International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 1(04), Sep 2022, pp. 18-29

Article Title: Efficient Intelligent Controller for Fly Back Converter with an Isolated Thirty One Level Inverter for Grid Connected
PV System

Efficient Intelligent Controller for Fly Back Converter with an Isolated Thirty One Level Inverter for Grid Connected PV System

C. Cheneesha[1], Anna Fernandaz[2]

[1]Assistant Professor, Marthandam College Of Engineering and Technology
[2]Marthandam College of Engineering and Technology

ABSTRACT

In this project, propose an efficient intelligent controller for FLY BACK converter with an isolated 31-level inverter for grid connected PV system is implemented. PV application based MLI requires multiple voltage sources and in most of the MLIs, the loads shared by the voltage sources are varying due to inverter's topology and switching methods. This reduces the utilization of the PV array. PI controller is employed to maximise the output of the PV system. For optimal PV module utilization, an asymmetric cascaded thirty one-level multilevel inverter (MLI) is introduced in this thesis as an intermediate stage between converter and grid. The controlling of inverter is made by synchronizing the grid current and voltage and current using the closed loop control technique. FLY BACK converter is used as it has excellent voltage-gain ratio. The PI controller is proposed to perform the grid synchronization operation. The simulation and modelling of the introduced FLYBACK converter and thirty one-level inverter configurations with their control techniques are done in MATLAB domain so as to demonstrate the grid connected PV system performances.

Keywords: FLY BACK converter, Multilevel inverter, PI controller, PV array.

1 Introduction

The Renewable sources are in great demand in the power generating process to meet people's power needs and to efficiently overcome fossil fuel exhaustion, because of which it is significantly preferred in various domestic and industrial applications as it operate well in enhancing the system performance with multiple advantageous features like maintenance less nature, minimum cost, zero emission of harmful CO_2, trouble free installation, etc. Moreover, the usage of these renewable sources has reached extensive attention among the people in the recent scenario because the people find it hard to prefer the existing fossil fuels because of the rapid increase of cost and so the people tend to prefer the usage of conventional sources to meet the daily power demand.

Now a days the generation of power from renewable sources of energy is gaining more attraction due to its reliability, non-pollutant, non-contribution to harmful effects and its abundance. Among the many benefits of MLIs are their quasi-sinusoidal output voltage (with a lower THD and enhanced harmonic spectrum), higher power and voltage capacity, fewer switching losses, lower dv/dt, and lower common mode voltage [1]-[2]. Numerous PWM strategies have been developed in recent decades for 2L and ML inverters because an inverter's performance largely depends on its modulation strategy [3]–[5]. Similar steps have been suggested in [6], with more advancements and insights but no experimental confirmations. In [7]–[10], the same study has been expanded to include multiphase inverters. However, the current ripple RMS was highlighted rather than the instantaneous ripple. Inverters for 2L three-phase PWM were the first to be evaluated for peak-to-peak current ripple [11]. A modular nine-level H-bridge cell and a three level H-bridge cell are joined in series to form the hybrid asymmetric cascaded MLIs suggested in [8]. A unique three-phase seven-level inverter topology is shown in Reference [12], which combines H-bridge cells with flying capacitors with two cascade-connected two-level inverters. Using a two-phase converter and a Scott-T transformer, a novel single-source five-level three-phase MLI has been presented in [13]. There are just two phase voltages produced by the five-level converter. The Scott-T transformer connection is used later to convert these voltages into three phases [14–15].

This paper propose a efficient intelligent controller for FLY BACK converter with an isolated 31-level inverter for grid connected PV system is implemented. PV application based MLI requires multiple voltage sources and in most of the MLIs, the loads shared by the voltage sources are varying due to inverter's topology and switching methods. This reduces the utilization of the PV array. To enhance maximum power from PV system, PI controller is used. For optimal PV module utilization, an asymmetric cascaded thirty one-level multilevel inverter (MLI) is introduced in this thesis as an intermediate stage between converter and grid. The controlling of inverter is made by synchronizing the grid current and voltage and current using the closed loop control technique. FLY BACK converter is used as it has excellent voltage-gain ratio. The PI controller is proposed to perform the grid synchronization operation.

