Power Technologies Workshop

Hosted by the Advanced Research Projects Agency – Energy (ARPA-E)
When: February 9, 2010
Where: Booz Allen Hamilton (3811 N. Fairfax Dr., Suite 600, Arlington, Virginia)

Purpose of Workshop:

This workshop will allow DOE to gather input from leading technical experts and to collectively develop new directions in methods, components, and systems related to electrical energy conversion.. Specifically, the goal is to gain a deeper understanding of those areas and technologies that have the highest potential to meet DOE's goal of developing the technical foundations necessary to improve the utilization of energy in power technologies. Topical areas include:

- **Photovoltaic Technology -** Power electronics requirements for emerging photovoltaic systems. The discussion will include requirements for next-generation centralized inverters. The goal of the breakout is to generate component specifications that will facilitate large-scale deployment of photovoltaics.
- **Compact Power Conversion: From PV to Solid State Lighting -** Component requirements that support power conversion in a scalable, energy efficient technology platform. In particular the session will seek to generate specifications for components that enable low-cost, efficient, highly functional LED drivers and compact module-integrated power converters.
- **Grid Scale High Voltage Transmission** - The session will explore the drivers for HV (>7.2kV) to UHV (>800 kV) transmission and the component technology required for dynamic connection in HV & UHV systems.
- **Power Converters Architectures** - Circuit topologies for efficient DC/DC and DC/AC power conversion. Applications include but are not limited to small-form factor converters for photovoltaics (e.g. module integrated converters) and solid-state lighting (advanced LED ballast).
- **Switch Technology** - Materials and devices for efficient power conversion. Switch technologies that enable the above applications while retaining high efficiency and scalability for wide deployment. Switch materials considered include wide-bandgap semiconductors and novel Silicon based designs.
- **Magnetics Technology** - Soft-magnetic materials and processes to support the applications above. Soft-magnetics considered will include new alloys, thin-films, and nanoparticles for low-core losses at the relevant switching frequencies and form-factors for advanced power converters.

Meeting Structure

A presentation by Mr. Ward Bower, Solar Technologies Department, Sandia National Laboratory will highlight the morning session. Additionally, both the morning and afternoon sessions will include short-talks by researchers on emerging power technologies.

The primary focus of the workshop will be the break-out sessions on the aforementioned topical areas. The break-out sessions will discuss a variety of topics that address the key parameters required to define a targeted funding opportunity. Subsequent to each break-out session, the session chair will brief all attendees on the findings. In addition, Dr. Arun Majumdar, Director of

ARPA-E, and others from ARPA-E will be available for one-on-one meetings immediately after the workshop.

Meeting Output/Outcomes:

As a result of the workshop, ARPA-E expects to have an understanding from leading experts on the most promising opportunities for high impact program areas and optimal program structures (i.e. application and technology focus, performance/cost targets, program/project size) for ARPA-E to support the most promising R&D pathways to improve the utilization of energy in power technologies. The output of the workshop will inform ARPA-E as they consider potential program formation in this topic area. This workshop also provides a venue for attendees to share knowledge, begin developing relationships, and consider collaborative efforts to develop novel approaches to solve complex problems.

A workshop summary document will be prepared after the meeting which will include all materials presented at the meeting as well as a summary of key ARPA-E takeaways and findings from the workshop. This workshop summary document will be posted publicly on a DOE website after the meeting.

Agenda

7:15 AM - 8:00 AM	Registration & Continental Breakfast
8:00 AM – 8:30 AM	Welcome Dr. Arun Majumdar Director, ARPA-E **Room: Booz & Allen**
8:30 AM – 8:50 AM	Balance of System Technology for Photovoltaics – Mr. Ward Bower, Solar Technologies Department, Sandia National Laboratory **Room: Booz & Allen**
8:50 AM – 9:10 AM	Integrated Power Converters Fred Lee, Virginia Tech **Room: Booz & Allen**
9:10 AM – 9:20 AM	Workshop Technical Overview and Introduction of Breakout Sessions Dr. Rajeev Ram Research Laboratory of Electronics, MIT **Room: Booz & Allen**
9:20 AM – 9:35 AM	Break- **Foyer**
9:35 AM – 11:35 PM	Concurrent Breakout Sessions Photovoltaic Converters Mr. Ward Bower, Sandia National Laboratory **Room: Booz** Compact Power Conversion: From PV to Solid State Lighting Dr. Satish Prabhakaran, GE Global Research **Room: Allen** Grid Scale High Voltage Converters Dr. Mark Johnson, North Carolina State University **Room: Hamilton**
11:35 PM – 12:25 PM	Lunch – **Buffet in Foyer; Return to Booz & Allen**
12:25 PM – 1:10 PM	Reports Out from Breakout Sessions Chairs brief whole group (15 min each)/Discussion **Room: Booz & Allen**
1:10 PM – 2:10 PM	Presentations on Emerging Methods of Power Technologies Dr. David Perreault, MIT Dr. Mark Johnson, North Carolina State University Dr. Charles Sullivan, Dartmouth **Room: Booz & Allen**

