# Multiple Buck-Chopper using Partial Resonant Switching


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## ABSTRACT


This paper proposed that an AC-DC converter system using multiple buck-chopper operates with four choppers connecting to a number of parallel circuits. To improve these, a large number of soft switching topologies included a resonant circuit have been proposed. And, some simulative results on computer are included to confirm the validity of th e analytical results. The partial resonant circuit makes use of an inductor using step-down and a condenser of loss-less snubber. The result is that the switching loss is very low and the efficiency of system is high. And the snubber condenser used in a partial resonant circuit makes charging energy regenerated at input power source for resonant operation.

The proposed conversion system is deemed the most suitable for high power applications where the power switching devices are used.


## 1. INTRODUCTION

Generally, an input type commutative circuit is often used for a commutative circuit in a power conversion device in order to convert AC to DC. Input current in the circuit is flowing at a pick point of input voltage with a type of pulse, making lower input power factor and affecting a power system badly because it has lots of harmonic elements. [1-4]

In order to solve these problems, "Multiple buck-chopper using partial resonant switching" is proposed in this paper. The came out converter operates with current discontinuous mode by static duty factor control. Thus, it operates with a high power converter and increases factor of the converter by making soft switching for turn-on and turn-off operating of switching. [5-8]

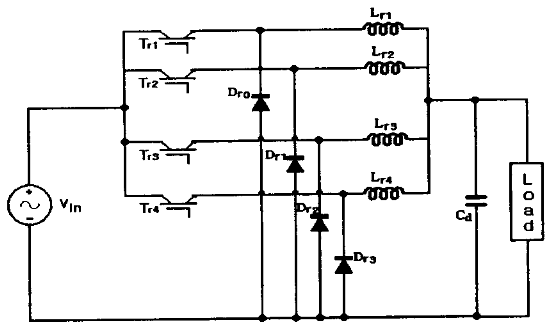
This paper is described basic feature of the proposed circuit; the partial-resonant AC-DC converter circuit for high power that is connected to several parallel types of four choppers, by analysis and simulation.

## 2. STRUCTURE OF THE CIRCUIT

According to the

+composition of the proposed partial resonant circuit the resonant inductor can be changed to an energy charge inductor that is used commonly in a step-down converter, and instead of the resonant condenser, a snubber condenser can be used which is in a snubber circuit of a switching mode power converter. Thus, this paper proposes topology of the circuit composition, which has those merits Figure 1 indicates a common hard switching circuit.

Figure 2 shows the main circuit of the AC-DC converter system using multiple buck-chopper. The structure of the circuit consists of a connected partial resonant circuit part between input and a load, which does switching and step-




down.

Fig.1 AC-DC Converter of Hard switching mode

The partial resonant circuit part consists of control elements, inductors for resonance, and a loss less snubber condenser. Energy that is charged in the condensers has a regenerated mode to a power device when switches are turned on. Turning on of the switches that are $S_1$ and $S_2$ makes zero current switching because current of the inductor is controlled discontinuously. On the other hand, turning off of the switches makes zero voltage switching because it operates when voltage of the condenser is zero. The inductor ($L_F$) and the condenser ($C_F$) at an input part are a low pass filter in order to eliminate harmonics of the input current.

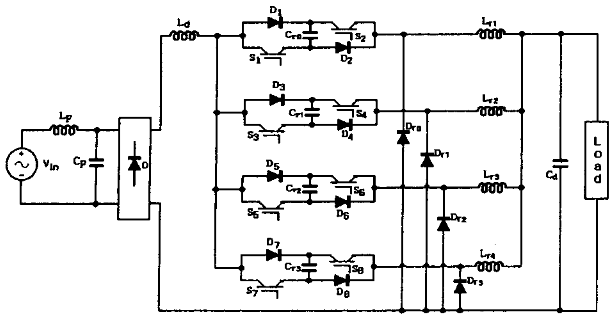


Fig.2 AC-DC converter system using multiple buck-chopper mode

## 3. OPERATION PRINCIPLE

When input inductance is compared with inductance at an output load part, if it is assumed that the input inductance is large enough, the load can be a constant current source, Io, during a period of resonance. Initial conditions for this part of partial resonant circuit are that 1) switches, $S_1$ and $S_2$, are off, 2) a capacitor $C_{r0}$ for resonance is charged by voltage $V_{cr0}$ of a smoothing condenser $C_d$ at the output part. Besides, the alternative input voltage $V_{in}$ and output voltage $V_0$ of a diode bridge full-wave rectifiers are showed blew equations.

