CHB-DVR Based Cotrol Strategy form Improved Voltage Compensation

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Abstract

*This work deals with improving the voltage quality of sensitive loads from voltage sags using a Cascaded H Bridge Dynamic Voltage Restorer (CHB-DVR). The existing control strategies either mitigate the phase jump or improve the utilization of dc link energy by 1) reducing the amplitude of the injected voltage or 2) optimizing the dc bus energy support. In this work, an enhanced sag compensation strategy is proposed, which mitigates the voltage sag in the load voltage while improving the overall sag compensation time. An analytical study shows that the proposed method significantly increases the FC-DVR sag support time (more than 50%) compared with the existing compensation methods. The performance of the proposed method is evaluated using simulation study and finally verified experimentally using MATLAB/SIMULINK.***

Keywords— *DVR; CHB; SRF; VSC;*

I. INTRODUCTION

The solicitation of voltage-sensitive equipment, such as automatic production lines, computer centers, hospital equipment, programmable logic controllers (PLC), and adjustable speed drives (ASD), and air-conditioning controllers [1] has been increasing. Voltage sag is defined as the decrease in voltage RMS between 0.1 and 0.9 PU within 0.5 cycles to a few seconds. Swell is defined as an increase in nominal voltage between 1.1 and 1.8 PU during 0.5 cycles to 1 minute. Faults or large induction motors starting in the power system may cause voltage sags or swell. Consequently, other equipment may shut down. A solution for power quality improvement is to use custom power devices like a dynamic voltage restorer (DVR). External energy storage is necessary to provide the requirement for real power. Thus, the maximum amount of real power that can be provided to the load during voltage sag mitigation is a deciding factor of the capability of a DVR. However, the energy requirement cannot be met by the application of such phase advance technology alone to compensate the deep sag of long duration [2]. Custom power devices are mainly of three categories such as series-connected compensators known as dynamic voltage restorers (DVRs), shunt-connected compensators such as distribution static compensators, and a combination of series- and shunt-connected compensators known as unified power quality conditioner [2]–[6]. The DVR can regulate the load

Voltage from the problems such as sag, swell, and harmonics in the supply voltages. Hence, it can protect the critical consumer loads from tripping and consequent losses [2]. The custom power devices are developed and installed at consumer point to meet the power quality standards such as IEEE-519 [7].

Voltage sags in an electrical grid are not always possible to avoid because of the finite clearing time of the faults that cause the voltage sags and the propagation of sags from the

Transmission and distribution systems to the low-voltage loads. Voltage sags are the common reasons for interruption in production plants and for end-user equipment malfunctions in general. In particular, tripping of equipment in a production line can cause production interruption and significant costs due to loss of production. One solution to this problem is to make the equipment itself more tolerant to sags, either by intelligent control or by storing “ride-through” energy in the equipment. An alternative solution, instead of modifying each component in a plant to be tolerant against voltage sags, is

to install a plant wide uninterruptible power supply system for longer power interruptions or a DVR on the incoming supply to mitigate voltage sags for shorter periods [8]–[23]. DVRs can eliminate most of the sags and minimize the risk of load tripping for very deep sags, but their main drawbacks are their standby losses, the equipment cost, and also the protection scheme required for downstream short circuits.

Many solutions and their problems using DVRs are reported, such as the voltages in a three-phase system are balanced [8] and an energy-optimized control of DVR is discussed in [10]. Industrial examples of DVRs are given in [11], and different control methods are analyzed for different types of voltage sags in [12]–[18]. A comparison of different topologies and control methods is presented for a DVR in [19]. The design of a capacitor-supported DVR that protects sag, swell, distortion, or unbalance in the supply voltages is discussed in [17]. The performance of a DVR with the high-frequency-link transformer is discussed in [24]. In this paper, the control and performance of a DVR are demonstrated with a reduced-rating voltage source converter (VSC). The synchronous reference frame (SRF) theory is used for the control of the DVR.

II. FUEL CELL

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent.[1] Fuel cells are different from batteries in that they require a continuous source of fuel and oxygen or air to sustain the chemical reaction, whereas in a battery the chemicals present in the battery react with each other to generate an electromotive force (emf). Fuel cells can produce electricity continuously for as long as these inputs are supplied.

