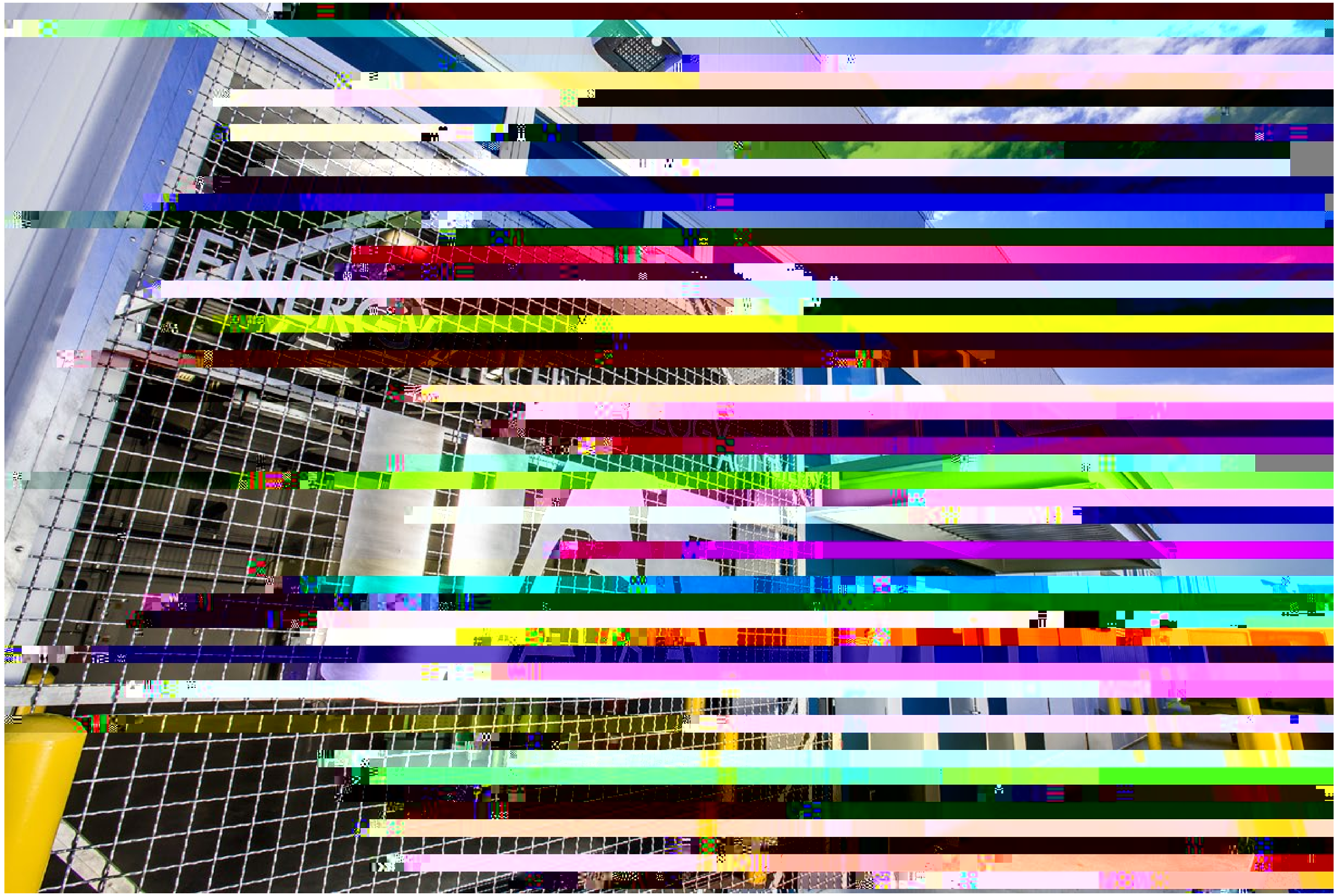
Power Systems Integration Lab

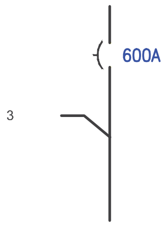


The Power Systems Integration Lab operates on the same scale as a village power system and has the ability to be modified for individual test scenarios.

The lab emulates an isolated hybrid-diesel grid at up to 500 kW of permanently installed capacity and potential capacity of several MW. The lab transforms a potentially chaotic field testing environment into a continuously improving process for optimizing efficiencies.

The R&D and testing capabilities of the PSI Lab are complemented with experienced faculty and staff providing engineering and research services from energy analysis, and design development and review, through full-scale in-system R&D, product testing and hardening.

