Self-Balanced 33-Level Inverter with Hybrid Double and HAIF-Mode Switched Capacitor

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***Abstract*— In power electronics industrial applications, one of the major problems is to reduce the harmonic distortion, without losses to provide a high-quality output voltage shape is benefited and reduced capacitor voltage ripple accumulation. The 33-level inverters based on switched-capacitor (SC) are presented and it involves three SC units and a neutral-point-piloted (NPP) unit in this article. Here, using a bidirectional switch and 12 number of transistors, 3 pair of diodes and 4 pairs of capacitors are employed. All of switching components are controlled by PWM signals and all capacitors' voltages are self-balanced. The proposed multilevel inverter performed excellent result showing in the experimental result. Also achieved its maximum efficiency through it.**

***Index Terms*—multilevel inverter, switched-capacitor, SHE modulation.**

I. INTRODUCTION

The multi-level inverter has been introduced since 1975 as an alternative in high power and medium voltage situations. With the growing demand for high-quality power supplies in industrial applications, obtaining the ac output voltage nearly sinusoidal waveform is much more important. The PWM modulation with a two-level inverter and low pass filter is capable of providing this desired output voltage waveform in theoretically. Although, the two-level inverter will cause more switching loss and the problem of electromagnetic interference (EMI) due to the high switching frequency and high dv/dt stress of inverting bridges employed in the two-level inverter.

Which is compared with the multi-level inverter (MLI) technique has been receiving much attention, in recent decades. Because its several alluring advantages such as reduced dv/dt stresses, pretty much sinusoidal staircase output voltage waveform and the operating with lower switching frequency etc. As in the case of unbalanced capacitor voltages and complex clamping circuits for increasing the output level, the neutral-point-clamped (NPC) and flying capacitor (FLC) MLIs suffer the problems. There-fore the advantage of simplex structure and self-balanced voltages to using a new model MLIs based on SC techniques.

The cascade H-bridge (CHB) MLI is different from the above types due to it requires multiple isolated dc sources and it has self-boosting capability by a single low voltage source is frequently employed in an SC-MLI. The SC-MLIs concept is firstly introduced by Mac and Ionovici. Then after the series (or) parallel SC-MLIs structure improved. From the parallel (or) series structure recruits n SC units and an inverting H-bridge to generate 2n+3 output voltage levels. The above mentioned each of level is equal to the dc source voltage. The limited ability for inductive loads of this structure is its main deficiency. In parallel (or) series case there resulting the more conduction loss and high ON-state voltage drop of switches.

The new SC-MLI were introduced with multiple switches. And it rated different voltages but, these switches needed to have a bipolar voltage blocking capability for reduce in last mentioned problems.

So, the proposed system of 17-level inverter is more efficient than other proposed types, then here to introducing explain the system of 33-level inverter switched capacitor MLIs with a neutral-point-piloted circuit and same components with its edited number of quantities.

II. COMPARISON BETWEEN EXISTING AND PROPOSED SYSTEM

A. The main difference between the existing system and proposed system is that the step of output waveform of voltage will be more than the existing system. This helps the waveform near sinusoidal waveform than the existing system.

B. So, this output gives the high-quality output without losses than existing system.

C. In the proposed system, there using the number of components is more than the existing system.

If, we adding the pair of components there the steps of the output waveform will increases.

III. OBJECTIVES

A. In order to improve the output voltage waveform near-sinusoidal.
B. In order to avoid CVRA from the system.
C. In order to reduce the power losses from the dc to ac conversion system.
D. In order to produce to high-quality power supplies.

