

MITIGATION OF POWER QUALITY ISSUES BY USING DYNAMIC VOLTAGE RESTORER

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Abstract : In this project different voltage injection schemes for dynamic voltage restorers (DVRs) are analyzed with particular focus on a new method used to minimize the rating of the voltage source converter (VSC) used in DVR. A new control technique is proposed to control the capacitor-supported DVR. The control of a DVR is demonstrated with a reduced-rating VSC. The reference load voltage is estimated using the unit vectors. The synchronous reference frame theory is used for the conversion of voltages from rotating vectors to the stationary frame. The compensation of the voltage sag, swell, and harmonics is demonstrated using a reduced-rating DVR.

I. 1.INTRODUCTION

The contemporary container crane industry, like many other industry segments, is often enamoured by the bells and whistles, colourful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the Foundation blocks. Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to support new crane installations. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

1.1 Power Quality Problems

The power issues which degrade power quality include:

- Power Factor
- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips
- Voltage Swells

The AC and DC variable speed drives utilized on board container cranes are significant contributors to total harmonic current and voltage distortion. Whereas SCR phase control creates the desirable average power factor, DC SCR drives operate at less than this. In addition, line notching occurs when SCR's commutate, creating transient peak recovery voltages that can be 3 to 4 times the nominal line voltage depending upon the system impedance and the size of the drives.

1.2 Flexible alternating current transmission system

Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. The development of FACTS-devices has started with the growing capabilities of power electronic components. Devices for high power levels have been made available in converters for high and even highest voltage levels. The overall starting points are network elements influencing the reactive power or the impedance of a part of the power system. Figure 2.1 shows a number of basic devices separated into the conventional ones and the FACTS-devices.

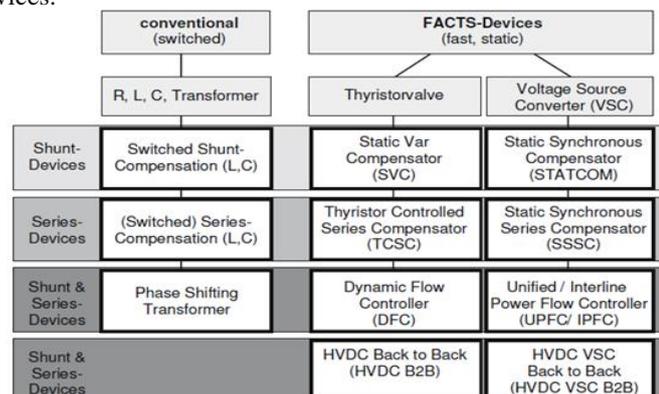


Fig.1.1. Over View of Major FACTS-Devices

II. OPERATION OF DVR

The schematic of a DVR-connected system is shown in Fig. 1(a). The voltage V_{inj} is inserted such that the load voltage V_{load} is constant in magnitude and is undistorted, although the supply voltage V_s is not constant in magnitude or is distorted. Fig. 1.2 shows the phasor diagram of different voltage injection. The DVR is operated in this scheme with a battery energy storage system (BESS).

