An effective Analysis between Pi and Fuzzy Controllers when Operated Through a Five Level Grid Tied Photo-Voltaic Inverter

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Abstract:

This paper grants a effective analysis between the PI and fuzzy controllers when functioned through a single-phase five-level photovoltaic (PV) inverter configuration for grid-connected PV systems with newly developed modulated (PWM) control scheme. It employs two reference signals and a carrier signal to produce PWM switching signals. The inverter compromises much less total harmonic distortion and quick steady state response when coupled through a fuzzy controller. This paper obtainable for a single-phase multilevel inverter for PV application. The circuit configuration, modulation law, and operational principle of the suggested inverter were examined in detail. MATLAB/SIMULINK results indicate that the THD of the Fuzzy Controller Circuit is much smaller than that of the THD of the PI Controller Circuit.

Keywords: *Photovoltaic inverter, Maximum power point tracking system, Single phase five level inverter and fuzzy logic controller, PI controller.*

I. INTRODUCTION

The photovoltaic systems have completed a successful transition from a stand-alone feature to large grid-connected systems. The term grid-connected, means that the photovoltaic modules are connected to the grid. These modules are used to supplement the grid. There are a two ways in which the modules can be integrated into the grid: Connected photovoltaic arrays on the residential, commercial sites (i.e. on rooftops) or, large array of photovoltaic modules that acts as generating stations

Grid connected photovoltaic systems can vary in size, but these systems have common components. Most of these systems have PV arrays, an inverter to convert the DC power to AC power, a controller (i.e. protect the PV arrays from any voltage and frequency deviations), metering equipment to monitor the power that is feed into the grid and vice versa, MPPT (Maximum Power Point Tracker) Segment and other structures for mounting. Arrays from the residential and infomercials sites could sell their additional power to the grid during the day when more power than needed is obtained. When these sites need more power, (i.e. at night) they might buy it from the grid. Therefore, the grid turns as storage means for the PV arrays during the day. Occasionally these PV arrays also have batteries connected to it, so it can select whether to store the excess power to the batteries before sell it to the grid[1].

These PV inverters which are the core of a PV system, is used to renovate dc power gained from PV modules into ac power to be fed into the grid. Successful output waveform of the inverterreduces its particular harmonic content and, hence, the extent of the filter used and the level of Electro magnetic Interference (EMI) produced by switching process of the inverter. In recent ages, multilevel inverters have developed more good-looking for researchers and manufacturers due to their rewards over conventional three level PWM Inverters. They bid improved output waveforms, minor filter size and inferior EMI, lower Total Harmonic Distortion (THD). The three joint topologies for multilevel inverters are as follows:

1) Diode clamped (neutral clamped),
2) Capacitor clamped (flying capacitors),
3) Cascaded H-bridge inverter.

In accumulation, several modulation and control strategies have been advanced or adopted formultilevel inverters, with the following multilevel sinusoidal (PWM), multilevel selective harmonic elimination, & Space Vector modulation[2].A distinctive single phase three-level inverter approves full-bridge configuration by using estimated sinusoidal modulation technique as the power circuits. The output voltage then has the succeeding three values: zero, positive (+Vdc), and negative(-V dc) supply dc voltage (assuming that Vdcis the supply voltage). The harmonic workings of the output voltage are wavered by the carrier frequency and switching utilities. Consequently, their Harmonic reduction is imperfect to a certain degree. Toover come this restriction, this paper offers a five-level PWM inverter whose output voltage can be represented in the following five levels: zero,+1/2Vdc, Vdc, , -1/2V dc , and -V dc . As the amount of output levels increases, the harmonic content can becondensed. This inverter topology practices two reference signals, instead of one reference signal, to produce PWM signals for the switches. Together the reference signals V ref1and Vref2are identical to each other, excluding for an offset value equivalent to the amplitude of the carrier signal V carrier, as shown inFig.1.