IV. PROPOSED SYSTEM

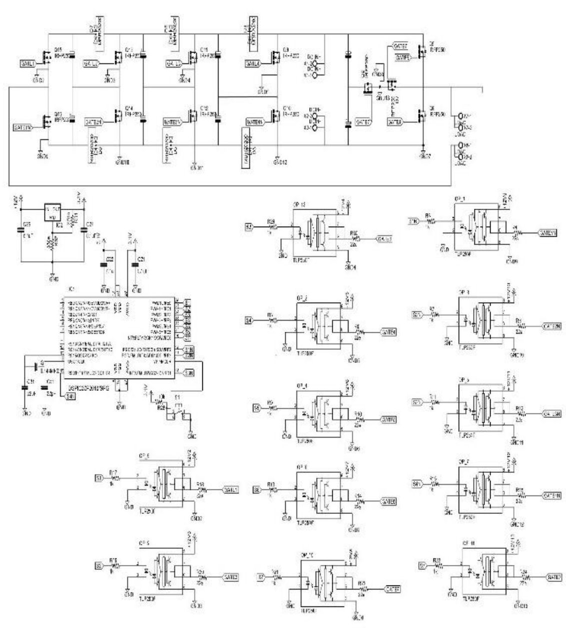

Fig 1 Circuit diagram for proposed system

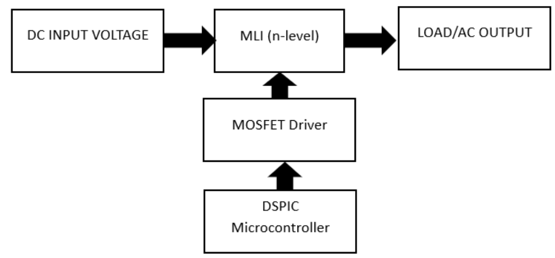

Fig 2 Block diagram of proposed System

Considering the working of the proposed system, when the pair of transistors operates in a complementary manner, the capacitors are alternately charged by the dc source through the diodes respectively. So, that they have the same voltage as the dc source. Correspondingly, with the complimentary operation of transistors, the pair of voltage divider capacitors discharge alternately to capacitors through diodes.

TABLE 1
OPERATION STATES OF PROPOSED INVERTER

OUTPUT LEVELS	SWITCHES						
	S1	S2	S3	S4	S5	S6	S7
-16	0	0	0	0	1	0	0
-15	0	0	0	0	0	0	1
-14	0	0	0	1	1	0	0
-13	0	0	0	1	0	0	1
-12	0	0	1	0	1	0	0
-11	0	0	1	0	0	0	1
-10	0	0	1	0	0	1	0
-9	0	0	1	1	0	0	1
-8	0	1	0	0	1	0	0
-7	0	1	0	0	0	0	1
-6	0	1	0	1	1	0	0
-5	0	1	0	1	0	0	1
-4	0	1	1	0	1	0	0
-3	0	1	1	0	0	0	1
-2	0	1	1	0	0	1	0
-1	0	1	1	1	0	0	1
0	0	1	1	1	0	1	0
1	1	0	0	0	0	0	1
2	1	0	0	1	1	0	0
3	1	0	0	1	0	0	1
4	1	0	0	1	0	1	0
5	1	0	1	0	0	0	1
6	1	0	1	0	0	1	0
7	1	0	1	1	0	0	1
8	1	0	1	1	0	1	0
9	1	1	0	0	1	0	0
10	1	1	0	0	0	0	1
11	1	1	0	1	1	0	0
12	1	1	0	1	0	0	1
13	1	1	0	1	0	1	0
14	1	1	1	0	0	0	1
15	1	1	1	0	0	1	0
16	1	1	1	1	0	0	1

Both the capacitors have a quarter of dc source voltage. Based on the assumption that all capacitors are so large that their voltage can be regarded as constant, the proposed inverter from the circuit. With the cooperation of switches, the inverter is generating 33 different level of ac output voltage as illustrated.

Similar to other SC-based inverters, the capacitors employed in the 33-level inverter operated alternately in charging and modes so that their voltages can be balanced, but with some ripples. In a charging process of SC-based MLIs, the power loss is determined by the capacitors' voltage ripple, and it is absorbed by parasitic resistors of the charging loop. As in the case of discharging process, the power load is determined mainly by the load current. And it also the parasitic resistors of discharging loop absorbed. The proposed inverter therefore the switching losses are neglected because of it controlled by conventional SPWM strategy.

V. ADVANTAGES DISADVANTAGES

Advantages

- Voltage derivatives (dv/dt) on semiconductor switches have been reduced as a result of dividing voltage stresses across switches at different levels.
- Due to the multiple-level output waveform, the power quality is improved (low THD output).
- In solar PV and electric drive applications, it is possible to avoid or lower common-mode voltages by utilizing appropriate switching methods.
- There is very little distortion in the input current.
- Multilevel inverters have a modular structure.
- It provides an easy interface to integrate renewable energy resources into the grid.
- Electromagnetic interference is reduced as a result of a reduction in dv/dt.