2 Proposed System

This present study has proposed the 31L MLI to acquire the enhanced output with multiple beneficial impacts. The conversion of the generated DC voltage into an acceptable AC for the benefit of consumer and utility connection is the primary requirement of power electronics between PV. To enhance and regulate the flow of power of the DC bus voltage for this DC-DC conversion, a fly back DC-DC converting system is used. The compensation of load demand, in which the implementation of Fly back converter is preferred to improve the low DC output of PV output in an efficient manner. In the proposed method with small number of switches, thirty one level inverter topology is connected to grid for high power applications.

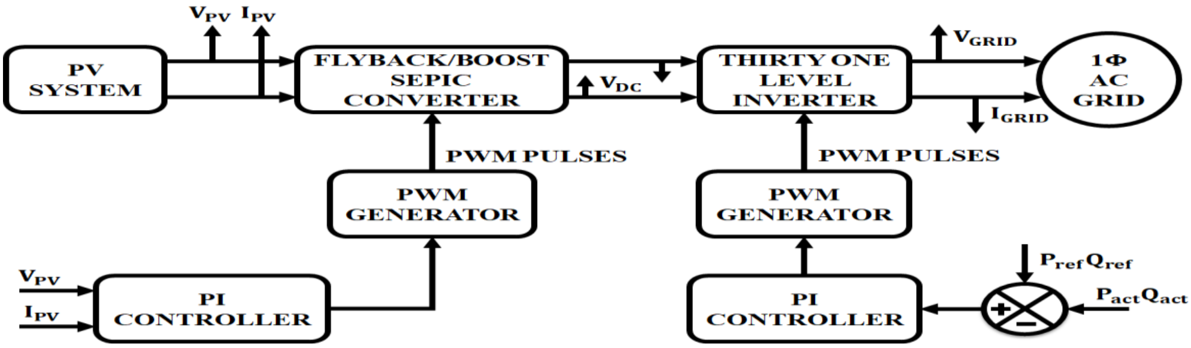

Figure 1: *Proposed System Block Diagram*

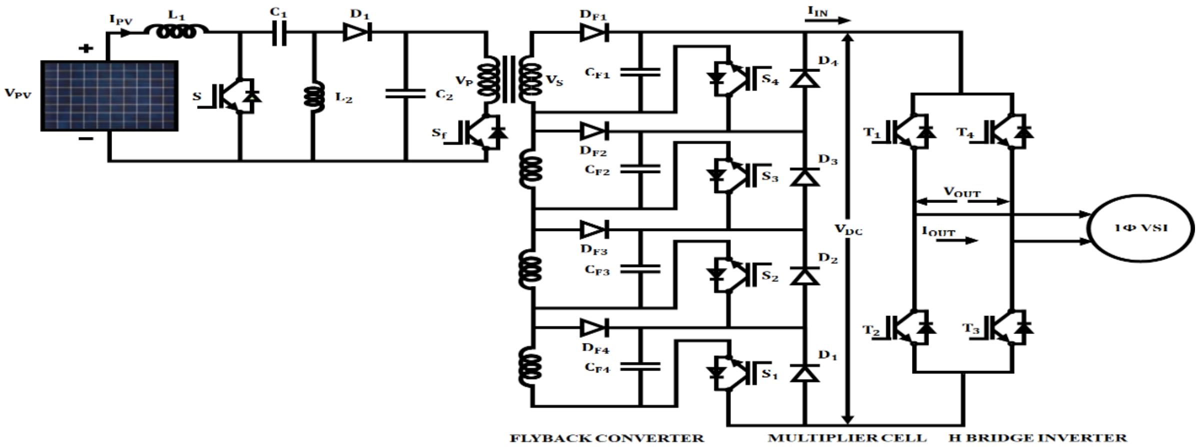

Figure 2: *Circuit Diagram*

2.1 PV System

The sun is a clean, dependable energy source that never runs out. Through the use of photovoltaic cells, the energy generated by the sun is directly captured for power generation. Photovoltaic (PV) technology, which uses the photovoltaic effect to turn sunlight into electricity, is one of the important methods used in solar power. Solar cells are the fundamental component of photovoltaic modules, which use the photovoltaic effect to generate electricity from light energy.

