Derivation of Boost-Buck Converter Based High-Efficiency PV Inverter

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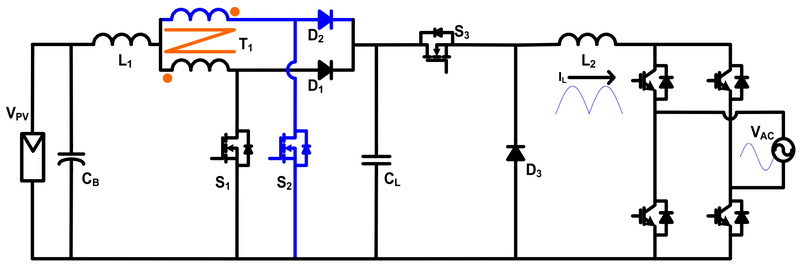
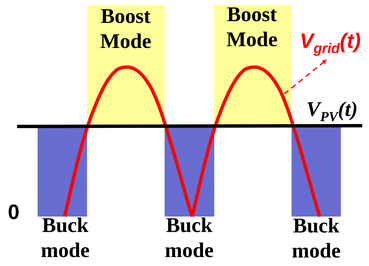
PROPOSED PV INVERTER



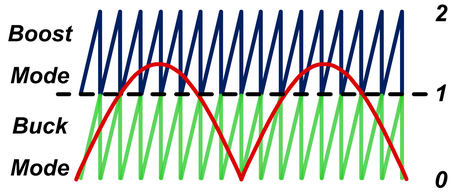
Boost-Buck Converter Based High-Efficiency Robust PV Inverter

OPERATION MODES



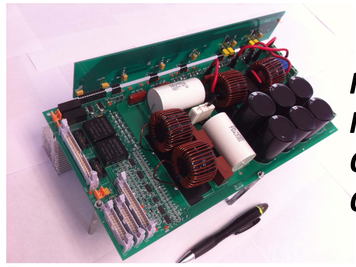
- Each mode operates separately based on instantaneous grid voltage.
- A universal control could be realized for both modes.

PWM MODULATOR



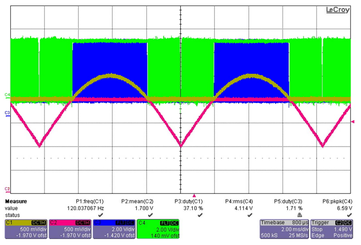
- An offset of the sawtooth ramp right on the top of the buck mode PWM modulator

EXPERIMENTAL RESULTS

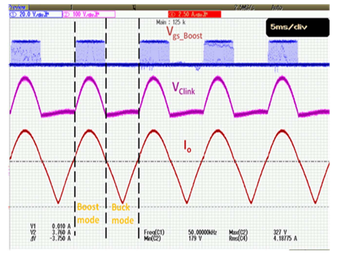


Rated power: 2.5 kW
Input voltage: 200 – 500 V
Output voltage: 208/240 V_{rms}
Output frequency: 60 Hz

