Solar Powered Smart Switching Multilevel Inverter for Smart Grid

Author

Dr. Suvetha Poyyamani Sunddararaj
Assistant Professor
M. Kumarasamy College of Engineering,
Karur, Tamil Nadu.

Co-Author(s)

Mr. S. Sanjai & Mr. P. Sakthivel
Undergraduate Students
MKCE
Karur, Tamil Nadu.

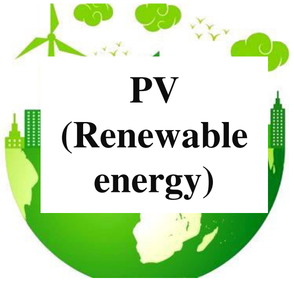
Introduction

Multilevel Inverter to AC loads

↑

High Step-up gain DC-DC converter

↑



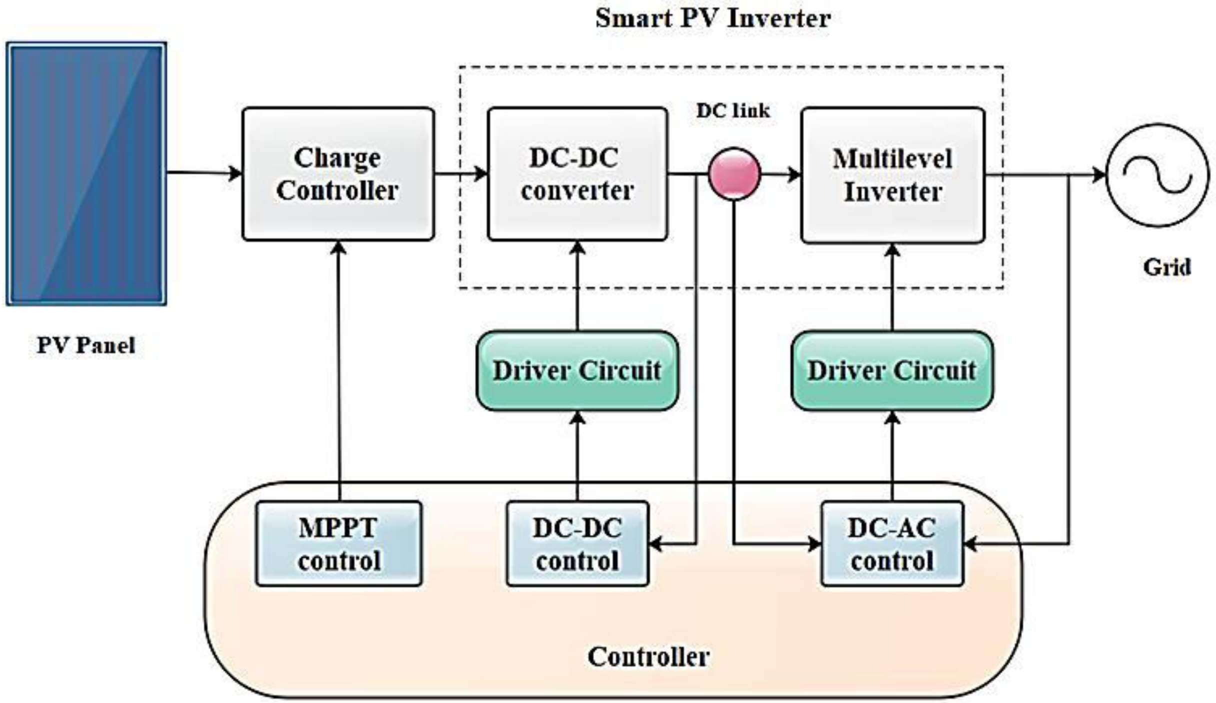
↓

Environmental and Economic concerns

↓

Motifs for Microgrid and Smartgrid

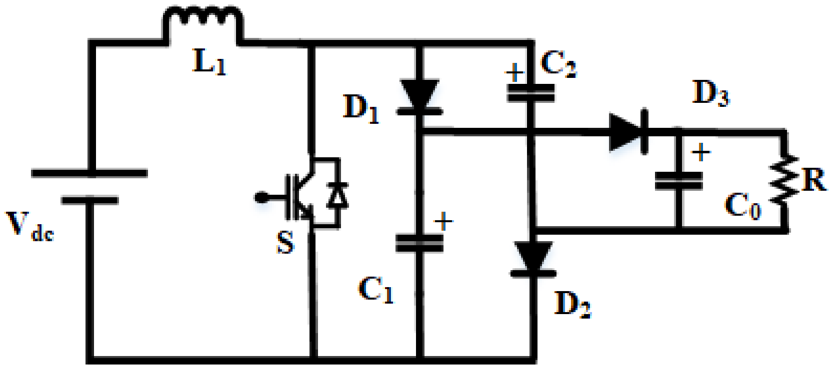
Functional Block Diagram



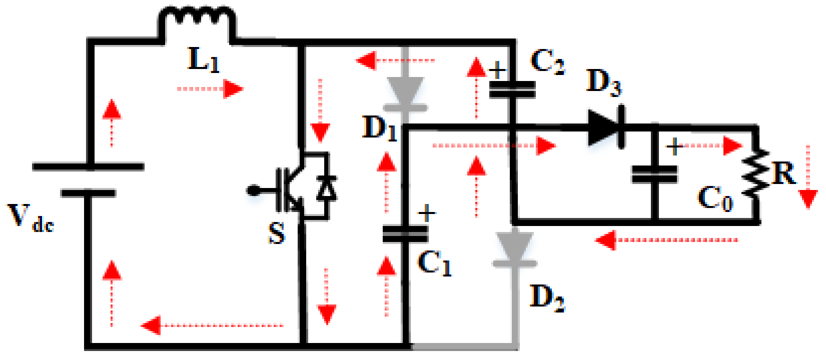
Overall block diagram of the proposed