The PV system used for power conversion is made up of a tracking controller, tracking controllers, and power converters like inverters and DC-DC converters. As a result, the DC voltage produced can be increased using a DC-DC converter, and the DC voltage can be converted to AC using an inverter. According to the load rating, the PV panel should be chosen.

The PV model constitutes current sources, R_{sh} is Shunt Resistance, R_s is Series Resistance, R_{sh} is a Shunt Resistance represent the cell surface leakage through the edges.
The total current I is the difference of the light generated current I_{ph}, current through $R_{sh}$and diode current I_d .

$$I = I_{ph} - I_d - I_{sh} \qquad (1)$$

Equations(2) (3) show Diode current I_d and Shunt Resistance current I_{sh}

$$I_d = I_0 \left\{\exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1\right\} \quad (2)$$

$$I_{sh} = \frac{V+IR_s}{R_{sh}} \quad (3)$$

Potential across cell =V
Idealizing factor =m
Charge of electron =q
Cell reverse saturation current =I_0
Boltzmann constant =K
Absolute temperature of cell=T_c
Potential across cell =V

By utilizing Equations is shown below

$$I = I_G - I_0 \left\{exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1\right\} - \frac{V+IR_s}{R_{sh}} \quad (4)$$

Usually shunt Resistance R_{sh} in PV cells is high hence $\frac{V+IR_s}{R_{sh}}$ is eliminated Hence,

$$I = I_G - I_0 \left\{exp\left[\frac{V+IR_s}{A}\right] - 1\right\} \quad (5)$$

Where curve fitting parameter= A

$$A = \frac{mkT_c}{q} \quad (6)$$

Determination of phase current I_{ph} at standard test condition is

$$I = I_{ph} - I_0\left[exp\left(\frac{V}{a}\right) - 1\right] \quad (7)$$

When PV cell is short circuited

$$I_{sc} = I_{ph} - I_0\left[exp\left(\frac{0}{a}\right) - 1\right] = I_{ph} \quad (8)$$

Only in ideal case Equation (4.8) is valid. Hence the equality is not accurate. Equation (4.9) is written as

$$I_{ph} \approx I_{sc} \quad (9)$$

Irradiance and temperature both depend upon the photocurrent.

$$I_{ph} = \frac{G}{G_{ref}}\left(I_{ph} + \mu_{sc}.\Delta T\right) \quad (10)$$

Irradiance = G
Irradiance at standard testing conditions =G_{ref}

Determination of I_0

Because the shunt Resistance is typically high in all applications, it can be minimised by applying three criteria.

Open circuit voltage ($\mathrm{I} = 0, \mathrm{V} = V_{oc}$)
Short circuit current ($\mathrm{V} = 0,\ \mathrm{I} = I_{sc}$)

The voltage (V_{mp}) and current (I_{mp}) at maximum power the following equation are written as

$$I_{sc} = I_{ph} - I_0\left[exp\left(\frac{I_{sc}.R_s}{A}\right) - 1\right] \quad (11)$$

$$O = I_{ph} - I_0\left[exp\left(\frac{V_{oc}}{A}\right) - 1\right] \quad (12)$$

$$I_{pm} = I_{ph} - I_0\left[exp\left(\frac{V_{pm}+I_{pm}R_s}{A}\right) - 1\right] \quad (13)$$

Term (-1) is eliminated as it is very small compared to exponential term. According to Equation (10) substituting (I_{ph}) in Equation (13)

$$0 \approx I_{sc} - I_0 exp\left(\frac{V_0}{A}\right) \quad (14)$$

Hence,

$$I_0 = I_{sc}\ exp\left(\frac{-V_{oc}}{A}\right) \quad (15)$$

2.2 Flyback Converter

Generally, the topology of fly back converter has a coupled inductor in which the primary side is provided with a PWM switch and the secondary side with a diode. A continuous or variable dc input is supplied to the FLYBACK converter. In accordance with the winding link of coupled inductor, the direction of diode can be changed. The secondary side windings can be increased corresponding to the uses. The circuit should be operated with a continuous dc source in order to reduce its complexity. The switch used should be a device having high switching frequency (“Q_1”). To achieve rapid dynamic control over duty ratio, MOSFET is used. The coupled inductor is used to isolate voltage.

