

Switched Capacitor Inverter Using Series/Parallel Conversion in Open Loop with Active Filter

Ms. Nishtha Choubisa ¹, Dr. Upendra Prasad ²

M.Tech (Power System) Department of Electrical Engineering B.I.T, Sindri, Dhanbad, Jharkhand, India ¹

Head of Department of Electrical Engineering B.I.T, Sindri, Dhanbad (Jharkhand) India ²

ABSTRACT: This paper introduces a new switched capacitor inverter topology. In this type of switched capacitor topology with the help of capacitors output voltage is greater than input voltage. Whenever the capacitors get connected in parallel, these are charged and when these are connected in series it discharges. This phenomenon is similar to charge pump. By increasing the no of capacitors output voltage magnitude also increases i.e. output voltage magnitude depends on number of capacitors. In prevailing time with inverter boost converters were there to increase the output magnitude; this type of circuitry requires inductor which also makes our system bulky. But in this type of topology no inductor is used thus it is smaller than the conventional. It produces lesser harmonics than previous one and with the help of active filter again its harmonics are reduced. The circuit configuration and simulation work with result is shown in this paper. Simulation is done with MATLAB software (R2010a).

KEYWORDS: switched capacitor, multicarrier PWM, active filters, charge pump.

I. INTRODUCTION

The current energy scenario is changing. With the increase of cost and depleting nature of fossil fuels electrical engineers are moving towards non conventional energy sources. With the commercialization of non-conventional sources advanced power electronics and motor drives will have already established themselves as prime components of advanced systems. Power electronics is the heart of recent dispersed systems [1]. With the invention of thyristor (silicon controlled rectifier) which was the first solid state device, power electronic demand has increased. Today almost all area uses power electronic devices for power flow control and to increase efficiency. Today automotive market is fastly making developments in case of the hybrid electric vehicles (HEVs). Commercially available HEV include the Toyota Prius, Toyota Highlander Hybrid, Toyota Camry Hybrid, Lexus RX 400 h, Honda Insight, Honda Civic Hybrid, Honda Accord Hybrid, and Ford Escape Hybrid [2]. In all these systems an inverter is required to convert dc into ac. But in most of cases input voltage is lower than output voltage so we use boost converter (in case of dc) or transformer (in case of ac) for increasing the voltage. All these require inductors in its circuitry for its working and transformer demands heavy and large magnetic cores for producing their working flux. So instead of all these charge pumps were used, which gives higher output voltage than input voltage with the help of switched capacitor.[3]-[6].

When capacitors are connected in parallel with voltage source it charges whereas when it is connected in series with supply it discharges. The sum of voltage of input source and voltage across capacitor is given by charge pump. But charge pump is not much used as it has very complex circuit as it has so many switching devices. So switched-capacitor inverter is used which generates multilevel voltage with switching capacitors in series or parallel. Working topology of switched capacitor and charge pump are same in nature.

In this paper switched capacitor inverter whose structure is simpler than conventional one has been proposed. It consists of Marx inverter structure and H-bridge. The sc inverter has more switching devices than Marx structure.

By switching capacitors in series or parallel this proposed inverter has more output voltage than the input voltage; with this multilevel type of output harmonics are also reduced. Multicarrier PWM technique is used to drive the system. Simulation work and circuit description is also presented in next section of this paper.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Active filters are used in conjunction with sc inverter in proposed paper, which reduces the harmonics of the output wave and improves the performance of the sc inverter and also avoid the need of inductors. With the help of power semiconductor devices performance of active filters have been increased. On the techniques of generation of reference current active filters working depend. Active filter compensates current harmonics. The compensation of current harmonics is done by generating a compensating current with 180 degree phase opposition and injects it back to the line so as to cancel out the current harmonics introduced by the nonlinear load.[7]

II. RELATED WORK

For increasing the voltage magnitude previously charge pump were introduced. Charge pumps are nothing but circuits that generate output voltage higher than input one. Charge pump also consists of source and capacitors for generating higher voltages[12].With the advances of power electronics devices multilevel converter topologies came into picture for generating more levels with high output voltage. In this series cascaded hybrid inverter firstly came in which inverter uses several H-bridge connected in series to provide output sinusoidal voltage. But it has more voltage stress on device and more dc sources so diode clamped multilevel inverter came into picture which uses clamping diodes to limit voltage stress on devices. In these series flying capacitors MLI also came into existence for getting higher levels and to overcome the disadvantages of all other MLI. Multilevel inverters using series/ parallel dc voltage sources was also used for getting high multilevel voltage but it was having so many switches and elements so switched capacitor inverter using series/parallel came for overcoming all disadvantages.

