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THREE-PHASE AC CHOPPER WITH IGBT's

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Abstract. *This paper describes two circuits three-phase ac chopper realised with IGBT's with high carrier wave frequency (chopper frequency). The first circuit described in this article is a three-phase chopper functioning with inductive load. In both situations the power sources are symmetrically three-phases. Also, the simulation waveforms of the load and input currents for the power circuits are presented.*

Introduction

A.C. Choppers have been widely used to control average load power from a fixed ac source. The common applications are industrial heating, light dimming, and ac motor speed control. The advantages of the ac choppers are simplicity, ability of controlling large amount of power, and high efficiency.

The IGBT's controls for both circuits are made using uniform technique PWM, presented in detail in (e.g. [5]), where the control signal V_{com1} is obtained by comparing a triangular wave with a reference voltage used for modifying the duty factor D and, implicitly, the load voltage. The control voltages V_{com1} and V_{com2} are opposite signals. In order to obtain identical voltages on the three-phase system, the index of modulation *m* must be multiple of six The chopper frequency was chosen to be f_S = 6kHz. The power circuits with filters are used to obtain the sinewave of the input current.

Power circuit

Figure 1 shows the power circuit of the three-phase ac chopper in the case of resistive load.

The circuit contains one ac switch Q with IGBT and six diodes. The IGBT control strategy is presented in Figure 2. Suppose the ac-input voltage is expressed as:

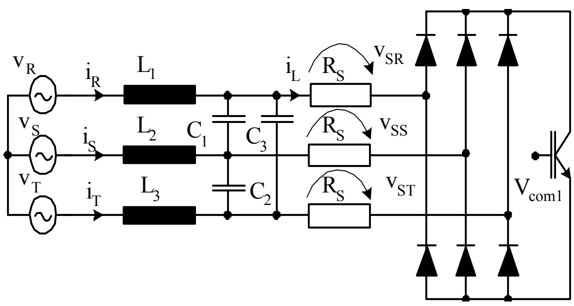

Figure 1. Power circuit of three-phase ac chopper for resistive loads.

$$v_R = V\sqrt{2}\cos\omega t, \quad i_R = I\sqrt{2}\cos(\omega t - \varphi), \quad \varpi = \frac{2\pi}{T}.$$

$$\begin{aligned} v_S &= V\sqrt{2}\cos(\omega t - \frac{2\pi}{3}) \\ i_R &= I\sqrt{2}\cos(\omega t - \frac{2\pi}{3} - \varphi) \\ v_T &= V\sqrt{2}\cos(\omega t - \frac{4\pi}{3}) \\ i_T &= I\sqrt{2}\cos(\omega t - \frac{4\pi}{3} - \varphi) \end{aligned} \tag{1}$$

φ - represent the shift angle between the voltage and the current of the power sources.

For a symmetrical three-phase system, we have

$$v_R + v_S + v_T = 0 \ ; \ i_R + i_S + i_T = 0 \tag{2}$$

The index of modulation is:

$$m = \frac{f_s}{f} = 6l, \quad l \in \mathrm{N} \tag{3}$$

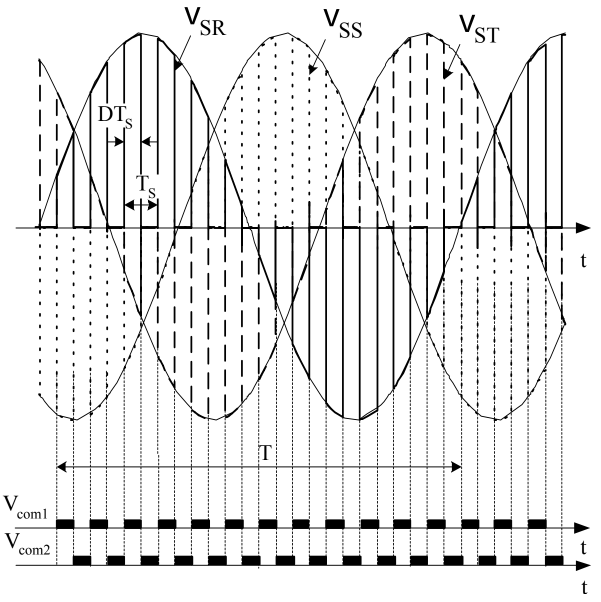

Figure 2 The waveforms of the load voltage and the control signal V_{com1}

Considering the condition (3) the waveforms of the load voltage are presented in Figure 2.

