Eng. Ovidiu Aurel Pop

~ Abstract of the PhD Thesis ~

Theoretical and Experimental Research about Improving of the Switching Power Supplies Performances

Scientific coordinator:
Prof. Dr.Eng. Şerban Lungu

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Abstract of the Thesis

Modern electronic systems require high quality input voltage, high efficiency power source, low volume, low cost etc. Usually these requirements cannot be achieved by linear electronic equipment, thus the need of using switching power converters.

The aim of this thesis is to analyze and gather some contributions regarding methods of improving the performances of switching power sources:

- Power factor correction achieved by using discontinuous current regime. With all the disadvantages this regime is introducing (higher current peak values through semiconductor devices and the voltage drop across them), using this regime a power factor almost equal to unity can be obtained. This method was implemented in a SEPIC converter, the theoretical results obtained from Pspice and Matlab simulations being verified on the experimental converter.

- Reducing semiconductor-switching power losses by using resonant converters with zero voltage or zero current switching. These types of converters are designed to have zero voltage across the drain-source junction of the switching transistor or zero drain current when switching occurs. This method was implemented in a quasi-resonant buck converter having both zero-voltage and zero-current switching.

- Replacing classical switching circuits with high performance switching circuits such as microcontrollers or digital signal processors.

In the first chapter of this thesis we presented a comprehensive analysis of the SEPIC converter functioning in both switching regimes (continuous and discontinuous conduction modes). The goal of this analysis is to study the possibilities of using this converter as a power factor correction preregulator. While the continuous current operation mode of this converter is extensively treated in literature, the discontinuous current mode is almost neglected. This converter was chosen for studying because it can generate any output voltage without polarity change and because of its topology, which makes it suitable for using as pre-stabilizer in power factor correction circuits. The converter analysis started from the uninterrupted conduction regime, boundary conditions were set and interrupted conduction regime analysis was made. As mentioned in the thesis, obtaining this functioning regime is conditioned by the values of the electronic components used in the circuit. In accordance with these values, each case was analyzed proving that the interrupted conduction regime appears only at the output of the converter. For each particular case analyzed the maximum and minimum current values through the inductances and the expression of the voltage transfer function. Interrupted conduction regime for the input can be obtained by modifying the switch (introducing a diode at the input). This new converter was analyzed using the same method as for the SEPIC classic converter. For each converter, the Pspice and Matlab simulation results verified the obtained theoretical results.

In the second chapter we presented the results obtained by using the discontinuous conduction regime in power factor correction circuits. The analysis for this regime was made for a boost and a SEPIC converter. For each converter the analytical expressions of
absorbed power, input current, and power factor were deduced. Starting with the operating equations of the converters a Matlab program was implemented to simulate them. In order to verify the results the converters were simulated in Pspice and practically built. The measurements taken from the experimental platform confirm the theoretical results, and a power factor of 0.99 being obtained.

The third chapter studies resonant converters which have the major advantage of eliminating power losses during switching of semiconductor devices. The method was exemplified on the quasi-resonant buck converter with both zero-voltage and zero-current switching. We analyzed both unidirectional and bi-directional switch types. For each type the transfer function of the circuit was computed, proving that the graph of the transfer function given in the field literature is not the correct one and presenting, using Matlab simulations, the differences between this transfer function and the real circuit transfer function.

Because simulating a close-loop quasi-resonant converter is not possible using usual simulators like Pspice (the libraries of these simulators do not include a model for the control circuit), in the second part of this chapter is presented a model of modeling such control circuit. The modeled circuit is UC1861 produced by Unitrode Company. In most cases modeling the circuit blocks was made using ideal components (taken from abm.lib library) in order to increase the working frequency. In the last part of the chapter the results obtained from simulating a buck converter with zero-voltage switching are presented. The converter (with unidirectional and bi-directional switch) is implemented using the model proposed for the control circuit. The results are compared with the practical results taken from the implemented test circuit.

