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# Improving the Quality of Output Power of H Bridge Inverter by the Novel P.C.C Method

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**Abstract:** *In the present paper, a novel Peak Current Mode Control is developed and simulated for single-phase H bridge inverter. Effective development current controller by low THD, fast and stable tracking for single phase inverter is not easy. However, some methods have been developed. In the present paper, a new controller is developed which meets international standards in terms of power quality. This paper concentrates on the main form of the H bridge inverter and the novel P.C.C method. In this method, two RS flip-flops are used. When the measured feedback current gets lower than the reference value, switches (2, 3) turn on and switches (1, 4) turn off. In this case, the inverter voltage undulates between 0 and V DC. But when the current reaches the reference value, switches (1, 4) turn off and switches (2, 3) turn on. In this case, the inverter voltage varies between 0 and –V DC. This makes the system unstable. In order to stabilize the inverter, a slope compensator saw tooth is added or removed from the controller. Then, two sinusoidal and square signals are added to the reference value. Inserting two L and LCL filters in the inverter output gives the desired sinusoidal waveform. Comparing these two filters reveals the superiority of LCL filter. Finally, using a PIS controller, 3rd, 5$^{th}$, and 7th harmonics are removed and the value of THD reaches 1%.*

**Keywords:** *Inverter, P.C.C, H Bridge Inverter, Elimination Harmonics, THD*

## 1. Introduction

Since the demand for renewable small scale energies is increasing, the need for power electronic inverters also increases. In recent years, power electronics has developed a lot by improving the faster semiconductor switches. In addition, the development of digital signal processing and microcontrollers has assisted in the implementation of advanced controllers. DC/AC single phase inverter is one of the main control and power electronics technologies. Inverter is needed in a system to produce sinusoidal wave in order to supply AC load or connect to the network [1]. There are many topologies for single phase inverters. One of the topologies is a half bridge inverter with the advantage of no dc current injection problem. This is used in many industrial inventers. A major problem of this half bridge inverter is the need for bigger DC capacitor because the full current at the fundamental frequency passes through the capacitor.

The other problem is the need for doubling DC voltage in full bridge inverter. Moreover, higher switching frequencies and bigger output filter are required. Overall, this would increase total loss, costs and inverter size. Single phase H bridge inverter has simple circuit and few constituents. Also, it is controlled easily.

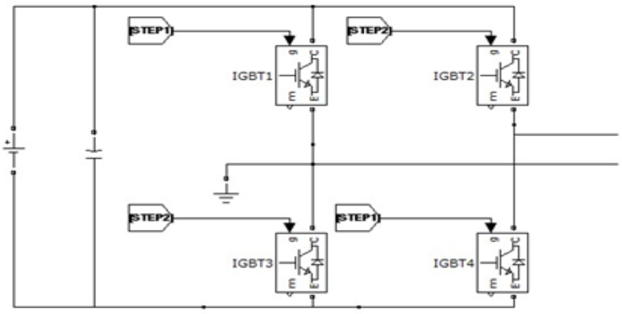


**Figure1.** *Simplified block diagram for H bridge inverter*

Current mode control is the commonly used control method for switched mode power supplies (SMPS). Compared to voltage mode control, methods has several advantages, such as faster control dynamics, better audio susceptibility, simple compensation and overcurrent protection. [2-3]

In small scale inverters, the PI controller is a form of inverter controllers which is commonly used because of its simple design. However, this controller performs weakly in case of steady state error with tracking the sinusoidal reference. Dynamic hysteresis controller has very fast and stable dynamics; however, it includes a wide bandwidth of harmonics. This makes the designing and implementation of the filter very difficult. Since the peak current controlling state is controlled by comparing the peak inductor current with the sinusoidal reference in a duty cycle, in terms of controlling, implementation of peak current control is a better option. However, peak current controlling method has an inherent problem because of sub-harmonic oscillations. This problem may be solved by addition of slope compensation.

In Section II, we provide the peak current control for PWM and output current control. In Section III, the simulation results of inserting two filters L and LCL in the inverter output are compared and in Section IV, selective harmonics are removed by the PIS controller.

