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Power Quality Improvement Using Cascaded Multilevel Statcom with Dc Voltage Control

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Abstract:
The "Multilevel converter" has drawn tremendous interest in the power industry. The general structure of the multilevel converter is to synthesize a sinusoidal voltage from several levels of voltages, Multilevel voltage source converters are emerging as a new breed of power converter options for high power applications, These converter topologies can generate high-quality voltage waveforms with power semiconductor switches operating at a frequency near the fundamental. Among the available multilevel converter topologies, the cascaded multilevel converter constitutes a promising alternative, providing a modular design that can be extended to allow a transformer less connection. A new control strategy is proposed in this paper with focus on dc voltage regulation. Clustered balancing control is realized by injecting a zero-sequence current to the delta-loop, while individual voltage control is achieved by adjusting the fundamental content of ac quasi-square-waveform voltage of high-voltage converter.

***Index Terms*:** Cascade H-bridge, dc voltage control, hybrid multilevel, static synchronous compensator (STATCOM).

I. INTRODUCTION

Hybrid multilevel converters are widely used because of high efficiency and low switching losses. The delta-type cascaded hybrid single-phase H-bridge topology is preferred because of modularity and simplicity. This paper proposed a new dc voltage control strategy for those hybrid multilevel converters. Clustered balancing control is achieved by injecting zero-sequence current to the delta-loop, and the individual voltage control is realized by trimming the fundamental content of quasi-square-wave voltage of high-voltage converters. Compared with other hybrid multilevel approaches, this control strategy along with the STATCOM system has the advantages of fast-speed response to load change, accurate unbalanced load compensation, no auxiliary circuit for dc links, less on-line calculation, specific unequal dc voltage regulation, as well as certain but unequal switching frequencies. Recently, some other interesting topologies have been published in [28]–[30]. In [28], a hybrid-source impedance network with the dc link of series-connected z-sources is presented for enhancing the three-phase ac voltage levels, but it is not suitable for STATCOM application because of the utilization of large amount of dc sources. The literature [29] describes a multilevel circuit topology based on switched-capacitors and diode clamped converters. The model related to switched-capacitor converters is given in the literature [30]. This kind of converters can successfully produce high-voltage levels and the issue with dc voltage balancing can be easily solved by choosing proper switching sequences. This structure requires a plenty of switching devices, so it have not widely been accepted in medium-voltage application.

The mentioned control method is not suitable for STATCOM system because the dc sources are replaced by capacitors in the STATCOM system. The literature[19]–[21] provides new solution with a high-voltage converter fed by dc supplies and a low-voltage converter fed by dc capacitor. In [19], a diode-clamped H-bridge with multi output boost rectifier functions as the high-voltage inverter. The utilization of clamped diode and rectifier increases the cost of whole system. In [20], dc voltage ratio of 4:2:1 is arranged to these ries-connected H-bridge converters. The expensive isolated dc supplies are required for ratio-4 and ratio-2 converters. Fundamental frequency modulation is adopted in the literature [21]for cascade hybrid H-bridge converters. In [21], the selective harmonic elimination method is adopted for hybrid modulation and selecting switching redundant states is applied for capacitor voltage control. The quality of output voltage waveform is not good, which prevents this method for STATCOM application. This project presents a transformer less static synchronous compensator (STATCOM) system based on hybrid multilevel H-bridge converter with delta configuration. A new control strategy is proposed in this paper with focus on dc voltage regulation. Clustered balancing control is realized by injecting a zero-sequence current to the delta-loop, while individual voltage control is achieved by adjusting the fundamental content of ac quasi-square-waveform voltage of high-voltage converter.

II.PROPOSED CONTROL STRATEGY

Constant dc link voltage of the statcom is achieved by the proposed control strategy. There are many control strategies were produced in many of the literatures which have the problems of switching losses , limited applications. This control strategy is having advantage of low switching loss and improves the efficiency of the system as well. The total control scheme comprises of the decoupled current control, overall voltage control, clustered balancing control and individual voltage control methods. DC link voltage is checked at each level.

A.decoupled current control

This control is used to produce three phase command voltages V^*_{iu}, V^*_{iv} and V^*_{iw}. The inputs to this control are Vsd,Vsq, The two phase command currents i^*_d,i^*_q and the capacitor currents i_d,i_q.

