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# MODULAR MULTILEVEL CASCADE CONVERTER (MMCC) BASED STATCOM FOR IMPROVEMENT POWER QUALITY

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***Abstract*-The objective of the paper is the application of modular multilevel cascade converter based on double star bridge cells (DSBCs) to a Static synchronous Compensator (STATCOM), for reactive-power control. The power consumed by the heavy load will create an unsymmetrical current will reducing the quality of the power in the electrical grid. Due to the unsymmetrical current the electrical power in the grid will not be stabilized .The Static synchronous compensator is a shunt compensation device based on the principle of power electronics. Recent development of FACTS devices provides the reliable solution to potential problems. A modular multilevel cascaded converter (MMCC) will be even designed by four methods to compensation the reactive power. Multilevel converter based FACTS offers improved voltage quality, decreased switching frequency and stress on individual power electronic devices. The PWM STATCOM based double star bridge converter (DSBC) is used to control reactive power with the help of circulating current that flows the inside the bridge converter.**

***Keywords- Multilevel converters, Reactive power, Flicker compensation.***

## I. INTRODUCTION

The modular multilevel cascade converters (MMCCs) are one of the next-generation power converters used for high-voltage or medium-voltage applications without line frequency transformers. The common concepts hidden in the family members are both “modular” structure and “cascade” connection. These common concepts and structure will allow the power electronics engineers to use the term “modular multilevel cascade converter (MMCC)” as a family name. The MMCCs will be classified into four types,

1) single-star bridge cells (SSBCs),
2) single-delta bridge cells (SDBCs),
3) double-star chopper cells (DSCCs),
4) double-star bridge cells (DSBCs).

The term bridge cell is a single-phase full bridge converter, and chopper cell consisting of a dc capacitor and two insulated-gate bipolar transistors (IGBT). The Double-star bridge cells is suitable for a Static synchronous Compensator (STATCOM) for voltage regulation problem of eliminating harmonics in switching converter has been the focus of research for many years. The current trends of modulation control for multilevel converter are to produce high quality of power output with high efficiency. In addition, multilevel converter has a low switching frequency than standard PWM inverters and thus has reduced switching losses. The output waveform of multilevel converter is in a stepped wave form resulting in reduced harmonics compared to square wave converter.

The VSC is the integral part of the STATCOM FACTS device, which supply or absorb the reactive power in transmission line to control the voltage of the bus to which it is connected. The reactive power exchanges between STATCOM and the AC system can be control by varying the magnitude and phase of VSC. The H-Bridge cascade multilevel converter eliminates the excessively large number of 1) Bulky transformers required by conventional multipulse inverters. 2) Clamping diodes are required by multilevel diode converters. 3) Flying capacitors required by multilevel flying capacitor converter. In case of H-bridge cascade VSC can operate at lower switching frequency. Therefore, the H-bridge cascade VSC is suitable application to the high power/high voltage system.

In the STATCOM, the capacitor banks, pumped storage hydroelectric system and Battery energy storage system (BESS) are used to maintain a constant DC voltage for the voltage source converter (VSC) operation. The drawbacks of a BESS are limited life cycle, voltage and current limitations. So we have to implement the DSBCs based STATCOM device. The DSBCs based STATCOM is capable of storing electric energy in the magnetic field generated by DC current flowing through it. The real power as well as reactive power absorbed and released from STATCOM according to system requirements.

The Static Synchronous Compensator (STATCOM) is the static counter part of the rotating synchronous condenser. In this principle, it performs the same voltage regulation function as the more robust manner. STATCOM is seen as an adjustable voltage source behind a reactance-meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a STATCOM a compact design, or small footprint, as well as low noise and low magnetic impact.