The most cases in practice the load has an inductive character. In this case, for a three-phase system, the load can be connected in the shape of triangle or of a star. Figure 3 presents the circuit of a three-phase ac chopper in which the load is connected in the shape of a star without a ground wire

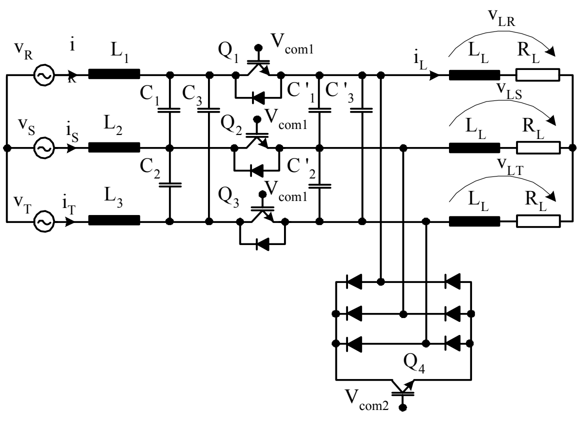

Figure 3. Three-phase ac chopper for an inductive load connected in the shape of a star without ground wire

The chopper in Figure 3 is realised by using nine switching diodes and four IGBT's. The three Q_1, Q_2, and Q_3 IGBT's directly connected to the three-phase system are controlled simultaneously with the control signal V_{com1} and the Q_4 IGBT with the control signal V_{com2}. The IGBT's Q_1, Q_2, Q_3 regulates the power delivered to the load, IGBT Q_4 provides the freewheeling path to discharge the stored energy when the series switch is turned off. The capacities C'_1, C'_2 and C'_3 are meant to ensure the freewheeling path to the load currents starting with the moment when the IGBT's Q_1, Q_2, Q_3, are off and the IGBT Q_4 is on. For the two circuits presented in Figure 1 and Figure 3, the inductors L_1, L_2, L_3 and the capacities C_1, C_2, C_3 form input filters and are meant to approximate the absorption of the sinusoidal current from the sources v_R, v_S and v_T.

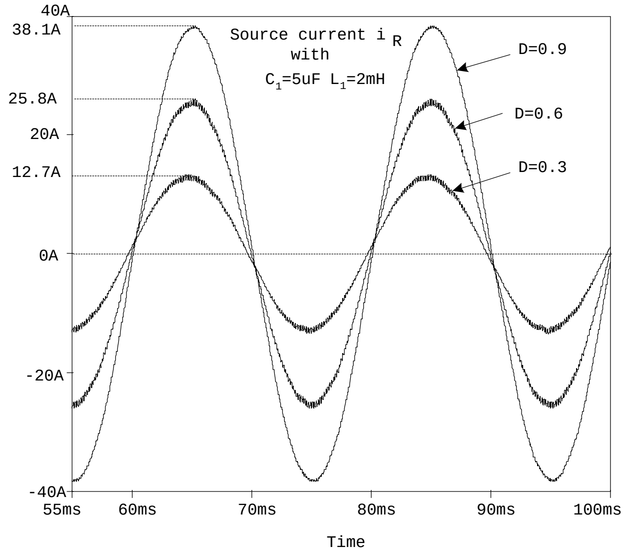

Figure 4. Source current i_R waveforms.

