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SINGLE-PHASE FULL BRIDGE TWO-PULSE CONVERTER SYSTEM

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Abstract: *In this paper, the single-phase full bridge two-pulse converter is appropriately examined. The study is intended to provide converter users with the appropriate qualities and characteristics of this phase controlled converter for various power applications and uses in the power system. Using fourier series the power factor of the converter was calculated and plotted in MATLAB, and from the end result, the power quality of the converter can be remedied and/or improved if the phase number is increased by introducing input transformers.*

Keywords: *Single-phase, Full bridge, Two-pulse, Converter system*

1.0 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[1]. The demand for power has obviously increased in recent times without commensurate increase in public awareness to the right choice of power utilities. The aim of this paper is to contribute its own quota in solving this problem and to help in creating the right power quality in the system. In a.c. to d.c. converters, diodes or thyristors are principally employed 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)[2] are preferred.

In phase control, thyristors are the most commonly used form of control because of their unidirectional conduction properties. Thyristors in a.c. circuit can be turned on by the gate at any angle α, with respect to the applied voltage; and this angle $\alpha$is the firing angle. The turn-off of the converter semi-conductor devices can also be brought about by the a.c supply reversal, a process called ***natural commutation*** [2].

Phase control is classified into two types, namely:

(i) Single-phase and (ii) Three-phase

The converters used for a particular application depend on[3]:

a. Available supply, whether single-phase or three-phase.
b. Rating of the device.
c. Amount of voltage ripple to be tolerated.
d. Reversible or non-reversible drive.
e. Need for regeneration.

Converter circuits employing combination of both diodes and thyristors are generally called ***half-controlled***. Note that both fully phase controlled and half-controlled converters allow an adjustable output voltage by controlling the phase angle. The load voltage of a fully controlled converter can reverse, allowing power flow into the supply, a process called ***inversion***. Thus, a fully phase controlled converter can be described as ***bi-directional*** converter as it facilitates power flow in either direction[3].

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 supply to the load, a process called ***rectification*** and are therefore, described as unidirectional converters. Although, all the converter types provide a d.c. output, they differ in characteristics, such as[3]:

a. Output ripple.
b. Mean voltage.
c. Efficiency and supply harmonics.

2.0 SINGLE-PHASE FULL-BRIDGE TWO-PULSE CONVERTER

The basic single-phase full-bridge two-pulse a.c to d.c converter circuit is shown in figure 2.1(a). The converter is fed from the a.c. voltage source (Vs) and employs two self commutated thyristor pairs TH_1 TH_2 and TH_3 TH_4 in its operation. The load is connected to the supply through the thyristors. Thyristors TH_1 and TH_2 conduct in the positive half cycle through the intervals ($\alpha<\omega_t<\pi+\alpha$) see fig. 2.1(b), thus connecting the load to the supply. At $\pi+\alpha$, thyristors TH_3 and TH_4 are fired. Immediately, the supply voltage appears across the thyristors TH_1 and TH_2 as reverse-bias voltage, it turns them off. With the commutation of the device, the load current (i_o) is instantaneously transferred to the thyristors TH_3 and TH_4. The output current (i_o) can be seen as unidirectional constant and continuous current.

