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Compensation of voltage disturbances using PEMFC supported Dynamic Voltage Restorer

C.K. Sundarabalan *, K. Selvi

Department of Electrical and Electronics Engineering, Thiagarajar College of Engineering, Madurai 625015, India

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ABSTRACT

The continuity of supply and quality of power are the two main significant aspects of today's power delivery system. The Dynamic Voltage Restorer (DVR) is a series connected custom power device which improves the quality of power delivered to the consumers. This paper deals with the effectual exploitation of DVR for interconnecting the proton exchange membrane fuel cell (PEMFC) stack to the grid based on optimized proportional integral (PI) and fuzzy logic (FL) Controller. The real coded Genetic algorithm (GA) is used to optimize the PI controller parameters. The PEMFC operated boost converter is used to boost up the fuel cell output voltage to balance the DC side necessities of the voltage source converter (VSC). The proposed DVR provides balanced and unbalanced voltage sag/swell compensation, harmonic reduction as well as an active power injection to the grid. The designed method also protects the sensitive loads from source side power quality disturbances including short term interruption. In addition, the harmonic compensation performance of the proposed work is validated by comparing with the results of the H^{∞} controller based DVR under medium level voltage condition. The simulation results from MATLAB/SIMULINK are discussed to prove the effectiveness of the planned method.

Introduction

The causes of PQ problems in today's power delivery system are complex due to the increased use of electronics equipment, electrical devices are becoming smaller and more sensitive to very short duration disturbances than the equipment previously used [1]. The occurrence of unbalanced loads will cause unbalanced voltage, negative sequence voltage and zero sequence voltage. The low quality power can cause loss of production, reducing the life of load equipment, improper operation of protective device and energy metering problem. So that, it is essential to retain high quality power [2]. The power electronic based compensating type Custom Power Devices (CPDs) can be effectually employed to enhance PQ in distribution system [3]. The compensating CPDs are either connected with system in series, parallel or combination of both. The Distribution Static Compensator (DSTATCOM) is a shunt connected CPD is used for compensation of PQ disturbances such as power factor improvement and current harmonics filtering. The DVR is a series connected CPD, which is one of victorious solution that deals with voltage flaw in the power delivery system [4–6]. The DVR is used to compensate different PQ phenomena such as voltage sag, voltage swell, voltage unbalance and harmonics [7–8]. The Unified Power Quality Conditioner (UPQC) is a CPD that integrates both shunt and series active filter with a common DC capacitor. The UPQC is used to compensate PQ disturbances in both voltage and current [9,10].

The increasing demand, shortage of fossil fuel and the necessity to reduce emission have been the main drivers for Distributed Generation (DG) [11]. The advantages of using fuel cells DG include slight green house gas emissions and reliable efficient system operation. Several types of fuel cell are available but PEMFC is the most suitable one for DG applications [12,13]. Usually, the interconnection of DG systems to the grid using power electronic converters for retaining PQ standards and the switching of these converters can inject surplus PQ disturbances to the grid [9]. The combination of Photovoltaic interfacing DVR reduces the PQ disturbance in the grid. Furthermore, it reduces the power utilization from the grid [14].

In [15], the PI controller based DVR is modelled, and the controller parameters are fixed so it gives better performance only in the local area. If the operation point of the converter is changed, the parameters of the PI controller should be designed it again. But the FL controller shaped to define suitable sensitivity for each operating point. The nonlinear controller based DVR gives better performance as compared with linear controllers [16]. The H^{∞}

* Corresponding author.
E-mail addresses: ckseee@yahoo.com (C.K. Sundarabalan), kseee@tce.edu (K. Selvi).

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controller is designed and implemented in medium voltage level DVR [17–18]. Ziegler-Nichols and Cohen-coon are the conventional methods for tuning the PI controller. Real coded GA with simulated binary crossover was successfully used in various optimization problems [19]. The real coded GA is used to find the optimal parameters of PI controller [20,21].

In this paper, the DVR is used for interconnecting the PEMFC stack to the grid based on real coded GA optimized PI controller and FL controller. The series active power filter is used to evacuate the power from the PEMFC stack in addition to the compensation of voltage sag, voltage swell, short term interruption and reduction of harmonics. Various levels of balanced and unbalanced voltage sag/swell compensation are analyzed with different types of faults and the complete results are presented. This work compares the voltage disturbance compensation performance of real coded GA optimized PI controller and FL controller. Both controllers are aiming to generate reference voltage signals to control VSC through the switching pulses generated by pulse width modulation (PWM) method. The harmonic compensation performance of the proposed work is validated by comparing with the results of the H^{∞} controller based medium voltage level DVR. The performance of the proposed DVR with PEMFC system was analyzed using MATLAB/Simulink.

