SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Power Electronics Program Kickoff

# Compact and Low-cost Microinverter for Residential Systems

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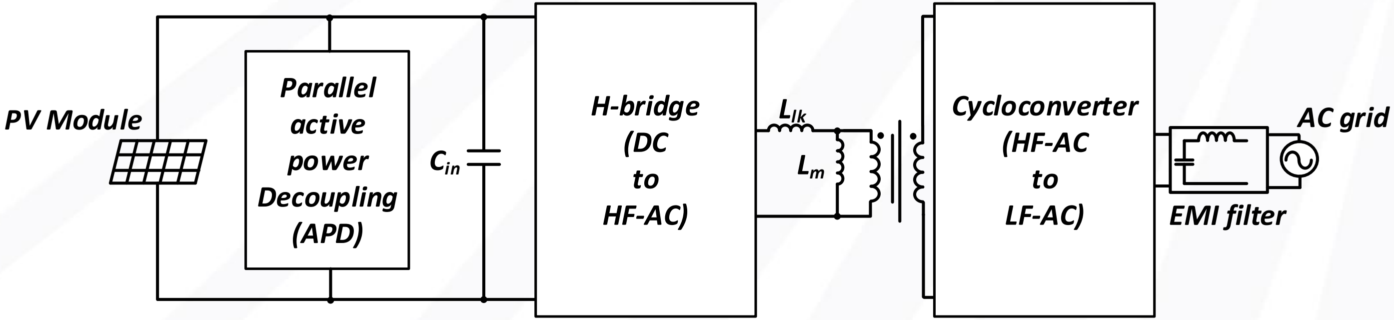
# Project Goals

- Holistic design for manufacturing approach for residential microinverters
  1. Reduce microinverter BOM cost ($\leq \$0.07/\mathrm{W}$)
  2. Enhanced efficiency ($\eta_{CEC} \geq 97\%$)
  3. High power density ($\geq 0.61\mathrm{W/cm^3}$)
  4. High specific power ($\geq 200\mathrm{W/kg}$)
  5. High reliability (250,000 hours MTTF)

# Proposed Technology

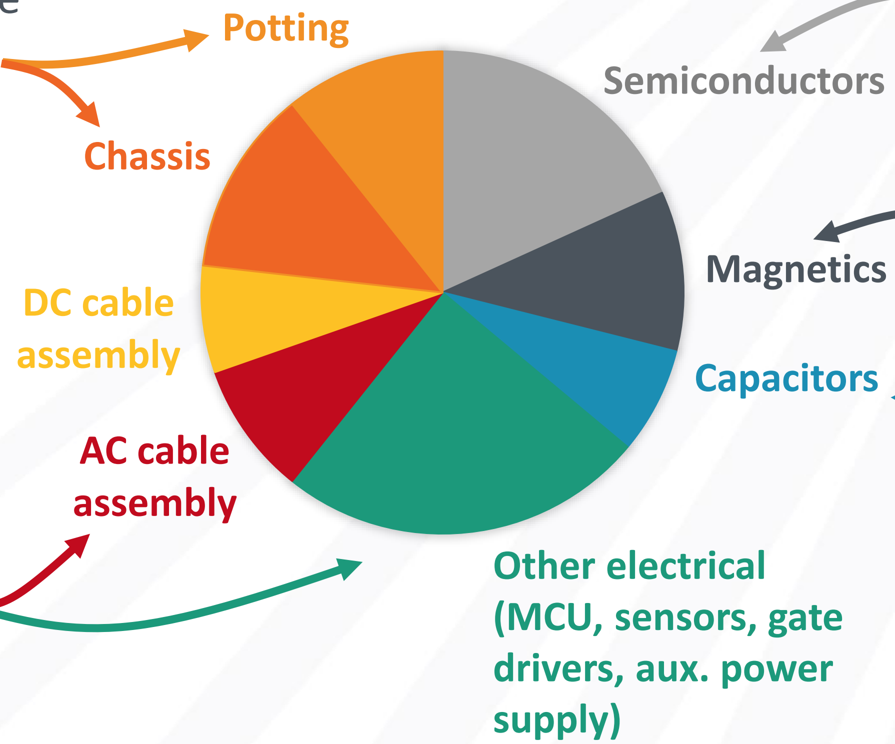
- Proposed solution (≤ $0.07/W)
  - WBG and Si CoolMOS semiconductors
  - No electrolytic capacitors
  - Fully integrated and planar magnetics
  - Active filter for 120Hz power decoupling
  - Soft-switching of main circuit and APD stage



