ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

27- Level inverter using Multi-Tapped Multi - Winding transformer with single input DC source

Dr.P.Suresh Pandiarajan
Assistant Professor, Department of Electronics and communication Engineering
P.S.R. Engineering College ,Sivakasi,Tamil nadu, India
e-mail: p.sureshpandiarajan@gmail.com
P. Tamilnesan
Assistant Professor, Department of Electrical and Electronics Engineering
Kongunadu college of Engineering and Technology,Tiruchirapalli,Tamilnadu,India.
e-mail: tamilnesaner@gmail.com
K.Karthik
Assistant Professor, Department of Electrical and Electronics Engineering
Kongunadu college of Engineering and Technology,Tiruchirapalli,Tamilnadu,India.
e-mail: karthikk@kongunnadu.ac.in
Dr.SP.Umayal
Professor, Department of Electrical and Electronics Engineering
PSN college of Engineering and Technology,Tirunelveli,Tamilnadu,India.
corresponding author e-mail:umayalbabu@gmail.com

Abstract:

To achieve a high quality of AC sinusoidal waveform by using inverter bridges with multi- winding multi-tapped transformer to eliminate the drawbacks in conventional techniques like unbalance in capacitor voltage, common mode voltage, stress on load and use of filters at output to minimize harmonics. This topology can generate 27 levels of voltage by addition and subtraction of transformer core magnetic flux in selective manner by using three full bridge diode rectifiers and eight switches. The performance of the proposed topology is verified with simulation and prototype results.

Keywords: Multi tapped transformer, multi winding transformer, Multilevel inverter, total harmonic distortion, common mode voltage.

1. INTRODUCTION

Increased demand for low harmonic distortion AC supplies with high power rating is needed in recent years. Multi level inverters normally make use of capacitor voltage sources and power electronic switches. MLI can generate high power low harmonic distortion AC power. By controlling the switching devices MLI generates stepped output voltage with less harmonic distortion [1,2]. Voltage stress across the switches can be reduced by series connection of converter module. Recently power conversion systems use multi level inverter due to its application in high power such as renewable energy converters, flexible AC transmission system, motor drives and device to improve power quality [3-8]. Depending on application MLI can operate both at high frequency and fundamental switching frequency. Reduced switching losses, small common mode voltage, low dv/dt stress on switches and better harmonic spectrum are other advantages of multi level inverters which increases its application. There are three commonly used topologies of multi level inverter. They are diode clamped, cascaded H bridge and flying capacitor. Diode clamped[9] is simple topology but the increase in level will quadratically increase the number of clamping diodes which are used for limiting voltage and reduce voltage stress across switches. Voltage unbalance and unequal current stress are the drawbacks of this topology. Due to more switches control of real, reactive power flow becomes complicated. In cascaded H bridge inverter [10-12] to get the desired output many H bridges are connected in series. The number of components is reduced but requires more number of separate DC sources which makes system costly. Switching losses can be reduced by soft switching techniques but reactive power control is complex. In flying capacitor topology clamping diodes are replaced by capacitor. This provides real and reactive power support but control circuit is complex and number of capacitor increase with increase in level which makes circuit bulkier and expensive. Pre charging of capacitor to the required voltage and start up is difficult. Neutral point voltage variations cause problems in multilevel inverter. A new topology of multi level inverter which makes use of multi-tapped multi-winding

transformer with single DC source and less number of switches to generate AC sinusoidal waveform is proposed in this work. A staircase waveform with low harmonic distortion can be generated by increasing the level in MLI. But this increases the number of switching devices, gate pulses and other passive elements. Voltage imbalance problem and control complexity increases with increase in number of level. The proposed topology eliminates these drawbacks. High frequency converters can use tapped transformers for smooth source voltage variations [13-15]. Isolated output voltages obtained from secondary tapped transformers can be used in high frequency power converters. Taps present in secondary can provide continuous output voltages. By adding or subtracting instantaneous voltage generated from various taps we can obtain continuous output voltages. Desired output voltage can be got by regulating the taps individually. According to variation in duty cycle and source voltage, secondary tap voltage varies between minimum and maximum limit.

