International Journal of Advanced Research in Engineering and Applied Sciences
ISSN: 2278-6252
Impact Factor: 7.358

PULSE WIDTH MODULATION (P.W.M), A PANACEA TO PHASE CONTROL PROBLEMS IN AC TO DC CONVERTERS

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Abstract: *The presence of low frequency current harmonics have brought about so many problems such as voltage distortion, limitations in the amount of available powers, heating in a.c. mains to mention but a few. Most of these problems are linked with the types of converters and their switching pattern. This paper is aimed at solving this problem by using PWM converters as can be seen from the simulated results.*

***Keywords**: PWM Converters, phase controlled converter, firing angle (α), switching control.*

1. INTRODUCTION

Phase control has to do with the varying of the firing angle of the converter semi-conductor devices in order to obtain power control [7]. In ac to dc converter, diodes or thyritors are principally employed in the conversion when phase control is involved but when Pulse Width Modulation (PWM) control is to be employed, transistors such as Bipolar Junction Transistors (BJT) and metal oxide semi-field effect transistors (MOSFET) [6] are preferred.

In phase control, thyristors are the most commonly used form of control because of their unidirectional conduction properties. Thyristors in an ac circuit can be turned on by the gate at any angle α, with respect to the applied voltage. This angle α is the firing angle. The turn-off of the converter semi-conductor devices can be brought about by ac supply reversal, a process called natural commutation [6]. Converter circuits employing combination of both diodes and thyristors are generally termed half-controlled while those employing thyristors only in their control are called fully-phase controlled converters. The uncontrolled converters contain only the diodes. Note that both fully-phase controlled and half-controlled converters allow an adjustable output voltage by controlling the phase angle (α).

The load voltage of a fully phase-controlled converter can reverse by allowing power flow into the supply, a process called inversion. Thus, a full-phase controlled converter can be described as bi-directional converters as it facilitates power flow in either direction [1].

Again, the half-controlled and the uncontrolled converters contain diodes, which prevent the output voltage power flow from going negative. Such converters only allow power flow from the source to the load, a process called rectification and therefore be described as unidirectional converters.

Phase control is classified into single-phase and three-phase. The converter circuits considered in this paper have in common, an ac supply input and a dc load. The function of the converter circuit is to convert the source into d.c. load power, mainly for high inductive loads. Although, all the converter types provide a dc output, they differ in characteristics such as [1]: (i) output ripple (ii) mean voltage (iii) efficiency and supply harmonics. The ac input power factor for all phase control rectifier circuits degenerate with decrease in load voltage, and therefore have poor output powers [3].

Under PWM therein, the objective is to make control independent of the firing angle (α). This eliminates the problem of phase control, which is the firing angle variation due to switching transients, and the consequent poor output powers.

2. UNIVERSAL FULLY PHASE-CONTROLLED AC TO DC CONVERTERS

In the single or three-phase control, we have the following converters.

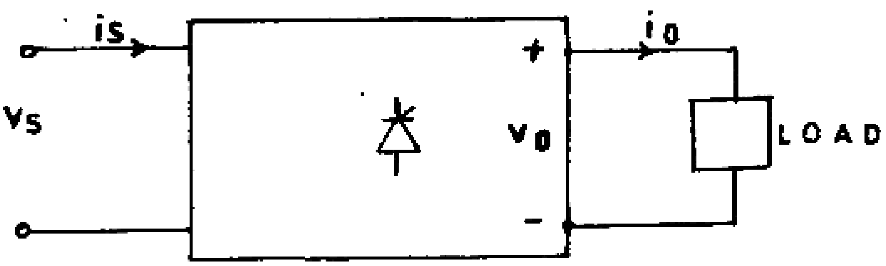
(a) Single-phase full bridge two-pulse, PF = $\frac{2\sqrt{2}}{\pi}\cos\alpha$.

