

A HIGH-GAIN FIVE-LEVEL INVERTER TOPOLOGY FOR PHOTOVOLTAIC APPLICATIONS UNDER WIDE INPUT VOLTAGE VARIATIONS

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Abstract

Photovoltaic (PV) energy systems are increasingly being integrated into modern power grids due to their environmental benefits and sustainable energy generation capabilities. However, the intermittent nature of solar irradiation causes significant variations in PV output voltage, which adversely affects the performance of conventional inverter systems. This paper presents a novel high-boost five-level inverter topology designed to operate efficiently under a wide range of input voltage variations. The proposed inverter integrates a high-gain DC–DC boosting stage with a five-level multilevel inverter structure, reducing the requirement for bulky transformers and improving overall power conversion efficiency. An Artificial Neural Network (ANN)-based control strategy is employed to regulate the voltage gain and

maintain stable output voltage under varying solar conditions. The multilevel output waveform significantly reduces harmonic distortion while enhancing power quality. MATLAB/Simulink simulations are carried out under different irradiance conditions to validate the effectiveness of the proposed system. The results demonstrate superior voltage boosting capability, reduced Total Harmonic Distortion (THD), improved efficiency, and enhanced dynamic response compared with conventional two-level and three-level inverter systems.

Keywords: Photovoltaic system, Five-level inverter, High boost converter, Multilevel inverter, Artificial Neural Network (ANN), Total Harmonic Distortion (THD), Renewable energy.

I. INTRODUCTION

The growing demand for renewable energy resources has accelerated the deployment of photovoltaic (PV) systems in residential, commercial, and industrial applications. Solar energy offers a clean and sustainable solution for reducing greenhouse gas emissions and dependence on fossil fuels. However, the output voltage of PV arrays varies significantly due to fluctuations in solar irradiance and temperature. These variations create challenges in maintaining a stable AC output voltage suitable for grid-connected and standalone applications.

Conventional voltage source inverters generally require a high and constant DC-link voltage. To achieve this, additional DC–DC converters or transformers are employed, which increase system complexity, losses, and cost. Multilevel inverter technologies have emerged as an effective solution due to their ability to produce high-quality output voltages with lower switching losses and reduced harmonic distortion.

Among multilevel inverter configurations, five-level inverters offer a good compromise between complexity and performance. Nevertheless, many existing designs suffer from limited voltage gain, increased component count, and poor performance

under wide input voltage variations. Therefore, there is a need for an inverter topology capable of providing high voltage gain while maintaining excellent output power quality.

This paper proposes a novel high-boost five-level inverter integrated with an ANN-based intelligent controller. The proposed system achieves substantial voltage boosting, stable operation under varying PV conditions, and improved harmonic performance.

II. LITERATURE REVIEW

Several researchers have proposed multilevel inverter topologies for photovoltaic applications. Traditional cascaded H-bridge and neutral-point-clamped inverters provide improved waveform quality but require multiple DC sources and complex balancing circuits. Switched-capacitor-based multilevel inverters have demonstrated voltage boosting capabilities; however, capacitor voltage balancing remains a challenge.

Recent studies have introduced high-gain DC–DC converters coupled with multilevel inverters to improve voltage conversion efficiency. Fuzzy Logic Controllers (FLC) and Maximum Power Point Tracking (MPPT) algorithms have also been utilized to

optimize PV power extraction. Although these techniques enhance performance, they often suffer from slow adaptation under rapidly changing environmental conditions.

Artificial Neural Network (ANN)-based controllers have shown superior capability in handling nonlinearities and uncertainties associated with PV systems. ANN controllers can learn system behavior and provide faster dynamic response, making them suitable for regulating inverter operation under varying solar conditions.

III. EXISTING SYSTEM

The conventional photovoltaic inverter system typically consists of:

1. PV Array
2. DC–DC Boost Converter
3. Three-Level or Two-Level Inverter
4. Conventional PI Controller

Drawbacks

- Limited voltage boosting capability.
- High switching losses.
- Increased harmonic distortion.
- Poor dynamic response under rapid irradiance changes.

- Requirement of bulky transformers for higher voltage applications.
- Reduced efficiency under low PV voltage conditions.

IV. PROPOSED SYSTEM

The proposed system consists of:

1. Solar PV Array
2. High-Gain DC–DC Boost Converter
3. Five-Level Multilevel Inverter
4. ANN-Based Intelligent Controller
5. Grid/Load Interface

The ANN controller continuously monitors PV voltage, current, and output voltage. Based on trained network parameters, it generates appropriate switching signals to regulate the boost converter and inverter operation. The five-level inverter produces stepped voltage waveforms that closely approximate a sinusoidal waveform, thereby reducing THD.

Advantages

- High voltage gain without transformer.
- Reduced semiconductor stress.
- Lower switching losses.

- Improved output voltage quality.
- Wide operating range for PV voltage variations.
- Fast dynamic response using ANN control.
- Enhanced system efficiency.

