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Modeling and development of a bridgeless PFC Boost rectifier

Modelamiento y desarrollo de un rectificador Boost PFC sin puente

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ABSTRACT: This paper proposes a model of the bridgeless PFC (Power Factor Correction) boost rectifier for control purposes based on an averaged small-signal analysis. From circuital laws, four operation modes are defined and explained, ensuring a relationship of physical variables in the converter. Based on the proposed model, two-loop cascade control structures composed of Proportional-Integral (PI) lineal controllers are proposed. Design consideration for dimensioning reactive elements is included, providing minimum values for their inductance and capacitance. Implementation of a laboratory prototype of 900 W and experimental results are presented to validate and reaffirm the proposed model. Experimental results demonstrate that the use of the bridgeless PFC boost converter model allows the Power Factor (PF) to be elevated up to 0.99, to reduce the THD_i (Total Harmonic Distortion of the Current) to 3.9% and to control the DC voltage level on output. Compliance of standards of power quality EN 61000-3-2 (IEC 1000-3-2) are experimentally verified.

RESUMEN: Este artículo propone un modelo para rectificadores elevadores PFC (Power Factor Correction por sus siglas en inglés) sin puente para propósitos de control y basado en el análisis del promedio de pequeña señal. A partir de las leyes circuitales, cuatro modos de operación son definidos y explicados, asegurando una relación entre las variables físicas del convertidor. Basados en el modelo propuesto, dos lazos cerrados de control compuestos por controladores lineales Proporcionales e Integrales (PI) son propuestos. Algunas consideraciones de diseño para dimensionar los elementos reactivos son incluidas, de tal forma que se obtienen valores mínimos para su inductancia y capacitancia. Se presenta la implementación de un prototipo de 900 W con resultados experimentales que permite validar y reafirmar el modelo propuesto. Los resultados experimentales demuestran que el uso del convertidor PFC permite elevar el factor de potencia FP a 0,99 o más y reducir el THD_i (Total Harmonic Distortion of the Current por sus siglas en Inglés) a 3,9 %, además de controlar el bus DC en la salida. Se verifica experimentalmente que el convertidor PFC desarrollado está de acuerdo con los estándares de calidad de la potencia EN 61000-3-2 (IEC 1000-3-2).

1. Introduction

AC-DC power converters, also known as rectifiers, allow obtaining direct current from an AC power source. Rectifiers are widely used in applications such as consumer electronics products, switching power supplies, uninterrupted power supplies and charging systems for hybrid vehicles [1, 2]. Usually, conventional rectifiers are reliable and easy to design. These rectifiers are composed of a full bridge-diode and a capacitor. The capacitor charge leads to current peaks in the source; consequently, the use of conventional rectifiers in AC distribution systems is responsible for increments in the THD_i, reducing the Power Factor PF and efficiency of distribution networks [1, 2].

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An increase of the THD_i in distribution networks can lead to higher power losses in cables, transformers and generators. Besides, a high THD_i can cause the magnification of resonant currents, failures in protection devices, and degradation of voltage waveform in large-impedance lines [2-4].

Compliance of power quality standards such as IEEE 519-20142 [5] and IEC 61000-3-2 suggests decreasing the THD_i, improving the PF and reducing the Electromagnetic Interference (EMI) [6].

The reduction of the THD_i and increase in PF at the source can be achieved by using passive filters or controlled rectifiers. Usually, passive filters are tuned LC filters [7]. Capacitors and inductors used in such filters exhibit high

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