III. CIRCUIT DESCRIPTION

The circuit topology of the proposed SC inverter for 7 level is as shown in fig.

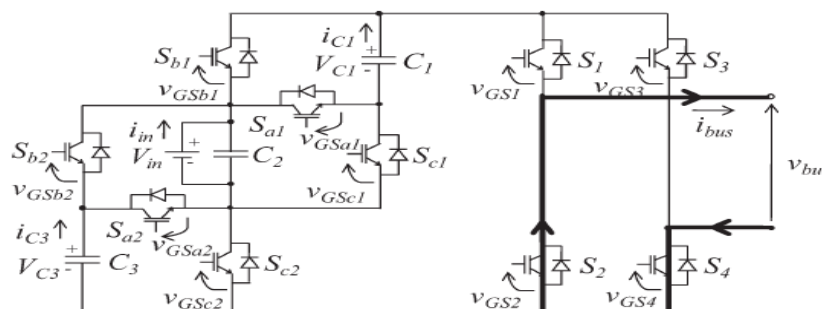


Fig:1. Circuit topology of the switched capacitor inverter using series parallel conversion

In the circuits of SC inverter 10 switches are there, which are less than conventional multilevel inverter of same level which has 12 switches. In this circuit switches S1 to S4 are in H-bridge mode. Vin is the input voltage source. Remaining switches (Sa1 Sa2 Sb1 Sb2 Sc1 Sc2) are switched with their own gate drive circuitry to switch the capacitors in series or parallel.[2]

III. CONTROL STRATEGY

In this paper multilevel PWM is used for the proposed inverter. In this technique high frequency carrier wave which is triangular wave for proposed inverter is compared with low frequency reference wave which is sine wave for proposed inverter and in accordance trigger pulse is generated which is used to drive the system. The block diagram of the control circuit for proposed concept is shown in fig 2.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

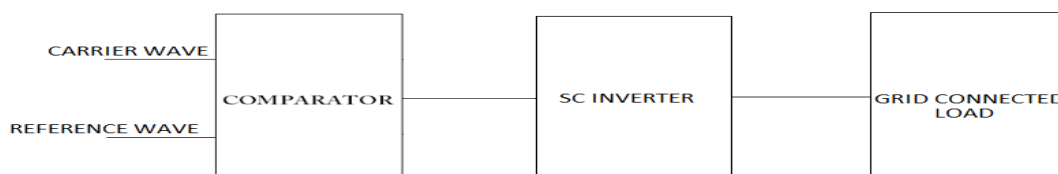


Fig:2. Block diagram of the control circuit of proposed inverter

Fig 3 shows the modulation method for the proposed inverter. When the time is between 0 and t_1 ($0 < t < t_1$) the switches S1 and S2 are driven by their own gate to source voltage V_{gs1} and V_{gs2} , respectively. Switch S1 and S2 can never be turned on simultaneously. The other switches are maintained on or off while S1 and S2 are switched alternatively. List of on state switches of proposed inverter when driven by above strategy is shown in Table I. When time is between t_1 and t_2 ($t_1 < t < t_2$) the gate to source voltage V_{gsa1} , V_{gsb1} , V_{gsc1} drives the switches Sa1, Sb1, Sc1, respectively, at this time capacitor C_1 is charged. Therefore proposed inverter gives output V_{bus} while the capacitor is charged. When the time is between t_2 and t_3 ($t_2 < t < t_3$) the switches Sa2, Sb2, Sc2 are driven by their own gate to source voltage which are V_{gsa2} , V_{gsb2} , V_{gsc2} respectively.[8]