The highlights a flying capacitor multilevel fly back converter which uses switched-diode-capacitor (SDC) stage in order to get higher conversion ratio above 10:1 with efficiency greater than 95%. Red outline shows the single SDC stage. The volume of the inductor, switch stress and capacitor are reduced by the cascaded output stages of SDC.

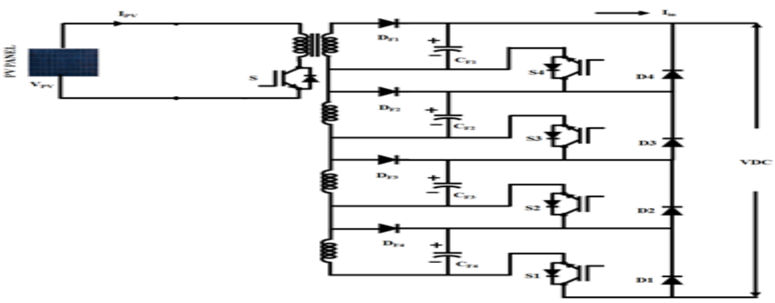

Figure 3: *Flyback converter topology*

Various output stages are cascaded in conventional boost converter, in which the MLFC (Multilevel Flying Capacitor) converter is generally employed in buck, boost inverter uses. The additional three stages of SDC (flying capacitors Cf1 to Cf3) reduces the output by a factor of five which is liable by each stage. The voltage (k*Vout) / (N-1) is equalized by the flying capacitors during the operation of steady-state, where k denotes the interest stage and N denotes level of converters. The necessary voltage rating of the components and their volume can be reduced by dividing the electronic system stress among multiple stages.

The flying capacitor multilevel fly back converter (FCMFC) consists of *M* number of fly back converters which are serially connected at the output, which has *N* number of stages of voltage (*N*-1 SDC stages) in every FLYBACK. Every FLYBACK transformer consists of *n* number of turn's ratio.

2.3 31- Level Inverter

Asymmetric configuration has the capability to generate high output level for semiconductor devices of same quantity and voltage sources while comparing with its symmetric equivalent. The number of output phase voltage levels in a standard cascaded multilevel inverter is given by n= 2m+1, where m is the quantity of dc voltage sources. For each H-bridge, a dc source and 4 switches are required. Because an inverter needs 12 switching devices for the first 7 levels, 16 for the next 9 levels, and 20 for the final 31 levels, it is challenging. However, the suggested inverter produces 12n + 7 levels, where n is the quantity of dc voltage sources in the series/parallel circuit. The output voltage of the inverter is nearly sinusoidal because of the total number of switching devices required, which is 3n + 9. Figure 4.8 illustrates the suggested topology for a 31-level output, which uses two voltage sources in a series-and-parallel circuit. The MLI configuration which is developed with an H-bridge inverter circuit know as Polarity generation circuit and an asymmetric fundamental circuit known as Level generator unit. While comparing the switches in level generation unit, those that are in the polarity generation circuit has higher stress.