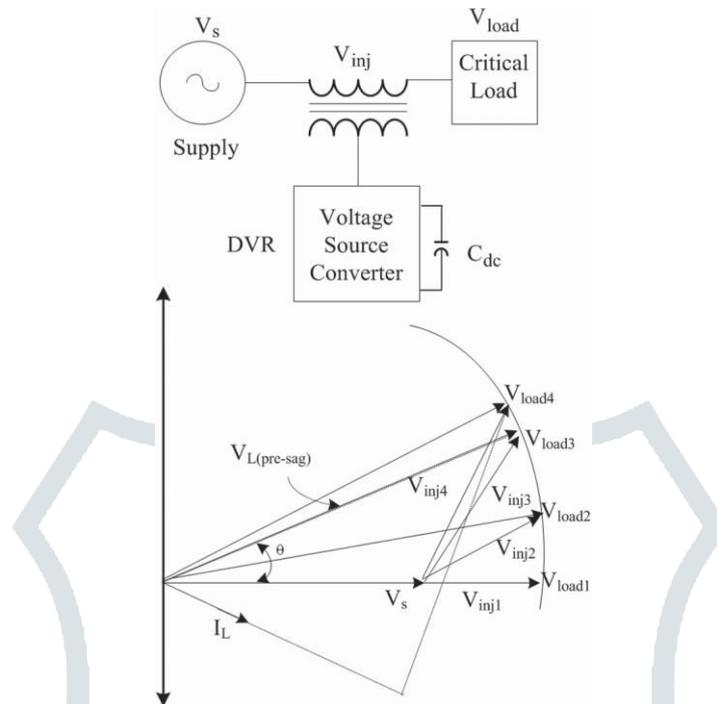


Fig. 1.2 Basic circuit of DVR. (b) Phasor diagram of the DVR voltage injection schemes

Fig.1.2 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. 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, a battery 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.

III. CONTROL OF DVR

The compensation for voltage sags using a DVR can be performed by injecting or absorbing the reactive power or the real power. 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, a battery 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.

3.1 Control of DVR With BESS for Voltage Sag, Swell, and Harmonics Compensation

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_L are sensed for deriving the IGBTs' gate signals. The reference load voltage V_{is} is extracted using the derived unit vector. Load voltage (V_{La}, V_{Lb}, V_{Lc}) are converted to the rotating reference frame using $abc-dqo$ conversion using Park's transformation with unit vectors ($\sin, \theta, \cos, \theta$) derived using a phase-locked loop. Similarly, reference load voltages ($V_{la}^*, V_{lb}^*, V_{lc}^*$) and voltages at the PCC v_s are also converted to the rotating reference frame. Then, the DVR voltages are obtained in the rotating reference frame as

