

Modular Cascaded H-Bridge Multilevel PV Inverter with Distributed MPPT for Grid-Connected Applications

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Abstract

This paper exhibits a secluded fell H-bridge multilevel photovoltaic (PV) inverter for single or three stage lattice associated applications. The measured fell multilevel topology enhances the effectiveness and adaptability of PV frameworks. To acknowledge better usage of PV modules and expand the sun based vitality extraction, a dispersed greatest forced point control plan connected to both single-and three-stage multilevel inverters, which permits autonomous control of every dc-join voltage. For three-stage network associated applications, PV criss crosses may present unequal supplied power, prompting lopsided framework current. To fathom this issue, a control plan with balance remuneration is proposed. Here fuzzy logic is used for controlling and compared with other controller the simpered systems tool has proved that the combined system will at the same time inject maximum power. A trial three stage seven level fell H-bridge inverter has been assembled using nine H-span modules (three modules for every stage). Every H-span module is associated with a 185-W sunlight based board. Reproduction and exploratory results are introduced to confirm the plausibility of the proposed approach.

Keywords: *Cascaded multilevel inverter, distributed maximum power point (MPP) tracking (MPPT), modular, modulation compensation, photovoltaic (PV).*

INTRODUCTION

Because of the deficiency of fossil powers and ecological issues on by traditional force era, renewable vitality, especially sun oriented vitality, has turned out to be exceptionally mainstream. Sun oriented electric-vitality request has become reliably by 20%–25% for every annum in the course of recent years, and the development is for the most part in matrix associated applications.

Inverter has identified with various designs of the PV framework: 1) focal inverters 2) string inverters 3) multi string inverters 4) air conditioning module inverters and 5) fell inverters. The setups of PV frameworks are in Fig. 1. Fell inverters comprise of a few converters associated in arrangement; consequently, the high power and/or high voltage.

There are two sorts of fell inverters. Fig. 1(e) demonstrates a fell dc/dc converter

association of PV modules. Each PV module has its own particular dc/dc converter, and the modules with their related converters are still associated in arrangement to make a high dc voltage, which is given to a rearranged dc/air conditioning inverter. This methodology consolidates parts of string inverters and air conditioning module inverters and offers the upsides of individual module most extreme force point (MPP) following (MPPT). Another fell inverter is appear in Fig. 1(f), where each PV board is associated with its own dc/air conditioning inverter, and those inverters are then set in arrangement to achieve a high-voltage level.

The advantages are "one converter for every board, better usage PV module, capacity of blending distinctive sources. Likewise, this dc/air conditioning fell inverter expels the requirement for the perstring dc transport and the focal dc/air conditioning inverter, which further enhances the general effectiveness.

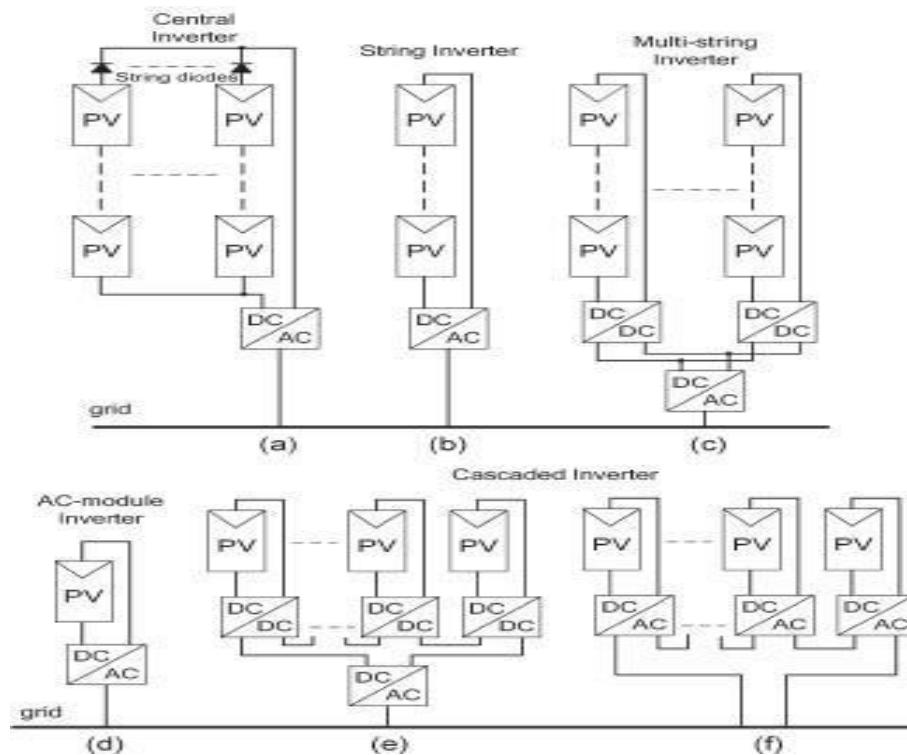


Fig. 1: Configurations of PV systems (a) Central inverter (b) String inverter (c) Multistring inverter (d) AC-module inverter (e) Cascaded dc/dc converter (f) Cascaded dc/ac inverter

The measured fell H-span multilevel inverter, which requires a disconnected dc hotspot for every H-scaffold, is one dc/fell inverter topology. The different dc joins in the multilevel inverter make autonomous voltage control conceivable. In the interim, the measured quality and minimal effort of multilevel converters would position them as a prime contender for the up and coming era of productive, strong, and solid network associated sun oriented force hardware.