# Cost Breakdown and Major Cost Reductions

Microinverter volume reduction and low profile design

Unique design for manufacturability

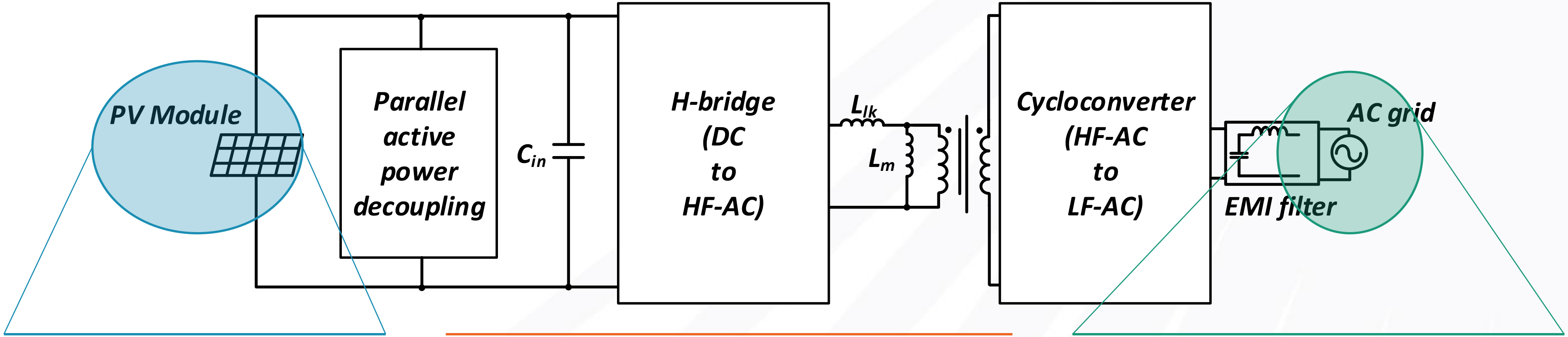



Projected WBG semiconductor cost reductions

Low magnetic component count

High switching frequency and active filter to reduce required capacitance

# Converter Specifications




**Input PV specs.**

| | |
|---|---|
| $V_{mpp}$ [V] | 25-60 |
| $P_{mpp}$ [W] | 400 |
| $\eta_{mpp}$ [%] | 99 |

**Converter specs.**

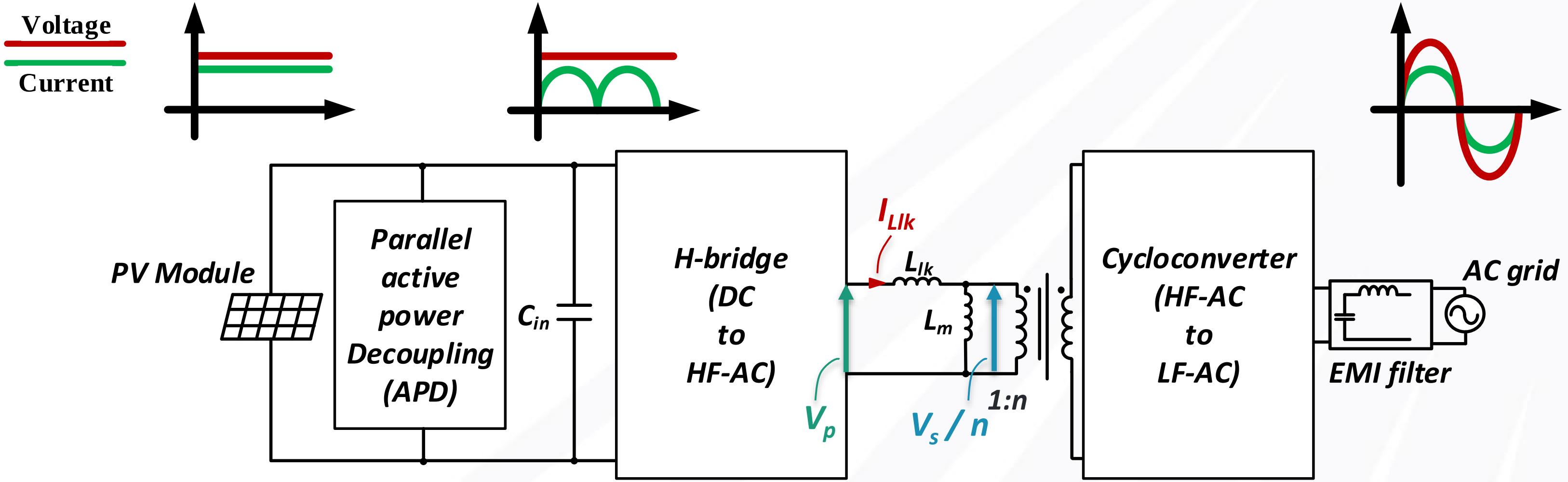
| | |
|---|---|
| $f_{sw}$ [kHz] | ~300 |
| ZVS | $S_1$-$S_8$ |
| $\eta_{max}$ [%] | ≥ 97 |
| $\eta_{CEC}$ [%] | 96.9 |

**Output specs.**

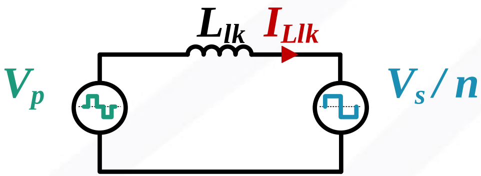
| | |
|---|---|
| $V_{ac}$ [$V_{rms}$] | 240 |
| IEEE1547 | THD < 4% |
| CA Rule 21 P1 & UL1741 | Smart grid features |