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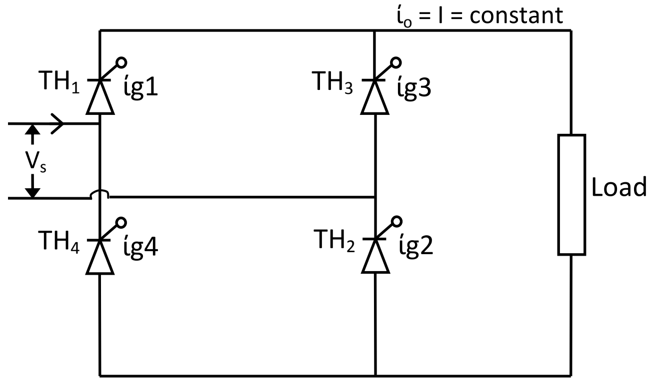
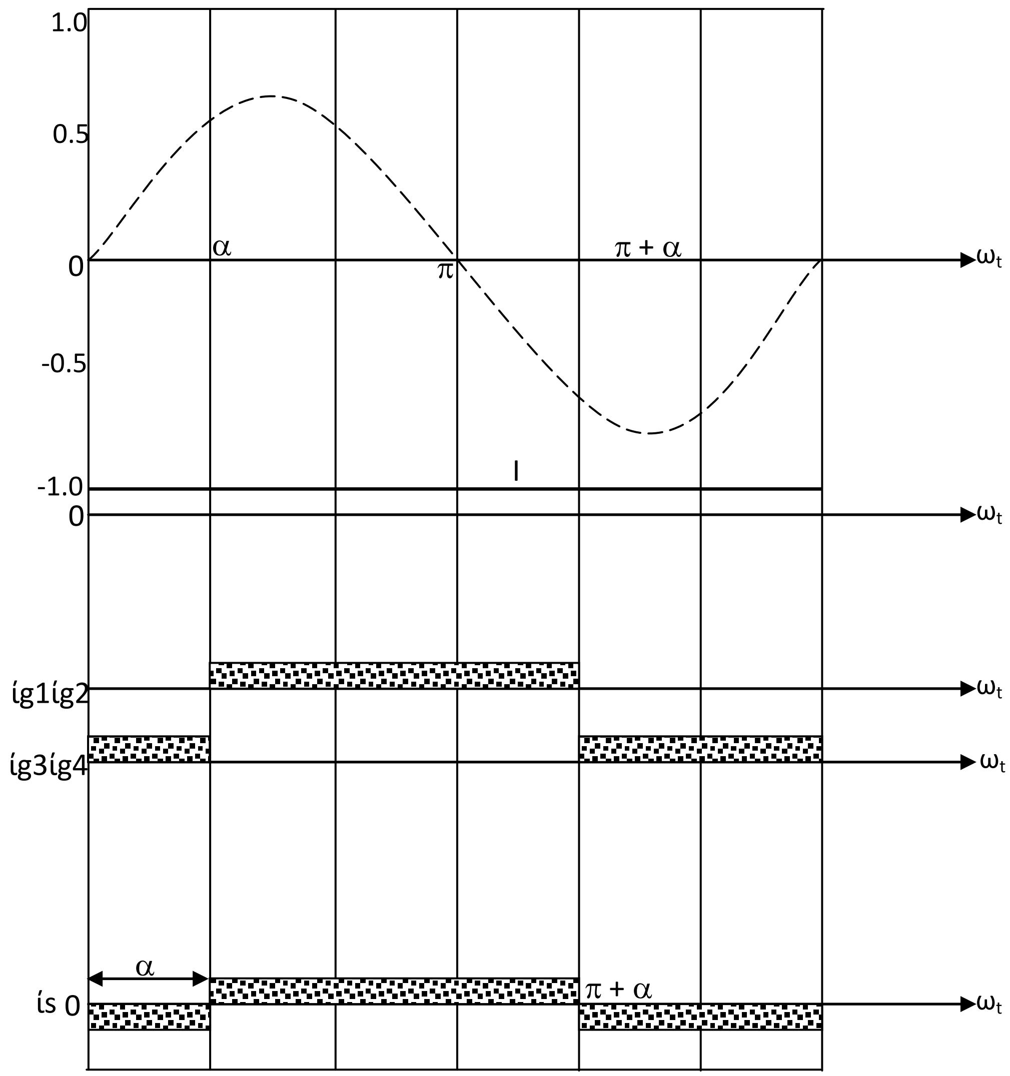


(a)



(b)

Fig. 2.1: (a) Single-phase full bridge two-pulse converter

(b) Thyristor gate pulses of current and voltage

2.1 Power Factor Consideration for the Full-Bridge Two-Pulse Converter

Now, from the waveforms in fig. 2.1(b), i_s is a square wave whose fourier series is given by:

$$i_s = \Sigma \frac{4I}{n\pi} \sin n\,(\omega_t - \alpha) \qquad (2.1)$$

n – 1, 3, 5 ….