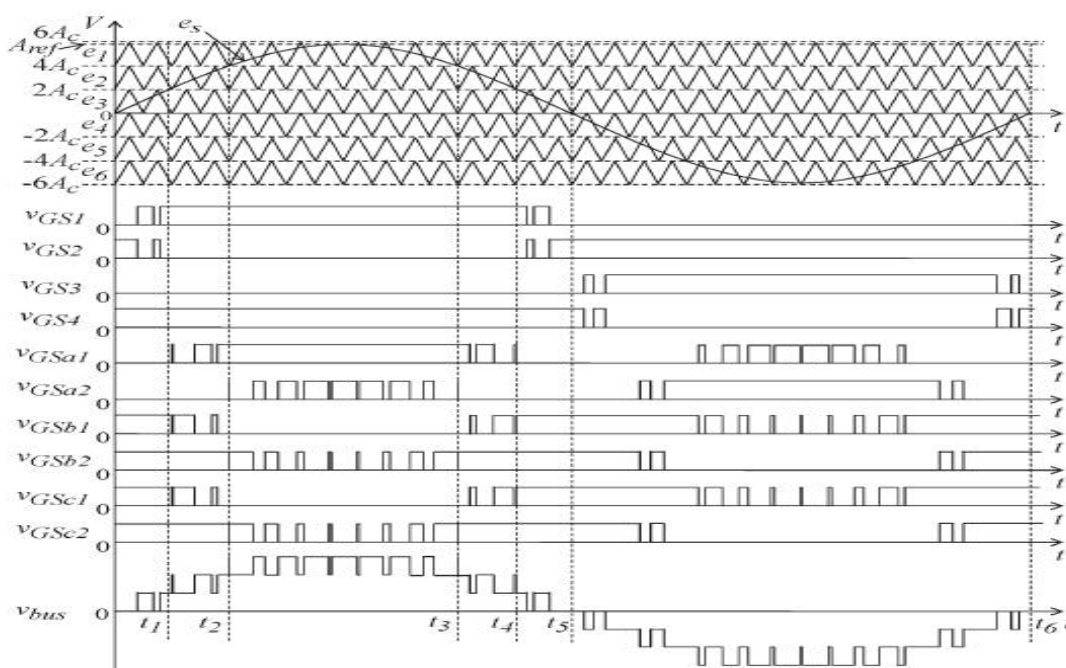


Fig:3. Modulation method of proposed inverter

The above four stages of proposed inverter repeats and thus we get 7 level output.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

TABLE I: LIST OF THE ON STATE SWITCHES IN EACH STAGE

Relationship between e_p and e_k	On –state switches	Ideal bus voltage V_{bus}
$e_1 \vee e_2 \vee e_3$	S_1, S_4, S_{a1}, S_{a2}	$3V_{in}$
$e_1 \vee e_2 \vee e_3 \vee e_4$	$S_1, S_4, S_{a1}, S_{b2}, S_{c2}$	$2V_{in}$
$e_2 \vee e_3 \vee e_4$	$S_1, S_4, S_{b1}, S_{c1}, S_{b2}, S_{c2}$	V_{in}
$e_3 \vee e_4 \vee e_5$	$S_2, S_4, S_{b1}, S_{c1}, S_{b2}, S_{c2}$	0
$e_4 \vee e_5 \vee e_6$	$S_2, S_3, S_{b1}, S_{c1}, S_{b2}, S_{c2}$	$-V_{in}$
$e_5 \vee e_6 \vee e_7$	$S_2, S_3, S_{b1}, S_{c1}, S_{a2}$	$-2V_{in}$
$e_6 \vee e_7$	S_2, S_3, S_{a1}, S_{a2}	$-3V_{in}$

IV. SIMULATION AND RESULTS

Simulation is done with two different types of filter.

- 1) Passive filter
- 2) Active filter

Both filters give fewer harmonic compared to without filter. But active filter produces fewest harmonics. So it has been observed from simulation result that the proposed sc inverter produces fewest harmonics with shunt active filter.

Passive filter: simulation circuit of proposed sc inverter with passive filter is shown in fig:4.