Opposite: Conceptual overview of the laboratory configuration.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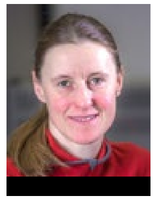
Power Systems Integration Lab Staff and Affiliates

Dr. Marc Mueller-Stoffels

Marc is the Director of the Power Systems Integration Program and Research Assistant Professor with the Institute of Northern Engineering.

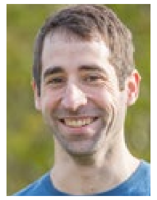
David Light

David is a Research Engineer for the Power Systems Integration Program and the Chief Engineer for the PSI Lab.



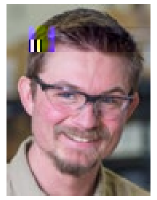
Heike Merkel

Heike is a Research Engineer in charge of Project Management for the PSI Lab.



Luis Miranda

Luis is a Research Engineer for the Power Systems Integration Program.

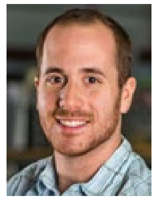


Jeremy Vandermeer

Jeremy is a Research Engineer for the Power Systems Integration Program.

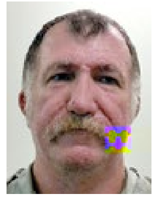
Dr. Daisy Huang

Daisy is the Assistant Professor for Energy in Mechanical Engineering.



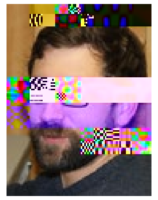
Nick Konefal

Nick is a Research Engineer for the Power Systems Integration Program.



Phil Maker

Phil is an Adjunct Research Professor for the Power Systems Integration Program.



Dr. Hendrik Schaede

Hendrik joined ACEP as a Postdoctoral Fellow (faculty employee) for three months, working on energy storage application modeling, sizing and control integration. Hendrik also spent one month at Cordova Electric Corporation (CEC) to support an ongoing project with ACEP to maximize CEC's hydropower utilization.

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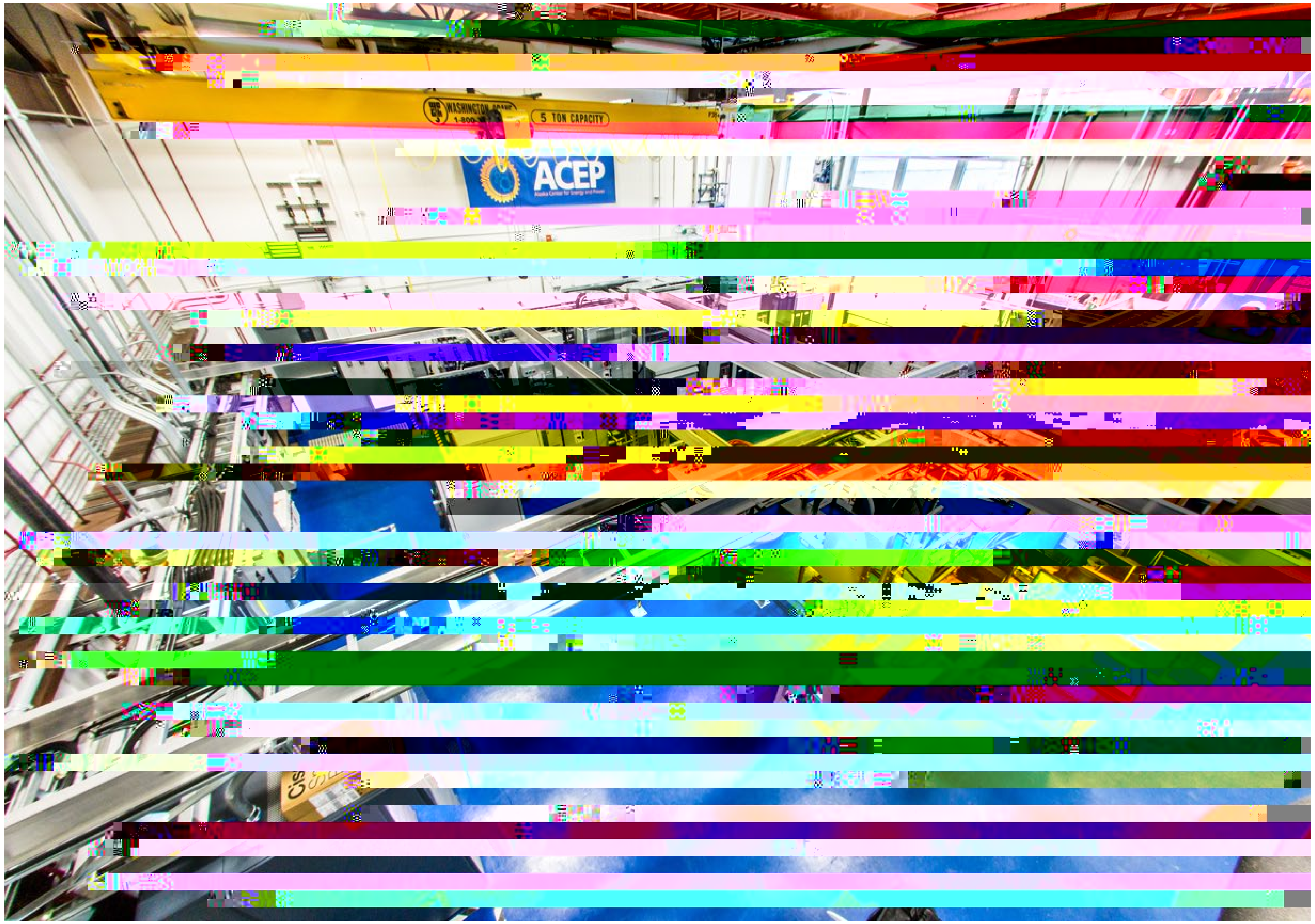
Power Systems Integration Lab **Hardware**



