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Fuzzy Controlled Multilevel Inverter Based MPPT Controllable PV for Grid Connected Applications

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Abstract- Inverters are classified by PV system configuration, inverter conversion rate, and whether they use transformers. After introducing state-of-the-art inverters for PV systems with and without transformers, the article focuses on some known problems and challenges of transformer less systems. Transformation-free topologies have great advantages such as low weight, volume and cost. In addition, they often achieve higher efficiency than topologies with transformers. Elimination of leakage current is one of the most important problems of transformer less inverters in grid-connected PV systems, where the technical challenge is how to keep the common mode voltage of the system constant to reduce the leakage current. To maximize the utilization of PV modules and the absorption of solar energy, a distributed maximum power point monitoring system is applied to both single-phase and three-phase multilevel inverters, which allows independent control of the voltage of each DC circuit. . For three-phase grid-connected applications, PV mismatches can cause asymmetric input power, resulting in asymmetric grid current.

Index Terms*—*cascaded multilevel inverter, distributed maximum power point (MPP) tracking (MPPT), modular, modulation Compensation.

I. INTRODUCTION

In recent years, the use of renewable energy sources instead of polluting fossil fuels and other forms has begun to spread. Photovoltaic systems offer the possibility of converting sunlight into electricity. Converting electrical energy using solar electricity enables installation, maintenance and becomes more affordable. One of the most common control strategy structures for distributed power generators is based on direct power control, which uses a DC-link voltage regulator and a regulator that regulates the current supplied to the grid. System components and power control model are modeled based on dynamic behavior. [1-3] presented an improved MPPT converter with a current compensation method for small-scale PV applications. Author's proposed a method that uses maximum power point tracking (MPPT) with a variable reference current that is continuously changed during one sampling period. Monitoring the maximum power point of a photovoltaic cell has been widely studied. He presented a new maximum power point tracking algorithm for solar arrays [4]. Algorithm detects the maximum power point of the PV. The calculated maximum power is used as a reference value for the control system. The proposed MPPT has several advantages: simplicity, high convergence speed, and independent of PV array characteristics. Many different techniques for monitoring the maximum power point of a photovoltaic (PV) system are discussed and convenient reference for future work in solar power generation repreented [5,6]. The Modular Sequential H-Bridge multilevel inverter, which requires a separate DC power supply for each H-Bridge, is a single DC/AC inverter topology. The separate DC connections of the multilevel inverter allow independent voltage regulation. As a result, individual MPPT control can be achieved in each PV module and the energy harvested from the PV panels can be maximized. At the same time, the modularity and low cost of multilevel converters would make them prime candidates for the next generation of efficient, robust and reliable grid-connected solar electronics. Author deals with a modular series H-bridge multilevel inverter topology for single or three-phase grid-connected PV systems. Panel mismatch problems are discussed to show the necessity of individual MPPT control, and then a control system with distributed MPPT control is proposed. The distributed MPPT control system can be applied to both single-phase and three-phase systems [7-9]. Furthermore, in the presented three-phase grid-connected PV system, when each PV module is operated at its own MPP, PV mismatches can cause asymmetric power from the three-phase multilevel inverter, resulting in asymmetric input grid current. Modulation compensation is also included in the control system to balance the three-phase network current.

An Improved Disturbance and Detection Maximum Power Point Tracking Algorithm for PV Arrays.

Improved Disturbance and Detection Maximum Power Point Tracking Algorithm for PV Arrays. Improved disturbance and detection method in monitoring control of the maximum power point of solar energy systems [10]. He explained the method of detecting disturbances. A maximum solar energy monitoring algorithm for rapidly changing atmospheric conditions was explained [11]. Evaluation of maximum power point monitoring methods for grid-connected photovoltaic systems is discussed in [12]. There are so many methods available in the maximum power tracking method, but he used a proper tracking device. Fuzzy inference is performed using Sugeno's method [13]. So this is Sugeno or Takagi Sugeno-Kang, the method of fuzzy reasoning. It was introduced in 1985 [9] and is similar in many ways to the Mamdani method. The hardware implementation of the maximum power point tracking controller on PV system fuzzy logic is explained in [1]. The electricity produced by a photovoltaic system depends on solar radiation and temperature. A rule-based fuzzy logic controller for a PWM inverter in a photovoltaic energy conversion scheme is discussed in [14]. Modeling and simulation of the electrical part of a grid-connected solar energy system was explained. In this work, a controller based on fuzzy logic was proposed for MPPT monitoring in solar cells.

