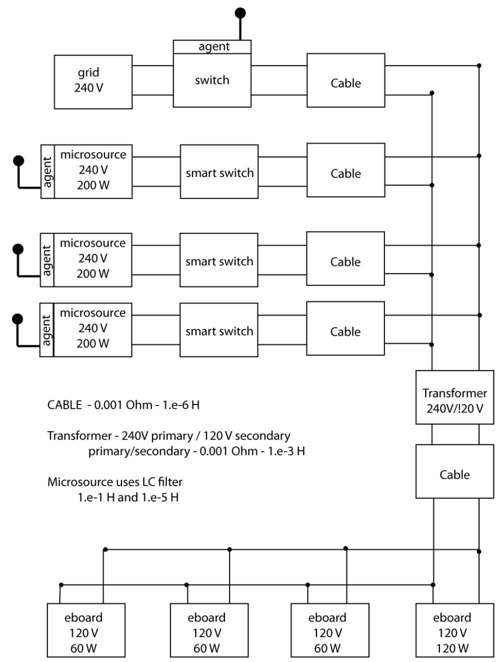
MONTHLY PROGRESS REPORT	
Contractor Name: University of Notre Dame (Michael Lemmon)	
Contractor Address: Office of Research, 940 Grace Hall, Notre Dame, IN 46556	
Contract/Purchase Order No. W9132T-10-C-0008 (prime contract no.)	Task Order No.
Project Title: Design and Simulation of Intelligent Control Architecture for Military Microgrids	
Period Covered: April 1 2011 – May 1, 2011	
POC/COR (Reference Paragraph 5 of the SOW):	
Achievements (Describe by task. Add additional tasks, if needed.): task numbers refer to tasks in Odyssian's original contract	
Task II: Model and Simulate Intelligent Microgrid Extended single-phase simulation of Odyssian testbed to consist of 3 200 W microsources and 4 e-boards handling 120 W loads. A preliminary dispatch logic was developed and tested on this simulation.	
Task III: Distributed Control Algorithm Development Began development of dispatch logic for Odyssian single phase testbed.	
Task VI: Develop Wireless Communication No activity	
Task VII: Develop Wireless Distributed Control No activity	
Problems Encountered (Describe by task. Add additional tasks, if needed):	
Task II: None	
Task III: None	
Task VI: None	
Task VII: None	
Open Items (List items that require action by the Contractor or the Government):s No open items	

Summary Assessment and Forecast (Provide an overall assessment of the work and a forecast of contract completion):

The simulation of Odyssian's single phase testbed was extended to include 3 microsources (200 W) with 4 eboards (120 W). The simulation models were developed from last month's microsource models which modeled the inverter as a controlled voltage source. A block diagram for the simulated single phase testbed is shown to the right. The total amount of microgrid genertion is 600 W with a total load of 480 W. This dispatch logic is implemented using "computational agents" attached to the point of common coupling (PCC) and each microsources. This network of agents is used to adjust the microsource requires real power (P_{req}).



The dispatch algorithms for the Odyssian testbed are simpler than the earlier dispatch agents for mesh microgrids. In the first place, we don't use event-triggered signaling in these dispatch agents. This will simplify the demonstration's implementation. Secondly, there is no need for a highly distributed algorithm since all sources and loads in this testbed are directly interconnected. The dispatch logic, therefore, is much simpler. A preliminary form of the logic was developed this month and implemented on the simulation.

The agent at the PCC monitors the real power flowing through the switch. This agent determines whether or not the microgrid has islanded from the main grid. That information is then transmitted to each of the microsource computational agents.

The agents attached to the microsources adjust the requested power to the UWM controller in a manner that reduces the cost of power generation subject to meeting the power balance relation. We use the commanded frequency from the UWM controller as a measure of the power balance. This leads to the following update algorithm for the requested power,