The Grid

The PSI Lab grid is based on a 480 VAC three-phase architecture, with secondary 208 VAC connections available.

The basic bus infrastructure is a 12 station switchgear that can carry up to 600 A continuous capacity. Particular grid configurations are achieved by switching of main circuit breakers.

Each piece of equipment is further protected by individual secondary circuit breakers, which generally also act as the switching breakers in automated control schemes.

Data Collection and Management

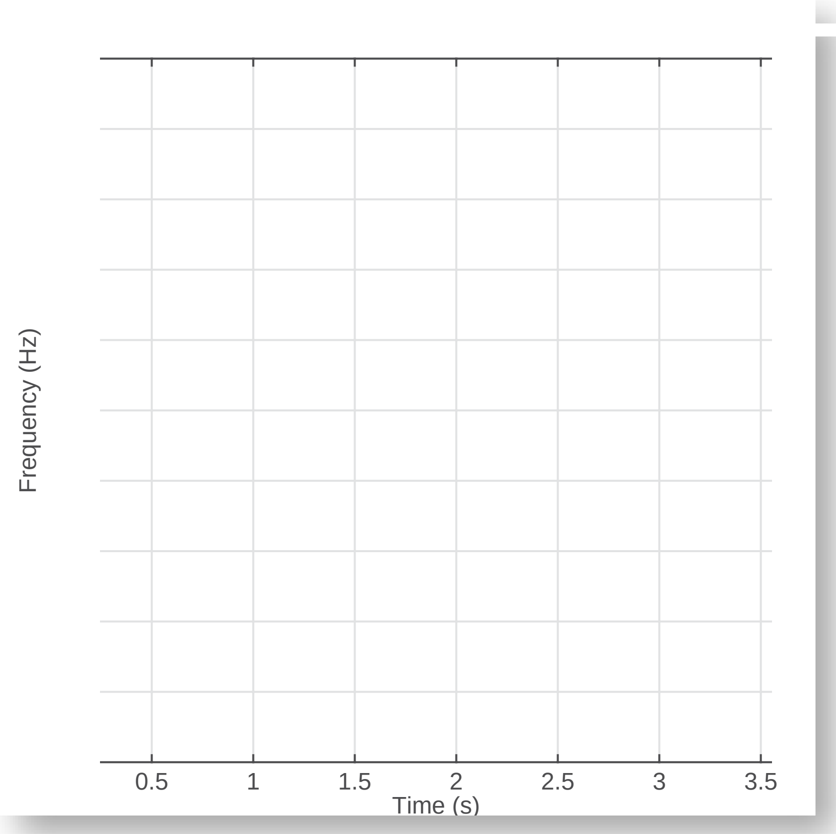
Data from over 1000 channels is permanently logged when the laboratory is in operation. This data ranges from basic electrical measurements to all available diesel generator data, and independent fuel consumption measurements. All data is stored in daily files, one per channel, in netCDF format, and can quickly be retrieved and searched for relevant events on the fly.

Meters

Meters used for general data acquisition from all energy sources and sinks are either Electro Industries' Shark 100 B and T, or Elkor WattsOn. All meters communicate via Modbus TCP. The meters provide data at a rate of about 5 S/s. In addition to the standard utility-grade meters, an Elspec GS4300 BlackBox power quality analyzer is permanently installed on the feeder to the 480 VAC load bank. This meter provides permanent logging of voltage and current waveforms at 1024 S/cycle and 512 S/cycle respectively.