- The output of the PV panel is controlled using an MPPT controller to retrieve the maximum power.
- It acts as the source for the novel DC-DC converter, which boosts the voltage generated from the PV panel.
- The voltage of the boost converter is fed to the multilevel inverter via a DC link and it is synchronized with the AC grid.

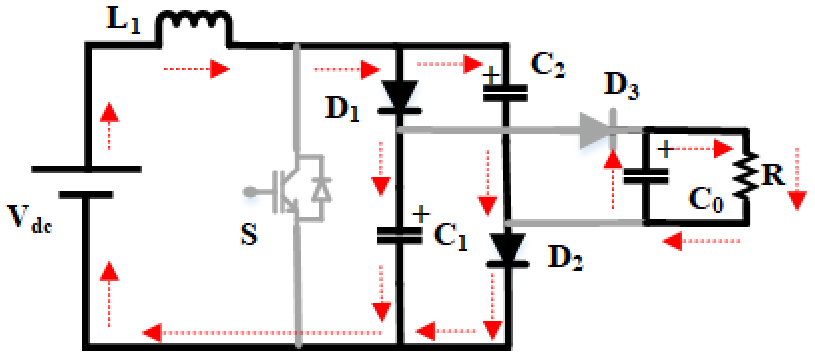
Switched Capacitor Cell DC-DC Boost Converter



Circuit diagram of Switched Capacitor Cell Boost Converter



Equivalent Circuit for Mode –I



Equivalent Circuit for Mode –II

Mode I:

- Switch ‘S’ is kept in ON-state, and the inductor L_1, capacitors C_1, C_2 and D_3 are also forward biased simultaneously.