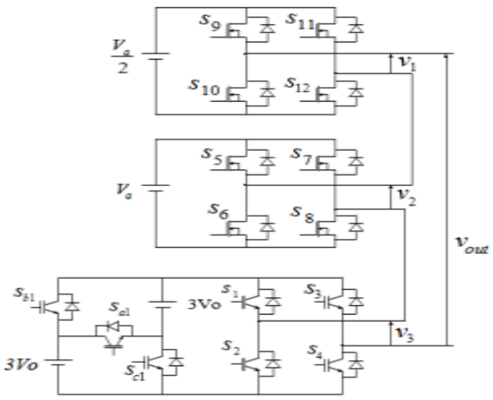

Figure 4: *For 31-level inverter.*

The circuit consists of semiconductor switching components which are in the same direction; because of which it has equal amount of driver circuits and MOSFETs. Multilevel inverter circuit has some amount of switching losses which is on the basis of the parameters namely switching frequency, current and blocking voltage. Zero level can be obtained by switching OFF S1, S2, S3 and S4. Positive and negative half cycle shall be in symmetry. So, S1, S2, S3, and S4 in the unit of level generation as well as T2 and T3 in the unit of polarity generation produces it.For an example, the switches S1 and S2 are ON and the diodes D3 and D4 are forward biased at state 3. Vo = V1 + V2 is obtained in positive half cycle. To obtain the values of output voltage, repetition of this process is made for all other states.

2.4 PI Controller

The proportional integral controller, sometimes known as the PI controller, is a feedback controller. It operates the plant that must be regulated using the integral of that value and a weighted sum of error. PI-Controllers have been used to regulate practically every process currently in use, from motion control to aerospace, and from slow to fast systems.

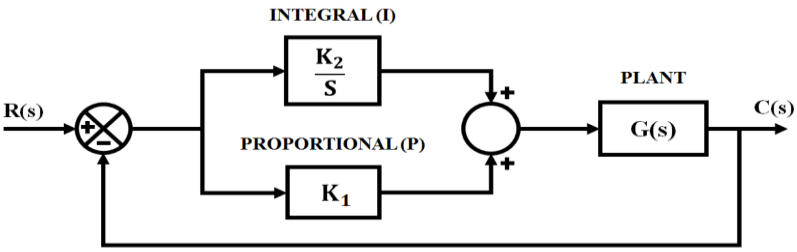

Figure 5: *Basic block of PI Controller*

The order and type of the system are both increased by one by the PI controller. Additionally, it results in a steady state error reduction to zero, which is not typically the case for proportional alone control. Maximum overshoot is decreased and damping is improved via PI controller. Additionally, it reduces bandwidth while enhancing rising time. In the event of noisy data, the inclusion of derivative action may make the system more stable in the steady state. This is because the inputs' high frequency phrases have a greater impact on the derivative activity. In the lack of derivative action, the PI controlled system is less responsive to actual (non-noise).

3 Results and Discussion

The simulation results are examined using a software MATLAB/SIMULINK.