A particular fell H-bridge multilevel inverter topology for single-or three-stage lattice associated PV frameworks has displayed in this paper. To adjust the three-stage framework current, balance pay has added to the control framework.

A three-stage secluded fell multilevel inverter proto sort has fabricated. Every Hextension is associated with a 185-Wsolar board. The measured outline will build the adaptability of the framework and lessen the expense.

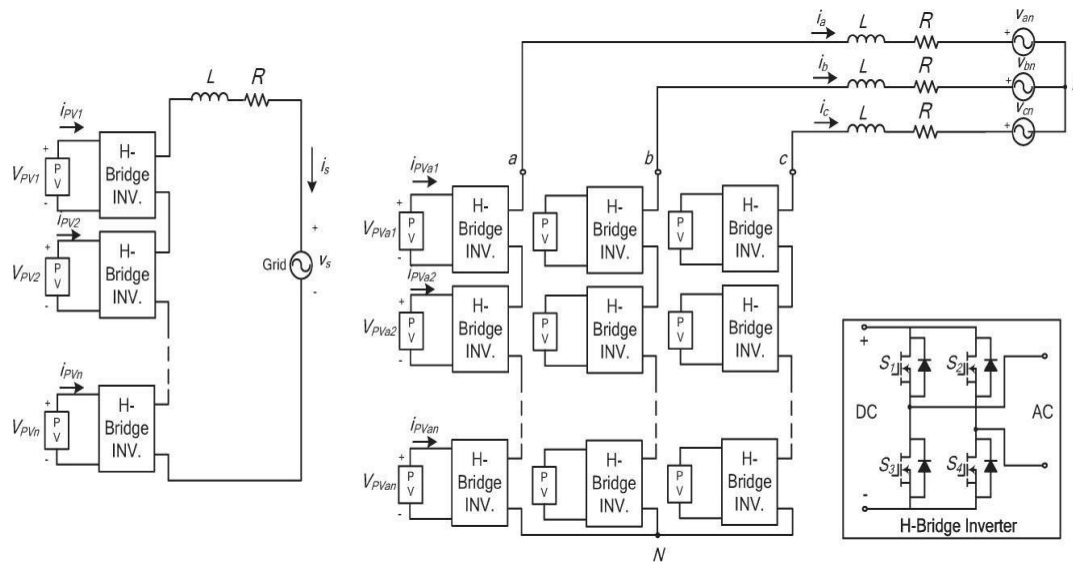


Fig. 2: Topology of the modular cascaded H-bridge multilevel inverter for gridconnected PV systems.

SYSTEM DESCRIPTION

Modular cascaded H-bridge multilevel inverters for single and three phase grid connected PV systems are shown in Fig. 2. Each phase consists of an H-bridge converters connected in series, and the dc link of each H-bridge can be fed by a PV panel or a short string of PV panels. The cascaded multilevel inverter is connected to the grid through L filters, which are used to reduce the switching harmonics in the current. By different combinations of the four switches in each bridge module, three output voltage levels can be generated: $-v_{dc}$, 0, or $+v_{dc}$. A cascaded multilevel inverter has an input sources will provide $2n + 1$ levels to synthesize the ac output waveform.

This $(2n + 1)$ level voltage waveform enables the reduction of harmonics in the synthesized current, reducing the size of the needed output filters. Multilevel inverters also have other advantages such as reduced voltage stresses on the semiconductor switches and having higher efficiency when compared to other converter topologies.

CONTROL SCHEME

In order to eliminate the adverse effect of the PV modules mismatches and increase the efficiency to operate at different voltages and to improve the utilization of PV module. The separate dc links in the cascaded H-bridge multilevel inverter make independent voltage control possible. The distributed

MPPT control of the three-phase cascaded H-bridge inverter is shown in Fig. 5. In each H-bridge module, an MPPT controller is added to generate the dc-link voltage reference. The reactive current reference I_{qref} can be set to zero, or if reactive power compensation is required, I_{qref} can also be given by a reactive current calculator.

As the classic control scheme in three-phase systems, the grid currents in abc coordinates are converted to dq coordinates and regulated through proportional– integral (PI) controllers to generate the modulation index

in the dq coordinates, which is then converted back to three phases.

SIMULATION RESULTS

Simulation and experimental tests are carried out to validate the proposed ideas. A modular cascaded multilevel inverter switches operating at 1.5 kHz. A three-phase seven-level cascaded H-bridge inverter is simulated and tested. Each H-bridge has its own 185-W PV panel. The inverter is connected to the grid through a transformer, and the phase voltage of the secondary side is 60 Vrms. The system parameters are shown in Table I