Where

i_s = a square wave current

n = harmonic order

α = firing angle

I = direct current contributing to the fourier series of the square wave

$$I_{s1} = \frac{i_s}{n=1} = \frac{4I}{\pi} sin(\omega_t - \alpha) \qquad (2.2)$$

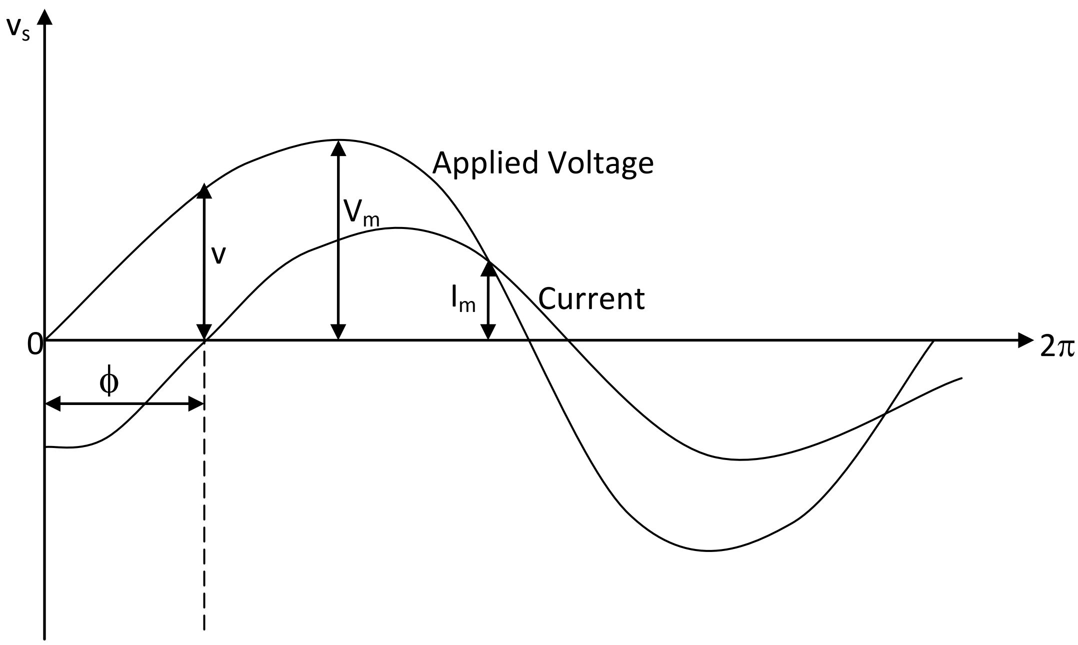


Fig. 2.2: Voltage and current waveforms

But v = $V_m \sin \omega_t$ (2.3)

V_m = $\sqrt{2} v_s$ (2.4)

∴ v = $\sqrt{2} V_s \sin \omega_t$ (2.5)

