



AFRL-RX-TY-TP-2010-0101

**TYNDALL AIR FORCE BASE SERVES AS TEST
BED FOR DEPLOYED BASE SMART GRID
(POSTPRINT)**

Marcus D. Smith

Airbase Technologies Division
Air Force Research Laboratory
139 Barnes Drive, Suite 2
Tyndall Air Force Base, FL 32403-5323

Contract No. FA4819-09-C-0031

July 2010

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**AIR FORCE RESEARCH LABORATORY
MATERIALS AND MANUFACTURING DIRECTORATE**

REPORT DOCUMENTATION PAGE				<i>Form Approved OMB No. 0704-0188</i>							
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1. REPORT DATE (DD-MM-YYYY) 31-JUL-2010		2. REPORT TYPE Journal Article POSTPRINT		3. DATES COVERED (From - To) 01-OCT-2009 -- 30-JUN-2010							
4. TITLE AND SUBTITLE Tyndall Air Force Base Serves as Test Bed for Deployed Base Smart Grid (POSTPRINT)				5a. CONTRACT NUMBER FA4819-09-C-0031							
				5b. GRANT NUMBER 							
				5c. PROGRAM ELEMENT NUMBER 0909999F							
6. AUTHOR(S) Smith, Marcus D.				5d. PROJECT NUMBER GOVT							
				5e. TASK NUMBER D0							
				5f. WORK UNIT NUMBER Q110D8B3							
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory Materials and Manufacturing Directorate, Airbase Technologies Division 139 Barnes Drive, Suite 2 Tyndall Air Force Base, FL 32403-5323				8. PERFORMING ORGANIZATION REPORT NUMBER 							
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory Materials and Manufacturing Directorate Airbase Technologies Division 139 Barnes Drive, Suite 2 Tyndall Air Force Base, FL 32403-5323				10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/RXQES							
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RX-TY-TP-2010-0101							
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution Statement A: Approved for public release, distribution unlimited.											
13. SUPPLEMENTARY NOTES Ref AFRL/RXQ Public Affairs Case # 10-116. Document contains color images. Article was published in AF Facility Energy 2010, pp 28-29.											
14. ABSTRACT Developed a test bed for evaluation and characterization of a smart grid power system and integration with renewable energy sources and its compatibility potential with the existing Air Force Power systems. This test bed will provide Air Force users with an unbiased "honest-Broker" option for evaluating smart grid power technology and integration with renewable energy solutions for Warfighter applications.											
15. SUBJECT TERMS Smart Grid, Renewable Energy, Convertor, Inverter, Energy Storage, power genertaion											
16. SECURITY CLASSIFICATION OF: <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; padding: 2px;">a. REPORT</td> <td style="width: 33%; padding: 2px;">b. ABSTRACT</td> <td style="width: 33%; padding: 2px;">c. THIS PAGE</td> </tr> <tr> <td style="text-align: center; padding: 2px;">U</td> <td style="text-align: center; padding: 2px;">U</td> <td style="text-align: center; padding: 2px;">U</td> </tr> </table>			a. REPORT	b. ABSTRACT	c. THIS PAGE	U	U	U	17. LIMITATION OF ABSTRACT UU		18. NUMBER OF PAGES 2
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			19b. TELEPHONE NUMBER (Include area code) 								

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Tyndall AFB Serves as Test Bed for Deployed Base Smart Grid

Mr. Marcus D. Smith
AFRL/RXQD

Providing energy to the battlefield is dangerous, as well as a significant logistical burden. The Air Force Research Laboratory (AFRL), Tyndall AFB, Fla., has set up a test bed to investigate ways to reduce the amount of energy transported to the battlefield by producing more power on site and maximizing the efficiency of the overall system. Both of these goals are greatly enhanced by adding smart grid capabilities to Air Force's deployed base power system. The Air Force definition of a smart grid is called the Energy Surety Microgrid (ESM). This designation, originally developed for fixed Air Force installations, has relevance for the deployed environment. These crossover areas include many of the features seen in our deployed base smart grid test bed.

A truly smart grid is able to integrate renewable and alternative power sources throughout the grid infrastructure. Additional benefits include increased survivability, optimized grid performance, and reduction in the amount of fuel consumed. Key aspects of the ESM include priority power routing, on-demand load shedding, power quality compensation, energy storage, seamless transition to backup power supplies, and peak load management.

There are many existing potential energy solutions and many that are in development at research facilities around the world. Many of these technologies are incompatible with one another and do not adhere to any particular set of standards. Research at Tyndall includes a test bed where candidate technologies for deployed locations can be

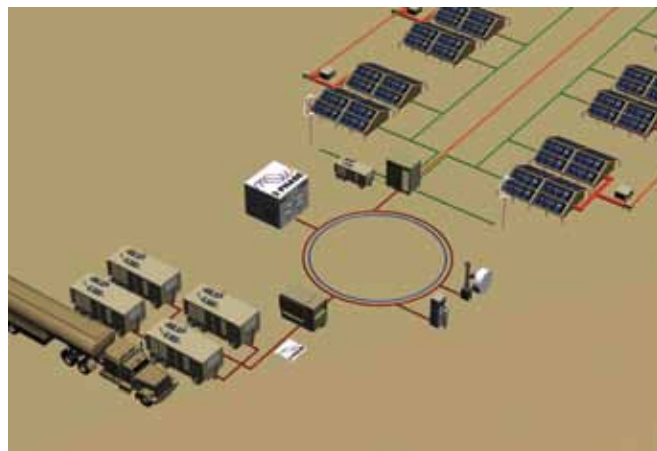


Figure: Advanced Integrated Power System (AIPS)

modeled and evaluated. Data acquired at the test bed will be used to develop a set of integration and communication standards for ESM technologies.