$$v_{Dd} = v_{Sd} - v_{Ld}$$

$$v_{Dq} = v_{Sq} - v_{Lq}$$

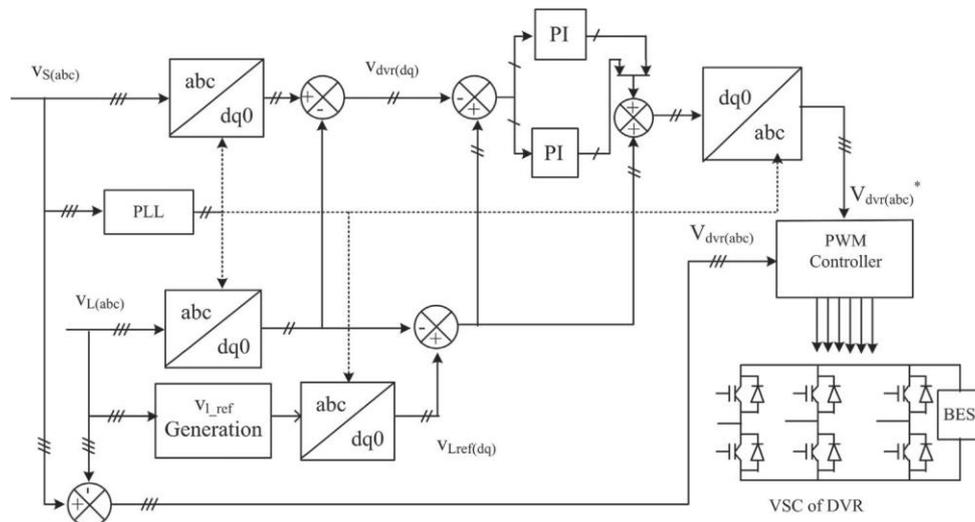
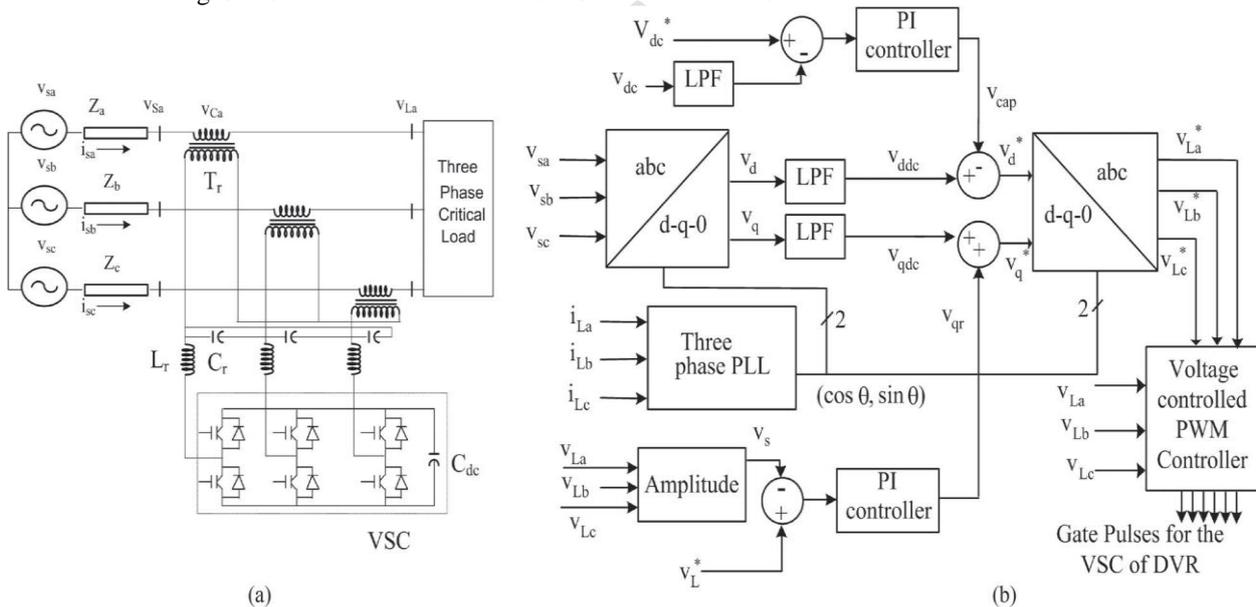


Fig .3.1 Control of DVR Which uses SRF method of Control



3.2 (a) Schematic of the self-supported DVR. (b) Control block of the DVR that uses the SRF method of control.

The reference DVR voltages are obtained in the rotating reference frame as

$$V^*_{Dd} = V^*_{SD} - V_{ld}$$

$$V^*_{Dq} = V^*_{Sq} - V_{lq}$$

The error between the reference and actual DVR voltages in the rotating reference frame is regulated using two proportional–integral (PI) controllers. Reference DVR voltages and actual DVR voltages are used in PWM controller to generate gating pulses to a VSC of the DVR. The PWM controller is operated with a switching frequency of 10 kHz.

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4.1: COMPARISON OF DVR RATING FOR SAG MITIGATION

	Scheme-1	Scheme-2	Scheme-3	Scheme-4
Phase Voltage (V)	90	100	121	135
Phase Current (A)	13	13	13	13
VA per phase	1170	1300	1573	1755
KVA (% of Load)	37.5%	41.67%	50.42%	56.25%

The required rating of compensation of the same using Scheme-1 is much less than that of Scheme-4. The performance of the self-supported DVR (Scheme-4) for compensation of voltage sag is shown in Fig. 12(a) and that of a voltage swell is shown in Fig. 12(b). It is observed that the injected voltage is in quadrature with the supply current, and hence, a capacitor can support the dc bus of the DVR. However, the injected voltage is higher compared with an in-phase injected voltage (Scheme-1).

V. CONCLUSION

The operation of a DVR has been demonstrated with a new control technique using various voltage injection schemes. A comparison of the performance of the DVR with different schemes has been performed with a reduced-rating VSC, including a capacitor-supported DVR. The reference load voltage has been estimated using the method of unit vectors, and the control of DVR has been achieved, which minimizes the error of voltage injection.

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