2:10 PM – 2:25 PM	Coffee Break- **Foyer**
2:25 PM – 4:25 PM	Concurrent Breakout Sessions Power Converters Dr. David Perreault, MIT **Room: Booz** Switch Technology Dr. Mark Johnson, North Carolina State University **Room: Allen** Magnetics Technology Dr. Charles Sullivan, Dartmouth **Room: Hamilton**
4:25 PM – 4:40 PM	Coffee Break- **Foyer**
4:40 PM – 5:25 PM	Reports Out from Breakout Sessions Chairs brief whole group (15 min each)/Discussion **Room: Booz & Allen**
5:25 PM – 5:55 PM	Wrap-Up Rajeev Ram **Room: Booz & Allen**

Breakout Questions

Over-Arching Questions or Discussion Topics

1) What is the present state-of-art of these technologies and what is their performance and cost?

2) What are the technical challenges and barriers (circuit breakers, valves, switches, control)?

3) In each identified topical area, what are the critical technologies that are required? What are the unique/transformational approaches to overcome these barriers/challenges?

4) What are specific performance and cost metrics for solid-state technologies?
   a) Power converters at the module level, residential scale, and commercial scale
   b) Integrated power converters for at the module and sub-module level for PV
   c) Integrated power converters for SSL (dimmable & non-dimmable)
   d) Solid-states switches for grid-scale high and ultra-high voltage conversion

5) Which technologies need to be developed for the:
   a) Near-term
   b) Mid-term
   c) Long-term

6) What is the strategy to move from one to the next?

7) What are the challenges and barriers for the adoption of these technologies?

8) What level of investment would be required to develop and deploy these technologies? What is the return on investment?

Photovoltaic Technology
Session Chair: Ward Bower, Sandia National Lab

1) What are the critical performance metrics for power converters at the module-scale, residential-scale, and commercial-scale?
   a) Reliability (15, 20, 25 years, etc)
   b) Power and voltage levels
   c) Efficiency (90%, 95%, etc.)
   d) Pluggability (5 minute, 20 minute replacement?)
   e) Communication & Control (building integration, grid-tied, etc)
   f) Cost
   g) Distortion
   h) Operating temperature
   i) Surge protection

2) Which component technologies (solid-state switches, magnetics, electrostatics, thermal management) need to be developed for the:
   a) Near-term
   b) Mid-term
   c) Long-term

3) What are the optimal locations for inverter integration?
   a) Module integrated (module back, module frame, etc)
   b) Residential
   c) Small- and large-commercial

4) For small- and large-commercial PV, what are optimal approaches (siting, converter technology, etc) to MPPT?

5) Is there an opportunity for exploiting reactive power in the inverter? What time scale is desirable and feasible (ms)? At what power scale would have a direct impact?

6) Fire safety for PV systems is an emerging concern. What can be done within the PV installation & power converter to mitigate fire safety risks?

Compact Power Conversion: From PV to Solid State Lighting
Session Chair: Satish Prabhakaran, GE

1. For power converter technology (DC/DC), what are the drivers for integration?
   a) Packaging costs
   b) Footprint
   c) Efficiency
   d) Ease of use

2. For power converter technology (DC/DC) what are the barriers for integration?
   a) Performance
   b) Yield
   c) Thermal management
   d) Design complexity

3. 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?

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

5. 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
   b) 600 V DC to 220 V AC

6. 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?

7. Which component technologies (solid-state switches, magnetics, electrostatics, thermal management/packaging technology) need to be developed for integrated power conversion:
   a) Dimmable 10 W drivers
   b) Dimmable 50 W drivers

8. What is the appropriate target for SSL driver integration?
   a) Controller + power electronics

b) Power electronics + magnetics
c) Power electronics + electrostatics

Grid-Scale High Voltage Converters
Session Chair: Mark Johnson, ARPA-E

1. What are the drivers (performance, cost, cooling, installation, etc) for higher voltage solid-state valves?

2. What are the critical performance metrics for power converters at the HV and UHV scale?
   a) Reliability (years?)
   b) Power and blocking voltage for switches
   c) Power and blocking voltage for valve stack
   d) Efficiency (%, etc.)(on resistance)

3. What are the technical challenges for switched HVDC transmission and distribution?
   a) HV sub-transmission (33kV-115kV)
   b) HV transmission (115kV – 800kV)
   c) UHV transmission (800 kV and beyond)

4. Which technologies need to be developed for the:
   a) Near-term
   b) Mid-term
   c) Long-term

5. What are the challenges and barriers for the validation and adoption of these technologies?

6. What level of investment would be required to develop and deploy these technologies? What is the return on investment?