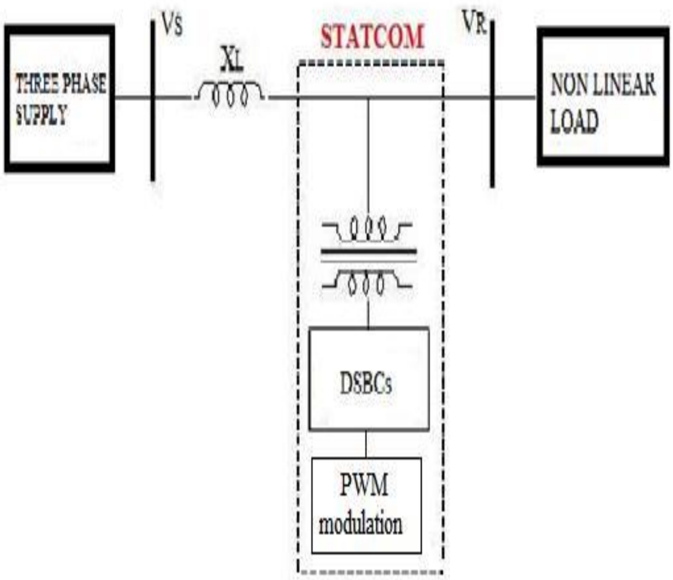


Figure.1. Overview diagram of STATCOM

The power transaction in the STATCOM is shown in the fig.1. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage of the converter. That is, if the amplitude of the output voltage is increased above that of the utility bus voltage then a current flow through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the AC system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the AC system to the converter and the converter absorbs inductive-reactive power from the AC system. If the output voltage equals the AC system voltage, the reactive power exchange becomes zero, in which case the STATCOM is said to be in a intermediate state. Then the phase shift between the converter-output voltage and the AC system voltage can be adjusting similarly control real -power exchange between the converter and the AC system.

In other words, the converter can supply real power to the AC system from its DC energy storage if the converter-output voltage is made to lead the AC system voltage. On the other hand, it can absorb real power from the AC system for the DC system if its voltage lags behind the AC system voltage. A STATCOM provides the desired reactive power by exchanging the instantaneous reactive power among the phases of the ac system.

## II. FLICKER COMPENSATORS OF ARC FURNACE.

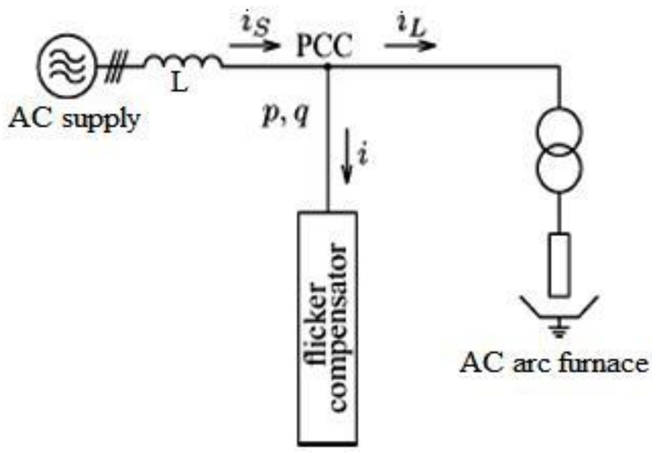


Figure. 2 Simplified circuit configuration ac arc furnaces,.

A typical system configuration of AC arc furnace with flicker compensator and passive filter is shown in fig 2. In which input is an AC supply and *is* is the supply current, *iL* is the load current, and *i* is the compensating current. The P and Q are the instantaneous active power and reactive powers in the three-phase AC terminals of the compensator. Due to the varying the load will drawn by the arc furnace will create an voltage flicker. To compensate the voltage flicker we add a flicker compensator in the electrical grid with the help of PCC. The flicker compensator will compensate the both active power (P) and reactive power (Q) in the electrical grid. The controller of a flicker compensator calculates power commands from P and Q from the load current detected in the ac arc furnace. Then the current commands of the compensating currents are calculated from P and Q. Due to the connecting of PCC will balanced the three phase sinusoidal current waveform and the compensator will work properly.

