Three-Phase PWM-Switched Autotransformer Voltage-Sag Compensator Based on Phase Angle Analysis

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Abstract

Many voltage sag compensators have been introduced, including the traditional dynamic voltage restorer (DVR), which requires an energy storage device but is inadequate for compensating deep and long-duration voltage sags. The AC-AC sag compensators introduced next do not require a storage device and they are capable of compensating voltage sags. This type of compensator needs an AC-AC converter to regulate the output voltage. Presented in this paper is a three-phase PWM-switched autotransformer voltage sag compensator based on an AC-AC converter that uses a proposed detection technique and PWM voltage control as a controller. Its effectiveness and capability in instantly detecting and compensating voltage sags were verified via MATLAB/Simulink simulations and further investigated through a laboratory prototype developed with a TMS320F2812 DSP as the main controller.

Key Words: Peak detection, RMS detection, Voltage sag, Voltage sag compensator, Voltage sag detection

I. INTRODUCTION

Voltage sags cause expensive downtime, making them the focus of considerable research. They are a phenomenon of RMS voltage rapidly declining from 90% to 10% of the rated voltage, typically for 0.5 to 30 cycles [1]. Voltage sags are generally caused by lightning, accidental short circuits, loose connections, the starting of large motors (or air-conditioners), or abnormal use of AC mains [2]. Even short periods of voltage sag can cause irreversible damage to sensitive equipment and cause significant economic losses, owing to interruptions in industrial production [3].

Disturbances caused by voltage sags cause losses to not only production but also to utilities [4], [5]. There are increases in the demand for clean power as the use of microelectronic processors increases in various types of equipment such as computer terminals, programmable logic controllers, and diagnostic systems. These types of equipment are susceptible to disturbances in their supply voltage, and the widespread application of nonlinear electronic devices in power apparatuses and systems makes waveform distortions more significant.

One of the most popular topologies for voltage-sag compensators is the dynamic voltage restorer (DVR), which requires a voltage-source inverter (VSI) for the line-injection of series voltage, an injection transformer, and a dc link. One obvious disadvantage of this topology is its inability to compensate deep and long-duration voltage sags. Increasing its capability requires more energy storage devices, thereby increasing cost. Another consideration is environmental, since a battery is used as the energy storage device. Also, the voltage regulation of the dc link demands use of a separate ac-dc converter, which requires one more stage of power conversion, increasing size, cost, control complexity, and power losses [6].

Energy storage is unnecessary in AC-AC sag compensators. However, an AC-AC converter is needed to convert the dropped ac voltage to regulated ac voltage. The three-phase PWM-switched autotransformer voltage sag compensator presented here uses an AC-AC converter and a proposed voltage sag detection technique based on phase angle analysis. The proposed detection technique is able to detect and compensate voltage sags the moment they occur, even with the presence of harmonic content in the input voltage. A PWM voltage controller is chosen as the PWM control strategy.

II. VOLTAGE SAG DETECTION TECHNIQUES

The speed of voltage-sag detection affects the dynamic performance of a compensator. Therefore, precise and fast voltage-sag detection is essential. Determined are the start, the end, and the severity, of voltage sags. Many techniques for voltage sag detection have been introduced include RMS-Value Evaluation and Peak-Value Evaluation.