# Phase Shift Control Scheme of Modular Multilevel DC/DC Converters for HVDC-Based Systems

Shruthi H U[#1],Rupesh K C[#2]
*#1: P G Student Department of Electrical and Electronics, Siddaganga Institute of Technology*
*#2: Asst Professor Department of Electrical and Electronics, Siddaganga Institute of Technology*
*Tumakuru, Karnataka India*

***Abstract***

*Flying capacitor and neutral point clamping TLC combination of phase shift control in multi level DC to Dc converter is used. The multi level DC-DC converter suggests to reduces the high switch voltage stress in the primary side of the circuit. In this proposed circuit low power voltage device can be employed to obtain the low conduction losses. The cascaded modules are used to attain the voltage auto balanced ability in the circuit by using flying capacitor.In this DC-DC converter circuit, we can reduce the switching losses by using Zero - Voltage (ZVS) switching performances for all the active switch can be provided in the Phase - Shift controller scheme.*

*In the primary side,the high switch voltage stress are reduced with the full-bridge modules which are in the sequence(series). The voltage auto- balance ability among the cascaded modules are achieved by adding together with the flying capacitor, which use to removes the additional achievable active control loops. The Zero - Voltage switching performance for all the active switches could be provide because of the phase shift control scheme, hence reduces the switching losses. The high step down ratio is achieved by increasing one more stage/level. Finally the performance of the three level converters is used by increasing one stage also verified the simulations and results expected of 2KW prototype.*

**Keywords** - *Neutral point clamping, TLC Multilevel DC to DC Converter, ZVS performance, phase shift control scheme.*

## I. INTRODUCTION

Modular multilevel converters(MMC) are usually comes from essential of 2 different kinds of converters - High power converters and high output frequency converters with low switching frequencies. For the high power converters which are needed the design should be found on conventional circuits, paralleling of power switches are also considered. But, this option represents a few essential drawbacks- basically parelleling switching devices are highly difficult to apply. As current or voltages shares among the devices which is not an easy assignment. The major purpose for high power converters are mostly centred on power machine drives which is in high and also for grid applications for example high voltage- based systems.

With the dissimilar multilevel topology,the Modular Multilevel Converter has now become a focus of extreme investigation. Even it shares the interesting property of additional multilevel designs, it may offer some remarkable & valuable elements. Thus nowadays the Modular Multilevel Converter has became a research subjects. Although its of advantage, the controling of MMC has became a tough task.Therfore of its facts it is not a matured technology & also there is no universal contract about this classification, control strategies. By the systematization of the MMC with the capacitor filters will be the main target of this proposal.

### *A. DC/DC Converters*

DC to DC converters are an electronic circuitary device which converts direct current to another. It is one of the power converter whose power varies as of low to high.

### *B. Uses of DC to DC converter*

DC/DC converters are used in portable devices such as cellular phones & laptops,the power supplies which is powered by batteries. Electronic device comprises the various sub circuits where each circuit has its own requirement in terms of voltage level which is either supplied by external supply or battery.

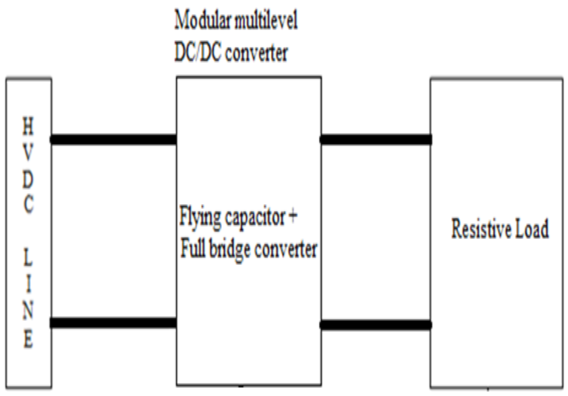
DC/DC converter is mainly used for the regulation of output voltage with their certain exceptions such as high efficiency.LED source converter are regulates the current through the LEDs, and easy charge pumps where output voltages is twice or thrice.

