ECEN5817 Lecture 31
The resonant switch concept

A general idea:
1. PWM switch network is replaced by a resonant switch network
2. This leads to a quasi-resonant version of the original PWM converter

Example: realization of the switch cell in the buck converter
Averaged-switch model of the PWM switch cell

\[ i_2(t) \approx \langle i_2 \rangle \approx I_2 = DC \]

= on-state switch current

(small-ripple, ccm
filt. inductor current)

\[ \mu = d \]

\[ v_2 \]

\[ = d v_1 \]

\[ I_2 \]

\[ dT_s \]

\[ T_s \]

\[ \langle v_1 \rangle \approx V_1 = DC \]

= off-state switch voltage.

small-ripple capacitor voltage
or input voltage.
20.1 The zero-current-switching quasi-resonant switch cell

Tank inductor $L_r$ in series with transistor: transistor switches at zero crossings of inductor current waveform

Tank capacitor $C_r$ in parallel with diode $D_2$: diode switches at zero crossings of capacitor voltage waveform

Two-quadrant switch is required:

**Half-wave:** $Q_1$ and $D_1$ in series, transistor turns off at first zero crossing of current waveform

**Full-wave:** $Q_1$ and $D_1$ in parallel, transistor turns off at second zero crossing of current waveform

Performances of half-wave and full-wave cells differ significantly
Two quasi-resonant switch cells

Insert either of the above switch cells into the buck converter, to obtain a ZCS quasi-resonant version of the buck converter. $L_r$ and $C_r$ are small in value, and their resonant frequency $f_0$ is greater than the switching frequency $f_s$.

$$f_0 = \frac{1}{2\pi \sqrt{L_r C_r}} = \frac{\omega_0}{2\pi}$$
The switch conversion ratio $\mu$

A generalization of the duty cycle $d(t)$

The switch conversion ratio $\mu$ is the ratio of the average terminal voltages of the switch network. It can be applied to non-PWM switch networks. For the CCM PWM case, $\mu = d$.

If $V/V_g = M(d)$ for a PWM CCM converter, then $V/V_g = M(\mu)$ for the same converter with a switch network having conversion ratio $\mu$.

Generalized switch averaging, and $\mu$, are defined and discussed in Section 10.3.

In steady state:

$$i_2(t) \approx \langle i_2(t) \rangle_{T_s}$$

$$v_1(t) \approx \langle v_1(t) \rangle_{T_s}$$

$$\mu = \frac{\langle v_2(t) \rangle_{T_s}}{\langle v_{1r}(t) \rangle_{T_s}} = \frac{\langle i_1(t) \rangle_{T_s}}{\langle i_{2r}(t) \rangle_{T_s}}$$

Analyzers: find $\mu$
20.1.1 Waveforms of the half-wave ZCS quasi-resonant switch cell

The half-wave ZCS quasi-resonant switch cell, driven by the terminal quantities $\langle v_1(t) \rangle_{Ts}$ and $\langle i_2(t) \rangle_{Ts}$

![Switch network diagram]

Waveforms:
- $v_1(t)$ and $i_2(t)$
- $L_r$ and $C_r$
- $D_1$ and $D_2$
- $Q_1$ and $Q_2$

Conducting devices:
- $Q_1$ and $D_1$
- $Q_2$ and $D_2$

Subinterval:
1 - $Q_1$ turn on
2 - Resonance
3 - $Q_2$ turn off
4 - $Q_1$ turn on

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