In the forth chapter we present another method that can be used with success for improving the performances of power equipments by replacing the traditional control circuits with specialized digital circuits such as microcontrollers and digital signal processors. The major developments in the field of electronic circuits lead to lower production price but also at an increase of functionality and working frequency of these devices. These considerations make them attractive for high-power electronic equipment use. Also the high computational power these devices offer make them more attractive than their analog counterparts.

In this chapter it is presented a method of implementing a true-sine power inverter, which is controlled by a Motorola Digital Signal Processor. The topology chosen for this circuit is full-bridge because of its advantages compared with the half-bridge topology. In the first part of the chapter the theory of operation is presented and in the second part we presented the implementation of this inverter. The theoretical results confirm the experimental results. For a quality estimation of the output signal, we samples the signal and computed it’s total harmonic distortion factor using a program implemented in Labview. The obtained THD of 2.74% validates the proposed method for implementing the inverter.

Using one of the facilities the Digital Signal Processor offers we implemented a remote monitoring platform, via Internet, of the true-sine power inverter. This platform utilizes the PCMaster program produced by Motorola. With this platform the DSP memory can be accessed and various data can be displayed on a WEB page.

In the fifth chapter is presented a measurement instruments of power quality, implemented using a Motorola Digital Signal Processor. Using these instruments is
mandatory because the interferences introduced by power electronic equipment in the power grid lead to a distorted voltage waveform and to a lower quality of the supplied electric energy. Evaluation of power quality impose the knowledge of the main quality indicators of the electric energy and more important their variation in time.

The implementation of this instrument was made using a Digital Signal Processor DSP56F805 and is presented in this thesis. The voltage and current waveforms is measured using galvanically isolated circuits and sampled with the DSP on-board analog-to-digital converters. The computation of the performance parameters is done based upon the harmonic content of the voltage and current waveforms. The harmonic content is obtained by using the Fourier Transform on these signals.

In order to verify the computed power factor, this was measured for the boost and SEPIC converters, presented in the second chapter, and compared with the values obtained from the simulation of these converters.

By elaborating this PHD thesis the author considers that he gained some contributions, which are synthesized in the following paragraphs:

**In the first chapter** the author contributions are:

- A detailed analysis (compared to the similar analyses found in the field literature) of the discontinuous conduction regime of the SEPIC converter;
- Computation of the conditions for obtaining the boundary regime of the discontinuous conduction mode;
- Finding the particular working cases of the SEPIC converter, classic and with input diode, in discontinuous current regime, regarding the values of the electronic components;
- Finding the voltage transfer function of the converter for each particular case and computing the maximum and minimum allowed values of the current flowing through the two inductances;
- Implementation of a modified SEPIC converter topology in order to obtain the discontinuous current regime at the input and a detailed analysis of this converter for each particular case;
- Verifying the analytical results by simulating using Pspice;
- Developing a Matlab program for simulating the SEPIC converter, classic and with input diode, based on the SEPIC functioning operating equations;

**In the second chapter** the author contributions are:

- Analysis of the boost converter in discontinuous conduction regime and determining the analithycal expression of the power factor;
- Comparing the theoretical results, obtained by Matlab and Pspice simulation of the boost converter, with the experimental results measured on the laboratory circuit;
- Analysis of the SEPIC converter in discontinuous conduction regime and determining the analithycal expression of the power factor;
- Comparing the theoretical results, obtained by Matlab and Pspice simulation of the SEPIC converter, with the experimental results measured on the laboratory circuit;
• Developing of a Matlab platform for simulating the boost and SEPIC converters based on their operating equations.

**In the third chapter** the author contributions are:
• Determining the analytical expressions of the voltage transfer function for each type of converter and representing them using Matlab;
• Pspice simulation of each type of buck quasi-resonant converter with zero-voltage or zero-current commutation.
• Determining the expressions 3.29, 3.61, 3.95 and 3.124 of the real control characteristics of each converter and representing these characteristics using Matlab;
• Determining, by comparative representation, of the approximation degree of the real characteristics using the simplified characteristics;
• Determining of Tr/Ts ratio limits, a duty cycle limits and Characteristic impedance limits;
• Implementing a Pspice model for the control circuit UC1861 produced by UNITRODE company and simulating a resonant converter with full-wave zero-voltage commutation with the purpose of evaluating the proposed model;
• Building a laboratory quasi-resonant converter controlled by the UC1861 circuit and comparing the theoretical and experimental results.

