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Research Article

Design of Dynamic Voltage Restorer for Power Quality Enhancement in Distribution System

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Abstract

This paper proposes a three phase topology as dynamic voltage restorer. In this work, a series active filter is explored as dynamic voltage restorer to correct the quality power. Using the proposed design, the voltage compensation has been verified for a three-phase system with non-linear load. The simulation has been done using MATLAB/Simulink. The proposed method provides better results as voltage regulator for unbalanced applied input voltage. With the increase of nonlinear loads in the power system, more and more filters are required. Thus, dynamic voltage restorer is designed and analyzed to improve the power quality at ac power supply.

Keywords: *Dynamic voltage restorer, series active filter, load voltage, total harmonic distortion, three phase network.*

1. Introduction

In this modern era of science, the energy generation and distribution with high power quality is one of the major issues (R. Omar *et al*, 2011). The power quality can be analyzed on the basis of either voltage unbalance, that is, voltage sag or swell and the partial or total loss of power in one or more phases. The voltage unbalance occurs due to uneven distribution of energy on the phases of the loads which may continuously changes across a three-phase system (D. M. Vilathgamuwa *et al*, 2006). The deficient quality power can cause several disadvantages such as energy production losses, equipment breakdown, noise in communication lines, etc (K. P. Kumar *et al*, 2014). Different equipments along with techniques have been proposed by various researchers to overcome these problems. Dynamic voltage restorer (DVR) is one of the systems that work by injecting ac voltages in series with the incoming three-phase network (J. R. Vazquez *et al*, 2005) (S. Ota *et al*, 2005). The basic purpose of DVR is to improve voltage quality by adjustment in voltage magnitude, wave-shape and phase shift. DVR in-combination with filters is widely used to enhance the quality of the voltage. Passive filter have been used especially in industrial sectors to reduce mitigating the distortion due to harmonics. But they possess several drawbacks such as resonance, impedance dependency, and absorption of harmonic current in nonlinear load (H. Akagi *et al*, 2006). On the other hand, active filters have no such drawbacks. They can cancel the harmonics of nonlinear loads by introducing harmonic voltage or current with appropriate magnitudes and phase angle into the system (P. Parkatti *et al*, 2008) (A. A. Rockhill *et al*, 2011). No doubt, they also have certain drawbacks like, high initial cost and high power losses due to which it limits there wide application, especially with high power rating system. The working of the DVR depends on their control systems (Y. Sato *et al*, 2002). Generally, there are two such control systems used in DVR applications; open loop and closed loop systems (A. Ghosh *et al*, 2002). The unbalanced voltage can be compensated using DVR with three-phase series active filter that can regulate the voltage to the desired level (M. R. Banaei *et al*, 2006) (J. W. Liu *et al*, 2003) (R. Madhusudan *et al*, 2012).

In this paper, the design for a three phase series active filter for unbalance voltage compensation has been simulated. The paper is organized as follows. Section II presents the methodology for the propose design while the results are discussed in Section III. The conclusion is presented in Section IV.

2. Methodology

The DVR is modeled and simulated using the MATLAB and its Simulink. The block diagram for the DVR connected system is shown in Fig. 1 with a system configuration of a single-phase or three-phase series active filter for harmonic-voltage filtering of a single-phase or three-phase diode rectifier. The series active filter is connected in series with the input grid voltage through a three-phase transformer. The series active filter is controlled on the basis of the following points.

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- The controller detects the instantaneous supply current IS.
- It extracts the harmonic current from the detected supply current by means of digital signal processing,
- The active filter applies the compensating voltage across the primary of the transformer.

This results in significant reduction of the harmonic current for high value of feedback gain.

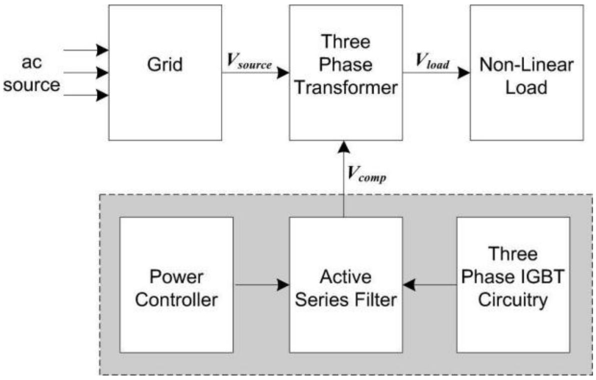

Fig.1 Block diagram of proposed DVR system

A dc voltage source PWM converter equipped with a resistor acts as power circuit to DVR and is shown in Fig. 2. The circuit is IGBT based and is more suitable for the voltage-source PWM converter because a free-wheeling diode is connected in anti-parallel with each IGBT. This means that the IGBT does not need to provide the capability of reverse blocking in itself, thus bringing more flexibility to device design as a compromise among conducting and switching losses and short-circuit capability than the reverse-blocking IGBT.