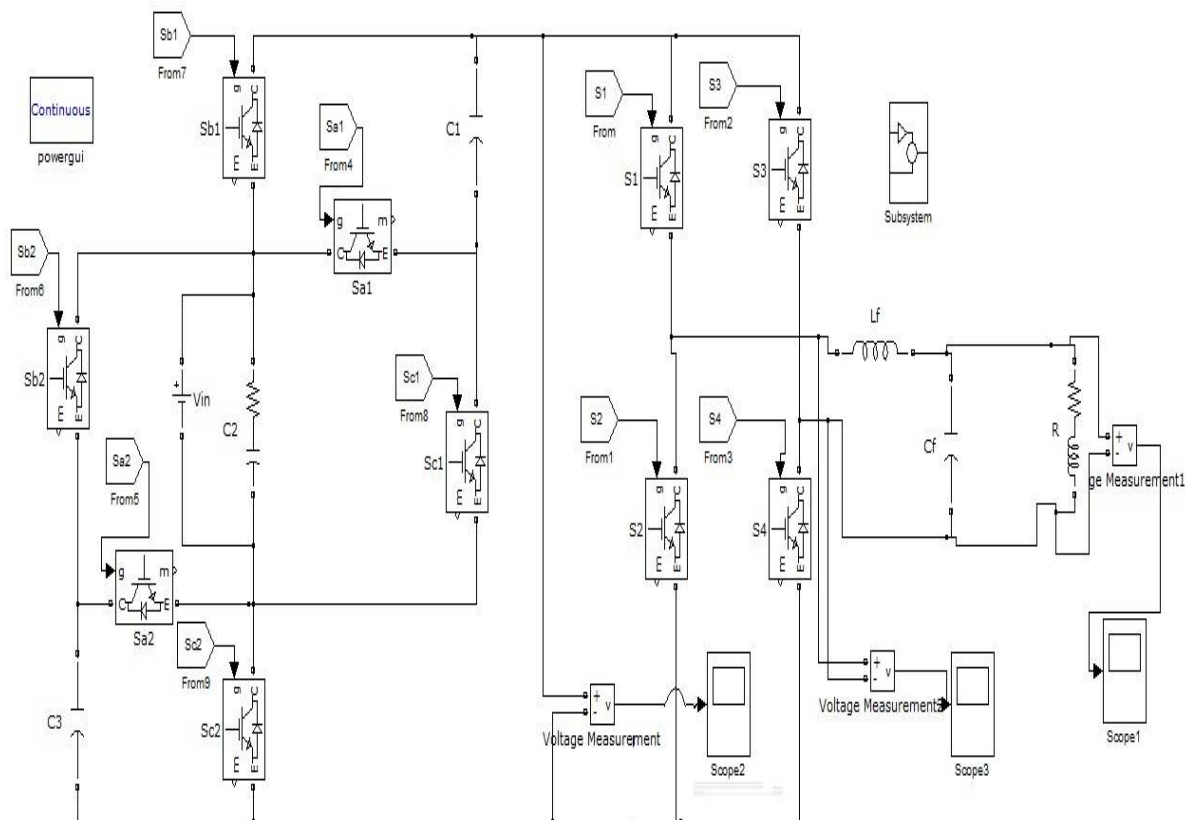


Fig:4. simulink model of proposed sc inverter with passive filter

Bus voltage waveform before filter is shown in fig:5. As

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

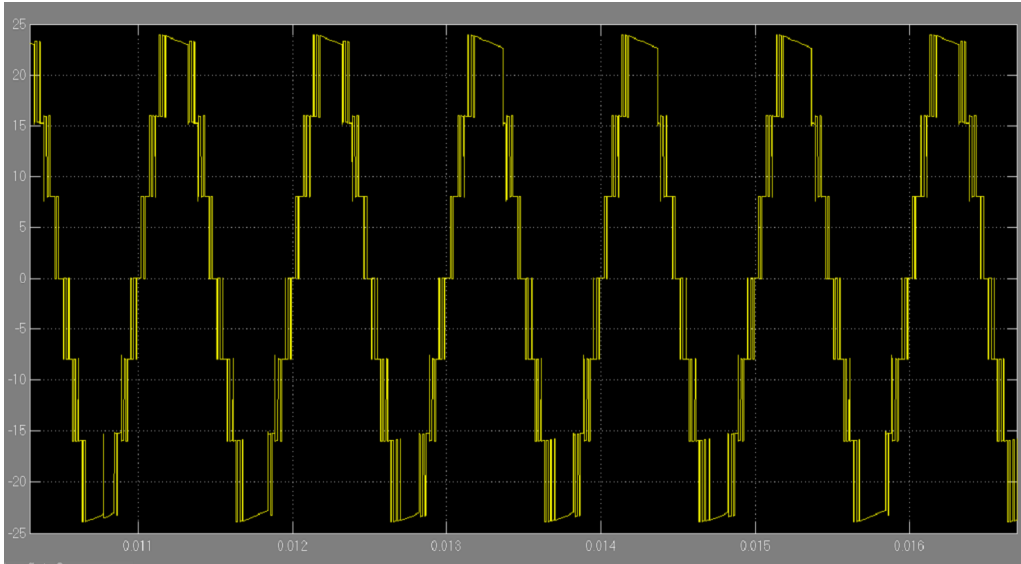


Fig:5. bus voltage before filter

The above waveform indicates the 7 level(multilevel) with