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# Nine-Level Inverter For Hybrid Wind And Solar Energy System

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**Abstract:** As humans use extensive amount of conventional energy sources we are in the urge to move to renewable energy sources. The renewable sources are not constant so there is a need to find new topologies in energy production and increase the efficiency. To get the energy all over the year in energy weather condition hybrid systems are used. The most efficient is wind solar energy system. Wind system is used during the rainy seasons and solar is suitable sunny climates. The energy produced by them must be converted into a suitable form which can be connected to the grid. For this I have propose nine-level inverter system for the Hybrid wind and solar energy system.

*Key words: wind generator, Photo voltaic, multi-level inverter.*

## 1. INTRODUCTION

The renewable energy sources are friendly to environment. Hybrid renewable energy systems consist of two energy sources and a storage system. These systems are very popular in remote area power generation. In this project is the combination of wind and photovoltaic power systems. Solar panels can produce evenly throughout the sunny day but the power output is uneven during the cloudy days. Similarly, wind high power output but due to the unpredicted wind flow they alone not enough to produce a constant power flow. The common drawback of solar and wind power systems does not produce power evenly due to the weather conditions, but the combined utilization of these two systems increase the efficiency and reliability of the system.

When a source is insufficient or unavailable in meeting load demands then the other system will compensate the difference. In order to obtain maximum power demand from both the renewable source separate DC/DC boost converters are connected.

The wind turbine generators produce high frequency current harmonics to reduce these high frequency current harmonics passive input filters are used. These harmonics in generator will increase the power losses and reduce the lifespan. For this an alternative multi-input rectifier is connected to the wind system. The boosts converters from both the system are connected with single phase nine-level inverter to get sinusoidal waveform.

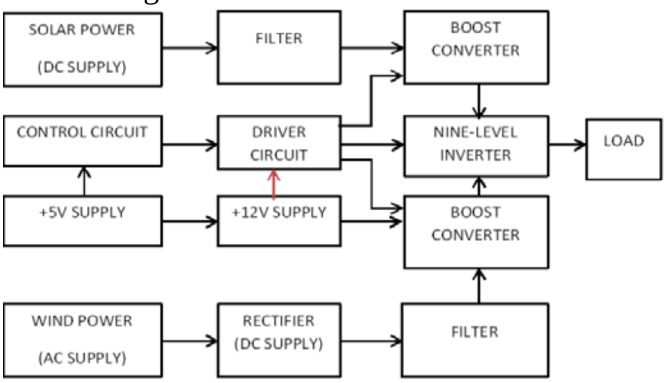


Fig.1 Block diagram of nine-level inverter for Hybrid Wind and Solar Energy System.

## 2. CIRCUIT OPERATION

The circuit diagram of hybrid wind and solar energy system is shown in the fig.2. Here both the output of the wind and solar power systems are connected

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together using a bridge rectifier. Each converter can be operated separately or normally.

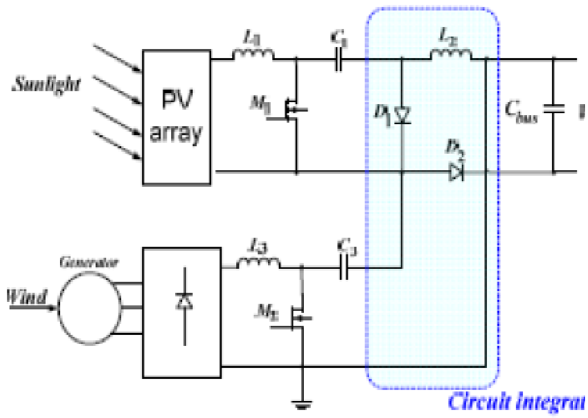



Fig.2 Hybrid wind and solar energy system.