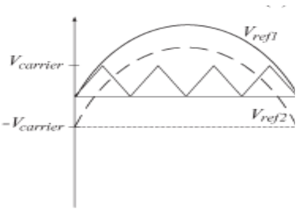


Fig.1 Carrier and Reference Signals

Since the inverter is used in a PV system, a Fuzzy control scheme is hired to keepthe output current sinusoidal and to have extraordinary dynamic performance under rapidly varying atmospheric conditions and to maintain the power factor at near unity. Simulation results are presented to validate the proposed inverter configuration.

II. CONFIGURATIONND MODELING OF A SYSTEM

The equivalent circuit of a PV panel by means of a load is shown in fig 2. The current assembly of the PV panel is constructed up by the specified equations [3]. Every parameters have given in Table 1.

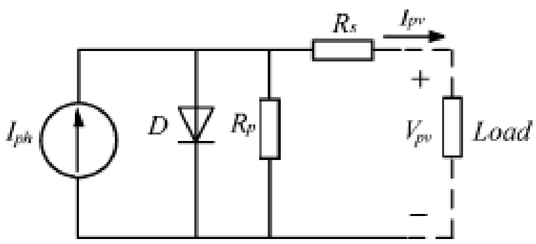


Fig 2: Equivalent Circuit Of A Solar Cell

$$I_{pv} = n_p I_{ph} - n_p I_{sat} * [\exp\left(\left(\frac{q}{AKT}\right)\left(\frac{V_{pv}}{n_s} + \right.\right.$$

IpvRs−1]

$$I_{pv} = \left(I_{sso} + K_i(T - T_r)\right) * \frac{S}{1000}$$

$$I_{sat} = I_{rr}\left(\frac{T}{T_r}\right)^3 \exp\left(\left(\frac{qE_{gap}}{KA}\right)\left(\frac{1}{T_r} - \frac{1}{T}\right)\right)$$

Table1: Parameters For Photovoltaic Panel

Max Power	75W
Short Circuit current, Isc	4.8A
MPPT Current, Imppt	4.4A
Open Circuit Voltage, Voc	21.7V
MPPT Voltage, Vmppt	17.0V

III. FIVE LEVEL INVERTER TOPOLOGY AND PWM LAW

The anticipatedsingle phase five level inverter topology is exposed in Fig.3. The inverter espouses afull-bridge configuration with an auxiliary circuit.PV arrays are allied to the inverter via a dc–dcBoost converter [4].

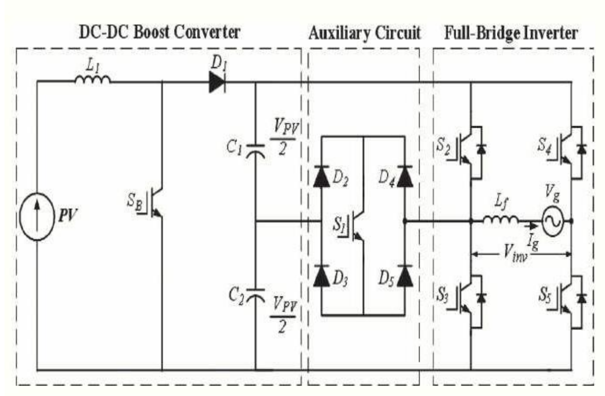


Fig.3 Single Phase Five Level Inverter Topology

Because the proposed inverter is used in a grid-connected PV system, utility grid is used in its place of load. The dc–dc boost converter is to be used to pace up inverter output voltage V into be more than 2 of grid voltage Vg to guarantee power flow from the PV arrays into the grid.

A filtering inductance Lf is used to filter the current injected into the grid. The injected current requisite be sinusoidal with low harmonic distortion. In order to produce sinusoidal current, sinusoidal PWM is used because it is one of the most effective methods. Sinusoidal PWM is found by comparing a high frequency carrier with a low frequency sinusoid, which is the modulating or reference signal. The carrier has a constant period; therefore, the switches have continuous switching frequency[5,6]. The switching instant is dogged from the crossing of the carrier and the modulating signal.

