

RPPR Final Report
as of 13-Jul-2022

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Final Report for Period Beginning 13-Sep-2019 and Ending 12-Sep-2021

Title: Acquisition of a Laboratory-Scale Steam Power Plant to Advance Thermal Power Systems Research and Education

Begin Performance Period: 13-Sep-2019

End Performance Period: 12-Sep-2021

Report Term: 0-Other

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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 0

STEM Participants: 9

Major Goals: Goal 1: Acquire and install a steam-turbine power plant in the unit operation laboratory.
Goal 2: Retrofit the steam-turbine machine by integrating a LabVIEW-based automatic control system.
Goal 3: Collect the operational data for thermal process modeling.

Accomplishments: Major activities: Acquire, install, and operate a laboratory-scale steam-turbine plant

Specific objectives: Test and operate the equipment to ensure the performance and collect enough process data.

We have achieved above objectives by running the equipment for many hours. Operating data has been collected for the process modeling work. We also tuned the system to achieve nearly maximum power output (50 W).

The future work is to develop a modern control system for the steam power plant. Our team has acquired the hardware (FPGA: CompactRIO) and made the control scheme in LabVIEW. The retrofit of this steam power plant by embedding a new control system will be our next objective.

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Training Opportunities: The PI has collaborated with the mechanical engineering department instructor to run this steam-turbine power plant and collect data. A Ph.D. student from mechanical engineering department was involved in training to operate the system.

A PhD student from chemical engineering department is using the data and system setting of this equipment to build an Organic Rankine Cycle model based upon MATLAB Simulink.

Totally 7 undergraduate students enrolled in chemical engineering department course: Thermodynamics II, are training to use this machine to model the basic Rankine cycle.

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

Partners

I certify that the information in the report is complete and accurate:

Signature: Yu Yang

Signature Date: 11/16/21 7:22PM

Final Report to DoD-ARO (Contract NO. W911NF1910499)

**Acquisition of a laboratory-scale steam power plant to
advance thermal power systems research and education**

By

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Nov. 2021

Abstract

This final technical report shows the status of a laboratory-scale steam-turbine system at the California State University Long Beach (CSULB), a Hispanic-Serving Institution. We acquired this power plant from G.U.N.T. under the support from DoD HBCU/MI equipment grant. This equipment will contribute to the research and education on the real control system development and optimization techniques for thermal energy systems. We achieved the educational mission by training several undergraduate students from both the Chemical and Mechanical departments through this equipment. Two PhD students are using the data and system setting of this equipment to design the organic Rankine cycle model for control and optimization purposes. Our future plan is to retrofit this power plant by integrating a modern control system developed by our research team.

Scientific Progress and Accomplishments

The Chemical Engineering Department at CSULB (a Hispanic-Serving Institution) uses HBCU/MI equipment grant to acquire and install a steam-turbine system in the building EN4-125. The purchased equipment includes:

- ET 850: Steam Generator
- ET 851: Steam Turbine

We overcame the troubles of COVID-19, coordinated vendors, and successfully installed the system at the end of 2020. We guarantee that the equipment and space meet all safety protocols.

This laboratory-scale steam power plant will have broad impacts to enhance the research and education capability of the college of engineering at CSULB.

- For research, it generates a large amount of operational data for process modeling and serves as a testbed for process control methods validation.
- For education, it is relevant and applicable to a wide range of disciplines in both chemical and mechanical engineering, such as thermodynamics, heat transfer, control systems and fluid dynamics.

This steam-turbine system has safely operated for many hours in our laboratory and used for thermodynamic courses in both Chemical and Mechanical Engineering departments. There are 7 undergraduate and 2 PhD students using this equipment during Summer and Fall semesters 2021 to learn and conduct the research of thermal-power system. We will allow all students enrolled in these two departments to use the data generated from this machine to learn thermodynamics.

The PI has been leading the research team on the process identification, machine learning, control system design, and real time optimization of the steam-turbine system.

- A research proposal based on the data collected from this steam-turbine system has been submitted to American Chemical Society-Petroleum Research Fund (ACS-PRF). The research topic is the machine learning of energy systems.
- A PhD student is working on the process modeling of organic Rankine cycle (ORC) by using the data and system setting of this laboratory-scale power plant. A MATLAB Simulink based model has been created by replacing the steam by isobutane. A model predictive control algorithm is under developing.

PI and his team plan to retrofit the system as the next step. We will mount FPGA on the cooling water and fuel injection modules to enable the automatic control of the entire plant. The objective is to design advanced control algorithms for the steam-turbine and optimize the energy conversion (from natural gas to electricity).

The new knowledge and techniques developed using this equipment will help the U.S. military to improve the energy efficiency in their base, ships and other battle agents powered by microturbines.

