Power Factor Correction of Three Phase AC-DC

By Saidah Saidah

POWER FACTOR CORRECTION OF THREE PHASE AC-DC CONVERTER VIA CURRENT CONTROLLER AND PWM TECHNIQUE

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ABSTRACT

Use of three phase AC-DC converters for DC loads can cause high harmonics on the AC side, reducing power factor. To improve the power factor can not be done by adding a passive filter on the input side of the conveter. This paper proposes the improvement of power factor through the regulation of current on the AC side and the PWM technique. The current control method uses PI and the exact PWM technique is SVPWM. The System behavior and power factor observations are studied through simulations.

Keywords: *AC-DC Converter, SVPWM, Current Controller*

1. INTRODUCTION

The AC/DC power converters are extensively used in various applications like household electric appliances, power conversion, dc motor drives, adjustable-speed ac drives, HVDC transmission and UPS. The main problem faced by using switchs on an AC-DC converter is to generate high harmonics on the AC side, reducing power factor in low or medium power applications. Normally the input voltage to an AC-to-DC converter is sinusoidal but the input current is non-sinusoidal i.e. harmonic currents are present in the ac sides. Harmonics have a negative effect on the power factor as well. The addition of harmonic currents to the fundamental component increases the total rms current hence harmonics will affect the power factor of the circuit. Unity power factor, lower harmonic current or low input current THD and fixed DC output voltage with minimum ripple are the important parameters in rectifier.

The switch used in this research already uses the transistor family and has left diode and thiristor [1-2]. The use of switch components is IGBT, because IGBT has a higher switching speed / working frequency than other transistors. That's why IGBT is often used in drivers (motor drives) that require large currents and operate in high voltage, because it has better efficiency than other transistor types [3-4]. In figure 1. A three phase phase rectifier with an igbt switch component has been shown. To flatten the ripple on the DC side added capacitor components.

Several ways have been done by researchers for power factor improvements such as by adding passive filters on the input side [5-12]. But the addition of this passive filter does not solve the problem of power factor decline. The method used in this paper by SVPWM technique is a pulse width modulation technique on the IGBT switch component and adjusts the current amplitude on the AC side.

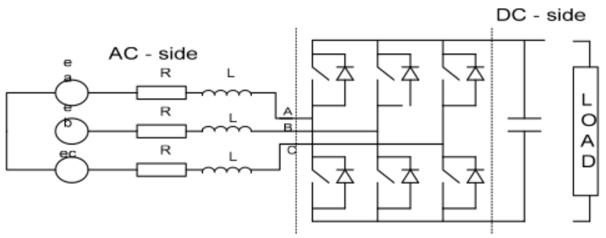


Fig. 1 System of Three-Phase AC-DC converter

2. DESCRIPTION OF SYSTEM

System of the three phase AC-DC converter is shown in Fig. 1. The System is consist of the AC voltage is a balanced three phase supply, IGBT is ideal switch and lossless. Where e_a , e_b and e_c are the phase voltage of three phase balanced voltage source , R and L are mean resistance and inductance respectively, C is smoothing capacitor across the DC bus, R_L is DC side Load.

The following equation describe the dynamic behaviour of the AC-DC converter using space vector :[13]

$$v(t) = e(t) - Ri(t) - L\, di(t)/dt \qquad (1)$$
$$v(t) = \tfrac{1}{2}\, s(t)v_o(t) \qquad (2)$$
$$i_o(t) = (3/4)\, \mathrm{Re}\{s(t)i^*(t)\} \qquad (3)$$
$$i_c(t) = C\, dv_o/dt = i_o(t) - i_L(t) \qquad (4)$$

Where
$v(t)$ = rectifier input voltages
$i(t)$ = rectifier input currents
$i^+(t)$ = complex conjugate of $i(t)$
$e(t)$ = the input line voltages
$i_o(t)$ = rectifier output current
$i_c(t)$ = capacitor current
$i_L(t)$ = load current
$s(t)$ = switching function
$v_o(t)$ = output voltage

3. METHODE OF THE SYSTEMS

3.1 SPACE VECTOR PWM (SVPWM)

SVPWM is to form or encode analog signals into on-off signals for switching using space vector. A Three Phase AC-DC converter has eight active states comprising six active states and two zero states. If depicted in the space vector field, the space vector voltage of the six active states divides the space vector into the same six sectors while the space vector voltage of the zero state lies at the center of the reference plane.