2. WORKING OF THE CIRCUIT

Fig.1. shows a 27 level multilevel inverter with multi-tapped multi-winding transformer. The circuit has two inverter stages. Multiple DC level are obtained at the secondary tapping from single input DC source with first stage inverter. First and second stage inverters are interfaced with full bridge diode rectifier. Twenty seven output voltage levels are synthesized from single DC input by selective addition and subtraction of magnetic flux in transformer core. The full bridge rectifier at the interface acts as separate DC input source for second stage inverter. Diodes and capacitors serves two function in the circuit. Diodes help in rectification and freewheeling. Switching spikes are eliminated by freewheeling diode. Capacitor helps to filter the first stage DC output and it serves as DC link for second stage. This minimizes the voltage unbalance problem in the circuit. The controller regulates the output by generating compensating gating pulses for the switches.

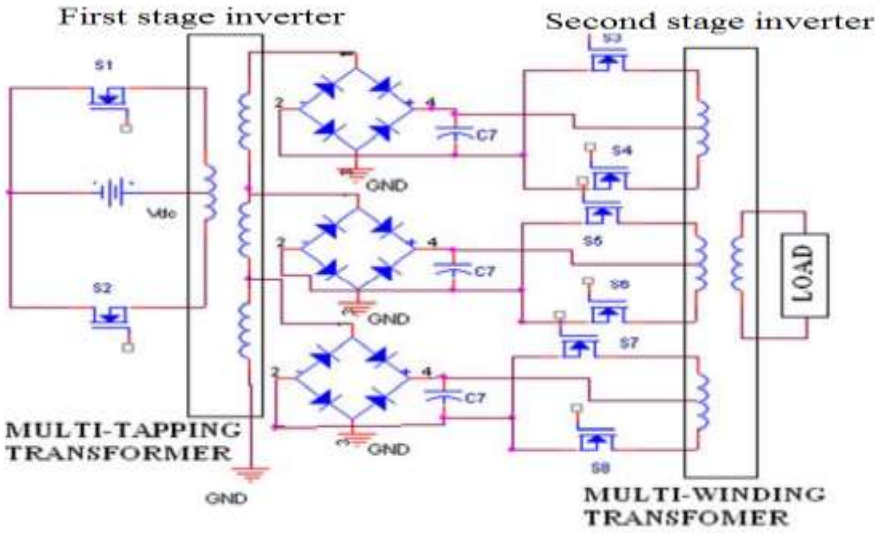

Fig.1.Circuit Diagram

TABLE 1 Switching states of the switches

Switches ON/OFF states						**Output voltage**
+1V	**-1V**	**+3V**	**-3V**	**+9V**	**-9V**	**TRINARY LOGIC**
S_3	S_4	S_5	S_6	S_7	S_8	VOLTAGE LEVEL (V)
OFF	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	0
ON	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	1
OFF	**ON**	**ON**	**OFF**	**OFF**	**OFF**	2
OFF	**OFF**	**ON**	**OFF**	**OFF**	**OFF**	3
ON	**OFF**	**ON**	**OFF**	**OFF**	**OFF**	4

OFF	**ON**	**OFF**	**ON**	**ON**	**OFF**	5
OFF	**OFF**	**OFF**	**ON**	**ON**	**OFF**	6
ON	**OFF**	**OFF**	**ON**	**ON**	**OFF**	7
OFF	**ON**	**OFF**	**OFF**	**ON**	**OFF**	8
OFF	**OFF**	**OFF**	**OFF**	**ON**	**OFF**	9
ON	**OFF**	**OFF**	**OFF**	**ON**	**OFF**	10
OFF	**ON**	**ON**	**OFF**	**ON**	**OFF**	11
OFF	**OFF**	**ON**	**OFF**	**ON**	**OFF**	12
ON	**OFF**	**ON**	**OFF**	**ON**	**OFF**	13
OFF	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	0
OFF	**ON**	**OFF**	**OFF**	**OFF**	**OFF**	-1
ON	**OFF**	**OFF**	**ON**	**OFF**	**OFF**	-2
OFF	**OFF**	**OFF**	**ON**	**OFF**	**OFF**	-3
OFF	**ON**	**OFF**	**ON**	**OFF**	**OFF**	-4
ON	**OFF**	**ON**	**OFF**	**OFF**	**ON**	-5
OFF	**OFF**	**ON**	**OFF**	**OFF**	**ON**	**-6**
OFF	**ON**	**ON**	**OFF**	**OFF**	**ON**	**-7**
ON	**OFF**	**OFF**	**OFF**	**OFF**	**ON**	**-8**
OFF	**OFF**	**OFF**	**OFF**	**OFF**	**ON**	**-9**
OFF	**ON**	**OFF**	**OFF**	**OFF**	**ON**	**-10**
ON	**OFF**	**OFF**	**ON**	**OFF**	**ON**	**-11**
OFF	**OFF**	**OFF**	**ON**	**OFF**	**ON**	**-12**
OFF	**ON**	**OFF**	**ON**	**OFF**	**ON**	**-13**