**Smart grid features:** Voltage/frequency ride through, fixed and dynamic power factor, soft-start reconnection, ramp-rate controls, anti-islanding

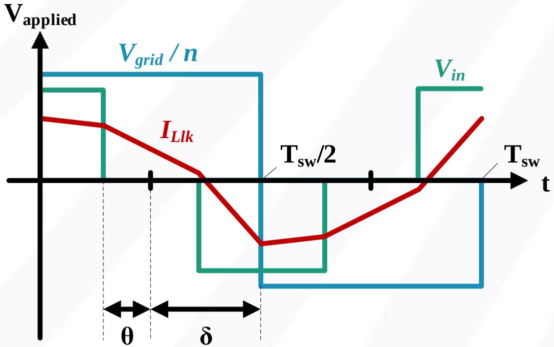
# Principle of Operation



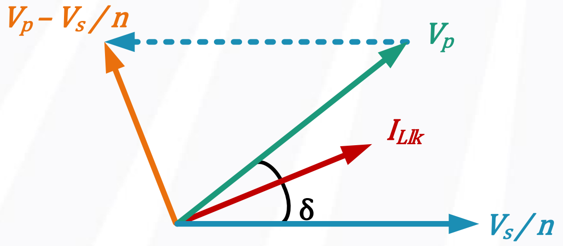

## Equivalent circuit



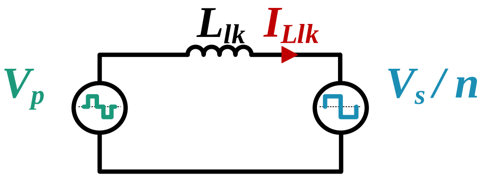

## Transformer waveforms

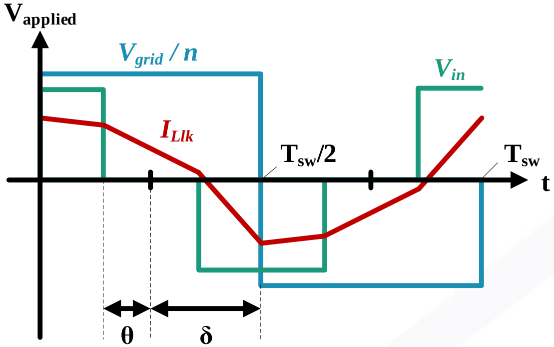


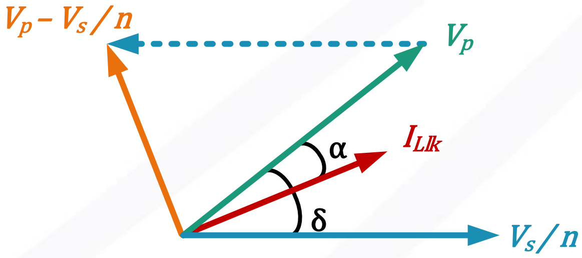

## Phasor equivalent diagram



# Control




- **Fundamental voltage amplitudes (FHA)**

$$< V_p >_1 = \frac{4V_{in}}{\pi} \cos(\theta)$$

$$< V_s >_1 = \frac{4V_{grid,pk}}{n\pi} \sin(\omega_{line} t)$$

- **Power transfer**

$$P = V_p i_L \cos(\alpha) = A\cos(\theta) \sin(\delta) \sin(\omega_{line} t)\,, where\ A = \frac{4V_{in}V_{grid,pk}}{n\pi^3 f_{sw} L_{lk}}$$

- **Active power control (PFC)**

$$P = A\cos(\theta) \sin(\delta) \sin(\omega_{line} t) = V_{grid,pk} I_{o,pk} \sin^2(\omega_{line} t)$$

$$\rightarrow \cos(\theta) \sin(\delta) = B\sin(\omega_{line} t), where\ B = \frac{V_{g,pk} I_{o,pk}}{A}$$

- **Conclusions**
  - **$\theta$ controls current shaping (varies over line cycle)**
  - **$\delta$ controls average power delivery (constant over line cycle)**

# Main Tasks – Budget Period 1

1. **Hardware Benchmark Prototyping and Proof of Concept**
    1. Circuit analysis, loss calculation, modeling and simulation, component selection
    2. Auxiliary power supply design and generate schematic
    3. Component placement, thermal simulation, reliability analysis, layout design
    4. Build prototype, electrical testing and verification plan, design performance analysis

*Go/No-Go #1: BOM cost, reliability analysis, and electrical performance are on track to meet proposed specifications*

# Main Tasks – Budget Period 2

## 2. Mechanical Design and Packaging

5. Thermal interface and potting material analysis, enclosure design and prototyping
6. Enclosure thermal and electrical testing

*Go/No-Go #2: Enclosure cost, thermal, and electrical performance meet proposed specifications*

# Main Tasks – Budget Period 3

## 3. Compliance and Testing

7. Project metric evaluation, environmental testing, safety regulation, and EMI demonstrations
8. Field trials and data collection

*Go/No-Go #3: Microinverter LCOE, safety, EMI performance, grid compliance, and field trials meet proposed specifications*

# Questions?