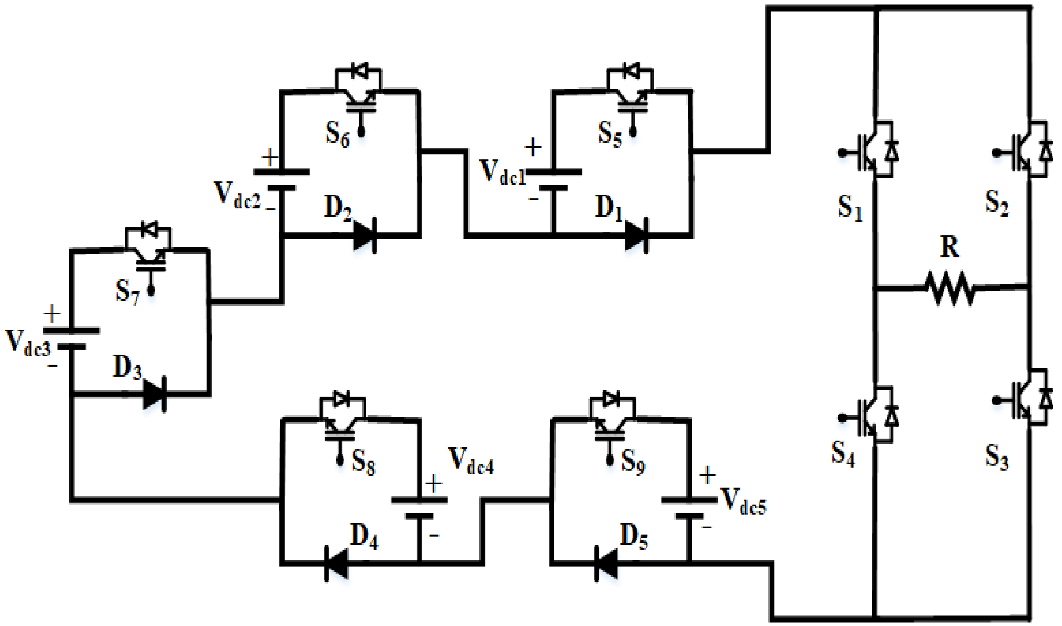
- The voltage across the inductor L_1 becomes equal to Vdc. The capacitor C_1 and C_2 gets discharged, and it charges the capacitor C_0.

Mode II:

- Switch ‘S’ is kept in OFF-state

- The inductor connected at the input side discharge and transfer energy to the capacitor C1 and C2. Meanwhile, the capacitor C0 is discharged and supplies the load.