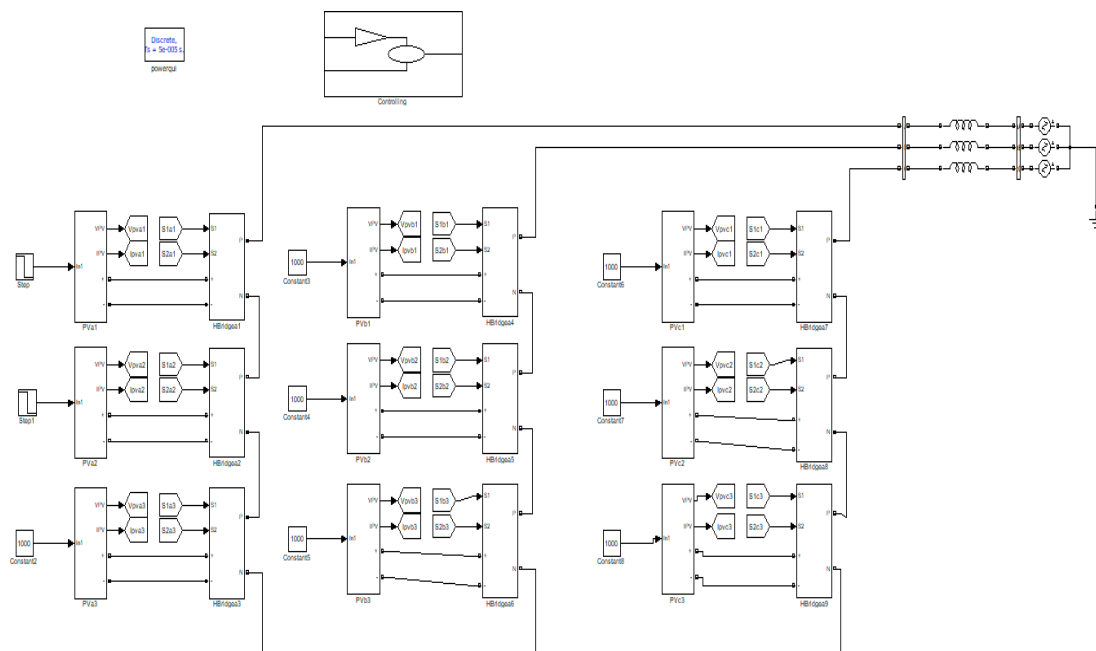


Fig. 3 proposed system in Simulink model

A. Simulation Results with PI Controller

To verify the proposed control scheme, the three-phase gridconnected PV inverter is simulated in two different conditions. First, all PV panels are operated under the same irradiance $S = 1000 \text{ W/m}^2$ and temperature $T = 25^\circ\text{C}$. At $t = 0.8 \text{ s}$, the solar irradiance on the first and second panels of phase a decreases to 600 W/m^2 , and that for the other panels stays the same. The dc-link voltages of phase a are shown in Fig. 2. At the beginning, all PV panels are operated at an MPP voltage of 36.4 V . As the irradiance changes, the first and second dc-link voltages decrease and track the new MPP

voltage of 36 V , while the third panel is still operated at 36.4 V . The PV current waveforms of phase a are shown in Fig. 2. After $t = 0.8 \text{ s}$, the currents of the first and second PV panels are much smaller due to the low irradiance, and the lower ripple of the dc-link voltage can be found in Fig. 2(a).

The dc-link voltages of phase b are shown in Fig. 3. All phase-b panels track the MPP voltage of 36.4 V , which shows that they are not influenced by other phases. With the distributed MPPT control, the dc-link voltage of each H-bridge can be controlled independently.

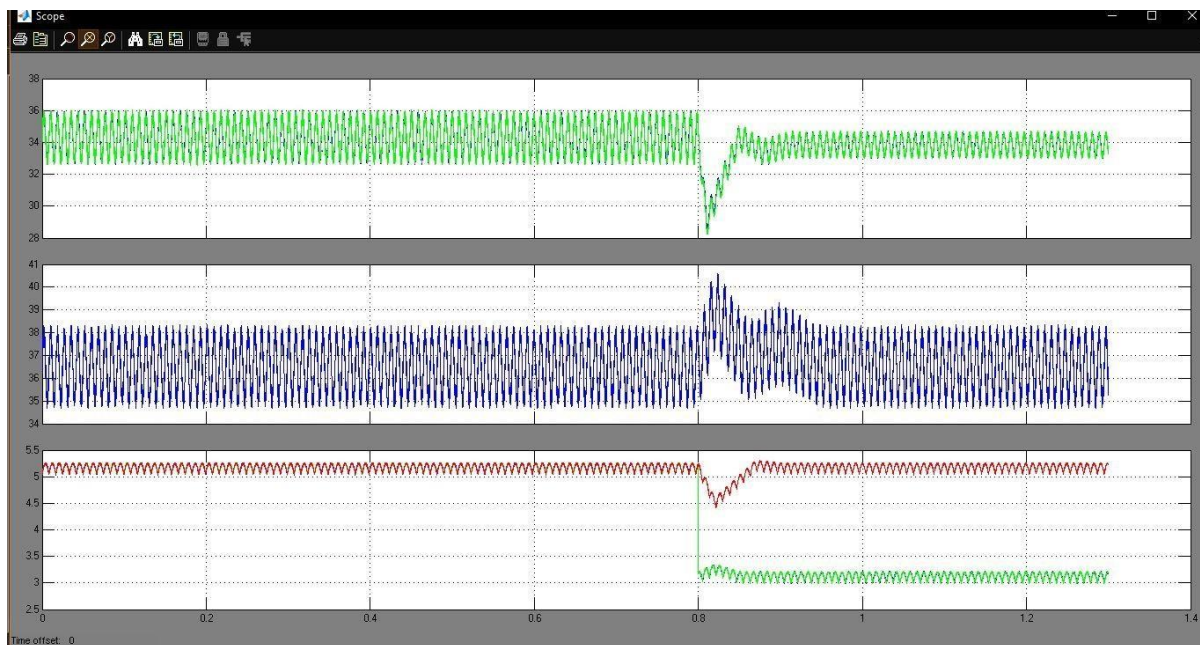


Fig. 1. (a) DC-link voltage of modules 1 and 2. (b) DC-link voltage of module 3. (c) PV currents of phase a with distributed MPPT ($T = 25^\circ\text{C}$).

