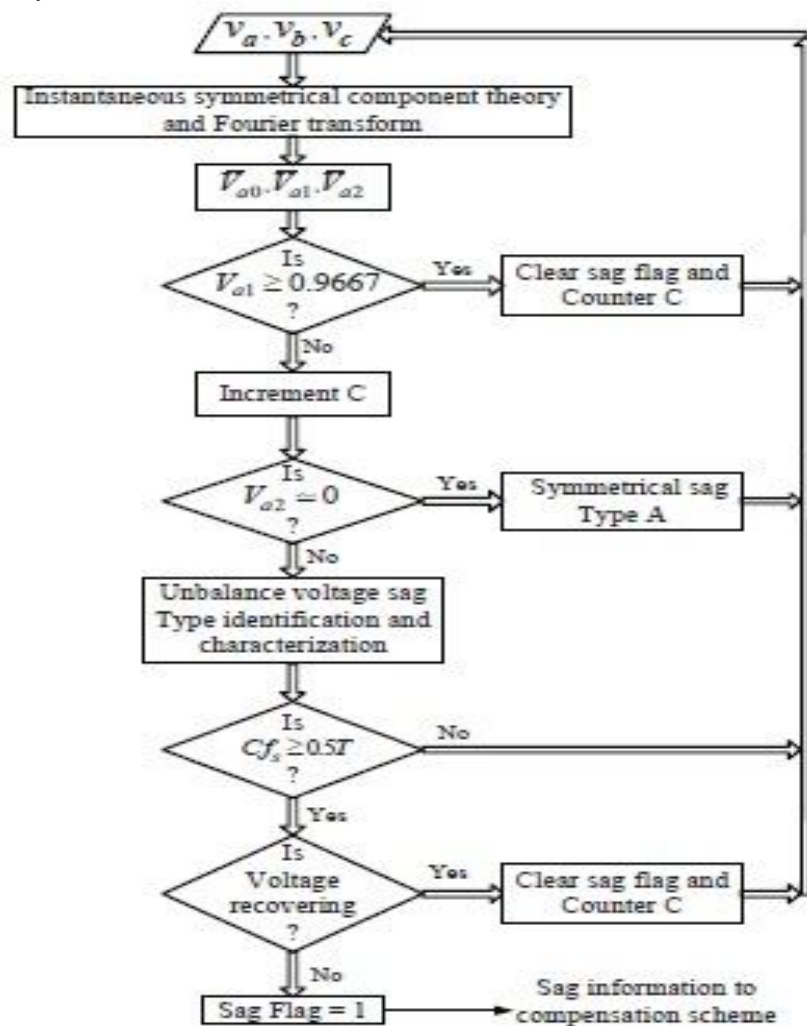
Fig. 2 Algorithm Flowchart

IV. RESULT AND DISCUSSION

The simulation is carried out in MATLAB/SIMULINK. The sag occurs when the fault is applied from 0.4s to 0.6s. The fig.3 below shows the graph between time vs sag flag. When the sag is detected, sag flag is set at 1.
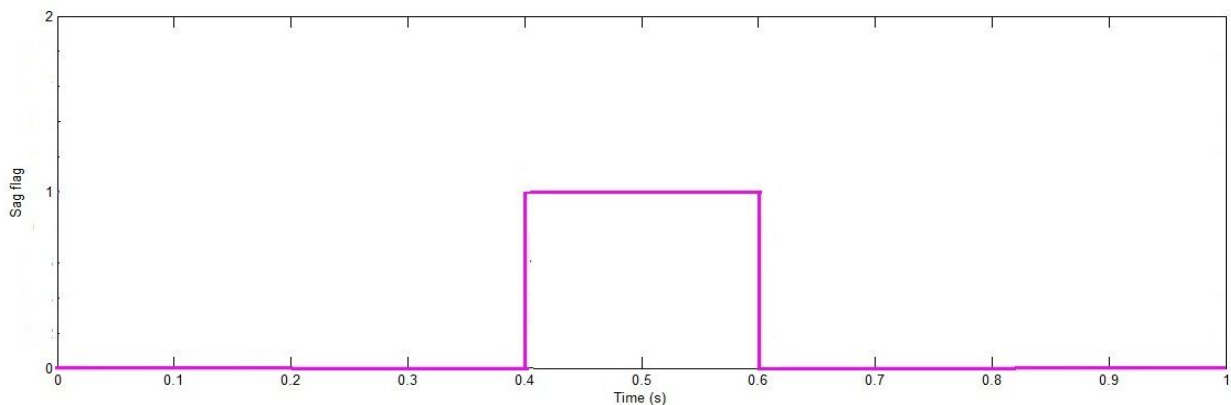