Additional Equipment

The laboratory LAN is managed by a Netgear FSV318G router. Additional ports are made available via several switches. A WAN connection can be made available via an eWON Cozy router and eWON's VPN software. Time keeping for data acquisition and control is provided by a Tekron NTP server. Data acquisition is driven by a PC with Fedora Linux OS and data is routed to a Buffalo TerraStation, striped and mirrored RAID, network attached storage drive with four physical hard-drives.



Custom Control Architecture

The ETF SCADA is a Supervisory Control and Data Acquisition (SCADA) system, developed by ACEP to control the Energy Technology Facility (ETF) power generation and permanently monitor all available data channels.

It is a modular software composed of two separate programs:

- Data Acquisition (DA) module, responsible for requesting data from each individual device and broadcasting the data throughout the network;
- Supervisor Control (SC) module, receives the data from a DA module, which afterwards processes, catalogues and analyses the data in order to check if the values are within compliance or if an operator should be notified.

The ETF SCADA was designed to be fully customizable, adapting to any

Supervisory Control Module

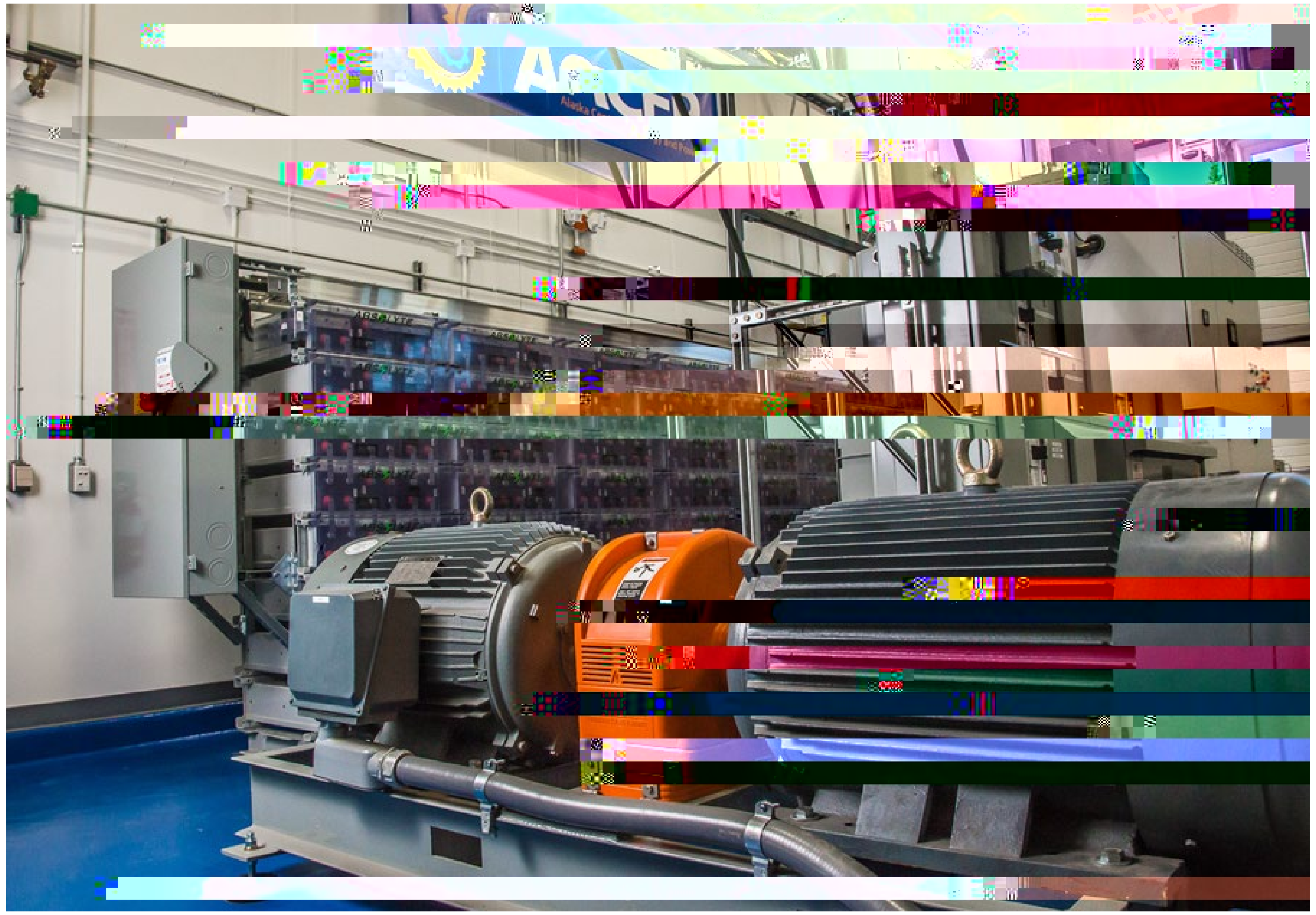
This module can act as a passive terminal, collecting the data sent from a DA module. In this configuration the DA module can send data to an