IV. THEINVERTER SWITCHING OPERATION

Since PV arrays are cast-off as input voltage sources, the voltage shaped by the arrays is recognized as V arrays. V arrays boosted by a dc–dc boost Converter to exceed 2Vg. The voltage across the dc-bus capacitors is identified as V pv. The working principle of the projected inverter is to generate five level output voltage, i.e., 0, +Vpv/2, +Vpv , -Vpv /2, and -Vpv. Proper switching control of the auxiliary circuit can cause half level of PV. Supply voltage, i.e., +Vpv/2, +V pv, -Vpv /2. Two reference signals V ref1 and V ref2 will take turns to be related with the carrier signal at a time. If V ref1 surpasses the peak amplitude of the carrier signal V carrier, V ref2 will be matched with the carrier signal until it reaches zero. At this point onward, V ref1 takes over the comparison process till it exceeds V carrier . Switches S1–S3 will be switching at the speed of the carrier signal frequency, whereas S4 and S5 will function at a frequency equivalent to the fundamental frequency. Table I illustrates the level of *V*inv during S1–S5 switch on and off and the switching pattern is shown in figure 4 and figure 5.

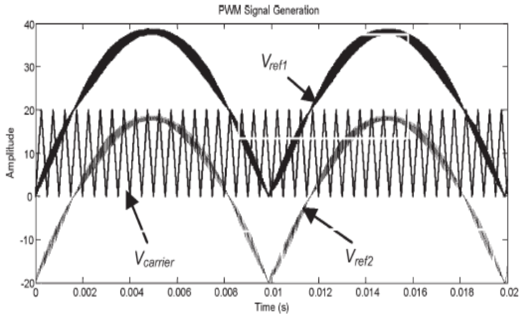


Fig 4: PWM Switching Strategy

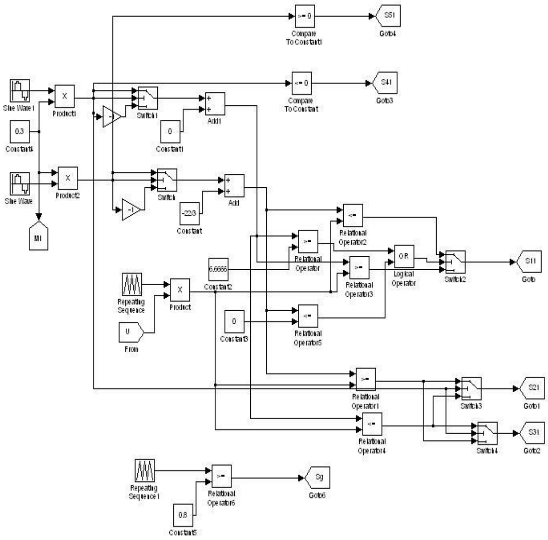


Fig 5: PWM Switching Control

V. CONTROL SYSTEM ALGORI-THM AND IMPLEMENTATION USING FUZZY CONTROLLER

The feedback controller cast-off in this request uses the FUZZY algorithm. As shown in Fig., the current injected into the grid, also known as grid current I g, is detected and fed back to a comparator which links it with the reference current I ref. I refis obtained by sending the grid voltage and converting it to reference current and reproducing it with constant m. This is to ensure that Igis inphase with grid voltage V g and always sat near-unity power factor. One of the complications in the PV generation systems is the extent of the electric power caused by solar arrays always changing with weather conditions, i.e., the intensity of the solar radiation.