Dc to DC converters are able to improvise the energy produce for PhotoVoltaic system and also the wind turbines which are usually termed as power optimizers.

Transformers are designed for the purpose of transfer of voltage to the supply frequency maybe 50 or 60 Hz.

This is more expensive, when eddy current in their core energy starts losses in their windings. Dc/dc converter uses transformers or inductors with its higher frequencies, along with some wound components which are cheaper, smaller, and lighter.

## II. METHODOLOGY




The above diagram shows the methodology of the module with the high Direct current voltage are stepped down to low voltage with the input auto balance ability. To design the MMC, the full bridge converter and flying capacitor are combined and integrated. By employing the phase shift control scheme, the switching losses will be reduced.

## III. SYSTEM DESIGN

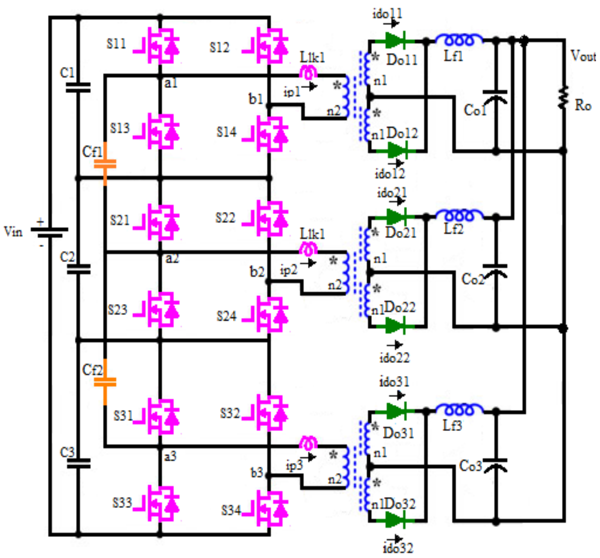



**Fig-1 Circuit diagram of MMC (3 STAGE CONVERTER)**

The 3 stage converter is designed to increase the step down ratio, compared to 2 stage converter here one more stage is increased, this means that three FB Converters are connected in series and also one more flying capacitor is added. For example, for the purpose of simplicity, considered the input voltage as 600V, in 2 stage converters the input voltage is stepped down to 53V. In 3 stage converter, the input voltage is stepped down 26v.

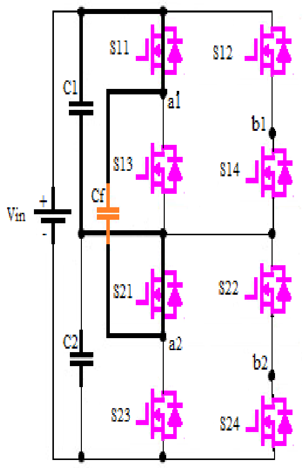
Here the stepped ratio is increased. The operation of the 3 stage converter is similar to 2 stage converter to 26v. Here the stepped ratio is increased. The operation of the 3 stage converter is similar to 2 stage converter.

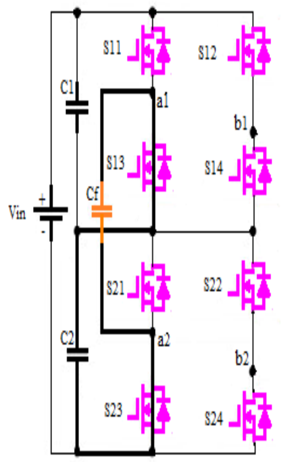
In the secondary side of the derived MMC, the full wave rectifier, full bridge rectifier, current doublers rectifier, and on the other side the higher current type rectifier are to be implemented. Here it is greatly adapted to the full wave rectifier. It is an symbolic to explore the circuit presentation of the projected modular level topology which is shown in the above figure.