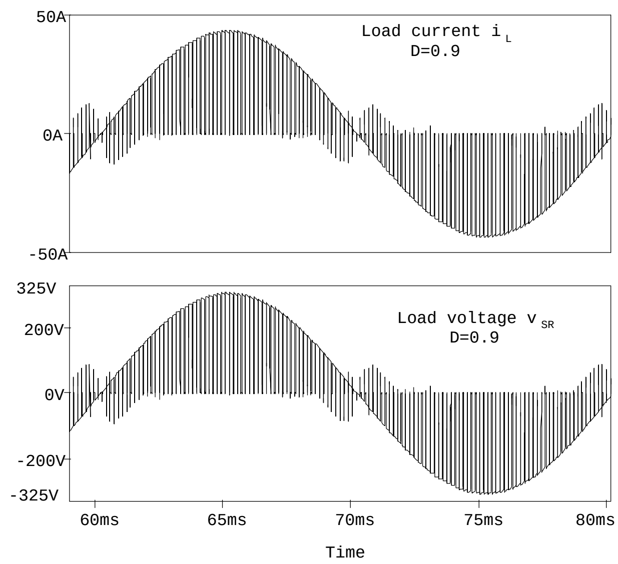

Figure 5. Load current i_L and load voltage v_{SR}

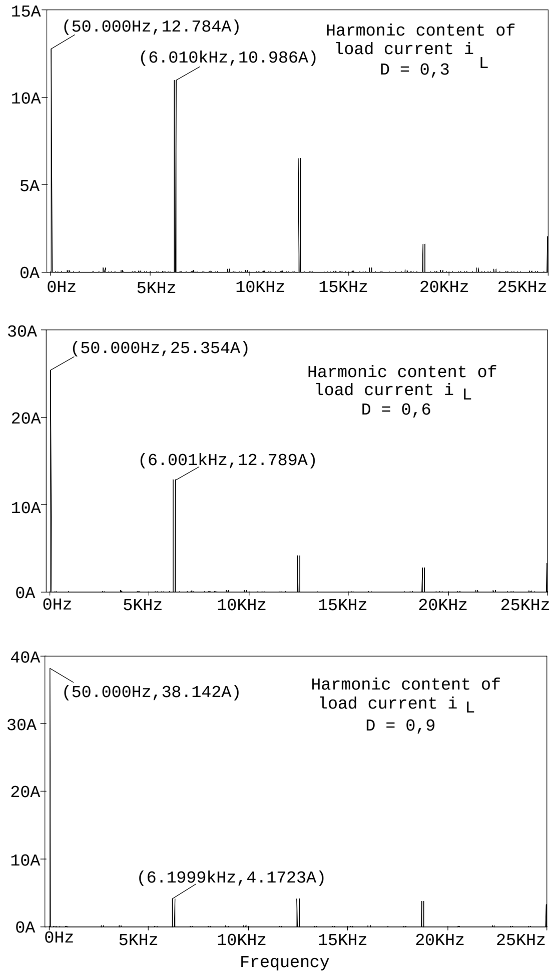

Figure 6. Harmonic contents of load current i_L

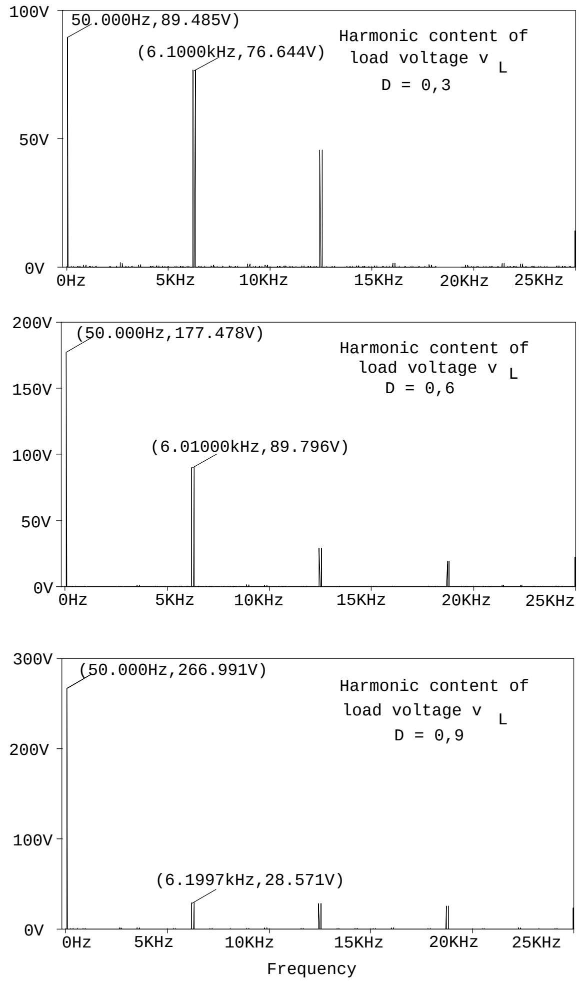

Figure 7. Harmonic contents of load voltage v_L

Simulation results

The presented power circuits of the three-phase ac choppers were tested by simulation. A strong inductive load was considered with R_L = 7 ohms, L_L = 32 mH, and amplitude of mains phase voltage $V\sqrt{2}$ =310V Carrier frequency was $f_s = 1/T_S$ = 6 kHz and $m = f_S/f$ = 120.
Figure 4 shows the waveforms of the source current i_R for three values of the duty factor D.