In other words, the connected PV panel of each H-bridge can be operated at its own MPP voltage and will not be influenced by the panels connected to other H-bridges.

Thus, more solar energy can be extracted, and the efficiency of the overall PV system will be increased.

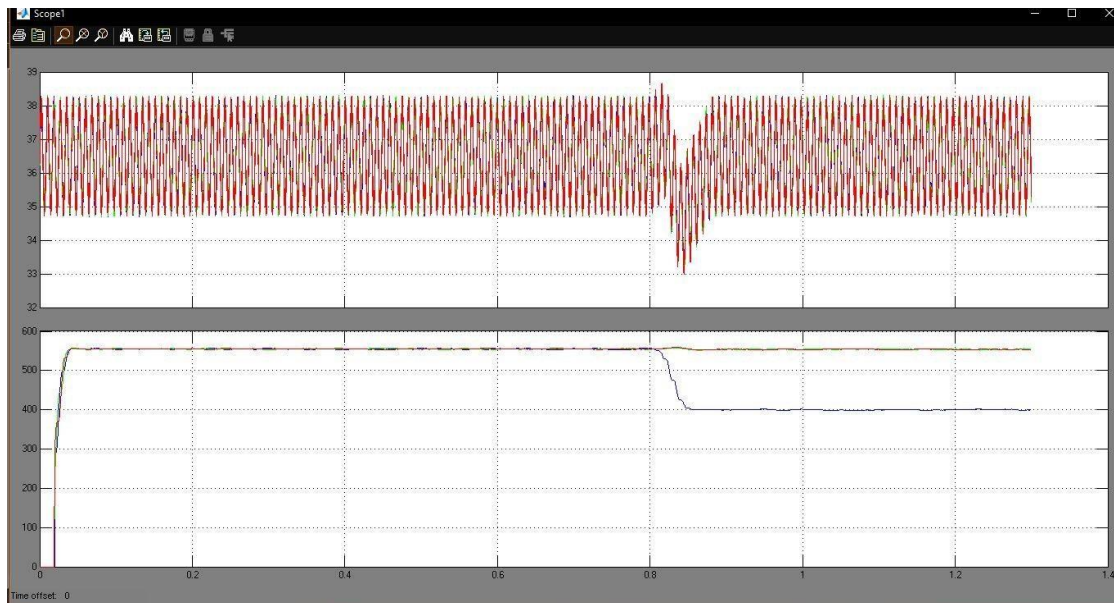


Fig. 3. (a) DC-link voltages of phase b with distributed MPPT ($T = 25^{\circ}\text{C}$). (b) Power extracted from PV panels with distributed MPPT.

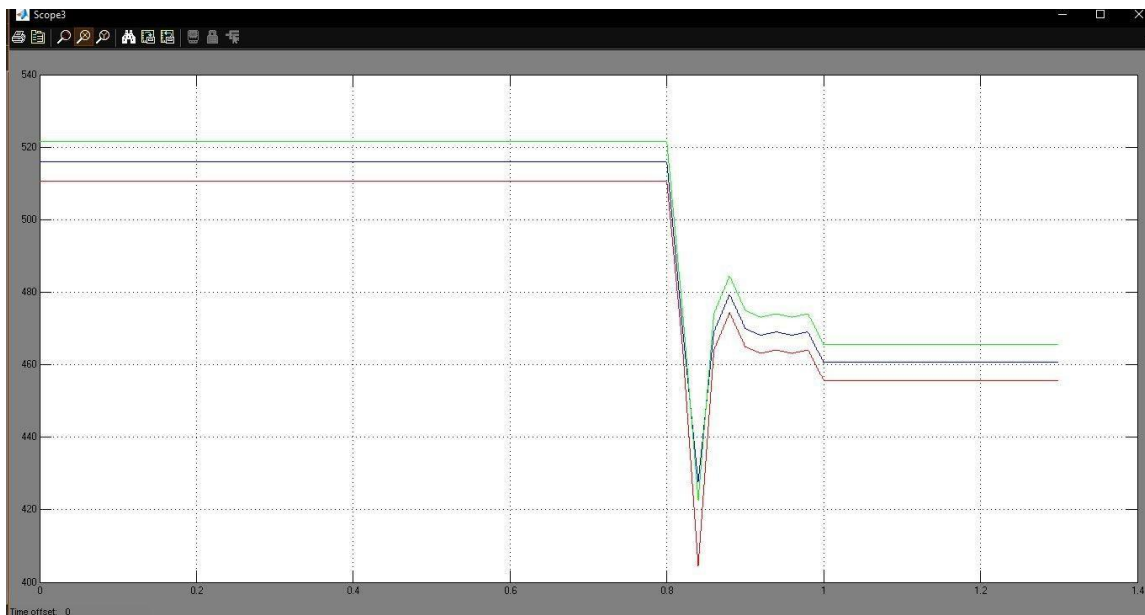


Fig. 4. Power injected to the grid with modulation compensation.

