THE FIFTH ANNUAL
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VPEC-PARTNERSHIP PROGRAM

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PURPOSE

This seminar provides a forum for engineers and researchers from industry, Government, and the University to exchange ideas, promote advanced concepts in research and its applications, and to encourage cooperative R&D programs in power electronics.

Sponsored by

Virginia Power Electronics Center
A Technology Development Center of the
Virginia Center for Innovative Technology
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TUTORIAL

HIGH-FREQUENCY QUASI-RESONANT CONVERTERS: TOPOLOGIES, ANALYSIS AND DESIGN

1. HIGH-FREQUENCY QUASI-RESONANT CONVERTER TOPOLOGIES  
   F.C. Lee  
   The fundamental characteristics of the zero-current and zero-voltage switching techniques are reviewed. The merits and limitations of these technologies for off-line and distributed-power applications are highlighted.

2. EQUIVALENT CIRCUIT MODELS FOR RESONANT AND PWM SWITCHES  
   V. Vorperian  
   The switching action in quasi-resonant and pulse-width-modulated converters is attributed to a nonlinear three-terminal switching device for which simple circuit models are obtained. These equivalent circuit models render the dc and small-signal analyses of many PWM and quasi-resonant converters analogous to transistor circuit analysis whereby the transistor is replaced by its equivalent circuit model.

3. DESIGN ASPECTS OF HIGH-FREQUENCY OFF-LINE QUASI-RESONANT CONVERTERS  
   M.M. Jovanovic  
   Performance comparison of three isolated zero-current-switched quasi-resonant converter (ZCS-QRC) topologies is presented. It is shown that the half-bridge topology is the most suitable for high-frequency off-line applications. A complete analysis and design of an offline half-bridge ZCS-QRC with secondary-side resonance is given.

4. ZERO-VOLTAGE-SWITCHED QUASI-RESONANT BUCK AND FLYBACK CONVERTERS - EXPERIMENTAL RESULTS AT 10MHZ  
   W.A. Tabisz and P. Gradzki  
   Experimental results of buck and flyback zero-voltage-switched quasi-resonant converters operating above 5MHz are presented. A design procedure is presented that minimizes voltage stress to the transistor while maintaining zero-voltage switching for all loads.

5. MULTI-LOOP CONTROL FOR QUASI-RESONANT CONVERTERS  
   R. B. Ridley  
   A new, multi-loop control scheme for quasi-resonant converters is proposed. Similar to current-mode control for PWM converters, this control offers excellent transient response and eliminates the need for a voltage-controlled oscillator.

TECHNICAL SESSIONS

SESSION I: HIGH-FREQUENCY POWER CONVERSION TECHNIQUES

1.1 APPLICATION OF A NOVEL, MULTI-RESONANT SWITCH IN HIGH-FREQUENCY DC/DC CONVERTERS  
   W. Tabisz  
   A novel, generalized, multi-resonant switch that combines current-mode and voltage-mode resonant switches is introduced. Application of the new resonant switch in the zero-voltage-switched quasi-resonant converters results in a reduction of voltage stress to the switching transistor, an increase of the load range, and a reduction of the switching frequency bandwidth.

1.2 QUASI-SQUARE-WAVE CONVERTERS: TOPOLOGIES AND ANALYSIS  
   V. Vorperian  
   A new class of converters with zero-voltage or zero-current switching char-
characteristics is presented. The voltage and current waveforms in these converters are essentially square-like except during the turn-on and turn-off switching intervals.

1.3 DC-TO-AC INVERSION USING QUASI-RESONANT TECHNIQUES
R. Tymerski

The zero-current switching technique is applied to dc-to-ac inversion. A number of different topologies are proposed that are useful in amplifier or inverter applications.

SESSION II: DESIGN OF HIGH-FREQUENCY OFF-LINE QUASI-RESONANT POWER SUPPLIES

2.1 TWO-MEGAHertz OFF-LINE HYBRIDIZED QUASI-RESONANT CONVERTERS
D.C. Hopkins, M.M. Jovanovic, F.C. Lee and F.W. Stephenson

Thick-film hybrid technology is employed to fabricate a zero-current-switched, half-bridge, quasi-resonant converter for a 300Vdc off-line application. With a conversion frequency of 2MHz the converter delivers 80W at a power density of 21W/cu.in. This paper describes the theory of operation, detailed design rules, and benefits of hybridization.

2.2 OFF-LINE ZERO-VOLTAGE-SWITCHED QUASI-RESONANT CONVERTERS
M.M. Jovanovic

The half-bridge topology is used to implement the zero-voltage-switching technique in off-line applications. This paper presents the analysis and design for a 300V, 75W converter operating with conversion frequencies above 2MHz.

2.3 COMPARISON OF STRESSES IN QUASI-RESONANT AND PULSE-WIDTH-MODULATED CONVERTERS
A. Lotfi

Device stress analysis is performed in a normalized fashion that allows comparison of various topologies. Basic design guidelines are given to minimize component stresses for quasi-resonant converters.

