

# Comparative analysis of harmonic suppression on single phase conventional PWM rectifier and back to back PWM rectifier

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## ABSTRACT

Conventional converters have a trouble with the high amount of source current harmonics, poor power factor and more ripples. To overcome the above issues, direct parallel connection of two 2-pulse converter has been proposed. Here, Two MOSFET converter circuits are connected in anti parallel with the common DC load. These MOSFET converters are fed from PWM sources, the PWM pulses are generated from the microcontroller. Configuration consists of two MOSFET converters connected back to back. Converter one is operated during positive half cycle (0-90 deg) and the converter two is sustained during negative half cycle (90-180 deg). This strategy accomplishes and yields the desired output signals without ripples and input signal is same for converting time. This converter helps to reduce the source current harmonics and improve the performance factors compared with conventional circuits. There is no additional circuit required for all operating conditions. This converter modifies naturally to guarantee that base consonant execution over the wide voltage range.

**Keywords:** Primary-side regulation (PSR), Total Harmonic distortion (THD), Discontinuous conduction mode (DCM), Continuous conduction mode (CCM), power-factor-correction (PFC), pulse width modulation (PWM).

## I. INTRODUCTION

In the two 2-pulse converter circuit, two converters are connected as anti parallel manner. When the number of pulses is high, the harmonics impact on the source current is lesser during each commutation. This setup helps to eliminate the notch width. The output power of the commonly used electrical load is not maintained constant, its keep varying depends on the time and load characteristics. The load variation causing high THD and poor power factor, which are to be maintained below the specified level as per the IEEE standards [1]. The source impedance is inversely proportional to the load connected with the power supply and hence when the load decreases the source impedance [2] has reached its peak and causing more problems includes distortion in the source current &

notches in the output supply [3]. The MOSFETs in the converter circuit causing voltage distortion in the supply voltage side during the switching [4]. During the commutation of the converter circuit, the supply side of the converter may get shot circuited and causing more disturbance and rapid changes in the supply current [5]. The width of the notches can be easily determined with the help of current flow through the MOSFET with rapid changes in current [6]. This converter operates under the continuous conduction mode, hence the ripples are high at input and output side [7], source harmonics are high and also the performance factors of this converter will be affected [8].

To reduce the source current harmonics different topology have been used includes FPGA, ANN &

Fuzzy based controllers [8-13]. Some converters use the multiple numbers of pulses to mitigate the harmonics which results in complex circuit [14]. Conventional AC to DC converter contains diode bridge rectifier which contains high harmonics and less power factor [15]. By using a large capacitor at output side, the ripples can be minimized [16]. Conventional converters used for power factor correction are Buck, Boost, Buck-Boost, CUK and SEPIC [17]. The direct parallel of two 2-pulse converter circuit provides less harmonic impact on the source current [18], improves the overall efficiency and better performance throughout the operation of the converter and also it eliminates the necessary of filter circuits [19]. Controlled converters are providing less losses, better reliability and simple construction and minimize the number of pulses. But the drawback of this converter is it will create the harmonics which affects the power quality.

By controlling the converter phase angle, the harmonics can be controlled and also the ripples will be reduced. Number of Methods has been used to minimize the output voltage waveform distortion with a multiple pulse configuration [20]. Some converters utilize a front-end phase-shifting transformer feeding with a number of pulse converters connected in parallel for high-current applications [21]. Conventional passive filters are used to suppress harmonic distortion, but the passive filters have some limitations [22]. A pulse multiplication technique, where higher pulse operation is obtained based on multiple pulse converters, with additional circuitry. This adds additional thyristors, transformers and passive elements [23]. The addition of a complex active injection circuit in the converter dc side reduces the harmonic distortion in both the ac and dc sides. Other harmonic current injection methods are based on injecting ripple into the converter dc side but the RF improvement is limited and does not guarantee compensation if used with controlled rectifiers. For higher voltage applications, the passive elements of these circuits must be designed to