Where

v = instantaneous voltage

V_m = maximum voltage (fig. 2.2)

v_s = r.m.s a.c. input voltage

$\Phi_1 = \alpha$ = displacement angle and phase angle respectively

Note: In fully controlled rectifier circuit with perfectly filtered load[6], $\Phi_1 = \alpha$

$$P_{FAC} = \frac{I_{S1}}{I_S} COS\,\phi[4] = \frac{I_{S1} COS\alpha}{I_S} \qquad (2.6)$$

$$I_{S1}(r.m.s) = \frac{4I}{\pi\sqrt{2}} = \frac{2\sqrt{2}}{\pi} I \qquad (2.7)$$

$$I_s = \sqrt{\frac{1}{2\pi}\int_o^{2\pi} i_s\, d(\omega_t)} \qquad (2.8)$$

$$I_s = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} I^2\, d(\omega_t) + \int_{\pi+\alpha}^{2\pi+\alpha} I^2\, d(\omega_t)} \qquad (2.9)$$

$$\therefore I_s = I\sqrt{\frac{1}{2\pi}[\pi + \pi]} = I \qquad (2.10)$$

$$P_{FAC} = \frac{2\sqrt{2}\ I}{\pi} Cos\alpha / I \qquad (2.11)$$

$$\therefore P_{FAC} = \frac{2\sqrt{2}}{\pi} Cos\,\alpha \qquad (2.12)$$

Equation (2.12) is the power factor (P_{FAC}) for the single phase, two-pulse, fully controlled converter with constant continuous current. The plot of the power factor against the firing angle α is shown in figure 2.3. From the plot, it can be observed that as α increases to $\pi/2$, P_{FAC} decreases from $\frac{2\sqrt{2}}{\pi}$ to zero. This is the case also for other phase controlled converters with various phase control methods and thus, phase control method gives a very poor output power[5].

Again, controlled switching causes increase in I_s and/or Φ_1 or decrease in I_{s1} to degrade power factor so that power factor can even be zero. All controlled communication and industrial systems have a.c to d.c converter interface which can degrade power factor input and that is why public awareness to the right choice of power utilities is being created.