$S = 1000 \text{ W/m}^2$, and every phase is generating a maximum power of 555 W. After $t = 0.8 \text{ s}$, the power harvested from phase a decreases to 400 W, and those from the other two phases stay the same. Obviously, the power supplied to the three-phase grid-connected inverter is unbalanced. However, by applying the modulation compensation scheme, the power injected to the grid is still balanced, as shown in Fig. 4. In addition, by comparing the total power

extracted from the PV panels with the total power injected to the grid, it can be seen that there is no extra power loss caused by the modulation compensation scheme.

Fig. 5 shows the output voltages (v_{jN}) of the three-phase inverter. Due to the injected zero sequence component, they are unbalanced after $t = 0.8 \text{ s}$, which help to balance the grid current shown in Fig. 5.

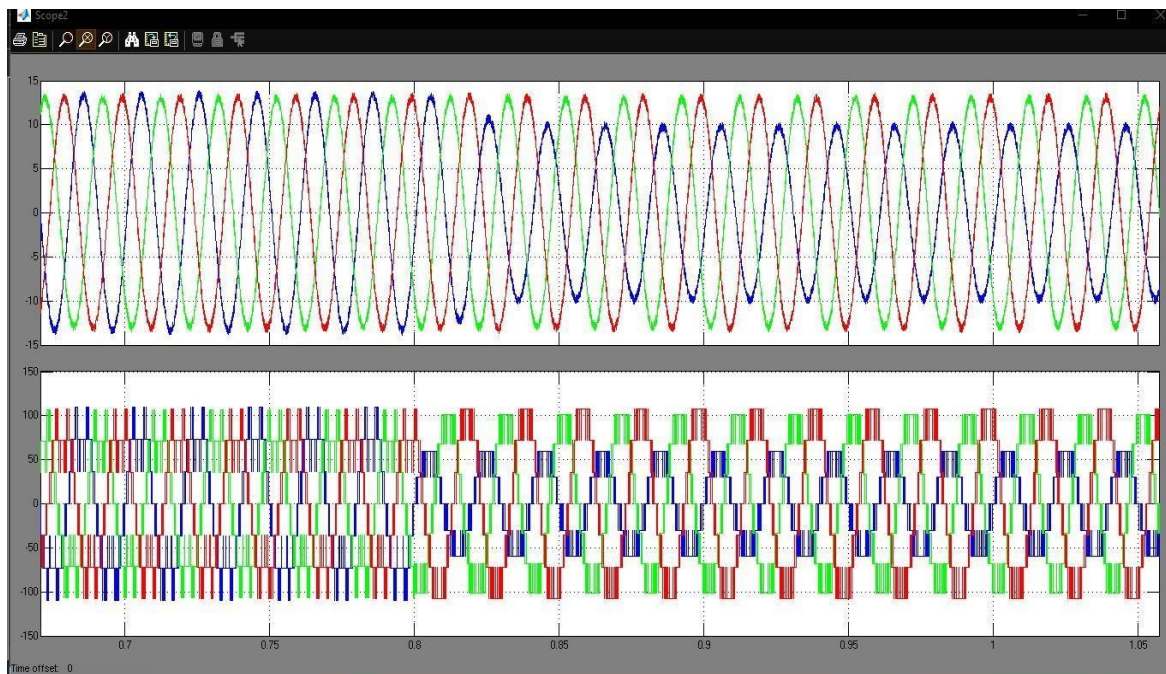


Fig. 5 (a) Three-phase inverter output voltage waveforms with modulation compensation.
(b) Three-phase grid current waveforms with modulation compensation

