Modeling Power Factor Correction Circuits with LTspice

Michael G Giesselmann and Vishwajit Roy
Texas Tech University
Center for Pulsed Power and Power Electronics

2018 IEEE IPMHV Conference, Oral Session
Abstract

LTspice is a powerful simulation language that is specifically optimized for modeling Switch Mode Power conversion. It is not limited to small numbers of nodes and freely available [1]. We are presenting several examples of simulations for popular electronic power factor correction circuits that improve the input power factor of AC Power Supplies by active wave-shaping of the AC input current and the associated avoidance of harmonics. The simulations are performed using a cycle-by-cycle switching approach as well as using a time averaged PWM model. A fast inner current loop is controlling the shape of the input current such that it matches the sinusoidal shape of the AC input voltage. A time averaged PWM model is useful for fast simulations covering many cycles to design and study secondary feedback control that regulates the output voltage of the converter.

Keywords—Boost converter; Power Factor Correction; Time Averaged models; Feedback control; LTspice
AC rectifier without Power Factor Correction

AC-Rectifier Circuit with no Power Factor Correction

SINE(0V {Ampl} 60)  May 22, 2018

.PARAM Ampl = Sqrt(2)*120
.tran 0 66.666ms 0us 1us startup uic
Waveforms & Spectrum of AC rectifier with no PF Correction

- DC-Bus Voltage
- AC-Input Current
- Current Harmonics
AC-Rectifier with Boost Converter for Power Factor Correction

Boost Converter for Power Factor Correction

PARAM I_Amp = 10
PARAM Amp1 = Sqrt(2)*120
.tran 0 33.333ms 0us 100ns startup uic

May 22, 2018
Pre-Charge & PWM Controller Sub-circuits

PreCharge Circuit

Vsw1

SW1
SW_init

PULSE(10 0.0 1.8ms 1us)

PreCharge1

1MEG

.model SW_init SW( Ron=0.2 Roff=1000k Vt=1)

Hysteresis PWM Modulator

Ref
Ref1
R_ref1
1.0

V = V(Ref) + V(PWM)*V(In)*Hyst

V = V(In)*ABS(Sin(2*Pi*60*Time))

Ref2
Pwm1

Hyst_Ref

PWM

Dr1

C1

Out+

Out-

PARAM Hyst = 0.05

PARAM Gain = 500
Waveforms of AC rectifier with PF Correction

DC-Bus Voltage

AC-Input Current
Spectrum of AC rectifier with PF Correction
Switch-Mode & Time Averaged Models
Time Averaged PWM Sub-circuit

Average PWM Switch

\[ l = -l(E_{out})V(D_{Cyl}) \]

\[ V = V(In, Diode) V(D_{Cyl}) \]
Waveforms of AC rectifier with PF Correction

Duty Cycle

DC-Bus Voltage

AC-Input Current
Conclusions

In this paper we have shown simulations of Boost converters used to draw a nearly sinusoidal input current from a AC source and thus avoiding harmonics. This will result in a power factor which is close to unity. We compared a conventional model that uses a cycle-by-cycle switching approach with a model using a time-averaged switch. We found that the results of both models agree very closely. Since there are no high frequency switching transitions that need to be followed, the model with the time-averaged switch can run orders of magnitude faster in a stand-alone simulation. This model can also be used in a frequency domain simulation with the duty cycle input being an analog control variable. The basic model of the time averaged switch shown in Fig. 10 is further expanded by Ned Mohan as a basic pole of a power electronics converter suitable for a wide variety of applications.
References

1. LTspice, Analog Devices, One Technology Way, P. O. Box 9106