Figure 5 presents the waveforms of the voltage v_{SR} and of the current i_L for D = 0,9.
Figure 6 shows the harmonic contents of the load current i_L for three values of the duty factor D.
Figure 7 shows the harmonic contents of the load voltage v_L for three values of the duty factor D.

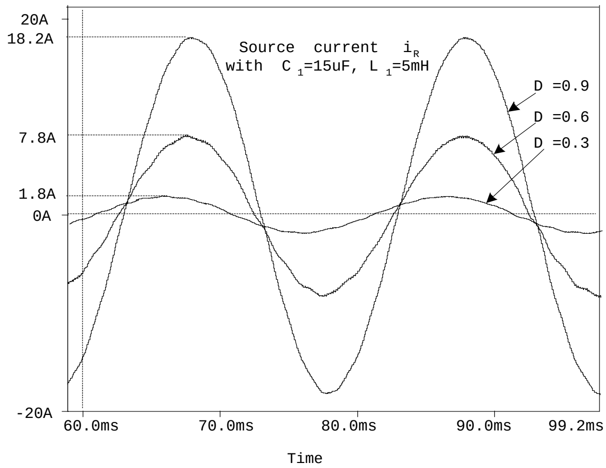

Figure 8. Source current i_R waveforms.

In order to approximate the sinusoidal currents absorbed i_R, i_S, i_T, we have consider that $L_1 = L_2 = L_3$ =2mH, and the capacities $C_1 = C_2 = C_3$ =16uF.
Figure 10 represent the waveforms obtained by

simulation of the absorbed currents i_R ,i_S ,i_T, sum of these currents $i_R + i_S + i_T$, and sum of the voltages $v_R + v_S + v_T$. Obtained results confirm theoretical affirmation presented in relation (2).