Configuration

The configuration of the proposed DVR system is exposed in Fig. 1. The primary role of the DVR is to compensate the voltage flaw by injecting the appropriate voltage [22]. The voltage injected by the DVR (V_{DVR}) is in series with the sensitive load through an injection transformer and an LC filter [23–24]. The purpose of the LC filter and injection transformer are used to prevent switching harmonics produced by the VSC and boost up the V_{DVR} respectively. The DC voltage generated by the PEMFC is stepped up by the DC–DC boost converter and the boosted DC voltage is connected in the DC side of VSC through a capacitor.

In order to verify the effectiveness of the DVR, the proposed system composed of two types of load. Three-phase uncontrolled rectifier with resistive and inductive load on its DC side is considered as a nonlinear load. A three single-phase unbalanced resistive and inductive load are connected in parallel with nonlinear load. The combination of nonlinear load and the unbalanced load are connected in the feeder-1 and the load voltage at feeder-1 is represented as V_{L1}. Three-phase resistive and inductive loads are considered as a sensitive linear load, which is connected at feeder-2. The DVR is connected before the sensitive linear load to protect the load from any voltage distortions from source side and making the load voltage as sinusoidal. The load voltage of feeder-2 is represented by V_{L2}. All the parameters used in this simulation model are presented in the Appendix. The comparison of the proposed topology with the existing FL controlled DVR topology is shown in Table 1.

The balanced and unbalanced voltage sag disturbances are analyzed in all the existing FL controlled DVR topologies, but it fails to analyze voltage swell issues and DG integration. In [28] voltage sag and swell disturbances are analyzed but open loop control strategy was used. The interconnection of DG with DVR topology is not available in the existing FL controlled DVR topologies. The proposed PEMFC supported DVR system is analyzed with balanced and unbalanced voltage sag/swell disturbances with the closed loop controller.

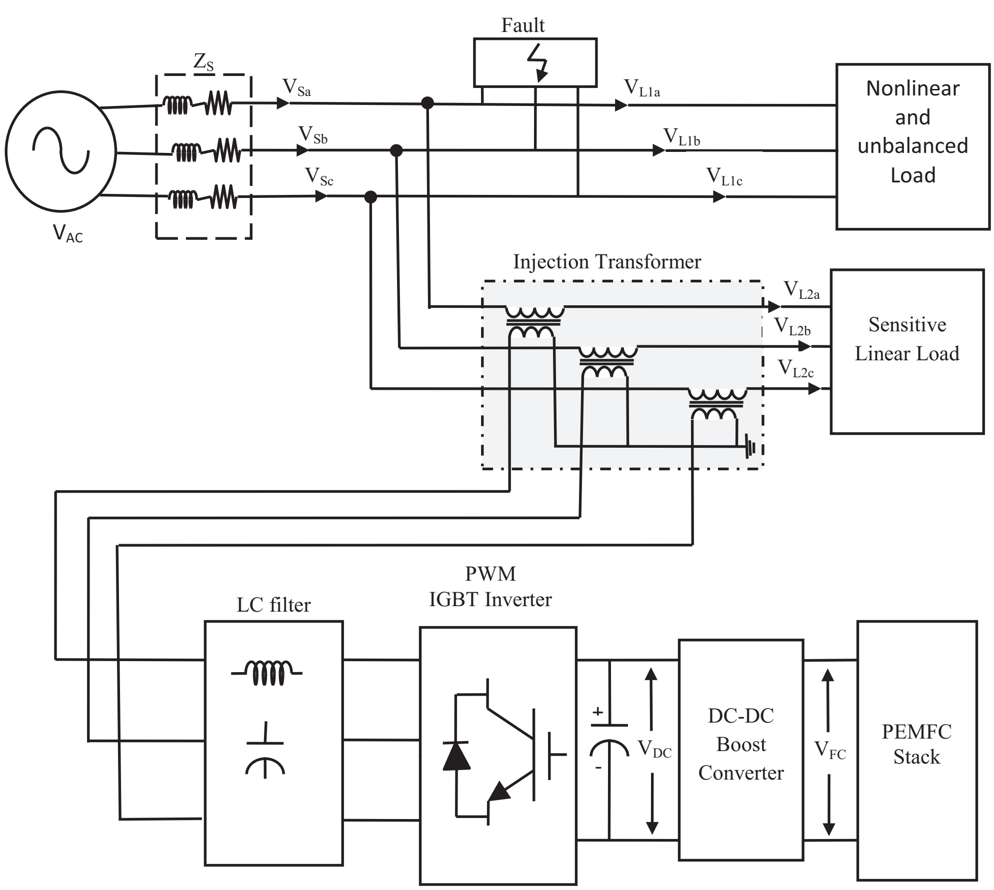

Fig. 1. Proposed system configuration.