Operating Regime as Rectifier with Power Factor Correction of Two – Quadrant Converter with RNSIC

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Abstract: A new topology for a two-quadrant converter is presented. In the AC/DC transfer mode the converter works as a rectifier with near sinusoidal input currents (RNSIC), while in the DC/AC transfer mode it works as a square – wave pulse switching inverter. Some suggestions for the converter is characterized by smaller power losses, reduced EMI problems and higher reliability. This new converter topology could have numerous applications. For example, in adjustable speed drives with regenerative braking, wind energy conversion systems and small hydro interconnections with induction generators.

INTRODUCTION

A new converter for two – quadrant is presented in this paper; it is equipped with 6 transistors (e.g. IGBT) having square-wave pulse switching (that is not PWM) operation, as shown in Fig. (1a). When the energy is transferred from the AC side to DC side, the transistors are off and the converter works as a RNSIC (Rectifier with Near Sinusoidal Input Currents), as show in Fig. (1a). When the energy is transferred from the DC side to the AC side, the transistors are controlled to conduct for $\theta$ angles (square-wave pulse switching) and the converter works as inverter, as show in Fig. (1b).

AC/DC OPERATION MODE

Which is a module of the two quadrant converter in Fig. (1a). The capacitors $C_1$ – $C_6$ have the same value C and they are DC capacitors. The inductors $L_R$, $L_S$ and $L_T$ have the same value, denoted by $L_1$, and they are connected on the AC side. $L_1$ and C fulfil the condition $0,05 \leq L_1 C_1^2 \leq 0,10$ in order for the phase currents $i_R$, $i_S$, $i_T$ to be practically sinusoidal ($\omega$ denotes the mains angular frequency), [7-9].

Considering that the currents $i_R$, $i_S$, $i_T$ are practically sinusoidal and have the amplitude $I_1$, a function of the load...
The Open Electrical and Electronic Engineering Journal, 2008, Volume 2

Pletea et al.

Fig. 2). Configuration of RNSIC converter.

The rated operation of the RNSIC converter is defined for \( \varphi = 0^\circ \) and \( \frac{R_r}{R_i} = 1 \). For this case, the variations of the rated angle \( (\omega t_1) \), the angle corresponding to when diodes begin to conduct, and the ratio \( \frac{R_r}{R_i} \), as function of the parameter \( L_1C\omega^2 \). The interval between 45° and 60° for \( (\omega t_1) \) ensures a reduced content of higher harmonics for the input currents.

**DC/AC OPERATION MODE**

In what follows we describe the operation of the converter in Fig. (1a) as an inverter. During the first stage, which starts at \( t_0 \), the transistor \( T_1 \) begins to conduct and the capacitor \( C_1 \), charged at initial voltage \( U_{in} \), is discharged to final voltage, \( U_{end} \), while capacitor \( C_4 \), initially charged at voltage \( U_{d2} - U_{m1} \), is charged to \( U_{in} \) by the help of the oscillatory processes in which transistor \( T_1 \) and inductor \( L_2 \) take part. After the blocking of transistor \( T_1 \), made at \( t_1 \), the second stage begins, when the energy accumulated in inductor \( L_2 \) is rapidly transferred to DC and AC sources through diode \( D_4 \). Finally, in the third stage, which lasts between \( t_2 \) and \( t_3 \), the current \( i_U \) is zero, and the current \( i_R \) has a practically sinusoidal waveform, flowing through capacitors \( C_1 \) and \( C_4 \). At the end of this stage, capacitor \( C_4 \) is charged at voltage \( U_{in} \), and \( C_1 \) at voltage \( U_{d2} - U_{m1} \). Inductors \( L_2 \) have values two times smaller than \( L_1 \). For the case of operation in inverter mode, the voltage \( U_d \) is considered to be 15-25 \% greater than for the case of rectifier system operation. Diodes \( D_1 - D_6 \) are chosen according to the RNSIC component design specification, while the diodes \( D_1 - D_6 \) are rated for much smaller average currents.

The current \( i_R \) is given by:

\[
i_R = \frac{U_{m1} - U_{m2}}{j\omega L_1}
\]

while its active value, \( i_Ra \), is given by:

\[
i_Ra = U_{m2} \left[ \frac{\sin(\omega t + \alpha)}{U_{m1}} \right] - \frac{U_{m1}}{2\omega L_1} \sin \omega t
\]

The active power transferred to the AC source is given by:

\[
P = \frac{3}{2\pi} \int_0^{2\pi} i_Ra U_{m2} \cos \alpha d\omega = \frac{3U_{m2} U_{m1} \sin \alpha}{2\omega L_1}
\]

In order to obtain a unitary power factor at the AC source, it results from formula (4) that:

\[
\cos \alpha = \frac{U_{m1}}{U_{m2}}
\]

It results that the value of the power transmitted to the AC source could be varied by modifying the amplitude \( U_{m2} \) (thus the angle \( \beta \)) and the angle \( \alpha \) (thus the angle \( \beta \)).

The switch of the converter in Fig. (1a) from the inverter operation mode to the rectifier operation mode and reverse can be rapidly accomplished during a utility grid cycle

\[
T = \frac{2\pi}{\omega}
\]
Operating Regime as Rectifier with Power Factor Correction

Fig. (3). Rectifier operation mode of the proposed converter (a) Waveforms of the phase current $i_{RNSIC}$ and the phase voltage $v_{RO}$ in steady-state; (b) Waveforms of the phase current $i_{RPFC}$

REFERENCES


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