STATCOMs, and the levels of VARs that can be supplied are comparable [2].

II. DUAL VIRTUAL QUADRATURE SOURCE CONCEPT

Dynamic control of the AC line voltage is important but the ability to control line voltage and branch current simultaneously is critical. To achieve dynamic control of voltage and phase angle, a power converter like AC chopper circuit is used to synthesize a desired voltage (current) from available voltages (currents) through the use of PWM techniques. It has a low component count and having no stored energy. The synthesis of output voltages with controllable phase and/or harmonics, "Dual Virtual Quadrature Sources" is applied [4].

To ensure the physical constraints, two quadrature sources are added to the fundamental component of the voltage, one quadrature component at the fundamental frequency, and other quadrature source at an odd harmonic, like 3rd, is added. The resultant voltage V_o*, is now entirely follow the envelope provided by the incoming voltage V_{in}, and can thus be synthesized. The voltage V_o, after synthesis, would consist of a direct and quadrature component of the fundamental voltage, as well as a 3rd harmonic voltage as shown in fig.1.

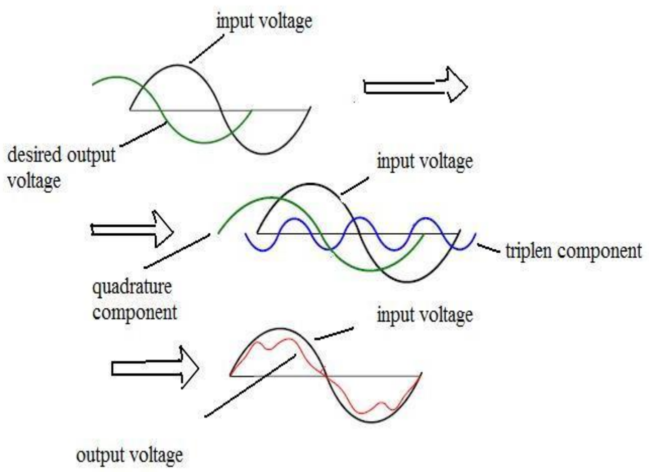

Fig.1 Voltage synthesis waveforms

Using the concept of dual virtual quadrature source concept[4] we realize the equation as given below:

$$|V| = V_m\sqrt{\frac{K_2^2}{4} - K_0K_2\sin\varphi_2 + K_0^2}$$

$$\varphi = \tan^{-1}\left[\frac{\frac{K_2}{2}\cos\varphi_2}{K_0 - \frac{K_2}{2}\sin\varphi_2}\right]$$

$$V_3 = -\frac{K_2}{2}\cos(\omega t + \varphi_2)$$

Above equations show that an arbitrary phase shifted fundamental voltage as well as a controllable harmonic voltage can be generated by controlling the variables K_0, K_2 and Φ_2. The control limits are defined as 0 < D (θ) < 1.

III. C-BUCK AND C-BOOST CELLS

The C-buck cell is configured in the buck mode as it provieds the reduced voltage across C with respect to the input voltage. The C-buck cell configuration is shown in fig.2.

In the C-buck cell configuration an AC chopper circuit is inserted between the input voltage and the C-buck capacitor as shown by the dotted lines in fig.2. Now as in AC chopper the output voltage is varied according to equation

$$V_o = DV_{in}$$

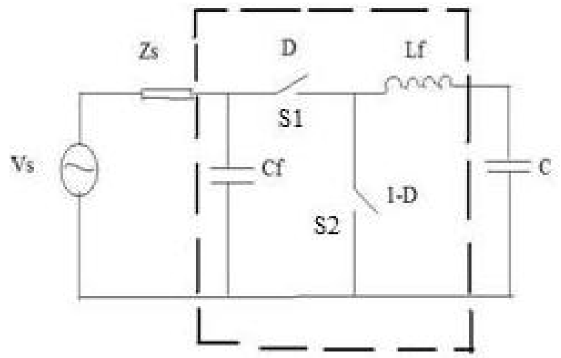

Fig.2 IL-STATCOM- buck cell

Therefore the output voltage is accordingly changed with the variation in the duty cycle and hence the variable capacitance is observed as C_{eq}=D.C where D is the duty cycle. Thus the capacitance is varied from 0 to C.