withstand the maximum voltage [24]. Because of power quality issues, more importance is now being given to compensation using active power filters (APFs), made possible because of semiconductor improvements, such as increased switching frequency, ratings, and cost, and also the availability of microelectronics and measurement sensors. However, dc-side compensation has received less attention even though the output voltage waveform has a direct impact on the load. A series APF could be a candidate for dc-side compensation [25]. When a series APF is used to compensate the output voltage harmonics the APF inverter switches have to conduct the full-load current including the principal dc component. The shunt APF is used to inject the compensating current necessary to cancel the output current harmonics.

## II. PULSE CONVERTER

### A. Conventional Converter

An The conventional converter of 2-pulse converter system contains transformer or ac voltage source in the supply side and the output of the converter is connected with a common DC load.

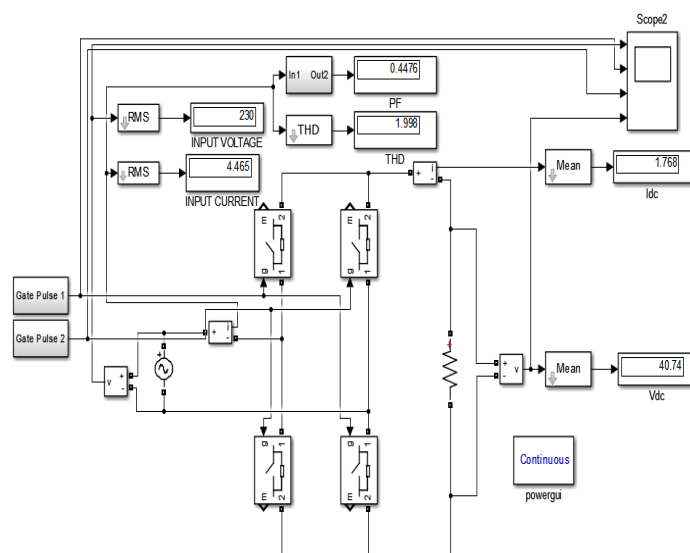


Figure 1. Conventional converter circuit

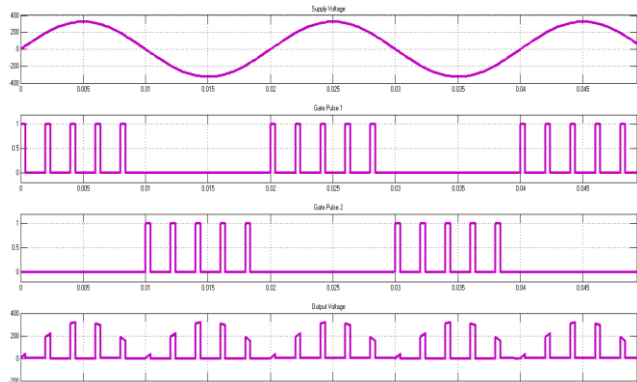


Figure 2. Input and Output Wave forms

This converter has been operated in continuous conduction mode in order to achieve the better performance and hence the load current is continuous. The ripples are high at the load current and the source current harmonics are high at the source side and also power factor affected. The supply transformer has been designed such that to cancel the harmonics order of 3<sup>rd</sup>, 5<sup>th</sup>, 7<sup>th</sup>, 17<sup>th</sup> and 19<sup>th</sup>. Figure1 shows the circuit diagram of 2-pulse conventional converter & Figure 2 shows the input and output waveforms of the converter.

**B. Directly paralleled converters**

In directly parallel converter, the output DC terminals are connected parallel with load terminals. This design offers different modes of operation with more freedom. While the convertor is in the operation, the load power variation causes the variation in the supply current. When the current from one converter increases, the current from other converter automatically decreases and compensate the total load current. Hence the consideration for the load current balancing gives another degree of freedom which will be balanced automatically and helps to reduce the notches during commutation. Figure 3 shows the directly parallel two 2 pulse converter & Figure 4 shows the supply current and output current waveform. Further analysis and studies shows that the source current harmonics reduced compared with the conventional 2 pulse converter.