Fig. 3 Simulation time vs Sag flag

In the fig 4, it shows the graph of time Vs type of sag. The applied sag is phase to phase fault between a and c phases. It is of type C_b where phase b is healthy and other phases are affected. From the table 1, it can be seen that this sag is numerically denoted by 2.
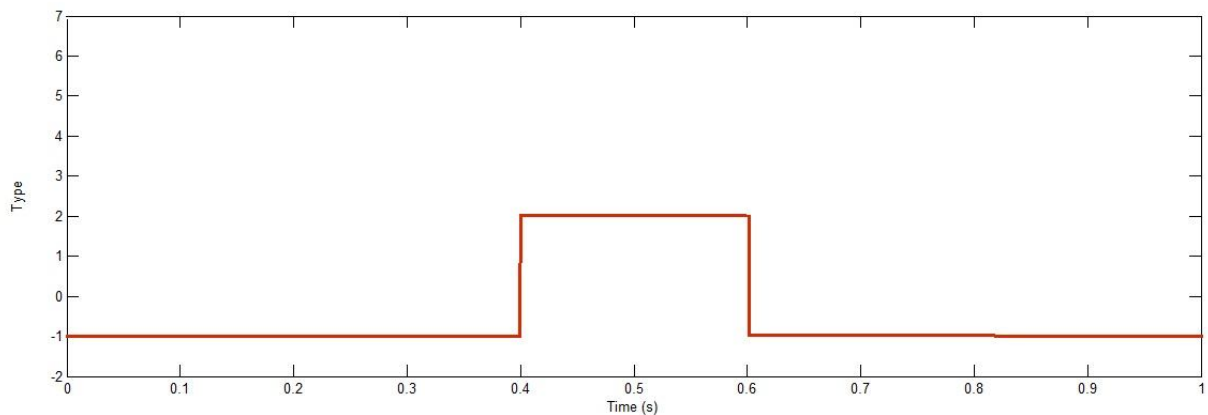

Fig. 4 Simulation time vs Sag type

In Fig 5 (a) and 5 (b) , the graphs of magnitude and phase respectively of characteristic voltage is plotted against time. The characteristic voltage magnitude gives the information about the voltage sag magnitude whereas the phase of characteristic voltage gives the information regarding the phase angle jump due to sag. Here, a voltage sag of 0.3 p.u. and phase angle jump of 40 degree is shown.
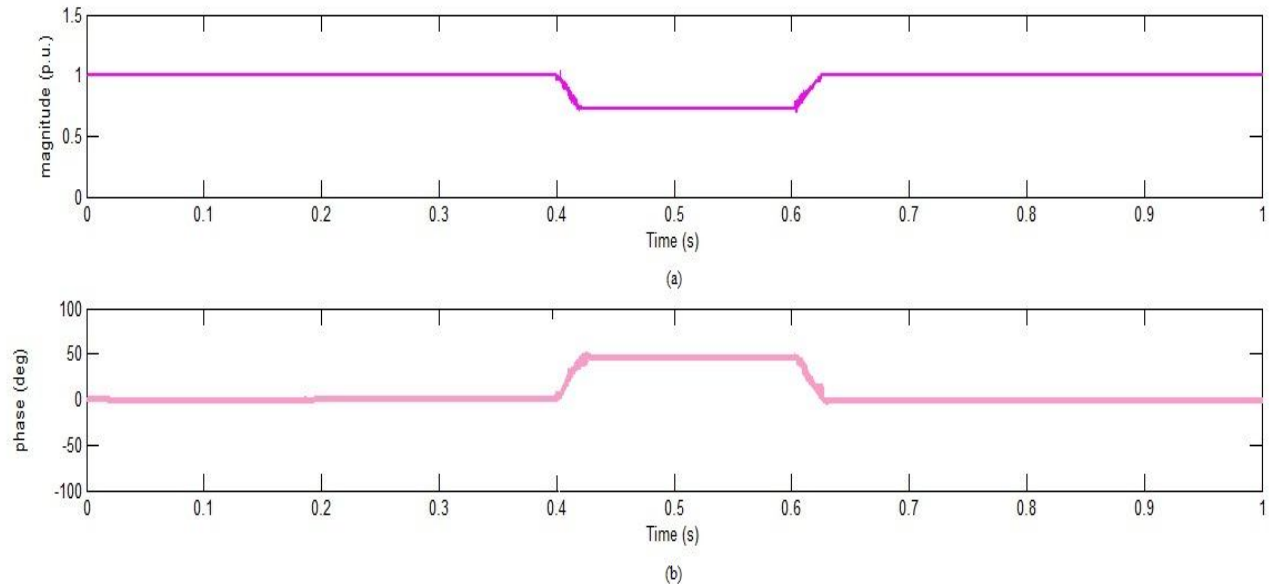
Fig .5 (a) Magnitude of characteristic voltage Vs time. (b) Phase of characteristic voltage Vs time.

V. CONCLUSION

The instantaneous symmetrical component theory based algorithm detects and characterizes voltage dip. It can be used effectively in distorted voltage also. For DVR topologies which require information regarding the phases affected and the sag magnitude, this algorithm can be used. The d-q transform method does not give these information readily. The proposed characterization method utilizing symmetrical component, may prove to be useful for these DVR topologies.

REFERENCES

[1]   M. H. J. Bollen, Understanding power quality problems, IEEE press New York, 2000.
[2]   R. C. Dugan, M. F. McGranaghan, S. Santoso, and H.W. Beaty, Electrical Power Systems Quality. New York, USA:McGraw-Hill, 2004.
[3]   J. G. Nielsen and F. Blaabjerg, "A detailed comparison of system topologies for dynamic voltage restorers," IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1272–1280, Sep./Oct. 2005.
[4]   B. Bae, J. Jeong, J. Lee, and B. Han, "Novel sag detection method for line-interactive dynamic voltage restorer," Power Delivery, IEEE Transactions on, vol. 25, no. 2, pp. 1210 –1211, april 2010.
[5]   S. Subramanian and M. Mishra, "Interphase AC-AC topology for voltage sag supporter," Power Electronics, IEEE Transactions on, vol. 25, no. 2, pp. 514–518, 2010.
[6]   M. Bollen, "Algorithms for characterizing measured three-phase unbalanced voltage dips," Power Delivery, IEEE Transactions on, vol. 18, no. 3, pp. 937 – 944, july 2003.
[7]   M. I. Marei, E. F. El-Saadany, and M. M. A. Salama, "A new approach to control DVR based on symmetrical components estimation," IEEE Trans. Power Del., vol. 22, no. 4, pp. 2017–2024, Oct. 2007.