Potential Military Applications of Energy Micro-grids

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Introduction

Increasing energy security and decreasing dependence on fossil fuels are major objectives for the Department of Defense (DoD). An important step towards these objectives is to generate, store, and distribute power from local sources, such as renewable energy systems like wind, solar, geothermal and biomass. Energy micro-grids promise to provide the capability to incorporate these renewable energy sources, convert and store the energy derived from them, and distribute this energy when and where it is needed. These micro-grids can operate independent of national grid systems, or they can be connected to external grids. They can also accommodate other advanced non-polluting distributed generation (DG) technologies like fuel cells and micro-turbines.

Currently, renewable energy technologies are being integrated into military installation power grids through custom engineering, one system at a time, to interconnect and run in parallel with the local utility. This configuration gives the military users very little control over the power that is generated and no capability at all of redistributing power to mission critical facilities during a commercial power outage or any off-grid situation. Further, this approach serves only on-grid, fixed facilities – and doesn't easily plug-and-play across the spectrum of military power needs, "from home station to foxhole."

In addition, emergency back-up power capability for mission critical facilities at military installations is presently supplied by conventional engine-driven generators, typically diesel generators, which release high levels of toxic air contaminants, criteria pollutants, and greenhouse gases. Usually, these units are oversized and sometimes a redundant generator is provided, to ensure that the critical loads are served. If these units fail to come on line during an emergency, it is difficult and time consuming to replace them with working generators. Also, determination of which facilities are mission critical can be a very dynamic process, depending on the specific situation. However, moving the generators to where they are needed is also difficult and time consuming.

One way to overcome these problems is to network power systems together in an intelligent micro-grid. Through the development of a plug-and-play interconnected micro-grid, the military will be able to: 1.) more readily install future renewable energy systems; and 2.) more effectively control and optimally benefit from the power that is generated from all of its DG assets. The micro-grid can provide these capabilities during both normal grid-connected, and emergency "islanded", operating conditions. Additionally, micro-grids can be scaled to serve fixed facilities in remote off-grid areas, forward operating bases, tactical operating centers, and for reconstruction missions.

The reconstruction mission application can be further defined as the use of the micro-grid concept to initially restore power to a conventional grid, which has been damaged through natural disaster or combat operations. Until the central power plant and distribution system are repaired, available and appropriate DG units can be moved into place and networked together in a micro-grid fashion. The most critical loads would be served at first and then, if more DG becomes available and integrated with the micro-grid, secondary loads could also be served.

The emergency micro-grid would remain in place until the repaired central power plant is transitioned back into the distribution network. The key advantage here is the ability to restore power to critical facilities in a matter of days or even hours, rather than the weeks or months to re-energize the conventional grid.

Description of the Military Micro-grid Concept

A scalable, onsite power grid architecture is an aggregation of load, supply, energy storage interconnections points (nodes), and controllers, networked along low voltage distribution feeders (see figure on page 3). This system provides a sustainable and seamless energy solution for the military installation to transition its power posture, during times of high peak power demand (peak shaving mode), other commercial power modes of operation (economic decision-making mode), and commercial power disruptions (islanding mode), resulting from natural or man-made events. This architecture facilitates onsite renewable power conditioning and routing to any section of the grid, at the discretion of the military commander. Some characteristics of a military micro-grid include:

Scalability: Micro-grids provide plug-and-play implementation of sustainable and renewable DG technologies, with reduction in fossil fuel consumption and associated air emissions, and enhanced use of the energy that is delivered to the power grid by these systems. The network control systems are sustainable and can scale up or down to fit the specific military operation, including utility grid-connected facilities, off-grid training areas, contingency operations such as forward operating bases (FOBs) and tactical operation centers (TOCs), and reconstruction missions.

