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A novel controller for a voltage controlled voltage source inverter to mitigation voltage fluctuations measured at the point of common coupling

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ABSTRACT

One of the most important concerns in manufacturing industries and utilities over the utilization of voltage controlled voltage source inverters (VCVSIs) is to generate and maintain a steady sinusoidal output voltage to the critical load which has been the focus of considerable research in recent years. VCVSIs output voltage fluctuation may be caused by abrupt or periodic changes of the load current that are significant. The purpose of this paper is to keep the amplitude of the output voltage wave form at the reference level under these conditions. The proposed method presents a fast voltage variation detection technique using phase space mathematical method to improve voltage fluctuation. A controller that takes advantage of this detection method is applied to a full bridge inverter to keep the voltage level at the desired point. To investigate the efficiency and accuracy of the proposed controller, a system is modeled using Matlab/Simulink and the results is compared with open-loop and RMS controllers. The simulation results approve the capability of the proposed controller to provide a sinusoidal output voltage and mitigate voltage fluctuation to a considerable level by using phase space method.

1. Introduction

Voltage controlled voltage source inverters (VCVSIs) are extensively used in industrial, military and marine applications, power quality compensators, renewable energy technologies and power supplies [1]. They are located at the heart of all applications that require converting a direct voltage to an alternating one. Accordingly, designing an efficient and robust VCVSI is momentous, especially in some fields such as renewable-energy applications and remote areas where the disturbance in inverter output will cause course inconvenience and the available power will be restricted.

One of the most important concerns in manufacturing industries and utilities over the utilization of VCVSIs is the voltage variation that may cause disruption in the processing plant, causing hours down. For example a study in South Africa estimates that 891 min of down-time in 1996 due to such of voltage variations caused around $2 million turnover loss for that year [2]. Voltage variation can be described as repetitive or random fluctuation of the voltage envelope due to the sudden changes in the power drawn by a load. The characteristics of the voltage variations depend on the load type and capacity, it may happen when the loads draw or inject currents with significant

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sudden or periodic variations. The fluctuating current that is drawn or injected from the supply causes additional voltage drops or rises in the power system leading to fluctuations in the supply voltage. Therefore, loads that exhibit continuous rapid variations are thus the most likely cause of voltage fluctuations. Various solutions have been proposed in literature to mitigate voltage variation. There are two main approaches to cope with this problem, improving hardware performance and improving voltage variation detection time and control. The second approach, which is considered in this paper, is described in Section 2.

In this paper, a fast voltage variation detection technique is proposed through the implementation of Phase space mathematical method which is rapidly able to track the amplitude of the load voltage and its variations in real time. The proposed controller is also carried out in a test system to investigate its performance under different loading conditions. The results also compared with the system with open-loop and RMS controllers, which verify the effectiveness of the proposed phase space controller.

2. Voltage fluctuation detection methods

Up to now, many procedures have been proposed to specify the voltage fluctuation detection in a system. Technically, three principal attentions including the response time, the implementation complexity and the precision should be considered for choosing the appropriate method. The most well-known methods in voltage alteration detection are highlighted as follows:

2.1. Peak value detection

In this procedure, the absolute peak voltage amount of the output voltage is computed and monitored. There are two approaches to recognize the peak voltage value. The first method is to discover the voltage gradient for each sample, and the peak voltage is the voltage instant when the gradient is zero [3]. The second method involves finding the maximum of the absolute voltage. Hence, the maximum absolute value of the voltage over the preceding half period is calculated [4]. The drawback of this method is half cycle delay and also noise and harmonics effect on the precision of this detection method. To improve this method of detection, a new approach was proposed based on peak value detection by 90° shifting of the momentary voltage value [5].

2.2. Monitoring synchronous reference (d–q) component

Synchronous reference (*d*–*q*) component, also known as park transformation, maps three-phase balanced voltages into two-phase direct current parameters [6]. Therefore using this technique, the procedure of control can be simplified by reducing the number of variables. In the case of voltage fluctuation detection in three phase system, if the voltage is symmetrical, V_q is zero and V_d can be monitored to find the level of voltage variation. Nonetheless, if balanced variation voltage is attained by a balanced phase offset then the V_d relation is no longer valid since the PLL has to first track the new angle. In case of unbalanced variation or presence of harmonic components, the ability of this method to return the information regarding the individual supply phases is compromised as the oscillations may be seen in the V_d and V_q components which make it useless for voltage fluctuation detection. However, an advantage of this method is the relative ease of implementation within a practical real-time control system [7].

2.3. Artificial neural network

Artificial neural network (ANN) method is a bit slower than synchronous reference component method, but more suitable for unbalanced systems. This method can be used to estimate the reference signal using the least mean square (LMS) algorithm. In each case, neural weights are adjusted in each cycle based on the inputs and outputs. The convergence coefficient which decides the rate of convergence and the accuracy of the control signal simultaneously plays an important role in this method. Although higher values of the coefficient provide faster convergence towards the final value, the accuracy of the result will be decreased as well [8]. The main weakness of the ANN-based methods is the need of a massive training data to improve the training process. In addition any increment in the number of the network features can increase the complexity of the system.

2.4. Kalman filter

The Kalman filter (KF) requires a state variable model for the parameters to be estimated, and a measurement equation that relates the discrete measurement to the state variables [9,10]. It also is a recursive optimal estimator, well suited for on-line applications. The results of KF approach are highly dependent upon original conditions. Another drawback of the KF-based methods is fairly complex mathematical require large computations. In addition, this method requires fairly complex and large mathematical computations [11].

2.5. Least square method

In the least square method, which is very simple for practical implementations, the essential harmonic of the desired signal is specified by achieving the coefficients of Fourier transform for minimizing the error between the Fourier series and the actual data [12–15]. This method uses some algebraic manipulation to simplify the complex calculation of the least square method. This approach manipulates the general Digital Fourier Transform (DFT) matrix and decomposes it to two matrixes and also uses a rotation matrix to avoid complicated calculations. Therefore, the number of matrix calculations is dramatically decreased. In addition, this method requires a pre-calculated matrix that will be a constant factor for fundamental component manipulation. The required detection time is also half a cycle. This method is usually done by matrix manipulation, and it requires massive calculations, which make it unsuitable for practical on-line applications.