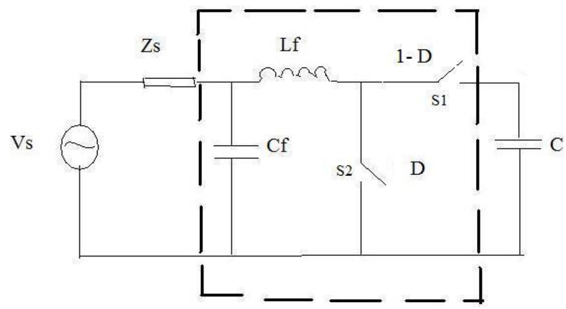

Fig.3 IL-STATCOM boost cell

Fig.3 shows the 'C-buck' cell configured to operate backwards, i.e. as a 'C-boost' cell. It is operated in boost mode as the output voltage can be varied to higher magnitude with respect to input voltage. The equivalent capacitance observed is C / (1 – D). Now the C-boost capacitance can be varied more than the value of C as D is limited to 0 < D < 1.

C- buck cell and C-bost cell are the configration in which voltage across the capacitor of capacitance C can be instantaniously varied.

IV. IMPLEMENTATION OF INVERTER-LESS STATCOM

Implementation of a full-scale IL-STATCOM is done with C-buck-boost cell configuration and simulated by using the VQS even harmonic modulation technique. The three phase system with non linear load is simulated in MATLAB given in fig.4 where the C-buck-boost controller is connected between the two buses B_1 & B_2 as shown in figure. These buses are used to measure the instantaneous value of current and voltage.

The C-buck-boost controller is a shunt compensator which is used to supply the reactive power to improve the voltage profile of the system. The C-buck-boost cell controller has five C-buck cell in one phase and ten C-boost cell in other two phases provide the dynamic VAR support to the line as the reactance of the C-buck-boost cell can be varied dynamically with VQS modulation technique

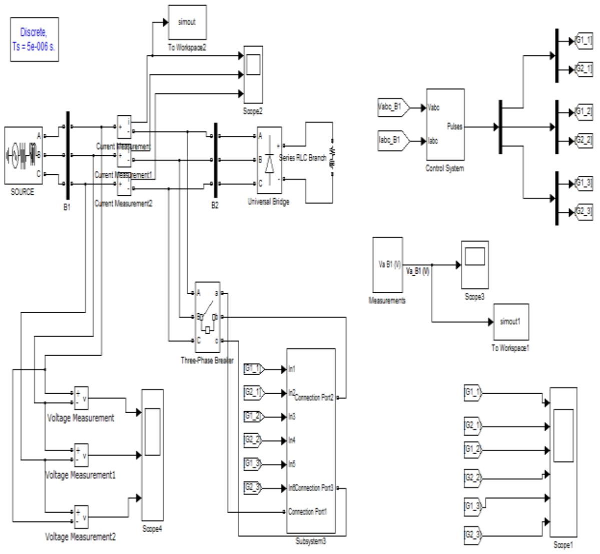

Fig.4 Inverter-less STATCOM simulation circuit

The subsystem-3 in the fig.5 incorporates 15 subsystems which are showing five C-buck cells in phase1 and ten C-boost cells as given in fig.5.

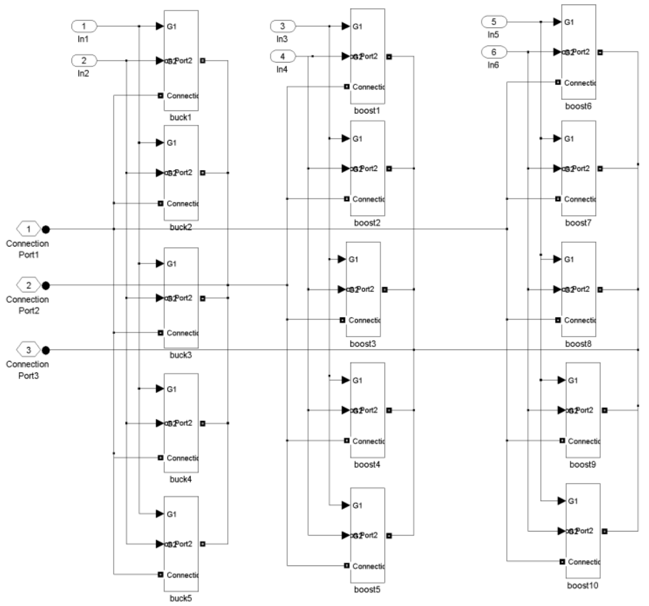

Fig.5 C-buck-boost controller consist of 5-buck cell in phase 1 and 5 boost cell in other two phases

There are 15 subsystems shown in fig.5 and each subsystem is the C-buck cell and C-boost cell as given in fig.6 and fig.7.

