Phase II STTR Proposal to Odyssian Technology LLC.
Submittal Date: March 16, 2009.

Title:
Design and Simulation of Intelligent Control Architecture for Military Microgrids

University of Notre Dame's Statement of Work (SOW)

Dr. Michael Lemmon (Department of Electrical Engineering, University of Notre Dame) will be responsible for the following tasks.

Task 1: Power System Simulation and Monitoring

Odyssian's Phase II STTR project will develop hardware and software for microgrid systems that can be later scaled up to field-deployable systems. An important component of that effort is the development of a comprehensive simulation that accurately models the microgrid sources, loads, controllers, and associated communication infrastructure.

The University of Notre Dame (UND) will develop a single-phase and three-phase simulation for candidate microgrids that are specified by the University of Wisconsin – Madison (UW). The University of Illinois – Urbana-Champaign (UIUC) will supply models of microsource inverters. UND will develop models of the eBoard load controllers in consultation with Odyssian Technology LLC. UND will be responsible for integrating these models into the microgrid layouts specified by UW. UND will be responsible for integrating distributed load-shedding and power dispatch algorithms into the simulation using a realistic model of communication network. UND will validate the simulation against a bench-scale hardware microgrid. UND will perform simulation experiments to study the scalability of the proposed intelligent hybrid control architecture with regard to system cost, communication network performance, and overall network reliability.

The deliverables from this task will be 1) the source code for the microgrid simulation and 2) a technical report detailing the results of the scalability and performance studies.

Task 2: Distributed Control Algorithm Development

A two-layer control architecture is a major component of Odyssian's proposed microgrid system. The lowest level of this architecture is a local controller for microsources that mimics droop controllers for synchronous machines. The highest level of the architecture is a supervisory layer that uses a distributed set of "decision agents" for economical power dispatch and intelligent load shedding. These agents function in a "distributed" manner by exchanging information over an ad hoc wireless communication network.

UND will develop distributed power dispatch and intelligent load-shedding algorithms for Odyssian's microgrid system. These algorithms will be integrated into the power system simulation developed under task 1.

The distributed power dispatch algorithms were originally developed by UND as part of Odyssian's Phase I STTR contract. For phase II of this project, UND will extend the power dispatch algorithms to account for limits on transmission line power. These algorithms will be locally embedded at the microsource inverter. UND, in consultation with UIUC, will be responsible for specifying the interface between the power dispatch agents and the inverter.

A preliminary load-shedding algorithm was developed by UND as part of Odyssian's Phase I STTR contract. UND will continue development of these load shedding algorithms under Phase II. In particular, UND will develop automated load forecasting algorithms that in concert with measures of "power quality" can be used to manage load connection in a way that assures overall microgrid stability. These algorithms will be integrated into the simulation developed under task 1 and they will be embedded at the eBoard load controller. UND, in consultation with Odyssian, will be responsible for specifying the interface between the load shedding agents and the eBoard load controller.

The deliverables of this task are 1) distributed power dispatch algorithm accounting for transmission line power limits, 2) load-shedding algorithms that incorporate load forecasting and power-quality measures, 3) interface specifications between the power dispatch agent and the microsource inverter, and 4) interface specifications between the load-shedding agents and the eBoard load controller.

Task 3: Wireless Distributed Control Software.

This project's distributed algorithms for power dispatch and load shedding will be implemented as "agents" that are embedded at the generation and load assets. These agents will communicate over an ad hoc wireless network. The agent software will be embedded in wireless sensor network (WSN) modules. These modules will be interfaced to the microsource inverters developed by UIUC and the eBoard load control devices developed by Odyssian LLC. UND will work with Odyssian to develop the embedded software implementing the power dispatch and load shedding algorithms on the WSN modules. UND will be responsible for determining what information must be transmitted between cooperating agents in the system.

The deliverables from this task consist of 1) embedded implementation of the power dispatch and load-shedding algorithms and 2) interface specification characterizing the information exchanged over the system's communication network.

Task 4: Wireless Communication

This project uses an ad hoc wireless network to exchange messages supervising power dispatch and load connection. This wireless network will be formed from WSN modules that are connected to generation and load assets. These wireless networks have inherent reliability issues due to their reliance on radio frequency (RF) signaling. Assuring reliable real-time delivery of messages over such RF networks requires adaptable networking middleware that can reconfigure to changes in communication network topology and link connectivity.

UND will assist Odyssian to 1) integrate the communication network with the distributed power dispatch and load-shedding algorithms and 2) improve the reliability and real-time performance of the communication network.