(b) Single-phase full bridge with controlled fly wheeling, PF = $\frac{2\sqrt{2}\cos^2\left[\frac{\alpha}{2}\right]}{\sqrt{\pi(\pi-\alpha)}}$

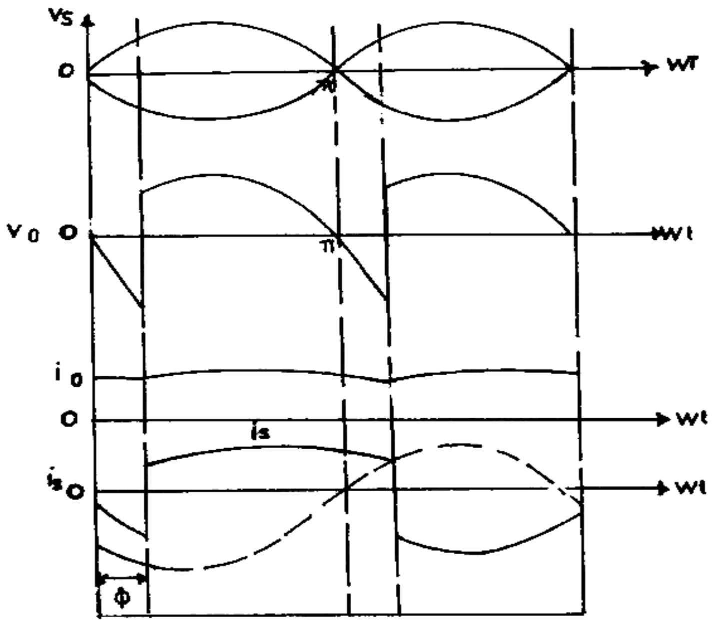
(c) Three-phase full bridge six-pulse

(d) Three-phase full bridge with controlled fly wheel.

The general diagram representing all the fully phase-controlled ac to dc converters with the voltage and current wave forms are shown in figure 2.1.



(a)



(b)

Flg.2.1: (a) Generalized ac to dc converter

(b) The voltage and current waveforms.

The power factor, P_{FAC}, for the single phase two-pulse, fully controlled converter with constant continuous current for instance, was calculated using Fourier series. The calculated power factor is given as:

$$P_{FAC} = \frac{2\sqrt{2}}{\pi} \cos\alpha \qquad (2.1)$$

Where P_{FAC} is the power factor

α is the phase angle difference between voltage and current.

The plot of power factor, P_{FAC}, against the firing angle α of equation (2.1) is shown in figure (2.2).

From the plot, it can be observed that as α increases to $\pi/2$, power factor decreases from $2\sqrt{2}/\pi$ to zero. This is the case also for other phase controlled converters with various phase control methods hence, phase control gives a very poor output power [8]. Usually, controlled switching causes increase in source current (Is) and/or displacement angle (Φ_1) or decrease in fundamental current (I_{SI}) to degrade the power factor, so that power factor can even be zero. All controlled communications and industrial systems have one ac to dc converter interface or the other, which can degrade power factor input [8].