$$V_{in} = V_m \sin\omega_s t \quad (1)$$

$$V_0 = |V_{in}| = |V_m \sin\omega_s t| \quad (2)$$

## 4. RESULTS OF SIMULATION AND INVESTIGATION

Parameters for PSpice simulation are regarded as that a control switch is a variable resistor, and other elements are ideal..

Table 1 Parameters of simulated circuit

| | |
|---|---|
| Source Voltage | Vin = 141.4 [V]<br>f = 60[Hz] |
| Switching | $f_s$ = 20[kHz]<br>D.F = 40[%] |
| Inductor | $L_{r1.2.3.4}$ = 40uH |
| Smoothing Capacitor | $C_d$ = 1000[uF] |
| Filter Inductor | $L_F$ = 80[uH] |
| Filter Capacitor | $C_F$ = 100[uF] |
| Snubber Capacitor | $C_{r\ 1.2.3.4}$ = 100[nF] |
| Load | Variable resistance |

Figure 3 indicates simulation waveform of each parts over a period of switching in order to examine the partial resonant AC-DC converter and subordinate operation of the converter's soft switching by 20[kH$_z$] for switching frequency and 40[%] for duty factor From the simulation waveform at the figure 3, the partial resonant circuit is not continuous over a resonance period. Also, partial resonant operation is show when the switch is turned on and off. By the operation, shared capacity and stress of resonant elements are reduced and loss of the resonance is decreased when output current is increased. In addition, the figure 3 shows intervals of each mode. When the switches $S_1$ and $S_2$ are turned on, a condenser $C_{r0}$ in a part of serial resonant circuit starts to discharge and an inductor $L_{r1}$ starts to charge energy at $t_0$.

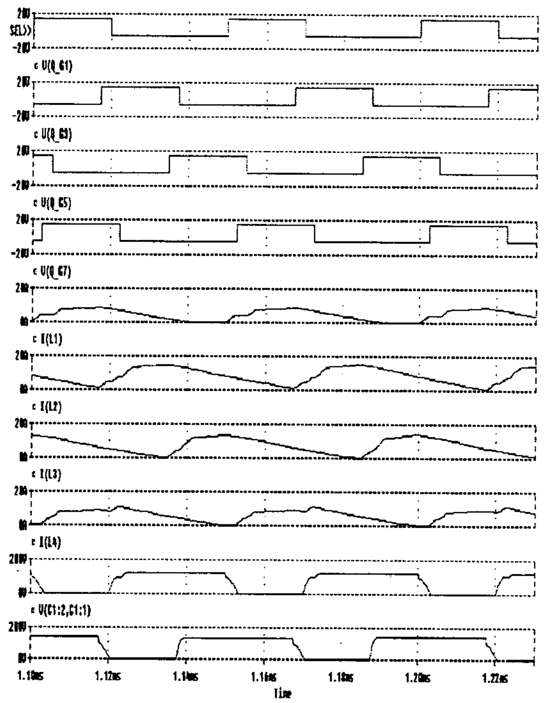


Fig.3 Simulation waveforms of each part in one cycle switching

At this point, current $i_s$ through the switches $S_1$ and $S_2$ is same as the inductor current $i_{Lr1}$ that makes the switches operate zero current switching. When the voltage of the condenser is zero at $t_1$, the control switches make short circuit, and the current of inductor $L_{r1}$, thus, increases linearly and charges energy.