PV array is the input to the filter and wind source is the input to the converter. The converters are fused together by reconfiguring the existing two diodes from each converter and the sharing output. This configuration allows each converter to operate normally individually in the event that one source is unavailable. When only wind source is available the voltage conversion relationship is given by

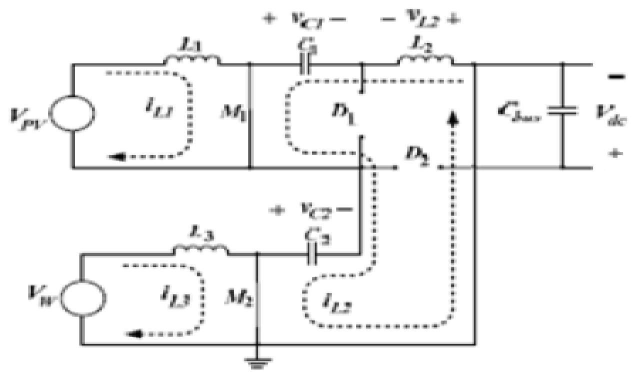
$$\frac{V_{dc}}{V_w} = \frac{d_2}{1 - d_2} \quad (1)$$

When only PV source is available the voltage conversion relationship is given by

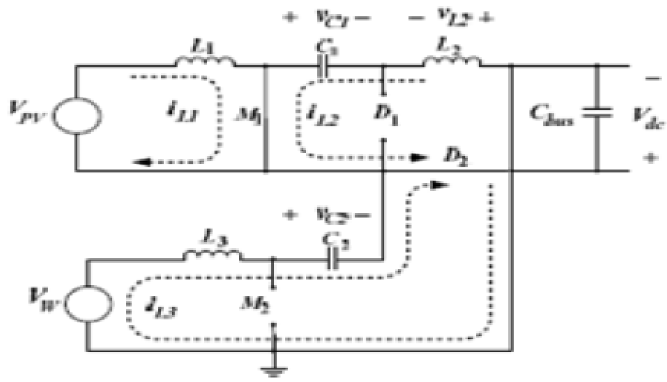
$$\frac{V_{dc}}{V_{pv}} = \frac{d_1}{1 - d_1} \quad (2)$$

The switching modes of the converters are illustrated below. There are four modes of operation from mode I to mode IV. Mode I is when M1, M2 is ON. Mode II is M1 ON, M2 OFF. Mode III is M1 is off, M2 is ON, Mode IV is M1 off, and M2 is on. The mathematical expression for each mode is illustrated below.

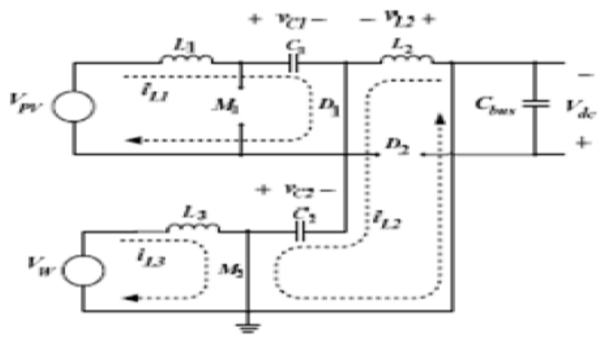
**Mode- I (M1 on, M2 on):**



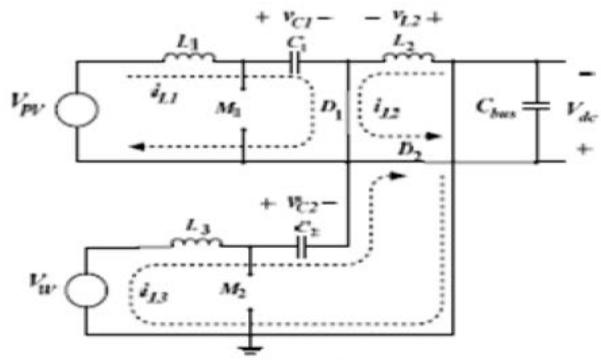
**Mode- II (M1 on, M2 off):**



**Mode-III (M1 off, M2 on):**



**Mode-IV (M1 off, M2 off):**



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The voltage and current waveforms illustrate the switching modes of the converter.

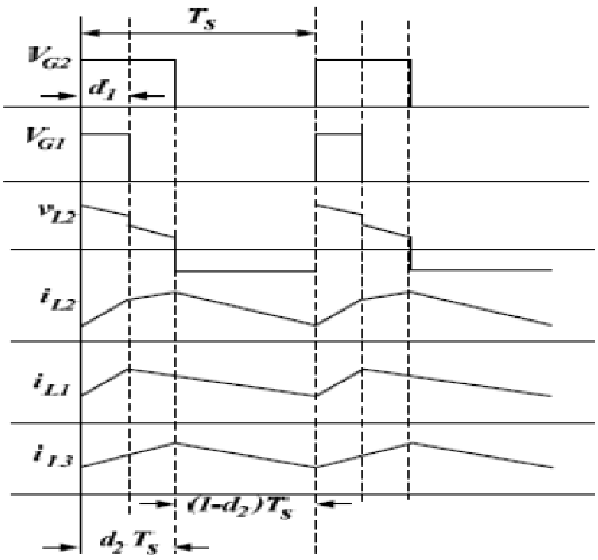



Fig.3 Waveforms of inductor current for Switching modes M2 is longer than or equal to *M*1.