Smart Switching Multilevel Inverter

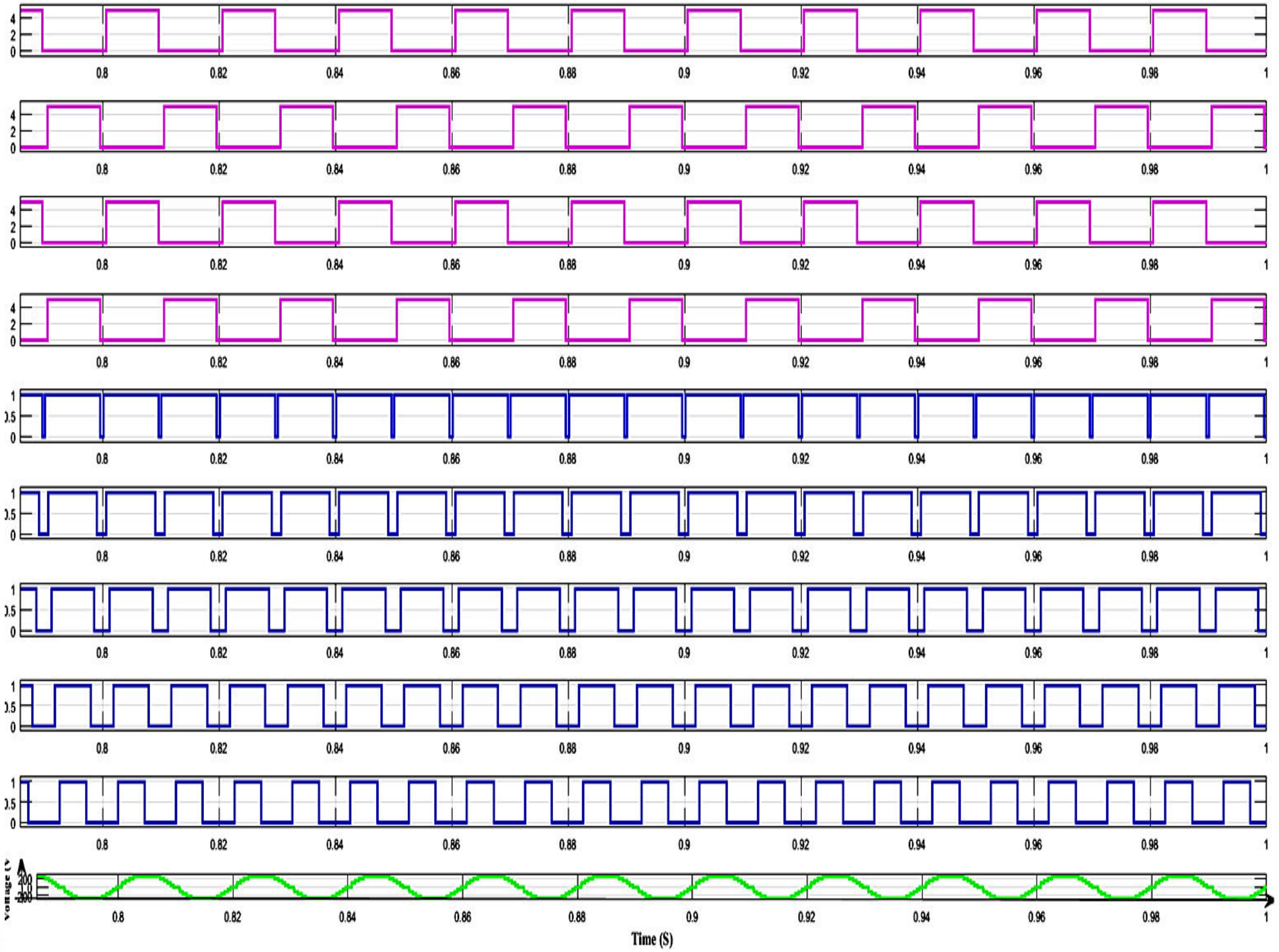


Circuit Configuration of Proposed Multilevel Inverter

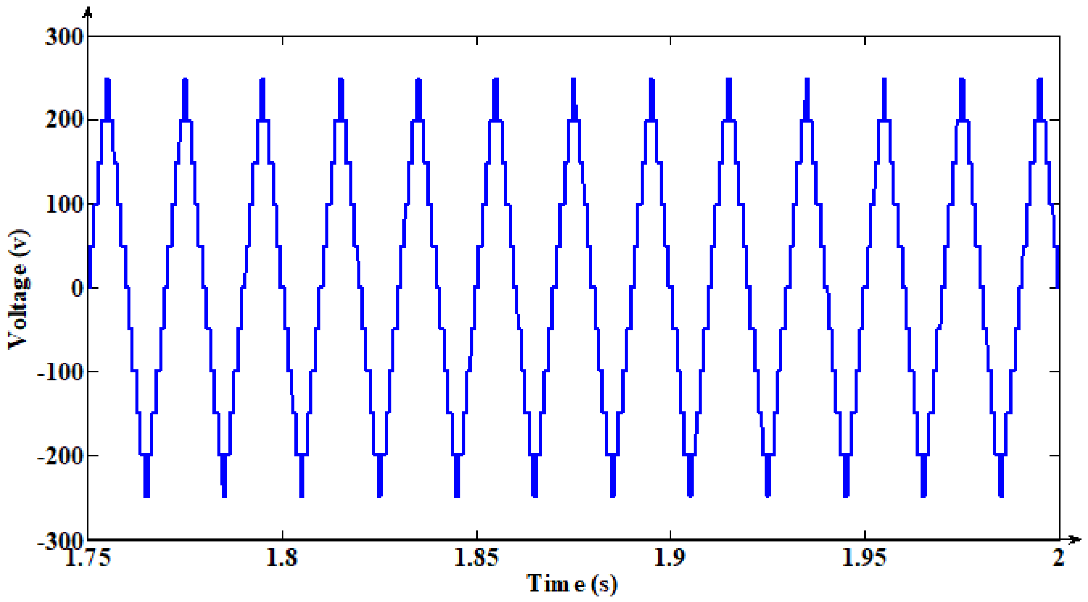
$+5V_{dc}$	S_1, S_3 of the H-bridge circuit and switches S_5 - S_9 are also in ON state
$+4V_{dc}$	S_1, S_3 of the H-bridge circuit and switches S_5 - S_8 are also in ON state
$+3V_{dc}$	S_1, S_3 of the H-bridge circuit and switches S_5 - S_7 are also in ON state
$+2V_{dc}$	S_1, S_3 of the H-bridge circuit and switches S_5 - S_6 are also in ON state
$+V_{dc}$	S_1, S_3 of the H-bridge circuit and switch S_5 is also in ON state
0	S_2 , S_4 of the H-bridge circuit are in ON state
$-V_{dc}$	S_2 , S_4 of the H-bridge circuit and switch S_5 is also in ON state
$-2V_{dc}$	S_2 , S_4 of the H-bridge circuit and switches S_5- S_6 are also in ON state
$-3V_{dc}$	S_2 , S_4 of the H-bridge circuit and switches S_5 - S_7 are also in ON state
$-4V_{dc}$	S_2 , S_4 of the H-bridge circuit and switches S_5 - S_8 are also in ON state
-5 Vdc	S_2 , S_4 of the H-bridge circuit and switches S_5 - S_8 are also in ON state