## III. CIRCUIT CONFIGURATION OF THE DSBCS:

### *A.* Circuit Configuration

Fig. 3 shows the circuit configuration of the 100V 50HZ 5 kVA STATCOM will be implemented in the experiments. Each single bridge of the DSBC consists of cascade connection of three phase bridge cells (i.e., single-phase full-bridge PWM converters), and the three bridge cell are connected in delta configuration via a single coupled inductor *L*. The DSBC is even connected to a three-phase AC mains of 100 V 50 HZ ac supply via a three-phase AC-link inductor *LS* that corresponds to the leakage inductance LL of the grid transformer. The *vuv* , *vvw*, and *vwu* are the cluster voltages, *iuv*, *ivw*, and *iwu* are the cluster currents, and P and Q are the instantaneous active and reactive powers at the PCC. The equation 1 exists between the compensating currents and the cluster currents.

iu = iuv – iwu iv = ivw – iuv iw = iwu – ivw (1)

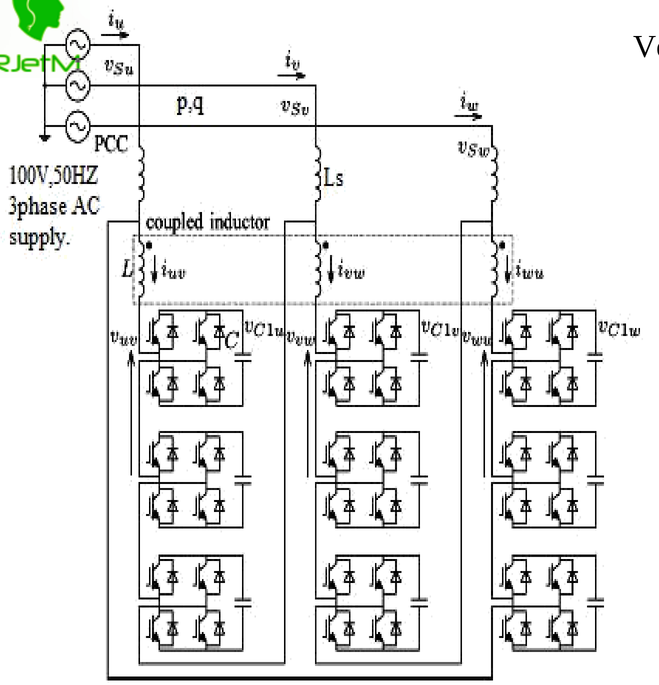


Figure.3. Circuit configuration of PWM STATCOM used in proposed system.

### *B.* Circuit Parameters.

| PARAMETERS | VALUES |
|---|---|
| Input voltage | 100 V |
| Frequency | 50 HZ |
| Input current | 29 A |
| Capacitor | 16.4 mf |
| Dc capacitor voltage reference | 60 V |
| Coupled inductor | 2.3 mH |

Table 1

Table 1 shows the circuit parameters used in the proposed system design. The input side is an three phase Ac supply of 100 V and frequency is 50 HZ and the current is 29 A. The DC capacitor range is 16.4 mf and its reference voltage is 60V. The ac side inductor and the coupled inductor were set as LS = 0.5 mH and L = 2.3 mH respectively.

### *C. Active-Power, Reactive-Power, and Overall Voltage Controls.*

Therefore P* and Q* represent the power commands of P and Q at the PCC. The dc component of Q is adjusted to control positive-sequence reactive power keeping the relation of P = 0.

On the other way, a couple of second-order components (100 Hz) with the same amplitude but a phase difference of 90 degree on P and Q, respectively, to control negative-sequence reactive power. A low-frequency component is super imposed on P to control active power, keeping the relation of Q = 0. The line to line voltage commands $V^*_{uv}$, V* vw, and V* wu are determined by decoupled current control of the compensating currents. A voltage major loop intended for compensating the converter loss which forces DC to follow its command V*c. The voltage command is normalized by each DC-capacitor voltage. Then, it is compared with a triangular waveform having a maximal value of 1 and a minimal value of −1 with a carrier frequency.