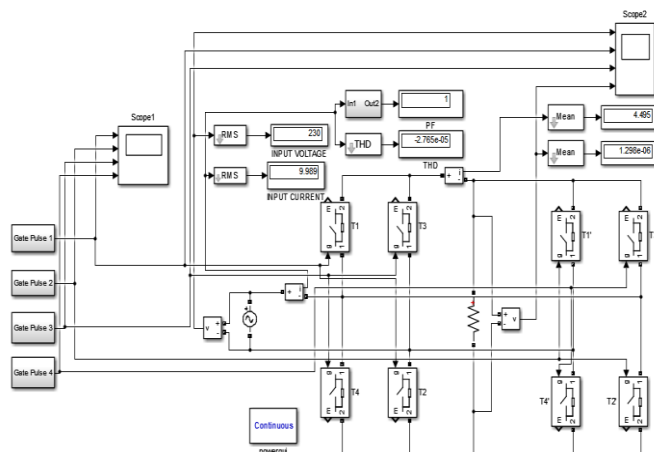


Figure 3. Direct parallel connection of two 2-pulse converter

**III. PULSE WIDTH MODULATION SCHEME**

The ultimate objective is to maintain the DC bus voltage as desired value apart from the disturbance in load side and supply side. Hence PID controlled PWM technique has been employed to control the output voltage of the two 2-pulse converter. Figure 5 shows the generation of PWM pulses, which is very popular in most of the application.

There are two major consideration related to the PWM pulse generation. First is to eliminate the harmonics generated from switching frequency. The second consideration is to reduce the lower order harmonic generation in the output voltage side. The general principle of generation of square PWM can be done by comparison of triangular carrier signal and the control signal. The triangular carrier signal is high frequency with fixed amplitude and the amplitude of the reference signal is made adjustable. The THD content is very significant in the square PWM and also the order of harmonics in the square PWM is based on the number of pulses used in the one half cycle. Figure 6 shows the simulink model of PWM generation.