Even though there are total eight switches in the circuit the output voltage depends on the switching states of six switches present at the input of the second stage inverter. Selecting correct combination of switches will lead to selective addition and subtraction of magnetic flux linked with transformer core of multi tapped transformer. Switching strategy of the proposed system is shown in Table1. Twenty seven output voltage levels are obtained with six switches at the input of the second stage inverter. Proper design of first stage multi tapped transformer helps to achieve output voltage levels of the three rectifier bridges in the ratio of 9:3:1. By selecting different switching combinations various output voltage levels can be obtained as shown in the table 1. The rectifier bridge outputs are combined by multi winding transformer to give smooth sinusoidal output voltage with low harmonics. Another advantage of this topology is the second stage inverter can act as a standalone multi level inverter with isolated multiple DC sources. Renewable power conversion system like solar and wind energy systems with same DC input of 9:3:1 ratio can make use of this topology.

3. SIMULATION CIRCUIT

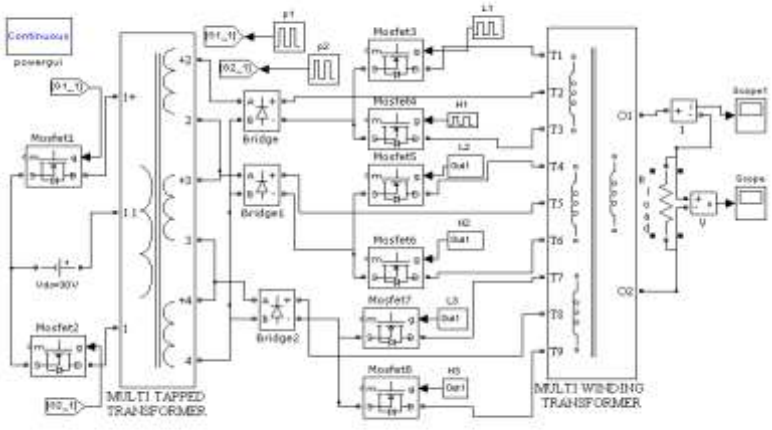

Fig.2. Simulation Circuit

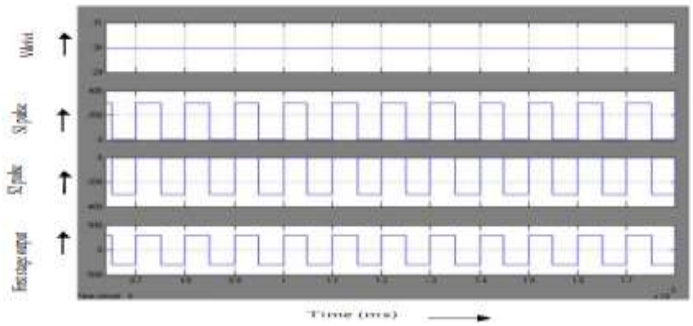

Fig.3.First stage inverter output with its gate pulse and DC input

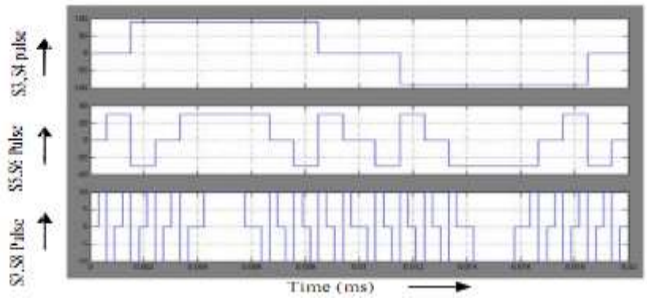

Fig.4.Gate pulse of switches in second stage inverter

Fig.2. shows the simulation circuit of the proposed multilevel inverter. Fig.3 .shows the gate pulse of switch S_1 ,S_2 and first stage inverter output. Fig.4 shows the gate pulse for switches in second stage inverter.Fig.5 shows the rectifier bridge voltage outputs.

