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IMPROVEMENT OF POWER QUALITY USING 11-LEVEL CMC BASED DSATCOM WITH OPTIMAL HYBRID MODULATION SCHEME

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Abstract - Enhancement of power quality features is the superior attention in power system advanced component, situations such as harmonics, reactive/active power exchange, and correction of power factor, balance the load condition & so on, due to higher effect on greater sensitive/nonlinear loads are to be advocate in distribution system. To amplify these situations, advanced custom power contraption are required, in that CMC based 11-level D-STATCOM is a precise high power appliance for mitigating the harmonic distortions coming from high power semiconductor switching device, exchanging the both active & reactive power, improve power factor and to regulate the power quality issues in power distribution network. This work highlights a new spawn of multi-carrier modulation technique is called as hybrid modulation scheme, is supported to evaluation of proposed CMC applications to DSTATCOM for getting favourable advantage nothing but very low amount of THD at (Vo) output voltage as compared to formal modulation schemes like (PSHM) phase shift and level shift (LSHM) switching schemes and reference currents are founded by IRP methodology and proposed advanced system is evaluated dynamically with Matlab/Simulink environment.

Keywords: Cascaded H-Bridge Multilevel Inverter (CHB);Instantaneous Real-Reactive Power Theory (IRP Theory); Hybrid Modulation Scheme; Cascaded Multilevel Converter (CMC); Total Harmonic Distortion (THD).

INTRODUCTION

The conveyance of clean energy has been evermore a very important task for many utilities system. In the past situation the clearness of the power system network with the presence of genuine linear loads maintained as easy task, today the very quickest growth of advanced technology with high power range of semiconductors are utilized & employed this type of advanced technology in industrial & domestic applications such as to control over the drives & energy generation systems becomes the transmission/distribution ofgood power through these networks basically very big adventure. The major problem for this type of devices is the very poor response because of passive components and huge space is required for this methodology need to install [1]-[3].In this paper proposes a good performance based high power range distributed compensator is implemented at PCC in distribution lines to achieve power maintained as qualitated. This novel technology is nothing but 11-level CMC based DSTATCOM with hybrid modulation scheme, a pure DSTATCOM connected in parallel will be acquired and simulated with different evaluations by various modulation schemes. Moreover, as electric energy is produced, transferred, and utilizes, voltage as well as current distortions are achieved due to semi- conductor devices [4]. This is noticed that nonlinear current/ voltage may eventuate, so many problems for the utility side system such as low efficiency, power factor should be low, high electromagnetic interference (EMI), current/voltage distortions at PCC.The common devices are used to deal with these problems such as switched capacitors, static Var compensator (SVC), and passive harmonic filters.

This paper highlights the usage of different modulation schemes with proposed distributed compensator for enhancing the power quality (PQ) problems, moreover implementation of proposed DSTATCOM device with CMC as ample opportunity as well as production of such reference currents are supported by instantaneous theory and fed to advanced PWM schemes to generate pulses to operate the shunt device [5], it can contribute good transient response no need of any loop compensation systems. With the advancement of easy design & minimized cost, it is very accepted for power quality enhancing problems and improves the high maintenance of

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PCC stability. High accomplished MLI's topologies are preferred morely& synthesize of staircase form of output voltage is obtained by merging the several dc input voltages pertain as a source. That's why it was very high suitability range for many applications requires high voltage/power range of applications with the minimization of low dv/dt stress and also less distorted output voltage compare to conventional inverter topologies and it may results to reduction/no need of high range of load side filter component, noise as well as no importance of (EMI) electromagnetic interference, reduces the output filterquantity [6]. Nevertheless, there are more numbers of custom power active devices, in that CMC based distributed compensator (MLI-DSTATCOM) to compensate harmonic distortions coming from load at PCC level and required to exchange active & reactive power, power factor to be maintained as unity, accosts the unbalanced load condition with various modulation scheme are highly favoured for pervasive operations and achieved best results [7]. The extensive design of MLI topology is achieved near to more sinusoidal output voltage by several voltage levels based on fundamental & high switching frequency schemes, mostly there are three major types of MLI topologies such as follows:

- Cascaded type Multi-level Converter topology (CMC)
- Flying Capacitor type Multilevel Converter topology (FCMC).
- Diode Clamped type Multilevel Converter topology (DCMC).