Diesel Generators

The lab provides a flexible infrastructure to test diesel engines from 50 kW to several MW nameplate capacity. The built-in cooling and exhaust systems can receive generators up to 400 kW nameplate capacity. Larger generators require their own cooling system.

ABB PCS100 ESS

A 313 kVA ABB PCS100 line-up is used as the power conversion unit for energy storage systems. The line-up comprises six PCS100 modules which are directly controlled and coordinated via CAN bus and a control computer. The interface for basic HMI, interaction with battery management systems, and external control is provided by an ABB AC800M PLC via Modbus TCP. This PLC coordinates AC and DC motorized breakers, provides top-level controls and status, as well as coordination for various protective settings. The PCS100 modules are of the high DC voltage type, and designed to achieve nominal AC output voltage (318 VAC) between 450 VDC and 1100 VDC. Grid voltage is achieved via 318 to 480 VAC Delta-Wye isolation transformer. The inverter can be operated at voltages between 250 VDC and 450 VDC. At these lower DC inputs it only achieves 254 VAC, additional



PV Emulator (DC Power Source)

Capacity
100 kVA DC

Controller
NI LabView/C++ API

Protocol
Modbus TCP, others

Switching
Contractor

Status
Operational

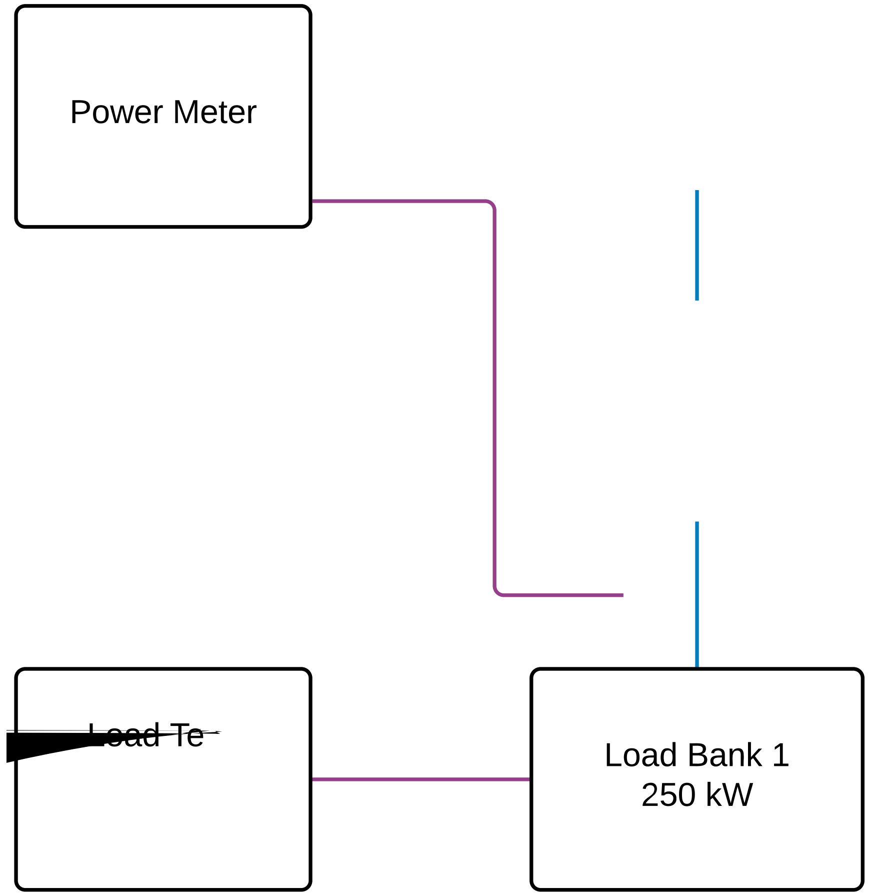
LoadTec Load Banks

Two 313 kVA reactive load banks on separate feeders are available. Both load banks can be controlled in 5 kW/3.75 kvar load steps and can operate down to 0.8 power factor at full load. The older load bank operates at 208 VAC and is couple to the grid via Delta-Wye step down transformer. This load bank can be controlled via an HMI panel or via a software tool with RS-232 connection. Efforts are underway to decode the communications protocol and place an RS-232 to Modbus TCP decoder as the main communications interface.