higher magnitude than input voltage. If we apply this wave to passive filters to this wave it will look like as shown in fig 6

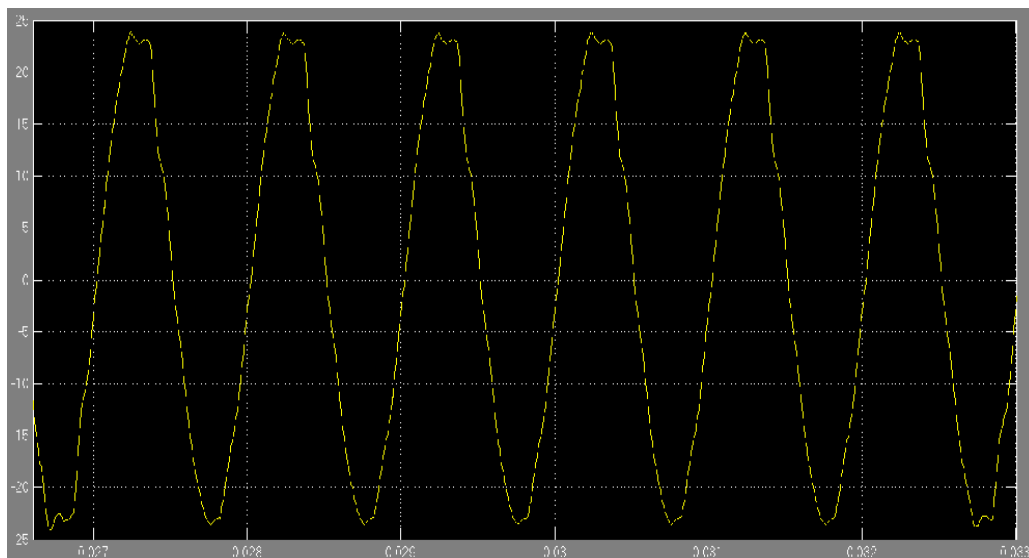


Fig:6. bus voltage after passive filter

To know the THD of the above waveforms FFT analysis has been done which shows following results.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

