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Hysteresis Current Control and Filtration

Md. Imran Azim
EEE, RUET, Bangladesh

Md. Fayzur Rahman
EEE, DIU, Bangladesh

Tamal Sarkar
EEE, RUET, Bangladesh

ABSTRACT

This paper presents an approach of harmonics control when harmonic components are present at the inverter output. The reduction of harmonics is important due to the fact that harmonic components have plenty of problematic features, including imbalanced and excessive neutral currents, interference in nearby communication networks and disturbance to other consumers, torque pulsations in electric motor drives and so forth. In order to get harmonics free output from a single phase half bridge inverter, an advanced modulation technique, based on the concept of minimizing the Total Harmonic Distortion (THD), which represents the ratio of non fundamental components to the fundamental components, by controlling current, has been illustrated in this paper. Furthermore, the implementation of an LC low pass filter, that is capable of blocking the higher harmonic components, is more convincing, as the comparative results of MATLAB simulation shows that the deviation of the actual modulated output current from the fundament modulated output current is only 0.013% .

General Terms

Terms of Power Electronics

Keywords

Voltage feed Half Bridge Inverter, Hysteresis Modulation, LC low pass Filter, Harmonics Analysis, Power Spectral Density (PSD), Total Harmonic Distortion (THD).

1. INTRODUCTION

An illustration of how to get a waveform of output current of a single phase half bridge inverter, which is close to the fundamental component, has been provided in this paper. The process involves the implementation of the hysteresis modulator as well as the appendage of an LC low pass filter. The overall process has been demonstrated in Figure 1,

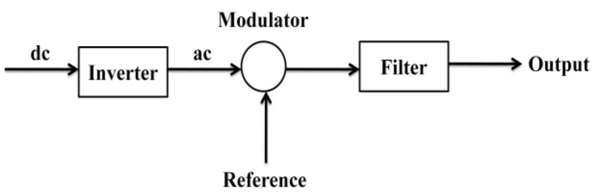

Fig 1: Block diagram of attaining better output from inverter.

An inverter is a device, working as a dc to ac converter whose output response could be fixed or variable at fixed or variable frequency. In ideal cases, this response is supposed to be sinusoidal which is not possible in actual practice because of the presence of certain harmonics at the output terminals, that can be easily understood if the time domain response is converted into frequency domain analysis. By using modern switching techniques, the harmonic contents could be minimized to a considerable state [1].

The control of the output response of an inverter is often necessary to cope with the variations of dc input voltage, to regulate voltage of inverters, and to satisfy the constant voltage and frequency control requirements. There are various techniques to vary the inverter gain. The most efficient method of controlling the output voltage is to incorporate Pulse-Width Modulation (PWM) within the inverter. In this paper, the hysteresis modulation technique has been used as it provides better fundamental response and improved performance, compared to Sinusoidal Pulse-Width Modulation (SPWM).

Total Harmonic Distortion (THD) measures the closeness in shape between a response and its fundamental component and can be represented by the ratio of the value of all odd number of non fundamental frequency terms to value of the fundamental frequency, Im_1 such as [2]:

$$THD = \sqrt{\frac{\mathrm{Im}^2 - \mathrm{Im}_1{}^2}{\mathrm{Im}^2{}_1}} \qquad (1)$$

Where, Im is the value of total components.

With a view to improving THD, a LC Low pass filter is appended at the modulator terminal so that low harmonic impedance to ground can be provided [3].

2. HYSTERESIS MODULATION TECHNIQUE

The hysteresis modulation for power electronic converters is preferred for applications, where performance requirements are more demanding, such as to achieve good dynamic response, unconditional stability, and wide command-tracking bandwidth [4]. This paper deals with hysteresis modulation technique on a half bridge inverter.

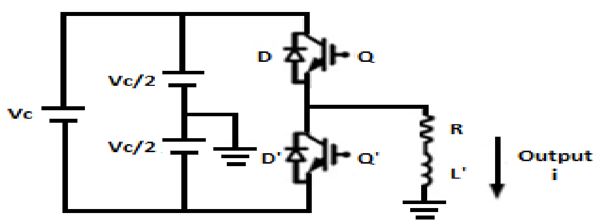

Fig 2: Single phase half bridge inverter.

The core idea of hysteresis modulation is to make a comparison between the input current signal detected by the modulator and the actual inverter current signal [5]. The output current of the hysteresis inverter can be controlled by compelling the inverter line current to track a sinusoidal reference current within a specified error margin in order to attain an adequate switching optimization, excellent dynamic responses and high accuracy in steady-state operation [6]. Hysteresis Current controlled inverter is used in many low and medium voltage utility applications. The line harmonic generation from this inverter depends principally on the particular switching pattern applied to the valves. The switching pattern of hysteresis inverter is produced through line current feedback and it is not pre-determined unlike the case, for instance, of Sinusoidal Pulse-Width Modulation (SPWM) where the inverter switching function is independent of the instantaneous line current and the inverter harmonics can be obtained from the switching function harmonics [7-8].

