

# NETL/ORISE OPPORTUNITY ANNOUNCEMENT

<b>TITLE:</b>	Summer Projects for CIESESE (Consortium for Integrating Energy Systems in Engineering & Science Education)
<b>DEPARTMENT:</b>	U.S. Department of Energy/National Energy Technology Laboratory (NETL)
<b>NETL CONTACT:</b>	David Tucker, <a href="mailto:David.Tucker@netl.doe.gov">David.Tucker@netl.doe.gov</a>
<b>DUTY LOCATION:</b>	Morgantown, WV; Albany, OR
<b>LEVEL:</b>	Undergraduate; Graduate; Faculty
<b>POSITION INFORMATION:</b>	Summer appointments (10 weeks - full time)
<b>CLOSING DATE:</b>	January 31 <sup>st</sup> , 2018
<b>WHO MAY BE CONSIDERED:</b>	United States Citizens

## SUMMARY:

Students and visiting scholar candidates are sought to engage in collaborative research with scientists at NETL's Research and Innovation Center (R&IC). Individual projects will be modified to accommodate the interest of students or professors participating in the project. It is expected that sufficient novelty from each of these projects could result in one or more peer-reviewed publications. Also, other projects could be developed if there is sufficient interest. NETL is seeking researchers for projects in the following research areas:

### 1. Cyber-Physical Chemical Looping Reactor Observer

NETL has pioneered the use of cyber physical systems to develop promising advanced technologies. This approach has provided a new paradigm when integrating complex processes and its utility has been demonstrated on concepts even before a process concept reaches full maturity, as in the case of the solid oxide fuel cell – gas turbine (SOFC-GT) hybrid power system demonstrated as part of the Hyper project (hybrid performance). NETL now wants to extend this approach to another developing technology – chemical looping systems. Chemical looping is a process that converts fossil fuels using a solid oxygen carrier, enabling highly efficient clean-up of the products of combustion. Using a cyber physical observer, a multi-stage, fluidized bed, chemical looping reactor (CLR) are being developed to control and speed the development of this technology. This concept uses an ambient temperature or cold flow transparent reactor to enable direct observation of the granular oxygen carrier particles to establish the process state in the hot CLR. In this way, unstable solids flow conditions and process upsets can be avoided and process improvements can be evaluated. Existing cold flow test apparatus must be adapted, system identification studies conducted, real time models and controls developed, and performance validated by running both the cold flow test facility and the pilot scale hot test rig. There are ample opportunities to contribute to this exciting new approach combining real time computational modeling with operational physical hardware and to

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publishing the results in Scientific and Engineering journals. Location: NETL Morgantown, WV; Mentor: Lawrence Shadle ([Lawrence.Shadle@netl.doe.gov](mailto:Lawrence.Shadle@netl.doe.gov)), David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 2. Online Recursive System Identification and Adaptive Control of Hybrid Power Systems

Hyper facility couples a physical gas turbine with the SOFC model through a cycle physical approach. This project consists of running Hyper facility to obtain dynamic data in real time while simultaneously run the algorithms of on-line system identification to obtain recursive models (state spaces models). The models obtained will be utilized for real time adaptive control. The outcome of this project would facilitate the application of linear controls in the complete bounded fuel cell turbine hybrid power system envelope. The linear identification and control could be obtained for any operating point of the system and work with several actuators at the same time. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 3. Compressor Surge and Stall

The first step in improving the operability of Hyper is to develop a control strategy to minimize risk of compressor stall during transient operations. This represents a formidable task considering the impact of the added pressure drop and compressor plenum volume introduced to the problem. The use of bleed air will be considered initially because of its application in avoiding surge and stall in commercial turbines. Because the turbine in a hybrid cycle is fired remotely, fuel modulation is not expected to have as much of an impact on surge avoidance, especially considering the time response required. This project will focus on examining several methods for detecting and mitigating compressor surge and stall during transient operation. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 4. Fuel Flexibility in Hybrid Systems

