Request for Proposals
High Power Density Inverters

Description

Google is soliciting proposals for groundbreaking research in the area of increasing the power density for DC-to-AC power conversion. This funding opportunity is available only to academics who are full time faculty at degree granting Universities. This solicitation is occurring in parallel with the ***Little Box Challenge presented by Google and the IEEE Power Electronics Society.*** Successful award recipients must outline in detail a plan for how to practically construct an inverter that meets or exceeds the specifications outlined in the ***Little Box Challenge***. It is envisioned that award recipients could use their grant funding to assist in building an inverter that could win the competition. Applying for or receiving an award will not affect an entrant's chances of winning the grand prize.

The proposed research should work towards methods of achieving power densities greater than **50 W/in^3** in a **2 kVA** DC-to-AC conversion device. Preference will be given to proposals that describe the highest credible targeted power densities above **50 W/in^3**. Preferably, the methods used should be widely applicable to a range of voltage inputs, power levels and operating conditions even if some modification is required from the device designed to try to win the prize. The architecture and research plan proposed should outline how a device can be built that has the required power density and upon being fed a DC voltage of **450 Volts** through a **10 Ω** resistor is able to:

- Handle up to **2** kVA loads, with power factors of **0.7** - **1**, leading or lagging
- Operate in a non grid-tied mode with load changes similar to a residential household
- Output **240 +/- 12** Volts single phase AC
- Output at a frequency of **59.7-60.3** Hertz
- Fit into a rectangular enclosure of no more than **40** inches^3 with no dimension smaller than **0.5** inches and no dimension greater than **20** inches
- Have a voltage total harmonic distortion + noise (THD+N) of < **5**%
- Have a current total harmonic distortion + noise (THD+N) of < **5**%
- Have an input ripple current of < **20%** when driven off a **450 V** supply in series with a **10 Ω** resistor

- Have an input ripple voltage of < **3%** when driven off a **450 V** supply in series with a **10 Ω** resistor
- All finger accessible locations of the device must remain below **60°**C during operation when tested at **15-30°**C ambient
- Have a minimum DC to AC conversion efficiency of **95** %
- Galvanic Isolation is not required
- Adhere to the limits on electromagnetic interference specified in **FCC Part 15 B**
- May only take in air and electrical connections from the outside, no external liquid, or other means of cooling is allowed
- Be consistent with standard safety requirements such as ground fault current interruption, safe grounding and under/over voltage protection
- Have a long operating life with minimal service requirements

Applicants are encouraged to look in detail at the specifications and testing procedure provided in the Little Box Challenge for further guidance on Google's areas and specifications of interest. In order to meet all these criteria, it is expected that the researchers would have to pioneer substantial innovation in several areas:

- **Suppression of 120 Hz input current ripple:** The typical solution to minimizing the input current ripple on the DC side of the inverter, which is detrimental to the operation of PV, battery and other systems, has been to include large amounts of energy storage in the form of unreliable, large volume electrolytic capacitors. The incorporation of alternate means of suppressing this 120 Hz while consuming minimal volume, either by using different topologies, devices or both is a key interest of this solicitation and motivation for the Little Box Challenge.

- **Miniaturization of components by operation at higher frequencies:** The typical methods of switching a fixed voltage DC signal into AC, such as Pulse Width Modulation, require the use of passive components to smooth square wave pulses into a sine wave with minimal harmonic distortion. The energy storage requirement, and thus the size, of these passive components can diminish as the frequency of these square wave pulses is increased. These higher frequencies may now be attainable either through the use of wide bandgap semiconductors such as Gallium Nitride (GaN) and Silicon Carbide (SiC), or through new topologies using traditional silicon semiconductors. Utilizing advances in the passive components themselves are also of interest.

- **Thermal Management:** The amount of heat generated by the system will decrease as the efficiency of the system increases. The local thermal management requirements in the system may also be relaxed by using devices (e.g. wide bandgap semiconductors) that can operate reliably at elevated temperatures. New passive or active thermal management approaches may also be used to manage the heat that does get generated and distribute it evenly across the surface area of the enclosure to avoid the presence of hot spots above **60°C**.

