31-Level Asymmetrical Cascaded Multilevel Inverter with DC-DC Flyback converter for hybrid power distribution

Gaddala Jayaraju\textsuperscript{1*}, Dr. Gudapati Sambasiva Rao\textsuperscript{2}

\textsuperscript{1}Research scholar, University College of Engineering & Technology, Electrical and Electronic Engineering, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur, Andhra Pradesh, India, jayaraju2006@gmail.com

\textsuperscript{2}Professor, Electrical & Electronics Engineering Department, R.V.R. & J.C. College of Engineering, Guntur, Andhra Pradesh, sambasiva.gudapati@gmail.com

ABSTRACT

A Single-Phase thirty one level inverter using eight switches with reverse voltage configuration with DC-DC Flyback converter with single DC source for hybrid power system. In this paper the photovoltaic (PV) and wind system is given input to the primary side of DC-DC converter, whereas the secondary side of the converter consists four different output voltage. Inverter is capable of producing thirty one levels of the output voltage levels (6V, 12V, 18V, 24V, 30V, 36V, 42V, 48V, 54V, 60V, 66V, 72V, 78V, 84V, 90V, –6V, –12V, –18V, –24V, –30V, –36V, –42V, –48V, –54V, –60V, –66V, –72V, –78V, –84V, –90V) from the four DC source voltages are acquired in the proportion of 1 : 2 : 4 : 8. The configuration used in this inverter is asymmetrical configuration. Multilevel inverter output voltage level increasing by using less number of switches driven by the multicarrier modulation techniques. A digital multi carrier PWM algorithm is implemented in a MATLAB simulation.

I INTRODUCTION

In each and every day the demand for energy is increasing throughout the world. At present about 80% of energy is generated from conventional source of energy whereas these sources of energy are unfavorable to the environment causing global warming, greenhouse effect. Hence to stop polluting and to favour the environment, it is necessary to use renewable sources of energy. Most of the surveys mentioned that the demand for energy will rise three times the present scenario by 2050. Now a day’s 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 abundancy. Due to these reasons, renewable sources of energy are used for power generation. Numerous renewable sources of energy like wind, tidal, hydro, biomass and PV are utilized due to their reliability and ability to generate clean power. Among these non-conventional sources of energy, wind energy and photovoltaic are the widely used sources of power generation due to non-emission of carbon and wide availability. The irradiation from the sun determines the power from PV system. So maximum power point tracking algorithm is used for efficient tracking of power from PV. As the existence of sun is isolated, wind energy conversion system can be integrated with solar PV system. As the wind is also isolated by nature, PV and wind are complement to
one another. Thus sun and wind based hybrid systems are embedded for effective use of natural resources and to minimize energy storage requirements. Conversion of solar PV system integrated with wind energy system into power is accomplished due to the advanced techniques in power electronics. The major necessity of power electronics between PV and wind is to transform the produced DC voltage into an appropriate AC for the benefit of consumer and utility connection. Usually DC voltage magnitude of wind and PV array need to be amplified to a greater value by using DC-DC converter before transforming it to an AC voltage. For this DC-DC conversion a flyback DC-DC converting system is utilized to boost and control flow of power of DC bus voltage. The generated power from wind integrated PV is fed to power network through grid connected inverter.

For high power applications it is necessary to transform the generated DC into AC. For this conversion, traditional two level inverter is not sufficient due to distortion of harmonics, losses in switching. Hence multilevel inverters are used to overcome these drawbacks. The three major classifications of multilevel inverters are diode clamped, cascaded H Bridge and flying capacitor. In traditional multilevel inverters number of component required is too high to accomplish high number of levels. AC signal with reduced harmonics was produced when the number of levels of inverter was increased. Advanced inverter topologies overcome the limitations of traditional inverters. In the proposed method shown in below fig.1 with small number of switches, thirty one level inverter topology is connected to grid for high power applications.