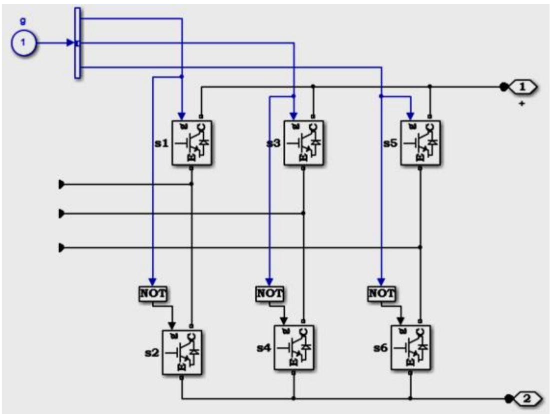

Fig.2 IGBT based power circuit to DVR system

In Fig. 2, all the three pairs of complementary-symmetry IGBT's are connected via NOT gate. The ac signal frequency is set at 50 Hz for this simulation. The input voltage is set to 230 Volts rms for all the three phases, in a balanced condition and then it is subsequently altered. The reference load voltages are derived from the sensed terminal voltages, load supply voltages and the dc bus voltage of the DVR. A pulse width modulation (PWM) controller is used over the reference and sensed load voltages to generate gate signals for the IGBT's of the power circuit.

3. Results and Discussions

The three phase source of 100 MVA, 230 V, 50 Hz is applied to a non-linear load of the diodes (R=60Ω, L=15mH) is considered. The simulation has been performed for unbalanced source supplying to non linear load. Fig. 3 shows the terminal voltage of thyristor fed RL load with balanced source. The load current is shown in Fig. 4.

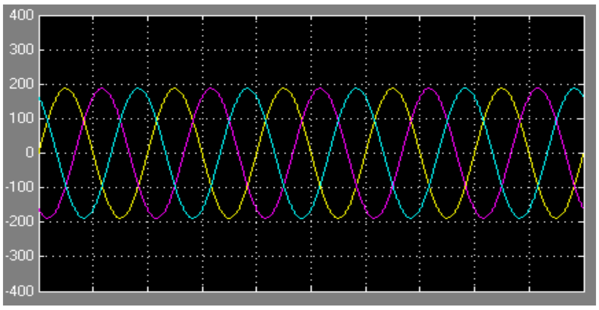

Fig.3 Three phase terminal voltage

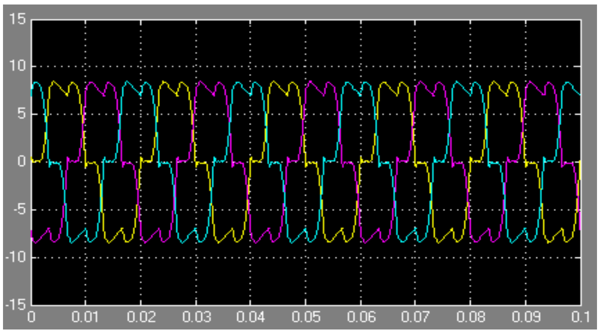

Fig.4 Three phase terminal current

Fig.5 shows the source voltage after voltage compensation using power control circuitry. The controller gives better results on load side which is shown in Fig. 6. From Fig. 6, one can understand for first two cycle's controller not producing output properly due to sampling period under considered for calculating the power.