NETL has made a significant progress in understanding the dynamics of a solid oxide fuel cell gas turbine hybrid power system. One particular research interest is exploring the capability of this hybrid technology under fuel flexible environment. With the potential to run SOFC systems using many different types of fuel, NETL believes that transitioning one fuel composition to another can be advantageous for load following or cycling mode operations to vary output products, such as liquid fuels and electricity for polygeneration plants. As such, this system can offer a greater flexibility to improve the availability of power infrastructure and economic viability. The fuel flexibility is also beneficial to handle fuel cell thermal management, as an example of using high methane content fuel. To date, the actual range of fuel flexibility that could be implemented in the SOFC/GT hybrid system under different transient circumstances is still unknown. As there are high coupling issues between the SOFC/GT components, system identification is very critical to understand the transient response in the system to fuel types and fuel processing units. Controls for thermal management and fuel cell degradation for fuel flexible SOFC/GT systems are also not yet available. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 5. RAMAN Gas Analyzer for Control in Advanced Power Systems

With the purpose of studying advanced hybrid power systems utilizing gasifier technology, the effect of fuel composition changes on the system dynamics must be addressed. Outlet syngas

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compositions from different gasifiers vary depending on the type of coal. Small changes in composition can cause significant variations in turbine speed and other system parameters if no control strategy is applied. Without a direct measurement of composition system stability could be a significant issue, especially during transient conditions. The Raman Gas Analyzer (RGA) was designed and constructed at NETL to provide a fast (realtime) measurement of the major components of a fuel gas, to design novel control algorithms based on advanced power systems under sudden variation of fuel compositions. Two RGA prototypes have been constructed. Installation and testing in the Hyper facility provides the opportunity to demonstrate new control strategies applied to a gas turbine recuperated cycle designed for hybrid configuration. To demonstrate a rapid change in fuel composition, in a short-term test, the approach selected is to blend bottled nitrogen into the natural gas supply line. The dilution will be adequate to change the combustion conditions (reduce the heat produced) in the turbine combustor, and controls can be developed. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 6. Supervisory Control

The purpose of this project is to develop a supervisory control scheme for load following in SOFC-GT hybrid system. The objective is to divide power generation between the fuel cell and the turbine during power demand changes, i.e. responding faster with the gas turbine and then adjusting the fuel cell load over a sufficient time in order to avoid excessive temperature oscillation in the fuel cell. Temperature variation represents a constraint in the control problem. In the first stage, the control architecture will be implemented and tested on a numerical model. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 7. MISO + MIMO or Feed Forward MISO

The design of a baseline control strategy is essential to evaluate the controllability of advanced hybrid power systems. The coupling of diverse devices into advanced hybrids represents one of the most important advantages to increase the efficiency of future power technologies. Hybrid power systems currently being considered for development and deployment include coupled fuel cell – gas turbine, concentrated solar power (CSP) – gas turbine, thermal energy storage – gas turbine hybrids, and CSP – geothermal systems. In many cases, these coupled hybrid systems present significant controllability challenges because of the tight nonlinear coupling between two or more systems, each with different time scales, dynamics, and thermal energy needs. Specifically, the most challenging aspect is represented by the strong variability in the thermal energy source from upstream devices during transient operations, such as sunlight unpredictability or load following operations. As a result, new control strategies are needed that can timely provide turbine speed stable operation under sudden thermal source variability using one or more actuators. This project will focus on multi-input single-output (MISO) and multi-input multi-output (MIMO) control strategies to control the turbine speed using a simultaneous control of the auxiliary fuel valve and the bleed air valve in a fuel cell turbine hybrid system. A non-linear programming procedure based on the state-space concept was developed in the simulation environment. Turbine electric load perturbations will be used to test the algorithm. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 8. Startup and Electrochemical Light-off

