A Survey on Control Method for the Transformer-Less STATCOM

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Abstract - STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system. In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances. The three-level cascaded-based STATCOM is used as a starting case. The control of the STATCOM is designed in DQ0 coordinates. The modeling accuracy and control performance are studied.

Keywords :- Active disturbances rejection controller (ADRC), H-bridge cascaded, passivity-based control (PBC), proportional resonant (PR) controller, shifting modulation wave, static synchronous compensator (STATCOM).

I. INTRODUCTION

A STATCOM consists of a three phase inverter (generally a PWM inverter) using SCRs, MOSFETs or IGBTs, a D.C capacitor which provides the D.C voltage for the inverter, a link reactor which links the inverter output to the a.c supply side, filter components to filter out the high frequency components due to the PWM inverter. From the d.c. side capacitor, a three phase voltage is generated by the inverter. This is synchronized with the a.c supply. The link inductor links this voltage to the a.c supply side. This is the basic principle of operation of STATCOM

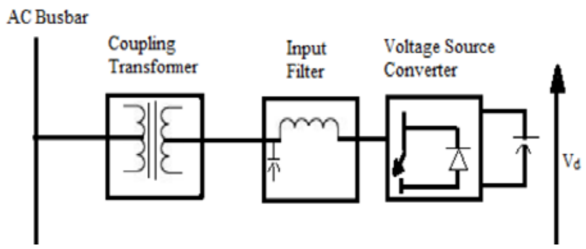

Figure 1.1 basic principle operation of STATCOM

For two AC sources which have the same frequency and are connected through a series inductance, the active power flows from the leading source to the lagging source and the reactive power flows from the higher voltage magnitude source to the lower voltage magnitude source. The phase angle difference between the sources determines the active power flow and the voltage magnitude difference between the sources determines the reactive power flow. Thus, a STATCOM can be used to regulate the reactive power flow by changing the magnitude of the VSC voltage with respect to source bus voltage

The STATCOM can operate properly and effectively as long as the following two sets of key electrical parameters are watchfully controlled: three-phase output currents and multiple DC capacitor voltages. The output currents determine the amount of reactive power exchanged with the power network. A single-line diagram of the STATCOM shown in Figure 1.2 is used as an example. At this point, the CMC is assumed to be lossless.

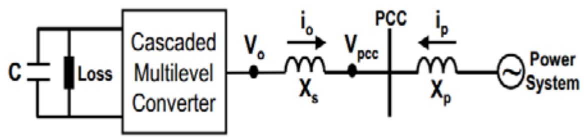

Figure 1.2 Single – line Diagram of cascaded – STATCOM system.

The STATCOM behaves as an adjustable capacitive load, which injects reactive power into the power network, when its output voltage is controlled to be greater than that of the power network

II. RELATED WORK

R. Xu et al [1] this research presents a transformer-less static synchronous compensator (STATCOM) system based on multilevel H-bridge converter with star configuration. This control method devote themselves not only to the current loop control but also to the dc capacitor voltage control. With regards to the current loop control, a nonlinear controller based on the passivity-based control (PBC) theory is used in this cascaded structure STATCOM for the first time. As to the dc capacitor voltage control, overall voltage control is realized by adopting a proportional resonant controller. Clustered balancing control is obtained by using an active disturbances rejection controller. Individual balancing control is achieved by shifting the modulation wave vertically which can be easily implemented in a field-programmable gate array. Two actual H-bridge cascaded STATCOMs rated at 10 kV 2 MVA are constructed and a series of verification tests are executed. The experimental results prove that H-bridge cascaded STATCOM with the proposed control methods has excellent dynamic performance and strong robustness. The dc capacitor voltage can be maintained at the given value effectively.