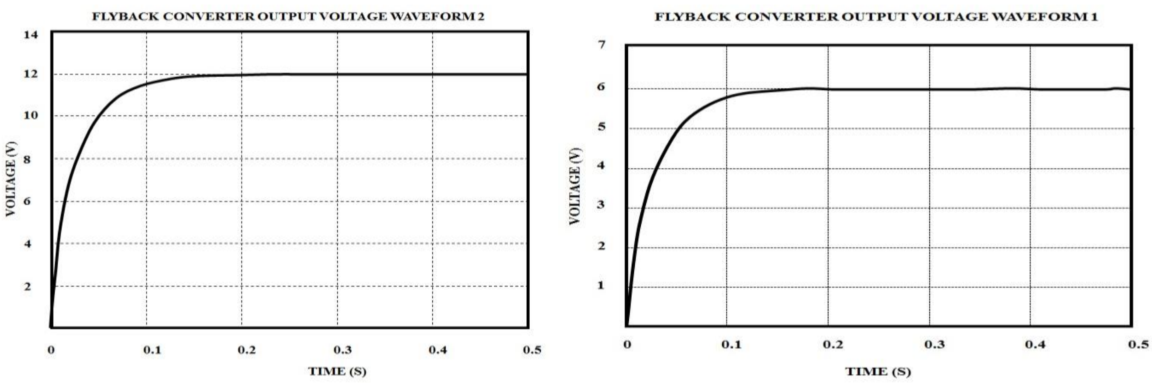

Figure 6: *Output of the 1st and 2nd DC voltage of FLYBACK Converter to the MLI*

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 1(04), Sep 2022, pp. 18-29

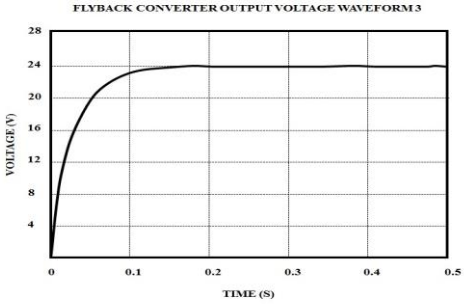

Figure 7: *Output of the 3rd DC voltage of FLYBACK Converter to the MLI*

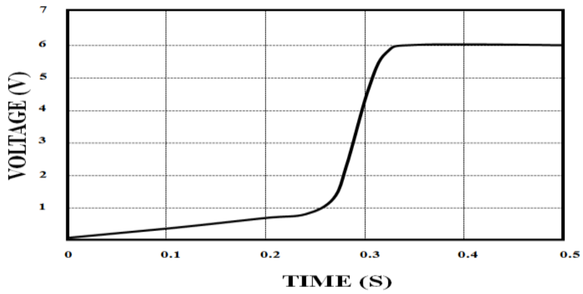

Figure 8: *Result of the 4th DC voltage of FLYBACK Converter with PI Controller*

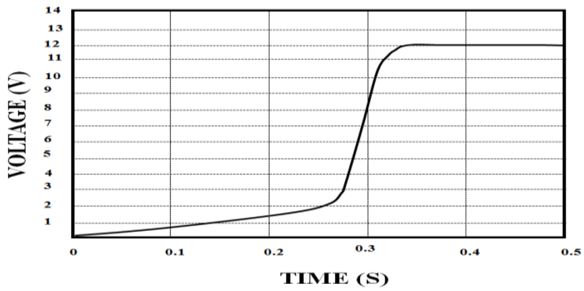

Figure 9: *Result of the 4th DC voltage of FLYBACK Converter with PI Controller*

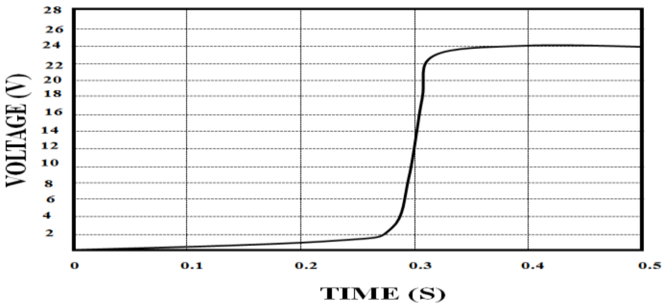

Figure 10: *Result of the 4th DC voltage of FLYBACK Converter with PI Controller*

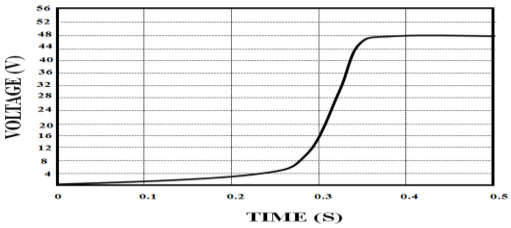

Figure 11: *Result of the 4th DC voltage of FLYBACK Converter with PI Controller*

Four stages of Flyback converters are used whose outputs 6V, 12V, 24V and 48V are coupled at the common point. The maximum voltage (48V) of boost converter is fed as input to voltage source inverter.

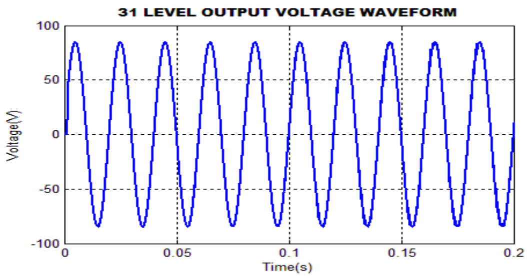

Figure 12: *Waveform of thirty one-level voltage with PI controller*

The converter's output voltage is supplied to a 31-level multilevel inverter with a decreased switch. The multilayer inverter is managed by the multiple references PWM technique. To change the modulation index and generate an output voltage with thirty levels, the reference signal is compared to a single high frequency carrier signal. Both an experimental setup and a Matlab simulation have been used to implement the suggested study. The thirty one-level output voltage with PI controller is shown in figure 12.