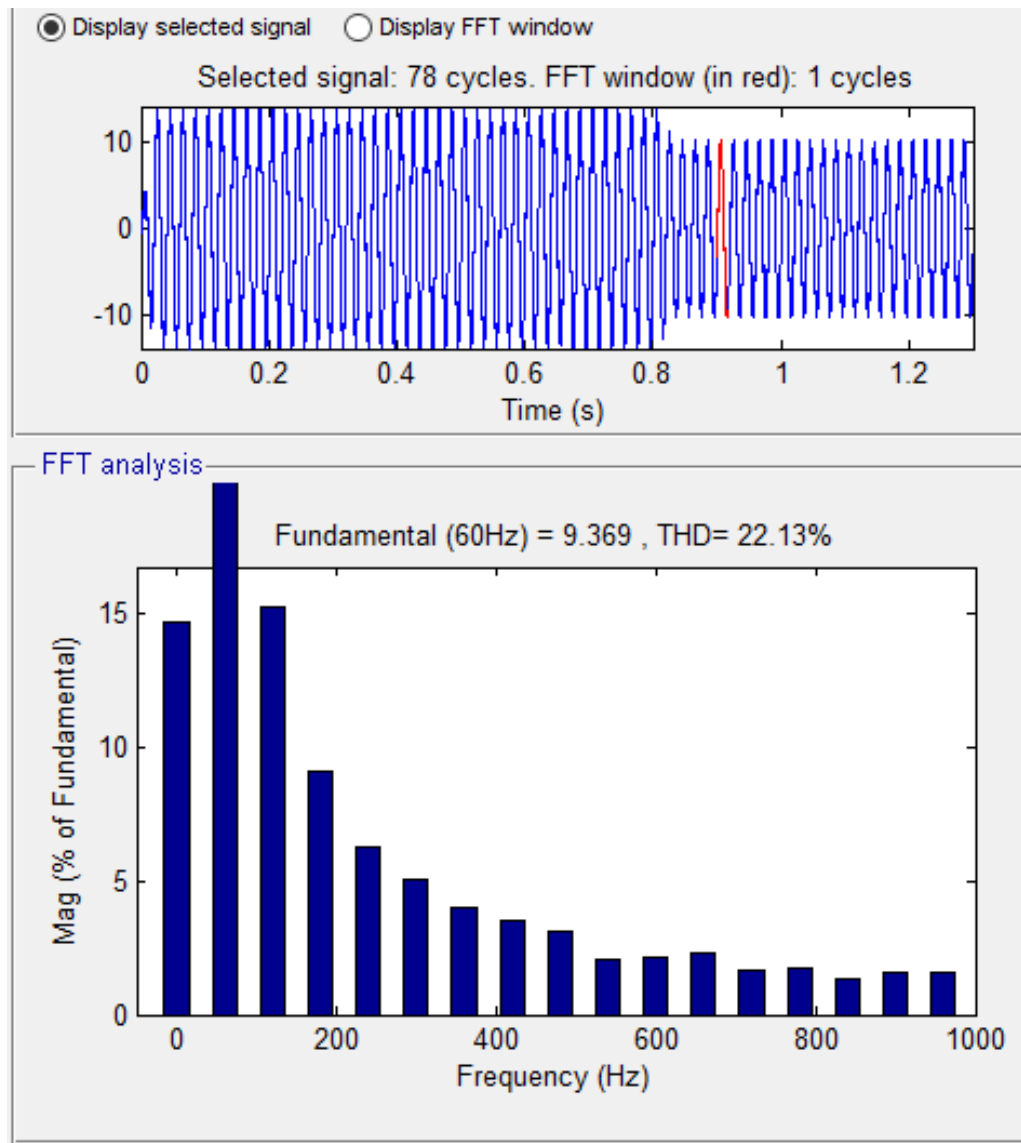


Fig: 6 THD analysis with PI Controller

B. Simulation Results with Fuzzy Controller

To verify the proposed control scheme, the three-phase grid connected PV inverter is simulated in two different conditions. First, all PV panels are operated under the same irradiance $S = 1000 \text{ W/m}^2$ and temperature $T = 25 \text{ }^\circ\text{C}$. At $t = 0.8 \text{ s}$, the solar irradiance

on the first and second panels of phase a decreases to 600 W/m^2 , and that for the other panels stays the same. The dc-link voltages of phase a are shown in Fig. 7. At the beginning, all PV panels are operated at an MPP voltage of 36.4 V . As the irradiance changes, the first and second dc-

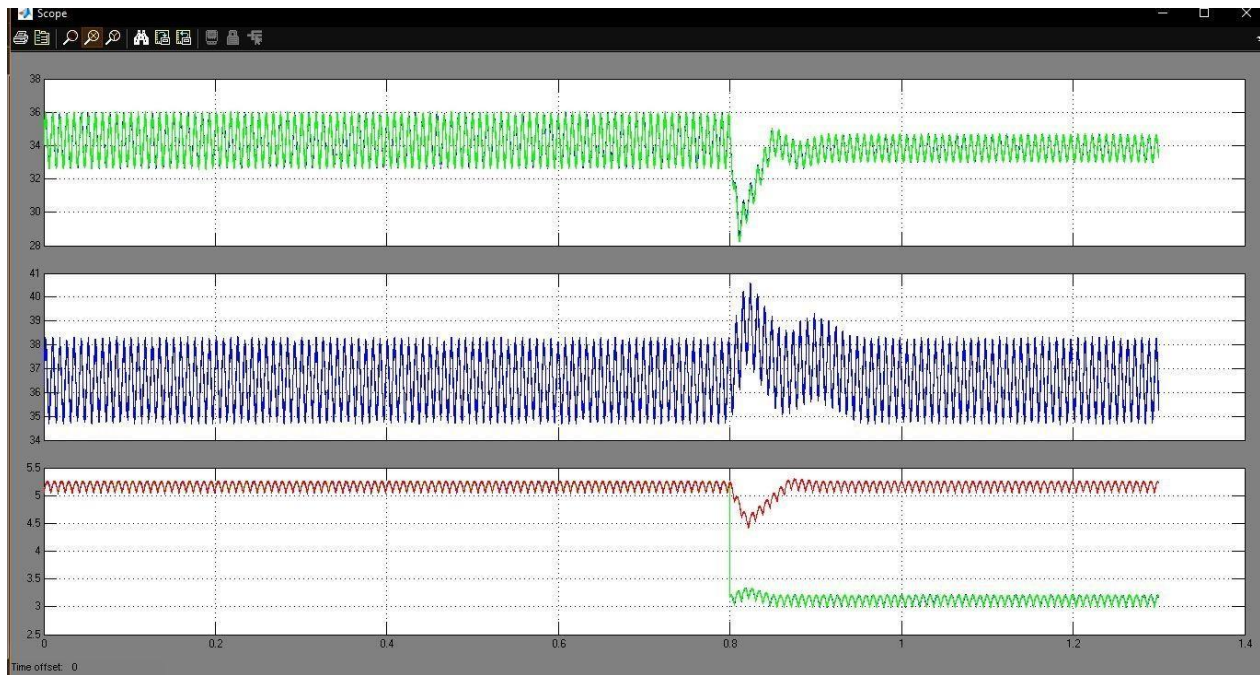


Fig. 7. (a) DC-link voltage of modules 1 and 2. (b) DC-link voltage of module 3. (c) PV currents of phase a with distributed MPPT ($T = 25^{\circ}\text{C}$).

link voltages decrease and track the new MPP voltage of 36 V, while the third panel is still operated at 36.4 V. The PV current waveforms of phase an are shown in Fig. 7. After $t = 0.8$ s, the currents of the first and second PV panels are much smaller due to the low irradiance, and the lower ripple of the dc-link voltage can be found in Fig. 7(a). The dc-link voltages of phase b are shown in Fig. 8. All phase-b panels track the MPP voltage of 36.4 V, which shows that they are not influenced by other phases. With the distributed MPPT control, the dc-link voltage of each H-bridge can be controlled independently. In other words, the

connected PV panel of each H-bridge can be operated at its own MPP voltage and will not be influenced by the panels connected to other H-bridges. Thus, more solar energy can be extracted, and the efficiency of the overall PV system will be increased.

