Advances in Micro-inverter Technology

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Outline

• Introduction
  – Three-phase vs. Single-phase Micro-inverter
• Micro-inverter Control Based Soft Switching Technique
• Micro-inverter Efficiency Improvement
• Conclusion
Solar Farm Based on Three-phase Micro-inverters:

• **What is Micro-inverter?**
  – It converts and controls the DC power from each PV module into grid-compliant AC power.

• **Three-phase vs. Single-phase:**
  – Minimized Power Decoupling Capacitance
  – Eliminated the need of an expensive custom AC cable
  – Improved Reliability
  – Reduced Cost ($/W)

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Courtesy of Petra Systems
PV Power Plant:

Micro Inverter based:
- MPPT for each PV panel
- Ease of installation and maintenance (plug and play)
- No DC cabling
- Flexibility in system expansion
- Possible cost reduction due to mass production
- High cost of inverter
- Low efficiency (power conversion)
- Harsh operation conditions
- Long life time required (>25 Year)

Centralized Inverter based:
- Low cost of inverter
- High efficiency (power conversion)
- MPPT for the PV array, not for each panel (low efficiency in power harvest)
- Complex DC wiring
- Power harvest affected a lot when inverters fail
- Laborious installation
Development Targets for Three-phase Micro-inverter:

- High efficiency comparable to those of centralized inverter (>96%)
- Low cost (0.3$/W)
- High reliability (25 Year Warranty)
- Low profile to be fit into PV panel (Power Density > 12W/in3)
Three-phase Micro-inverter Prototype:

- **Overview:**
  - 400W Nominal Output Power
  - 50 VDC Nominal Input Voltage
  - 208 VAC Three-phase Output Voltage
  - 60Hz Output Frequency
  - Two Stage Topology
System Architecture:

- Two Stage Topology:
  - LLC Resonant DC/DC Converter
  - Three-phase Half Bridge DC/AC Stage
Control Based Soft Switching Technique:

- Transition from switch S2 to S1

- Hybrid Control is a combination of predictive control and hardware reset

![Figure. Hybrid BCM Current Control](image1)

![Figure. DSP Implementation of Hybrid BCM Current Control](image2)

![Figure. Current and Voltage Waveforms for ZVS BCM Current Control](image3)
Cost Reduction (0.28$/W):

- Inductors:
  - (3~14mH→270uH)
  - (0.013J→0.0019J)

- MOSFETs
Micro-inverter Efficiency Improvement:

• Break-down power loss analysis of different current modulation schemes
• Proposed dual-mode ZVS ZCS current modulation scheme
Light Load Efficiency Enhancement:

• Phase Skipping Control:

![Diagram showing normal operation and phase skipping control for converter efficiency]

- **Normal Operation**
- **Phase Skipping Control**

![Graph showing converter efficiency versus output power]

- **Phase Skipping Control**
- **Original Hybrid BCM Current Control**

Figure. Converter Efficiency versus Output Power

![Diagram showing solar farm architecture based on three phase micro-inverters]

- Three Micro-inverters are Operating in Phase Skipping Mode

Figure. Solar Farm Architecture based on Three Phase Micro-inverter, Three Micro-inverters are Operating in Phase Skipping Mode
Conclusion:

• A soft switching three-phase micro-inverter has been proposed. It has the advantage of high efficiency, high power density and low cost.
• To further improve the efficiency of the micro inverter a new current modulation scheme combining the ZVS and ZCS operations was proposed.
• A phase skipping method has been proposed to maintain high power conversion efficiency across the entire load range of the three-phase micro-inverter.
• System total CEC efficiency of 96% was achieved.
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