## 2. Operating Principle

Peak current control (P.C.C) algorithm is developed in this study and adjusted to conform to international standards in current waveform quality. In the following a control method is developed which is a new variation from the P.C.C method that was applied for single phase H bridge inverter. In this method, by two RS flip-flops, 4 switches are turned ON/OFF. Overall, it may be said that he controller is divided into two states. In the first state, the reference current is higher than the feedback current, and the second one, is a state where the measured feedback current is higher than the reference current; i.e. each flip-flop and each switch pair act in a separate state. Adding/removing saw tooth slope compensator, too, make the inverter more stable. A square signal, because of better tracking reference current and a small- amplitude sinusoidal signal, as an offset, are added to the reference current. Peak current control (P.C.C) algorithm is developed in here and adjusted to conform to international standards in current waveform quality. In the following a control method is developed which is a new variation from the P.C.C method that was applied for single phase H bridge inverter.

Peak current controlling has been applied from the beginning for choppers [4]; this is implemented by DC/DC converters in analogue or digital forms. This method is implemented by a clock very easily, to keep switching frequency constant. it is described as follows:

When the measured feedback current is lower than the reference value, the switch turns on. When current reaches the reference value, the switch turns off. This makes the system unstable [5-6]. Therefore, a saw tooth signal is added from the reference current control signal. The slope of saw tooth signal is chosen so that the lowest possible undulation and highest stability are maintained [7-8]. The output voltage produced by this switching orientation is unipolar. Simplified bock diagram illustrates a primary control type shown in Figure. (1). this is as simple as controlling hysteresis current controlling with constant frequency.

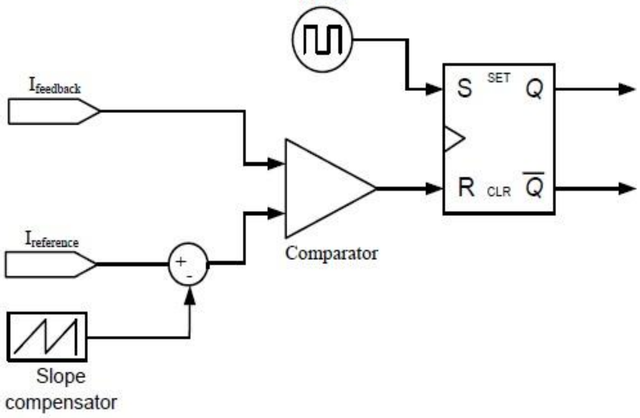


**Figure2.** *A simplified block diagram for p.c.c*

Modified single-phase P.C.C strategy is shown in Figure (3). The method has previously been described in Figure. (2). Two SR flip flops are used for switching four inverter IGBTs. Slope compensator is added to the reference current and is compared for switching 1st and 4th IGBTs by the feedback signal. In order to switch 2nd and 3rd IGBTs, the slope compensator is removed from feedback current.

In order to improve the output current quality and decrease its THD, a square signal is added to the reference because it may lower zero crossing error significantly. Also, a sinusoidal signal is added as offset to the reference. As can be seen in figure 5 by adding these two signals, output current THD is decreased from 12 to 1.2, this is resulted when an LCL filter is inserted in the inverter. In the following, this issue is described.