![Fig. 1. Block Diagram of 31-Level Asymmetrical Cascaded Multilevel inverter for PV and wind System](image)

Fig. 1 shows the hybrid renewable energy system under the change in climatic conditions such as wind speed, radiation of sun and temperature. The main goal of system is to maintain DC link voltage constant across DC link capacitor or at DC bus. The proposed Flyback converter requires only one source but here we uses two generating sources PV and Wind are complicated and connected in parallel. PV and Wind output is connected to series with a diode to block reverse voltage. Two (PV and Wind) outputs are connected to point of common coupling with one MOSFET. To generate high voltages all lower voltage rating devices are connected in series.
multi-level inverter topology gives the best performance also it has a potential to get a high quality output voltage by producing multi output voltage levels. In Asymmetrical 31 level inverter it needs \((m-1)/2*4\) switching devices and \((m-1)/2\) input sources are needed. Therefore it needs 60 switching devices and 15 input voltage sources. But in this proposed design uses single voltage source and 8 switches for getting 31 level output.

II. PROPOSED FLYBACK CONVERTER

The main advantage of proposed flyback converter is required single input source, less cost and conversion efficiency is very high. The Fig. 2 shows the proposed DC-DC Fly back converter based 31-level asymmetrical multi-level inverter with single DC source for hybrid system. In this paper a hybrid PV-Wind system output voltage \(V_{in}=12.49\) V is given input to the primary side of DC-DC converter connected in series with a MOSFET switch in DC-DC Fly back converter, whereas the secondary side of the converter with different output voltage in binary form as \(V_1=6V\), \(V_2=12V\), \(V_3=12V\) and \(V_4=48\) V respectively. The four different DC voltage source are fed to 31-level ASCHBMLI.

Fig. 2. Fly-back converter based 31-level asymmetrical multi-level inverter

In the below Fig 2(a), when switch ‘S’ is on, the primary winding of the transformer gets connected to the input supply with its dotted end connected to the positive side. At this time the diode ‘Df1’ connected in series with the secondary winding gets reverse biased due to the induced voltage in the secondary (dotted end potential being higher). Thus with the turning on of switch ‘S’, primary winding is able to carry current but current in the secondary winding is blocked due to the reverse biased diode. The flux established in the transformer core and linking the windings is entirely due to the primary winding current. This mode of circuit has been described here...
as Mode-1 of circuit operation. Fig.2(a) shows the current carrying part of the circuit and Fig.2 (b) shows the circuit that is functionally equivalent to the fly-back circuit during mode-1. In the equivalent circuit shown, the conducting switch or diode is taken as a shorted switch and the device that is not conducting is taken as an open switch. This representation of switch is in line with our assumption where the switches and diodes are assumed to have ideal nature, having zero voltage drop during conduction and zero leakage current during off state.

Under Mode-1, the input supply voltage appears across the primary winding inductance and the primary current rises linearly. The following mathematical relation gives an expression for current rise through the primary winding:

\[
V = L_{pri} \times \frac{di}{dt} \hspace{5cm} (1)
\]

Where \( V \) is the input dc voltage, \( L_{pri} \) is inductance of the primary winding and \( i \) is the instantaneous current through primary winding.

The energy stored in the magnetic field of the fly back inductor-transformer is equal to

\[
E = L_{pri} i_{pri}^2 \hspace{5cm} (2)
\]

Where \( i_{pri} \) denotes the magnitude of primary current at the end of conduction period. Even though the secondary winding does not conduct during this mode, the load connected to the output capacitor gets uninterrupted current due to the previously stored charge on the capacitor. During mode-1, assuming a large capacitor, the secondary winding voltage remains almost constant and equals to

\[
V_{sec} = V \times (N2/N1) \hspace{5cm} (3)
\]
During mode-1, dotted end of secondary winding remains at higher potential than the other end. Under this condition, voltage stress across the diode connected to secondary winding (which is now reverse biased) is the sum of the induced voltage in secondary and the output voltage

\[ V_{\text{diode}} = V_o + V \times \frac{N_2}{N_1} \]  

Mode-2 of circuit operation starts when switch ‘S’ is turned off after conducting for some time. The primary winding current path is broken and according to laws of magnetic induction, the voltage polarities across the windings reverse. Reversal of voltage polarities makes the diode in the secondary circuit forward biased. Fig.2(c) shows the current path during mode-2 of circuit operation while Fig.2 (d) shows the functional equivalent of the circuit during this mode. In mode-2, though primary winding current is interrupted due to turning off of the switch ‘S’, the secondary winding immediately starts conducting such that the net mmf produced by the windings do not change abruptly. Fig.2(c) shows switching circuit for flyback converter.