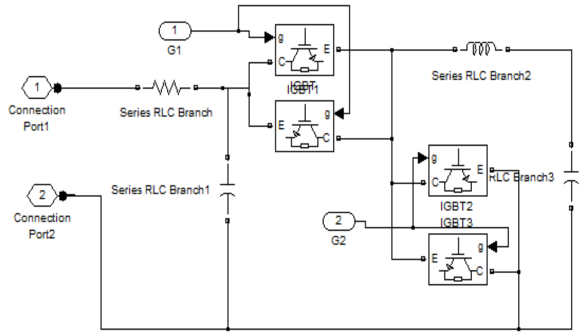

Fig.6 C-Buck Cell

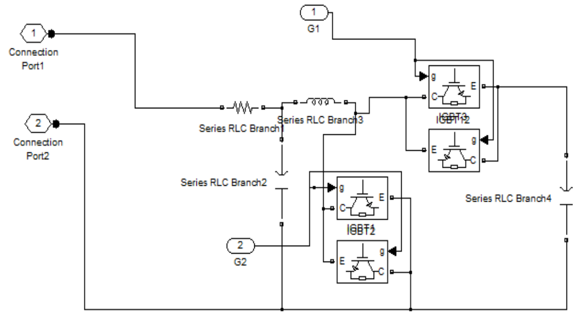

Fig.7 C-Boost Cell

Fig.8 and fig.9 shows the distortion-less three phase input current and voltage using C-buck-boost controller.

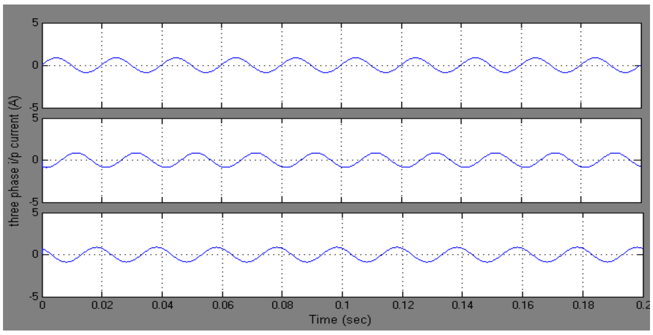

Fig.8 Distortion-lees three-phase input current using C-buck-boost controller

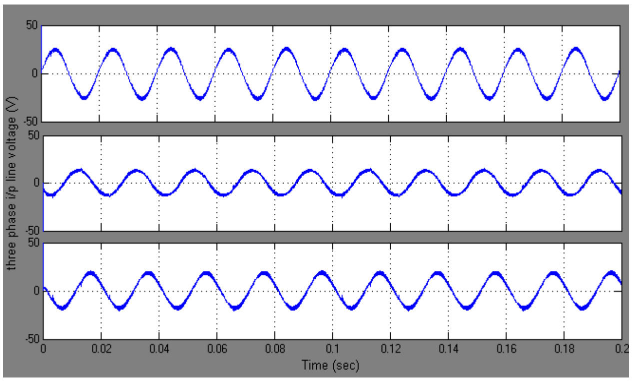

Fig.9 Distortion-lees three phase input line voltage using C-buck-boost controller

The distortion in the line voltage as well as in line current which can be measured by the Total harmonic distortion (THD) obtained by fast Fourier transform analysis (FFT) as shown in the fig.10 and fig.11 for input current and input voltage respectively. This shows the 0.14% THD in line current and 4.86% THD in the line voltage. This FFT analysis is achieved by the SIMOUT block in the MATLAB tools.