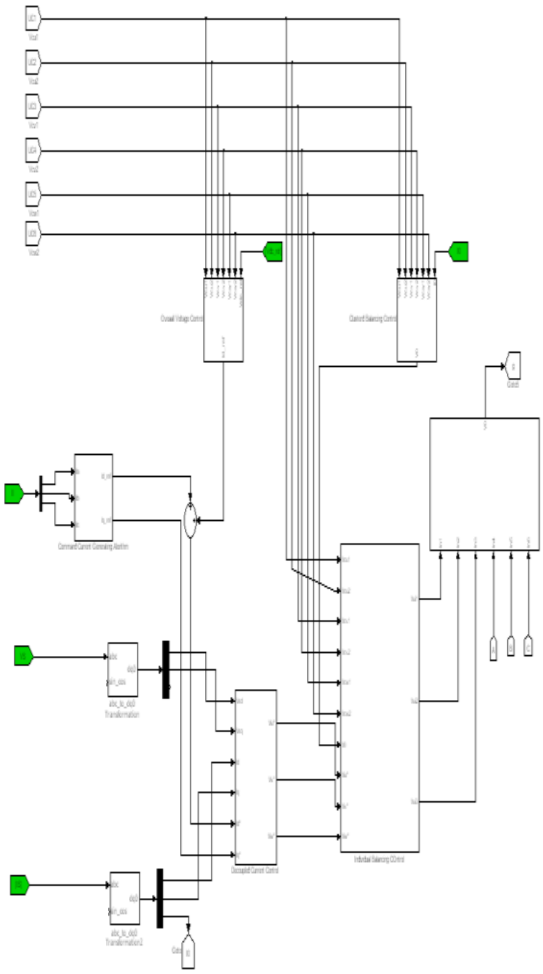

Fig.1 Block diagram of control scheme

$$L_{AC}di_{cu}+R_Li_{cu}=v_{sab}-v_{iu}$$
$$L_{AC}di_{cv}+R_Li_{cv}=v_{sab}-v_{iv}$$
$$L_{AC}di_{cw}+R_Li_{cw}=v_{sab}-v_{iw} \qquad (1)$$

where R_L is the equivalent series resistance of the inductor.Applying d-q transformation to equation (1) becomes

$$L_{AC}di_d - \omega L_{AC}\, i_q+R_Li_d=v_{sd}-v_{id}$$
$$L_{AC}di_q + \omega L_{AC}\, I_d+R_Li_q=v_{sq}-v_{iq} \qquad (2)$$

The proportional and intrgral regulators with parameters are introduced for closed loop control,the command voltages in the d-q axis are given by

v_{id} , v_{iq}. The three phase command voltages V^*_{iu}, V^*_{iv} and V^*_{iw} can be obtained by applying the inverse d-q transformation to v_{id} , v_{iq}.

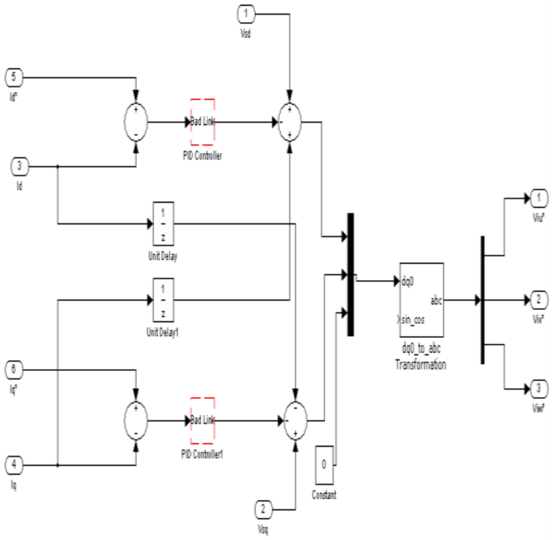

Fig.2 Block diagram of decoupled current control

B. Over all control

The sum of all the dc capacitors voltage V_{dc_sum} is compared with the reference voltage V_{dc_ref} .The PI plus fuzzy regulator is used for the over all control. The output of the regulator is the active component of command current $I_{d\text{-}ref.}$ This reference command current is along with reference command current of current generating algorithm to produce i^*_d. Because of the symmetry of the three phases only u phase is shown in the paper.