The newer load bank operates at 480 VAC and is directly coupled to the grid. This load bank can be controlled via an HMI panel or via a software tool with TCP communication.

The TCP communication has been decoded such that the load bank can be controlled via ACEP-custom developed software. This will also allow to simulate demand management with this load bank. An auxiliary connection is available on this feeder to connect a 55 kW manually operated load bank such that moderate phase imbalances can be created for testing.

Capacity	2 x 313 kVA
Controller	LoadTec
Protocol	Proprietary TCP/Serial
Switching	Contactor
Status	Operational



Power Systems Integration Lab Expansion Plans

Fault Emulator

The fault emulator provides the means of creating bolted faults in the PSI Laboratory grid with fault currents up to 10 kA at 480 VAC. This capability allows us to ascertain the fault response of equipment in the laboratory that could be encountered under typical fault conditions in the distribution grid, both under phase-to-phase and phase-to-ground fault conditions.

Understanding fault dynamics is important when transitioning from synchronous machine-based to power electronics-based generation. For the latter, fault dynamics are less well understood, and configurations of breaker coordination and trip dynamics may have to be reassessed.

At the core of the fault emulator are distribution cut-out fuses, which can be selected for fast, high-current fault characteristics or slower lower current fault characteristics. The emulator can be controlled such that a it can close into a particular point in