The cascaded converter offers extra degrees of freedom and greater possibilities in terms of device utilization, state redundancies, and effective switching frequency. In this paper, hybrid PWM scheme is presented which take advantage of the special properties available in conventional PWM methods and to minimize switching losses with better harmonic performance.

## IV CASCADED H-BRIDGES

A single-phase structure of an m-level cascaded converter is illustrated in Figure 4. Each separate DC source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $–V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, $S_1$, $S_2$, $S_3$, and $S_4$. To obtain $+V_{dc}$, switches $S_1$ and $S_4$ are turned on, whereas $–V_{dc}$ can be obtained by turning on switches $S_2$ and $S_3$. By turning on $S_1$ and $S_2$ or $S_3$ and $S_4$, the output voltage is 0.

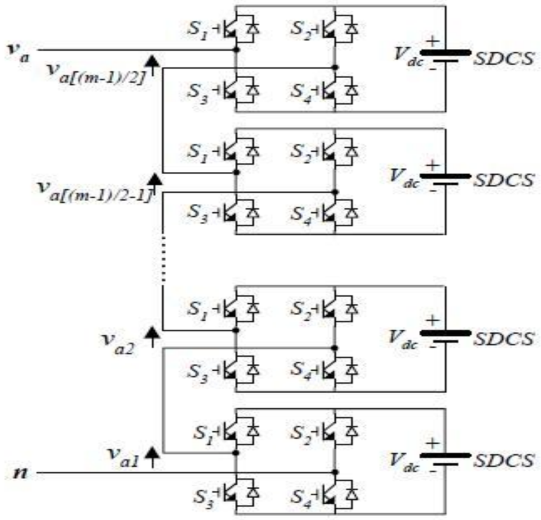


Figure 4. Single-phase structure of a multilevel cascaded H-bridges converter.

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The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the converter outputs. The number of output phase voltage levels m in a cascade converter is defined by m = 2s+1, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge converter with 5 SDCSs and 5 full bridges is shown in Figure 4.

The phase voltage $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$ (2)

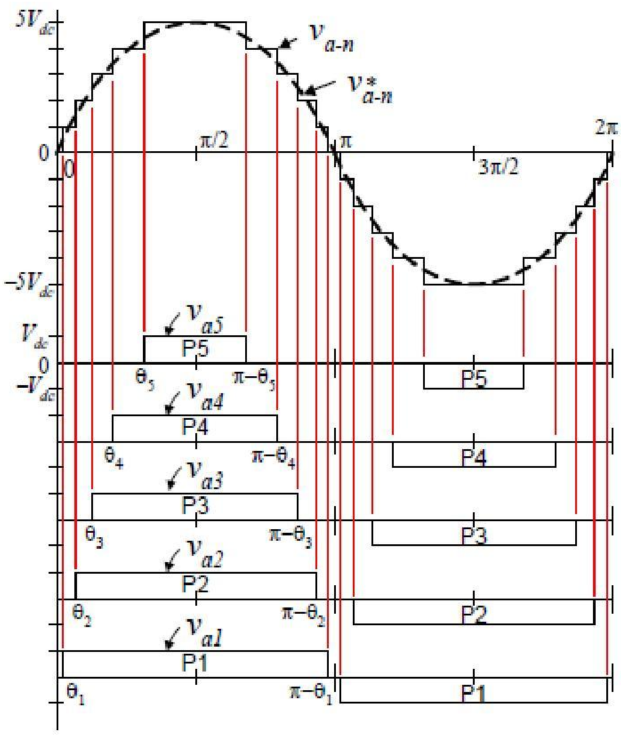


Figure 5. Output phase voltage waveform of an cascade converter with 5 separate dc sources.

