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VOLTAGE CONTROL AND HARMONICS MITIGATION IN INVERTER USING HYSTERESIS CONTROLLER

Asim Rahman Ansari
Department of Electrical Engineering, FET, MJP Rohilkhand University, Bareilly, India

ABSTRACT

Single-phase and three phase (converters) inverters are broadly implemented in industrial applications such as industrial heating, backup power and UPS for personal computers. The square wave output of inverter suffers from the following major drawbacks.
For fixed voltage source, there is no control on the inverter output voltage. To achieve voltage control the inverter must be fed either from an ac-dc or dc-dc converter. The output voltage contain appreciable harmonics (low frequency range) total harmonics distortion is very high.
As the prolong pulses are provided to the gating circuits of inverter so the incurred losses are more that affect the performance of the inverter and reduces the efficiency of the device, which causes voltage fluctuation and the output is not purely sinusoidal. To obtain controlled voltage within the inverter and to lower the harmonics content for the output voltage, Pulse width modulation (PWM) inverters are taken into consideration. In PWM inverters width of output are modulated to have controlled output voltage.
Different types of inverters and the schemes for pulse width modulation (PWM) have been discussed and accordingly simulated the above mentioned techniques. These are in the accordance with the theoretical results.

Keywords-- voltage control, harmonics reduction, hysteresis band limit and hysteresis controller

INTRODUCTION

From the very beginning of late nineteenth century till the middle of the twentieth century, DC to AC and DC to AC power transformation was practiced using rotary converters or motor-generator sets. In the early twentieth century, vacuum conventional solid state switches were given freedom to be taken as switches in inverter circuits. Earlier thyratron was the only device to be taken as the element for inverter circuit.

The process of converting DC power into AC power at a demanding output voltage and frequency is known as inversion. A fully controlled converter can be utilized with thyristors, connected to the AC main. This is called line commutated inverter and operates at the line frequency only. There is an extra circuit required for turning on and turning off of the thyristors. Inverter is supposed to be large in circuit and cost effective. So thyristor based inverters are used only in applications where

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high power is required. For low and medium power applications BJTs MOSFETs, GTOs etc are used.
Another important aspect of fully controlled, these inverters have high switching frequencies. Hence these devices may be very effectively used in inverter where output voltage is to be controlled using pulse width modulation (PWM) techniques.
Classification of inverters can be divided into two types.

1. VOLTAGE SOURCE INVERTER (VSI)

VSI type of inverter, the dc source has small or negligible impedance i.e. VSI has almost constant dc voltage at its input terminals. From ac side, the voltage at the output terminals remains very near to constant, whether the load is of any nature and does not depend upon the load current.

2. CURRENT SOURCE INVERTERS (CSI)

In CSI, high impedance of the dc source offers the constant current i.e input current remains the constant. In a CSI fed with constant current source, output current waves are not altered or varied with the load. Therefore supply current does not change quickly in VSI using thyristors. The different type of commutation which is needed to make the thyristor off in known as forced commutation.

As these types of devices have become available, solid state devices and various other types of semiconductor switches are introduced and applied into inverter circuit designs.

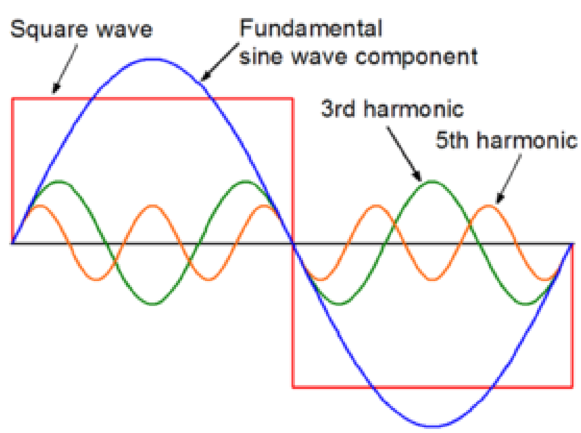

Fig1. Typical waveform with fundamental sine wave component, 3rd harmonic and 5th harmonic

Inverter Design

various applications in which variable voltage and variable frequency ac supply is needed, inverter plays an important role.. Some of the prominent applications can be as follows

- ac motors speed variation
- Efficient power backup
- High voltage dc transmission system
- SMPS

To meet above requirement, many types of power circuit topologies are and control strategies are used in inverter designs. Different design techniques address various issues that an inverter can accommodate in order to give optimum performance.

waveform quality issue can be considered in many ways. the waveform of the output voltage can be filtered with the help of active elements like capacitors and inductors. Every load which can be considered contain inductance, feedback converters or diodes in anti parallel configuration are often connected across each semiconductor switch to provide a freewheeling path for the peak load current to flow through load and freewheeling diode.