Here used advanced hybrid multi-carrier (HMC) modulation schemes have favourable advantages. Simulation results are acquitted with the need of different modulation techniques with proposed 11-level DSTATCOM and to validate the dynamic stability of system using Matlab/Simulink Software platform with Sim-power system environment.

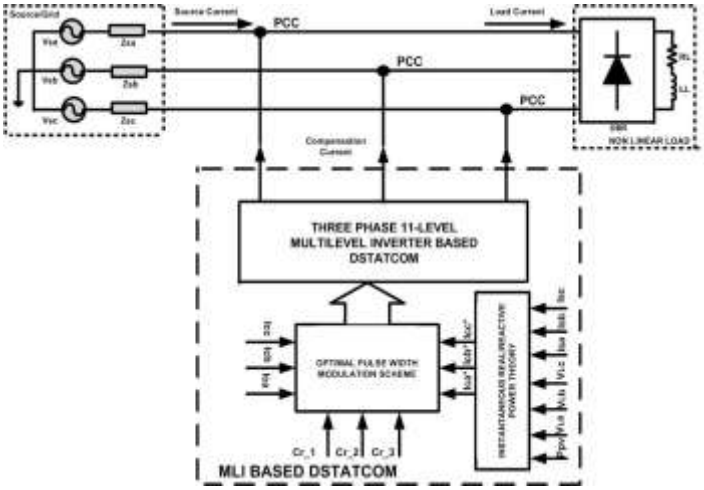
II. PROPOSED MULTILEVEL BASED D-STATCOM WITHENERGY SOURCE

Power semiconductor device based high flexible AC transmitted System (FACTS technology) have been encouraged due to provision of heavy knowledge and more control on power system networks. Conventionally, so many techniques are used to maintain power as a qualitated, but with the development of power electronics technology in power systems applications such as active distributed compensator (D-STATCOM) were available and accepted many more attention during present days [8]-[10]. Utilization of multilevel inverter based D-STATCOM for high power applications & it is a power semiconductor artifice that would be placed in between a source & a distribution load not only to support the active power for load achievement but also to control the reactive power on the entire network, eliminate the harmonics coming from diode bridge rectifier & improve the power factor and operated as high stability with high reliability.

In Figure.1 depicts the structure of proposed three phased CMC based 11-level D-STATCOM with generation, a three phase diode bridge rectifier (DBR) topologies are enormously used as load for conversion purposes. This type ofpower electronic loads acquire heavy harmonic currents at PCC side, and it consists infinite odd extent of fundamental frequency component, due to these distorted currents may compel the crucial problems and also deteriorate the power system quality in distribution network side level, due to this reason shunt/parallel device was more perfect to eradicate those distorted harmonic currents, and improve the PCC parameters as a constant & also amend the power quality features [11].

Figure. 1 Structure of Proposed Three Phase CMC Based 11-level D-STATCOM

As depicted in Figure. 1, a CMC based 11-level



DSTATCOM is interfaced as resemble at (PCC) point of common coupling with the help of interfacing inductors, energy production of that proposed DSTATCOM is accomplished with high range of dc link capacitor as well as incorporated battery storage system with proposed real time instantaneous strategy.

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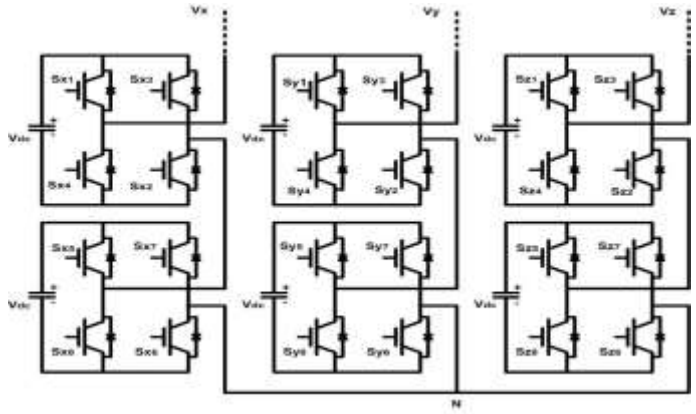

Figure.2 Structure of Series Connected type Multilevel Converter (CMC)

Composition of this active shunt compensator can fulfil the harmonic distortion minimization and improving the reactive power, maintain high power factor nearby unity withthe operating principle of direct in phase competing. For this condition, a control strategy for the control action of 11-level DSTATCOM in distribution systems is based on reference currents generated by instantaneous *p–q* theory was highlighted and applied to modulation schemes, here preferred various hybrid modulations are applied to CMC based 11-level DSTATCOM as shown in Figure.2, to validate the performance and applications to distribution networks.