An optimized sequential signal added to the hybrid PWM pulses to overcome this problem. The low and high frequency PWM signal are shown in fig.5. An optimized hybrid PWM method commutates the power switches at high frequency and low frequency sequentially. A common sequential signal and low frequency PWM signals are used for all cells in cascaded converter. A high frequency PWM for each cell is obtained by the comparison of the rectified modulation waveform with corresponding phase disposition carrier signal. The low frequency PWM signal should be synchronized with the modulation waveform. This controller is designed to mix the sequential signal, low frequency PWM and high frequency phase disposition sinusoidal PWM and to generate the appropriate gate pulses for cascaded converter.

## V. SIMULATION RESULTS

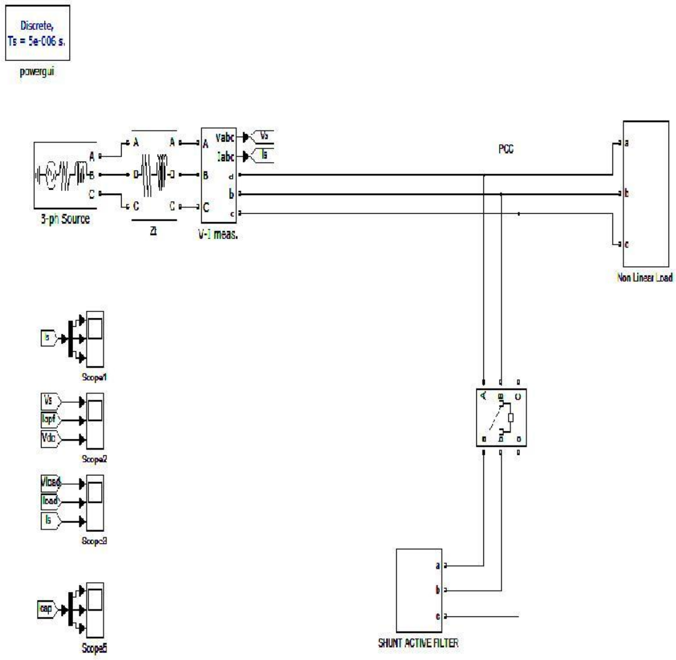


Figure 6. Simulation diagram of proposed system.

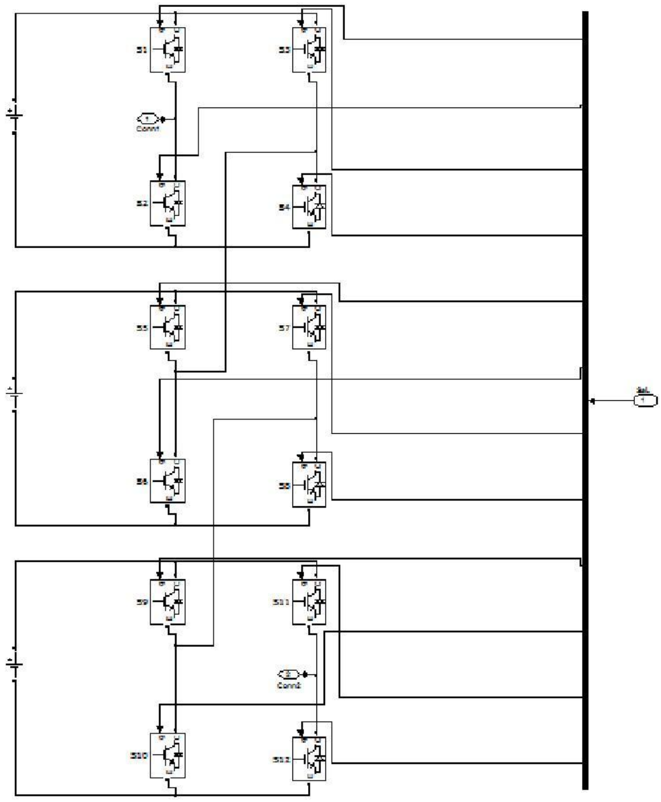

Figure 7. Simulation diagram of DSBCs based STATCOM.