## 3. MODELING OF PV PANEL

A photovoltaic cell consists of P-N junction silicon material which produces current due to photovoltaic effect. When photon from the light source falls on the solar cell the electrons will be knocked out from the atoms. If conductors are attached to the contacts electrical circuit is formed where the knocked out electrons are used as electrical energy. The energy produced from the solar cell is very low which is of 0.5Volts. So many solar cells are connected in parallel or series to obtain the desired output.

## 4. MODELING OF WIND TURBINE

The wind turbine rotates when high speed strikes the turbine blades. This turbine is connected the generator where the energy is produced. The number of blade is usually three. The electrical energy produced by the mechanical energy delivered by the turbine. Mostly induction generator or synchronous generator is used.

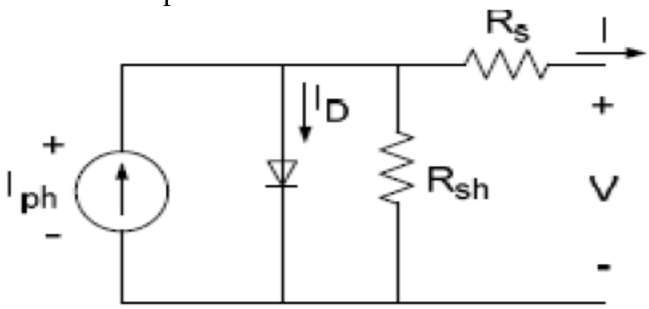
The mechanical energy that is generated is given by.

$$P_m=0.5\ \rho A C p(\lambda,\beta)\ V_w^3$$

Where
$A$ = rotor swept area
$\rho$ = air density
$C_p(\lambda,\beta)$ = power coefficient function
$\beta$ = pitch angle
$\lambda$ = tip speed ratio
$V_\omega$ = wind speed

## 5. PHOTOVOLTAIC EQUIVALENT CIRCUIT

The Photovoltaic cell can be represented by current source with a diode connected in parallel.




Where
*ph I* = photo current
*D I* = diode current
0 *I* = saturation current
$q$ = electronic charge $1.6\text{x}10^{-9}$
$A$ = ideality factor
$B_k$ = Boltzmann's gas constant ($1.38\text{x}10^{-23}$)
$T$ = cell temperature
$R_s$ = series resistance
$R_{sh}$ = shunt resistance
$I$ = cell current
$V$ = cell voltage

## 6. NINE LEVEL INVERER

The multilevel inverters are increased in practical usage since last decade. These multilevel inverters have high power application and high voltage output as they can produce waveforms with better harmonic spectrum. The nine-level inverter has two modified H-Bridge which can produce 9 output voltage levels.

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Pulse width modulation technique is used to achieve balanced power distribution among the power cells.

The fig shows the circuit diagram of the nine-level inverter. The inverter consists of single H-Bridge module which can produce five level output voltage. Each module can capable of producing -2E, -E, 0, E, 2E. So combining two H-Bridge modules nine level voltages is produced. The nine voltage levels are -4E, -3E, -2E, -E, 0, E, 2E, 3E, 4E. The main advantages of the nine-level inverter are the numbers of the switches are less, the cost and the complexity of the circuit is simple.

In order to produce nine voltage levels the dc output from the hybrid power source is divided into two voltage sources. The output voltages of two H-Bridge inverter are connected in series so the output is the sum of the two inverters. The gating signals of the inverter are generated using the PWM technique.