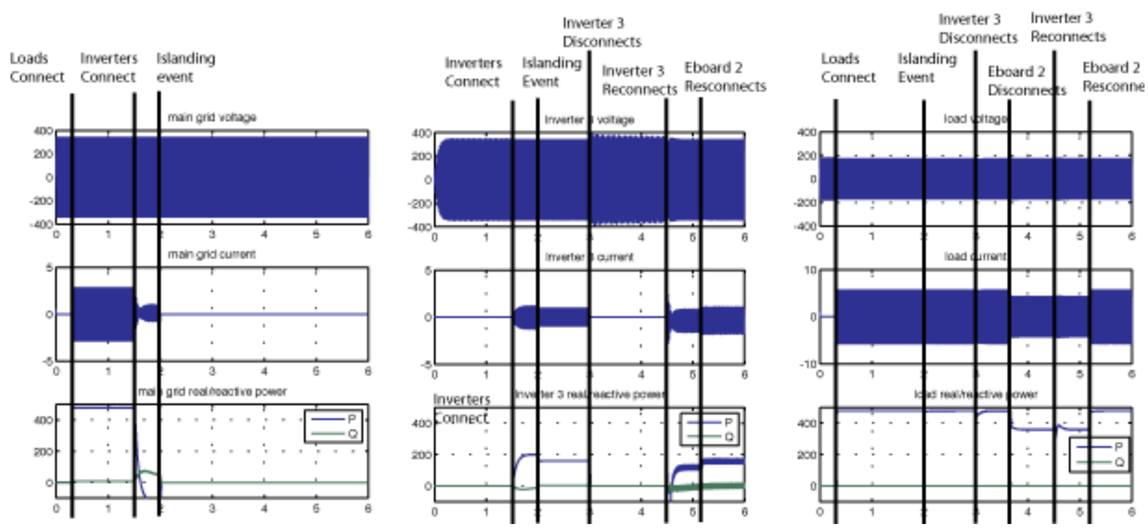
$$P_{\text{req}} = \max\left\{0, P_{\text{req}} - \alpha\left(k(\omega - 1)P_{\text{req}} - \max\{0, P_{\text{req}} - 1\}\right)\right\}$$

where α is a constant (step size) and k is a gain. The line frequency, ω, and the requested power are in pu. The update consists of two terms. The first term is a function of frequency and increases or decreases P_{req} to keep the frequency at 1 pu (60 Hz). The second term is a slack term that decreases the requested power if it exceeds 1 pu. The above adjustment is only performed by a microsource if there is no power flowing through the PCC (i.e. the microgrid is islanded). If there is power flowing through the PCC, then all dispatch agents simply set P_{req} to 1 pu.

The following simulation illustrates the operation of the dispatch logic. The simulation scenario has the following time line

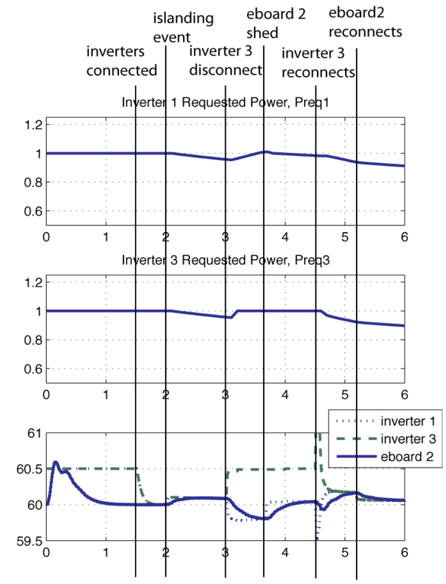
Time seconds	Event
0.0	Simulation starts with main grid connected, e-boards disconnected, and Inverters disconnected
0.1	All e-board loads (480 W) connect.
1.5	All inverters (600W) connects and exports power to the main grid
2.0	Islanding event with all inverters (600W) serving the eboards (480W)
3.0	Inverter number 3 disconnects (total available power drops to 400W)
3.7	Non-critical e-board sheds 120W load
4.5	Inverter number 3 reconnects to the grid
5.1	e-board reconnects non-critical load to the microgrid

The following plot shows the time histories for the main grid (at PCC), inverter 3 (at its smart switch), and the terminal leading to all loads.



From this figure we can see that the system is able to maintain the voltage levels to the loads during islanding events, disconnection/reconnection of loads, and disconnection/reconnection of inverter.

The frequency response and the requested powers generated by the dispatch agent are shown in the figure to the right. Prior to the islanding event, the requested power is set to 1 pu. Upon islanding, there is excess capacity (since frequency is greater than 1 pu) and the requested power setpoints begin to reduce. When inverter 3 drops off, we see an increase in inverter 3's frequency (since it has no load) and the requested power is set to 1 pu (in anticipation of reconnecting later). In the meanwhile, the dispatch logic begins increasing the requested power level in order to raise the line frequency. When inverter 3 reconnects, there is a short transient in the frequency estimate as it converges to the commanded line frequency and the requested power level begins to decrease since there is now excess capacity.



The simulation results indicate that this simple dispatch logic functions as expected. Some discussion should probably take place with Odyssian to see precisely what their plans are for the demonstration scenario.