B. Gultekin and M. Ermis [2] This research deals with the design methodology for cascaded multilevel converter (CMC)-based transmission-type STATCOM (T-STATCOM) and the development of a ±12 MVAR, 12 kV line-to-line wye-connected, 11-level CMC. Sizing of the CMC module, the number of H-bridges (HBs) in each phase of the CMC, ac voltage rating of the CMC, the number of paralleled CMC modules in the T-STATCOM system, the optimum value of series filter reactors, and the determination of busbar in the power grid to which the T-STATCOM system is going to be connected are also discussed in this research in view of the IEEE Std. 519-1992, current status of high voltage (HV) insulated gate bipolar transistor (IGBT) technology, and the required reactive power variation range for the T-STATCOM application. In the field prototype of the CMC module, the ac voltages are approximated to sinusoidal waves by the selective harmonic elimination method (SHEM). The equalization of dc-link capacitor voltages is achieved according to the modified selective swapping (MSS) algorithm. In this study, an L-shaped laminated bus has been designed and the HV IGBT driver circuit has been modified for the optimum switching performance of HV IGBT modules in each HB. The laboratory and field performances of the CMC module and of the resulting T-STATCOM system are found to be satisfactory and quite consistent with the design objectives.

S. Kouro et al [3] Multilevel converters have been under research and development for more than three decades and have found successful industrial application. However, this is still a technology under development, and many new contributions and new commercial topologies have been reported in the last few years. The aim of this study is to group and review these recent contributions, in order to establish the current state of the art and trends of the technology, to provide readers with a comprehensive and insightful review of where multilevel converter technology stands and is heading. This research first presents a brief overview of well-established multilevel converters strongly oriented to their current state in industrial applications to then center the discussion on the new converters that have made their way into the industry. In addition, new promising topologies are discussed. Recent advances made in modulation and control of multilevel converters are also addressed. A great part of this research is devoted to show nontraditional applications powered by multilevel converters and how multilevel converters are becoming an enabling technology in many industrial sectors. Finally, some future trends and challenges in the further development of this technology are discussed to motivate future contributions that address open problems and explore new possibilities

Fang Zheng Peng, Jih-Sheng Lai, J. McKeever and J. VanCoevering, [4] A new multilevel voltage-source inverter with separate DC sources is proposed for high-voltage, high power applications, such as flexible AC transmission systems (FACTS) including static VAr generation (SVG), power line conditioning, series compensation, phase shifting, voltage balancing, fuel cell and photovoltaic utility systems interfacing, etc. The new M-level inverter consists of (M-1)/2 single phase full bridges in which each bridge has its own separate DC source. This inverter can generate almost sinusoidal waveform voltage with only one time switching per cycle as the number of levels increases. It can solve the problems of conventional transformer-based multipulse inverters and the problems of the multilevel diode-clamped inverter and the multilevel living capacitor inverter. To demonstrate the superiority of the new inverter, a SVG system using the new inverter topology is discussed through analysis, simulation and experiment

inverter; VSI; applications; flexible AC transmission systems; fuel cell; multilevel voltage-source inverter; phase shifting; photovoltaic utility systems; power line conditioning; series compensation; single phase full bridges; sinusoidal waveform voltage; static VAr generation; voltage balancing; AC generators; Bridge circuits; DC generators; Flexible AC transmission systems; Fuel cells

Y. S. Lai and F. S. Shyu [5] A new topology for a hybrid multilevel inverter is presented, which significantly increases the level number of the output waveform and thereby dramatically reduces the low-order harmonics and total harmonic distortion. To the best of the authors' knowledge, the presented topology has the greatest level number for a given number of stages. Moreover, the stage with higher DC link voltage has lower switching frequency; and thereby reduces the switching losses. Comparison of the results of various multilevel inverters is investigated to reflect the merits of the presented topology. The details of the PWM control using the harmonic elimination technique for the hybrid inverter are presented and confirmed by both simulation and experimental results.