Fig. 8 shows the power extracted from each phase. At the beginning, all panels are operated under irradiance $S = 1000 \text{ W/m}^2$, and every phase is generating a maximum power of 555 W. After $t = 0.8$ s, the power harvested from phase a decreases to 400 W, and those from the other two phases stay the same. Obviously, the power supplied to the

three-phase grid-connected inverter is unbalanced. However, by applying the modulation compensation scheme, the power injected to the grid is still balanced, as shown in Fig. 9. In addition, by

comparing the total power extracted from the PV panels with the total power injected to the grid, it can be seen that there is no extra power loss caused by the modulation compensation scheme.

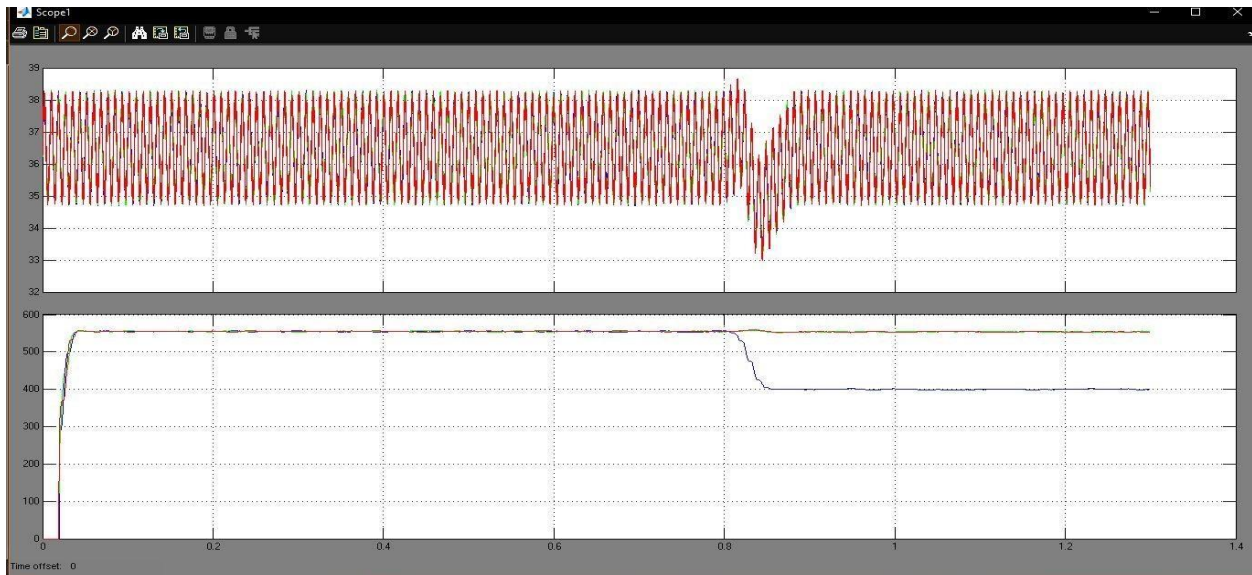


Fig. 8. (a) DC-link voltages of phase b with distributed MPPT ($T = 25^{\circ}\text{C}$). (b) Power extracted from PV panels with distributed MPPT.