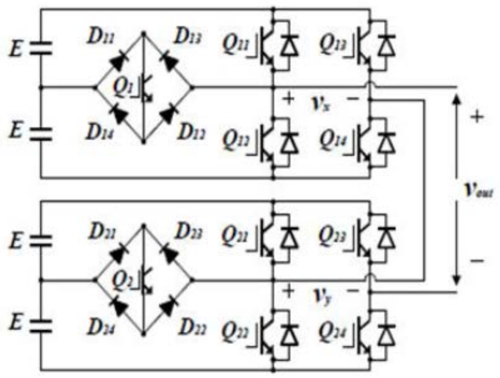


Fig.4 Nine level cascaded H-bridge multilevel inverter

## 7. PWM MODULATION

Using pulse width modulation the two switches are turned on and off alternatively for every half cycle and the output voltage is obtained. Lower order harmonics are eliminated by selecting the modulation type and the number of pulses. Higher order harmonics may increase but they can be reduced by using the filters. The modulation index of the nine-level inverter is M= ½ ( $V_{ref}$ / $V_{cr}$).

Where

$V_{ref}$ is the amplitude of the voltage reference

$V_{cr}$ is the amplitude of the carrier signal.

The amplitude and frequency of all triangular carriers are the same as well as the phase shifts between adjacent carriers. The number of carrier phase shift for each cell θcr,n can be from θcr,n = 2π(n-1)/Nc, n= 1,2,……….Nc

For signal generation in each cell, one carrier signal and two voltage references are used. $V_{ref}$ is defined by

$$Vref = M \sin \omega t$$

$$V_{ref1} = | V_{ref} |$$

$$V_{ref2} = | V_{ref} – 1/2 |$$

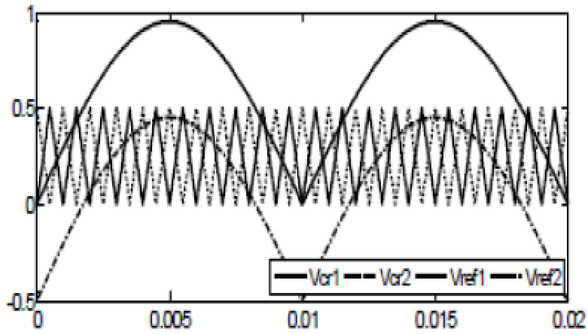


Fig.5 Multicarrier phase-shifted PWM for two-cell configuration

## 8. SIMULATION AND RESULTS

The simulation model was designed using MATLAB/Simulink. The gating signals for the inverter are generated by using multi-carrier modulation technique. The circuit was simulated with RL load.

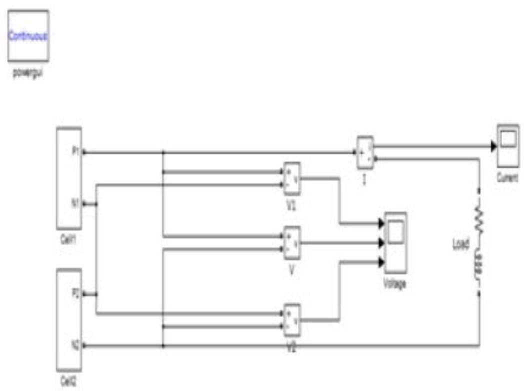

Fig.6 Circuit for Nine-level Cascaded H-bridge Multilevel Inverter.

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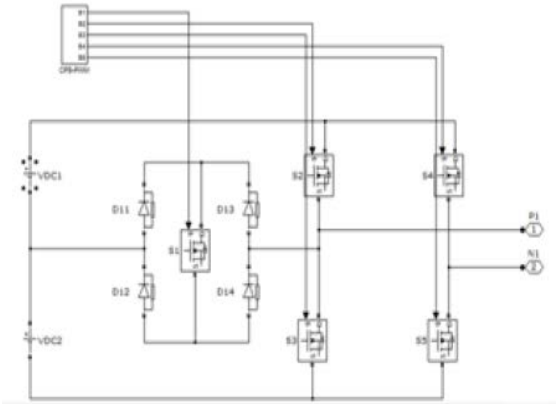