Disadvantages

Since this inverter offer advantages, it also has some disadvantages that needs to be considered

- There has been a significant increase in the number of switching devices. This increases the complexity and cost of the circuit. There have also been instances where reliability has been affected.
- Due to the many switches in multilevel inverters, multiple gate pulses must be generated, which again requires the use of advanced PWM-based digital signal processors.
- System become more expensive.

VI.APPLICATION

The multi-level inverters are used in various application where a high-quality voltage is required. They provide to voltage output without losses.

- Industrial applications
- Reactive power compensation
- Static var compensation
- Power electronics and electrical

VII. RESULT AND DISCUSSION

This paper deal with the problems related to generate an output waveform resembling staircase to near-sinusoidal waveform and to decrease the high harmonic losses MLI are used in order to have highly efficient power electronics and drive systems. To verify the feasibility of the 17-level to 33-level inverter with fundamental modulation strategy, a prototype was built. Due to miscellaneous losses, the calculated value is always higher the measured efficiency but their variations trends are the same. The measured efficiency is always above and the maximum value. Finally, an efficiency comparison for the different SC-MLI is cleared from this study. And which introducing that the proposed inverter has a relatively high efficiency under the premise of ensuring more output levels.

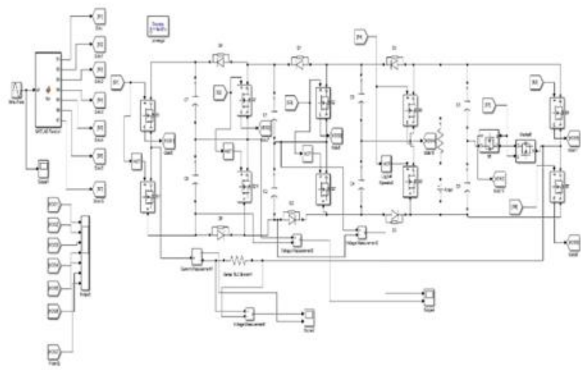

Fig 3 Simulink Model of proposed system

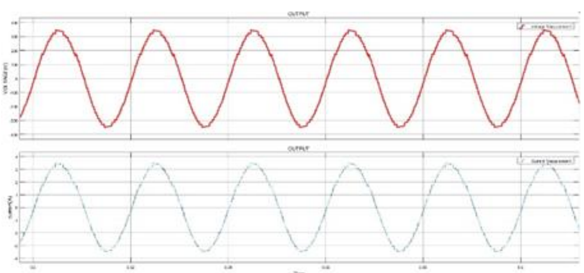

Fig 4 Output Wave Form

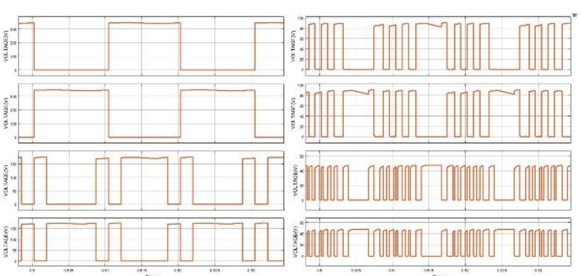

Fig 5 Pulse across the capacitors

VIII.CONCLUSION& FUTURE SCOPE

In this paper the concept of consolidating the hybrid double- and half-mode Switched capacitor units, and SC-MLIs are proposed to generate 33-levels of output voltage. Nevertheless, this research article is an attempt to broadly classify all possible types of MLIs depending upon the structure of DC source (either single or multiple units) used. The multiple uses of capacitors can produce multiple voltage levels. Then summarizes the significant advantages and disadvantages of various MLI configurations. The 33-level inverter have better output voltage shape as well as self-balanced capacitor voltages. In the reduction of switching loss will contributes the low switching frequency of components. And also advanced in boosting capability. These proposed solutions promising to be a good micro-inverter for PV and fuel cells. Which are renewable energy sources.

In further the edition can be implemented in this system for improving the output voltage waveform produces smoother than the above cases. By providing, to increase the number of switched-capacitors there also improving step of the waveform as near to sinusoidal with low losses. The outlook on the development of various topologies of MLI is depicted in the throughout study of this evaluation has seen discussed in this section. The future scope is to determine the PWM techniques of asymmetrical multilevel inverters then to reduce the harmonic content in the output of the asymmetrical multilevel inverters.