Table II: Inverter Output Voltage During S1-S5 Switch ON And OFF

S1	S2	S3	S4	S5	Vinv
ON	OFF	OFF	OFF	ON	+Vpv/2
OFF	ON	OFF	OFF	ON	+Vpv
OFF	OFF	OFF	ON	ON	0
ON	OFF	OFF	ON	OFF	-Vpv/2
OFF	OFF	ON	ON	OFF	Vpv

A determined maximum power point tracking (MPPT) method or algorithm, which takes quick-response characteristics and is able to make good use of the electric power generated in any weather, is desirable to solve the above-mentioned problem. Constant mis derived from the MPPT algorithm. The perturb and observe algorithm is used to excerpt maximum power from PV arrays and deliver it to the inverter. The prompt current error is fed to a FUZZY controller. The integral term in the FUZZY controller advances the tracking by falling the instantaneous error between the reference and the actual current. The resulting error signal u which forms Vref1 and V ref2 is compared with a triangular carrier signal and intersections are sought to produce PWM signals for the inverter switches.

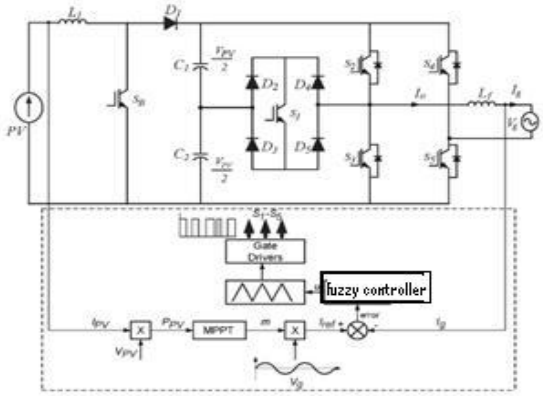


Fig.6 Five Level Inverter with FUZZY Control.

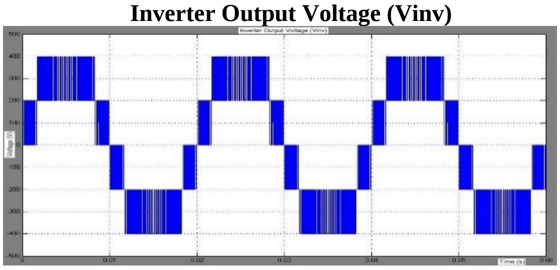
The Trapezoidal sum calculation is cast-off totrans form the integral term into the discrete time domain as it is the most straight forward technique. The proportional term is in a straight line used without approximation.

Similarly the control block was calculated using the PI controller and the Simulation results of five level inverter for grid connected PV system when connected through both the controllers is shown below.

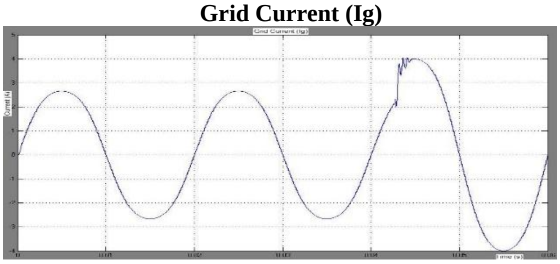
VI. SIMULATION RESULTS

A. Using PI Controller at Modulation Index M=0.8

Inverter Output Voltage (Vinv)

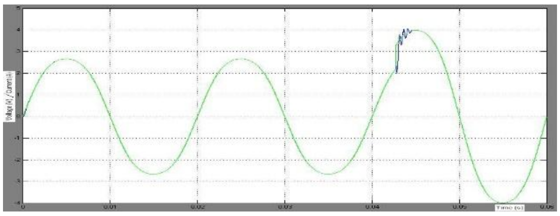


Grid Current (Ig)

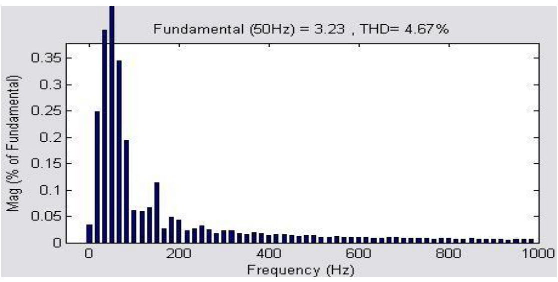


To optimize the power transported from PV arrays to the grid, it is recommended to operate at $0.5 \le M \le 1.0$. *V*inv and *Ig*for optimal operating condition are shown in both waveforms respectively.