Figure 4 and 5 show change of the output voltage and current in regard to resistance by the results of the simulations when duty factor is constant. The table1 bases other parameters, which are used in the simulations.

Figure 6, 7 show charge of efficiency and quantity of output according the duty factor. Compared with a common hard switching and a buck type converter, the proposed partial resonant soft switching converter has merits, those are the proposed converter can make the same output under lower duty factor in switching and the same electric energy.

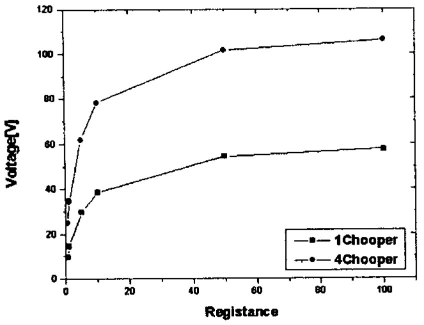



Fig.4 Relationship between output voltage and Resistance

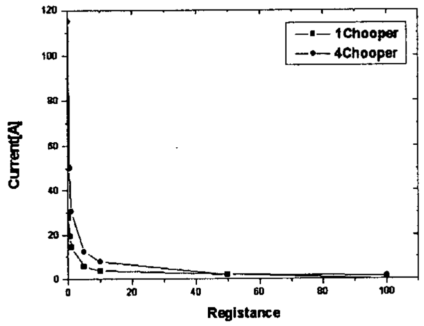



Fig.5 Relationship between output current and Resistance

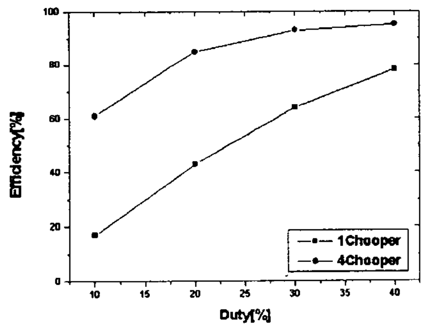



Fig.6 Relationship between efficiency and duty cycle

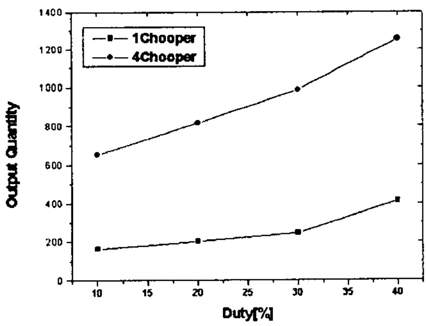



Fig.7 Relationship between output quantity and duty cycle

It is due to the charged energy in a loss less snubber condenser, which is used for partial resonance by turning on of a switch, re-operates toward the input part Waveform of input voltage and current of a common hard switching AC-DC step-down converter is shown at Figure 8.

$$I_{in} = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} K_{mn} e^{j(mx+ny)} \quad (3)$$

$$K_{mn} = \frac{1}{(2\pi)^2} \int_0^{2\pi} \int_0^{2\pi} i_{Lr}(x, y) \cdot e^{-j(mx+ny)} d_x d_y \quad (4)$$

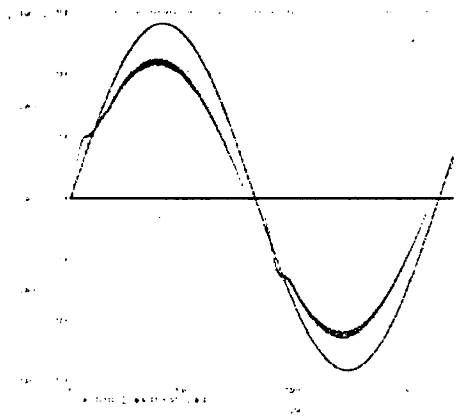


Fig.8 Simulation waveform with input voltage and current of conventional hard switching circuit