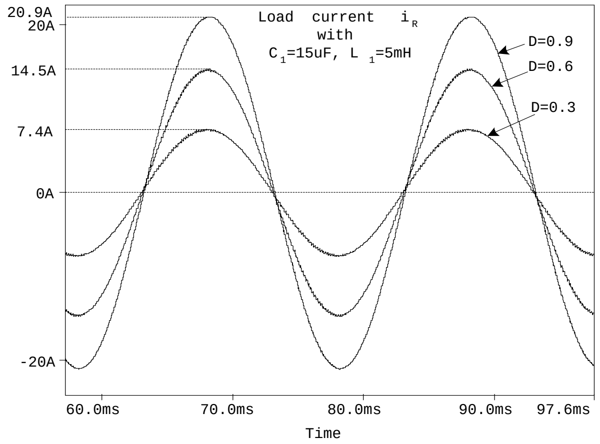

Figure 9. Load current i_L

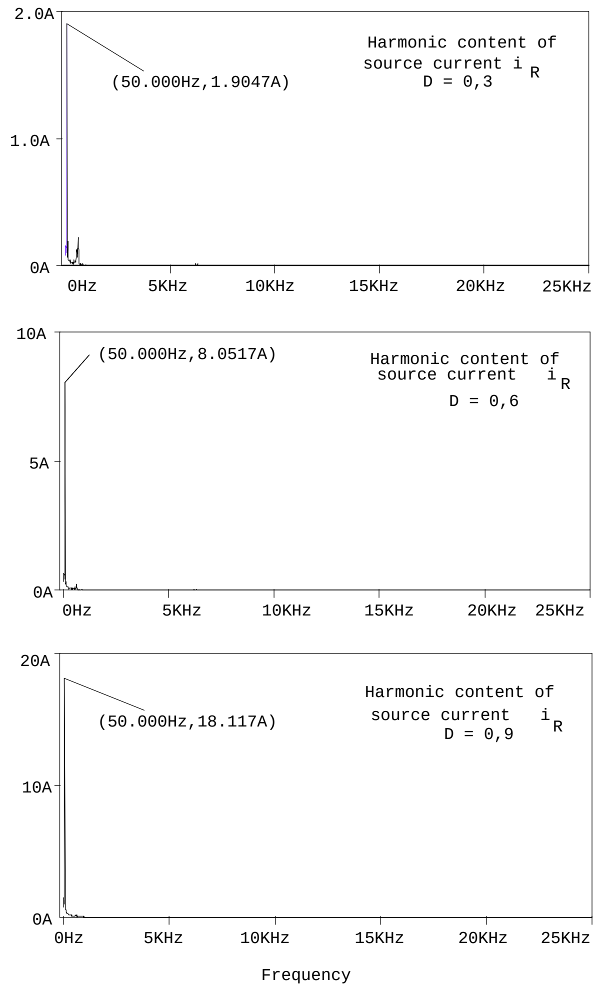

Figure 11. Harmonic contents of source current i_R

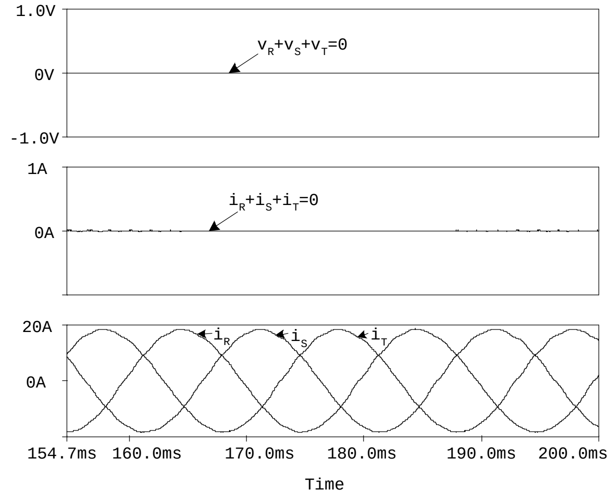

Figure 10. Source currents i_R , i_S , i_T waveforms, sum of the currents $i_R + i_S + i_T$ and sum of the voltages $v_R + v_S + v_T$

Figure 11 shows the harmonic contents of the source current i_R, Figure 12 presents the harmonic contents of the load current i_L and Figure13 presents the harmonic contents of the load voltage v_L for three value of duty factor D. Figure 8 shows the input currents i_R, and figure 9 presents the wave forms of the load current i_L for three value of duty factor D , when the

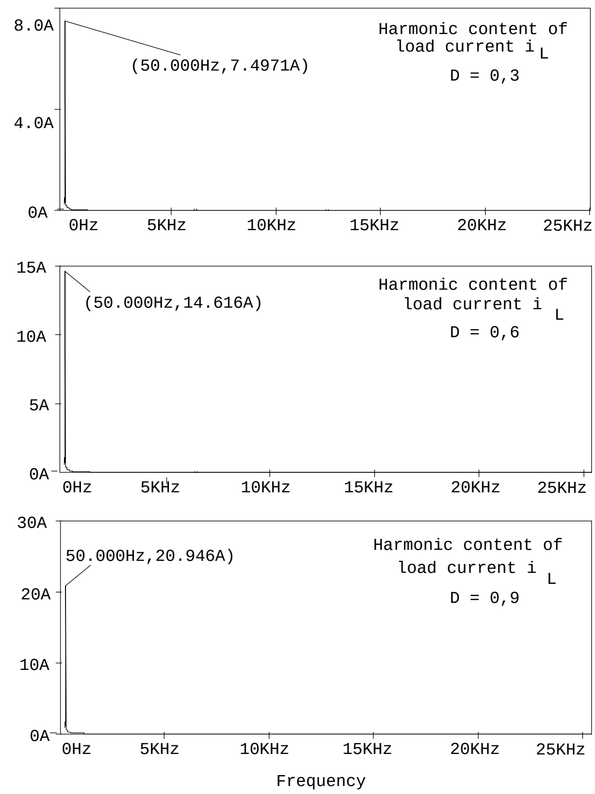

Figure 12. Harmonic contents of the load current

power circuit in Figure 3 is used, with $C_1 = C_2 = C_3 = 15\mu F$, $L_1 = L_2 = L_3 = 5mH$, $C'_1 = C'_2 = C'_3 = 1\mu F$. Sinusoidal waveforms for i_S have been obtained.