Comparison between Reference Current (Iref) and Gate Current (Ig)

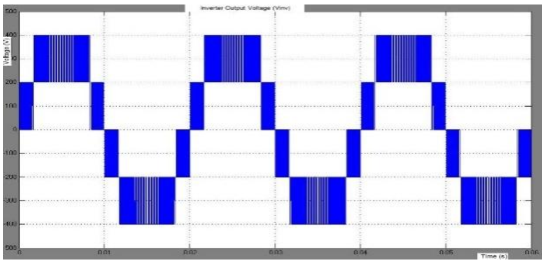


THD

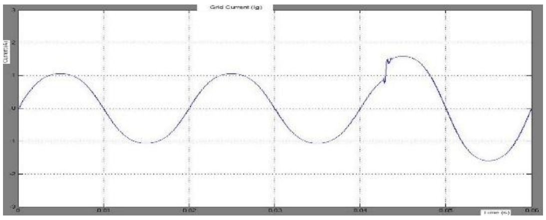


B.Using Fuzzy Controller at same modulation index of M=0.8

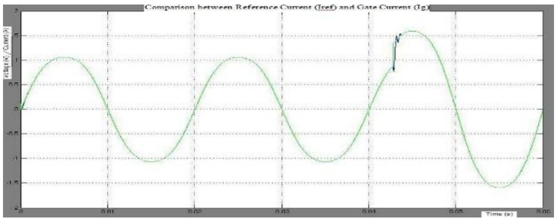
Inverter Output Voltage (Vinv)



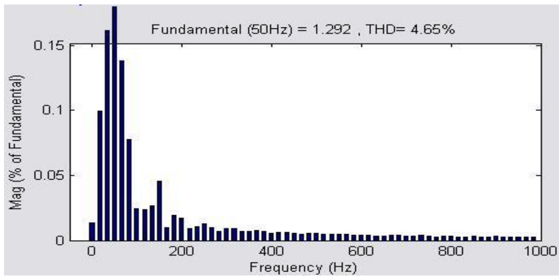
Grid Current (Ig)



Comparison between Reference Current (Iref) and Gate Current (Ig)



Total harmonic Distortions (THD)



In command to prove that the projected inverter can be practically executed in a PV system, simulations were performed by using MATLAB SIMULINK. It also supports to confirm the PWM switching strategy which then can be executed. It comprises of two reference signals and a triangular carrier signal. Together the reference signals are compared with the triangular carrier signal to produce PWM switching signals for switches S1−S5. Note that one leg of the inverter is functioning at a high switching rate equivalent to the frequency of the carrier signal, while the other leg is functioning at the rate of fundamental frequency (i.e., 50 Hz). The switch at the auxiliary circuit S1 also functions at the rate of the carrier signal. As mentioned former, the modulation index *M* will regulate the shape of the inverter output voltage *V*inv and the grid current *Ig*. Records shows *V*inv and *Ig* for different controls used Total Harmonic Distortion of A five level inverter for grid connected PV System engaging fuzzy controller is Very less at a Modulation Index M is 0.8 when related to other Modulation Index and as PI controller. So, at Modulation Index M is 0.8 the THD is 4.65%, consequently it is an almost a pure sine wave.

VII. CONCLUSION

This paper presented a single-phase multilevel inverter for PV submission. It exploits two reference signals and a carrier signal to produce PWM switching signals. The circuit topology, modulation law, and operational standard of the proposed inverter were analyzed in detail. A PI and FUZZY control is implemented to improve the performance of the inverter.

MATLAB/SIMULINK results specify that the THD of the Fuzzy Controller Circuit is ample lesser than that of the THD of the PI Controller Circuit. Besides, both the grid voltage and the grid current are in phase at near-unity power factor.

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