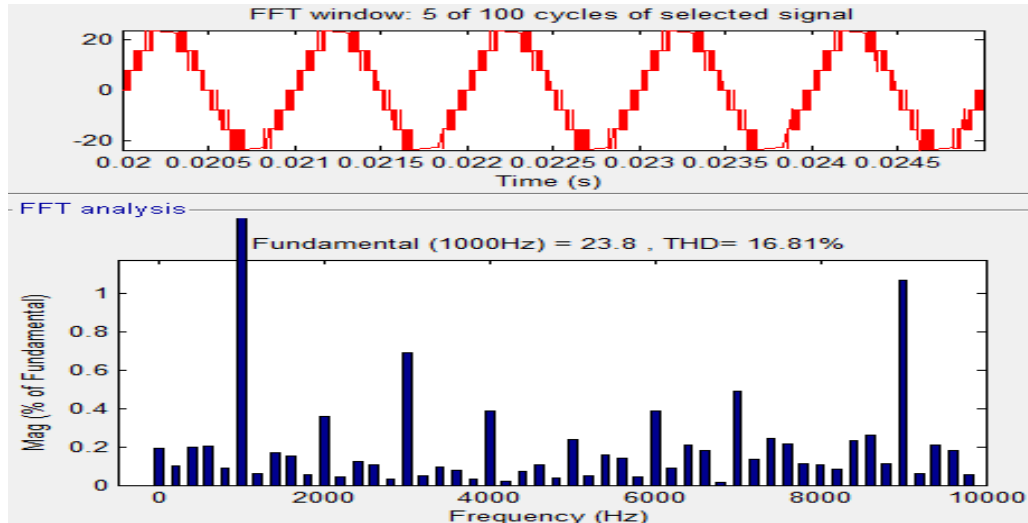


Fig:7. THD before filter

Without filter the harmonics content was very high which is 16.81% but with passive filter these harmonics are reduced to 2.46% which is shown in fig 8

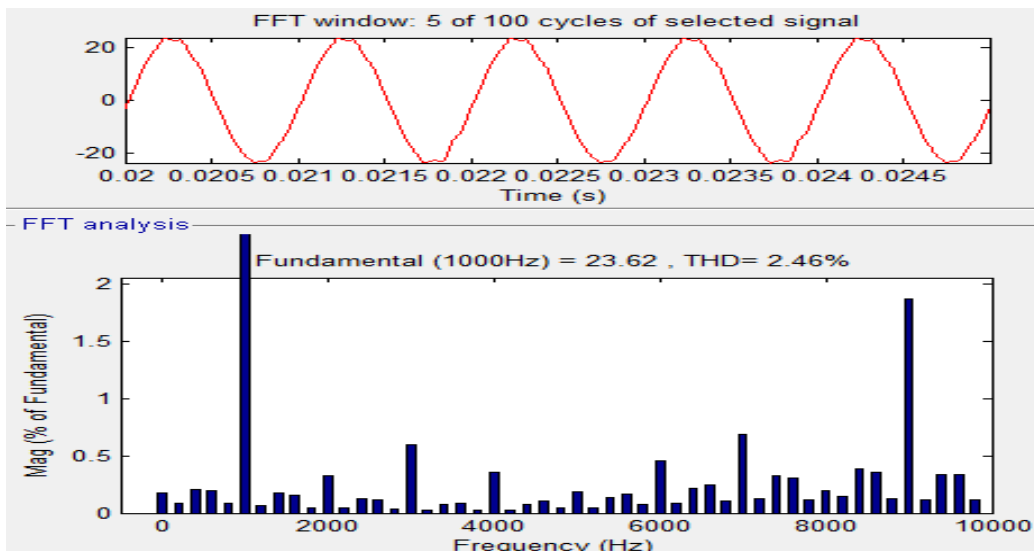


Fig:8. THD after passive filter

The simulink model of proposed sc inverter with passive filter is shown fig:4. and resultant waveforms and FFT analysis is shown from fig:5. to fig:8.

Active filter: with active filter proposed inverter simulink model is shown in fig:9.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