III. INSTANTANEOUS P-Q POWER THEORY

The counteract approach of this proposed CMC based 11-level DSTATCOM refers to two major parts. One of the parts are instantaneous reference estimation current value to composition the harmonics coming from load & maintained as constant reactive power [12]. Another part is propagate the pulses with the help of phase shift (PSPWM) & level shifted (LSPWM) types to diffuse the compensation of harmonics current immolate at PCC voltage. The primary intension of this proposed methodology is to control/exchange the power at PCC. While acquire the some energy due to administration operation, the CMC based DSTATCOM is controlled essentially such a way it always supports or injects real/imaginary power from main source with respect to fundamental frequency nature.

This protruding instantaneous (P) real power should be in α-β reference frame is widely adjudged by the eq. (1)

$$p = v_\alpha i_\alpha + v_\beta i_\beta \qquad (1)$$

This premeditated instantaneous (Q) imaginary power should be evaluated and shifting in to α-β reference frame by the eq. (2)

$$q \triangleq v_\alpha i_\beta - v_\beta i_\alpha$$

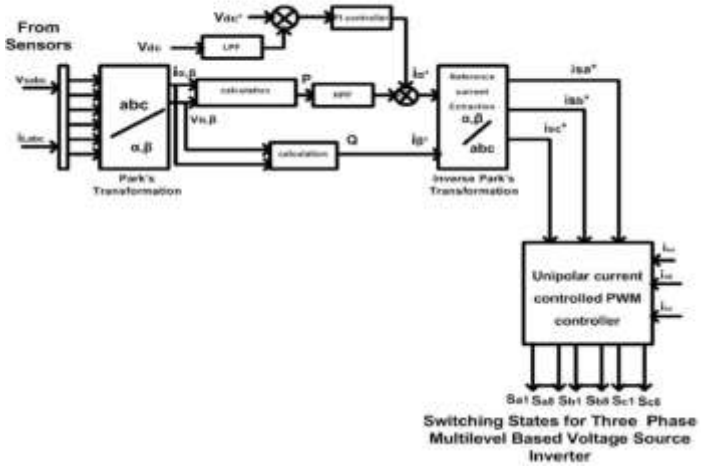

Figure. 3 Block Diagram of Fundamental Reference Current Calculator by using Instantaneous P-Q Theory

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \qquad (3)$$

With the differentiate of active & reactive component into two major things such as, AC part as well as DC part as followed in eq. (4) and eq. (5). For achieving the DC component (P&Q), by using the high pass filter to filter out the uneven demanded signals

$$p = \bar{p} + \tilde{p} \qquad (4)$$

$$q = \bar{q} + \tilde{q} \qquad (5)$$

In Accordance of this power theory, the concern of active component (P) is characterized by DC component of instantaneous nature of α-β reference current. Furthermore accurate reference current component for CMC based 11-level static compensator might be assistance as followed in eq. (6)

$$i^*_{abc} = \sqrt{2/3} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3/2} \\ -1/2 & -\sqrt{3/2} \end{bmatrix} i^*_{\alpha\beta} \qquad (6)$$

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Instantaneous reference current calculator generates the reference component are accosted by analyzing proposed theory as shown in Figure. 3, after that associate the reference current signals getting from the actual system signals [13], [14]. Based on these signals refer to various modulation scheme it will generate the switching signals & control over the switches of the CMC 11-level DSTATCOM then dampen the current harmonics and compensating the reactive power and mainly enhancing power quality.