Figure 2 shows the voltage space vector for the AC-DC converter. Vector Vs1, Vs2 .... Vs8 is a vector stationer, meaning it does not rotate by time so its magnitude is determined by dc voltage and its argument is unchanged. Using the PWM modulation technique, it is possible to generate dc voltage with reference voltage vector Vs through vector state synthesis

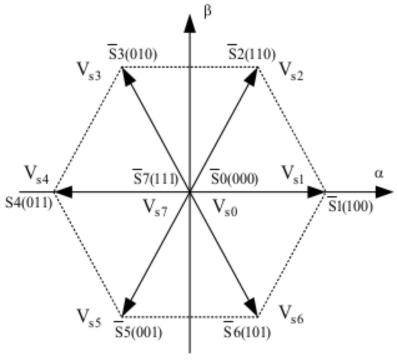


Fig. 2. Space Vector PWM

The six sectors are

$$0^0 < \text{sektor I} < 60^0 \qquad 180^0 < \text{sektor IV} < 240^0$$
$$60^0 < \text{sektor II} < 120^0 \qquad 240^0 < \text{sektor V} < 300^0$$
$$120^0 < \text{sektor III} < 180^0 \qquad 300^0 < \text{sektor VI} < 360^0$$

.

When state 1 and state 2 voltages are generated alternately and at high speeds with respective durations are T1 and T2 in a given time interval, the space vector voltage generated by state1 and state 2 forms the resultant space vector voltage Vs as:

$$V_s = V_\alpha + V_\beta \tag{5}$$
$$V_\alpha = T_1\ V_{s1} \quad \text{and} \quad V_\beta = T_2\ V_{s2} \tag{6}$$

Generally the space vector voltage Vs is formed by the vector of adjacent states in the sector where the desired vector voltage space is located. Thus the space vector voltage Vs in sector 2 is formed by vector state 2 and state 3 and so on in other sectors.

The process of calculating the time duration of the active states and the zero state is performed, when both components of the reference voltage vector and sector position are known. Time state zero T0, active state time T1 and T2 can be calculated by considering triangle on sector 1

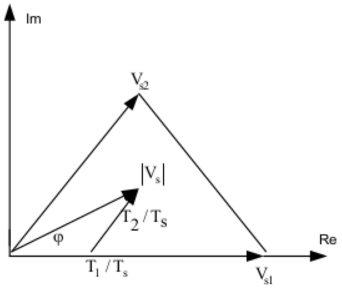


Fig. 3. Determine the switching time of each Sektor I

T 1 dan T 2, can be obtained by considering the following relationship.:

$$\frac{T_1/T_s}{\sin(\pi/3-\varphi)} = \frac{T_2/T_s}{\sin\varphi} = \frac{|V_s|}{\sin 2\pi/3} \tag{7}$$

$$\frac{T_1/T_s}{\sin(\pi/3-\varphi)} = \frac{|V_s|}{\sin 2\pi/3} \quad , \quad \text{then} \quad \frac{T_1}{T_s|V_s|} = \frac{\sqrt{3}}{2}\sin(\pi/3-\varphi_n) = \frac{\sqrt{3}}{2}\cos(\varphi_n+\pi/6) \tag{8}$$

$$\frac{T_2/T_s}{\sin\varphi} = \frac{|V_S|}{\sin 2\pi/3} \quad , \text{then} \quad \frac{T_2}{T_s|V_s|} = \frac{\sqrt{3}}{2}\sin\varphi_n \tag{9}$$

Determine T0 = Ts - Tm - Tm + 1 used for OFF time for AC-DC converter. So in each sampling period there are two active states m and m + 1. T1, T2 and T0 times, it can be determined which combination of switches should be activated according to state and the length of time the active states and zero state.

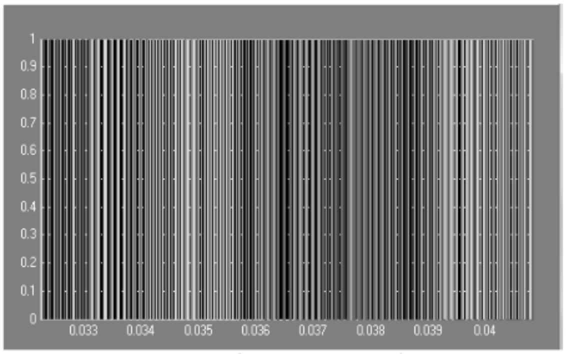


Fig 4. Combinationi T0, T1 and T2

2.2 Current Controller

The control current to get variation of the DC voltage based on SVPWM for three phase of Converter and uses switching variable in d–q frame (s_d , s_q) as input instead of voltage (v_d , v_q) or current (i_d , i_q) that are often used. The system also used a PI controller to control the amplitude of the line current based on the error of the DC voltage. Therefore, a regulated variation of line current amplitude will obtained a low Total harmonic distortion of the line current, a DC voltage variation stable, unity power factor, low ripple. The PI Current Control Proposed was showed in Fig 5.

