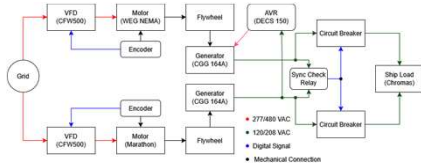


Executive Summary

This project builds a small-scale electrical microgrid in UTA's Pulsed Power and Energy Laboratory that mimics how power is managed on. The goal is a testbed where two motor-generator sets run in parallel, share load, and stay stable even when the electrical demand changes suddenly. A microgrid is a small, self-contained power system that can generate, store, and distribute electricity independently. This project builds one from the ground up.

The testbed runs two motor-generator sets in parallel, feeding a shared DC bus. Voltage regulators keep generator output steady. Variable frequency drives control motor speed to hold frequency at 60 Hz. A hybrid energy storage module, combining ultracapacitors and a battery pack, sits on the DC bus and absorbs sudden load spikes before they reach the generators. This semester, the drives were commissioned and running stable. The voltage regulators were wired and configured.

Testing immediately surfaced a problem: the generators were drawing far more excitation current than expected at no load, and a protection limit kept shutting the system down. Gain tuning did not fix it. The team is now running targeted diagnostics to isolate whether the fault is in the sensing wiring, the configuration, or the excitation hardware itself.



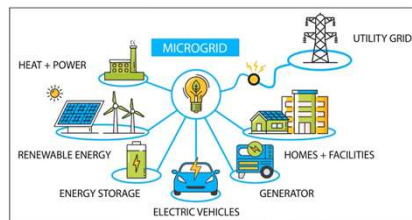
Background

The microgrid we are implementing uses two paralleled generator sets feeding a DC bus through a multi-pulse rectifier. VFDs are used to control the speed of the motors driving the generators, which allows the system to maintain a constant output frequency of 60 Hz. Depending on the load's needs, the Hybrid Energy Storage Module (HESM) will supply or draw energy during transient conditions to help stabilize the system. The AVR controls the field excitation of each generator to maintain stable terminal voltage.

The system under development follows a low-voltage distributed shipboard power system per MIL-STD-1399-300B, which gives safety targets for voltage consistency to be within $\pm 5\%$ and frequency consistency to be within $\pm 3\%$ of nominal values.

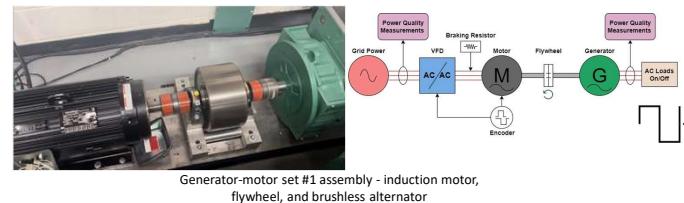
This military standard section establishes electrical interface characteristics for shipboard equipment utilizing AC electric power to ensure compatibility between user equipment and the electric power system. Characteristics of the electric power system are defined, and tolerances are established, as well as requirements and test methods for ensuring compatibility of shipboard user equipment with the power system.

The University of California, San Diego (UCSD) completed a microgrid project that shows a methodology that can give success. This project integrated an energy storage system with a 10 MW / 40 MWh battery system and a 3.8-million-gallon thermal energy storage tank which allows their system to automatically island. Using these fundamentals and an understanding of general microgrids from that project to develop the naval solution to be hosted on a similar Microgrid frame.



Experimental Setup

- How the system is connected:** Grid power feeds two variable frequency drives, each of which runs an induction motor coupled to a flywheel and generator. The generators produce three-phase AC, which is rectified into a 24 V DC bus. Voltage regulators on each generator monitor terminal voltage and adjust field excitation to keep output steady. The hybrid storage module connects directly to the DC bus and responds to load transients faster than the regulators can.
- The system equipment for the testbed includes two parallel motor-generator sets, Basler DECS-150 AVRs, WEG CFW500 VFDs, a multi-pulse rectifier, a hybrid battery and super-capacitor system (HESM), and a PXIe-based control system.
- This work primarily focuses on integrating and testing the generator, AVR, and VFD subsystems to achieve stable voltage and frequency control.
- The DECS-150 AVR is used to regulate generator terminal voltage, while the CFW500 VFD controlled motor speed to maintain a nominal output frequency of 60 Hz.
- What we ran into:** Wiring between the generator and voltage regulator was verified against manufacturer documentation. Configuration was entered through software — rated voltage, power factor, current, and PID control gains. No-load startup testing showed the generator pulling nearly full-load excitation current just to reach nominal voltage. The protection system tripped repeatedly. Adjusting control gains had no effect, pointing to a hardware or sensing problem rather than a software one.