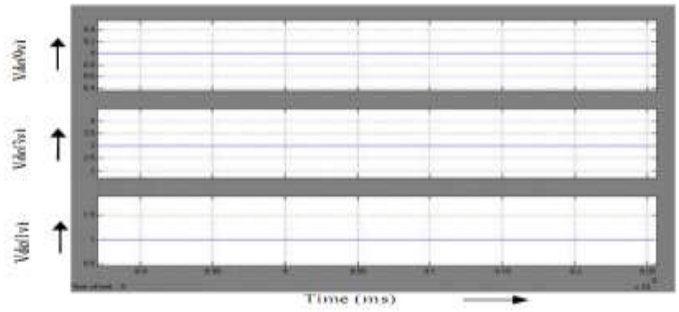

Fig.5.Rectifier bridge output

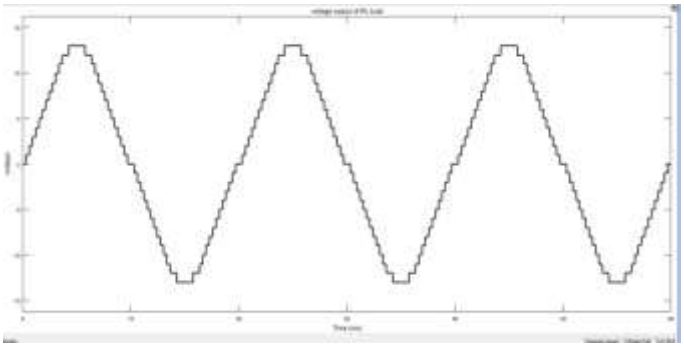

Fig.6.Voltage output across load

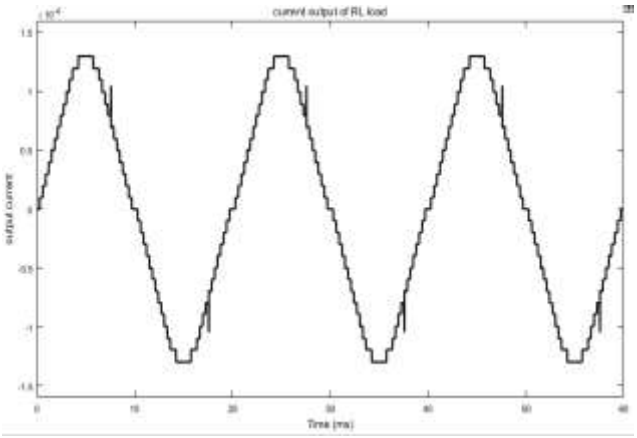

Fig.7.Current output across load

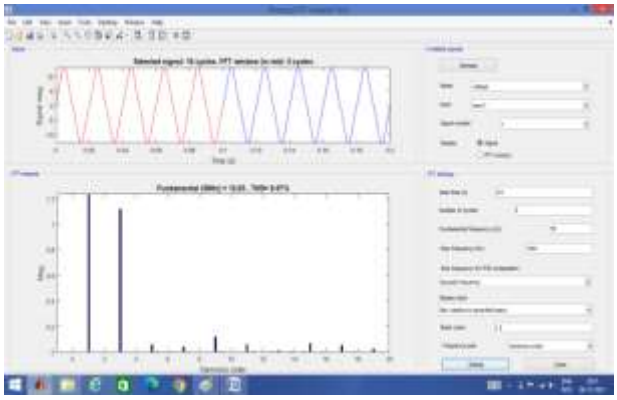

Fig.8.Total Harmonic Distortion of voltage

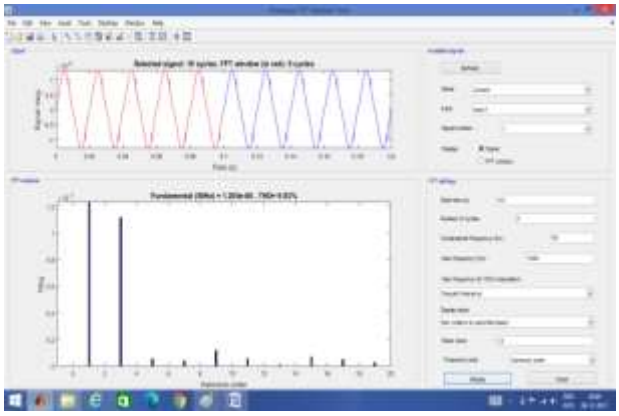

Fig.9. Total Harmonic Distortion of current

Fig.6. Show the voltage output across the load. Fig.7 shows the current output across the load. Fig.8., Fig..9. shows Total Harmonic Distortion of voltage which is 9.97% and Total Harmonic Distortion of current which is 9.93% obtained by simulation.