**In the forth chapter** the author contributions are:
• Analyzing the methods of implementation of a PWM controlled true-sine inverter and analyzing the possibilities of implementing this inverter using a Digital Signal Processor;
• Designing a development board for the Motorola DSP56F805 Digital Signal Processor;
• Designing and building the true-sine power inverter;
• Developing the necessary embedded software for controlling the inverter;
• Modeling the inverter using Matlab Simulink and Pspice in order to verify the proposed solution;
• Sampling the inverter output voltage and developing a Labview program for displaying the output voltage, computing and displaying the spectral components of the output voltage and computing the output voltage total harmonic distortion factor in order to make a quality evaluation of the waveform;
• Implementing an application remote monitoring platform using PCMaster software supplied by Motorola.

**In the fifth chapter** the author contributions are:
• Study of the measuring techniques and analysis of the methods for determining the performance parameters of the power grid;
• Implementing the current measuring solution using an inductive current sensor having a good quality/price ratio. The solution must permit a precise measurement of the absorbed current while providing good galvanic isolation;
• Implementing the signal conditioning interface in order to scale the voltage and current signals to the levels accepted by the analog-to-digital converters;
• Testing the sensors and the interface in order to determine the linearity of the transfer characteristic and the errors to be minimized;
• Developing the software for sampling the voltage and current signals, Fourier analysis of these signals, computing the performance parameters of the power grid from the spectral components and displaying these parameters;
• Determining the relative error of the equipment compared to measurements made with other equipments.

In this thesis the author presents several solutions for improving the performances of power equipment, and mainly, of the switching power sources. Still, considering the broad spectrum of the problem and the complexity of the domain, the solutions proposed by the author represent just a small part of the multitude of possible approaches of this theme and a starting point for further developments of these solutions. As future developments of the solutions presented in this thesis can be reminded:

• Study of the interrupted conduction regime for other type of converters which can be used as power factor correction circuits;
• Considering that the input stage of the Cuk and SEPIC converters is the same, developing a combined topology of these two converters in order to obtain bipolar output voltage
• Determining the real voltage transfer functions for other topologies of quasi-resonant converters;
• Creating new Pspice models for switching power supply control circuits;
• Using Digital Signal Processors for controlling switching power supplies;
• Implementing new high-power true-sine inverters using digital control circuits;
• Developing a system for transferring measured data using the power grid (PowerLine Modem)
Curriculum Vitae

Personal Data:
- Ovidiu Aurel Pop
- Date and place of birth: 26th of February 1971, Nasaud, Bistrita-Nasaud
- Contact address: 26-28 Baritiu Str., 400027 Cluj-Napoca, Romania

Education:
- Graduated in 1994 in Electronics, Faculty of Electronics and Telecommunications, Cluj-Napoca
- Intensive course diploma (Europractice) in “Microelectronics and Microengineering”, 12-16 May 2003, Budapest, Hungary

Professional Experience:
- 1995-1996 Engineer at the “Romtelecom SA”, Cluj-Napoca
- 1996-2002 Assistant at the Applied Electronics Department, teaching “Electronics Devices and Circuits”, “Design of Electronics Circuits” and “Computer Aided Design” (seminary, laboratory and projects for Romanian and English sections);
- Since 2002, Lecturer at the Applied Electronics Department, teaching “Electronics Devices and Circuits”, “Design of Electronics Circuits” and “Computer Aided Design” (course, seminary, laboratory and projects for Romanian and English sections);

Mobilities:
- September-December 1999 mobility at National technical University of Athens, Greece, during the program Tempus S-JEP 12531

Scientific and Research Activities:
- Published books (1);
- Published papers in national and international magazines and conferences proceedings (34)
- Member in 6 national research contracts and 1 international contract.

Foreign Languages:
- English- very good, French – good