

A Novel Approach on Reactive Current Reference Algorithm for the Facts Based Multilevel Inverters

Balaji S¹, Priyama Kasuna A², Ganesh V.N³

Asst. Prof, Dept of EEE, SRM University, Chennai, India¹

PG Scholar, Dept of EEE, SRM University, Chennai, India²

Asst. Prof, Dept of EEE, SRM University, Chennai, India³

ABSTRACT: In this paper, a power line conditioner using a cascade multilevel inverter is presented for voltage regulation, reactive power (var) compensation, and harmonic filtering. The cascade M-level inverter consists of $(M-1)/2$ H bridges, in which each bridge has its own separate dc source. This new inverter can: 1) generate almost sinusoidal waveform voltage with only one time switching per line cycle; 2) eliminate transformers of multipulse inverters used in the conventional static var compensators; and 3) make possible direct connection to the 13.8-kV power distribution system in parallel and series without any transformer. In other words, the power line conditioner is much more efficient and more suitable to var compensation and harmonic filtering of distribution systems than traditional multipulse and pulsewidth modulation inverters. It has been shown that the new inverter is especially suited for var compensation. This paper focuses on feasibility and control schemes of the cascade inverter for voltage regulation and harmonic filtering in distribution systems. Analytical, simulated, and experimental results show the superiority of the new power line conditioner. Index Terms—Active power filter, multilevel inverter, power line conditioner.

I. INTRODUCTION

Power quality and custom power have been hot topics because of the widespread use of nonlinear electronic equipment and the stricter power quality requirements of sensitive loads. To provide high power quality at the point of common coupling (PCC) of a distribution system, line conditioning, including voltage regulation and reactive power (var)/harmonic compensation, is an indispensably necessary remedy. Traditionally, a multipulse inverter consisting of several voltage-source inverters connected together through zigzag arrangement transformers is used for var compensation [1]–[6]. These transformers: 1) are the most expensive equipment in the system; 2) produce about 50% of the total losses of the system; 3) occupy a large area of real estate, about 40% of the total system; 4) cause difficulties in control due to dc magnetizing and surge overvoltage problems resulting from saturation of the transformers; and 5) are unreliable. Correspondingly, pulsewidth modulation (PWM) inverters with 10 kHz of high switching frequency have been used for harmonic compensation [7]–[10] and static var compensation [13]–[17]. However, the high initial and running costs have been hindering their practical use in power distribution systems. In addition, it is difficult for PWM-inverter-based active filters to comply with electromagnetic interference (EMI) requirements (e.g., IEC and FCC Class A and B EMI regulations). A cascade multilevel inverter has been proposed for static var compensation/generation applications [11], [12]. The new cascade inverter eliminates the bulky transformers required by static var compensators (SVC's) that employ the multipulse inverter and can respond much faster. This inverter generates almost sinusoidal staircase voltage with only one time switching per line cycle. Its superior suitability has been demonstrated for var compensation. When the cascade inverter is applied to line conditioning and active filtering of a distribution system, it is expected that the initial and running costs and the EMI will be dramatically reduced below that of the traditional PWM inverter. The new multilevel inverter, however, poses challenging problems for harmonic filtering, such as voltage control and balance of each dc capacitor. This paper focuses on these issues and presents a voltage control scheme that solves the problem. A prototype of a power line conditioning system (10 kVA)

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Vol. 5, Issue 3, March 2016

using an 11-level cascade inverter (21-level line-to-line voltage waveform) has been built. Analytical, simulated, and experimental results show the feasibility and superiority of the proposed power line conditioner.

II. PRINCIPLES OF OPERATION

The STATCOM provides reactive power compensation and voltage regulation by acting as a controlled current source connected in parallel with the system bus. The controlled current source in the proposed system is realized using a current-controlled CMC. A typical configuration of a CMC based STATCOM The system consists of three bus grid which bus B2 is considered as source point for STATCOM. The CMC based STATCOM is connected through bus B2 with coupling transformer and harmonics elimination filter three types of loads are connected through transformer in bus B3 for load variation purpose. The load and STATCOM currents are directed in the three bus system.