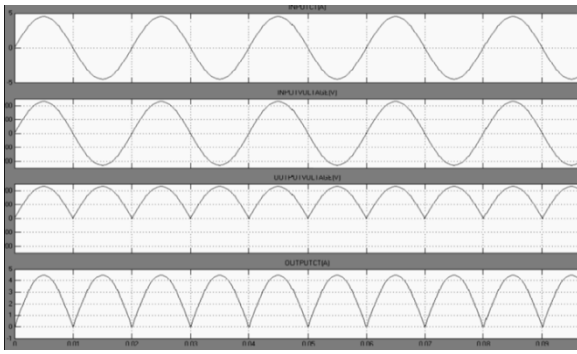


Figure 4. Input and output current waveforms

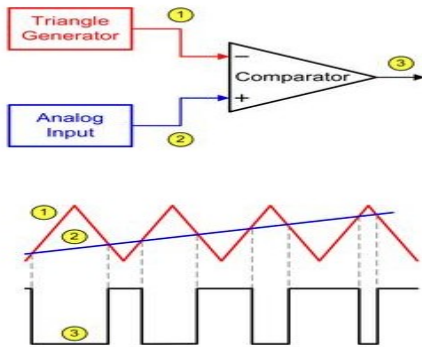


Figure 5. Generation of PWM pulses

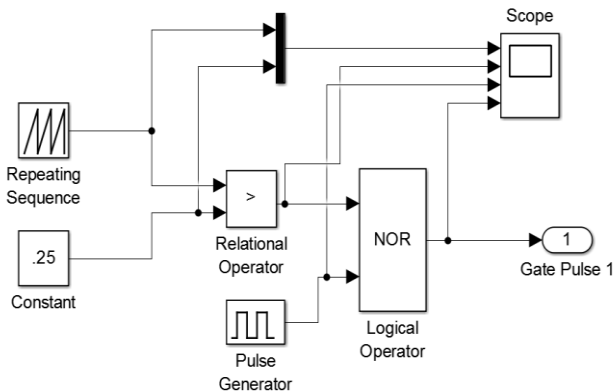


Figure 6. Simulink model of pwm generation

If square PWM is implemented in a converter with a large number of pulses in one half cycle, the harmonic frequencies will be so large that for many applications, such as motor speed control, no separate filter may be needed on the output side. Square PWM offers great support to reduce the THD in the source current, cost and size will be reduced and additional reactive power support with inverter functional capabilities.

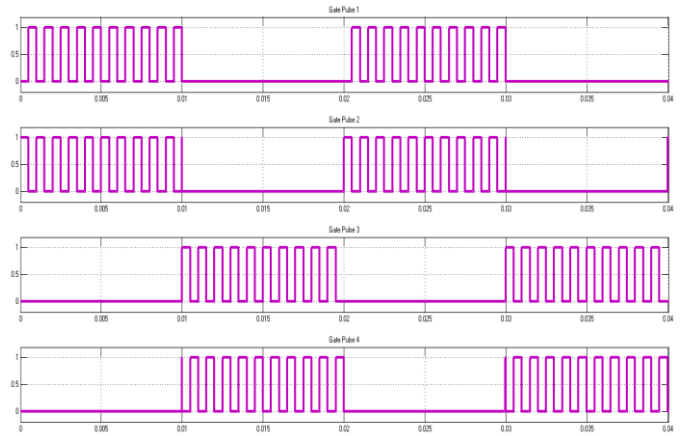


Figure 7. PWM gating signals

#### IV. OPERATION OF TWO 2-PULSE DIRECTLY PARALLELED CONVERTERS

Here, two 2 pulse converters which are connected directly parallel. The AC supply is fed from transformer or Ac voltage source and the output of the converter is connected to common dc load. In this circuit  $T_1$  and  $T_2$  are positive group MOSFET switches and  $T_3$  and  $T_4$  are negative group switches. The gate pulses are generated by using PWM technique. Generally 68hc11 microcontroller has been used to generate the gate pulses in the hardware. The PWM signals are shown in Figure 7. During the conduction of positive half cycle, the positive group the switches  $T_1, T_2$  and  $T_1', T_2'$  are turned on for period of 0 to 90 degrees. Similarly during negative half cycle, the negative group switches  $T_3, T_4$  and  $T_3', T_4'$  are turned on and will conduct up to 90 to 180 degree.

Hence there is a huge reduction in the source current harmonics compared with conventional converter. Similarly there is less ripples in the output voltage and also the power factor increased compared with conventional circuit. The open circuit voltage difference desires the current flow through the load and the current needs to be supplied from each individual converter operated with different gate pulses. The maximum voltage occurs at the positive half cycle while  $T_1, T_2$  switches are turn on until (0 to 90), then  $T_1', T_2'$  will conduct until (90 to 180).

## VI. CONCLUSION

The superior two 2-pulse converter has been designed, modelled and simulated using MATLAB. The component arrangements and the operation of the

The current flow through the load is actually supplied & shared by both of the converter, which will be maintained constantly. During commutation the MOSFET switches become reverses biased and turned off automatically. The converter maintained the constant load current during the whole conduction period. The voltage regulation has been achieved by changing the pulse width of gate pulse.