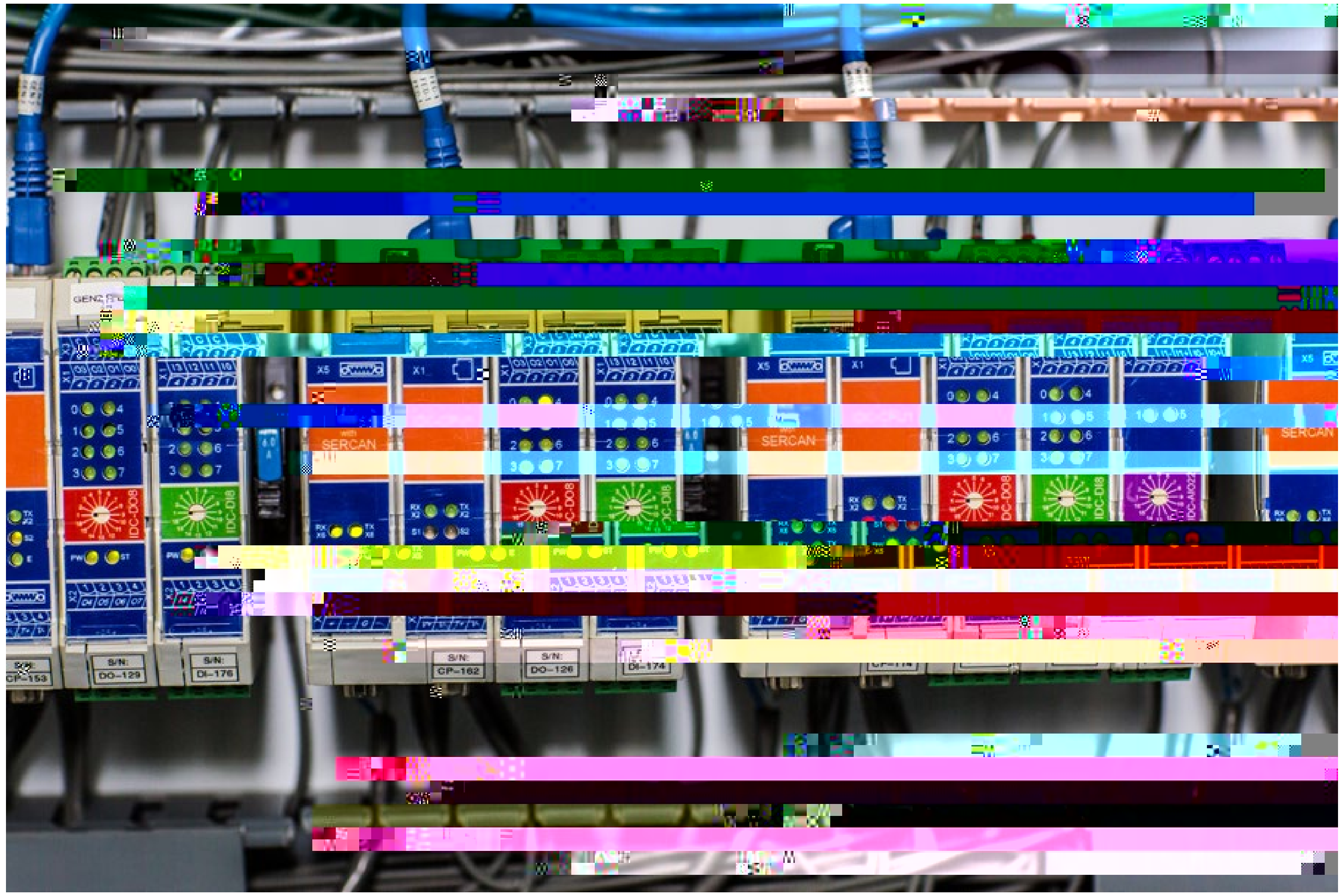
ABB MGC600 Distributed Control System

The ABB M+ Control System is a distributed top-level control system specifically developed for islanded microgrids. The system is comprised of dedicated control modules for each generation source and feeder (MGC600), and a central data aggregator and HMI interface (M+ Operations). The M+ manages dispatch of renewable and diesel power, controls services provided by energy storage systems, and provides the ability to automate a remote power plant, including black start capabilities, if equipment permits.

Depending on the underlying local controller, the M+ communicates via Modbus TCP, Modbus RTU, or hardwire I/O, where time sensitive decisions have to be transmitted.

The M+ system in the PSI Lab consists of two MGC600G (diesel), two MGC600F (feeder), MGC600W (wind), MGC600P (PV), and MGC600E (energy storage). Additional modules can be added as required for a particular system configuration.

M+ Operat



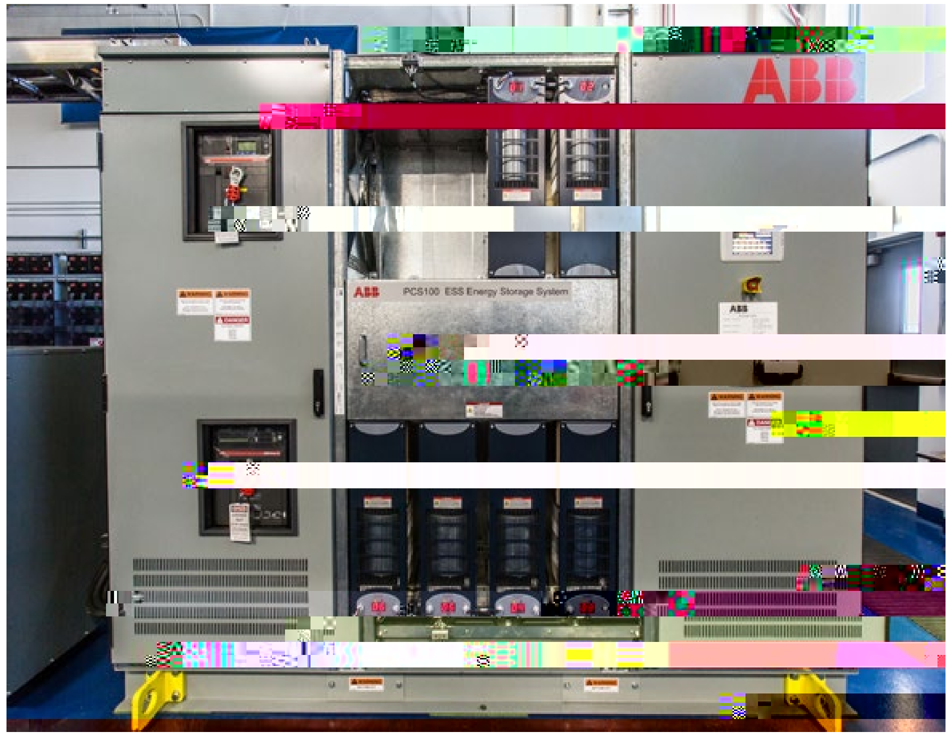
Project Spotlight: Hatch Associates Consultants, Inc.

FLYWHEEL ENERGY STORAGE INTEGRATION

From the summer of 2014 to mid-January 2015 Hatch tested a flywheel energy storage system (FESS) and associated control system in ACEP's Energy Technology Facility (ETF). The project integrated a Williams MLC200 flywheel (200 kW/1.5 kWh), an ABB PCS100 inverter, a 320 kW diesel generator, and the Hatch Microgrid Control System which coordinated the flywheel and diesel power outputs in response to variations caused by the programmable wind tubine simulator and load bank.

