THE DESIGN AND IMPLEMENTATION OF A SINGLE-PHASE POWER FACTOR CORRECTION CIRCUIT

Prabodh Kumar Khampariya
Electrical Department
NIIST
Bhopal, India
khampariya5@gmail.com

Asfaque Khan
Electrical Department
NIIST
Bhopal, India
techno.ashfaque@gmail.com

Dr. Amita Mahore
Electrical Department
NIIST
Bhopal, India
amitamahor@yahoo.co.in

ABSTRACT

The focus of the present work is on introducing the power electronics community to the modeling and simulation of power factor corrected (PFC) converters. These techniques not only help to develop a deeper understanding of these converters but also to evaluate performance and feasibility of control strategies and topological features without fabrication of an actual system. Important PFC converter topologies are modeled and simulated. Simulation results of a single-phase boost converter are then compared to simulation results obtained by SIMULINK/ SimPower Systems as well as experimental results to provide an overview of the capabilities and limitations of various approaches. It is expected that this work will be of use to students as well as researchers who are interested in studying and researching PFC converters.

Keywords- power factor; topology; boost;

I. INTRODUCTION

Switching converter circuits are power electronic systems that convert one form of electrical energy into another by switching action. They are very popular these days because of their high efficiency and small size [2-4]. Switching converter circuits are used extensively in personal computers peripherals, uninterruptible power sources, and inverter drives for industrial motors, to provide dc or ac electrical energy. The widespread use of switching converter circuits in many electronic systems makes the fundamental understanding of them a necessity for many electronic system design engineers. Unfortunately, learning the design philosophy of the switching converter circuits is interesting but difficult [5-8], because it includes many areas of knowledge, e.g., converter circuits and electronics, linear and nonlinear control system theory [9-11], and magnetic, etc. Teaching the design of switching converters, especially feedback controller design, is a challenging undertaking because one
cannot assume that all students enrolled in the class have solid prerequisite knowledge in all relevant areas. Therefore, to speed up the learning process, the application of user-friendly and powerful computer-aided simulation software tools to help students get acquainted with the dynamic behavior of switching converter circuits is inevitable [1, 5-8, 11-13]. In this regard, the simulation environment MATLAB/ SIMULINK is quite suitable for students to learn feedback controller design techniques if the corresponding simulation models of switching converter circuits can be constructed without too much effort and still give accurate results. It is, therefore, the purpose of this paper to propose an alternative method of producing computer aided feedback controller designs for switching converter circuits for both students and engineers, so that it will be less difficult to learn.

SIMULINK is a window-oriented, software package built on top of the MATLAB numerical workspace. An advantage is that models are entered as block diagrams with an intuitive graphical interface when the corresponding mathematical descriptions are available for the target systems. This application is not difficult to do for basic topologies of dc-dc switching converters. Furthermore, a set of blocks with signal interconnections can be masked as a subsystem for convenience in the SIMULINK environment. The parameters of masked subsystems are then entered in dialog windows and can be changed interactively during a simulation. Simulation results can be viewed during the simulation via a virtual oscilloscope, and then exported to the MATLAB workspace for subsequent off-line analysis.

As stated in [1, 8, 11-13], the abundant library blocks which the SIMULINK modeling environment provides make construction of simple dynamic systems quite easy. This is also true for the design and verification of feedback controllers for switching converter circuits. If the mathematical way of using Kirchhoff’s laws to construct the corresponding dynamical systems is not favored, the MATLAB environment can also be used to develop mathematical models from input-output data via system identification tools [5].

II. BOOST CONVERTER HEART OF POWER CONVERTER

Boost converter topology is used to accomplish this active power-factor correction in many discontinuous/continuous modes. The boost converter is used because it is easy to implement and works well. The simple circuit in Figure 2 is a short refresher of how inductors can produce very high voltages. Initially, the inductor is assumed to be uncharged, so the voltage $V_o$ is equal to $V_{IN}$. When the switch closes, the current ($I_L$) gradually increases through it linearly since:

$$I_L = \frac{1}{L} \int V_i dt$$
Voltage \( V_L \) across it increases exponentially until it stabilizes at \( V_{IN} \). Notice the polarity of the voltage across the inductor, as it is defined by the current direction (inflow side is positive). When the switch opens causing the current to change from \( I_{max} \) to zero (which is a decrease, or a negative slope). Looking at it mathematically:

\[
V_L = L \frac{di}{dt} = L \frac{Ai}{\Delta t}
\]

or \( L \) times the change in current per unit time, the voltage approaches negative infinity (the inductor reverses polarity). Because the inductor is not ideal, it contains some amount of series resistance, which loads this “infinite” voltage to a finite number. With the switch open, and the inductor discharging, the voltage across it reverses and becomes additive with the source voltage \( V_{IN} \). If a diode and capacitor were connected to the output of this circuit, the capacitor would charge to this high voltage (perhaps after many switch cycles). This is how boost converters boost voltage, as shown in Figure 3.

The input to the converter is the full-rectified AC line voltage. No bulk filtering is applied following the bridge rectifier, so the input voltage to the boost converter ranges (at twice line frequency) from zero volts to the peak value of the AC input and back to zero. The boost converter must meet two simultaneous conditions: 1) the output voltage of the boost converter must be set higher than the peak value (hence the word boost) of the line voltage (a commonly used value is 385VDC to allow for a high line of 270VACrms), and 2) the current drawn from the line at any given instant must be proportional to the line voltage.

### III. SIMULATION STUDY

The SIMULINK model is presented here is to improve the power factor of the circuit which is shown in figure 5. This scheme controls both the input current and the output voltage. Figure 4 shows the Current controller which is designed to generate the reference signal for using to generate PWM pulse for MOSFET.
An analog multiplier generates the current programming signal by multiplying the rectified line voltage with the output of the voltage error amplifier. This modulation makes the current programming signal follow the shape of input voltage. The current programming signal acts as a reference current. It is compared with the switch current in a PWM comparator.

The resulting pulses drive a MOSFET. Thus output voltage is controlled by changing the average value of current programming signal. When a current mode control technique is implemented practically, it is feasible to sense the peak inductor current instead of the average value. As the peak inductor current is equal to the peak switch current, the latter can be used in the inner loop, which often simplifies the current sensor. As the peak inductor (switch) current is proportional to the input voltage. Hence, the inner loop of the current-mode control naturally accomplishes the input voltage-feed forward technique.

Fig. 4 PFC Current Controller

Fig. 5 PFC Simulink Circuit
IV. SIMULATION RESULT
The PFC circuit is simulated in the SIMULINK/MATLAB. The simulation is run for time duration of 0.1s. The following results obtained.

Fig. 6 Input AC supply in Rectifier circuit

![Input AC supply in Rectifier circuit graph](image1)

Fig. 7 Output of Rectifier circuit

![Output of Rectifier circuit graph](image2)

Fig. 8 Output of PFC Boost circuit

![Output of PFC Boost circuit graph](image3)

V. CONCLUSION
Key PFC converter topologies have been modeled and simulated. Important results from modeling and simulation of PFC converters are compared with results obtained from an experimental prototype as well as from a standard MATLAB package to highlight the capabilities and limitations of the approach. It has been observed that the modeling and simulation approach is quite adequate for design, development and academic research. This method accurately captures the various intricacies of PFC converters; while at the same time has unsurpassed performance in terms of speed. Additionally, this method is uniquely suited to the academic community since it also helps in developing an intimate understanding of the converter system.
REFERENCES