Referring to "Fig. 2", positive voltage is obtained if valve, *Q* is on, while the turning on of valve, *Q'* gives negative voltage response. On the contrary, if both the valves either open or close at the same time, no output response can be got. Moreover, the output current can be derived by dividing the instantaneous value of the output voltage by the R-L load.

$$i = \sum_{n=1}^{\infty} \frac{2v_C}{n\pi\sqrt{R^2 + (nwL)^2}} \sin(nwt - \theta n) \qquad (2)$$

Hysteresis modulated current is the difference between the reference current and the inverter output current. If the actual current is more than the given value, then it is decreased by changing the switching state and vice versa. So, the actual current changes around the reference current waveform and hysteresis current control makes the deviation within a certain range [9].

$$m(t) = i_{ref} - i \qquad (3)$$

3. LC LOW PASS FILTER

The basic hysteresis technique is affected by the drawbacks of a variable switching frequency, large ripple current in steady state, generation of sub harmonic components and so on [10] that urges the necessity of filtering the output response [11].

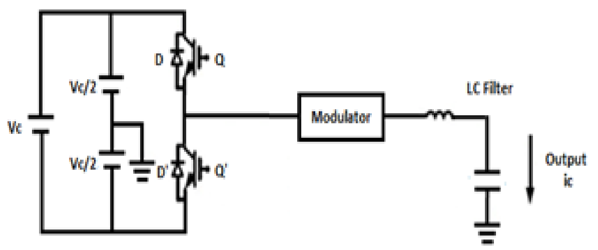

Fig 3: Single phase half bridge inverter with LC filter.

The implementation of an LC filter at the inverter ac terminals could trigger a parallel resonance, which tends to amplify the harmonic components in ac network, Owing to the fact that the filter capacitance has a profound impact on the performance of the controlling of harmonic contents; it can bring the harmonics into a lower state [12].

Now, the output current becomes,

$$i_C = \sum_{n=1}^{\infty} \frac{2v_C}{n\pi\sqrt{\left(-1/nwc\right)^2}} \sin(nwt - \theta c) \qquad (4)$$

4. MATLAB Simulation

For the simplicity of understanding, the responses derived from Figure 2 and Figure 3 by the MATLAB simulation, are converted into the per unit value, indicating the ratio between the actual responses and the maximum values of the responses. Besides, each response is represented in terms of frequency so as to realize the harmonic components.

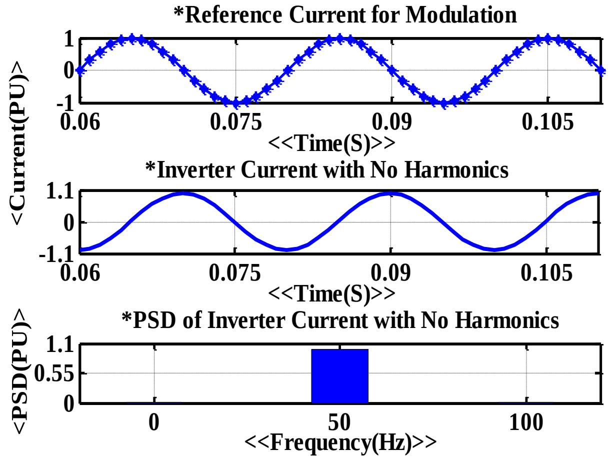

Fig 4: Inverter current in ideal case.

According to the depiction, Figure 4, deals with both the time domain and frequency domain responses of the inverter output current while there is no existence of harmonics. Whereas, Figure 5 indicates the modulated current, implying the difference between reference and inverter current, both in time domain and frequency domain under the same condition. Here, obtained THD is 0%. But in practical situations, it is cumbersome to get 0% THD.

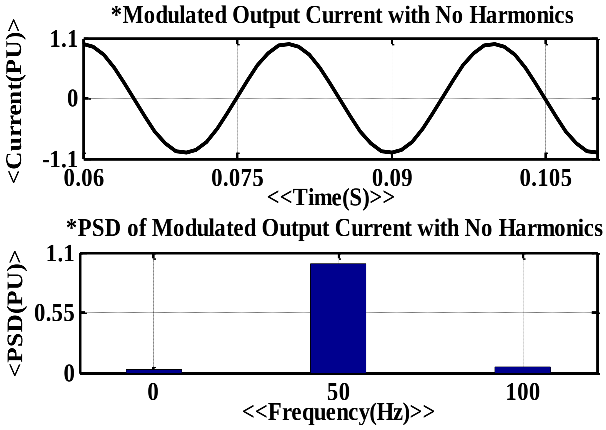

Fig 5: Modulated current in ideal case.

Later on, harmonics are considered so that the performance of hysteresis current controlled inverter under harmonics state can be realized and it is predicted that up to 9^{th} order odd harmonics are prevalent at the output of the inverter, indicating the value of *n*=3,5,7 and 9.