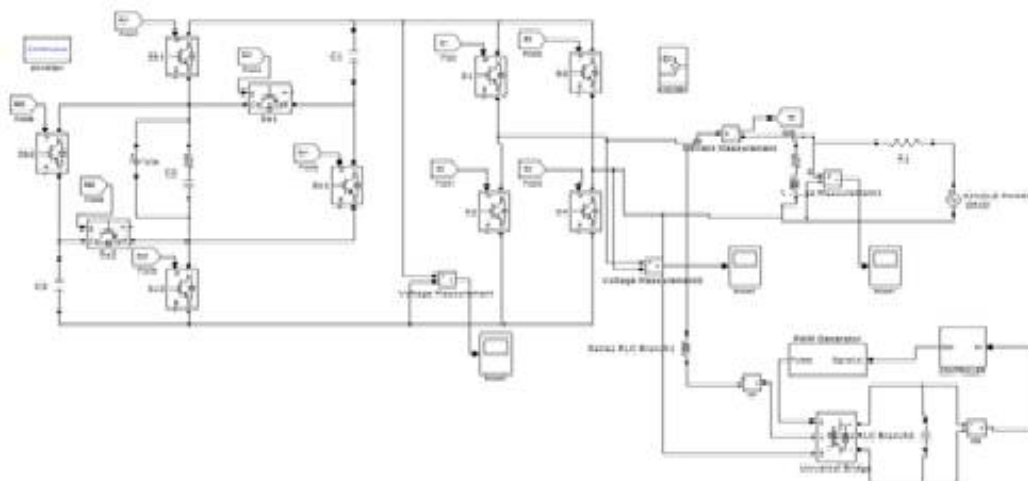


Fig:9. proposed concept with active filter

Output voltage waveform and THD without filter will be same as before only wave after filter and THD after active filter only changes which is shown in figure 10 and fig 11.

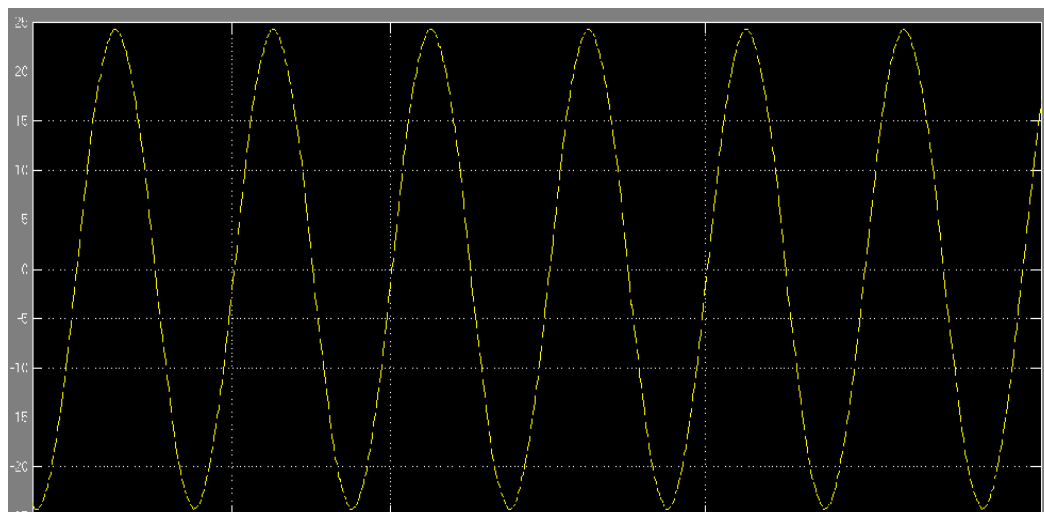


Fig:10. bus voltage after active filter

With the help of active filter the waveform quality again has been increased and harmonic contents get reduced, which are .38%. as shown in figure 11