SIMULATION

Accurate methods are needed for evaluating circuit performance of any Electronics switch, because of the complexity involved in the modern integrated circuits. Simulation is done and real time results are obtained and can provide accurate and precise information about be circuits performance that is almost not possible to obtain with practically fabricated electronics circuits.
So the processing or working of a system with some tool without actually making the real system is known as simulation.
Power Electronics is one of the Engineering areas, where simulation plays a very important role. It contains various electronics circuits whose behavior should be known to the users.
With the advancement in the software by introduction of Graphic User Interface technology the job of simulation tool developer's become easy.
Power electronics circuits i.e. rectifiers & circuits can be simulated by

(i) Circuit oriented simulators e.g. PSIM or by

(ii) Real time simulation tools or high level language based software tools (MATLAB)

MATLAB & SIMULINK

These are very powerful mathematical model based equation solver mathematical software tool. These are mainly used to study the system behavior. In this package the mathematical model of any system can be simulated in the form of model.

CURRENT CONTROLLED INVERTERS

The current controller scheme is depicted in fig. 2 for consideration of inverter. Hysteresis and ramp controllers uses the logic control build by the same current controller. The hysteresis controller is obtained by switching SW off, and the ramp controller is obtained by switching SW on and reducing the hysteresis band, blocks H to zero or to a minimum value, if required.

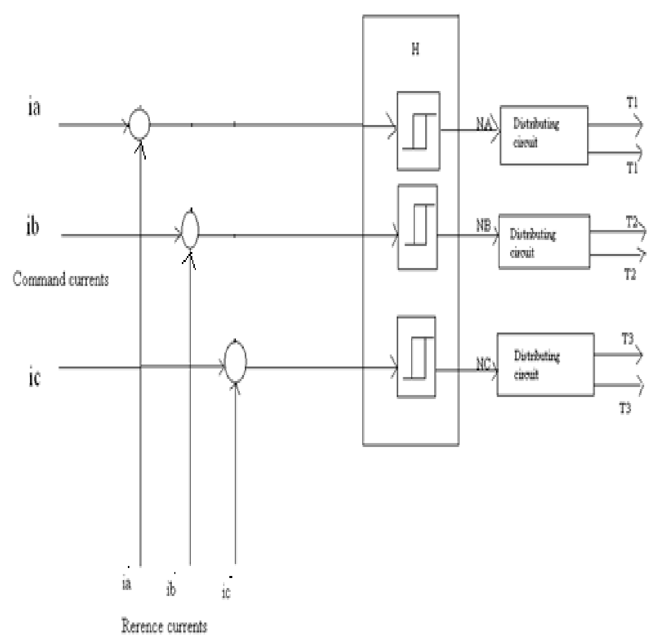

Fig. 2 Block diagram for current controller scheme

HYSTERESIS CONTROLLER

The current controller is used in the circuit to control the load current by forcing it to follow a reference signal which is taken in consideration for circuit. The inverter creates switching action to

keep the current within the hysteresis band. A simplified diagram of a typical three-phase hysteresis current controller is shown in Fig. 3, while SW is off. Sensing of load currents is taken and comparison is done with the respective command currents using three independent hysteresis comparators which has a hysteresis band H. The inverter power switches are activated with output signals of the comparators. The controller has very simple circuit and provides excellent dynamic performance. Thus, it is most extensively used switch in inverter circuit.. The only disadvantage which is associated with it is that the switching frequency varies during the fundamental period, resulting in irregular operation of the inverter at times. The switching losses are increased with variation in frequency. A number of strategies have been proposed in the literature to control or minimize the switching-frequency variation. With the advancement in power semiconductors technology, fast switching devices, such as insulted-gate bipolar transistors (IGBT's) and static induction transistors (SIT's), are broadly used in modern inverter systems., there are two types of current controllers which can be designed. The fixed-band hysteresis current controller and the sinusoidal-band hysteresis current controller are categorized based on the band. Fig. 4 shows current waveforms for these controllers. In a sinusoidal band controller, the hysteresis band varies in sinusoidal fashion over a fundamental period, which is shown in Fig. 4.
The fixed-band hysteresis current controller waveform is shown in Fig. 3. Which helps in reduction in the ripple current.