IV.SEVERAL MODULATION SCHEMES

A pulsed width modulation (PWM) scheme is the cognitive process of altering the width of pulses in some set of pulse train to be direct symmetry of small controlled signal; the higher the controlled voltage; wider the assisted pulses, there is very high possibility to generate a high range of power waveform regards average voltage changes sinusoidally in a such a manner to optimal way for drive the switches. Optimal exhaustible pulse width modulation techniques are mostly appropriate like (SVM) spaced vector modulation technique, (SPWM) sinusoidal pwm framework, [15]. High rated multilevel converter applications are more conducive & more nearby sinusoidal output voltage, with respect to good harmonic minimization, low dv/dt stress, which may reduces the switching losses in comparison of conventional two level topologies with the needless of output side load filter, and reduced EMI. Some of the multi carrier modulation techniques are used in this multilevel topology can be classified as :

1. Multi-carrier Phase Shifted Modulation Scheme
2. Multi-carrier Level Shifted Modulation Scheme
3. Optimal Modulation Scheme (Hybrid)

A. Multi-carrier Phase Shifted Modulation Scheme

The operating principle of this MCPSM scheme isindependently bi-polar &uni-polar sinusoidal modulation technique, shifting the carriers with respect to specified phase angle $360^0/m$ (q= number of carriers required) for the CMC is commence over the modules to procreate the multilevel staircase output voltage waveform with minimized harmonic distortions [16].

For p voltage levels (q = p – 1) no of triangular carriers are required, in this modulation scheme all the carriers (q) should have same frequency with respect to equal peak amplitude and that carrier is to be shifted based on angle based on below equation.

$$\emptyset_{shpwm} = \frac{360^{\circ}}{n}$$

The generation of switching pulses by relating the reference signal with carrier signal. The modulating principle of MCPSM scheme for one phase (CMC) cascaded multilevel converter as depicted in Figure.4.

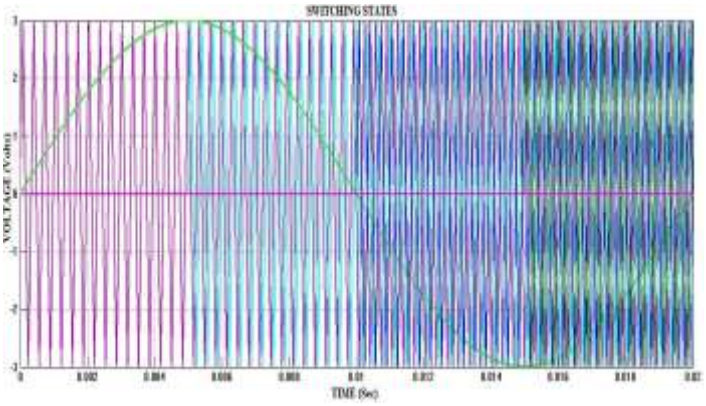

Figure. 4 Multi-carrier 3 Phase Shift Modulation Scheme

B. Multi-carrier Level Shift Modulation Scheme

The essential control action of MCLSM scheme is to prefer many more carrier signals which relate with a single reference sine signal in [17]. For a eleven level operation required 10 carrier signals for producing specific output waveform, and frequency of carrier and peak magnitude are equal as MCPSMscheme. WhereV_{mref}constituted the reference sine peakamplitude signal and V_{eer}constitutes the peak magnitude ofcarrier signal. The evaluated modulation index(amplitude)(MI_{amp}) is defined as:

$$MI_{amp} = \frac{V_{mref}}{V_{eer\ (q-1)}}$$

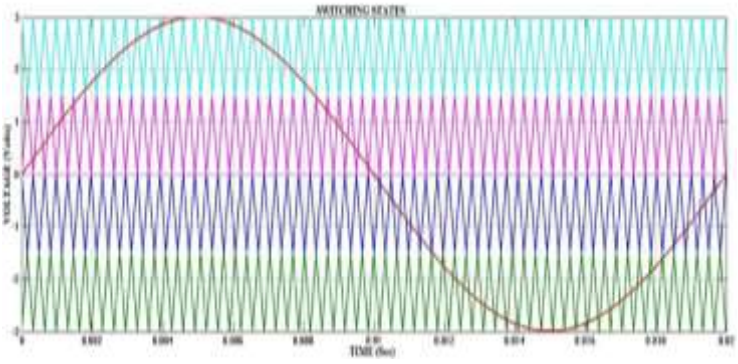

Figure.5 Multi-carrier Level Shift Modulation Scheme

Generation of switching signals for CMC based MCLSM scheme as depicted in Figure. 5. Three major

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several modulation schemes are (A-POD) Alternating Phase Opposition Deposition, (P-D) Phase Deposition, (P-OD) Phase Opposition Deposition.