Switching Pattern and Waveform

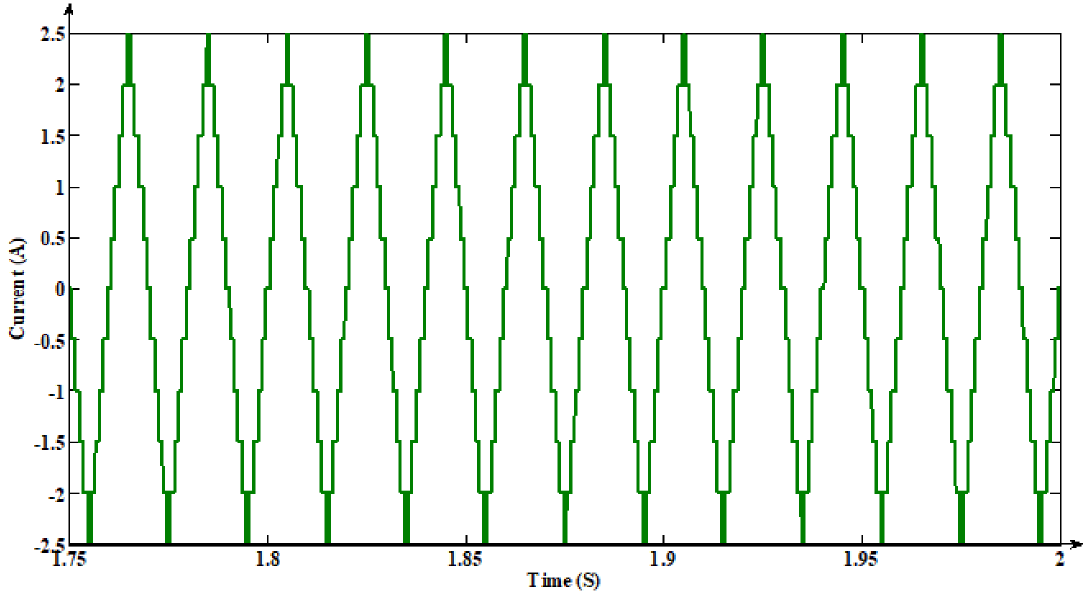
Voltage Levels	S1	S2	S3	S4	S5	S6	S7	S8	S9
5 Vdc	1	0	1	0	1	1	1	1	1
4 Vdc	1	0	1	0	1	1	1	1	0
3 Vdc	1	0	1	0	1	1	1	0	0
2 Vdc	1	0	1	0	1	1	0	0	0
Vdc	1	0	1	0	1	0	0	0	0
0	0	1	0	1	0	0	0	0	0
-Vdc	0	1	0	1	1	0	0	0	0
-2 Vdc	0	1	0	1	1	1	0	0	0
-3 Vdc	0	1	0	1	1	1	1	0	0
-4 Vdc	0	1	0	1	1	1	1	1	0
-5 Vdc	0	1	0	1	1	1	1	1	1