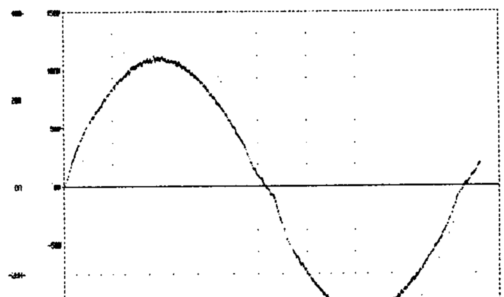


Fig.9 Simulation waveform with input voltage and current of proposed soft switching circuit

Figure 9 shows a simulation waveform about the input voltage and current by the parameters of the proposed partial resonant AC-DC converter for high power. Because the discharged current of the partial resonant snubber condenser re-operates toward the power device then bucks around zero of the input current, the waveform is much similar to sinusoid. Hence, this method features that distortion factor is improved by decreasing of low-level harmonics elements. By using the complex-double Fourier series for analyzing harmonics elements of the input current, the input current $I_{in}$ appears below equations. In the equations, the $i_{Lr}$ is the current of the inductor Lr, $x = \omega_c t$, $y = \omega_c t$, the $\omega_c$ is switching angular frequency, and the $\omega_s$ is angular frequency of an alternative input power source. Figure 10 and Figure 11 are frequency spectrum results for analyzing harmonics elements of input current about a common hard switching method and the proposed soft switching method.

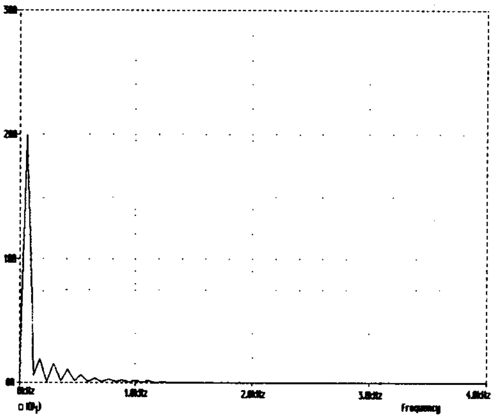


Fig.10 waveforms and frequency spectra of current of conventional hard switching circuit

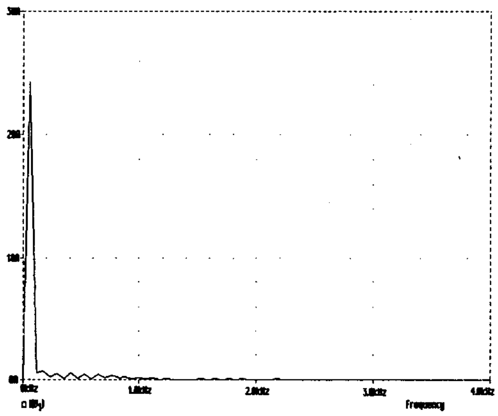


Fig.11 waveforms and frequency spectra of input current of proposed soft switching circuit

## 5. CONCLUSIONS

Commonly, a partial resonant converter circuit has lots of problems because of an increase in capacity share of a partial resonant element by repeated resonance, in pick voltage and current, and in circulating current of semiconductor device for power. It has a problem, which makes control mode of switching complicated as well.

This paper has proposed the AC-DC converter system using multiple buck-chopper, which makes partial improvement in those problems. The switches that are used by the partial resonant soft switching mode make a reduction in switching loss and the part of the resonant circuit takes a decrease in resonant loss and in the stress of resonant elements. Thus, the transducer operates with high power and efficiency. AC-DC converter system using multiple buck-chopper features that the distortion factor is more improved due to canceling out the third harmonics elements by the re-generation of the snubber condensers energy than a common AC-DC converter. Besides, the converters input power factor is as good as unit power factor because the input current becomes certain current on discontinuous sinusoidal pulse in proportion to the size of the sinusoidal input voltage by static duty factor control.

Efficiency and validity of this paper are supported by computer simulation and experiment. In the long run, the AC-DC converter will have higher power, power factor, and efficiency when the most adaptable filter and load current.

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