A High-Efficiency Soft-Switched DC/AC Inverter for SOFC Power Conditioning Systems

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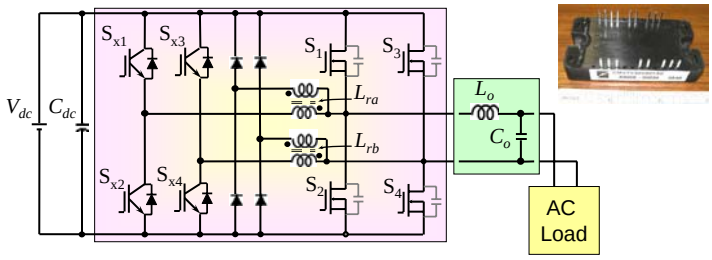
Requirements of SOFC Inverter

- High efficiency
- High power factor
- Controllable real and reactive power outputs by SOFC
- High reliability with protections from internal and external faults
- Switchable between standalone and grid connection modes
- Low fuel cell ripple current using V6 converter as the front end

Key Features of the Inverter Design

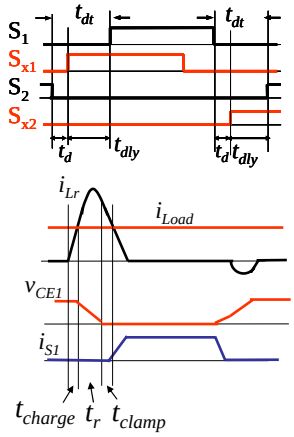
- Soft switching over a wide load range
- Custom module for parasitic reduction
- High efficiency (99% without filter, 98% with filter)
- Low electromagnetic interference (EMI)
- Closed-loop control for tight voltage regulation
- Phase-locked-loop control for utility grid synchronization
- Low-cost sensors and conditioning circuit
- Adaptive to different systems with DSP control

Inverter Circuit Diagram



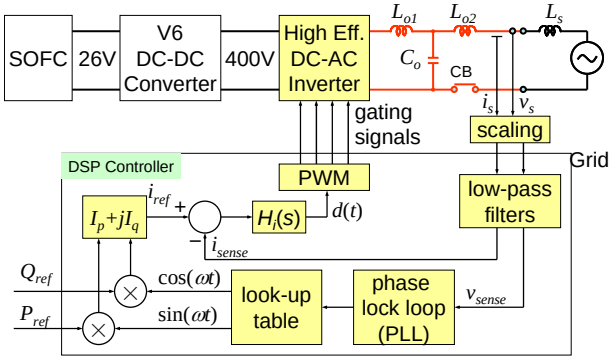
- CoolMOS as the main switch to avoid turn-off tail current and to reduce conduction loss
- Small IGBT as the auxiliary switch
- Small coupled resonant inductor charge/discharge device output capacitor energy to achieve zero-voltage switching
- Variable turns ratio to allow soft switching over a wide load range

Basic Operating Principle



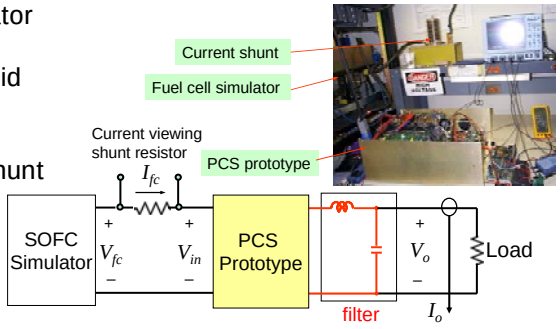
- Auxiliary switch turns on before turning on main switch to build up the resonant current
- Once resonant current exceeds load current, snubber capacitors are charged/ discharged to obtain zero voltage condition
- Main device turns on at zero voltage
- Main device turns off with lossless snubber capacitor
- Auxiliary device turns on and off at zero current

Block Diagram of SOFC Power Conditioning System

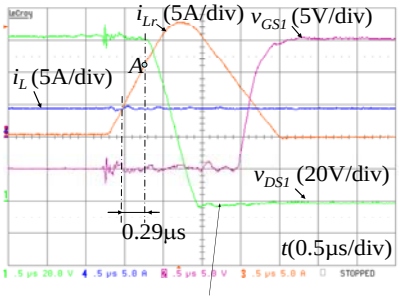


Experimental Setup

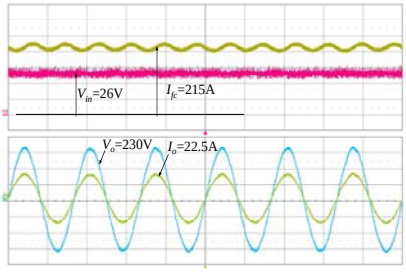
- Use fuel cell simulator as the source
- Resistive load or grid connection at the output
- Precision current shunt for current measurement



Waveform Measurement Results

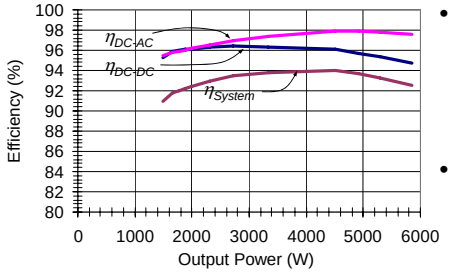


Device voltage V_{DS1} drops to zero before V_{GS1} turns on



- Output voltage is pure sinusoidal with virtually zero distortion
- Input ripple is about 4%

Efficiency Measurement Results



- Inverter including filter efficiency peaks at 98% between 4 and 5kW and maintains above 95% from 1.5kW and higher
- DC-DC converter efficiency peaks at 96.5% between 2 and 3kW and maintains 95% from 1.5kW and higher
- System efficiency peaks 94% between 3 and 5kW