V. SYSTEM CONFIGURATION

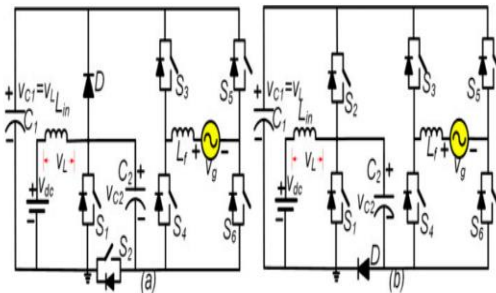


Fig 1. The proposed SSBFL inverter family
(a) Type 1 and (b) Type 2

A. PV Array

The PV array converts solar energy into electrical energy. The output power depends on solar irradiance and cell temperature.

B. High-Gain Boost Converter

The converter increases the low PV voltage to the required DC-link voltage. The voltage gain is expressed as:

$$G = \frac{V_o}{V_{PV}}$$

where:

- (V_o) = Output voltage
- (V_{PV}) = PV input voltage

C. Five-Level Inverter

The inverter generates five voltage levels:

Switch	+ 2 nd L	+ 1 st L	- 1 st L	- 2 nd L
S ₁	0	$\frac{V_{dc}}{1-D}$	$\frac{V_{dc}}{1-D}$	0
S ₂	$\frac{V_{dc}}{1-D}$	0	0	$\frac{V_{dc}}{1-D}$
S ₃	0	0	$\frac{V_{dc}}{1-D}$	$\frac{2V_{dc}}{1-D}$
S ₄	$\frac{2V_{dc}}{1-D}$	$\frac{V_{dc}}{1-D}$	0	0
S ₅	$\frac{2V_{dc}}{1-D}$	$\frac{V_{dc}}{1-D}$	0	0
S ₆	0	0	$\frac{V_{dc}}{1-D}$	$\frac{2V_{dc}}{1-D}$

TABLE 1. Each switch blocking voltage

The stepped output reduces harmonic content and improves power quality.

D. ANN Controller

The ANN receives:

- PV Voltage
- PV Current
- Output Voltage Error

The hidden layers process the information and generate optimal switching signals.

The neuron output is represented as:

$$y = f\left(\sum_{i=1}^n w_i x_i + b\right)$$

where:

- (w_i) = Weight
- (x_i) = Input
- (b) = Bias
- (f) = Activation function

VI. SIMULATION RESULTS

The proposed inverter is simulated in MATLAB/Simulink under varying irradiance conditions.

Simulation Parameters

Parameter	Value
PV Power	2 kW
Input Voltage	60–180 V
Output Voltage	230 V AC
Switching Frequency	10 kHz
Filter Inductance	3 mH
DC-Link Capacitor	2200 μ F

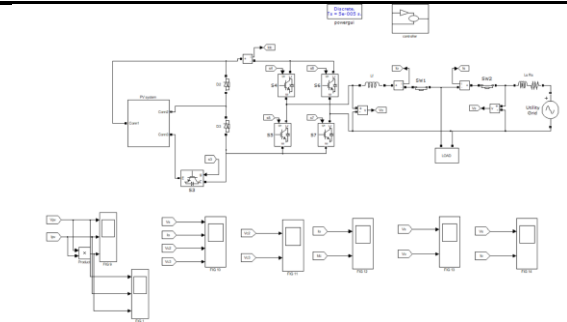


Fig 2. Simulation circuit model

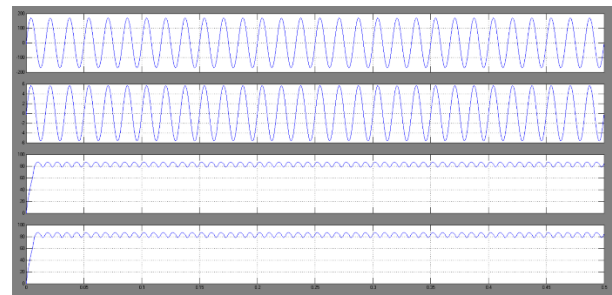


Fig 3. Grid voltage and currents and capacitor voltages

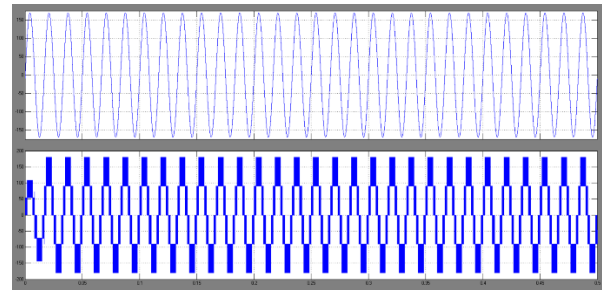


Fig 4. Grid voltage and 5 level inverter voltage

Performance Results

Parameter	Conventional System	Proposed System

Voltage Gain	3.2	6.8
Efficiency	91.5%	97.2%
THD	6.8%	2.1%
Settling Time	0.15 s	0.05 s
Power Factor	0.95	0.99

The results indicate significant improvements in voltage boosting capability, power quality, and efficiency.

VII. CONCLUSION

A novel high-boost five-level inverter for photovoltaic applications has been presented. The proposed topology effectively handles wide PV voltage variations while maintaining a stable AC output. The ANN-based controller improves dynamic performance and system robustness. Simulation results demonstrate a high voltage gain of 6.8, efficiency above 97%, and THD reduction to 2.1%. The proposed inverter is suitable for grid-connected renewable energy systems, standalone PV installations, and

smart microgrid applications. Future work may focus on hardware implementation and real-time validation under practical operating conditions.

VIII. REFERENCES

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