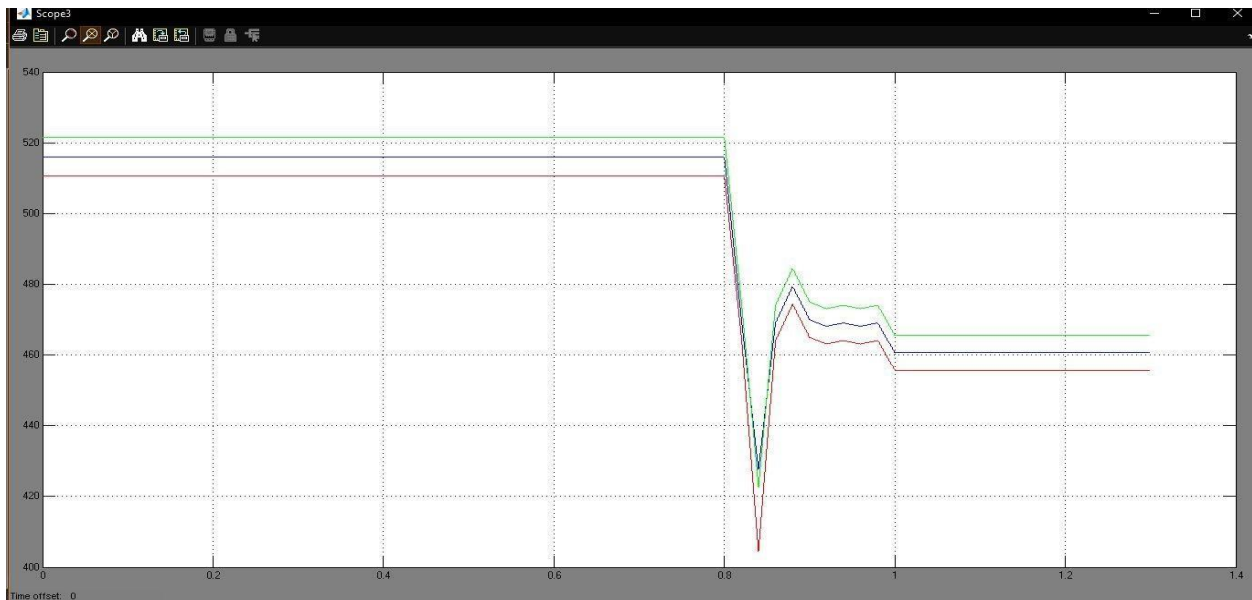


Fig. 9. Power injected to the grid with modulation compensation.

Fig. 10 shows the output voltages (v_{jN}) of the three-phase inverter. Due to the injected zero sequence component, they are unbalanced after $t = 0.8$ s, which help to balance the grid current shown in Fig. 10.

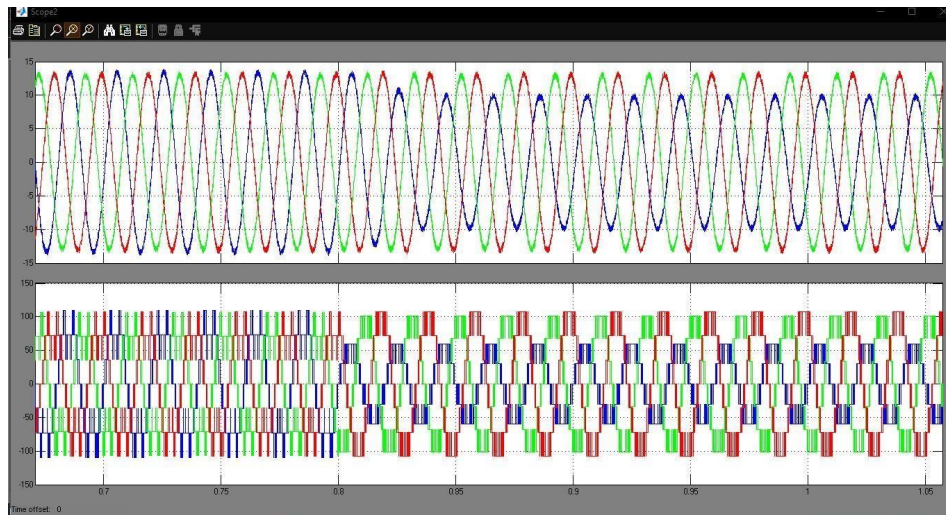


Fig. 10 (a) Three-phase inverter output voltage waveforms with modulation compensation. (b) Three-phase grid current waveforms with modulation compensation

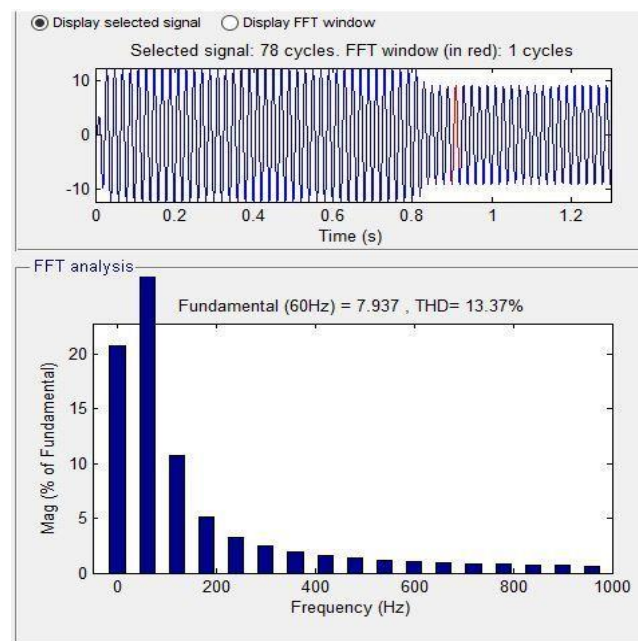


Fig: 11 THD Analysis using Fuzzy controller

CONCLUSION

A modular cascaded H-bridge multilevel inverter for grid-connected PV applications has presented by using fuzzy logic controller. The multilevel inverter topology will help to improve the utilization of connected PV modules if the voltages of the separated links has controlled independently. Thus, a distributed MPPT control scheme for both single and three phase PV systems has applied to increase the overall efficiency of PV systems in MATLAB simulink. The MATLAB/Simpower Systems simulation shows sensible performances of this controller. Here fuzzy controllers has used compared to alternative controllers because of its accurate performance.

For the three-phase grid-connected PV system; PV mismatches may introduce unbalanced supplied power, resulting in unbalanced injected grid current. A modulation compensation scheme, which will not increase the complexity of the control system or cause extra power loss, as added to balance the grid current. A modular three-phase seven-level cascaded H-bridge inverter has built in the laboratory and tested with PV panels under different partial shading conditions. With the proposed

control scheme, each PV module be operated at its own MPP to maximize the solar energy extraction, and the three-phase grid current is balanced even with the unbalanced supplied solar power.

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