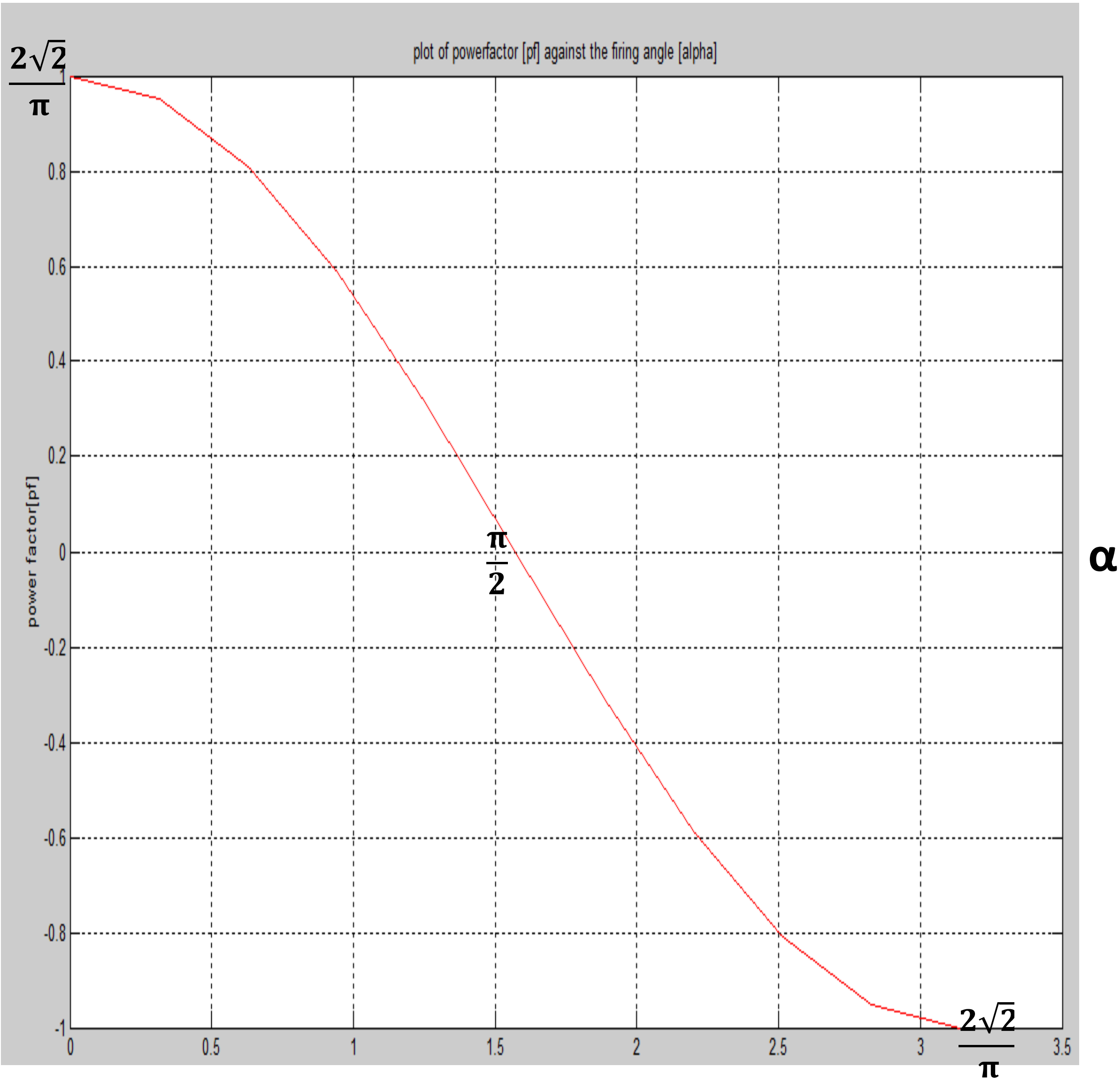


Fig. 2.2: Plot of power factor, P_{FAC} against the firing angle α for $0 \leq \alpha \leq \pi$.

3. PULSE WIDTH MODULATION (PWM) METHOD

Besides phase control, we have also PWM method where the source voltage (Vs) is placed across the load for a certain interval followed by shorting the load for the subsequent interval. PWM is a method of varying the mark-to-space ratio of the output voltage waveform during a cycle so as to minimize the magnitude of the harmonics in the output [8]. The modulation may be done using transistors as switches instead of thyristors because transistors have much higher switching frequencies, leading to improved and more efficient operation than the thyrsitors (switching time is about 1-2μ sec.) PWM are of two types: (i) voltage PWM (ii) current PWM. In this paper, voltage PWM is discussed.