III. CIRCUIT DESCRIPTION

Two important circuits are mainly discussed in STATCOM. They are, 1. Power Circuit 2. Control Circuit 3.1 .Power circuit The power circuit configuration is nothing but connection of a cascaded multilevel converter in the system. In reactive power compensation, seven level cascaded-multilevel converter with separated DC capacitors are constructed with a number of identical three H-bridge converters. The cascaded converter method is very simple and less components. The CMC based STATCOM improves the dynamic responses of the power system network. The control circuit is capable of independently controlling the direct axis component i_{td} and the quadrature axis component i_{tq} of the VSC/CMC current with minimal coupling between them. The controllers generate the desired values of dq components of the VSC/CMC terminals. The PWM pattern generator uses these signals to generate the gating pulses for converter Control scheme has some units as follows,

1. Step input control
2. RMS voltage control
3. Power factor control
4. DC voltage control
5. Cascaded control

The Three-Phase V-I Measurement unit is used to measure the voltages and currents in a circuit. It can be measured the voltages and currents in per unit (p.u.).The per unit values of main system bus are given to abc to dqo converter. RMS value is taken from system bus and i_{lq} value is known from load current for power factor reference value.

Reference current of quadrature axis is selected from maximum variation of any one of RMS value or i_{lq} value. In RMS voltage control mode, the RMS voltage control unit, shown in fig.4., generates i_{tqref} by first comparing the measured RMS voltage on the bus B2 with a user supplied reference and then feeding the error signal into a PI controller. The output of the PI controller is limited to avoid overload. Controlling the bus B2 voltage through i_{td} control is feasible because the bus B2 voltage is related to i_{tq} by, $V_{rms} = E_s - i_{lq} X_s - i_{tq} X_s$ (1) Where V_{rms} is the bus B2 voltage, E_s is the Thevenin voltage of the bus B2, and X_s is the Thevenin system inductance. Since this controller generates the current reference only, the current controller for i_{tq} must be enabled when the bus B2 voltage-control scheme is in operation. In power factor control mode, the power factor control shown in fig .5 assigns i_{tqref} to be the negative of i_{lq} , the quadrature component of the measured load current, provided i_{lq} is within the VSC operating range. Otherwise, it is set of the VSC maximum current rating. Since this controller for i_{tq} must be enabled when the power factor correction scheme in this operation. It should be noted that RMS voltage-control mode and power factor control mode are mutually exclusive. The DC voltage-control scheme compares the dc voltage on the capacitor with a user-supplied reference and feeds the error signal into a proportional-Integral (PI) controller that computes i_{tdref} as shown in fig.6. The output of the PI controller is limited to avoid overloading the VSC/CMC. DC capacitor has been assumed as a DC source for STATCOM and also considered for lossless compensator. Let us define the following error signal.

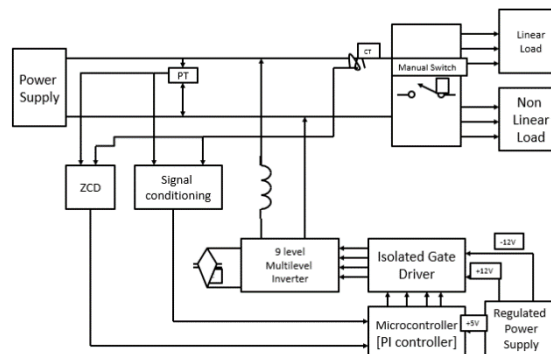


Fig. 1 Block Diagram

Cascaded controller based STATCOM is designed for seven level cascaded multilevel converter (CMC)[11]-[15]. This proposed controller reduced the THD values [16]. This result is given clearly in fig.14. THD value of voltage is 16.24% and current is 0.76% as shown in fig.15. THD values are minimized in the converter output voltage and current. Active and reactive power of source are shown in fig.16 and compensation is identified through reactive power variation. Power factor is improved as three phase supply output.

IV. POWER SYSTEM NETWORK

The Power system network considered is a 33kV network with a long transmission line. The 33kV is stepped down to 415V via a power transformer and feeds a 1.5MW non-linear load. The STATCOM is connected at the point of common coupling near the load. The coupling transformer of the STATCOM is rated at 5500V/33kV, 6MVA. The STATCOM is connected at the primary side of the coupling transformer.