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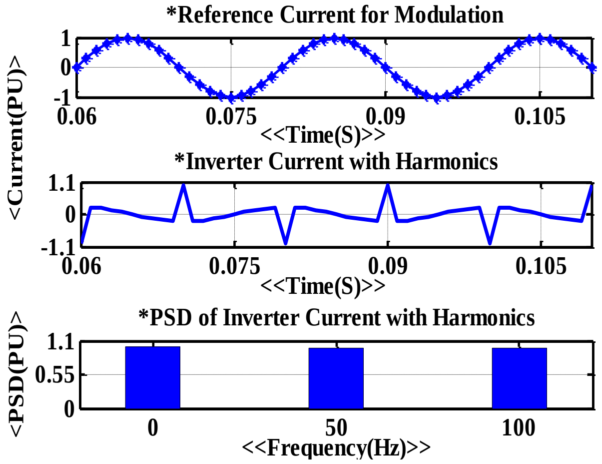

Fig 6: Inverter current under harmonics.

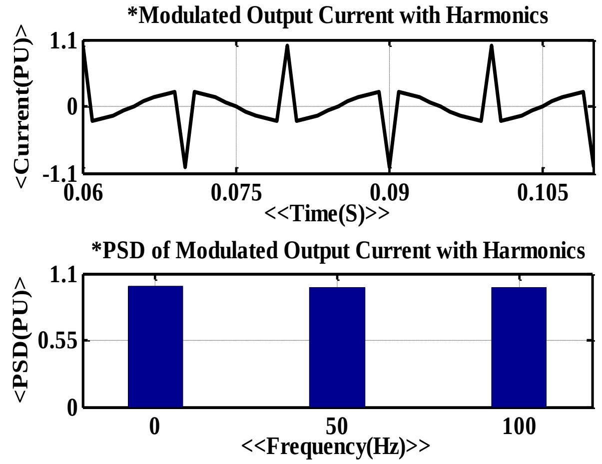

Fig 7: Modulated current under harmonics.

Figure 5, and Figure 6, reveal the responses of hysteres current controlled inverter when harmonics are present at the output terminal, in which output current is demonstrated in the first figure. On the other hand, Figure 6, represents the modulated current. As is observed, none of these figures show sinusoidal time domain responses due to the existence of unwanted frequencies called harmonics. Using "(1)", under this circumstance, THD is evaluated and is found 42.88%, which is not satisfactory at all.

There is no denying that for better performance, it is important to evade harmonics. Finally, in order to visualize the noteworthy performance of the filter, having leading current capability, the modulated output response is filtered.

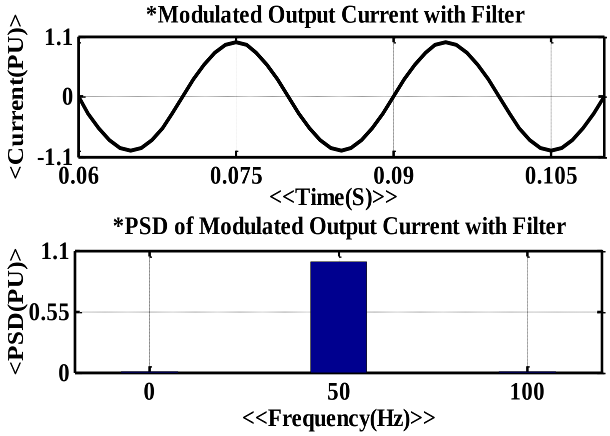

Fig 8: Filtered Output Current.

As far as Figure 8 is concerned, not only desired sinusoidal time domain response is achieved but also it is noticed that the fundamental component has the highest amplitude. Lastly, "(1)" is once again utilized and calculated THD is 0.013%, which can be regarded as a negligible amount. Therefore, harmonics have been suppressed to a great extent by the proposed methodology.

5. CONCLUSION

The proposed strategy mainly focuses on the harmonic free output current in a way that the THD is negligible. Although in practical life, 0% THD is not possible but it can be limited to a permissible amount by implementing proper modulation technique and the low pass filter as well. In this paper, hysteresis modulation has been implemented but analysis of the effect of this modulation on controlling the switching of two valves would be interesting in near future because it would decrease the THD much lower than 42.88%. However, the appendage of filter with the hysteresis modulator has played a significant role here, as it has caused the THD to drop to 0.013%. One of the researchers have found from their experimental results [13] that the Total Harmonic Distortion (THD) of three level, five level, seven level and nine level inverter systems are 10.95%, 4.82%, 4.65% and 3.09% respectively, referring THD is reduced with the enhancement of the level of inverter. In contrast, only 0.013% THD is derived in case of single phase inverter as demonstrated in this paper by the application of LC Low pass filter. In future, the practical implementation f the proposed methodology would be interesting as it is more lucking to aid Photovoltaic (PV) system.

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