ARPA-E Power Technologies Workshop

<u>Breakout Group</u>:

Compact Power Conversion

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For power converter technology (DC/DC), what are the drivers for integration?

The key driver for integration is the scaling down of converter volume for point of load applications:

a) Point of Load Applications: will revolutionize efficiency by offering local power conversion that is not centralized.
b) High performance and fast power conversion
c) Downward pressures to cost as technology matures

For power converter technology (DC/DC), what are the barriers for integration?

a) To make small, high power density (>100 W/in3) converters, a high efficiency (> 90%), high frequency switch (> 30 MHz) switch is critical

(b) Passive component development: a fast switch will shrink the size of passive components (inductors and capacitors) by approximately 1/frequency. Small volume = small size and higher level of integration.

(c) Magnetics vs Non-magnetics: magnetic materials are challenging to develop and integrate into semiconductor processes.

(d) Packaging Development: advanced power converters need compact, thermally efficient packaging to achieve the highest possible power density.

For power converter technology (DC/DC) what are the barriers for integration (con't)?

(e) Yield: Can we maintain yield as we scale up complexity and scale down volume of the converter

(f) Thermal management

- Thermal stresses on materials cause cracks, voids and eventually electrical or catostrophic failure.

(g) Design complexity

- Design for manufacturability

For power converter technology for photovoltaic inverters (DC/AC), what are the potential drivers [1a-d), module mismatch/MPPT, pluggability] for integration? What are the barriers to integration?

Driver: PV systems trends:

- >200 kW
- Microinverters: Integration with solar panels

Driver: Integration of PV systems draw parallels with SSL systems

Driver: Reliability

Driver: Higher frequency switching enables lower energy storage requirements

Barrier: Fault tolerance in all systems makes design challenging

Barrier: Scalability of magnetics. High temperature magnetics needed.

What are the optimal sites for integration of converters with PV modules? Module back, frame, etc.

The inverter component in the PV module is currently very large, inefficient and unreliable. We should seek to advance inverter design in order to develop a compact, state-of-the-art inverter module that is fully contained within the larger PV system. There was no general consensus as to exactly where the inverter should be placed within the PV module. More research is needed to identify this site.

Which component technologies (solid-state switches, magnetics, electrostatics, thermal management/packaging technology) need to be developed for integrated power conversion:

a) 48V DC to 220 V AC (single panel systems)

Motivation for >>10s of MHz

~100 W levels

Packaging limitations on HF switches

b) 600 V DC to 220 V AC

(conventional systems)

>>20 kHz

Additional comments: In general, the high frequency switches are the most important building block for integrated power converters. Once switch efficiency and performance is determined, a trade study would be conducted to determine which other components would be needed. It's very likely that magnetic or air core inductor development would be needed. This is particularly challenging in case (b) where higher voltage (and possibly power levels) are being addressed.

For power converter technology for SSL drivers (AC/DC), what are the potential drivers [1a-d, form-factor] for integration? What are the barriers to integration?

There is a significant technological barrier to integrating SSL drivers with the actual lighting component (LED). Such barriers include circuit performance, form factor and packaging.

The potential drivers for integration are being generated by the application space. Solid State Lighting (SSL) is a particularly convenient, low power, very reliable source of lighting for a variety of industrial and residential applications. These applications demand an easily deployable, robust lighting option, often in locations that are not conveniently accessible.

Which component technologies (solid-state switches, magnetics, electrostatics, thermal management/packaging technology) need to be developed for integrated power conversion:

- Dimmable 10 W drivers
- No discussion was conducted on this question. Based on my personal experience, some subset of these components would be needed, but it’s very difficult to comment on this without knowing the specifics of the driver circuitry for both the 10 W and 50 W case.

- Dimmable 50 W drivers

What is the appropriate target for SSL driver integration?

- Controller + power electronics: This is a feasible target, provided additional research is performed in circuit design and packaging.
- Power electronics + magnetics: This is perhaps the most challenging target, as the integration of magnetic materials into existing circuits is a major issue. Recommend we try to avoid this.
- Power electronics + electrostatics: Another feasible approach, and one that may be viewed in parallel with the first target, above. Perform a study to evaluate the trade-off in complexity, reliability and performance between these two approaches
  - DC-DC architectures offer reduction in capacitor requirements

Additional notes

- Possibility of converting AC to intermediate DC bus
- Architectures
  - Retrofit 60 Hz systems
  - Intermediate DC bus approach
- Sizing of luminaires
  - Thermal management determines sizing
  - LEDs and electronics have to be cooled
  - Active and passive cooling solutions
- Most products designed as point sources. More distributed light sources could offer advantages to thermal management
- System Efficiency
  - Tradeoff between efficiency of light source and electronics
- Control electronics need to sustain similar stresses as power electronics. More efforts