SESSION III: DESIGN OF RESONANT CONVERTERS

3.1 IMPLEMENTATION OF OPTIMAL TRAJECTORY CONTROL OF SERIES RESONANT CONVERTERS
R. Oruganti, J. Yang and F.C. Lee

Employing a state-plane analysis technique, a novel "optimal trajectory control" has been implemented for series resonant converters. The method predicts the fastest response possible with a minimum energy surge in the resonant tank.

3.2 COMPUTER-AIDED DESIGN AND ANALYSIS OF SERIES RESONANT CONVERTERS
J. Yang and F.C. Lee

A software package was developed to facilitate the design and analysis of a series resonant converter. Using the package, the values of the inductor and capacitor of the resonant tank can be easily determined to meet design specifications.

3.3 CONSTANT-FREQUENCY, CLAMPED-MODE RESONANT CONVERTERS
F.S. Tsai, P. Materu and F.C. Lee

Two, novel, clamped-mode resonant converters are proposed that operate at a constant frequency while retaining many desired features of conventional series- and parallel-resonant converters.

3.4 STATE-PLANE ANALYSIS OF CLAMPED-MODE PARALLEL-RESONANT CONVERTERS
F.S. Tsai, Y. Chin and F.C. Lee

A novel, constant-frequency, clamped-mode parallel-resonant converter is proposed and analyzed. The predicted operating modes are experimentally verified using a 105kHz prototype circuit.

SESSION IV: PWM CONVERTER TOPOLOGY, DESIGN AND ANALYSIS
4.1 GENERATION, CLASSIFICATION AND ANALYSIS OF SWITCHED-MODE DC-TO-DC CONVERTERS BY THE USE OF CONVERTER CELLS
R. Tymerski and V. Vorperian

A method is presented that combines generation, classification, and analysis of dc-to-dc PWM converters. Fundamental blocks known as converter cells can be used to generate a plethora of converters leading to a number of useful new converter topologies.

4.2 SECONDARY LC FILTER ANALYSIS AND DESIGN TECHNIQUES FOR CURRENT-MODE-CONTROLLED CONVERTERS
R. Ridley

A secondary filter can be designed to provide good attenuation of the switching ripple whilst maintaining adequate stability margins with capacitive loading. Design guidelines for the filter are given.

4.3 NONLINEAR ANALYSIS OF THE PWM SWITCH
R. Tymerski, V. Vorperian, F.C. Lee and W. Baumann

The PWM switch represents a static nonlinearity for which circuit models can easily be derived for frequencies harmonically related to the frequency of perturbation. Converter analysis is now becoming analogous to ordinary transistor circuit analysis whereby the nonlinear three-terminal device is replaced by its circuit model.

SESSION V: COMPUTER-AIDED DESIGN AND ANALYSIS TOOLS

5.1 COMPREHENSIVE COMPUTER-AIDED-DESIGN APPROACH FOR SWITCHING REGULATORS
S. Kelkar, R.B. Ridley, C.J. Hsiao, R. Ramkumar and F.C. Lee

A fully automated, computer-aided design approach based on a nonlinear optimization algorithm is presented. The approach results in an optimal power and control circuit design in a single iteration that meets all dc, small-signal, and large-signal closed-loop performance specifications.

5.2 PRACTICAL NONLINEAR DESIGN OPTIMIZATION TOOL FOR POWER CONVERTER COMPONENTS
R.B. Ridley and F.C. Lee

A much improved computer-aided design tool is presented that allows for easy interfacing with nonlinear design optimization software for power converters. Realistic component values may be readily incorporated into the design from vendor catalogs without using a data-base structure.

5.3 CIRCUIT-ORIENTED DISCRETE-TIME MODELING AND SIMULATION FOR SWITCHING CONVERTERS
C.J. Hsiao, R.B. Ridley, H. Naitoh and F.C. Lee

A generalized discrete-time modeling and simulation program has been developed. From a circuit description, this program automatically generates state-space equations corresponding to each switching interval and performs time-domain simulations using a fast-convergence algorithm for topological changes.

5.4 COMPUTER-AIDED GRAPHIC DESIGN OPTIMIZATION OF INDUCTORS FOR DC-DC CONVERTERS
R. Ramkumar, R.B. Ridley and F.C. Lee

A graphic, computer-aided design procedure has been developed for singly would inductors that perform the functions of energy storage and transfer in dc-dc switching power converters. The Lagrangian multiplier technique has been implemented to achieve a minimum weight design.

SESSION VI: MODELING OF SPACECRAFT/SPACE STATION POWER SYSTEMS

6.1 LARGE-SIGNAL STABILITY ANALYSIS OF SPACECRAFT POWER PROCESSING SYSTEMS

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Stability of a spacecraft power processing system is analyzed. Large-signal behavior of the solar array system is portrayed on the state plane. The stability and transient responses of the system operating near the solar array's maximum power point are evaluated.

6.2 COMPUTER MODELING AND SIMULATION OF A 20kHz AC DISTRIBUTION SYSTEM FOR SPACE STATION
F.S. Tsai and F.C. Lee

A computer model of a 20kHz, ac distribution system employing resonant power-conversion techniques is presented. The system consists of six resonant inverters, a one-hundred-meter transmission line, and three load receivers: a dc receiver, a bidirectional receiver, and an ac receiver.