4. HARDWARE CIRCUIT

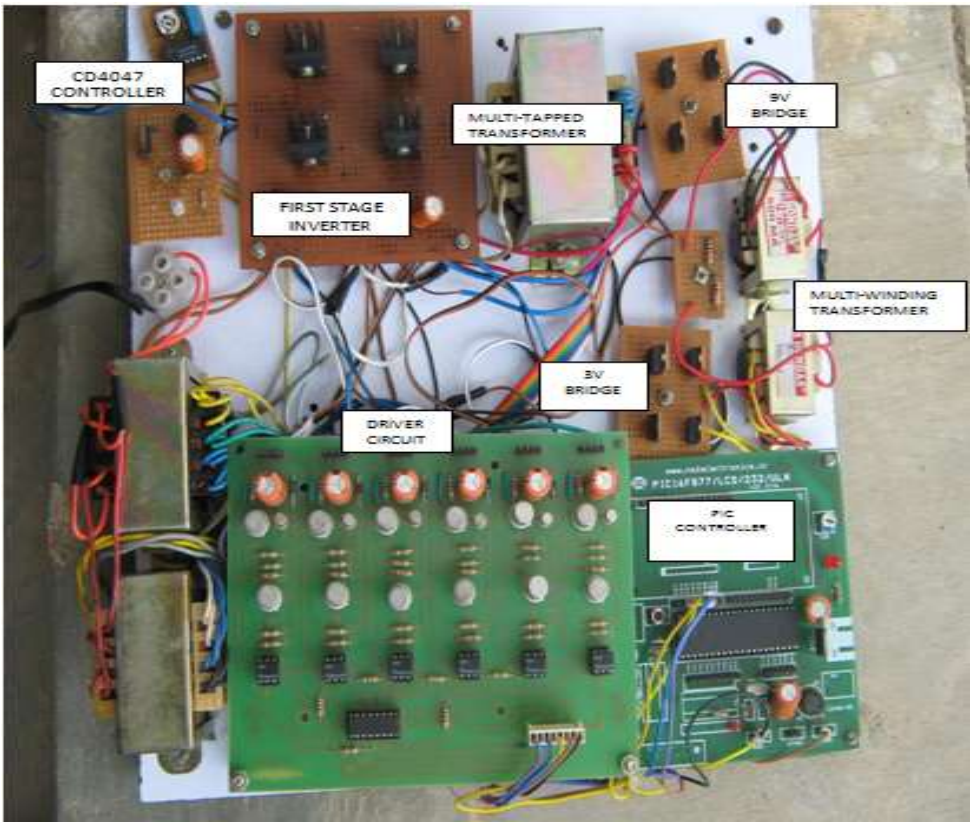

Fig.10. Prototype model

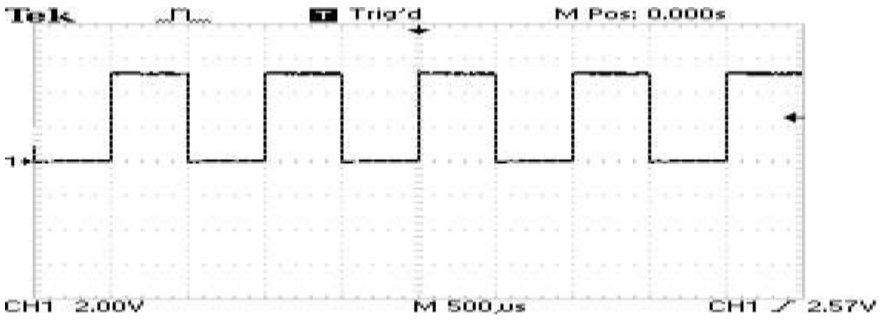

Fig.11. DSO output of Gate pulse for first stage inverter

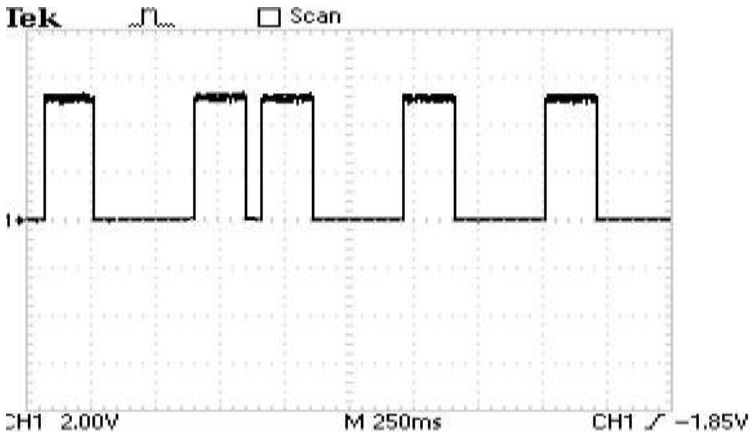

Fig.12.DSO output of Gate pulses for 3volt Bridge

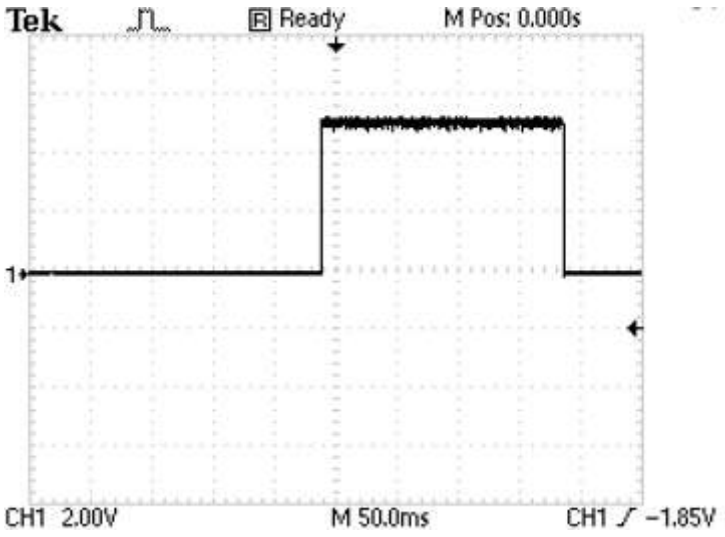

Fig.13.DSO output of Gate pulse for 9 volt bridge