REFERENCES

1. A. Taghvaie, J. Adabi and M. Rezanejad, “A Self-Balanced Step-Up Multilevel Inverter Based on Switched-Capacitor Structure,” IEEE Trans. Power Electron., vol. 33, no. 1, pp. 199-209, Jan. 2018.
2. S. S. Lee and K. Lee, “Switched-Capacitor-based Modular T-type Inverter (SC-MTI),” IEEE Trans. Ind. Electron., doi: 10.1109/TIE.2020.2992963
3. E. Zamiri, N. Vosoughi, S. H. Hosseini, R. Barzegarkhoo and M. Sabahi, “A New Cascaded Switched-Capacitor Multilevel Inverter Based on Improved Series-Parallel Conversion With Less Number of Components,” IEEE Trans. Ind. Electron., vol. 63, no. 6, pp. 3582-3594, June 2016.
4. B.-B. Ngo, M.-K. Nguyen, J.-H. Kim, F. Zare, “Single-phase multilevel inverter based on switched-capacitor structure,” IET Power Electron., vol. 11, no. 11, pp. 1858-1865, 2018.
5. M. Saeedian, M. E. Adabi, S. M. Hosseini, J. Adabi and E. Pouresmaeil, “A Novel Step-Up Single Source Multilevel Inverter: Topology, Operating Principle, and Modulation,” IEEE Trans. Power Electron., vol. 34, no. 4, pp. 3269-3282, April 2019.
6. T. Roy, P. K. Sadhu and A. Dasgupta, “Cross-Switched Multilevel Inverter using Novel Switched Capacitor Converters,” IEEE Trans. Ind. Electron., vol. 66, no. 11, pp. 8521-8532, Nov. 2019.
7. Y. Ye, S. Chen, X. Zhang and Y. Yi, “Half-Bridge Modular SwitchedCapacitor Multilevel Inverter With Hybrid Pulsewidth Modulation,” IEEE Trans. Power Electron., vol. 35, no. 8, pp. 8237-8247, Aug. 2020.

8. M. F. Talooki, M. Rezanejad, R. Khosravi and E. Samadaei, “A Novel High Step-Up Switched-Capacitor Multilevel Inverter With Self-Voltage Balancing,” IEEE Trans. Power Electron., vol. 36, no. 4, pp. 4352-4359, April 2021
9. W. Peng, Q. Ni, X. Qiu and Y. Ye, “Seven-Level Inverter with SelfBalanced Switched-Capacitor and Its Cascaded Extension,” IEEE Trans. Power Electron., vol. 34, no. 12, pp. 11889-11896, Dec. 2019.
10. Y. Nakagawa and H. Koizumi, “A Boost Type Nine-Level Switched Capacitor Inverter,” IEEE Trans. Power Electron. vol. 34, no. 7, pp. 6522-6532, July 2019.
11. M. Daula Siddique, S. Mekhilef, S. Padmanaban, M. A. Memon and C. Kumar, “Single Phase Step-up Switched-Capacitor Based Multilevel Inverter Topology with SHEPWM,” IEEE Trans. Ind. Appl., doi: 10.1109/TIA.2020.3002182.
12. K. P. Panda, P. R. Bana and G. Panda, “A Switched-Capacitor SelfBalanced High-Gain Multilevel Inverter Employing a Single DC Source,” in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 67, no. 12, pp. 3192-3196, Dec. 2020.
13. M. N. H. Khan, M. Forouzesh, Y. P. Siwakoti, L. Li and F. Blaabjerg, “Switched Capacitor Integrated (2n+1)-Level Step-Up Single-Phase Inverter,” IEEE Trans. Power Electron., vol. 35, no. 8, pp. 8248-8260, Aug. 2020.
14. Y. Xiong, S. Sun, H. Jia, P. Shea and Z. John Shen, “New Physical Insights on Power MOSFET Switching Losses,” IEEE Trans. Power Electron., vol. 24, no. 2, pp. 525-531, Feb. 2009.
15. R. Barzegarkhoo, M. Moradzadeh, E. Zamiri, H. Madadi Kojabadi and F. Blaabjerg, “A New Boost Switched-Capacitor Multilevel Converter With Reduced Circuit Devices,” IEEE Trans. Power Electron., vol. 33, no. 8, pp. 6738-6754, Aug. 2018.