C. Proposed Optimal Modulation Scheme (Hybrid)

This projected optimal multi-carrier (hybrid) modulation (OMCM) scheme is formation of both LSPWM and PSPWM scheme (in-phased deposition (IPD)) technique to trounce the some problem it regards to the switching action of level shift modulation scheme as well as to overcome the unequal output voltage phase imbalanced condition produced by CMC [18]. In this optimal scheme all the carriers requires equal frequency value and difference of peak magnitude is same, which are disposed vertically. The optimal modulation scheme for eleven levels (CMC) cascaded type multilevel converter as depicted in Figure.6.

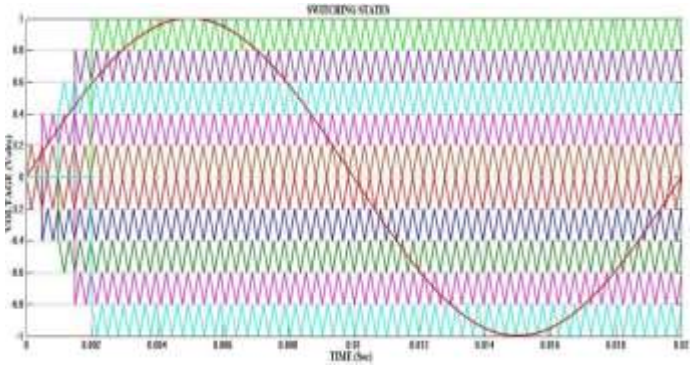

Figure.6 Level Shift Multi-carrier Modulation Technique

V. EVALUATION OF MATLAB/SIMULINK MODELING & RESULTS

The proposed CMC based 11-level DSTATCOM is designed to eradicate the harmonic current distortions entail from the power electronic loads, and voltage regulation, improve the source side power factor & maximization of PCC stability and simulation results are presented by using various modulation schemes is contemplate with the help of Matlab/Simulink modelling environment and fast fourier analysis also presented in terms of total harmonic distortions (THD), and compare to the harmonic standards concerned by IEEE/IEC international standards.

Table I. Parameters of Proposed CMC based 11-level DSTATCOM Topology to Improve Power Quality Features

S.No	Parameters	Values
01	Source Voltage (Ph to Ph)	11KV
02	System Fundamental Frequency	50 Hz
03	Source Side Impedance	0.1Ω, 0.9mH
04	Source Side LC Values	0.01 Ω, 10mH
05	Non-Linear Load (PE Device)	3-Phase Diode BridgeRectifier withResistorof 25 ΩConnectedacross DC side.
06	Value of Dc link Capacitor (C_{DC})	550 µF

The highlighted compensation system consists of a CMC based 11-level DSTATCOM with the need of IGBT power electronic device in place of bridge manner, So as to evaluation of that control scheme for series connected CMC has been acquit out by using several modulation schemes and applications to which one is highly imposed.

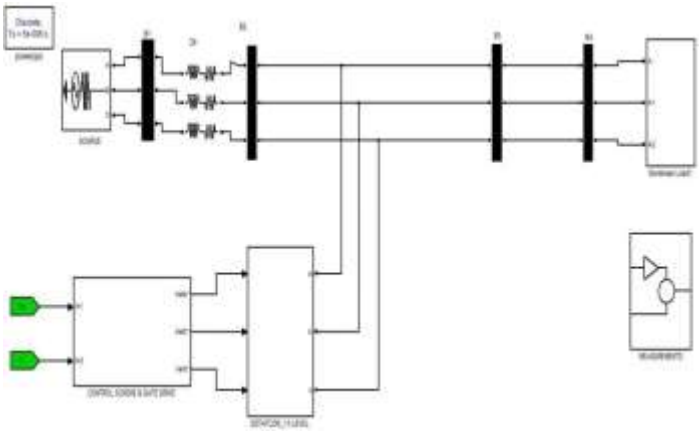

Figure. 7 Matlab/Simulink model of Overall structure of Proposed CMC basedusing matlab/simulinksim-power system environment.