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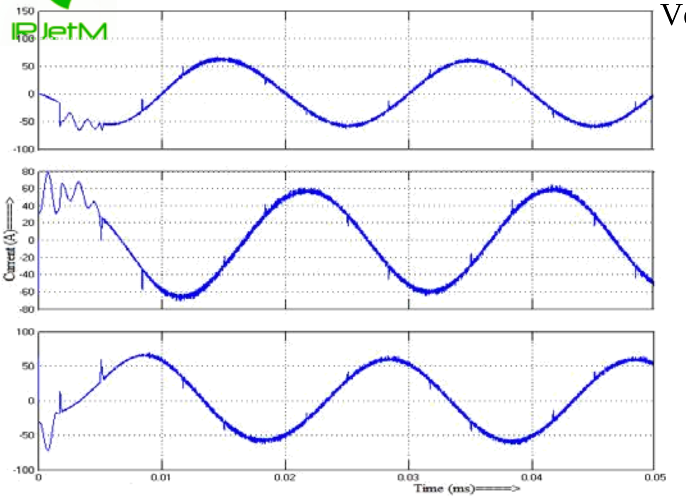


Figure 8.Three phase input current waveforms.

Fig 8 shows the three phase input current waveforms supplied by the source side. The input load voltage is 400V and the current is 29A.

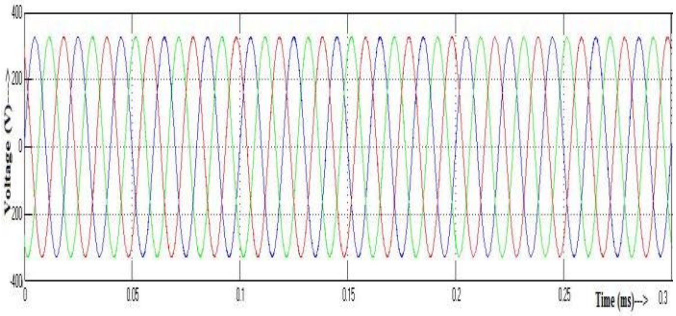


Figure 9. Load voltage waveforms.

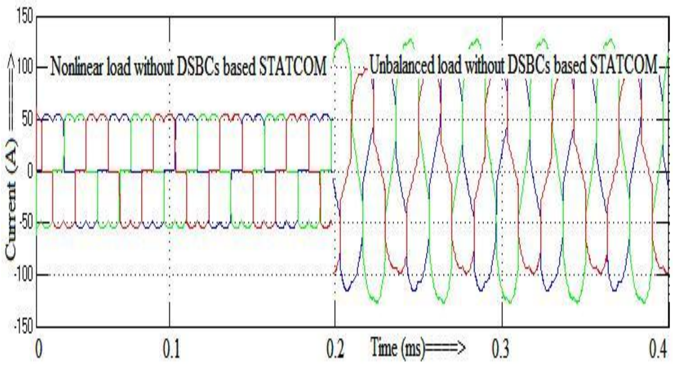


Figure 10. Output load current without DSBCs based STATCOM.

Fig 10 shows the output load current without DSBCs based STATCOM. The input supply grid will directly connected to the non linear load. Due to the non linear load and unbalanced it will create the unsymmentrical current.

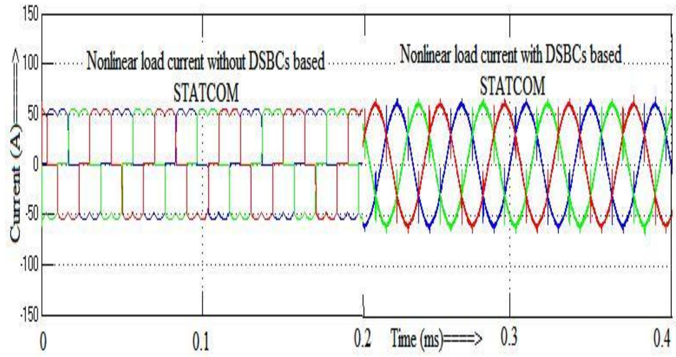


Figure 11.Output load current of nonlinear load with and without DSBCs based STATCOM.

