Electric Power Systems Research 81 (2011) 1572–1582

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Switching frequency determination of a bidirectional AC–DC converter to improve both power factor and efficiency

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ARTICLE INFO

Article history:
Received 23 October 2008
Received in revised form 6 February 2011
Accepted 6 March 2011
Available online 8 April 2011

Keywords:
Improvement of efficiency and power factor
Switching frequency determination
Bidirectional AC–DC converter

ABSTRACT

This paper investigates the possibility to optimize both the efficiency and the power factor of energy conversion systems which include power electronic converters. The values of these important power quantities depend on different parameters, such as the switching technique and the switching frequency of the power electronic elements. Comparing the already known and used switching techniques with each other we can conclude that the sPWM method offers the highest values of the efficiency and the power factor simultaneously. However, when using this technique the basic current harmonic lags as to the voltage in case of ohmic inductive loads resulting in the decrease in the power factor. In the present work a new sPWM switching technique is suggested in order to achieve higher power factor and efficiency compared to the traditional sPWM method. The aforementioned switching technique is a modified sPWM method based on an appropriate shifting of the input current to the grid voltage. But, the following question is raised: Is there a switching frequency value in a given converter topology by which both the efficiency and the power factor gain optimal value? Thus, the main aim of the present paper is determine this specific switching frequency value. This is achieved by using a simple method based on a criterion suggested in this work. In order to demonstrate how this specific frequency value can be found, a bidirectional AC–DC converter composed of a single phase bridge and two switching elements at the DC side is used. This proposed converter topology excels in that the total number of the switching elements is minimal. The study of this subject is carried out through Matlab/Simulink simulation and experimentation.

1. Introduction

It is known that the control of the output power, the torque and the speed of a DC machine is done through an AC–DC power electronic converter. In general, the power electronic converters affect both the power efficiency and the power factor. If the switching frequency of the converter is low (e.g. the same as that of the grid frequency), the power efficiency is high whereas the power factor is remarkably low. In this case, because the order of the main harmonics is low we need a large passive filter.

Various converter operation techniques have been applied to control the electrical or mechanical quantities, such as, the operation of a drive system consisting of electrical machines and power electronic converters. The choice of high switching frequency reduces the dimension of the filter and increases the power factor. However, the increase in the switching frequency and the resulting effects increase the converter switching losses. This paper, has investigated the possibility of a simultaneous optimization of both the power factor and the power efficiency. Firstly, the most important switching techniques [1–7] are compared with each other to find out which one achieves the highest value of the efficiency and the power factor. Then, by suggesting a modification of this method we have achieved an additional improvement on the power factor and the efficiency. Using that modified sPWM switching technique we can define the value of the switching frequency to achieve the highest possible value for both the power factor and efficiency. The procedure of the determination of this frequency value is based on a specific criterion later analyzed. So, a simple method is created which can be used for every other similar system. We have carried out an experimental investigation to confirm the simulation results. For that investigation we have considered the converter structure shown in Fig. 1, which consists of three classical converters: a buck rectifier, a boost DC converter and an inverter, composing, in this way, a bidirectional AC–DC converter. Through this converter the power of an *R*–*L* load or a DC machine can be controlled.

This converter structure is characterized by a reduced number of switching elements compared to other bidirectional AC–DC converter structures mentioned in the literature [8,9]. The analysis of the power efficiency and the power factor as functions of the

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doi:10.1016/j.epsr.2011.03.002

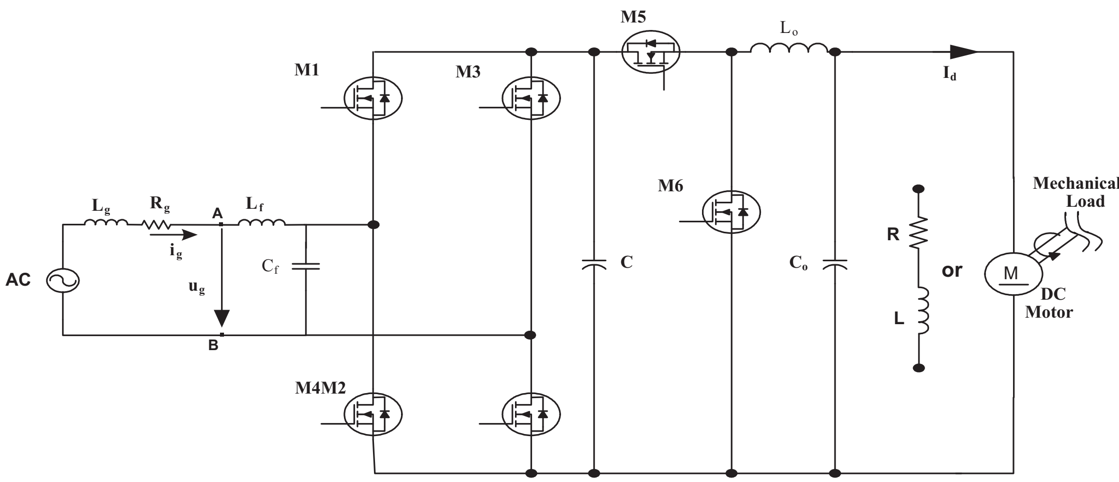

Fig. 1. Converter structure for bidirectional current flow.