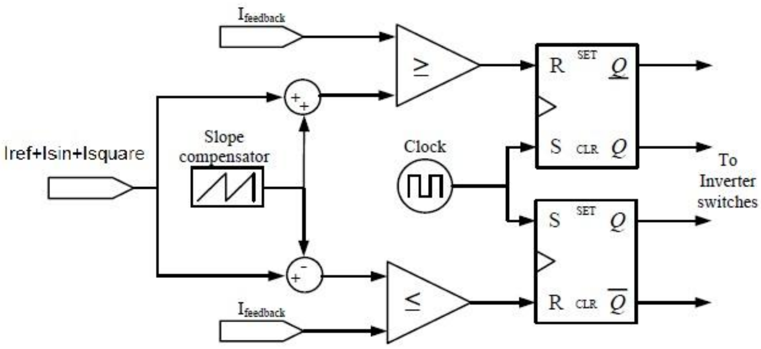


**Figure3.** *A simplified block diagram for novel P.C.C*

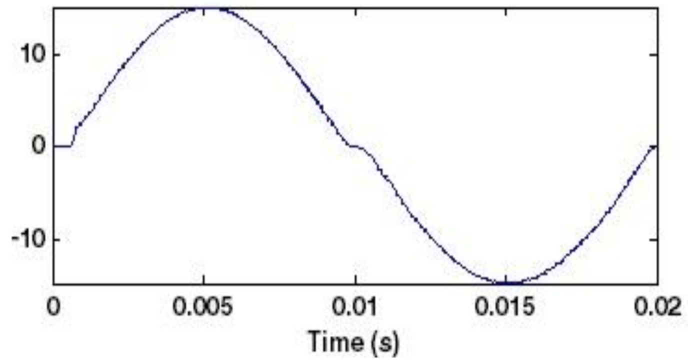


**Figure4.** *Output current without adding square signal*

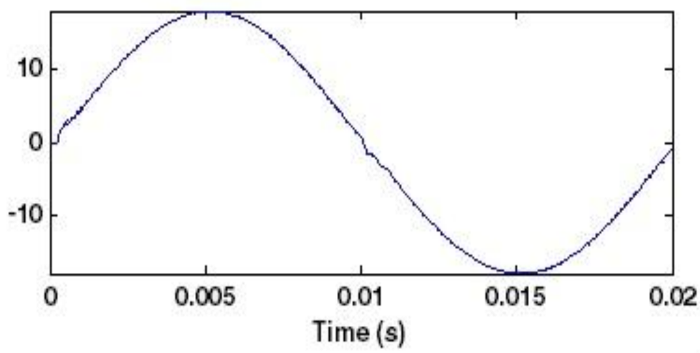


**Figure5.** *Output current with adding square signal*

## 3. Filters Comparison

Because of grid inverter switching, high frequency harmonics are produced, which can make problems for the system. A filter is needed for elimination or decreasing harmonics to reach the standard value. Passive line filters are L and LCL filters. LC filters are not used for inverters connected to the grid, because filter resonance frequency may be affected by grid inductance. In order to choose between L and LCL filters, Figure 5 and 6 compare two filters' results. The plotted Figure is based on a value 5 mh for the L filter and (3 mH, 3μF, 1.5 mH) for the LCL filter.

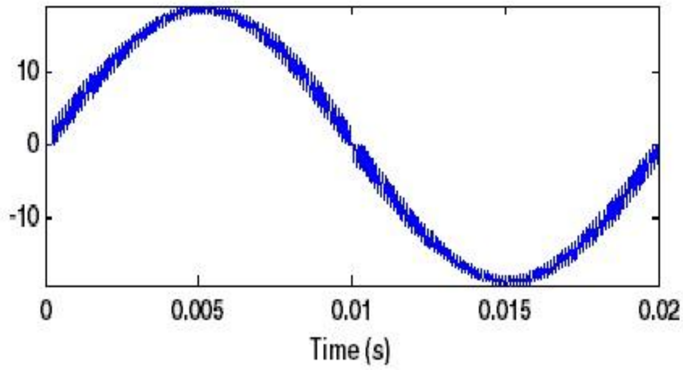


**Figure6.** *Output current with using L filter*

The filter LCL is more suitable than L. LCL filter has the following advantages:

- When (Lf1+Lf2 < Lf), voltage drop is lower for the same harmonics.
- Power coefficient is higher.
- The final cost of the filter is lower.
- Filter size is smaller.

Designing the LCL filter is not easy, as literature seeks this. This filter makes stability problems in the system and it needs designing the filter with high precision. Filter designing is not detailed in this paper. Based on the references, filter values are obtained [9].

Obviously, the LCL output current has a better THD. The measured THD for the LCL filter is 3.2%, whereas it is 5% for the L filter. The LCL filters works by a 5% limitation, presumed by the IEEE 929 standard.