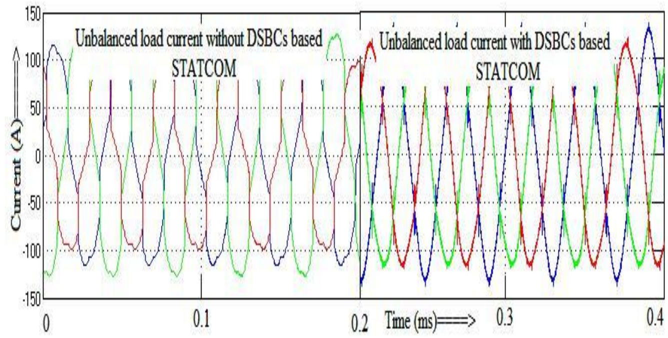


Figure 12.Output load current of unbalanced load with and without DSBCs based STATCOM.

Fig 11 and fig 12 shows the output load current with and without DSBCs based STATCOM for nonlinear load and unbalanced load current..Due to the extensive use of non linear and unbalanced load it will create the symmentrical current into unsymmentrical current.These current will be controlled by using DSBCs baseed STATCOM will connected to the lines with the help of PCC.These are all the Output summary of the bus system voltages and current when we apply the with load and with out load conditions.

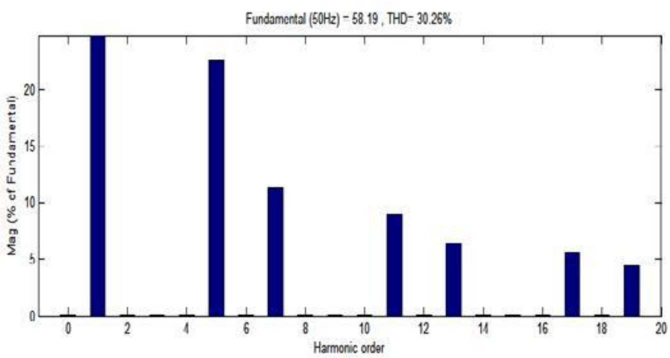


Figure 13. THD output of load current without DSBCs based STATCOM

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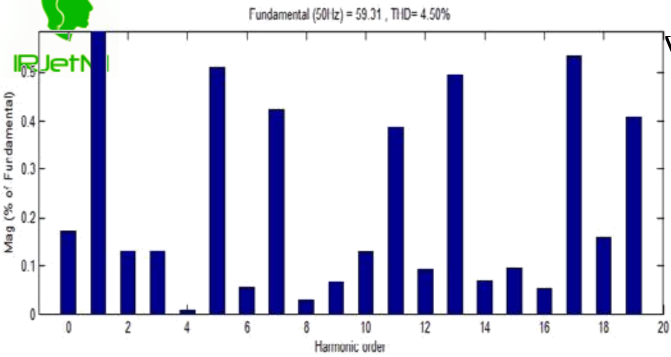


Figure 14.THD output of load current with DSBCs based STATCOM.

VI. COMPARISON OF RESULT.

| THD | WITHOUT STATCOM | WITH DSBCs BASED STATCOM |
|---|---|---|
| THD values of compensation current. | 30.36% | 4.50% |

Table 2 Comparison result of load current with STATCOM and without STATCOM.

The total harmonic distortion of the compensation current without STATCOM is 30.36%. Due to the connection of DSBCs based STATCOM the THD value is 4.50% only.

## VII . CONCLUSIONS

This project discussed a PWM STATCOM using an modular multilevel cascade converter -double star bridge cells, with focus on operating principle and performance. The experimental result obtained from model has led to the following conclusions.

1. Low voltage steps at the AC terminal of each cluster make a significant contribution to reduce the THD value of the compensation current.
2. The DSBCs characterized by having buck and boost function in addition to rectification and inversion although it requires a large number of power switching devices.
3. The DSBCs has a capability to control reactive power with the help of the circulating current.

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