3.1 VOLTAGE PULSE WIDTH MODULATION (PWM)

Under voltage PWM, we have (i) Equal PWM and (ii) sinusoidal PWM

Attributes of multi-pulse or equal PWM [8]:-

- Several equidistant pulse per cycle are used.
- Equal PWM is so-called because all the pulses have the same width for a given value of modulation index (m).
- Here using several pulses in each half cycle of the output voltage can reduce the harmonic contents.
- The method is a natural extension of the single pulse modulation and permits a reduction of harmonic content at low output voltage.

Attributes of sinusoidal PWM [7]:

- The dc reference signal (in equal PWM) is replaced by a sinusoid in which case, is called sinusoidal PWM.
- Sinusoidal PWM is so-called because the pulse width is a sinusoidal function of its angular position in a cycle.
- The method is also called triangulation or PWM with natural sampling.

Voltage PWM is made up of single-phase and three-phase systems.

3.2 CALCULATED POWER FACTORS

The power factor, P_{FAC}, for the single-phase PWM converter, for instance, was calculated using Fourier series and the plot compared with those of the single-phase control. The calculated power factor (P_{FAC}) for the single-phase PWM is given as:

$$P.F. = \frac{\sum(\cos\alpha_k - \cos\beta_k)}{\left\{\sum_{n=1}^{\infty}\left[\sum_{k=1}^{Np/2}\frac{1}{n}\sum(\cos n\alpha_k - \cos n\beta_k)\right]^2\right\}^{1/2}} \qquad 3.1$$

Where PF is the power factor

$$\alpha_k = \alpha_0 - \frac{m\sin\alpha_0 + \left(\frac{1}{\pi}\right)\alpha_0 + (4k-2)}{m\cos\alpha_0 + {}^{12}/_{\pi}}$$

$$\beta_k = \beta_0 - \frac{m\sin\beta_0 + \left(\frac{12}{\pi}\right)\beta_0 + (4k-2)}{m\cos\beta_0 + {}^{12}/_{\pi}}$$

$\alpha_0 = \beta_0$ = rough values of alpha and beta obtained graphically.

m = modulation index, range $0 \leq m \leq 1$

k = variable with range $1 \leq k \leq 3$

n = harmonic order, range n = 1, 3, 5 …. ∞

A plot of the calculated power factors, for single-phase full bridge, two-pulse converter and single-phase full bridge with controlled fly wheeling converters against their normalized average voltages (Voo) were carried out in the same axis with the plot of equation 3.1 of single-phase PWM converter. These were done in MATLAB and the end results are as displayed in figure 3.1