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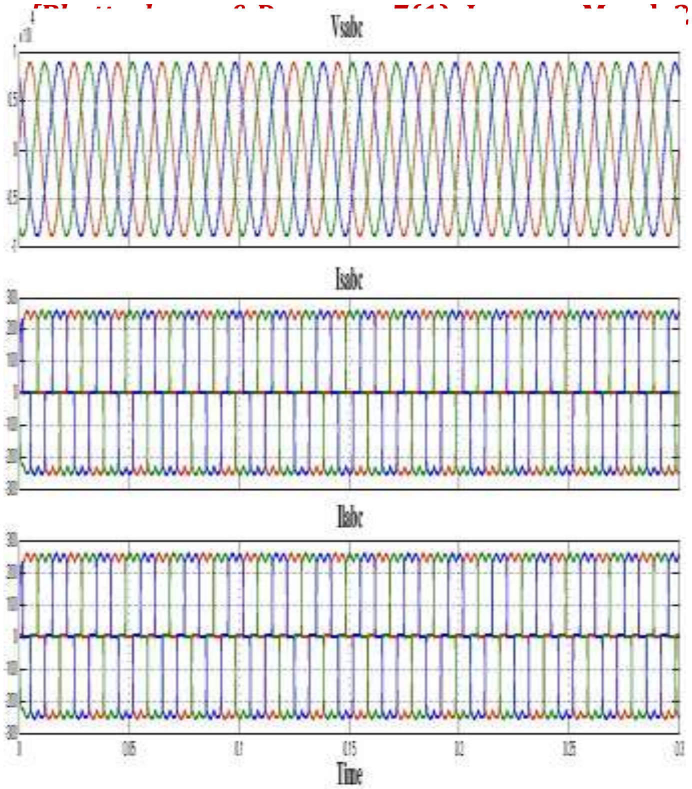


Figure. 8 (a) Source Voltage (Vsabc), (b) Source Current (Isabc), (c) Load Current (Ilabc)

As above Figure. 8 accords the source side voltage, source side current, load side current, without any presence of CMC D-Statcom with improved dynamic behaviour in that source current is always equal to load current with minor difference in magnitude value in this condition.

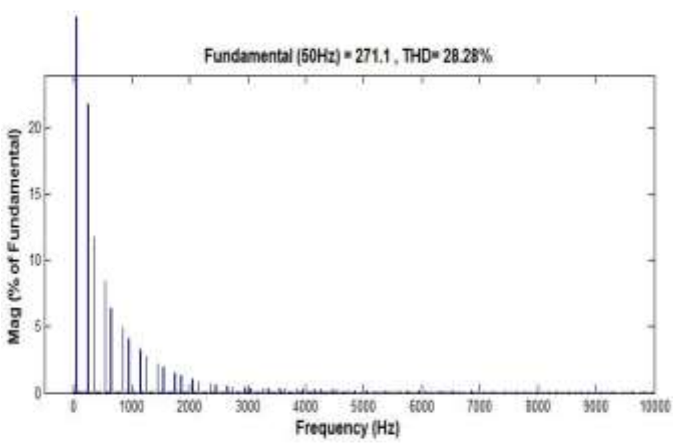


Figure. 9FFT Analysis of Source Current Without any Conditioner

Figure. 9 FFT analysis of source current without any CMC D-STATCOM with improved dynamic behaviour, THD of source side current is 28.28%.

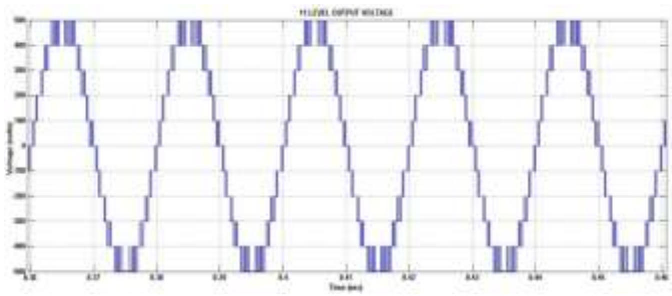
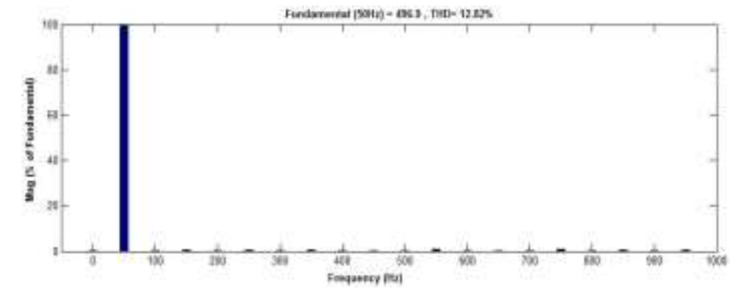


Figure.10 11-Level Output Voltage

Figure.10 shows the 11-Level Output Voltage of CMC based DSTATCOM using Optimal PD (Hybrid) Modulation Scheme applications to Proposed Distributed Compensation Scheme.