II. SYSTEM DESCRIPTION

Modular cascaded H-bridge multilevel inverters for single-phase and three-phase grid-connected PV systems are shown in Figure 1. Each phase consists of n H-bridge inverters are in series connection, and the DC power of each H-bridge. can be supplied with a PV panel or short PV panels. The cascaded multilevel inverter is connected to the grid via L-filters, which are used to reduce current switching ripples.

Different combinations of the four switches in each H-bridge module can produce three output levels: $-v_{dc}$, 0, or $+v_{dc}$. A multilevel inverter with n input sources provides 2n 1 levels to synthesize the AC output waveform. This (2n 1) level voltage waveform allows the harmonics of the synthesized current to be reduced, reducing the size of the output filters required. Multilevel inverters also have other advantages, such as lower voltages on solid-state switches and better efficiency compared to other converter topologies.

III. PANEL MISMATCHES

PV mismatch is a major problem of PV system. Due to uneven received radiation, different temperatures and aging of PV panels, the MPP of each PV module may be different. If each solar module is not controlled independently, the efficiency of the entire solar system will decrease. A five-level dual-H-bridge single-phase inverter is simulated in MATLAB/SIMULINK to demonstrate the need for individual MPPT control. Each H-bridge has its own 185 W PV panel connected as an isolated DC source. The PV panel is modeled after the specifications of the commercial Astronergy CHSM-5612M PV panel.

Consider the operating conditions that each panel has a different radiation from the sun; panel 1 irradiance S = 1000 W/m2 and panel 2 S = 600 W/m2. If only panel 1 is monitored and its MPPT controller determines the average voltage of the two panels, the power available from panel 1 would be 133W and the power from panel 2 would be 70W as seen. Without individual MPPT control, the total power harvested by the PV system is 203 W.

However, MPPs of PV panels at different irradiances. The maximum output power values are 185 and 108.5 W, while the S values are 1000 and 600 W/m2, which means that if one MPPT is achieved, the total power harvested by the PV system would be 293.5 W. This higher value is approximately 1.5 times the previous value. Thus, individual MPPT control is required in each PV module to increase the efficiency of the PV system.

PV mismatch can cause more problems in a three-phase grid-tied solar system. In addition to reducing overall efficiency, it can even cause unbalanced current in a three-phase grid-connected system. If there are PV differences between phases, the input power to each phase would be different. Since the mains voltage is balanced, this difference in input power causes an unbalanced current in the mains, which is not allowed by the mains standards. For example, an imbalance of currents per phase of more than 10% is not allowed in some plants, where the percentage imbalance is calculated by taking the maximum deviation from the average current and dividing it by the average current.