III. PROPOSED 31 ASYMMETRICAL CASCADED H BRIDGE MULTI LEVEL INVERTER

Fig.3 shows the proposed a 31 level asymmetrical cascaded H-bridge multilevel inverter by DC-DC fly back transformer by 1 DC source of hybrid (PV-WIND) distributed system utilizing large Power. Input DC voltage source for V1, V2, V3, V4 are planned at binary format (8421) of voltage for V1=6V, V2=12V, V3=24V & V4=48V individually. Level of output voltages as 2*(1+2+4+8) +1=31) 31 levels. Multi carrier Pulse Width Modulation methods utilized to manage Power semiconductor Switches at ASCHBMLI.
For an $m$-level ($31$) inverter using unipolar multicarrier technique, $(m-1)/2 = 15$ carriers with the same frequency $f_c$ and same peak-to-peak amplitude $A_c$ are used. The reference waveform has amplitude $A_m$ and frequency $f_m$, and it is placed at the zero reference. The reference wave is continuously compared with each of the carrier signals shown in fig.3(a). If the reference wave is more than a carrier signal, then the active devices corresponding to that carrier are switched on. Otherwise, the devices switch off. The frequency ratio $m_f$ is defined in the unipolar PWM strategy as follows: $m_f = f_c/f_m$. In this paper, $m_f = 200$ and modulation index $M.I = 0.993$.

**IV. SIMULATION RESULTS**

The performance of grid connected hybrid renewable system is designed by Matlab. The output voltage of the hybrid energy system contains higher order ripples due to the change in temperature, irradiation and wind speed. These ripples are reduced by the proposed converters and inverter and thereby a pure sinusoidal wave is fed to...
the grid through multilevel inverter. The multi tapped transformer split the voltage into 4-unsymmetrical dc voltages as 6V, 12V, 24V and 48V.

Fig 4 Simulation result of PV panel output voltage and power waveforms

Solar PV system voltage \( V = 12.49 \)V volts and power is \( P = 117 \)watts at temperature=25\(^\circ\)C and irradiance=250w/m\(^2\). output voltage of hybrid system connected to flyback converter in series with MOSFET switch having switching frequency is 1khz and duty ratio is 50% and it gives four different output voltages (6V,12V,24V and 48V) shown in below figures 5(a),5(b),5(c) and 5(d).

Fig.5 (a) flyback converter output voltage V1

Fig.5 (b) flyback converter output voltage V2
Above four flyback converter output voltages is connected with four switches S1, S2, S3 and S4 and four diodes to cascaded H bridge inverter having four switches H1, H2, H3, and H4. For an 31 level inverter using unipolar multicarrier technique, \((m-1)/2 = 15\) carriers with the same frequency \(f_c\) and same peak-to-peak amplitude \(A_c\) are used. The reference waveform has amplitude \(A_m\) and frequency \(f_m\) and it is placed at the zero reference. The reference wave is continuously compared with each of the carrier signals. If the reference wave is more than a carrier signal, then the active devices corresponding to that carrier are switched on. Otherwise, the devices switch off. The frequency ratio \(m_f\) is defined in the unipolar PD PWM strategy as follows: \(m_f = f_c/f_m\).

The proper switching can produce 31 levels in output voltage as \((6V, 12V, 18V, 24V, 30V, 36V, 42V, 48V, 54V, 60V, 66V, 72V, 78V, 84V, 90V, -6V, -12V, -18V, -24V, -30V, -36V, -42V, -48V, -54V, -60V, -66V, -72V, -78V, -84V, -90V)\). In positive cycle, the switches H1, H2 of H-bridge inverter are switched ON and H3, H4 are switched OFF. During negative cycle H1 and H2 are switched OFF and H3, H4 are switched ON. Fig. 6 and Fig. 7 shows the output voltage and output current waveform’s of 31 level inverter at single phase grid.
V. CONCLUSIONS

In this paper 31 level inverter have been designed in matlab using eight switches and one hybrid source with flyback converter. MOSFET is connected in series with flyback converter input to control the flyback converter operation, whereas secondary side of flyback converter produces four different voltages. The output of flyback converter is connected to 31 level asymmetrical MLI, all lower voltage levels connected in series to generate high voltages at the output of 31 level ACBMLI. Due to increase of level of inverter to 31 level it reduces harmonics in the output voltage and output current. The proposed topology has very suitable for high voltage applications.

REFERENCES