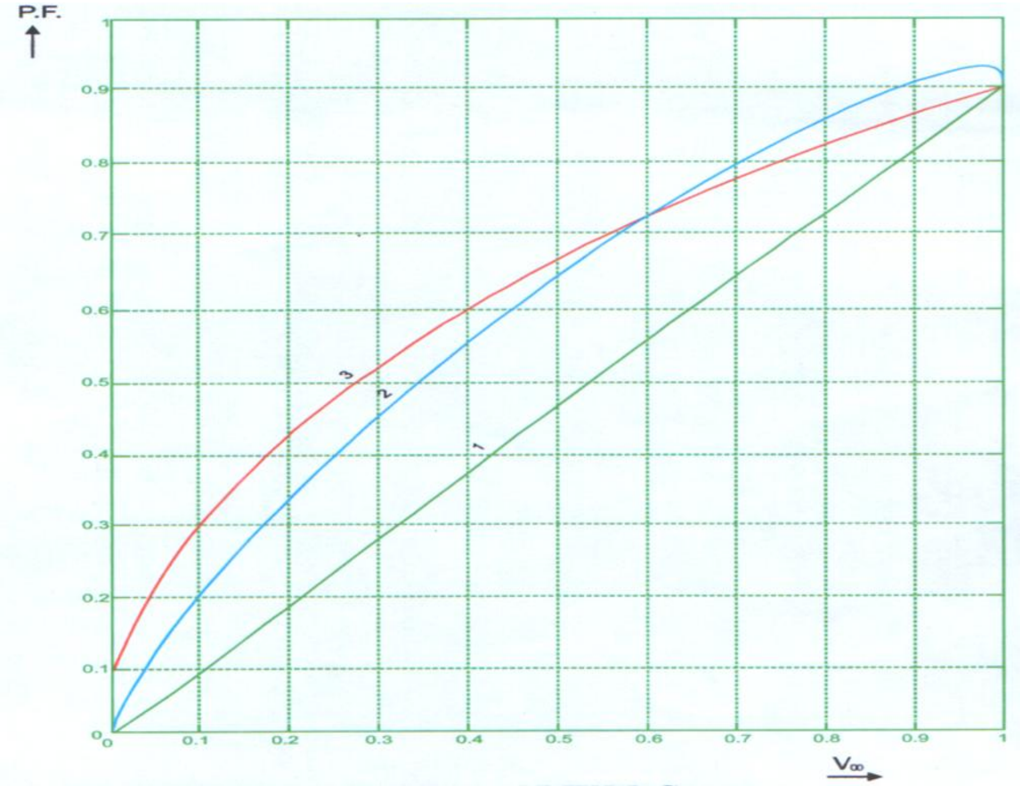


Fig. 3.1: Plots of phase control and PWM Power Factor (PF)

(1) Single –phase full bridge 2-pulse converter

(2) Single –phase full bridge with controlled fly wheeling

(3) Single –phase full bridge PWM converter

4.0 COMMENTS ON THE ANALYSIS RESULTS

It was observed from the plot of power factor against the firing angle in fig. 2.1, that as α increases to $\pi/2$ or 90^0, power factor decreases from $2\sqrt{2}/\pi$ to zero. This is the case for other phase controlled converters with various phase control methods and hence, phase control method gives a very poor output power.

Again, controlled switching causes increase in source current (Is) and/or displacement angle (Φ_1), or decrease in fundamental current (I_{SI}) to degrade the power factor, so that power factor can even be zero.

PWM method solves these problems by making control either independent of the firing angle αor by allowing modulation to be done using transistors as a witches instead of thyristors. This is because transistors have much higher switching frequencies leading to improved and more efficient operation than the thyristors.

Moreover, a plot of the power factors (PF) against the normalized average voltages (Voo), for the phase-controlled converters and PWM converters (in Fig. 3.1), revealed that PWM converters have shown remarkable improvement in power factors than the phase controlled types. Hence, PWM is a panacea to phase control problems.

REFERENCES

1. Berde, M.A. "Thyristor Engineering (Power Electronics)". Ninth Edition, Khama Publishers, 2000.
2. Duber, G.K., "Power semi-conductor controlled derive". Prentice Hall Int. Edition. 1989.
3. Harish, C.R., "Power Electronics', Third Edition" Golgothia, New Hew Delhi, 1999.
4. Holtz, J. and Schwellenberg (1983), "A new fast response current control scheme for the line controlled converters". IEEE Transaction on Industrial Appl. Vol. 1A – 19, No. 4, July 1983, pp. 127 – 134.
5. Mazda, F.F., "Power electronic handbook, components, circuit and applications" Butter Worth Heinemann, 1996.
6. Takashi et al, "Power factor improvement of diode rectifier circuit by dither signals". Conf. Rec. IEEE. IAS Annu. Meeting, 1990, pp. 2597 – 2601.
7. William, B.W., "Power electronic devise, drives, application and passive components", 2nd edition, Macmillian Ed. Ltd; 1992.
8. Wu, T. et al, "Generation of power converter with graft technique". Proc. 15th Symp. Elect. Power Engineering, Taiwon R.O.C, 1995, pp. 10 – 17.