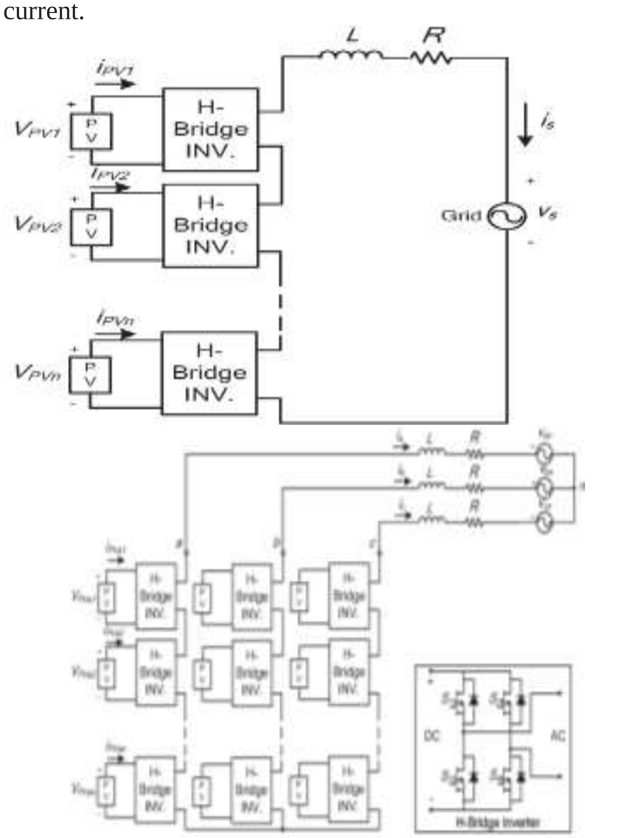


Fig. 1. Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

A control system with individual MPPT control and modulation compensation is proposed to solve the PV mismatch problem. The details of the monitoring system are discussed in the next section.

IV. CONTROL SCHEME

A. Distributed MPPT Control

In order to eliminate the harmful effects of mismatches and increase the efficiency of the PV system, the PV modules must operate at different voltages to improve the utilization of the PV module. Separate DC links in a multilevel H-bridge inverter provide independent voltage control. To realize individual MPPT control in each PV module, the control scheme proposed for this application is updated.

Distributed MPPT control of a three-phase series H-bridge converter is shown in Figure 2. An MPPT controller is added to each H-bridge module to generate a DC voltage reference. Each DC voltage is compared to the corresponding voltage reference and the sum of all errors is controlled by a summing voltage regulator that determines the current reference I_{dref}. The reactive current reference I_{qref} can be reset, or if reactive power compensation is required, I_{qref} can also be provided by a reactive current counter. A synchronous reference frame, a phase-locked circuit (PLL), was used to determine the phase angle of the mains voltage. In the classical control scheme of three-phase systems, grid currents in abc coordinates are converted to dq coordinates and proportionally controlled by integral (PI) controllers to form a module index in dq coordinates, which is then converted back to three phases. .

The distributed MPPT control scheme for a single-phase system is almost the same. The overall voltage regulator provides the magnitude of the active current reference value and the PLL provides the frequency and phase angle of the active current reference value. The circuit then provides the modulation index.

For each PV module to operate at its own MPP, take step a as an example; voltages v_{dca2} - v_{dcan} are controlled individually by n-1 loops. Each voltage regulator provides one module index part of the H-bridge module in phase a. Multiplying by the modulus index of phase a gives an n-1 modulus index. The first H-bridge modulation index can also be obtained by subtraction. The control schemes of steps b and c are almost the same. The only difference is that all DC link voltages are regulated by PI controllers and n module index sections are obtained for each phase.

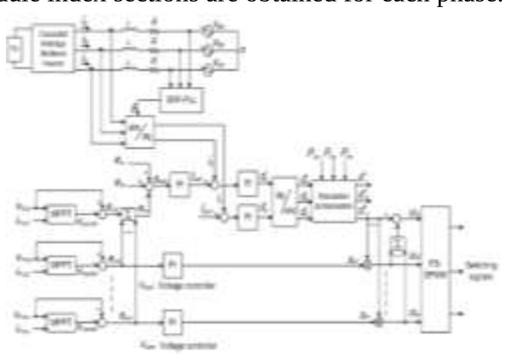


Fig.2. Control scheme for three-phase modular cascaded H-bridge multilevel PV inverter.

A phase-shift sinusoidal pulse-width modulation circuit is then implemented to drive each H-bridge switching device.

