This project aims to build a highly efficient, low-cost, rapid deployment power electronic building block that enables a flexible ad-hoc microgrid architecture to fulfill the needs of off-grid and poor-grid communities.

Background & Motivation

• For off-grid communities that are deprived of electric power and communities impacted by high-impact low-frequency events (such as hurricanes or wildfires), there are few sustainable power solutions available that are compact, flexible, capable of rapid deployment, and installed/operated/maintained without skilled technicians.
• This impacts thousands of people in the US, many living in Native American nations and communities, or impacted by unforeseen catastrophic events that compromise the bulk power system.
  • An estimated 14% of Native American households on reservations have no access to electricity. Several reservations have seen growth in small-scale solar PV systems and hybrid renewable-energy based microgrids, but considerable populations remain unelectrified.
  • The need for modular, rapid-deployment AC power sources has been evidenced by the forced grid outages following the 2019 wildfires in California and the widespread, long-duration (>120 days) loss of electricity in Puerto Rico due to Hurricane Maria in 2017.

Limitations of the State-of-the-Art

• State-of-the-art emergency and off-grid power solutions typically involve PV panels, batteries, and power converters to supply the AC power needed by single homes.
• Current solutions are often single-purpose designed, inflexible with respect to input power sources, not easily parallelized, and bulky/heavy.
• These solutions also require trained personnel and equipment to install and commission, and are very expensive on a power/energy delivered basis.
• A typical off-grid home may need between 1.5 kW to 10 kW at 120 volts at 60 Hz AC, and should support:
  • High peak power for certain loads such as microwaves and appliances.
  • Critical loads, such as lighting, phones, refrigerators, TVs, and internet modems/routers for sustained periods of time.
  • The “portable power station” market is rapidly growing, with products featuring 1 kW, 120 VAC output power with 1 kWh of energy storage.
  • However, reliance on conventional voltage source converter topologies limits the efficiency and practicability of modular and scalable systems.

Proposed Approach: Flexible Ad-Hoc Microgrid

• The AC Cube is a flexible power electronic building block that enables a flexible ad-hoc microgrid architecture to fulfill the needs of off-grid and poor-grid communities.
  • The Soft-Switching Solid-State Transformer (S4T) topology enables high efficiency, low electromagnetic interference, and high power quality.
  • The efficient, compact, and portable 1.5 kW multi-port converter can interface multiple sources, including solar PV, wind, and the AC grid.
  • A 48 VDC, 1 kWh lithium battery is integrated inside each module, and additional energy storage and generation sources can be interfaced as needed. Low-voltage (<60 VDC) sources ensure intrinsic touch safety.
  • Multiple AC Cubes can be interconnected to form a larger power subsystem to serve a single home. Multiple subsystems can be interconnected to form a larger multi-user system, enabling a scalable, modular microgrid architecture.
  • When the AC line is present, the system can be powered from both the PV panels and the AC line, and can also regenerate power back to the AC grid. During power outages, the system generates 120 VAC to power critical loads.

Impact & Contributions

• The modular and flexible AC Cube based microgrid embodies many novel elements, that taken together provide unique functionality and value.
• An arbitrary number of AC Cubes can be paralleled together in an ad-hoc manner to realize higher power levels.
• The system is intelligent and dynamically balances demand and generation, limiting energy supplied to non-priority loads as available stored energy decreases.
• Each AC Cube module will be able to autonomously detect the presence or absence of the grid, manage all transients associated with connect/disconnect, and manage the state of charge of the various batteries in the system.
• A low-cost monitoring and communications platform (GAMMA) is used to provide user inputs, user viewable data, as well as coordination, status and diagnostic information to the system operators.
• With a target price of <$800 for the 1.5 kW, 1 kWh per day system including batteries, PV panel & grid connection, up to $350/year of energy savings per AC Cube can be realized (assuming $0.30/kWh in CA).

Proposed Approach: Resilient and Flexible Power at the System Level

• The Soft-Switching Solid-State Transformer (S4T) topology enables high efficiency, low electromagnetic interference, and high power quality. The system is intelligent and dynamically balances demand and generation, limiting energy supplied to non-priority loads as available stored energy decreases.

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