CHAPTER

2

VOLTAGE SAG RECOGNITION VIA CONTINUOUS WAVELET TRANSFORM

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2.1 INTRODUCTION

Electrical disturbances, such as voltage sags can significantly impact the reliable operation of electrical power networks. Voltage sag is characterized by a reduction in voltage magnitude ranging from 0.1 per unit (p.u) to 0.9 p.u for a duration spanning from 0.5 cycle to one minute and represents a critical power quality issue in both distribution and transmission systems. This type of power quality event, often referred to as a "two-dimensional" occurrence, is elucidated using the minimum value or total time method. Statistical records indicate that over 80% of power quality-related grievances pertain to voltage sags (Turović et al., 2022). To ensure the stability and reliability of power systems, a robust tool is essential for classifying voltage sags, as these are primarily responsible for disruptions in power quality. Wavelet analysis and transformation are useful in analyzing non-periodic signals in power systems. The wavelet transform breaks down a signal into multiple frequency components and produces a time-frequency representation of the signal. It is preferred in identifying and characterizing transitory disturbances like voltage sag because it captures both the time and frequency characteristics of a signal (Priyadarshini et al., 2024). The wavelet transform can be either continuous or discrete, as voltage sag is a transient phenomenon that is continuous. When a wavelet transform is performed, different instances of the signal produce different coefficients known as wavelet coefficients.

Therefore, this chapter focuses on analyzing the coefficient values of wavelet transform to classify the type of voltage sags. The continuous wavelet transform (CWT) is used in this study with a focus on the morlet wavelet. An observation indicated that different types of voltage sags have ranges in terms of the values of CWT. The sags classified include phase-to-phase, phase-to-ground and multiple-phase faults, and all these have been classified based on the measurement of the coefficient of the CWT (Mohammadi et al., 2020). This chapter continues with Section 2.2, which provides a review of wavelet coefficients and voltage sag. Section 2.3 explains the approach method. Next, Section 2.4 elaborates on the simulation result and the concluding remarks for the study are presented in Section 2.5 of this chapter.

2.2 WAVELET TRANSFORM

The wavelet analysis can be used to analyze non-stationary signals, where the frequency content fluctuates over time, unlike fourier analysis which requires a periodic signal. Due to the frequent non-stationary behavior displayed by voltage sag events, this trait is very important for electrical fault analysis. Fourier analysis might not adequately capture the time-varying character of these faults. This constraint is overcome by wavelet analysis, which offers a time-frequency representation that is suitable for transient characteristics of electrical faults (Priyadarshini et al., 2024).

Wavelet coefficients are the results when a wavelet transformation is performed on a specific dataset like a signal or image. These coefficients serve as indicators of the contribution of each individual wavelet to the overall signal (Cohen & Atoui, 2020). When a high-magnitude wavelet coefficient is encountered, it signifies that the corresponding wavelet has a substantial impact on the signal at that particular scale and location. On the other hand, a coefficient of a smaller magnitude denotes a minor contribution from the associated wavelet. By examining these coefficients, the information about the signal's structure can be obtained. The CWT of the signal is mathematically defined as Equation (2.1):

$$W(a,b) = \int_{-\infty}^{\infty} x(t)\varphi^{*}\left(\frac{t-b}{a}\right)dt \qquad (2.1)$$

where the a is a scale parameter (related to frequency), b is the translation parameter (related to time), $W(a,b)$ is the wavelet coefficient at scale a and translation b, $x(t)$ is the original signal, $\varphi(t)$ is the mother wavelet function and φ^{*} denotes the complex conjugate of the wavelet,

The coefficients of the CWT exhibit a specific correlation level (Guo et al., 2022). This essentially means that the coefficients derived from two nearby points on the time-scale plane possess a degree of correlation. The nearer these points, the higher the correlation becomes. However, as the separation between these points widens, the strength of correlation diminishes quickly. In the context of electrical signals, the closer the coefficients are the more likely the signal to be in the steady state. If there is a significant change in the coefficients, then it can be said that the transient has occurred, and one possible cause is electrical fault.

2.3 VOLATGE SAG MODELING AND TEST SYSTEM SETUP

The main objective of the study presented in this chapter is to classify the types of voltage sags that occurred in the system by analyzing the coefficient values obtained from CWT implementation. Therefore, to achieve the objective, the voltage sag generation modelling and simulation works will be explained thoroughly in this section.

2.3.1 Voltage Sag Generation

The test system considered in the study consists of a generator, 11 kV bus, step-down transformer, and 400V low voltage load, which is simulated as shown in Figure 2.1.