III. CASCADED H-BRIDGE MULTILEVEL CONVERTERS

A cascaded H-bridge converter consists of several H-bridge cells connected in a series to form one phase of the converter. Each H-bridge cell generates a three-level output voltage and requires a separate dc voltage source. For multiphase converters several cascaded H-bridges are used and each cascaded H-bridge makes one leg of the converter. Figure 3.1 illustrates a three-phase cascaded H-bridge multilevel converter. Each phase consists of two H-bridge and

each H-bridge cell is supplied with an isolated voltage source

It is possible, however to replace all of the dc voltage sources (in case more than two cells exist) with capacitors but one of them. In this case, only one dc voltage source is needed for each phase of the converter. A three-phase cascaded H-bridge with capacitor fed H-bridge cells is depicted in Figure 3.2 With this change the cost of converter decreases because a fewer number of isolated dc voltage sources are used especially when dc sources are supplied through ac/dc rectifiers. However the voltage of the replacing capacitors must be

regulated to a certain voltage in order to have the required voltage level in the output voltage of the converter.

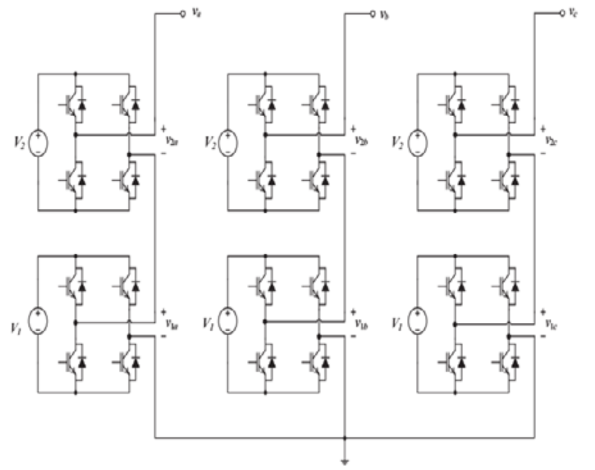

Figure 3.1 three phase H- Bridge converter

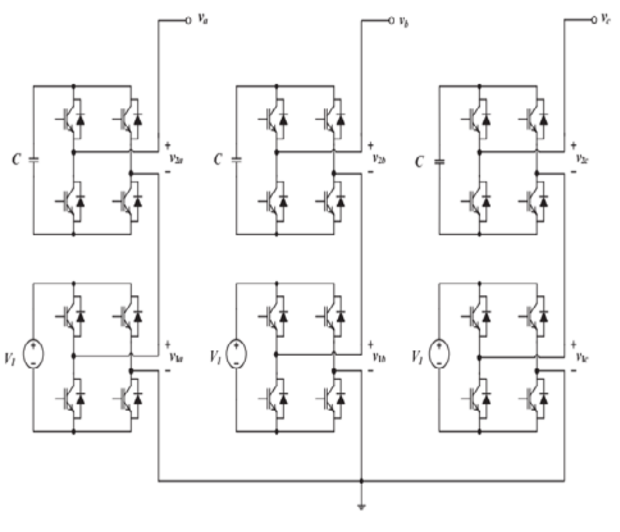

Figure 3.2 Three-phase cascaded H-bridge converter with capacitor fed H-bridge cells.

In this topology it is possible to use different modulation techniques [8][9] so that each cell of the converter can have different switching frequencies. For example, in a two cell converter, one of the H-bridge cells can be switched at the fundamental switching frequency (one turned on and off per switch per cycle) while another one can be switched with pulse width modulation (PWM) switching scheme, at a higher frequency.

Doing so helps reduce switching losses, especially when, the voltage sources and the power ratings of the cells are unequal.

IV. CONCLUSION

As of late, numerous topologies have been connected to the STATCOM. Among these diverse sorts of topology, H-connect fell STATCOM has been broadly acknowledged in high power applications. Contrasted and diode-braced converter or flying capacitor converter, H-connect fell STATCOM can acquire a high number of levels all the more effortlessly and can be associated with the framework specifically without the massive transformer. This empowers us to lessen cost and enhance execution of H-scaffold fell STATCOM.

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