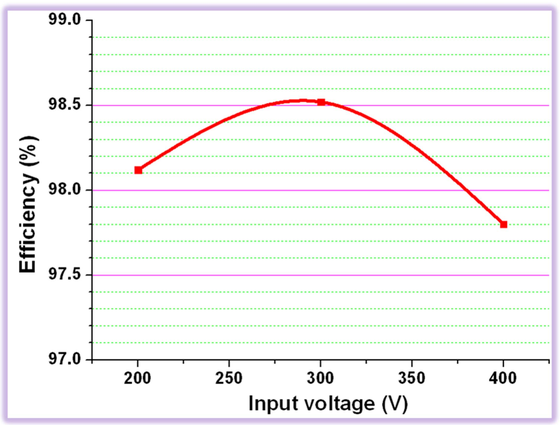
Photograph of Prototype



Experiment Results of PWM Signals

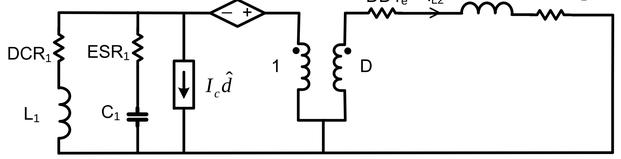


Experiment Results



Efficiency of the Boost-Buck Stage

MODELING of BUCK MODE



$$Z_{LC}(I_2\hat{d}+D\hat{i}_2)=\frac{V_{in}}{D}\hat{d}-Z_{Le}\cdot D\hat{i}_2$$

$$Z_{LC}=(sL_1+DCR_1)\left\|(\frac{1}{sC_1}+ESR_1)\right.$$

$$Z_{Le}=s\frac{L_2}{D^2}+\frac{DCR_2}{D^2}+\frac{D'}{D}r_e$$

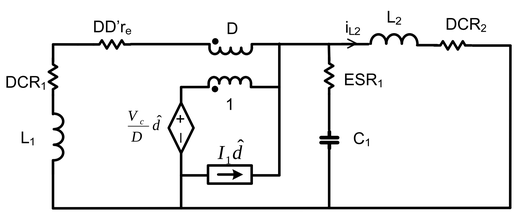
$$=s\frac{L_2}{D^2}+\frac{DCR_2}{D^2}+\frac{D'}{D}(DCR_1\|ESR_1)$$

$$r_e=DCR_1\|ESR_1$$

Buck Mode Transfer Function

Double-pole position	Double-zero position	Q
$s=\pm\sqrt{\frac{L_2+L_1\cdot D^2}{C_1L_1L_2}}j$	$s=\frac{\left[I_2D\cdot L_1/V_{in}-C_1\cdot(ESR_1+DCR_1)\right]\pm\sqrt{4C_1L_1}\,j}{2C_1L_1}$	$Q\approx\frac{\sqrt{\frac{L_1(2L_2+L_1\cdot D^2)}{C_1L_2}}}{ESR_1+DCR_1}$

MODELING of BOOST MODE



$$\begin{cases}\hat{i}_{L1}\cdot D+I_1\hat{d}=\hat{i}_{L1}+\hat{i}_{L2C}\\ D(\frac{V_c}{D}\hat{d}-\hat{i}_{L2C}Z_{L2C})+\hat{i}_{L2C}Z_{L2C}=\hat{i}_{L1}Z_{L1e}\end{cases}$$

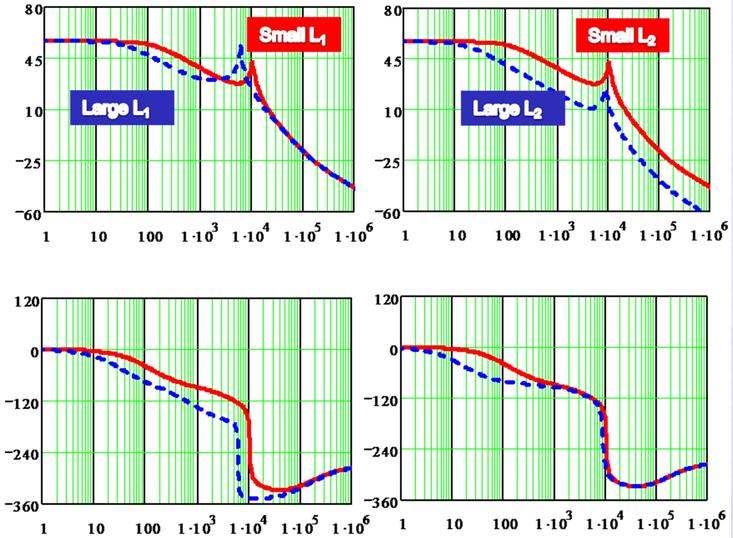
Where: $\hat{i}_{L2}=\hat{i}_{L2C}\frac{Z_C}{Z_{L2}+Z_C}$, $Z_{L2C}=\frac{Z_CZ_{L2}}{Z_{L2}+Z_C}$

$I_1=-I_{L1}$, $V_c=-V_o$ $r_e=DCR_2\|ESR_1$

Boost Mode Transfer Function

Double-pole position	Q
$s=\pm\sqrt{\frac{L_2D'^2+L_1}{C_1L_1L_2}}j$	$Q\approx\frac{\sqrt{\frac{(L_2\cdot D'^2+L_1)L_1}{D'^4C_1L_2}}}{ESR_1}$

INDUCTANCE'S IMPACT ON BOOST MODE



- Small L_1 leads to high frequency double-pole, high gain and small Q, which are all critical to controller design.
- Interleaved boost is proposed for smaller inductance of L_1 to achieve the same current ripple.

SUMMARY

- Efficiency peaks at 98.5%.
- High efficiency is achieved because of single-stage PWM operation.
- Ultra high control loop bandwidth with a multiphase interleaved boost stage, which allows a high resonant pole frequency.
- The proposed circuit along with its controller has been designed, simulated, and tested with a hardware prototype.