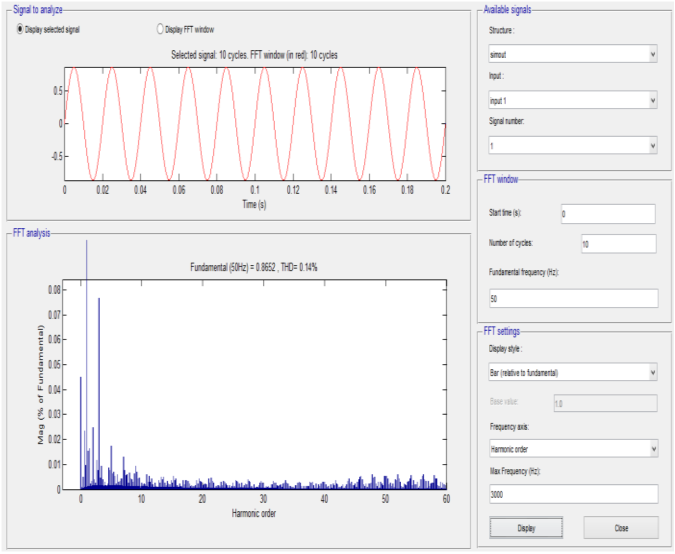

Fig.10 FFT analysis of distortion-less input current using C-buck-boost controller

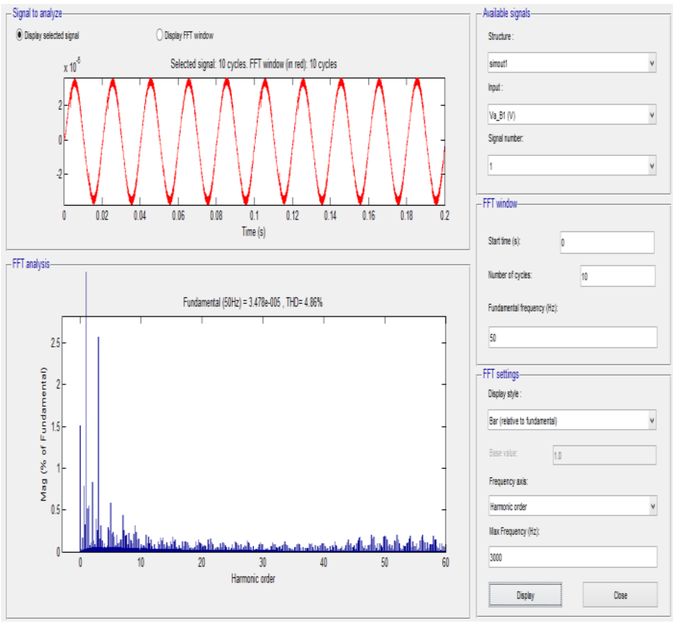

Fig.11 FFT analysis of distortion-less input voltage using C-buck-boost controller

When C-buck-boost controller is disconnected through circuit breaker then distorted voltage and current is resulted. This gives the comparative analysis of with and without controller in the circuit.

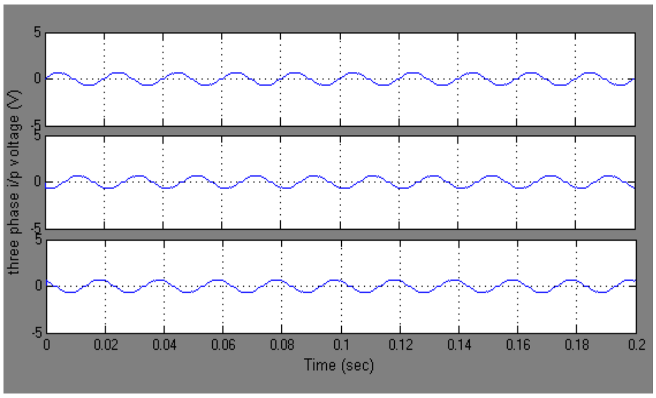

Fig.12 Distorted three phase input current

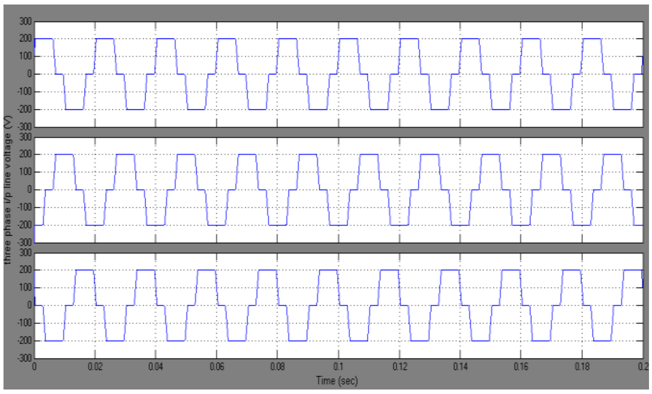

Fig.13 Distorted three phase input line voltage

Fig.12 and fig.13 shows the graph of distorted input line current and voltage respectively.