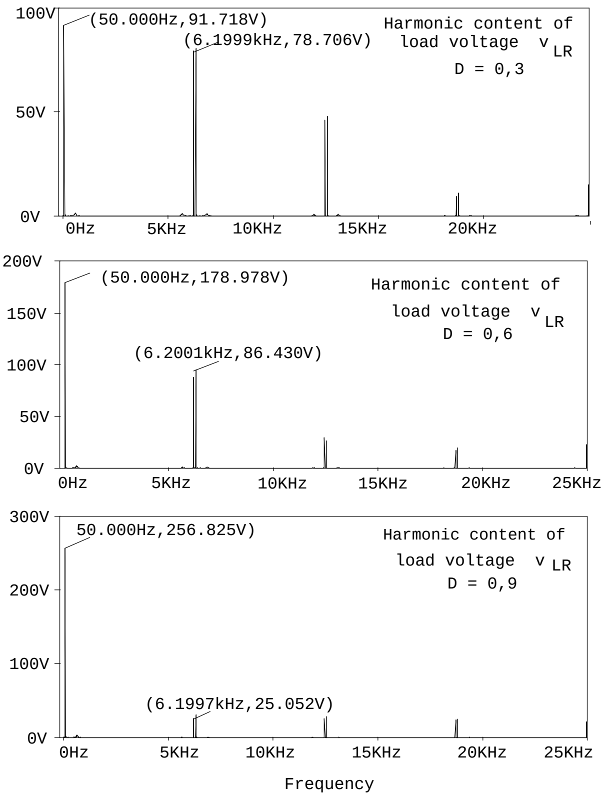

Figure 13. Harmonic contents of the load voltage

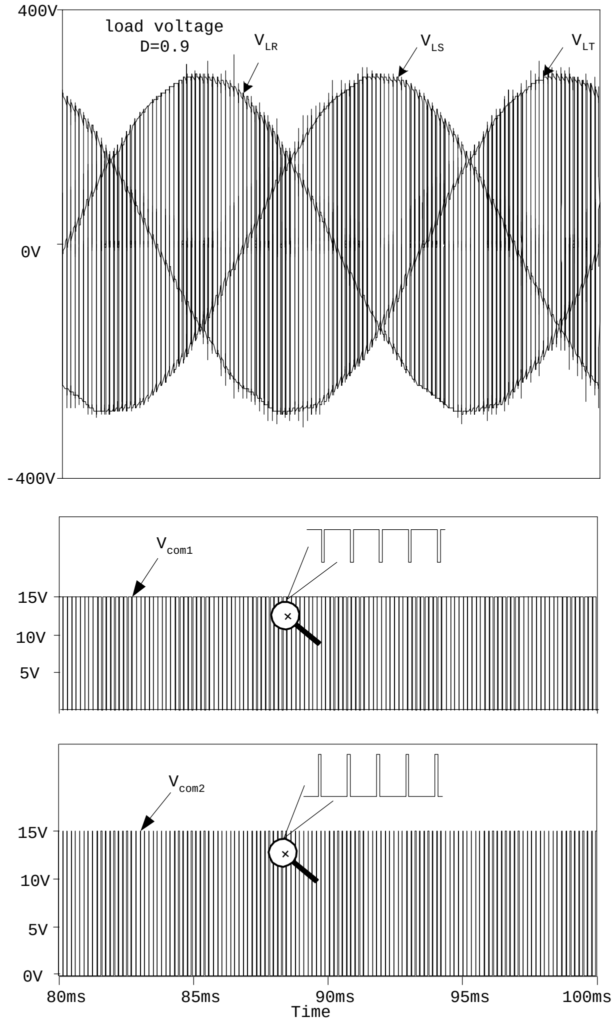

Figure 14. Load voltage v_{LR} ,v_{LS} ,v_{LT}, and the control signal V_{com1} , V_{com2} for the duty factor D=0.9

Figure 14 represent the waveforms obtained by simulation of the load voltage v_{LR} ,v_{LS} ,v_{LT}, and the control signal V_{com1} , V_{com2} .

Conclusion

The simulation results proved good performance of the three-phase ac chopper with IGBT's on high chopper frequency. A sinusoidal input current was obtained by using the power circuit with filter.

In the case of a symmetrical three-phase system, the ground wire is unusable. For this reason, the ground wire was not necessary in the power circuit.

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