## V. SIMULATION RESULTS

The two pulse converter helps to improve the power factor and reduce the harmonics. In conventional 2-pulse converter circuit, the ripple current is high in the DC load current as shown in Figure 8. Waveform analysis have been done for the two 2-pulse converter connected in back to back, the output DC current is maintained constant. In conventional and proposed circuits are simulated and compared with R, RL loads and their THD values are shown in Figure 8 ,9, 10, 11, 12, 13 and the distortions are tabulated in Table. 1. The line current can be expressed using Fourier series as

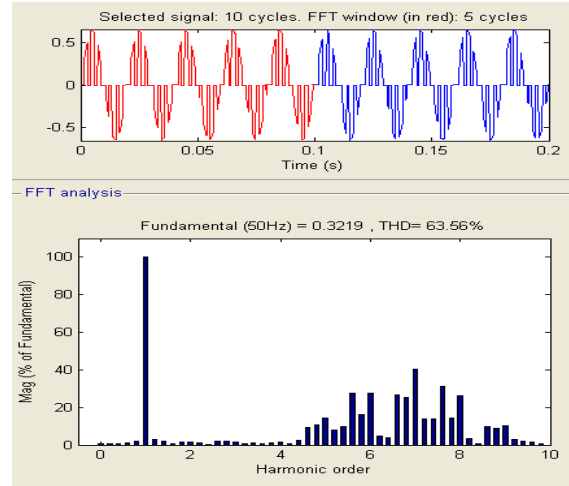
$$I = \frac{a_0}{2} + \sum_1^n A_n \cos(n\omega t) + \sum_1^n B_n \sin(n\omega t), n = 1, 2, 3, 4, 5, \dots$$

The Fourier analysis has proved that there is no even order harmonics due to the waveform symmetry. Hence the co-efficient  $a_0$  &  $a_n$  are zero. Thus the above equation can be simplified as

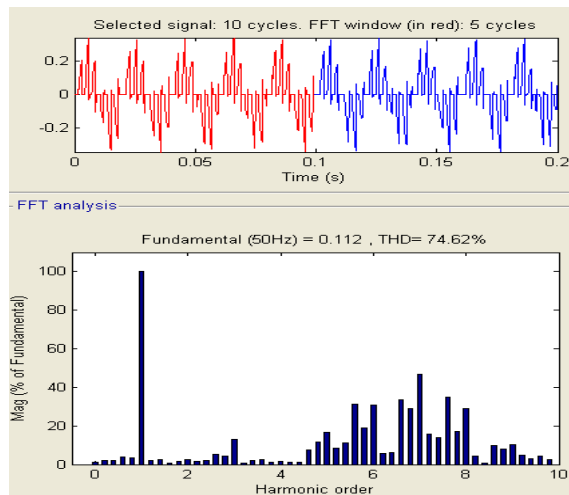
$$\%THD = \frac{\sqrt{H_2^2 + H_3^2 + H_4^2 \dots + H_n^2}}{\sqrt{H_1^2 + H_2^2 + H_3^2 + H_4^2 \dots + H_n^2}} \times 100$$

**TABLE 1.** COMPARISON OF HARMONICS DISTORTION PRODUCED BETWEEN PROPOSED AND CONVENTIONAL CONVERTER

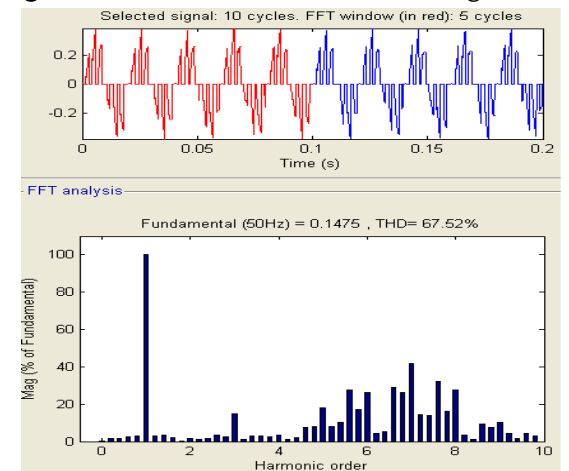
S.no	Load	Conventional converter % THD	Proposed converter %THD
1	R	63.59	2.15
2	RL	74.62	23.56
3	RL with FD	67.52	23.49



