Large Signal Modeling of Quasi-Resonant Buck Converter Using Regulated Unified Model

Che Tat Choi and Chi Kwong Li

Department of Electronic and Information Engineering
The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong
Phone: 852-27666218 Fax: 852-23628439 E-mail: ctchoi@ieee.org

***Abstract*-This paper analyzes the large signal model of a quasi-resonant buck converter using a unified model. The internal resistance of each component in the basic quasi-resonant switch model (QRSW) is taken into consideration. The parameters can be predicted under varying supply voltage and load current. In other words, the variation of switching frequency, which is a controller parameter, can be determined while the output voltage keeps regulating. It is useful for designing an adaptive feedback controller. The power dissipation is analyzed so that the efficiency can be estimated. Moreover, the conduction loss of each component can be found. The critical component in power dissipation is known and the maximum efficiency can be predicted.**

Index Terms -- Large signal modeling, unified quasi-resonant switches, quasi-resonant buck converter.

I. INTRODUCTION

The concept of quasi-resonant power conversion and zero-voltage switching (ZVS) were introduced by F. C. Lee and his collaborators in [1] and [2] respectively. The power loss and efficiency of quasi-resonant converters (QRCs) were analyzed in [3]. However, the modeling, synthesis and analysis of quasi-resonant converters (QRCs) were generalized and unified in [4]. The large signal model of this new unified model has not been investigated. Therefore, this paper introduces a new approach to analyze it.

The internal equivalent resistance of each component is taken into consideration so that the current and voltage waveforms can be found accurately. The switching waveforms of this near-practical model have already been derived in [5]. In order to achieve zero-voltage or zero-current switching condition, the system equations must be solved numerically. The regulated large signal model can be predicted under varying supply voltage and load current operating conditions by using the averaging techniques. In other words, the variation of switching frequency, which is a controller parameter, can be determined while output voltage is still kept regulating.

In this paper, Section II will consider the formation the unified quasi-resonant buck converter from the frequency modulation zero-voltage switching quasi-resonant switch (FM ZVS QRSW). In section III, the power distribution, the power loss and the power efficiency of this model will be shown.

II. MODELING OF FM ZVS QRSW

In order to analyze the efficiency of the QR buck converter, the internal resistance of each component should be considered. After inserting the lossy components in the ideal model, a new near-practical model can be formed as shown in Fig. 1. The resistor R_{i3} is added to the current branch i_3 because the inductor current is originally replaced by i_3. This component R_{i3} can be used to represent the equivalent resistance of the inductor. V_{FSD} , V_{FSMa} and V_{FSMb} are the forward bias voltage of the switch S_D , S_{Ma} and S_{Mb} respectively.

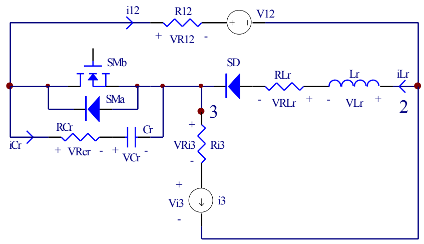

Fig. 1. Practical model of FM ZVS QR Buck Converter

III. ANALYSIS OF LARGE SIGNAL MODEL

The power distribution in the large signal model of a Buck Converter is predicted numerically by using an averaging technique. In order to simplify the analysis, all internal equivalent resistances and forward bias voltages are assumed to be 0.1Ω and 0.7V, respectively.

Fig. 2 shows the normalized power loss of each component. It is interesting to note that the loss in the inductor L_r, the diode S_D and the output equivalent resistance is very significant, especially, when the output current i_3 is large. On the other hand, the power loss in the R_{Cr} is the least significant.

The switching frequency fs, regulated load voltage vi3, supply current i12, input power Pv12 and output power Pi3 are shown in Fig. 3. The load voltage vi3 can be regulated at 30V because the switching frequency fs keeps changing under different operating conditions. The optimal switching frequency "fs" is found by numerical iteration. The function scalar minimization “fminbnd” in MATLAB is used.

The efficiency of this model is plotted in Fig. 4. Because the conduction power loss is considered only, it shows the maximum value of the efficiency that can be achieved under different operating points. They are the guidelines for the engineers to design an optimal converter.