Generator-motor set #1 assembly - induction motor, flywheel, and brushless alternator

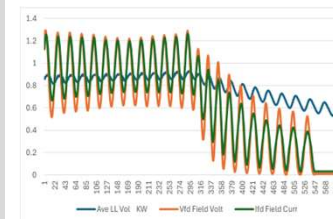
Experimental Test Plan

- The Problem:** Generator excitation current was ~ 1.9 A at no load. Expected: under 0.5 A. Protection limit tripped every startup. PID tuning did not change the behavior.
- Experimental tests were targeting this Overexcitation Limit shutdown
- System performance was evaluated based on stable voltage output, response to startup conditions, and identification of faults such as over-excitation limit (OEL) trips.
- FCR setpoints regulate field current at start up (no-load) set at 0.5Adc which should mean the generator output to be at nominal voltage (120/208Vac).
- If generator voltage is low, then we increase the field current at 0.1 Adc intervals.
- Future testing will include load testing, synchronization of both generators, and validation of parallel operation within the microgrid.

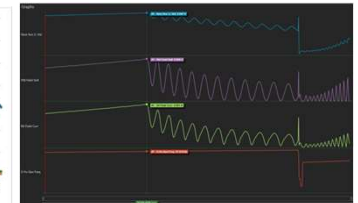
Test	Method	Goal
Wiring verification	Cross-check against manufacturer diagram	Confirm sensing connections are correct
No-load startup	Run generator unloaded, log voltage and field current	Establish baseline behavior
PID Tuning	Adjust Kp, Ki, Kd across test runs	Rule out control loop as root cause
FCR Mode	Command field current directly at 0.5 Adc, observe terminal voltage	Isolate excitation hardware from AVR feedback
Parallel sync	Replicate wiring and software on genset #2. Match voltage, frequency, and phase between gensets	Validate dual-generator-motor operation
Load step (future)	Apply 25%, 50%, 100% load via programmable load bank	Measure voltage recovery and stability

Experimental Results

- WEG CFW500 VFDs successfully calibrated for closed-loop vector control at 1800 RPM, maintaining 60 Hz output with encoder feedback verified through LabVIEW
- AVR communication successfully established via BESTCOMSPlus; rated machine data entered (208 V, 0.8 PF, 9.6 kVA, 26.65 A) and PID gains configured ($K_p = 60$, $K_i = 15$, $K_d = 15$)
- No-load startup testing revealed abnormally high field current demand (~ 1.9 A) to achieve nominal voltage, indicating a potential sensing mismatch or excitation system issue
- Over-Excitation Limiter (OEL) trips were observed during startup and when approaching 60 Hz, confirming the issue extends beyond control loop tuning
- Field Current Regulation (FCR) mode testing was initiated to isolate AVR control behavior from physical excitation system behavior



Generator phase voltage graphs before PID tuning – Shows oscillatory startup and OEL shutdown once generator reaches 1 p.u. V-phase



Generator phase voltage graphs after PID tuning – Shows overexcitation once generator reached 1 p.u. V-phase to achieve nominal voltage but normal soft startup (No more oscillatory startup)

Conclusions

This semester established the core hardware and control infrastructure for the microgrid testbed, representing a significant step forward from the simulation-based foundation left by prior teams. The WEG CFW500 Variable Frequency Drives were successfully commissioned for closed-loop vector control on both gensets, achieving stable 60 Hz generator output with encoder feedback verified through LabVIEW and Modbus RTU communication confirmed to the NI PXIe supervisory controller.

On the AVR side, both Basler DECS-150 units were physically mounted, labeled, and wired to their required sensing and excitation terminals. Generator 1 was brought fully online with BESTCOMSPlus communication established, rated machine data entered (208 V, 0.8 PF, 9.6 kVA, 26.65 A), field-rated data configured, and initial PID gains applied ($K_p = 60$, $K_i = 15$, $K_d = 15$). No-load startup testing was completed, and system behavior was logged across multiple test runs.

The most critical finding this semester was that persistent Over-Excitation Limiter trips and an anomalously high no-load field current demand of approximately 1.9 A (well above the expected sub-0.5 A baseline) could not be resolved through PID gain tuning alone. This confirms that the root cause lies in sensing, wiring, or excitation hardware rather than control loop behavior.

Field Current Regulation mode testing has been initiated as the diagnostic method to isolate excitation system behavior independent of the AVR control loop. So, the real takeaway from this semester is that digital AVR commissioning is mostly a hardware problem before it is ever a software one.

FCR mode testing allows us to confirm that with the unit producing 0.5Adc of field current while the machine is unloaded, then it would expect the generator to produce somewhere close to nominal voltage based upon the nameplate. If gen voltage is low, then we raise the FCR setpoint up until the generator voltage is at nominal voltage. Looking ahead, the remaining work is well-defined. Repairing the cross-current compensation resistor, completing Generator 2 commissioning, electrically integrating the HESM into the 24 V DC bus, and validating synchronization and parallel operation between both gensets are the critical path items. Once complete, this testbed will serve as a fully instrumented, hardware-validated naval microgrid research platform.

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