### *A. Operation analysis*

**MODE1**: The switches $S_{11}$, $S_{14}$, $S_{21}$, $S_{24}$, $S_{31}$ and $S_{34}$ are turned ON. The flying capacitor $C_1$ is connected in parallel with $C_f$. The capacitor discharges the switch and flows through the transformer and continues the loop through the switch. But in stage 3 the switch $S_{31}$ is turned on after some delay ($0.06T_S$). The primary voltage of the transformers is $V_{in}/2$ and the primary current of the transformers is increases linearly. The switch diodes $D_{o11}$, $D_{o21}$ and $D_{o31}$ are forward biased. **MODE2:** Here, the switches $S_{11}$, $S_{21}$, $S_{31}$ are turned OFF. The capacitors $C_1$, $C_2$, $C_3$ are disconnected from the circuit. The stored energy in the inductor flows to the transformer. The primary current starts to decay and the primary voltage starts decreases gradually. **MODE3:** In this mode, the switches $S_{13}$, $S_{23}$, $S_{33}$ are switched ON. There is no path for the current to flow.Hence both the primary voltage and current will be zero. **MODE4:** In mode 4, the switch $S_{14}$ is turned off. Here, the switch diode of the switch $S_{14}$ conducts, but it becomes reverse biased and also there is no energy in the inductance of the transformer $L_{lk1}$. In this mode also, both primary current and voltage will be zero. **MODE5:** Mode 5 is similar to the Mode 4 and in this mode, the switches $S_{24}$, $S_{34}$ is turned off when after some delay of $S_{24}$ gets turned off. Here also the primary voltage and current of both the transformers is zero. **MODE6:** Here switch $S_{12}$ is turned ON. In this mode $C_2$ is connected in parallel with $C_f$ . The $C_1$ discharges through switch $S_{12}$ and flows through the transformer in reverse direction and continues the switch $S_{13}$ through the loop. The primary voltage across the transformer1 is $-V_{in}$ /2 and the primary current of $T_1$ starts to flow in the negative half cycle. The other 2 bottom converters continues with the previous mode of operation. This means that the primary voltage and current will be zero. **MODE7:** In this mode, switch $S_{22}$ is turned on. Here also, $C_2$ is connected in parallel with $C_f$. The capacitor $C_1$ is discharged with the switch $S_{12}$ and flows through the transformer $T_1$ in reverse direction and continuous the loop through the switch $S_{13}$. The primary voltage of $T_1$ is $-V_{in}$ /2. For 2nd stage, the capacitor $C_2$ is discharged with the switch $S_{22}$ and flows through the transformer $T_2$ in reverse direction and continuous the loop through the switch $S_{23}$. The primary voltage of $T_2$ is $-V_{in}$ /2. For bottom stage, the capacitor $C_3$ is discharged with the switch $S_{32}$ and flows through the transformer $T_3$ in reverse direction and continuous the loop through the switch $S_{33}$. The primary voltage of $T_3$ is $-V_{in}$ /2. **MODE8:** In mode 8, the switches $S_{13,}$ $S_{23}$ and $S_{33}$ are turned to off. In this mode there is no path for current. But both primary voltage and the current of the transformers will be zero.

### *B. Voltage auto-balance mechanism*




C1is parallel with Cf

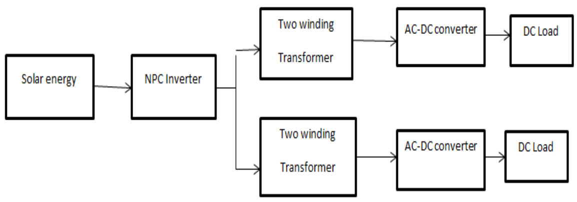
C2 is parallel with Cf

The input voltage of the auto-balance mechanism are used to propose modular multilevel dc to dc converter which is used to display the output and which is as shown in the above figure. The steady operation is future interested in the converter for the leading-leg switches $S_{11,}S_{12}$which is having the same time sequence and the switches $S_{13,}S_{23}$ is operated synchronously.

$V_{Cf}=V_{C1}$

Where switches S11, S21 are turned to the ON, $S_{13}$&$S_{23}$ switches to the OFF. The flying capacitor $C_f$ is connected in parallel with the input capacitor $C_{-1.}$The flying capacitor is used to connect with the lagging leg switches directly with it.The result of the operation on the flying capacitor is hardly affect to the state of the lagging leg switches. The two phase switches angles can be $\phi_1$and$\phi_2$ takes the control of the output voltage.