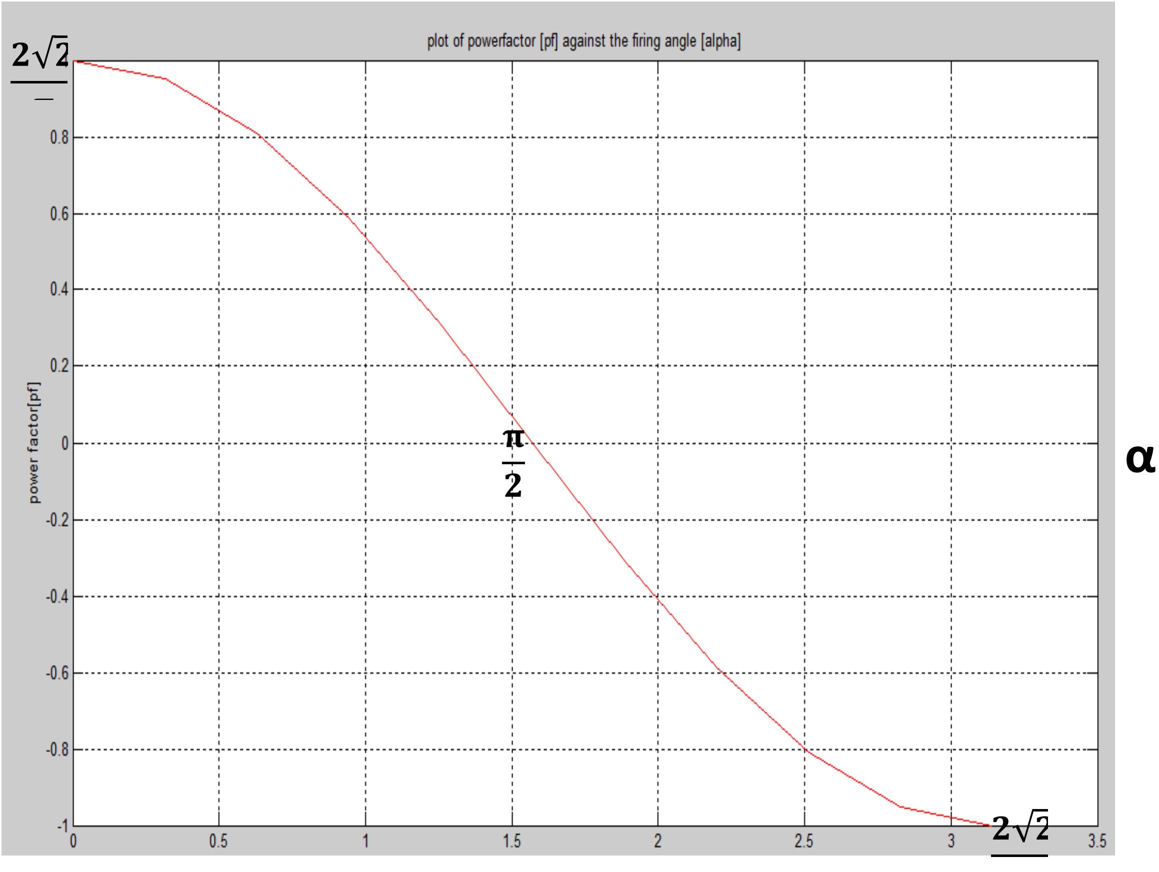


Fig. 2.3: Plot of power factor (P_{FAC}) against the firing angle (α) for $0 \leq \alpha \leq \pi$.

3.0 PROPERTIES OF THE SINGLE-PHASE FULL-BRIDGE TWO-PULSE CONVERTER

Features

i) This is a converter circuit employing thyristors only in its operation hence, the name fully-controlled converter.

ii) Input transformers might not be required in its operation thus, the bridge system is found much more economical to be used e.g. single-phase full-bridge 2-pulse converter. Bridge system is a connection made so that a different pair of rectifiers conducts for each direction of a.c input.

iii) However, input transformers can be required in some applications and then this converter takes the form of a ***push-pull*** either, for: (a) isolation, (b) for phase number increases or the transformer can be introduced if the load voltage rating is not compatible with a.c voltage rating.

iv) The larger the number of input phases, the lower the d.c voltage ripple and the higher the power the converter can handle.

v) Single-phase full-bridge 2-pulse circuits are relatively simple in construction but are limited in power handling capabilities (1 or 2KW only).

vi) They produce output voltage supplies much greater than from three-phase system.

Advantages

i) They are relatively simple in construction.

ii) Transformers with centre-tapped secondary winding can be employed in single-phase full wave bridge rectifier circuits to eliminate direct component of source current.

iii) The non-availability of three-phase supply or the cost of bringing the three-phase load to the terminals, may dictate a clear choice in favour of a single-phase converters.

Disadvantages

i) They are limited in power handling capabilities e.g. they are good for rectifier ratings of 1 or 2KW but for higher powers, three-phase a.c source is normally used.

ii) Another is the problem of current harmonics introduced into the supply system and load, and this calls for extra filters.

iii) Again, like other phase controlled methods, this gives a very poor output power, and is limited to locations where nonlinear load concentration is low.

Applications

It is widely applied in the d.c motor drives. Controller-rectifier-fed d.c drives are widely used in applications requiring a wide range of speed control and/or frequent starting, braking and reversing. Some other prominent applications are: mine winders, rolling mills and paper mills, printing press and machine tools.

4.0 ANALYSIS RESULTS

Although this converter like every other phase-controlled converter system gives a very poor output power as exemplified in the plot of figure 3.2, it can fit adequately in many various areas of applications like d.c motor drives, mine winders, rolling mills and paper mills, printing press and machine tools. Again, by introducing input transformers into the converter circuit, the input phase number increase is enhanced. And the larger the number of input phases, the lower the d.c voltage ripples and the higher the power the converter can handle. Moreover, single-phase full-bridge two-pulse convert can offer a better voltage supply much better than from three-phase system.

5.0 CONCLUSIONS

Like other phase control methods, this gives a very poor output power and must be limited to locations where nonlinear load concentration is low.

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