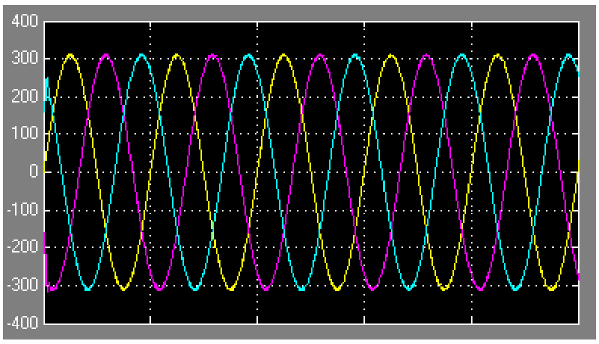

Fig.5 Source voltage after compensation

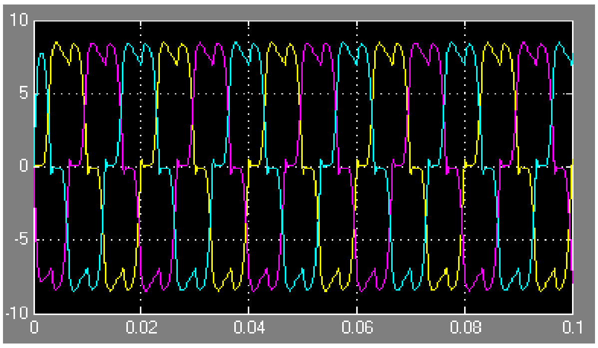

Fig.6 Source current after compensation

The simulation performance analysis of series active filter with unbalanced source voltage has been done with source voltages of Va=230 V, Vb=150 V, Vc=180 V on phases A, B and C respectively. The source voltage with unbalance is shown in Fig. 7. Fig.8 illustrates the current drawn by the non-linear load.

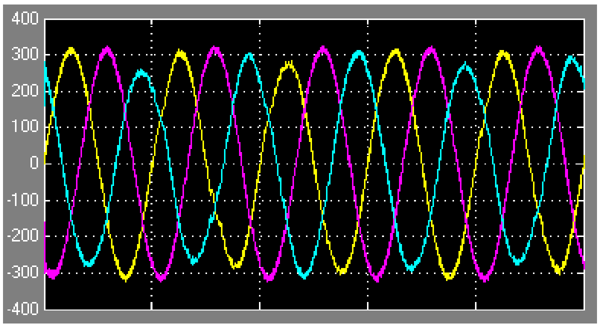

Fig.7 Source voltage with unbalanced load

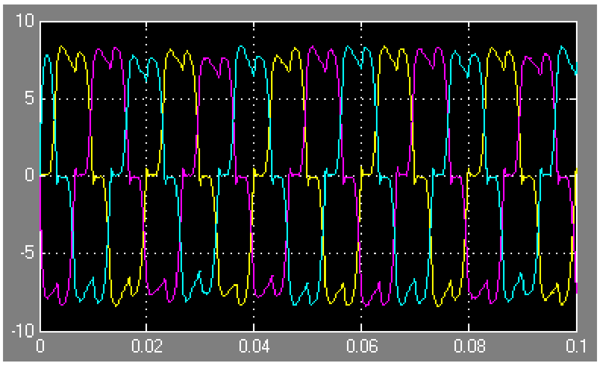

Fig.8 Source current with unbalanced load

Fig.9 represents the source voltage after voltage compensation using power control analysis. Here also the controller is not providing proper results for only two cycles after that controller perform well. The terminal voltage after compensation is presented in Fig.10.

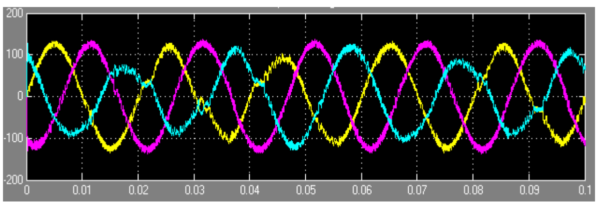

Fig.9 Source voltage after compensating the unbalanced load

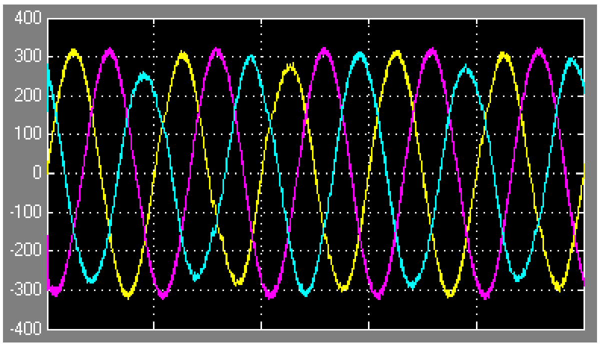

Fig.10 Terminal voltage after compensating the unbalanced load

The total harmonic distortion is also estimated and shown in table 1.

Table 1 TTHD values of unbalanced source voltage

S. No	Voltage	Conditions	%THD
1	Load Voltage	Balanced without compensation	22.24
2	Load Voltage	Unbalanced with compensation for NOT gate	2.89
3	Grid Voltage	Unbalanced with compensation for NOT gate	4.63
4	Injected Voltage	Unbalanced with compensation for NOT gate	16.23

Conclusions

In this paper, we analyzed a model for DVR using a series active filter with proper control scheme. The controller used has the capability to produce fast reference compensation voltage signal that has been presented and analyzed by computational load. The results showed that the series active filter can perform better in reducing total harmonic distortion (THD). The simulation results show a very good performance of the proposed algorithm and it was tested under unbalanced source applied to non-linear load. The controller was efficient to compensate unbalanced voltage at the load terminals.

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