The first fuel cells were invented in 1838. The first commercial use of fuel cells came more than a century later in NASA space programs to generate power for satellites and space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power fuel cell vehicles, including forklifts, automobiles, buses, boats, motorcycles and submarines.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (or protons) to move between the two sides of the fuel cell. The anode and cathode contain catalysts that cause the fuel to undergo oxidation reactions that generate positively charged hydrogen ions and electrons. The hydrogen ions are drawn through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, hydrogen ions, electrons, and oxygen react to form water. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements.[2] In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

III. WORKING OF DVR

The schematic of a DVR-Connected system is shown in Fig. 1. The voltage V_{inj} is inserted such that the load voltage V_{load} is constant in magnitude and is undistorted, although the supply voltage Vs is not constant in magnitude or is distorted.

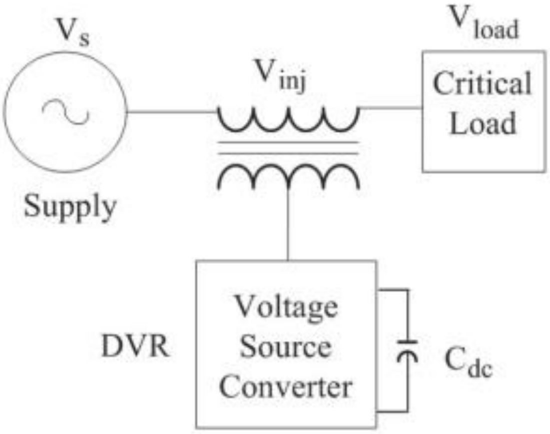

Fig. 1. Basic circuit of DVR.

Injection schemes of the DVR. V_L (pre–sag) is a voltage across the critical load prior to the voltage sag condition. During the Voltage sag, the voltage is reduced to Vs with a phase lag angle of θ. Now, the DVR injects a voltage such that the load voltage magnitude is maintained at the pre-sag condition.

The DVR is operated in this scheme with a Lithium-Ion battery energy storage system (LI-BESS). Fig. 2 shows a schematic of a three-phase DVR connected to restore the voltage of a three-phase critical load. A three-phase supply is connected to a critical and sensitive load through a three-phase series injection transformer. The equivalent voltage of the supply of phase a V_{Ma} is connected to the point of common coupling (PCC) V_{Sa} through short-circuit impedance Z_{sa}. The voltage injected by the DVR in phase a V_{Ca} is such that the load voltage V_{La} is of rated magnitude and undistorted. The three-phase DVR is connected to the line to inject a voltage in series using three single-phase transformers Tr. L_r and C_r represent the filter components used to filter the ripples in the injected voltage. A three-leg VSC with Insulated-Gate Bipolar Transistors (IGBTs) is used as a DVR, and a LI-BESS is connected to its DC bus.

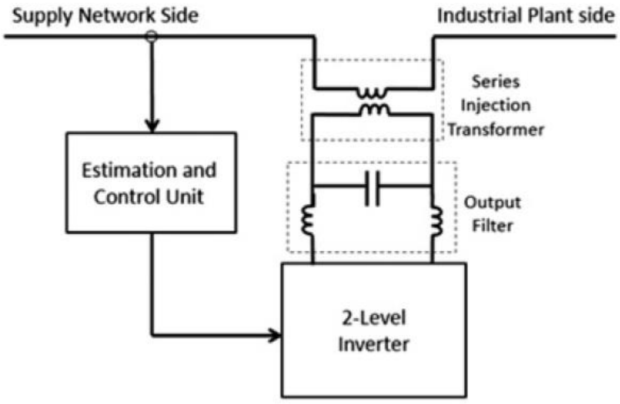

Fig. 2. Schematic of the Cascaded H Bridge DVR-connected system

The compensation for voltage sags using a DVR can be performed by injecting or absorbing the reactive power or the real power [17]. When the injected voltage is in quadrature with the current at the fundamental frequency, the compensation is made by injecting reactive power and the DVR is with a self-supported dc bus. However, if the injected voltage is in-phase with the current, DVR injects real power, and hence, Fuel Cell is required at the dc bus of the VSC. The control technique adopted should consider the limitations such as the voltage injection capability (converter and transformer rating) and optimization of the size of energy storage.

Fig. 3 shows a control block of the DVR in which the SRF theory is used for reference signal estimation. The voltages at the PCC V_S and at the load terminal V_{La} are sensed for deriving the IGBTs' gate signals. The reference load voltage V^* is extracted using the derived unit vector [23]. Load volt- ages (V_{La} , V_{Lb} , V_{Lc}) are converted to the rotating reference frame using abc−dqo conversion using Park's transformation with unit vectors (sin, θ, cos, θ) derived using a phase-locked loops.