It can be seen that there is one H-bridge module out of N modules whose module index is obtained by subtraction. In single-phase systems N = n and in three-phase systems N = 3n, where n is the number of H-bridge modules per phase. The reason is that N voltage circuits are required to control the different voltage levels of the N H Bridge, and one is the total voltage circuit that provides the current reference. Thus, only N - 1 modulation indices can be determined with the last N - 1 voltage chain, and one modulation index must be obtained by subtraction.

Many MPPT methods have been developed and implemented. This article uses the incremental conduction method. It is suitable for digital control, which can easily monitor past voltages and current values and make all decisions.

B. Modulation Compensation

As mentioned earlier, PV mismatch can cause more problems for the three-phase modular cascaded H-bridge multilevel PV inverter. If each H-bridge module has an individual MPPT control, the solar input power of each phase would be different, introducing an asymmetric current into the grid. To solve the problem, a zero-sequence voltage can be applied to the phase branches, which affects the current in each phase. If the output phase voltage of the upgraded inverter is proportional to the unbalanced power, the current is balanced.

Thus, the modular compensation block as shown in Figure 1. 3, is added to the control system of three-phase modular cascaded multi-level PV inverters. The key is how to update the modulation index of each phase without increasing the complexity of the control system. First, the asymmetric power is considered with the ratio r_j, which is

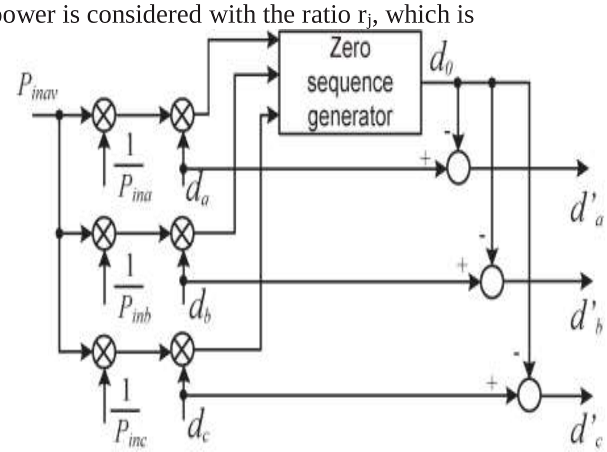


Fig. 3. Modulation compensation scheme.

$$r_j = \frac{P_{inav}}{P_{inj}} \tag{1}$$

Where P_{inj} is the input power of phase j ($j = a, b, c$), and P_{inav} is the average input power.

Then, the injected zero sequence modulation index can be generated as

$$d_0=\frac{1}{2}\left[\min\left(r_a\cdot d_a, r_b\cdot d_b, r_c\cdot d_c\right)+\max\left(r_a\cdot d_a, r_b\cdot d_b, r_c\cdot d_c\right)\right] \quad (2)$$

Where d_j is the modulation index of phase j ($j = a, b, c$) and is determined by the current loop controller.
The modulation index of each phase is updated by

$$d'_j = d_j - d_0 \quad (3)$$

Only simple calculations are needed in the scheme, which will not increase the complexity of the control system. An example is presented to show the modulation compensation scheme more clearly. Assume that the input power of each phase is unequal

$$P_{ina} = 0.8 \qquad P_{inb} = 1 \qquad P_{inc} = 1 \quad (4)$$

V.FUZZY LOGIC CONTROL

Fuzzy rules are frame error and derivative error with crisp members are given in the table and fuzzy methodology are shown in fig.(5) Fig.(6)to fig.(7) shows the membership functions.

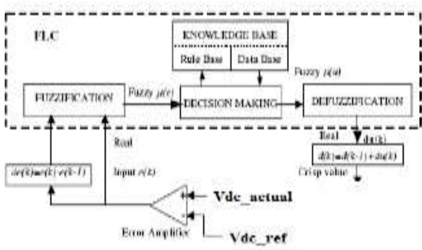


Fig.4. Block diagram of the Fuzzy Logic Controller (FLC) for Proposed Converter.