Adaptability: Micro-grids provide enhanced energy security for critical facilities during emergency operations, caused by equipment failure or human error on the local or regional grid, natural disaster, or deliberate sabotage or terrorist attack. This provides the military commander with the capability to dynamically load shed non-critical operations and strategically dispatch power wherever vital loads must be served at any point in time, without affecting grid stability.

Local Control: Micro-grids allow for rapid event response and adaptive control to accommodate time-intensive operations and digital power requirement loads that are sensitive to power quality disturbances (variations in sinusoidal waveform). This capability also mitigates potential instabilities that may result from high renewable power penetration on the installation's distribution grid.

Energy Storage: During normal operating conditions, micro-grid control architecture uses economic decision criteria for directing power flows and to meet load demand, so that all power from the local DG assets is used most cost-effectively, whether to help limit peak utility demand or to store the energy for use later. During emergency operations, stored energy is used strategically with dynamic load shedding to maximize finite locally-stored power and fuel, and to enhance grid stability. This extends local energy availability and the number of days that the islanded systems can survive the commercial power outage.

Security, Reliability, and Sustainability: An intelligent micro-grid is a holistic approach to power generation, energy storage, distribution, and demand-side dynamic load shedding, based on decision criteria that are determined through critical mission decomposition and consequence modeling. Micro-grids enhance security, reliability, and sustainability, by reducing dependence on external power grids and energy supplies, though greater use of local renewable resources and optimization of the power delivered by conventional DG sources.

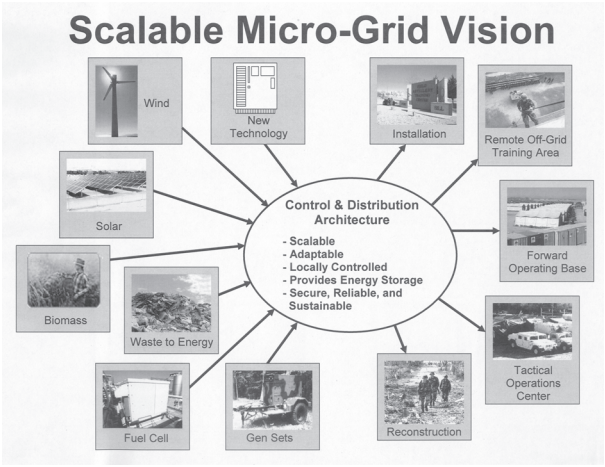
Environmental and Sustainability Benefits

In addition to the environmental and sustainability benefits already mentioned, a military micro-grid capability would also provide DoD with a means of meeting the goals of one new and one emerging requirement. The January 2007 Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, calls for at least half of the renewable energy consumed by a federal agency in a fiscal year, to come from new renewable sources and, to the extent possible, the agency should implement renewable energy generation projects on agency property, for agency use.

The emerging requirement is a part of draft recommendations by the Facilities Panel of the Defense Science Board Task Force on the development of a new DoD energy strategy. The recommendation says that by 2025 all installations will be able to sustain critical mission capabilities for a minimum period of six months, without any reliance on the off-post commercial power grids or fuel supplies. No such standard exists today; uninterrupted power generators for a few limited facilities like hospitals are currently designed to supply minimum power no longer than 3 to 5 days. The development of micro-grid capabilities for various military uses can be an important step towards facilitating expanded use of renewable energy technologies and optimizing the power they generate for enhanced mission sustainability.

Challenges, Solutions, and Conclusions

While there are several test micro-grids now in use at various locations, including some on military bases, there are still technical challenges to address before micro-grids can be widely used for military applications. Control architecture is the biggest challenge. Various control architectures that optimize scalable power grid performance, with respect to economics, sustainability, and energy security, must be evaluated.

Successful development of micro-grid capabilities for military applications will provide a number of economic, operational, and environmental benefits, including significant reduction in fossil fuel consumption and associated air pollution emissions. The micro-grid concept might also be used to more quickly re-energize a conventional power grid that has been damaged by natural disaster or combat operations.

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