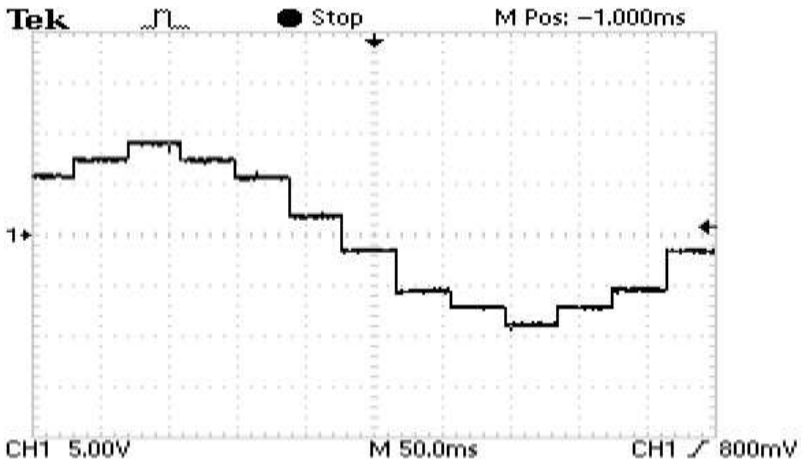

Fig.14.DSO output of Voltage across load

The proto type model of the proposed circuit is shown in the Fig.10. DSO output of gate pulse for first stage inverter is shown in Fig.11. Fig.12. and Fig.13. shows the DSO output of 3V and 9V bridge. The DSO output of voltage across load is shown in Fig.14.