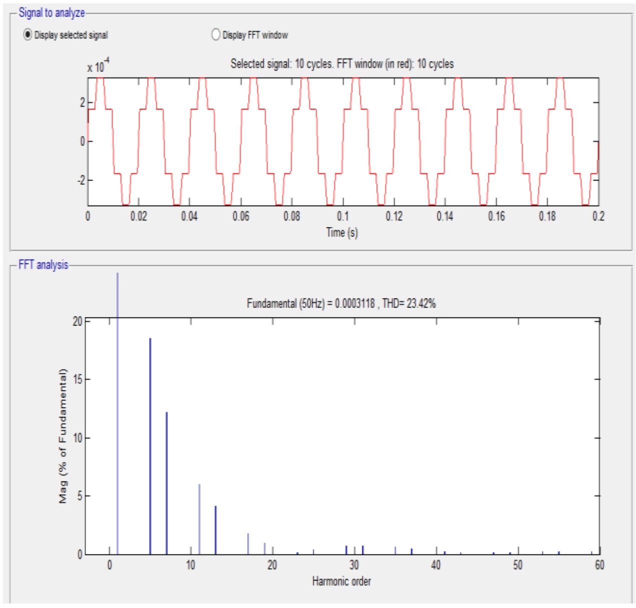

Fig.14 FFT analysis of distorted input voltage

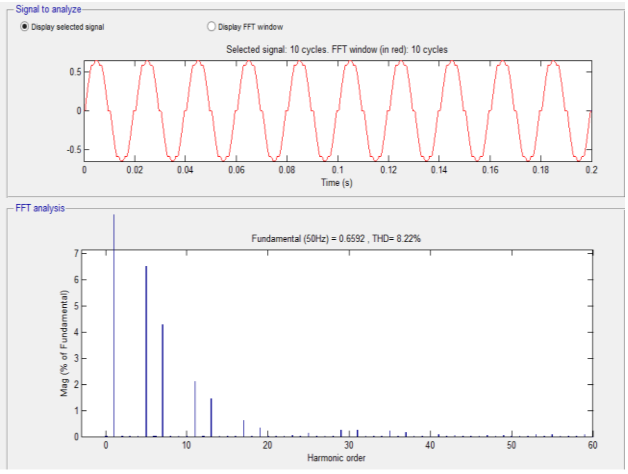

Fig.15 FFT analysis of distorted input current

Fig.14 and Fig.15 show the total harmonic distortion for distorted input voltage and current respectively. This shows the 8.22% THD in line current and 23.42% THD in the line voltage.

Table 1: THD of Input Current and Voltage in case of with and without Controller

Controller	Current THD (%)	Voltage THD (%)
C-buck Controller	0.40	7.47
C-boost Controller	0.13	10.39
C-buck-boost Controller	0.14	4.86
Without Controller	8.22	23.42

The performance analysis using different types of controller and without controller is shown in table 1.

V. CONCLUSION

In this paper a novel approach to implementing Inverter-Less STATCOM, or direct AC control of grid without using large dc-ac inverters using series stacking arrangement of C-buck and C-boost cell has been verified. IL-STATCOMs, using shunt VAR compensation capacitors coupled with readily available IGBTs configured into direct ac converters has been presented in this paper. The use of VQS PWM techniques allows dynamic VAR control and harmonic isolation functions. The proposed approach can be easily scaled using a variety of approaches to implement IL-STATCOMs suitable for high power and high voltage operation. The implementation of Inverter-Less STATCOM by using one series stacked C-buck cell configuration and two series stacked C-boost cell configuration has been presented. The comparative analysis of THD using with and without controller has been presented. The THD is reduced using C-buck cell controller or C-boost cell controller or C-buck-boost controller

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