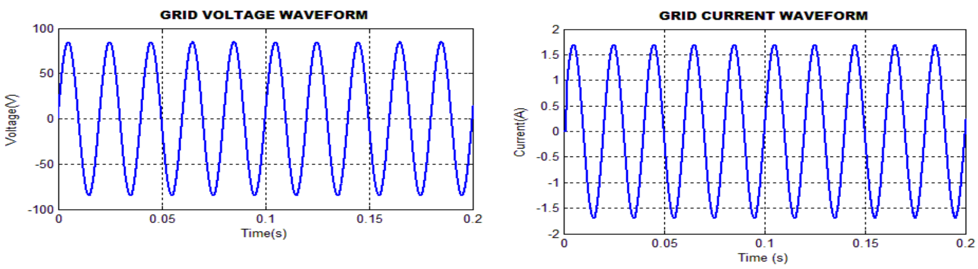

Figure 13: *Grid voltage and current waveforms with PI controller*

The output Grid voltage and current waveforms with PI controller for 31 level inverter is shown in Figure 13. The voltage value ranges from $+80V$ to $-80V$ for varying period of time in seconds.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 1(04), Sep 2022, pp. 18-29

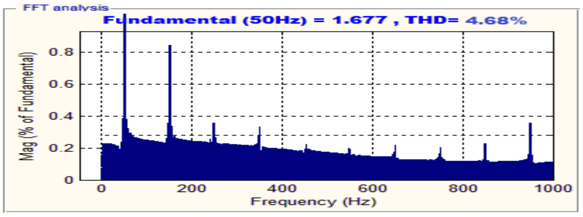

Figure 14: *THD waveform with PI Controller*

Figure 14 represent the PI controller THD waveforms of the 31 level inverter. The obtained values THD is given by 4.68%. Thus the proposed approach generates improved voltage outputs with minimized THD.

4 Conclusion

A new 31-level inverter has been designed with a reduced number of components for solar PV applications was proposed in this project. The algorithms track the variation of voltage at dc-link and change the switching frequency of FLYBACK converter. With the least amount of PV array and switching devices possible, the gain of the system can be increased by using numerous stages of converters. The PI controller uses the PV voltage, current, and voltage at the dc-link as control parameters. To supply the AC power to the grid, an asymmetric cascaded thirty one-level MLI is proposed. By modifying the modulation index using the multi-reference PWM approach, the requisite thirty-one levels are attained. Closed loop PI controllers based grid synchronization methods are combined with multi-reference PWM pulse to produce control signals for the inverter switches. The 31-level multilevel inverter produces greater output voltage levels with fewer circuit components and low THD than other inverters. Reduced losses, great efficiency, and relatively low total harmonic distortion were all features of the DC voltage source.

References

1. G. Zhang; J. Yu, Year: 2021, "Open-circuit fault diagnosis for cascaded H-bridge multilevel inverter based on LS-PWM technique," in *CPSS Transactions on Power Electronics and Applications*, Vol. 6, no. 3, pp. 201-208, September

2. T. Qanbari; B. Tousi, Year: 2021 "Single-Source Three-Phase Multilevel Inverter Assembled by Three-Phase Two-Level Inverter and Two Single-Phase Cascaded H-Bridge Inverters," in IEEE Transactions on Power Electronics, Vol. 36, no. 5, pp. 5204-5212, May.

3. M. T. Fard; W. A. Khan; J. He; N. Weise; M. Abarzadeh, Year: 2020, "Fast online diagnosis of open-circuit switching faults in flying capacitor multilevel inverters," in Chinese Journal of Electrical Engineering, Vol. 6, no. 4, pp. 53-62, December.