Results and Discussions



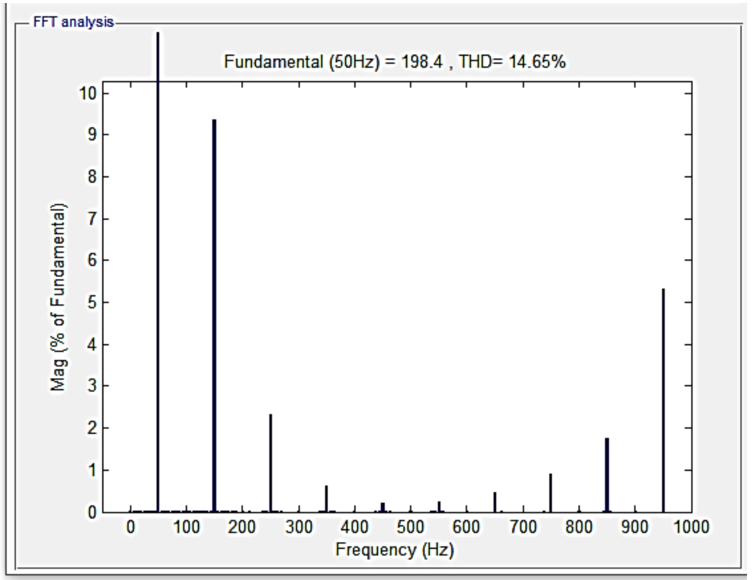
Voltage waveform of proposed inverter



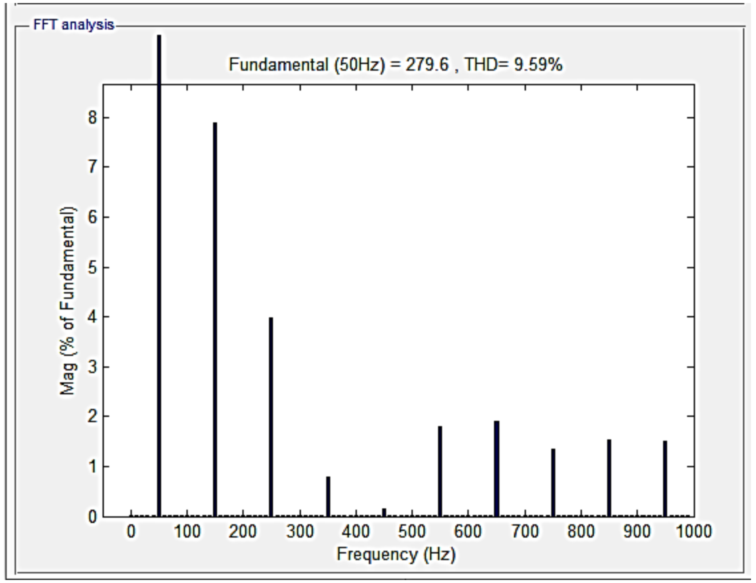
Current waveform of proposed inverter

The voltage amplitude is around **248.25 V with 11 steps** and the current value across the load is measured to be **2.5 A**