## IV. BLOCKDIAGRAM




**Block diagram of DC/DC converter**.

The above figure shows the 2 stage converter, in this there are normally three scopes. From the scope 1, the output of the current and voltage can be shown. From the scope2, the switching sequence of all the switches, primary voltage and primary current of the transformer1 and transformer 2 can be shown. In the scope3,the voltage across the input capacitors capacitor C1& C2 can be shown.

## V. SWITCHING SEQUENCE CONSIDERATION

Table-1 Switching sequence considerations.

| | | | | |
|---|---|---|---|---|
| Transformer 1 | $S_{11}$ | $S_{13}$ | $S_{14}$ | $S_{12}$ |
| | 0.75 | 0.25 | 0.95 | 0.45 |
| Transformer 2 | $S_{21}$ | $S_{23}$ | $S_{24}$ | $S_{22}$ |
| | 0.75 | 0.25 | 0.978 | 0.478 |
| Transformer 3 | $S_{31}$ | $S_{33}$ | $S_{34}$ | $S_{32}$ |
| | 0.75 | 0.25 | 0.006 | 0.506 |

## VI. PARAMETERS FOR DESIGN

Table-2 Shows the components list to design. Components are selected based on the requirements. Transformer, Diodes and MOSFETs are taken based on the requirements. The transformer turns ratio of primary, secondary and tertiary windings are selected.

### *A. Simulation parameters*

| COMPONENTS | PARAMETERS |
|---|---|
| Input voltage | 600V |
| Output voltage | 48V |
| Switching frequency | 100kHz |
| Max output power | 2000W |

**Table-2 List of simulation parameters.**

## VII.SIMULATION & RESULTS

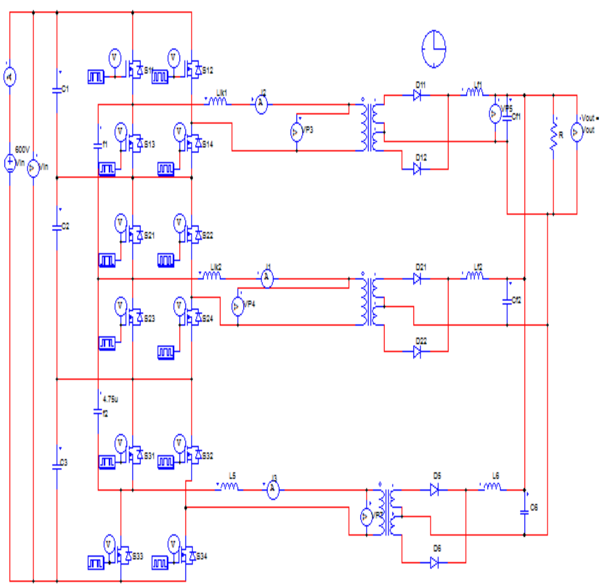


**Fig-3 Circuit diagram with and without Cf**

The 3 stage converter is designed to increase the step down ratio, compared to 2 stage converter here one more stage is increased, this means that three FB Converters are connected in series and also one more flying capacitor is added. For example, for the purpose of simplicity, considered the input voltage as 600V, in 2 stage converters the input voltage is stepped down to 53V. In 3 stage converter, the input voltage is stepped down to 26v. Here the stepped ratio is increased. The operation of the 3 stage converter is similar to 2 stage converter.

## VIII. INPUT WAVEFORMS

- WITH FILTER:

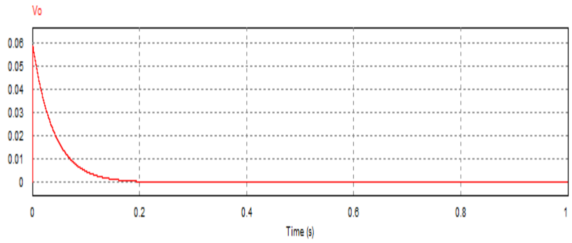



**Fig-3.1 Input waveform with Cf**

- WITHOUT FILTER:

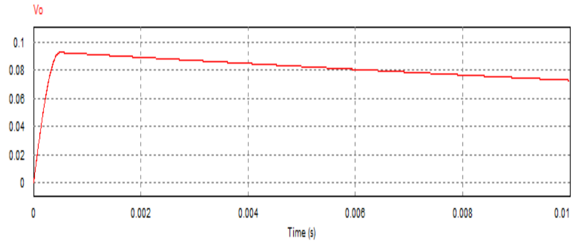



**Fig-3.2 shows that the input waveform without Cf**

After adding the Cf filter, harmonics get reduced. From the observation we came to knew that the reduction in harmonic level in the input side. But theoretical calculation will do in the future and working on it.

## IX. OUTPUT WAVEFORMS

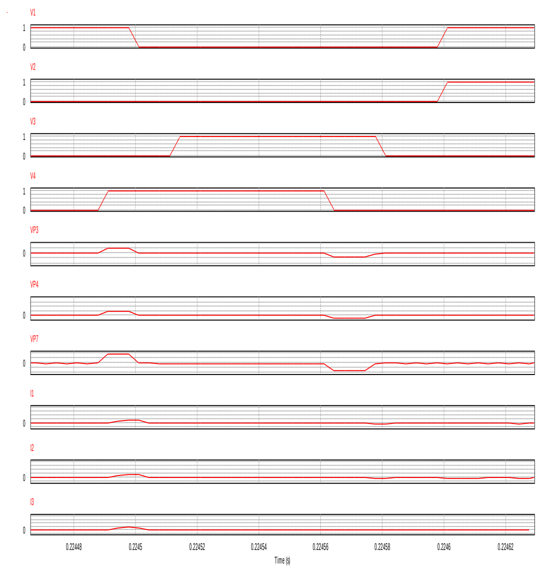


**Fig: 4 output waveforms of switches, voltages, current**

## X. CONCLUSION AND FUTURE WORK

In this work, the MMC based DC to DC converters are proposed for the HVDC systems. Because of the flying capacitor, it connects among the input capacitors alternatively. This leads to sharing of voltage automatically and balancing without any additional power components and control loops. As a result, the voltage stress across the switches are reduced, also the reliability of circuit is improved.

In addition to this high step down ratio is achieved by increasing one more stage. Compared to the 2 stage converter step down ratio is increased in 3 stage converter. This system is suitable for high power dc based applications and also used for high step down applications.

The MMC based DC to DC converter technique would be further extended to N number of stages with a load. The full-bridge modules are maintains, with the dreadfully high voltage applications.

## REFERENCES

[1] H.Kakigano, Y. Miura and T.Ise "Low-Voltage Bipolar-Type DC Micro-grid for Super High Quality Distribution," IEEE Trans. Power Electron, Dec 2010.

[2] S.Anand and B. G. Fernandes "Reduced-Order Model and Stability Analysis of Low-Voltage DC Micro grid," IEEE Trans. Ind. Electron,Nov 2013.

[3] S.Anand and B. G. Fernandes, "Optimal voltage level for DC microgrids," IEEE Conf. Ind. Electron (IECON), 2010.

[4] D.Salomonsson, L.Soder and A.Sannino, "An Adaptive Control System for a DC Microgrid for Data Centers," IEEE Trans. Ind. Appl Nov./Dec. 2008.

[5] K.B.Park, G. W. Moon and M. J. Youn, "Series-Input Series-Rectifier Interleaved Forward Converter With a Common Transformer Reset Circuit for High-Input-Voltage Applications," IEEE Trans. Power Electron Nov 2011.

[6] T.Qain and B. Lehman,"Coupled Input-Series and Output-Parallel Dual Interleaved Flyback Converter for High Input Voltage Application," IEEE Trans. Power Electron, Jan 2008.

[7] C.H.Chien,Y.H.Wang,B.R.Lin&C.H.Liu,"Implementation of an interleaved resonant converter for high- voltage applications," in Proc. IET Power Electron., vol. 5, No. 4, pp. 447-455, Apr 2012.