4. M. A. Hossein Zadeh; M. Sarebanzadeh; E. Babaei; M. Rivera; P. Wheeler, Year: 2021, "A Switched-DC Source Sub-Module Multilevel Inverter Topology for Renewable Energy Source Applications," in IEEE Access, Vol. 9, pp. 135964-135982.

5. L. V. Nguyen; H. -D. Tran; T. T. Johnson, Year: 2014 "Virtual Prototyping for Distributed Control of a Fault-Tolerant Modular Multilevel Inverter for PhotoVoltaics," in IEEE Transactions on Energy Conversion, Vol. 29, no. 4, pp. 841-850, December.

6. G. Grandi; J. Loncarski; O. Dordevic, Year: 2015, "Analysis and Comparison of Peak-to-Peak Current Ripple in Two-Level and Multilevel PWM Inverters," in IEEE Transactions on Industrial Electronics, Vol. 62, no. 5, pp. 2721-2730, May.

7. J. Yu, G. Zhang; M. Peng; D. Song; M. Liu, Year: 2020, "Power-matching based SOC balancing method for cascaded H-bridge multilevel inverter," in CPSS Transactions on Power Electronics and Applications, Vol. 5, no. 4, pp. 352-363, December.

8. A. Hota; S. Jain; V. Agarwal, Year: 2017 "An Optimized Three-Phase Multilevel Inverter Topology With Separate Level and Phase Sequence Generation Part," in IEEE Transactions on Power Electronics, Vol. 32, no. 10, pp. 7414-7418, October.

9. O. Lopez-Santos; C. A. Jacanamejoy-Jamioy; D. F. Salazar-D'Antonio; J. R. Corredor-Ramírez; G. Garcia; L. Martinez-Salamero, Year:2019, "A Single-Phase Transformer-Based Cascaded Asymmetric Multilevel Inverter With Balanced Power Distribution," in IEEE Access, Vol. 7, pp. 98182-98196.

10. C. -H. Hsieh; T. -J. Liang; S. -M. Chen; S. -W. Tsai, Year: 2016, "Design and Implementation of a Novel Multilevel DC–AC Inverter," in IEEE Transactions on Industry Applications, Vol. 52, no. 3, pp. 2436-2443, May-June.

11. M. Zeraati; M. E. Hamedani Golshan; J. M. Guerrero, Year: 2019, "A Consensus-Based Cooperative Control of PEV Battery and PV Active Power Curtailment for Voltage Regulation in Distribution Networks," IEEE Transactions on Smart Grid, Vol. 10, no. 1, pp. 670-680.

12. R. Kumar; B. Singh, Year: 2019 "Grid Interactive Solar PV-Based Water Pumping Using BLDC Motor Drive," IEEE Transactions on Industry Applications, Vol. 55, no. 5, pp. 5153-5165.

13. N. Priyadarshi; S. Padmanaban; J. B. Holm-Nielsen; F. Blaabjerg; M. S. Bhaskar, Year: 2020 "An Experimental Estimation of Hybrid ANFIS–PSO-Based MPPT for PV Grid Integration Under Fluctuating Sun Irradiance," IEEE Systems Journal, Vol. 14, no. 1, pp. 1218-1229.

14. Kumari Sarita; Sachin Kumar; Aanchal Singh S. Vardhan; Rajvikram Madurai Elavarasan; R. K. Saket; G. M. Shafiullah; Eklas Hossain, Year: 2020, “Power Enhancement With Grid Stabilization

of Renewable Energy-Based Generation System Using UPQC-FLC-EVA Technique", IEEE Access,Vol:8,pp:207443 – 207464.

15. C. Dhanamjayulu; Shaik Reddi Khasim; Sanjeevikumar Padmanaban; G. Arunkumar; Jens Bo Holm-Nielsen; Frede Blaabjerg, Year: 2020, "Design and Implementation of Multilevel Inverters for Fuel Cell Energy Conversion System", IEEE Access, Vol: 8,pp. 183690 – 183707.