In addition to demonstrating the performance of the flywheel, Hatch also developed and optimized control algorithms to manage the components of a wind diesel- flywheel system in order to maximize diesel fuel savings. Hatch aims to solve this problem with their FESS but first needed to test their technology in a controlled microgrid setting. ACEP was able to provide the needed test bed with its ETF located at the University of Alaska Fairbanks.

Subsequently, Hatch has deployed a system based on the design tested at ACEP at the Raglan Mine in Northern Canada.



Above: A new ABB Inverter was purchased by ACEP for the testing of Hatch's flywheel system. UAF PHOTO BY TODD PARIS

Right: Flywheel energy storage system in ACEP's ETF. ACEP/UAF PHOTO BY MAX FREY

> **"The ACEP team was a pleasure to work with and critical to the successful execution of our project. As a complement to the first class test facility, they brought a deep knowledge of remote microgrids and the technical know-how which resulted in an error free installation, so we could focus on testing our technology." — Dave Delves,** Manager, Technology Development–Project Delivery Group, Hatch Associates Consultants, Inc.

Project Need

Historically, Cordova's hydropower has been sufficient to meet nearly all demand during the summer months. However, recent increases in energy demand from the fish processing industry has exceeded the capacity of the hydropower plants, forcing CEC to supplement with diesel generation.

Currently, when hydropower is the sole generation source, one 3 MW hydropower turbine is used for frequency regulation, which results in a reduction of 500 kW of available capacity. While hydropower capacity is not sufficient to meet daytime demand, the hydropower plants do not operate at full capacity during off-peak hours. Since these hydropower systems do not include dams that provide water storage, the water that is normally diverted for power generation is simply spilled down the creeks. The result is significant loss of potential power production and, thus, power sales from a very cheap generation resource. The need for alternative frequency regulation services, along with the desire to maximize the use of hydropower, is the impetus for this study, which assesses the technical and economic feasibility of achieving maximal hydropower use via energy storage and demand response technologies.

Project Description

The project goal was to provide Nome Joint Utility Services (NJUS) with data analysis, models, and additional information to support technical and economic decision-making processes. The Power Systems Integration Program directly provides technical information to NJUS, and informs the Economic Analysis Group at ACEP of technical information relevant for economic modeling. The first phase was concerned with the interaction of energy resources (wind, geothermal, and diesel), to understand the impact of several generation scenarios on the overall amount of wind power that can be added to the grid, with risk of under-loading diesel generators. Since NJUS recently added additional wind resources and new diesel gensets, existing historic data could not be directly employed to drive model development. Statistical methods were employed to extrapolate wind power output from the extended wind farm. This data was fed into a time-series energy balance model (TSEBM). The TSEBM matched energy generation with demand while considering the operational envelope of the diesel generators (scheduling and minimum and maximum optimal loading) and general grid stability. Information gained from TSEBM outputs showed the amount of wind power that cannot be admitted to the grid (spilled wind) and the optimal diesel-scheduling scheme based on current generation assets. The second phase explored how energy storage solutions may be used to:

- ensure greater grid stability and power quality, should that be required, and
- determine if an energy storage solution can economically reduce the use of diesel fuel by replacing the spinning reserve generally provided by diesel generatorunt of20Bqded

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ACEP CLIENTS AND COLLABORATORS (2008 – PRESENT)

ABB
ABS Alaskan
Air Force Research Laboratory
AK Department of Environmental Conservation
AK Division of Geological and Geophysical Surveys
AK Division of Forestry
Alaska Energy Authority
Alaska Housing Finance Corporation
Alaska Power and Telephone
Alaska SeaLife Center
Alaska Village Electric Cooperative
Alaska Wood Energy Development Task Group
Ambri
Argonne National Lab
Battelle
Begich Middle School
Bering Straits Native Corporation

Boise State University
Boschma Research
BP
Bureau of Land Management
Bristol Bay Native Association
Charles Darwin University
Chena Hot Springs Resort
Chena Power
City of Galena
City of Nenana
City of Nome
City of Tanana
City of Tenakee Springs
City and Borough of Yakutat
Cold Climate Housing Research Center
Cordova Electric Cooperative
Crowley Marine Services
Denali Commission

Mount Edgecumbe High School
NANA Corporation
National Renewable Energy

National Energy Technology

Nenana Native Council
Nome Chamber of Commerce
Nome Joint Utility Systems
Norton Sound Economic Development Corporation
Northern Power

Northern AK Career and Technical Education Center
Northwest Arctic Borough
Northwest National Marine Renewable Energy Center
Ocean Renewable Power Company

Oregon Wave Energy Trust
Patriot Solutions

Prudent Energy

Southwest Alaska Municipal Conference
Stanford University
Susitna Energy Systems

TDX Power