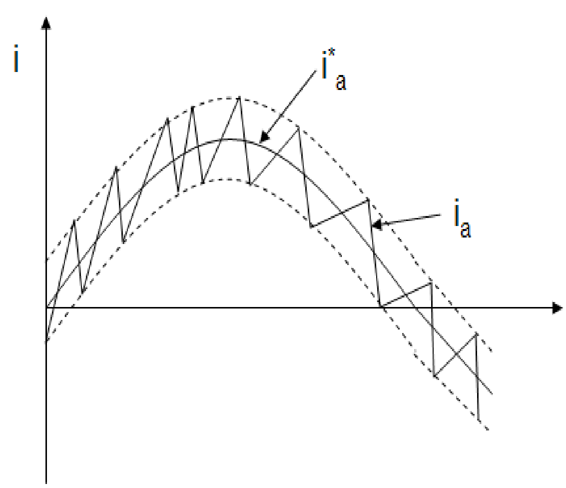

Fig. 3 Simulation for single phase inverter with Hysteresis Controller

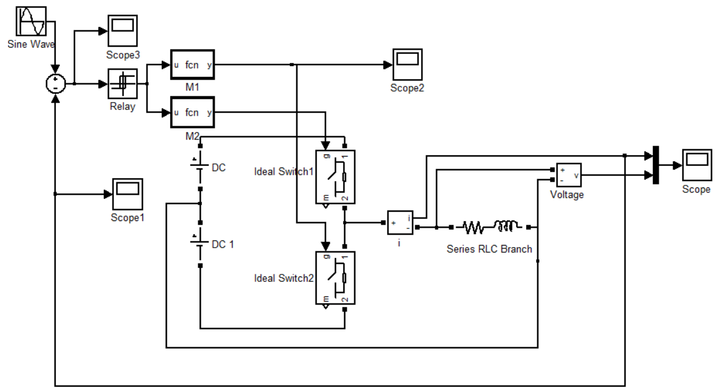

Fig. 4 Waveform of the fixed-band hysteresis current controller

In the fixed-band scheme, the hysteresis band is fixed over the fundamental period. The mathematical model for the fixed-
band scheme is given as

$i_{ref} = I_{max} \sin \omega t$ ……..(1)

$i_{up} = i_{ref} + H$ ……..(2)

$i_{lo} = i_{ref} - H$ ……..(3)

where, i_{up} is the upper band, i_{lo} is the lower band, and H is the hysteresis band limit. Referring to Fig.5, if $i_a > i_{up}$, then NA = 0, which means that the inverter output voltage switches to negative, in order to reduce the line current.

In the same manner, if $i_a < i_{lo}$, then NA = 1, where the inverter output voltage switches to positive, in order to increase the line current.

In the sinusoidal-band scheme, the hysteresis band varies sinusoidally over a fundamental period. The mathematical model for this scheme is given as

$I_{ref} = I_{max} \sin \omega t$ ……..(4)

$I_{up} = (I_{max} + H) \sin \omega t$ ……..(5)

$I_{lo} = (I_{max} - H) \sin \omega t$ ……..(6)

and the control logic is given as follows:

For $i_{ref} > 0.0$: if $i_a > i_{up}$, then NA = 0, else if $i_a < i_{lo}$, then NA = 1.

For $i_{ref} < 0.0$: if $i_a < i_{up}$, then NA = 0, else if $i_a > i_{lo}$, then NA = 0.

The same sequence is followed for the other two phases. So, by using these logic and referring to (5.7) and (5.8).

$$v_{abcN=\frac{1}{3}} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} v_{abc} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$v_{abc=}\begin{bmatrix}NA\\NB\\NC\end{bmatrix}V_B\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$\frac{di_a}{dt}=\frac{v_a}{L}-\frac{R}{L}i_a\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(9)$$

RESULT

The differential equation (9) representing the RL load can be solved with some boundary condition. The load current is derived and consequently waveforms are thus obtained, and simulation results have been carried out.

Fixed band controller with neutral connected (H=0.2) any arbitrary value, Simulates current waveform. Simulations of the sinusoidal and fixed band controller have been carried out for a single and three phase voltage source inverter with the same RL load. Fig. 5 shows the steady state waveform and the corresponding harmonic distribution for a fixed band current controller with the neutral point connected to the midpoint of the dc supply

The behavior of the controller for the inverter is most identical to those of three separate single phase controllers. The current is within the upper and lower hysteresis bands. Some of the higher order harmonics have significant magnitudes.

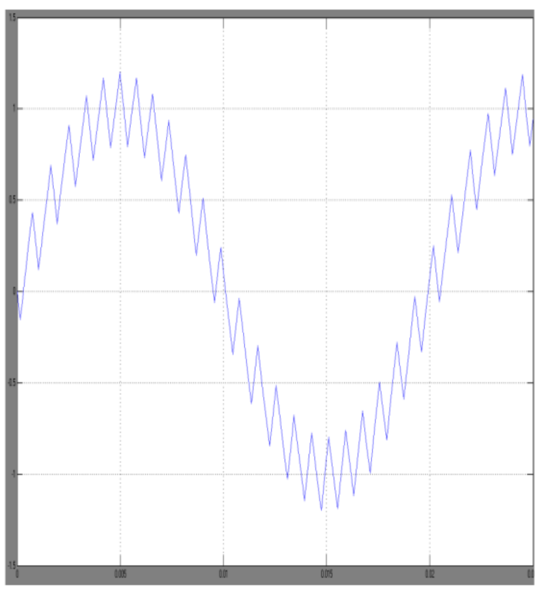

Fig. 5 steady state current waveform for single phase inverter

X Axis- Parameter- Time in seconds

Time period = 0.02 secs

Y Axis-Parameter- current in Ampere -1.5 A to +1.5A

CONCLUSION

For a fixed band hysteresis controller the steady state current is within the specified limits. The current is sinusoidal within the range of -1.0A to +1.0A. This simulation is being carried out with an input Voltage of 50 V having load parameters R= 5 Ω inductance L = 0.05H and capacitance of infinite value.

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