Power Converters
Session Chair: David Perreault, MIT

1) For integrated PV inverters (8V/40W & 48V/240 W), what are the critical performance metrics for components?
   a) Switches
   b) Electrolytic capacitors
   c) Magnetics
   d) Control electronics and power switches

2) Which component technologies (solid-state switches, magnetics, electrostatics, thermal management) need to be developed for the:
   a) Near-term
   b) Mid-term
   c) Long-term

3) For integrated SSL AC/DC (10W & 50W), what are the critical performance metrics?
   a) Switches
   b) Electrolytic capacitors
   c) Magnetics
   d) Control electronics and power switches

4) Which component technologies (solid-state switches, magnetics, electrostatics, thermal management) need to be developed for the:
   a) Near-term
   b) Mid-term
   c) Long-term

5) What is the application space for switched-capacitor (magnetics-free) converters? What are the technical barriers, performance trade-offs?

6) What is the performance impact of micro-inverters (40 - 240W/ 48V to 220VAC) and rectifiers (10-50W) of not using electrolytic capacitors? What are alternative circuit topologies (high freq effective ripple), alternative capacitors (thin film, fast ultracaps), and magnetics?

7) What level of investment would be required to develop and deploy these technologies? What is the return on investment?

8) What is the appropriate target for integration (at 10W (rectifier), 50W (rectifier/inv), 240W (inv))?
   a) Controller + power electronics
   b) Power electronics + magnetics
   c) Power electronics + electrostatics

<u>Switches</u>
Session Chair: Mark Johnson, ARPA-E

1) What are the critical performance metrics for switch <u>components</u> to support high switching frequency (>10 MHz) converters at 10 W (SSL), 50 W (SSL/PV), 250 W (PV), 3kW (PV), 300 kW (PV)?
   a) Blocking voltage
   b) Switching frequency
   c) On resistance
   d) Heat transfer
   e) Reliability
   f) Integration (lateral vs. vertical)
   g) Cost

2) What are the critical performance metrics for switch <u>materials</u> for high switching frequency (>10 MHz) converters at 10 W (SSL), 50 W (SSL/PV), 250 W (PV)?
   a) Mobility
   b) Bandgap
   c) Permittivity
   d) Material quality (defect)

3) What are the critical performance metrics for switch <u>materials</u> for high blocking voltage (1kV, 10kV, 100 kV)?
   a) Mobility
   b) Bandgap
   c) Permittivity
   d) Material quality (defect)

4) What level of investment would be required to develop and deploy these technologies? What is the return on investment?

5) For power converter technology (AC/DC & DC/AC), what are the drivers for integration?
   a) Packaging costs
   b) Footprint
   c) Efficiency
   d) Ease of use

6) For power converter technology (AC/DC & DC/AC), what are the barriers for integration?
   a) Performance
   b) Yield
   c) Thermal management
   d) Design complexity

Magnetics
Session Chair: Charles Sullivan, Dartmouth

1) What are the critical performance metrics for magnetic components for high switching frequency (>10 MHz) converters at 10 W, 50 W, 250 W, 3kW, 300 kW?
   a. Core loss (eddy & hysteresis), winding loss (skin, proximit, gap, end)
   b. Inductance
   c. Size
   d. Heat transfer
   e. Cost

2) What are the critical performance metrics for magnetic materials for high switching frequency (>10 MHz) converters at 10 W, 50 W, 250 W, 3kW, 300 kW?
   a. Conductivity
   b. Coercive field/Hysteresis
   c. Permeability
   d. Saturation flux density

3) What are the unique critical performance metrics for integrated magnetic components for high switching frequency (>10 MHz) converters at 10 W, 50 W, 250 W?

4) For power converter technology (AC/DC & DC/AC), what are the drivers for integration?
   a. Packaging costs
   b. Footprint
   c. Efficiency
   d. Ease of use

5) For power converter technology (AC/DC & DC/AC), what are the barriers for integration?
   a. Performance
   b. Yield
   c. Thermal management
   d. Design complexity