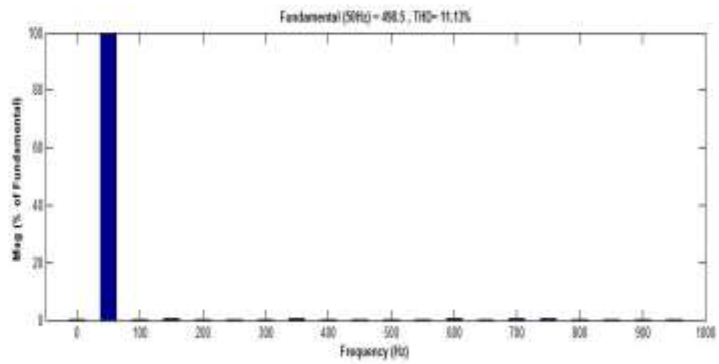


Figure.11 THD for 11-Level Output

Figure.11 shows the THD for 11-Level Output Voltage of Cascaded Multilevel Converter (CMC) with the help of OPD-PWM (Hybrid PD Modulation Scheme), then THD value is 12.82%.

Figure.12 THD for 11-Level Output Voltage

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Figure.12 shows the THD for 11-Level Output Voltage of Cascaded Multilevel Converter (CMC) by using OPOD-PWM (Hybrid POD Modulation Scheme), THD value is 11.13%

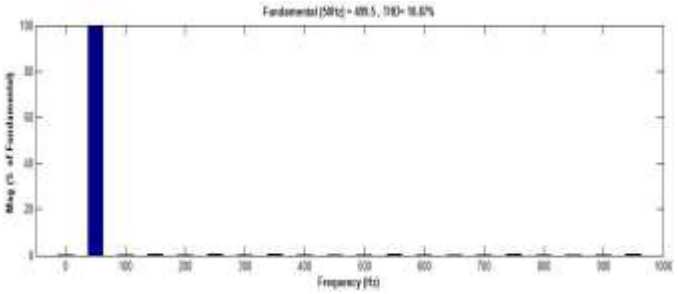

Figure.13 THD for 11-Level Output Voltage

Figure.13 shows the THD for 11-Level Output Voltage of Cascaded Multilevel Converter (CMC) using OAPOD-PWM (Hybrid APOD Modulation Scheme), THD value is 10.87%.

Table II
Fourier Transform Analysis of Output Voltage with Proposed Modulation Schemes

THD (%)	Hybrid PD	Hybrid POD	Hybrid APOD
11-Level Output Voltage (Vo)	12.82%	11.13%	10.87%

In Table II represents the fourier analysis of output voltage for projected CMC based 11-Level DSTATCOM, here getting expected high voltage quality, THD also enormously minimizes which compare the conventional modulation schemes, in that hybrid APOD have better regulated features has compare to formal PD & POD modulation schemes & applications to distributed compensator to drive the gating pulses of proposed DSTATCOM to control over the power system dynamics