Though the modern STATCOM configuration studies suggests the method of having a transformerless STATCOM for HV applications, in order to remove the burden of transformer cost, it has its own drawbacks, i.e., the switches required in such transformerless configurations are HV Switches which are difficult to control and the operating and replacement costs are high, moreover they require separate filter units in order to filter their harmonics. Hence the advantages of having a coupling transformer is that it itself acts as a harmonic filter, moreover the switches can also be operated at low voltages hence reduced cost and complexity.

V. STATCOM CONTROLLER

The Control circuit topology for the multilevel inverter (MLI-1 and MLI-2) voltage source V_{dc}. The STATCOM Voltage Magnitude controller compares the grid voltage magnitude with a reference voltage magnitude and generates the difference as an error signal. This error signal is amplified by a gain and is given as control input to the STATCOM inverter controlled DC voltage source.

The system configuration shown in Fig. 1 is considered for simulation. The simulation study is carried out using MATLAB/ SIMULINK. The system parameters are given in Table I. The following are the scenarios subjected to the simulation:

- The Source voltage is initially set at 1pu at 33kV base.
- Sag of 15% (i.e., 0.85pu) is created in the load voltage from the time 0.1 to 0.2secs
- A Swell of 10% (i.e., 1.1pu) is created in the load voltage from the time 0.2 to 0.3secs.
- Sag of 10% (i.e., 0.9pu) is created in the load voltage from the time 0.3 to 0.4secs along with an unbalanced loading of 10% in R-Phase

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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

- The load voltage is reset to 1pu at the time of 0.4secs and the simulation is stopped at 0.5secs. The load voltage waveform is observed for variations, as the expected result shall be a uniform load voltage waveform of 1pu without any abrupt fluctuations in the load voltage waveform as indicated in the source voltage scenarios.

Dynamic representation for load variation. The Load current and dq axis current variation is clearly shown through Fig.10 Due to fast stable operation of STATCOM, dq currents of source terminal get effective responses as shown in Fig.11. As shown in fig.8,the system reactance, X_{eq} , is a part of the feedback loop and it is crucial to note that X_{eq} varies as loads are added or rejected from the power system . Therefore the overall closed loop gain and the stability margin of the STATCOM are affected by X_{eq} . If the impedance of the power system increases (weak system) , the amount of voltage is varied. The STATCOM reactive current is also varied and the overall system tends to instability. If the power system impedance decreases (strongsystem), the system is stable, although the response is slower than that of the weak system.

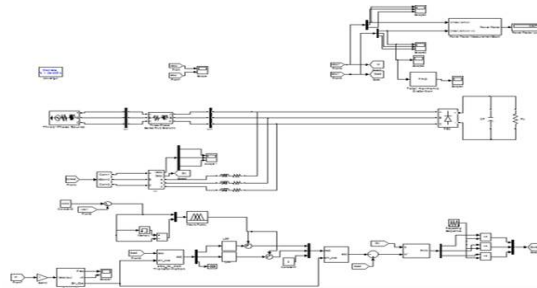


Fig. 2 Simulink Diagram

VI. CASCADED CONTROLLER.

Cascaded controller based STATCOM is designed for seven level cascaded multilevel converter (CMC)[11]-[15]. This proposed controller reduced the THD values [16]. This result is given clearly in fig.14. THD value of voltage is 16.24% and current is 0.76% as shown in fig.15. THD values are minimized in the converter output voltage and current. Active and reactive power of source are shown in fig.16 and compensation is identified through reactive power variation. Power factor is improved. Three phase supply output.

VII.RESULTS AND DISCUSSION SIMULATION OUTPUT

The STATCOM is connected to the bus B2 for 230KV, 50Hz through 20/230KV, 100MVA coupling transformer as shown in fig.1. On this power system network, the +/-100 MVAR STATCOM can compensate reactive power and maintain effective voltage profile. The reactive power generation or absorption by generating converter voltage which is in phase with the source voltage in bus B2 [11].When the CMC output voltage is lower than the source voltage , the STATCOM will absorb reactive power, when capacitor voltage is higher, it will generate the reactive power and supply the reactive power to bus B2.