Appendix



Figure 1: Steam-turbine plant in EN4-125 @ CSULB

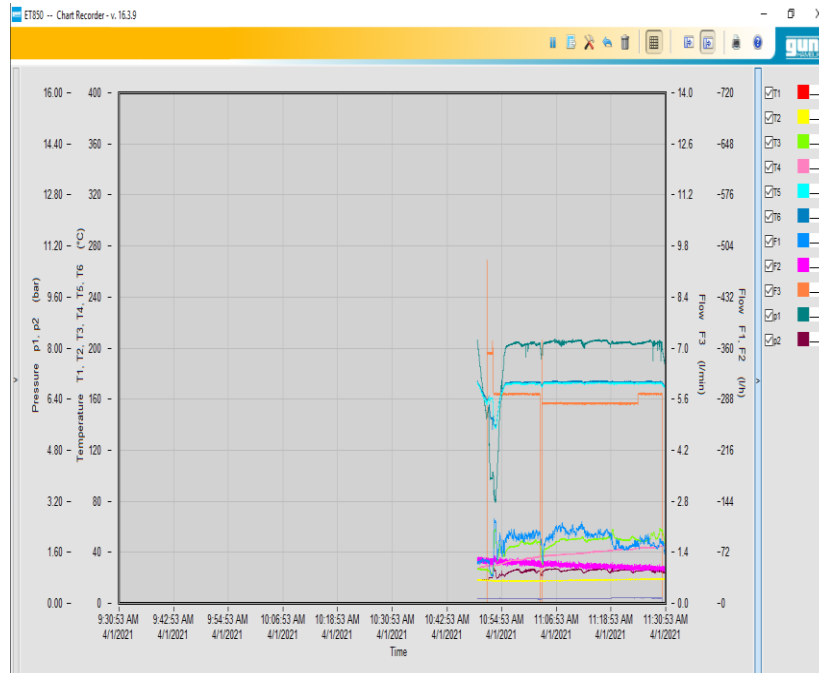


Figure 2: Data collection panel of the steam-turbine plant

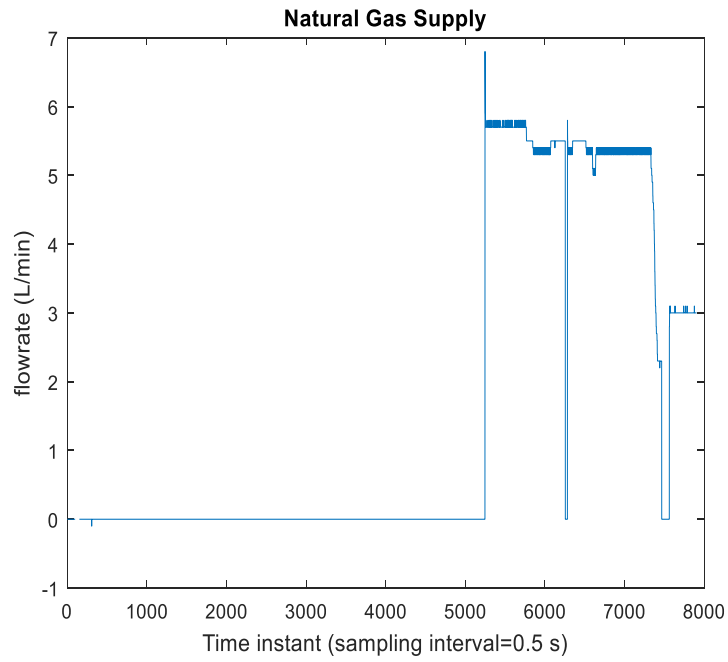


Figure 3: Natural gas supply

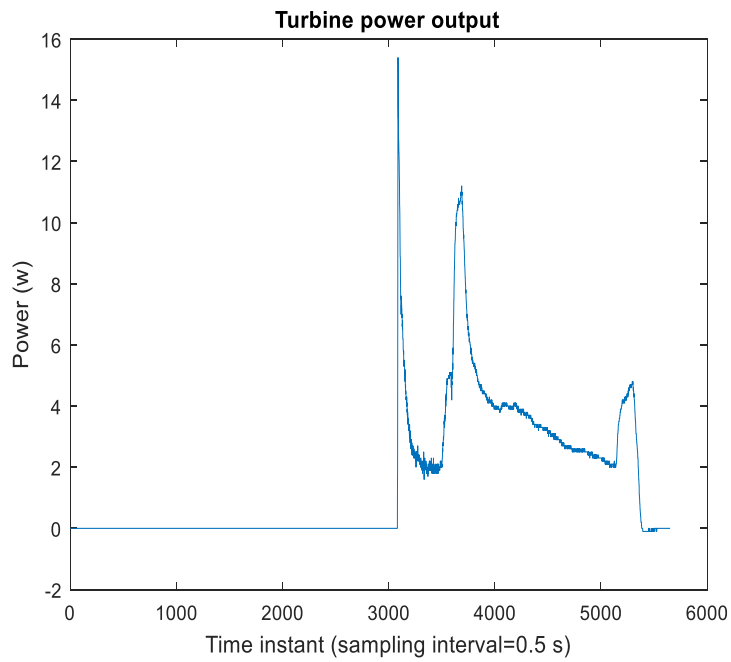


Figure 4: Turbine power output