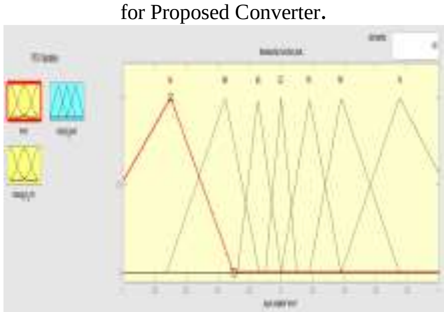


Fig.5. Membership Functions for Error.

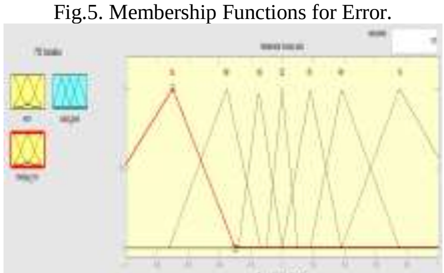


Fig.6. Membership functions for change_in_error.

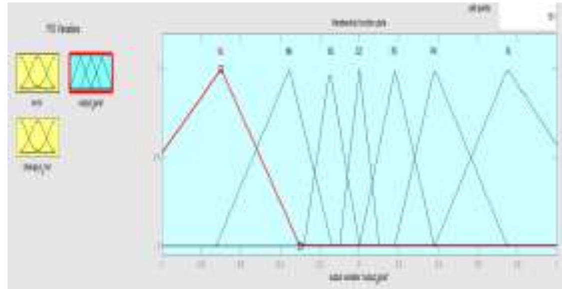


Fig.7. Membership functions for Output.

Table II

Table rules for error and change of error.

Error / Change error	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	NL
NM	NL	NL	NL	NM	NS	EZ	NM
NS	NL	NL	NM	NS	EZ	PS	NS
EZ	NL	NM	NS	EZ	PS	PM	EZ
PS	NM	NS	EZ	PS	PM	PL	PS
PM	NS	EZ	PS	PM	PL	PL	PM
PL	EZ	PS	PM	PL	PL	PL	PL

VI.MTALAB/SIMULATION RESULTS

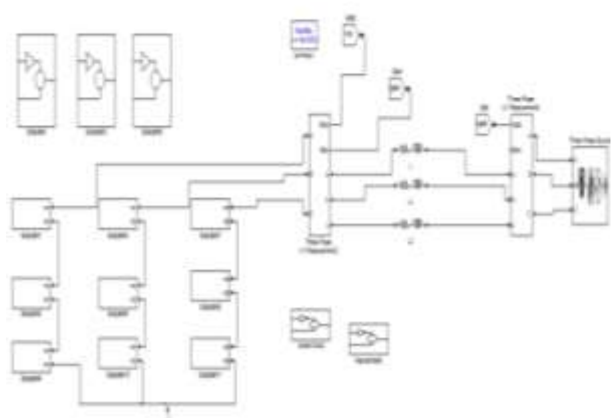
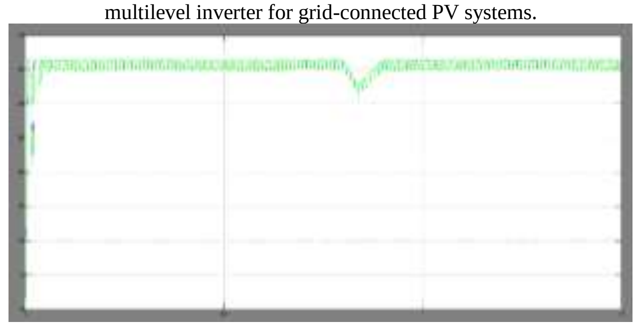


Fig.8.Matlab/Simulation model of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.



(a)

(b)

Fig. 9. DC-link voltages of phase a with distributed MPPT (T = 25 ◦C). (a) DC-link voltage of modules 1 and 2. (b) DC-link voltage of module 3.

