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Analysis, Design and Implementation of Single Phase SRF Controller for Dynamic Voltage Restorer under Distorted Supply Condition

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Abstract

The mitigation of single phase voltage sag under distorted supply condition has been effectively performed by Dynamic voltage restorer (DVR). The concept of inherently used three phase synchronous reference frame theory (SRFT) has been utilized to simply develop single phase SRFT. The single phase SRFT has been applied in the design of controller for DVR which generates reference instantaneous injected voltage. The proposed controller utilizes moving average filter (MAF) for the extraction of positive sequence fundamental component of distorted supply voltage. The simulation results of controller for DVR proves its effectiveness in mitigation of voltage sag under distorted supply voltage.

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Keywords: Power quality; voltage sag; Harmonics; Distorted supply; Single phase DVR; Single phase SRF d-q theory.

1. Introduction

To accommodate with the emerging distributed generation systems, power quality (PQ) improvement is a major concern [1]. The industrial load increases harmonic distortion in the supply voltage due to harmonic voltage drop in the line, particularly when the line reactance is large [2]. PQ covers many issues such as voltage sag/swell, unbalance voltage, harmonics, flickers, interruptions etc. [3]. However the major issues in single phase system are

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voltage sag and harmonics. To deal with sag according to IEEE std. 519 [4], Dynamic Voltage Restorer (DVR) is the prominent device due to its reliability, flexibility and effective restoration abilities.

In case of unbalanced voltage sag, supply voltages contain negative and zero-sequence components, which result in non-dc (sinusoidal) *d-q* components. Under these conditions, the conventional proportional-integral (PI) controller fails to track the reference signal properly [5]. Also, to minimize the harmonics, a passive LC filter is connected in shunt with the load [6] but such arrangement has certain drawbacks [7]-[8]. In majority of the existing controllers for DVR [9]-[10], zero-sequence component of voltage is not considered and hence only suitable for three wire distribution line. However, low-voltage distribution line in many countries are four wired [11]. Consequently, the propagation of zero sequence component in unbalance sag effects the performance of controller [12].

This paper deals with proposed novel method of fundamental positive sequence extraction by single phase SRFT for DVR. The proposed control algorithm is used for quick and accurate extraction of fundamental component of supply voltage which restores the sensitive load voltage to its desired value under voltage sag and distorted supply condition. The single phase to *α-β* transformation is carried out by quarter cycle delay of existing voltage signal and then PLL is utilized for SRF *d-q* transformation. The decoupled *d-q* components are applied for the generation of reference injected voltage by the DVR for sensitive load.

2. Operation Strategy for DVR Control

The system configuration along with the single phase DVR is indicated in Fig. 1. A single-phase DVR contains H-bridge Voltage source inverter (VSI) with self-supporting DC link connected in series with coupling transformer. The basic operation of the DVR is to inject the voltage (V_{inj}) at certain angle with the load current which maintains the load voltage (V_L) to its desired predefined value. In the system with DVR, load current (i_L) is assumed to equal to source current (i_s).In steady state condition, if supply voltage (V_s) is purely sinusoidal then DVR does not inject reactive power into the system. However, in case of distorted supply, reactive power is necessarily supplied by DVR resulting in pure sinusoidal voltage at the load terminal. The restoration is initiated by controlling the switches of VSI along with voltage (V_{dc}) of DC-link with capacity (C_{dc}). C_f and L_f denotes π passive filter values.

2.1. Generation of SRF d-q components from single phase supply

The existing signal along with fictitious signal, orthogonal to each other can be considered as equivalent representation of a single-phase system in orthogonal $\alpha-\beta$ frame [13]. Subsequently, this methodology has represented as generalized single-phase $p-q$ theory, validated effectively with experimental study [1]. Moreover, Zhang et al [14] has further extended this concept for obtaining $d-q$ components in SRF. In this paper, the fictitious phase is created by sampling the terminal voltage signal at 20 KHz frequency. The input signal is delayed

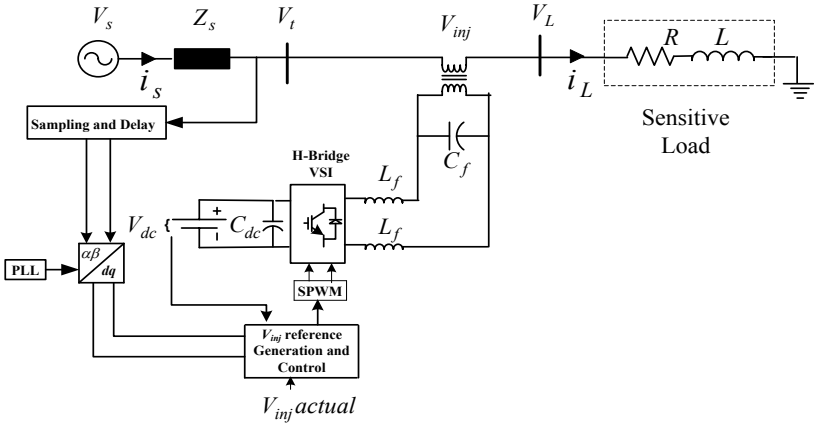

Fig. 1 Single phase DVR with proposed controller.