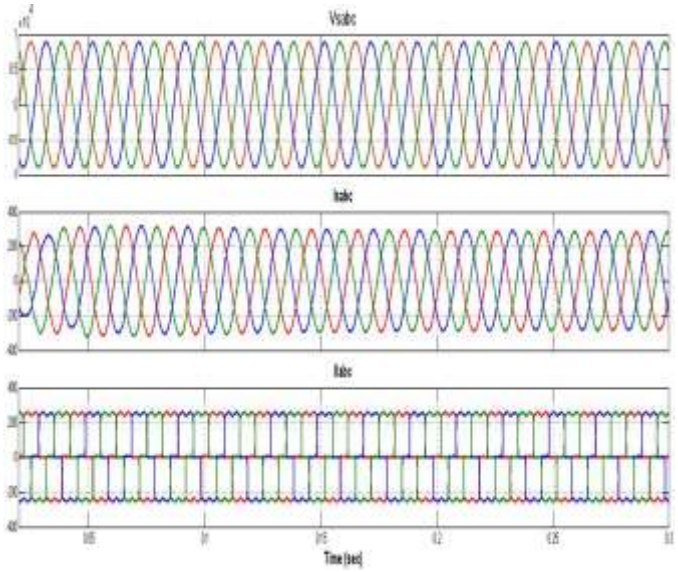

Figure. 14 (a) Source side Voltage (Vsabc), (b) Source side Current (Isabc), (c) Load side Current (Ilabc)

As above Figure. 14 shows the source side voltage, source side current, load side current, with the presence of 11-level CMC based DSTATCOM behaviour with hybrid OAPOD modulation scheme, in that source side current get pure sinusoidal nature & compensates the reactive power, power factor to be improved due to the act of distributed compensatorat PCC level as well as load current should be harmonic, with non presence of compensation.

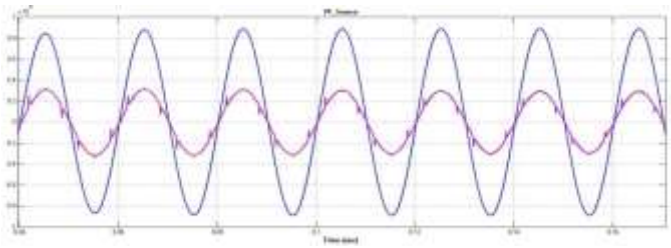

Figure.15 Source side Power Factor with Proposed Distributed Compensator

Figure.15 shows the Source side Power Factor with Proposed Distributed Compensator, both voltage & current

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will be in phase maintained as unity power factor at PCC level.

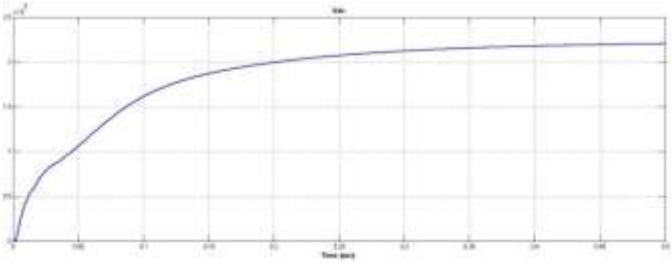

Figure.16 DC Link Voltage

Figure.16 DC Link Voltage of proposed 11-level CMC based Distributed compensator, maintain constant DC link voltage by using magnitude controller.

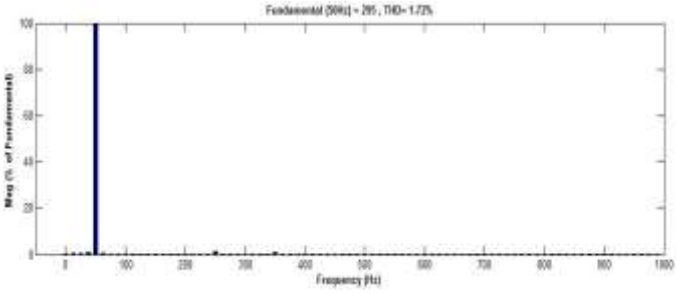

Figure.17 THD for Source Current

Figure.17 shows the THD for Source Current of Cascaded Multilevel Converter (CMC) using OAPOD-PWM (Hybrid APOD Modulation Scheme), THD value is 1.72% application to proposed DSTATCOM topology.

IV. Conclusion

At this time, the proposed a new way of CMC based 11-level DSTATCOM is the updated compensation scheme for very large scale industrial & commercial applications for intensifying the features of power quality with premeditated control circuit for reference currents generation, directly interfaced to modulation schemes for generation of switching pulses to CMC based 11-level DSTATCOM to contradict the harmonic distortions coming from high switching range powersemiconductor devices and should be affirm the load reactive power by using various modulation schemes and also enhancing power quality features entirely in power distribution network. At last assessment is on dynamic evaluation of these circuits done through Matlab/Simulink environment and also simulated results are presented to compare the performance of different PWM schemes have better advantages to be used in real time industrial applications.

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