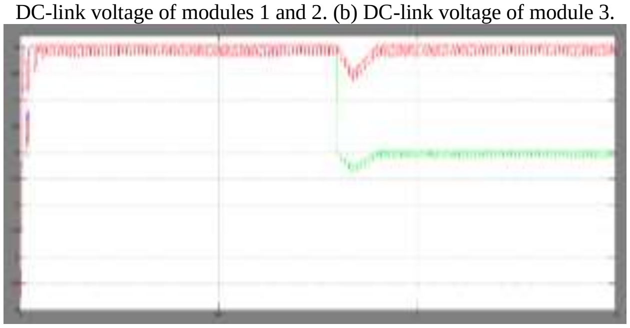


Fig.10. PV currents of phase a with distributed MPPT (T = 25 ◦C).

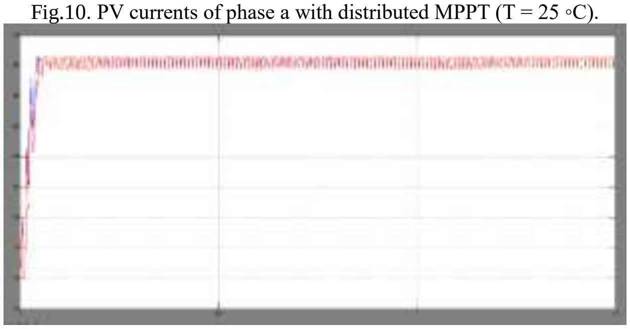


Fig.11. DC-link voltages of phase b with distributed MPPT (T = 25 ◦C).

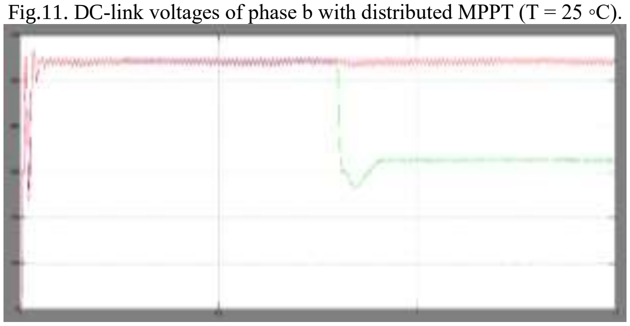


Fig.12. Power extracted from PV panels with distributed MPPT.

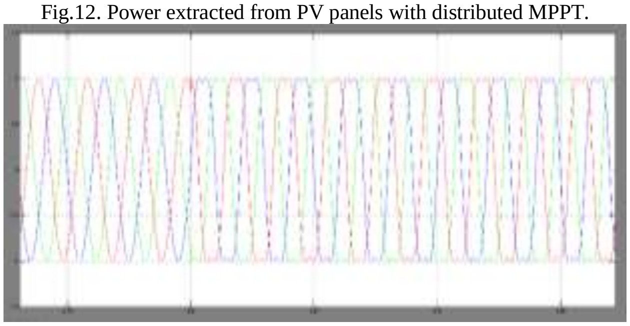


Fig.13. Modulation indices before and after modulation compensation.

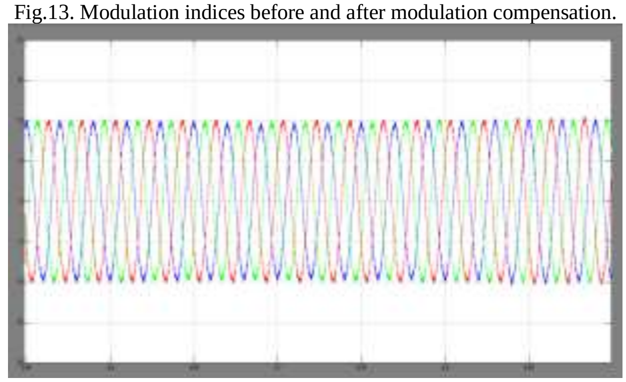


Fig. 14. Three-phase grid current waveforms with modulation compensation.