IV. SIMULATION AND MODELING

A. *Simulink of Cascaded H Bridge DVR:*

The Fuel Cell based DVR connected system consisting of a three-phase supply, three-phase critical loads, and the series injection transformers shown in Fig. 5 is simulated as follows.

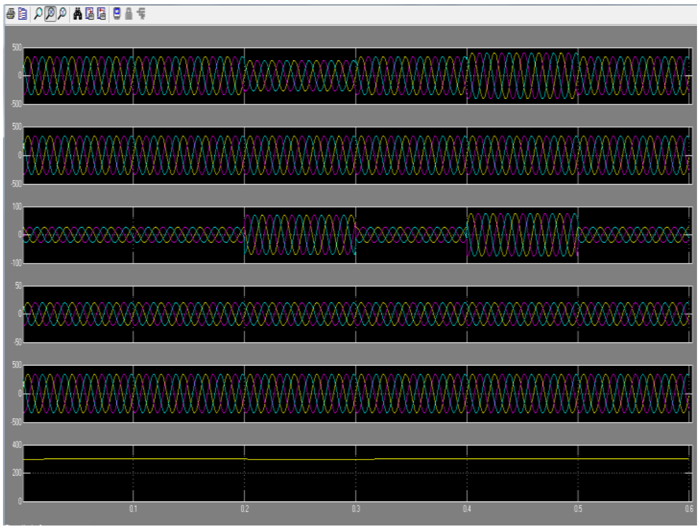

Fig. 3 Dynamic performance of CHB-DVR with in-phase injection during voltage sag and swell applied to critical load.

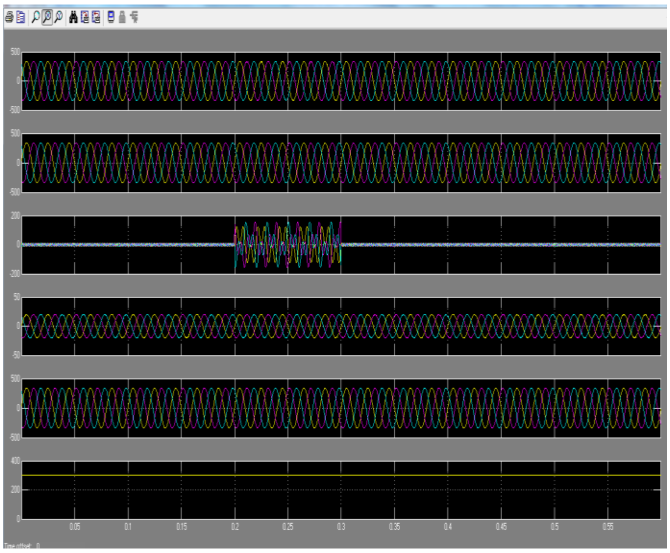

Fig 4 Dynamic performance of CHB-DVR during harmonics in supply voltage applied to critical load

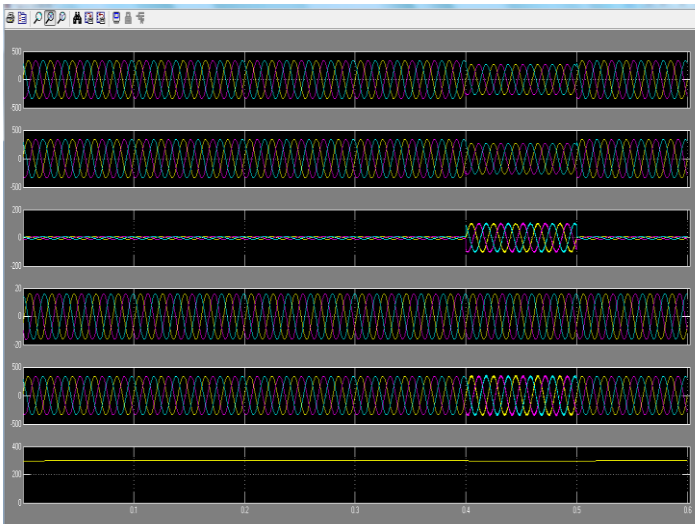

Fig 5 Dynamic performance of the capacitor-supported CHB-DVR during voltage sag

V. CONCLUSION

An enhanced sag compensation scheme has been proposed for the capacitor-supported CHB-DVR. The proposed strategy improves the voltage quality of sensitive loads by protecting them against the grid voltage sags involving the phase jump. In this Project CHB-DVR with has been presented. The simulation results clearly shows that the CHB DVR gives good performance.

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