The ESM test bed is part of the first phase of the Advanced Integrated Power System (AIPS) (Figure). The initial setup of AIPS has five sources: a solar integrated shelter, solar carport, proton exchange membrane fuel cell, vertical axis wind turbine, and a JP8 powered mobile electric power generator. The initial loads include the environmental conditioning unit (ECU), perimeter surveillance radar system, electric vehicle recharge station, convenience outlets, and programmable loads. Programmable loads are randomly varied in presence and intensity to simulate typical operational loads. Additional testing of ESM components is in the planning stage. AFRL will evaluate systems acquired from private industry, academia, and government sources.

The system will enable the base power manager to instantaneously determine grid health, and current system configuration, and make changes to the grid. The autonomous control algorithms being developed as part of the AIPS program are designed to maximize system efficiency and reduce the number of generators needed to power a forward operating base.

The data acquisition and system control functions will be handled by a series of microprocessor-based field controllers, distributed throughout the system, to serve as the brain of each major system component (e.g. power sources and loads). Multiple loads may be combined on a single addressable circuit breaker controlled by these units. Voltage and current transducers along with a host of other sensors will provide system performance data as well as instantaneous health monitoring of grid components. Inverters will take DC power generated by sources such as wind turbines or solar panels and prepare a synchronized and phase-matched AC power output. The current grid backbone is a high voltage (4,160-volt) 3-phase AC power system (currently based on the MEP-12 750 kW JP8 generator).

Inverters are the key piece of hardware needed to introduce clean power from renewable DC sources such as solar panels onto the grid. Distributed power generation on a grid can be dangerous to the grid maintenance team if safety measures aren't implemented. One of the key safety measures is known as islanding, which is the inverter's response to an outage on the grid. Once an outage is detected, the inverter disconnects itself from the grid, preventing power from accidentally being placed on the

grid and injuring linemen. Inverters that are compliant with safety measure *IEEE 1547* can work parallel with host nation power grids.

Optimizing grid performance through automation and real time control significantly impacts the amount of power needed. When a large load device is started there is an initial power requirement that can sometimes triple the amount of power compared to steady state operation. Optimizations such as staggering the start time of large load devices like the ECU can reduce the overall system power requirement.

The system has to be sized to accommodate an uncontrolled environment where multiple devices have the potential to start all at once. The ESM controller uses sensors throughout the grid to determine power consumption, power production, and power quality. Additional loads can be brought on line if resources become available. This method of power management eliminates power generation waste. The system will bring power generation on line as it is needed and remove it when the demand drops.

Additional optimization techniques include energy storage and power quality compensation. Energy storage for the first phase of AIPS will include a 10-kW zinc bromide flow battery to aid in peak power management. Because renewable power sources such as solar and wind do not produce a constant power level, storing the power for use during peak periods will reduce the size of the generation capacity needed to meet the demand. Power quality compensation can significantly reduce the risk of equipment damage.

Survivability is a critical issue in a forward operating base environment. Real time communication with all grid-interfaced components is crucial for system survivability. All of the loads connected to the ESM are put into a prioritized list kept by the master ESM controller, which also has access to all available power generation capability. If the base is attacked and portions of the grid are damaged, the ESM controller automatically reroutes the system's remaining power to the highest priority loads. The ESM controllers function as an ad hoc network of smart computers. Each controller is capable of running the entire grid, and if the master

controller is compromised, the next field controller in sequential order takes charge.

The communication scheme is designed to modulate control and data packets over the power cabling with an internet protocol-based quadrature phase-shift keying, or QPSK, modulated signal. This system is capable of a significant amount of forward error correction making it an ideal method of transmitting information between devices in a chaotic environment.

The testing strategy for components evaluated in the AIPS test bed involves five steps: technical evaluation, modeling, isolated testing, integration testing, and reporting. The technical evaluation will determine if the technology fits a warfighting need; the technology readiness level; portability; and field endurance capability. The modeling stage will allow engineers to determine how the system will affect the entire grid system before resources are allocated to do field testing. The isolation testing will determine system performance, and potential power quality impact. The integration testing stage is the most important stage and will allow researchers to determine the strengths and weaknesses of candidate technologies. The reporting stage involves sharing the information with the engineering community. The test plan calls for a full year of field testing in the AFRL outdoor laboratory.

AIPS fills a crucial DOD need to have a method and location to test ESM system components that could be deployed to the battlefield, where energy is one of the most important commodities. There are a significant number of potential solutions to reduce the amount of energy that needs to be shipped. AIPS will help organize these solutions and ensure the choices made are viable and enduring.

Mr. Smith is the Engineering Lead for the Deployed Base Energy Group, Air Force Research Laboratory, Tyndall AFB, Fla.



Deployable solar power is tested and evaluated at the Air Force Research Laboratory's Renewable Energy Tent City at Tyndall, AFB, Fla. (U.S. Air Force photo)