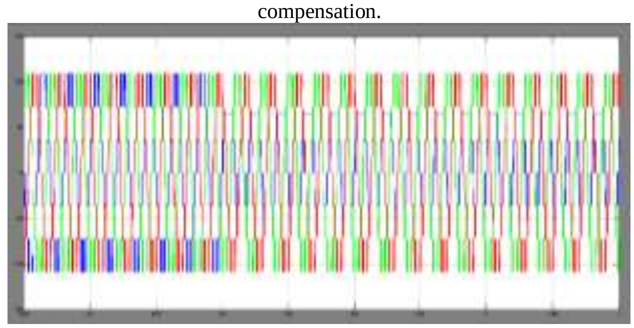


Fig. 15. Three-phase inverter output voltage waveforms with modulation compensation.

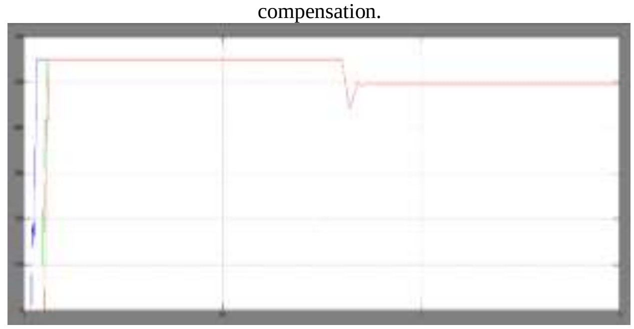


Fig.16. Power injected to the grid with modulation compensation.

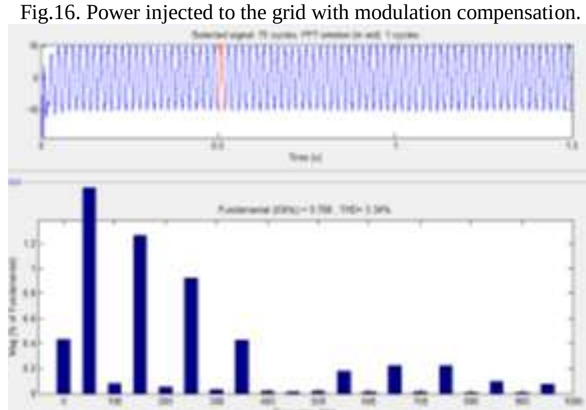


Fig.17.THD for PI Controller

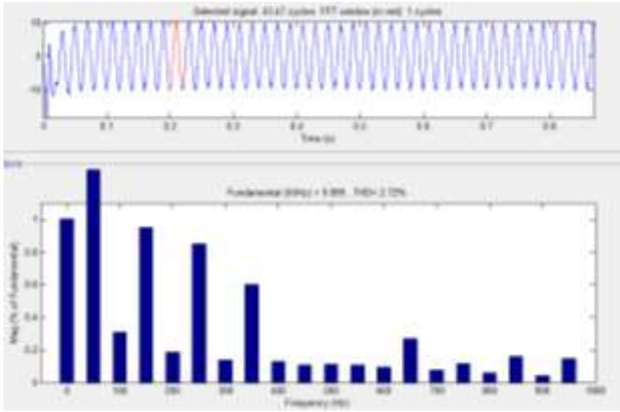


Fig.18.THD for Fuzzy logic controller.

VII.CONCLUSION

The purpose work is to investigate the harmonic profile of a grid-connected PV system for various MPPT methods including disturbance and incremental conductance detection and fuzzy controller. Using Matlab/Simulink environment, realizing the model of PV modules, the models of multi-level inverters and MPPT systems are combined with it to complete the PV simulation system with MPPT functions. The proposed fuzzy MPPT determines the optimal DC bus voltage reference for a converter without a DC-DC converter. Active and reactive power is controlled by a PI controller. A fuzzy three-phase single-phase grid-connected solar power system is proposed. A double resonant filter removes harmonic overtones. The power obtained from the PV array was enhanced by fuzzy-based MPPT, which improves the efficiency of the system under changing weather conditions.

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