5. CONCLUSION

High quality sinusoidal power supply is required for high power applications. Multi level inverter topology is used to satisfy this requirement. The proposed topology generates a sinusoidal waveform with less switches and low THD. Number of winding in the transformer can be increased to increase the number of level. Clamping diodes are eliminated in this system. Capacitor voltage unbalance is reduced by modifying the circuit such that the idle capacitor gets charged during switching period. By proper selection of switches the voltage available in transformer windings can be added and subtracted to obtain smooth sinusoidal wave at the output. This method uses voltage combination of transformers instead of using more number of DC sources. The effectiveness of the system can be seen through simulation and hardware results.

REFERENCES

1. Rodriguez J., Lai Jih Sheng, Peng Fang Zheng Multilevel inverters: a survey of topologies, controls,and applications. IEEE Transactions on Industrial Electronics, Vol. 49, Issue 4, 2002, p. 724-738.
2. L. Tolbert and T. G. Habetler, “Novel multilevel inverter carrier-based PWM method,” IEEE Trans. Ind. Applicat., vol. 35, pp. 1098–1107,Sept./Oct. 1999.
3. Raghavendra Reddy Karasani, Vijay Bhanuji Borghate, Prafullachandra M.Meshram, Hiralal Murlidhar Suryawanshi, Sidharth Sabyasachi A three-phase hybrid cascaded modular multilevel inverter for renewable energy environment. IEEE Transactions on Power Electronics, Vol. 32, Issue 2, 2017, p. 1070-1087.
4. Hajizadeh Mehdi, Fathi Seyed Hamid Fundamental frequency switching strategy for grid-connected cascaded H-bridge multilevel inverter to mitigate voltage harmonics at the point of common coupling. IET Power Electronics, Vol. 9, Issue 12, 2016, p. 2387-2393.
5. Law Kah Haw, Mohamed Dahidah S. A., Haider A. F. Almurib SHE-PWM cascaded multilevel inverter with adjustable DC voltage levels control for STATCOM applications. IEEE Transactions on Power Electronics, Vol. 29, Issue 12, 2014, p. 6433-6444.
6. Subash Kumar C. S., Gopalakrishnan V. Design of synchronous reference frame based harmonic detection and space vector pulse width modulation based switching of shunt active filter. Australian Journal of Electrical and Electronics Engineering, Vol. 10, Issue 3, 2013, p. 362-370.
7. Khalili T., Raihani A., Ouajji H., Bouattane O., Amri F. Efficient choice of a multilevel inverter for integration on a hybrid wind-solar power station. Journal of Power and Energy Engineering, Vol. 3, 2015, p. 9-44.
8. Gupta K. K., Jain S. A novel multilevel inverter based on switched DC sources. IEEE Transactionson Industrial Electronics, Vol. 61, Issue 7, 2014, p. 3269-3278.
9. X.Yuan and I. Barbi, “Fundamental of a new diode clamping multilevel inverter ,”IEEE Trans.on power Electronics, vol.15,No.4,July 2000,pp.711-718.
10. Matsa A., Ahmed I., Chaudhari M. A. Optimized space vector pulse-width modulation technique for a five-level cascaded H-bridge inverter. Journal of Power Electronics, Vol. 14, Issue 5, 2014, p. 937-945.

11. Rajesh Gupta, Arindam Ghosh, Avinash Joshi Switching characterization of cascaded multilevel-inverter-controlled systems. IEEE Transactions on Industrial Electronics, Vol. 55, Issue 3, 2008, p. 1047-1058.
12. Suresh Y., Venkataramanaiah J., Panda A. K., Dhanamjayulu C., Venugopal P. Investigation oncascade multilevel inverter with symmetric, asymmetric, hybrid and multi-cell configurations. A in Shams Engineering Journal, Vol. 8, Issue 2, 2017, p. 263-276.
13. F.S.Kang, S.J.Park, M.H.Lee C.U.Kin,"An efficient Multilevel synthesis approach and its application to a 27 level inverter," IEEE Trans. on industrial electronics vol.52, no.6,december 2005.
14. Panda A. K., Suresh Y. Research on cascade multilevel inverter with a single DC source by using three-phase transformers. International Journal of Electrical Power and Energy Systems, Vol. 40, Issue 1, 2012, p. 9-20.
15. Song S. G., Kang F. S., Park S.-J. Cascaded multilevel inverter employing three-phase transformersand single DC input. IEEE Transactions on Industrial Electronics, Vol. 56, Issue 6, 2009, p. 2005-2014.