THD Analysis

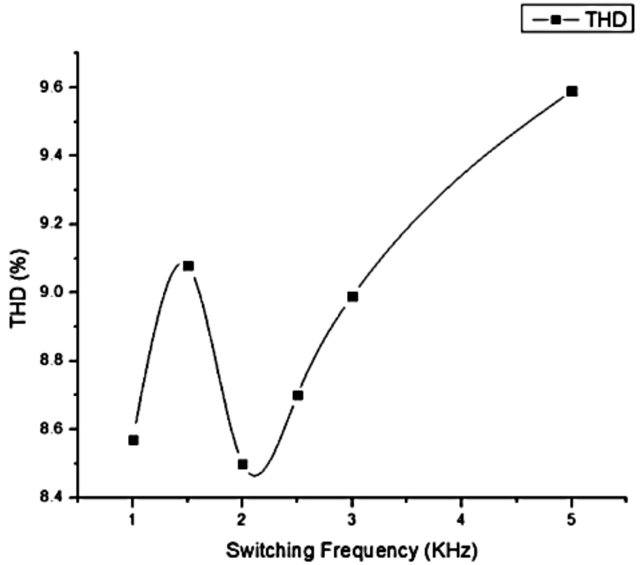


THD plot for proposed MLI (under Open loop condition)



THD plot for proposed MLI (under Closed loop condition)

Switching Frequency (kHz)	THD (%)
1.0	8.57
1.5	9.08
2.0	8.5
2.5	8.7
3.0	8.99
5.0	9.59



Summary

- The voltage gain of the proposed DC-DC converter topology is found to be ***6.75 for a duty ratio of 0.4***
- The input current ripple and output voltage ripple of the converter topology is also reduced. Thus, the efficiency of the converter is high.
- The ***hybrid switching technique used in the system produces higher levels of output with fewer switches*** and it also helps to improve the voltage profile of the inverter
- The ***THD*** of the output voltage ***is also at the nominal level*** (***without using a filter***)
- Thus, the proposed configuration is suitable for renewable and grid applications

REFERENCES

[1] Teichmann, R.; Bernet, S., "A comparison of three-level converters versus two-level converters for low-voltage drives, traction, and utility applications", IEEE Trans. Ind. Appl. 2005, 41, 855–865.

[2] Yuan, X., "Derivation of voltage source multilevel converter topologies", IEEE Trans. Ind. Electron. 2017, 64, 966–976.

[3] Cristian Verdugo, Samir Kouro, Christian A. Rojas, Marcelo A. Perez, Thierry Meynard and Mariusz Malinowski, "Five-Level T-type Cascade Converter for Rooftop Grid-Connected Photovoltaic Systems,", Energies MDPI, pp. 1–20.

[4] S. P. Sunddararaj and S. Ramalingam, "High gain DC-DC converter with Enhanced adaptive MPPT for PV Applications," vol. 38, no. 3, pp. 541–556, 2019.

[5] H. M. Bassi, "Floating Source Multilevel Inverter uses Hybrid Double Switching Frequencies," pp. 2–6, 2017.

[6] Sunddararaj, S.P.; Srinivasarangan Rangarajan, S.; N, Subashini, "An Extensive Review of Multilevel Inverters Based on Their Multifaceted Structural Configuration, Triggering Methods and Applications", *Electronics* 2020, *9*, 433.

[7] Manjrekar, M.D.; Steimer, P.K.; Lipo, T.A., "Hybrid multilevel power conversion system: A competitive solution for high-power applications.", IEEE Trans. Ind. Appl. 2000, 36, 834–841.

[8] Rodríguez, J.; Lai, J.S.; Peng, F.Z., "Multilevel inverters: A survey of topologies, controls, and applications",IEEE Trans. Ind. Electron. 2002, 49, 724–738.

[9] Kouro, S.; Malinowski, M.; Gopakumar, K.; Pou, J.; Franquelo, L.G.; Wu, B.; Rodriguez, J.; Pérez, M.A.; Leon, J.I., "Recent Advances and Industrial Applications of Multilevel Converters", IEEE Trans. Ind. Electron. 2010, 57, 2553–2580.

[10] Gupta, K.K.; Ranjan, A.; Bhatnagar, P.; Sahu, L.K.; Jain, S., "Multilevel Inverter Topologies With Reduced Device Count: A Review", IEEE Trans. Power Electron. 2016, 31, 135–151.