## 4. SELECTIVE HARMONIC ELIMINATION

In hysteresis controller, there is a wide frequency ripple for the bandwidth whereas the ripple bandwidth P.C.C is limited to smaller odd 3,5, and 7 harmonics. This makes elimination of the considered harmonics in the controller P.C.C easier. Figure 7 shows a P.C.C controller after harmonics elimination. A PIS controller is implemented by elimination of harmonics [9-10]. Figure 8 and 9 show the simulation results in two states of elimination and non-elimination of harmonics. It indicates that before harmonics elimination, there is a high value for the harmonics 3, 5, and 7 and THD is 3.2%. After elimination, the mentioned harmonics are eliminated and THD will get close to 1.2%. These values pertain to the output current. Elimination of the mentioned harmonics is very effective in this study.

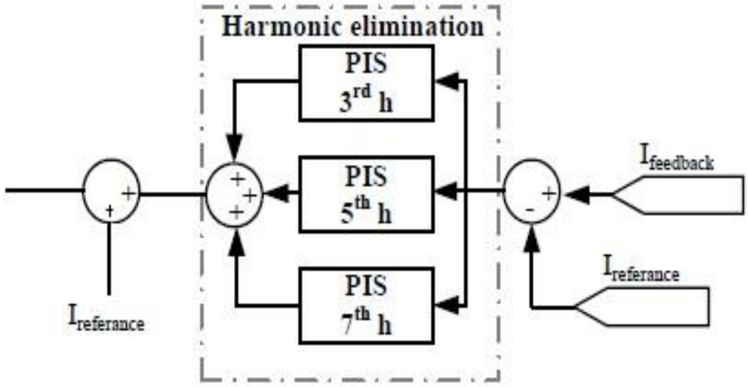


**Figure7.** *Harmonic elimination by PIS controller*

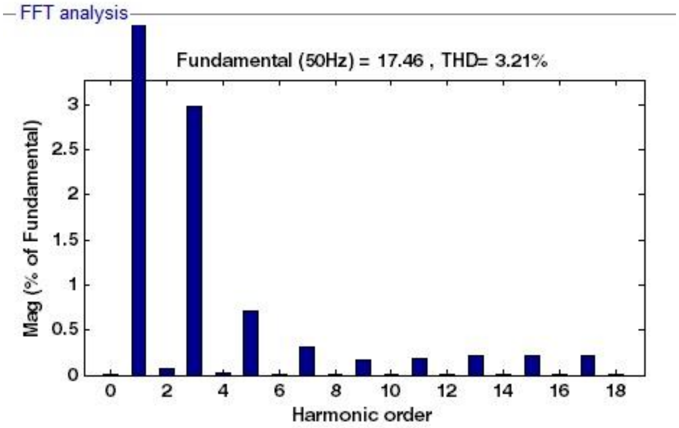


**Figure8.** *Harmonic spectrum and THD without selective harmonic elimination*

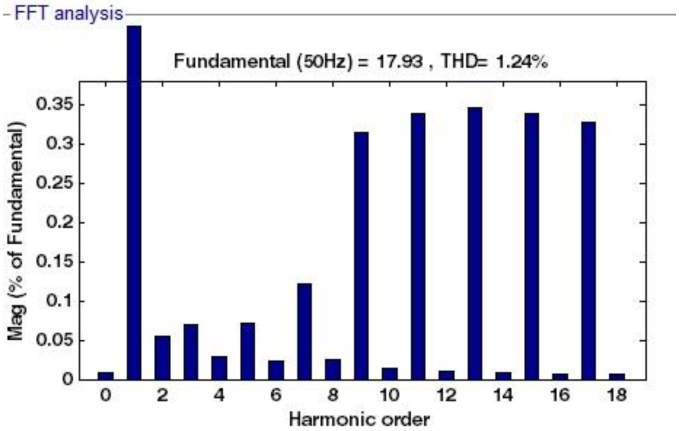


**Figure9.** *Harmonic spectrum and THD with selective harmonic elimination*

## 5. Conclusion

By adding slope compensator and also two sinusoidal and square signals to the reference current, the output current THD was reduced significantly. Before adding the square wave, the output current had a significant zero crossings error; i.e. the output current remained zero longer than usual. This problem was solved by adding a square wave. The L and LCL filters were compared and it was shown that LCL is more suitable in terms of economy and performance. Simulation results show that THD is 5% for L and 3.2% for LCL filters. Finally, by elimination of harmonics 3,5 and 7, the value of THD reached 1.2%.

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