- **Electromagnetic Compliance (EMC):** The possible use of higher frequencies, new components in a smaller form factor offers both challenges and opportunities for limiting both the electromagnetic interference within acceptable limits for FCC Part 15 B (or equivalent) compliance . Researchers must take a comprehensive approach to both system layout and small volume filtering strategies in order to meet the EMC requirements at this high power density.

The areas of innovation above are part of the reason that Google now believes that the higher power density sought after may now be achievable, albeit still very challenging. Successful applicants will outline in detail their approach to each of the challenges listed above.

The possible means of tackling each of these challenges is meant to be illustrative but not prescriptive. Applicants are free, and encouraged, to propose alternative ways of reaching these high power densities using methods not listed above, but must propose a credible explanation as to why they would be successful and preferable to those listed here. For example, if an applicant believes that this high power density is achievable without going to higher switching frequencies, they must explain why this is the case, and what they are doing over and above the state of the art.

Award Information

We expect to award 10-15 projects in amounts between 20,000 USD and 40,000 USD. Most gifts will be in the range of 25,000 USD - 30,000 USD and are intended to cover approximately 10 months of work. The funding will be in the form of a one time unrestricted gift given within 2 months of the award announcement. The award committee reserves the right to lower or increase the individual or total award amount given at its discretion.

The judging of the grant awards will be conducted by a panel of **5** individuals selected by Google and the IEEE Power Electronics Society. This committee will make a non-binding recommendation to Google that will then ultimately decide the grant recipients and amounts given.

The criteria for judging will be a determination as to which teams present:

- The most credible path and eagerness to build an inverter that can win the Little Box Challenge in the time frame of under a year.
- The most clear explanation of the approach to the four needed innovation areas listed above (suppression of 120 Hz input current ripple, miniaturization of components by operation at higher frequencies, thermal management and electromagnetic compliance).
- Credit will also be given to applications that raise credible innovation challenges or approaches not mentioned in this document.

- Credit will also be given for descriptions as to additional benefits of the methods used to different use cases such as grid tied inverters, rectifiers or other applications or testing criteria not specifically mentioned here or in Little Box Challenge.

How to Apply

Applicants for a grant must be Faculty at an accredited, degree-granting University in a country that is eligible to compete in the Little Box Challenge. Students are encouraged to recruit faculty members and apply as a team. All applications must be submitted in English.

In a written document (pdf only) of

- Maximum **4** pages
- **8.5”** by **11”** page size
- **12** point font for the main body. **Arial** preferred but not required
- Text in figures, captions, references, footnotes, endnotes and tables must be at least **10** point Font or equivalent, **Arial** preferred but not required
- **1** inch (**2.54** cm) margins on all sides

Please describe:

- The target power density you think is achievable while meeting all the constraints listed above and in The Little Box Challenge
- Clearly indicate your approach to
    - 120 Hz ripple suppression on the DC input
    - Miniaturization of components in the DC-AC conversion stage
    - Thermal management
    - Electromagnetic compliance

  that would enable the power density target listed
- Any other design features and approaches that you think are relevant that should be considered as virtues of your approach
- Applications that simply cite papers without elaborating on their virtues, how they can be incorporated into a complete system and what the proposed research would do to translate the content of the papers into a practical device will be looked down upon

Additional information required but not counting towards the 4 page limit.

- Principal Investigator(s) CV(s) (limit **3** co-PIs, **3** pages each)
- CVs of key team members that will be assisting in the research (limit **3** team members, **2** pages CVs each)

Optional information that may be provided at applicant’s discretion but not counting towards the 4 page limit.

- Potential partnerships with other entities, such as other academics, commercial device manufacturers, etc. that would aid in the construction of the system (**1** page max)

- Relevant research, work done by applicant(s) related to the content of the Little Box Challenge goals. **(1** page**, 5** citations max, **1** paragraph summary of relevance of each citation**)**

Your proposal must not contain any confidential or proprietary information.

The deadline for submissions is **September 30, 2014**. We expect to make final decisions by the end of **November, 2014**. Please follow the instructions on the relevant Research at Google webpage to submit your proposal and upload your pdf.