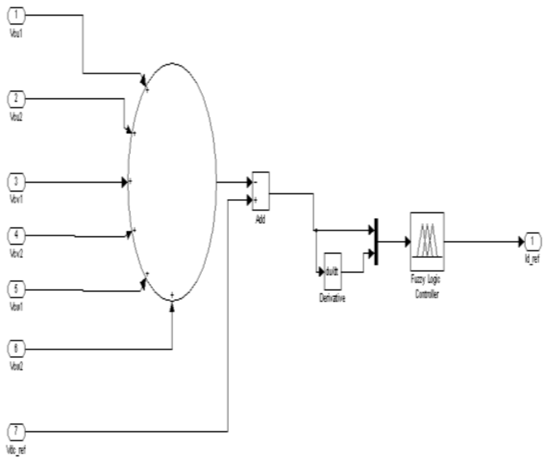

Fig.3 block diagram of over all control

C. Clustered balancing control

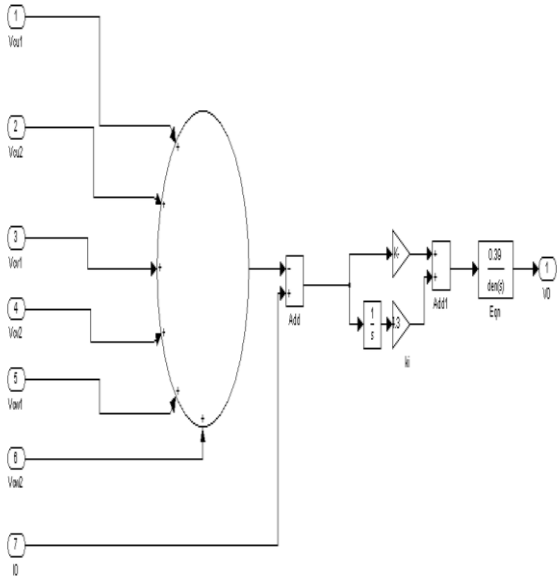

Fig.4 cluster balance control

Injection of Zero-Sequence Current for Clustered Balancing Control :

Zero sequence current is injected into the delta loop for redistribution of active power among the three clusters for cancelling the power caused by the unbalanced load as well as providing proper amount of power for balancing of dc voltages of the three phase cluster. The magnitude and phase angle of the zero sequence currents is given by

$$I_o = \frac{2}{V_s}\sqrt{(\overline{p_{oab}})^2 + \frac{1}{3}(\overline{p_{oab}} + 2\cdot\overline{p_{obc}})^2}$$

$$\varphi_o = \tan^{-1}\left[-\frac{1}{\sqrt{3}}\left(1+\frac{2\cdot\overline{p_{obc}}}{\overline{p_{oab}}}\right)\right].$$

D. Individual voltage control

Individual voltage control refers to the dc voltage control of each cell dc link voltage of the three phase cluster cascaded bridge consists of bridges connected in series each cell dc link voltage is to be maintained constant for proper application of the statcom.

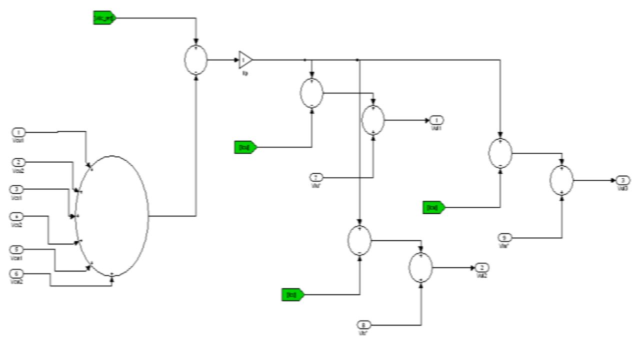

Fig.5 Block diagram of individual voltage control

III. Experiment results

Simulation:

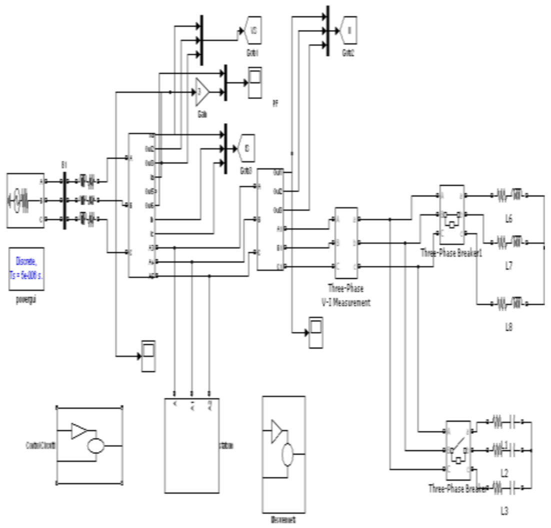

Fig.5 Simulation diagram

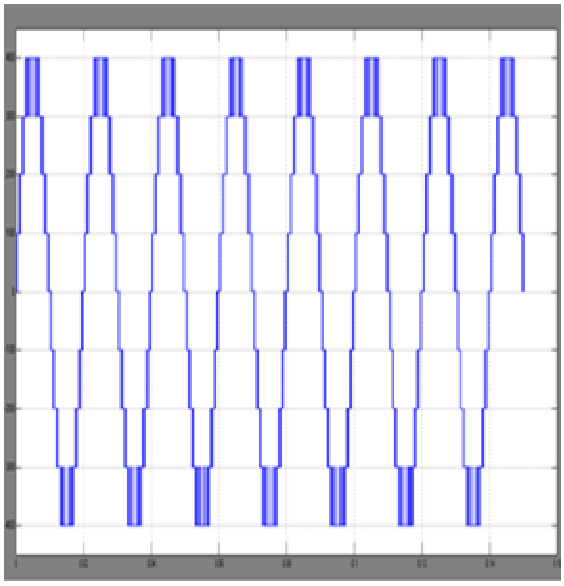

Fig.6 Output voltage of 9 level statcom

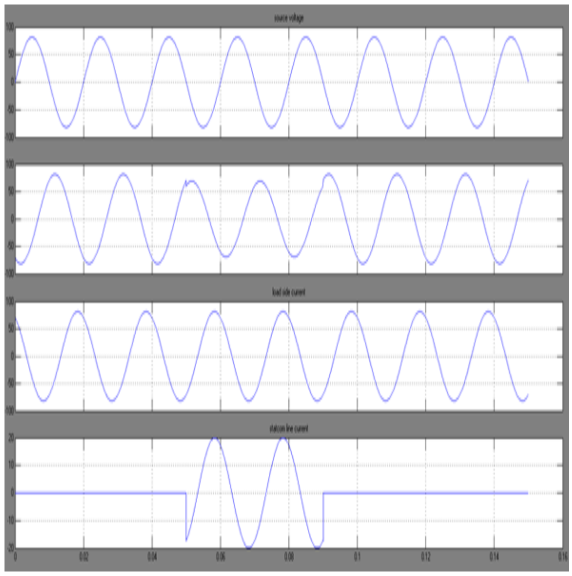

Fig.7 Voltage sag compensation by statcom

THD of the proposed control:

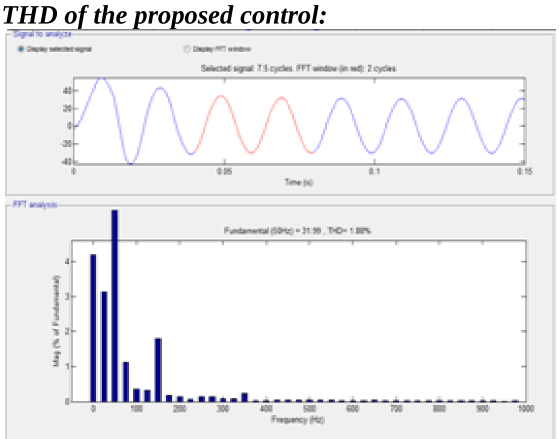

Fig.8 THD Graph

IV. HYBRID MULTILEVEL STATCOM

Multilevel statcom is widely used for power quality improvements. The output waveforms of the statcom is of good quality if the level is increased. with increase in level the number of switches increases which increases the switching loss. The other method to obtain good quality output is to increase the switching frequency, this introduces the problem of switching losses in the statcom. Fortunately, hybrid multilevel technology provides a good trade off between waveform quality and switching loss.

V. CONCLUSION

This project has analyzed the fundamentals of dc voltage control based on cascaded hybrid multilevel H-bridge converters. Then, a hybrid modulation for hybrid multilevel converter has been proposed and the control algorithm has also been designed in detail. The control scheme proposed in this paper is characterized by the capability of maintaining the unequal dc voltage at the given value without any additional circuit, as well as by the ability of compensating serious unbalanced load. This control strategy has taken full advantages of the available switching devices by operating the high-voltage device at low switching frequency and low-voltage device at high frequency.

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