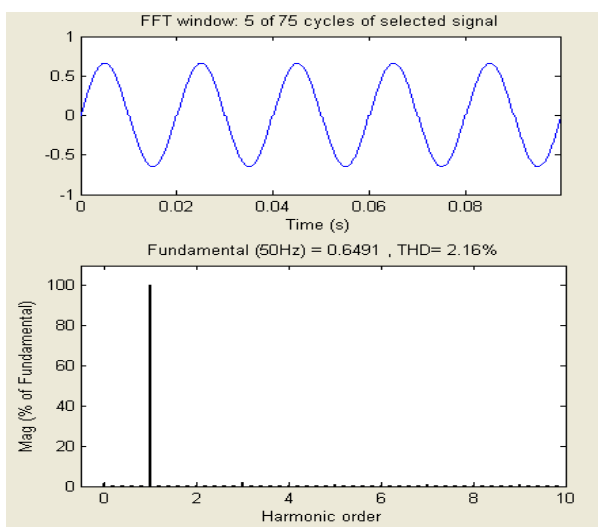
**Figure 8.** Conventional converter using R load



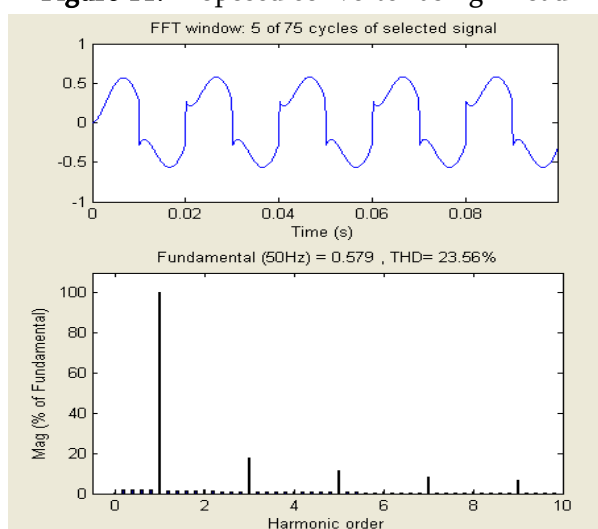
**Figure 9.** Conventional converter using RL load



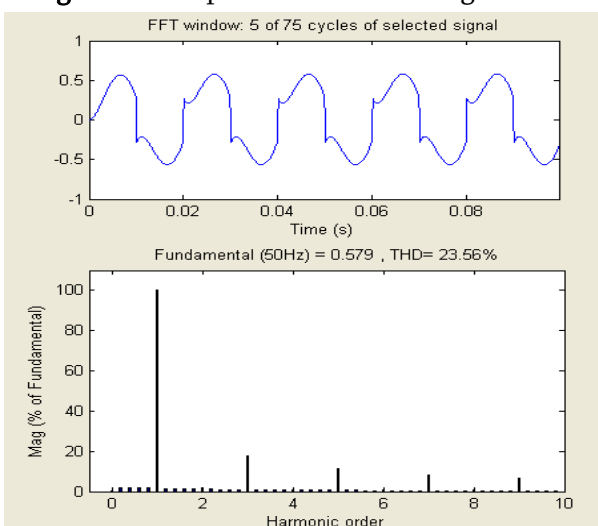
**Figure 10.** Conventional converter using RL load with FD



**Figure 11.** Proposed converter using R load



**Figure 12.** Proposed converter using RL load



**Figure 13.** Proposed converter using RL load with FD

converter have been described and analysed. The two 2- pulse converters provide reduced harmonic content without any additional components required. This arrangement extends the benefits of the very less harmonic content with full load current and wide voltage range. Also the converter operation presented here has very low switching losses in the semiconductor devices as commutation is carried out at zero current switching, hence it provides better efficiency.

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