Fig.7 Circuit of cell 1

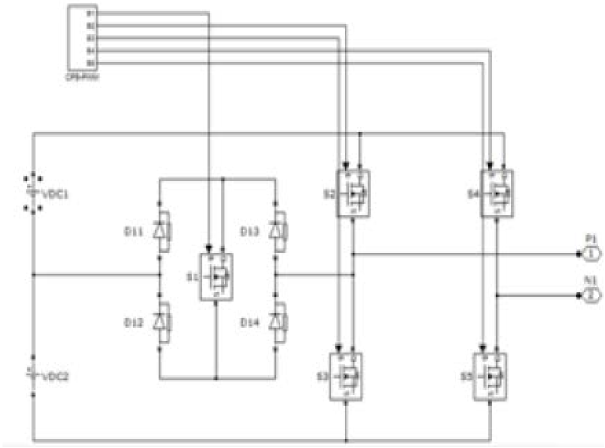


Fig.8 Circuit of cell 2

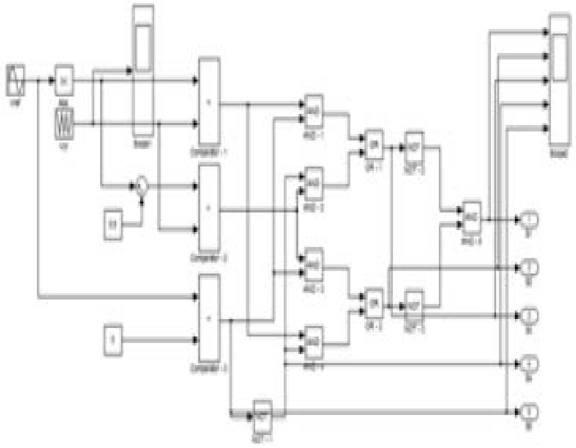

Fig .9 Circuit for PWM signal generation

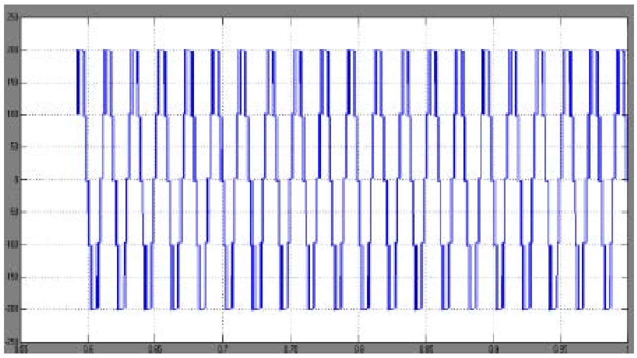

Fig.10. Output voltage waveform for cell 1

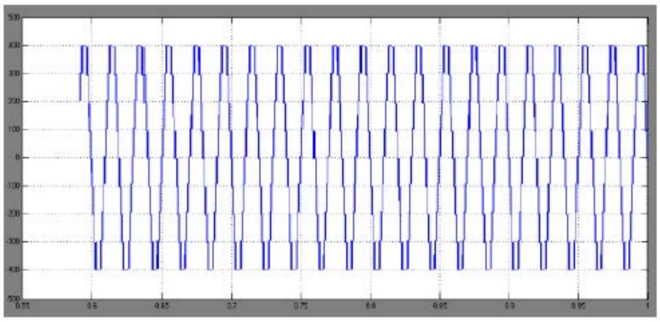

Fig.11 Output voltage waveform

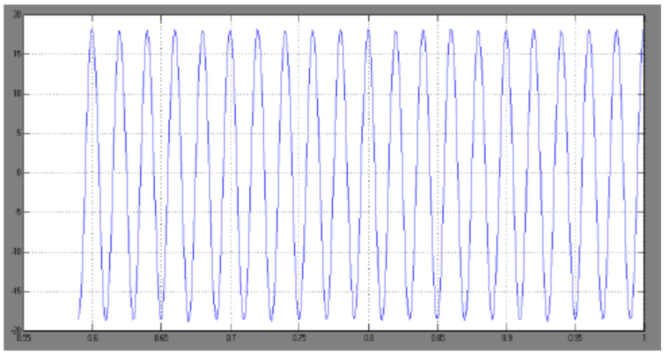

Fig.12. Output current waveform

## 9. CONCLUSION

In this paper a renewable hybrid wind solar energy system fed single phase multilevel inverter presented. The advantages of this circuit are: Additional input filters are not necessary to filter out high frequency harmonics. Both renewable sources can be stepped up/down. Individual and simultaneous operation is supported. Simulation results have been presented. Simulation models are constructed for the both single phase inverter and single phase multilevel inverter, hardware is implemented for single phase inverter.

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