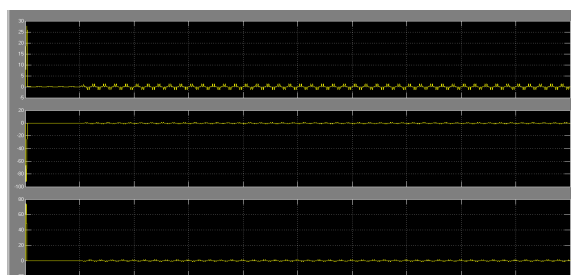


Fig. 3 Existing Output current

International Journal of Innovative Research in Science, Engineering and Technology

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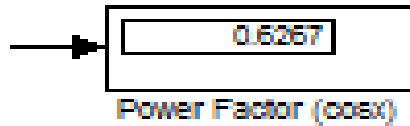


Fig. 4 Existing Power factor

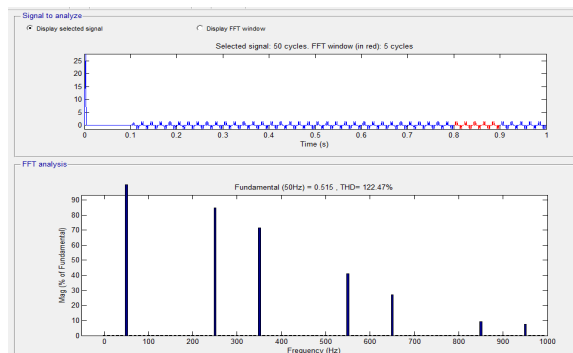


Fig. 5 Existing THD

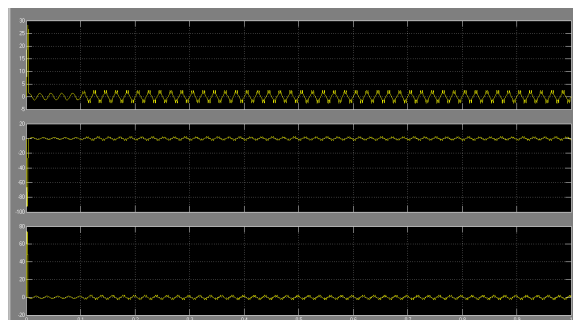


Fig. 6 Proposed Output current

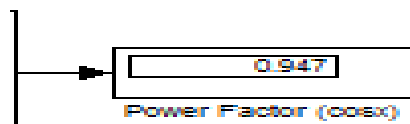


Fig. 7 Proposed PowerFactor

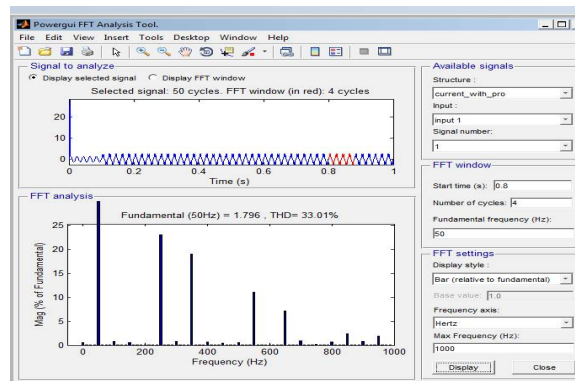


Fig. 8 Proposed THD

VIII. CONCLUSION

This Paper presents a comparative study on the MATLAB SIMULINK simulation results high power STATCOM which employs Voltage magnitude control for both Cascaded Multilevel Inverter and Multistring Multilevel Inverter. It is found from the above simulation result observations that the Improved Multistring Multilevel Inverter is best suitable configuration for High Power STATCOM Applications. Moreover the number of switches used is less when compared with Cascaded Multilevel inverter, hence the cost is also less and the switching losses are also low. The MATLAB/SIMULINK based simulation results confirm the feasibility and effectiveness of the proposed approach to regulate the load voltage using the improved Multi-String inverter based STATCOM.

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