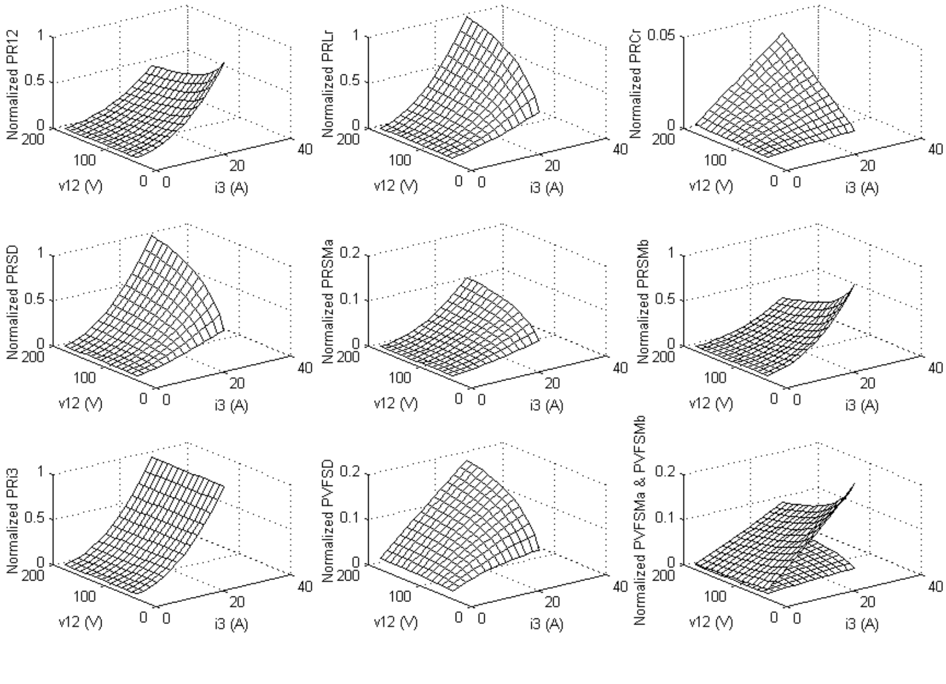

Fig. 2. Power loss of Each Component in FM ZVS QR Buck Converter.

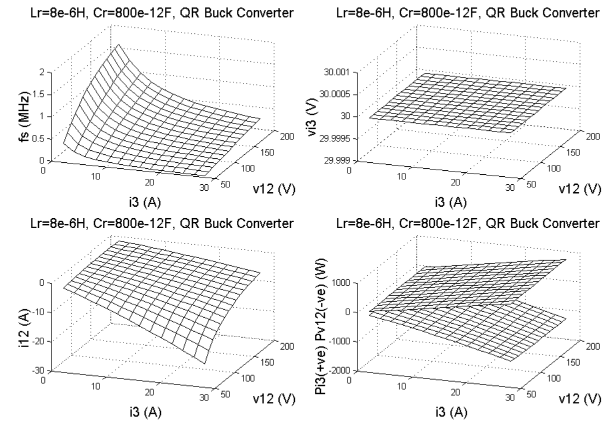

Fig. 3. (a) Switching Frequency fs, (b) Regulated Load Voltage vi3, (c) Supply Current i12, (d) Input Power Pv12 and Output Power Pi3.

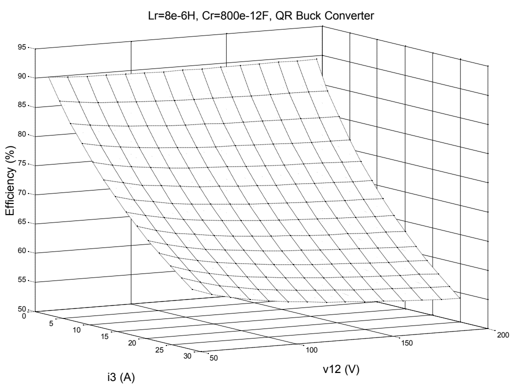

Fig. 4. Efficiency of Half-wave Type FM ZVS QR Buck Converter.

IV. CONCLUSION

The power dissipation and the efficiency of a QR Buck Converter can be estimated. It is known what the most critical components are in making the high efficiency converters. Most power is lost in the equivalent resistance of the current branch, the inductor and the main diode. Therefore, in order to improve the efficiency, the internal resistance of these components should be eliminated first. The power distribution can be analyzed in details. Finally, the power efficiency of the lossy models is considered. The efficiency will change when the operating point is varied but the output voltage keeps regulating. The maximum efficiency under varying operating conditions is known without doing cycle-by-cycle simulation. Although a Buck Converter is considered only in this paper, this analytical method can be applied in other converters.

V. REFERENCES

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