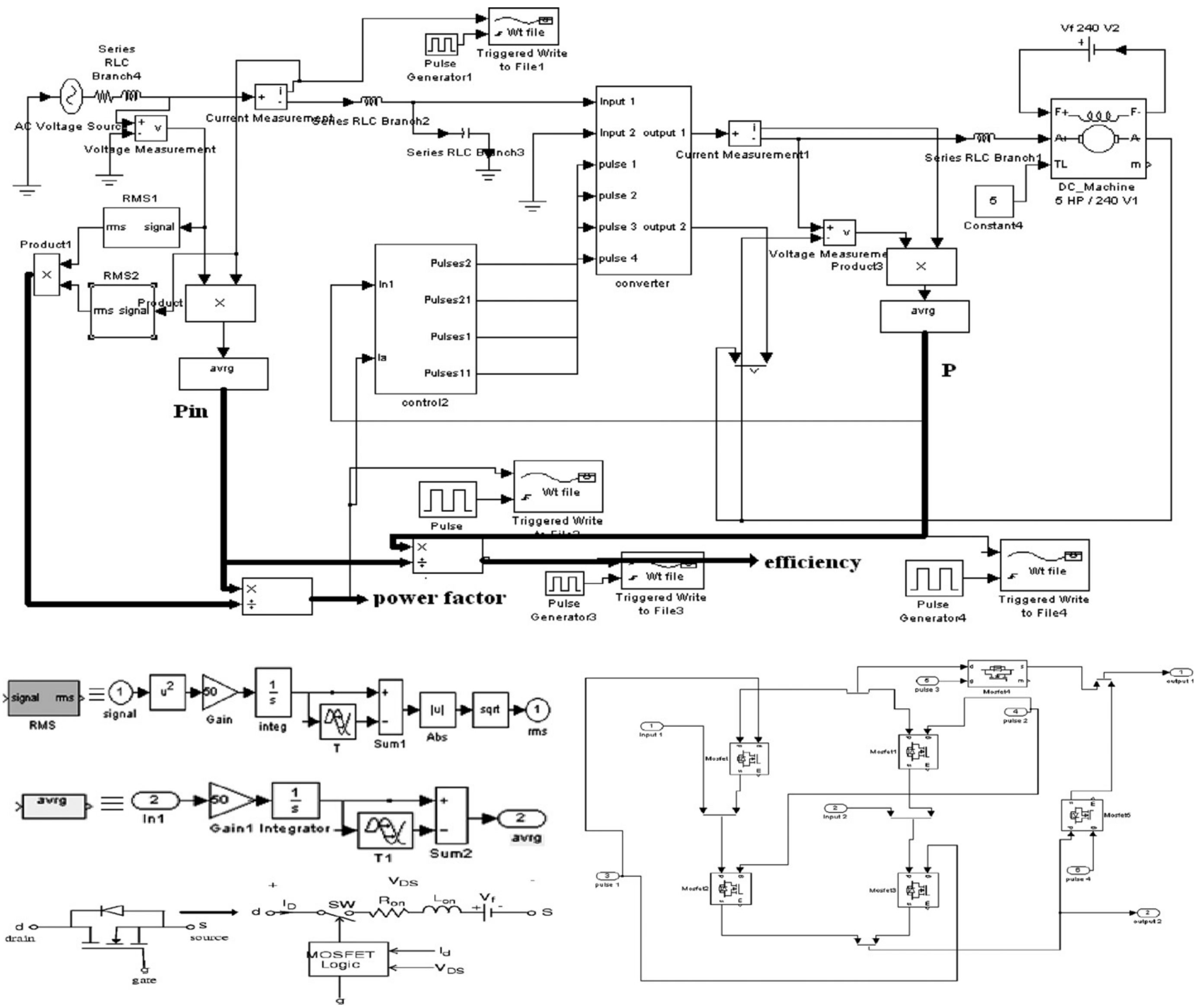

Fig. 2. Simulation model for the system topology.