ARPA-E Power Technologies Workshop

Breakout Group:

Photovoltaic Technology

(Chair: Ward Bower,
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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)

- need a metric to measure reliability (MBTF, design life, testing, accelerated)
- 25 years needs to be a minimum for integrated micro-inverters, could be less for non-integrated – module life and inverter life should be the same. Calculated life should be about 2x expected life.
- would like to see approaches that have more reliability, perhaps systems or converters that have a reason to be more reliable, and longer lifeline
- FOR COMMERCIAAL – wide range of possibilities depending on modularity, total operating cost, reparability is possible? Commercial size may not be applicable for ARPA E.

b) Power and voltage levels

- micro: bounded by module size – if in 235 watt range. May be for today's market. There is a tradeoff with size and cost.
- what about DC-DC comments should still apply
-COMMERCIAL: how do you decide to cut things up and arrange modules, etc. Need to consider where it makes sense, and what you gain.
- series vs. parallel question for building integrated brings up system architecture considerations
- how does it impact the arc fault?

a) Efficiency (90%, 95%, etc.)

b) Pluggability (5 minute, 20 minute replacement?)

What are the critical performance metrics for power converters at the module-scale, residential-scale, and commercial-scale? (slide 1)

- how does it impact the arc fault?

- Efficiency (90%, 95%, etc.)

  - 98%

  - state of the art on CEC efficiency is 95%

  - 96% is peak for microinverters

  - as panels get cheaper, you may care less about efficiency

  - COMMERCIAL – soa is 97% or 97.5% these are transformerless inverters that are big in Europe – evergreen solar

  - is efficiency gain a priority here? Cost may be higher priority

- Commercial DC bus – system issue that needs to be addressed. Looking at total efficiency. What goals? Problems of adding insertion lost under unshaded conditions. Need a system solution for best case for harvesting the most energy.

- Pluggability (5 minute, 20 minute replacement?)

What are the critical performance metrics for power converters at the module-scale, residential-scale, and commercial-scale? (slide 2)

Pluggability (5 minute, 20 minute replacement?)

- times are after the service guy gets there.
- just getting module off rack takes longest time. A challenges are more logistics on getting guy on roof to address
- can it give a warning sign, or shut down gracefully, add intelligence to the inverters
- what about sometihing where you don't have to pull the module off – an integrated approach. Frame-mounted vs. j box. – Need a more holistic system design. Balance of system is becoming a larger fraction of cost.

Commercial – assume that this is less of an issue here. Depends on system. A really high power system with single point of failure is a problem. Lifetime limitation warning could be valuable here as well. Prognostics in general.

What are the critical performance metrics for power converters at the module-scale, residential-scale, and commercial-scale? (slide 3)

- Communication & Control (building integration, grid-tied, etc)
- A lot being done. Be careful of information overload, and standardization with other communication standards used for small scale generation would be good. Should expect that PV system work with what is out there.
- A compelling story on integration with building standards would potentially be interesting
- Teams? Those building inverters are not communications experts. Need PV manufacturers, etc. Should encourage team building in FOA if possible. Better to achieve during design
- Cost
  – Need to also include lifetime cost of energy. If you have to replace inverter 3x – you need total cost of ownership.
  – Selling for right around $1/watt plus or minus 10 cents. ARPA goal could be . . . What is projection on panel cost? Power conversion and balance of system may dominate.
- Distortion
- Operating temperature
- Surge protection

What are the critical performance metrics for power converters at the module-scale, residential-scale, and commercial-scale? (slide 4)

- Distortion – not a problem now.
- Operating temperature – we are saying backskin temps of 85-90 C – that is back of module.

  - designs that spread the heat

  - a normal j box seems manageable. Hot spots are due to lack of airflow
- What kind of power electronics temps? Capacitors at 105. ceramics go higher. Degradation between types vary. Some replacement of electrolytic capacitors would be a big help. A design not reqiring a lot of electrolytic capacitors would also be an option. Also have ripple to worry about. DC approach has advnatage with smaller capacitors.
- Surge protection

  - again, system architecture has large bearing. Distributing microinverters means they have to take it. Surge protection architecture does not have to match inverter architecture – many possible architectures. Regardless, there is probably surge protection research, and standards, needed. Quantify for different environments. Relationship with surge proteteion and lifetime matters. Left out of mbtf. Some inverter folks indicate that they can only take a few hits.

Which component technologies (solid-state switches, magnetics, electrostatics, thermal management) need to be developed for the:

- Near-term
  - Need high-temperature for all of the above
  - A lot of adjacent electronic technology is not quite there
  - Magnetics as top area – need to understanding existing material, especially thin film. We apply high-field in power applications. We have little data on this.
  - Capacitors also
  - Maybe chipsets – inverters or converters on a chip.
  - Lowering the partcount
  - Packaging integration interconnects and connectors
- Mid-term
  - Fabricating meso-scale magnetics
  - Wide-bandgap switching semi-conductors (5years) – though silicon carbide already in use
- Long-term

  - converter on each panel

  - fabricated into a thin film

What are the optimal locations for inverter integration?

- Module integrated (module back, module frame, etc)

- Residential

- Small- and large-commercial

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

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?

Going to islanded approach will require reactive power.

- if a utility needs some reactive power, this could provide a cheaper option than some other reactive plant. But then you need bi-directional converters. We already know how to do this, but it is a regulatory issue.

- it is a desirable feature, but not new research topic. Known how to do it.

- What is feasible is as fast as you want. We can do micro-seconds. What do we want?
- IEEE 1547.4 working on when and how
- Not dropping out/ low voltage ride through is a related topic.
- A lot of this comes back to how much you can store to do any of this
- Scale? At a small scale, communication must be inexpensive. For 3 phase, energy storage is not an issue.
- Impact – microinverters will have their biggest impact if they have the largest penetration. Whatever has the scale has the biggest impact.

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

- Is this raised by codes, or manufacturers
  - It is now going into NEC, probably by 2014
  - Older systems are seeing degradation
- Opinions on what ARPA-E can do?
  - More intelligence upstream gives you a chance to do something about it
  - Firefighters are pretty conservative. If they see any PV system, reaction may be to not use water. Could be a fear factor.

In the power converter? How much of a problem is it? And should we devote research money to it?

Communications can be of assistance. Requiring detection near the inverter or combiner box may not be feasible in all cases.