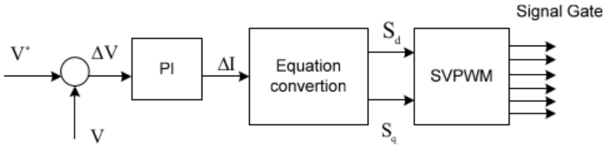


Fig. 5. Block Diagram of the current controller

Convertion Equation

$$s_d = \frac{2}{v_o}\left\{E_m - \frac{L}{T_s}\Delta I_m\right\} \qquad (10)$$

$$s_q = \frac{2}{v_o}\left[-\omega L I_m\right] \qquad (11)$$

4. RESULTS

The simulation has been done using MATLAB/SIMULINK software which it is easy to implement. Various Parameters Used for Simulation Study: AC input voltage = 220V with Supply frequency = 50Hz, Load resistance = 60Ω, DC reference voltage = 600V, Switching Frequency = 9KHz. Figure 6 shows the transient response of the DC link voltage for a switching frequency of 9KHz . The Line current shows on the AC side is stable at 0.04 sec with THD 2.457 on Fig. 7.

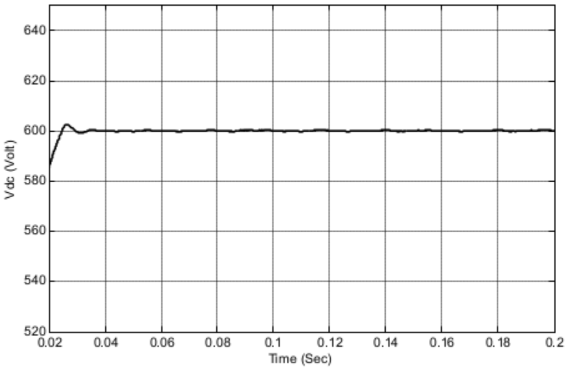


Fig. 6. Simulation result for DC-link voltage dynamics

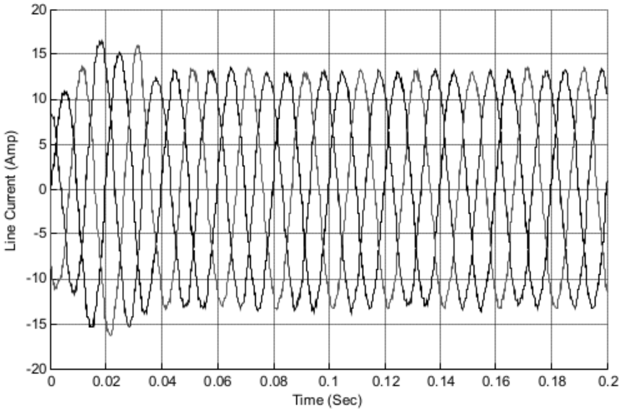


Fig. 7. Simulation result for line current

Fig. 8 shows the voltage and current on line side. We can see the current of sinusoidal wave is the same phase with the voltage. The power factor calculation is achieved using with difference switching frequency. Fig 9. Shows power factor at switching frequency 9 KHz and Fig. 9 shows Power Factor (PF) at switching frequency 5 KHz

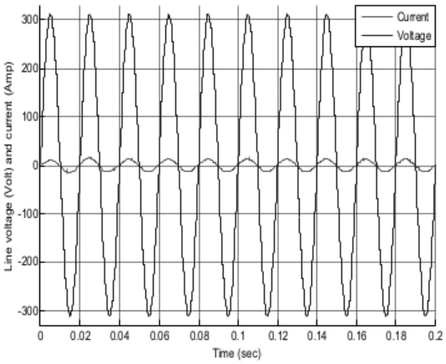


Fig. 8. Simulation result for line current and line voltage

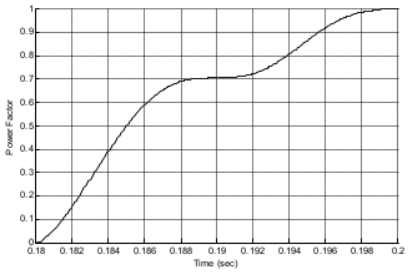
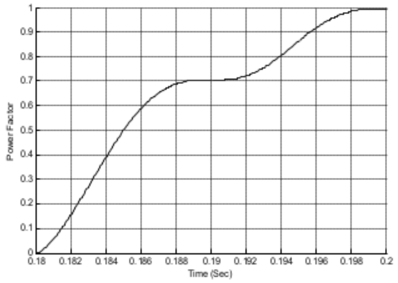


Fig.9 Power Factor (PF) with switching frequency 9 KHz



Power Factor (PF) with switching frequency 5 KHz

5. CONCLUSIONS

The System behavior and power factor observations are studied through simulations using matlab/simulink. From the simulation, power factor obtained for frequency switching 9 khz is 0.998, Total Harmonic Distortion 2.457 and for frequency switching 5 khz is 0.9968, Total Harmonic Distortion 4.136. Thus, using SVPWM method and PI current controller on three phase ac-dc converter are obtained unity power factor and minimum Total Harmonic Distortion, stable DC voltage

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