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

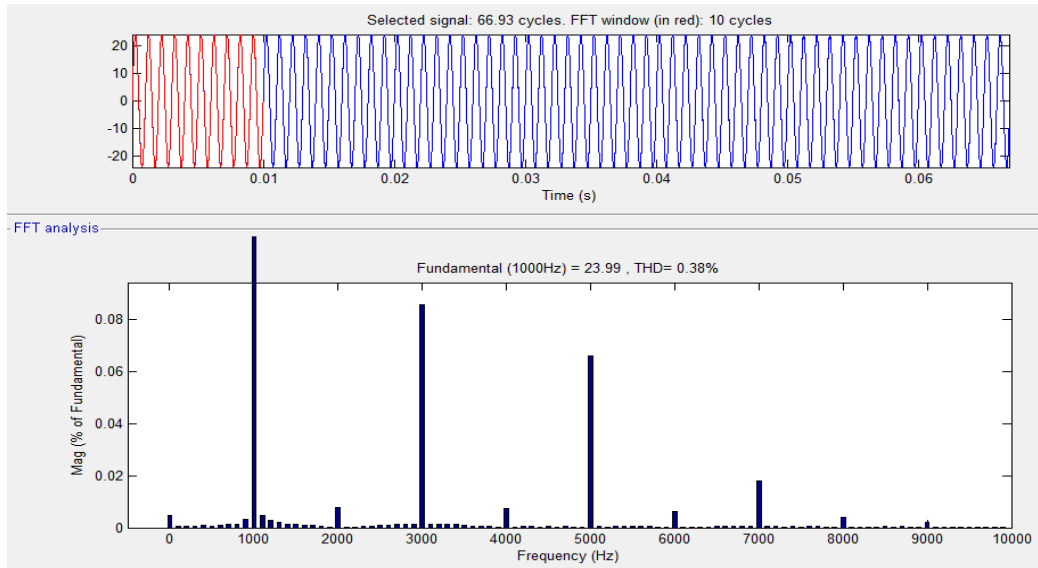


Fig:11. THD after active filter

From simulation results it has been observed that proposed sc inverter has 16.81% THD without filter and 2.46% THD with passive filter and .38% active filter which clearly shows that output harmonics are reduced with active filter.

V. CONCLUSION

This paper has presented novel switched capacitor without inductors. It has output voltage larger than the input voltage by switching the capacitors in series or parallel. With the simulation work circuit model has been confirmed. From simulation work it is observed that proposed inverter is suitable with stand alone load (resistive and inductive) and grid connected load. It also gives lesser harmonics compared to conventional one and with use of different filters & its harmonics are again reduced which is given in TABLE II.

TABLE II. different filters & its harmonics are shown in tabular form

Sr. no.	Configuration	THD
1	Sc inverter without filter	16.81%
2	Sc inverter with passive filter	2.46%
3	Sc inverter with active filter	0.38

REFERENCES

- [1] L. G. Franquelo, J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, and M. A. M. Prats, "The age of multilevel converters arrives," IEEE Ind. Electron. Mag., vol. 2, no. 2, pp. 28–39, Jun. 2008.
- [2] A. Emadi, S. S. Williamson, and A. Khaligh, "Power electronics intensive solutions for advanced electric, hybrid electric, and fuel cell vehicular power systems," IEEE Trans. Power Electron., vol. 21, no. 3, pp. 567–577, May 2006.
- [3] H. Liu, L. M. Tolbert, S. Khomfoi, B. Ozpineci, and Z. Du, "Hybrid cascaded multilevel inverter with PWM control method," in Proc. IEEE Power Electron. Spec. Conf., Jun. 2008, pp. 162–166.
- [4] Y. Hinago and H. Koizumi, "A single phase multilevel inverter using switched series/parallel DC voltage sources," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2643–2650, Aug. 2010.
- [5] S. Chandrasekaran and L. U. Gokdere, "Integrated magnetic forinter leaved DC–DC boost converter for fuel cell powered vehicles," in Proc. IEEE Power Electron. Spec. Conf., Jun. 2004, pp. 356–361.
- [6] Y. Hinago and H. Koizumi, "A single phase multilevel inverter using series/parallel conversion," in Proc. IEEE Int. Symp. Circuits Syst., May/Jun. 2010, pp. 3188–3191.
- [7] "Wikipedia the free encyclopedia"

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

- [8] Y. Hinago and H. Koizumi, "A switched-capacitor inverter using series/parallel conversion," in Proc. IEEE Int. Symp. Circuits Syst., May/Jun.2010, pp. 3188–3191.
- [9] J. Zhang, Y. Zou, X. Zhang, and K. Ding, "Study on a modified multilevel cascade inverter with hybrid modulation," in Proc. IEEE Power Electron. Drive Syst., Oct. 2001, pp. 379–383
- [10] X. Kou, K. A. Corzine, and Y. L. Familiant, "A unique fault-tolerant design for flying capacitor multilevel inverter," *IEEE Trans. Power Electron.*, vol. 19, no. 4, pp. 979–987, Jul. 2004.
- [11] O. C.Mak and A. Ioinovici, "Switched-capacitor inverter with high power density and enhanced regulation capability," *IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.*, vol. 45, no. 4, pp. 336–347, Apr. 1998
- [12] M. R. Hoque, T. Ahmad, T. R. McNutt, H. A. Mantooth, and M. M. Mojarradi, "A technique to increase the efficiency of high-voltage charge pumps," *IEEE Trans. Circuits Syst. II, Exp. Briefs*, vol. 53, no. 5, pp. 364–368, May 2006