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SOFC-GT hybrid power systems represent an opportunity to double the efficiency of standard pulverized coal power generation technology and reduce harmful emissions associated with power generation by 50%. To reach this level of efficiency, the complexities of the highly-coupled SOFC-GT cycles must be resolved. Hyper will examine all stages of operation but focus primarily on turbine startup and fuel cell heating. One inherent complexity of the SOFC-GT hybrid system comes from wide discrepancies in the individual component response times. It is well known that the mismatch between fuel cell and balance of plant time constants make the control task arduous for all operating regimes. This is most noticeable during the startup process of direct-fired hybrid cycles, where the compressor airflow feeds directly into the cathode side of the fuel cell. For synchronous operating speed, both the turbine and fuel cell must commence operations simultaneously under a coupled (fuel cell and turbine) hybrid configuration. This requires careful coordination of the turbine's startup ramp rate, and the cathode airflow input to avoid spatial and time dependent temperature gradients within the fuel cell material. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 9. Anode Recycle

The aim of this project is to fully characterize the system at different anode recycle rates (ARR), with the final goal of adding a degree of freedom to the present control strategy to Hyper facility. ARR will be considered an additional manipulated variable to increase the flexibility of the system, and a control strategy will be implemented to exploit this new flexibility. Possibly, ARR will be used to mitigate cell degradation over time and/or maintain fuel cell performance during degradation. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 10. Component Degradation

As part of the Hyper project, single input-single output controllers have been designed to regulate variables that directly affect fuel cell degradation in a hybrid system. A required work is to test the complete control strategy (all the controller simultaneously) on the Hyper facility and characterize the system in a broad range of operating conditions while the cell is degrading. This will give a better understanding of long-term operations of the system. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

## 11. Modeling the NETL Microgrid

In order to showcase advanced power technologies, NETL researchers have developed a concept for a microgrid to provide electric power to the Morgantown campus. This microgrid will assure continuity of power to safeguard equipment, resiliency to effectively serve as a refuge for the federal government in the event of evacuation of Washington DC, and meet the Net Zero Energy government wide operational goals, while also providing infrastructure to demonstrate new technologies. Preliminary designs are required to define the size and scope of this microgrid, defining the features needed and to model the manner in which it will operate. Of particular interest is the desire to incorporate cyber physical research approach that promises to reduce technology development time and assure that NETL retains our leadership in a quickly evolving electric power generation and supply network. This work will help to define the environmental footprint of a microgrid and well as provide the basis for "Greening" our power system. Location: NETL Morgantown, WV; Mentor: David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov)), Lawrence Shadle ([Lawrence.Shadle@netl.doe.gov](mailto:Lawrence.Shadle@netl.doe.gov))

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## 12. Magneto Hydro Dynamics

NETL's Direct Power Extraction Laboratory is located at the Albany Oregon site. In this lab, we perform experiments dealing with magnetohydrodynamic (MHD) power generation.

Experiments cover material response to the MHD environment (magnetic field, supersonic velocity, temperatures too high for current power-conversion technologies), and characteristics of the plasma jet and its ability to supply sustained power. The proposed project for the summer of 2017 is to work with the principal investigator to design and execute experiments which show how conductivity of the plasma-jet varies and what impacts arise from the boundary layer surrounding the jet. This will include design-adjustments to the channel which encloses the jet (built to both contain the plasma and allow sensors to read the jet without interfering with it); designing experiment campaigns; executing experiments; presenting results internally; submitting an article for publication in a peer-reviewed publication. Location: NETL Albany, OR; Mentor: Rigel Woodside ([rigel.woodside@netl.doe.gov](mailto:rigel.woodside@netl.doe.gov)), Danylo B. Oryshchyn ([Danylo.Oryshchyn@netl.doe.gov](mailto:Danylo.Oryshchyn@netl.doe.gov)), David Tucker ([David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov))

### HOW TO APPLY:

Applicants should apply through the Oak Ridge Institute for Science and Education (ORISE) program. The ORISE Program provides opportunities for undergraduate students, recent graduates, graduate students, and faculty researchers to apply classroom knowledge in a real-world setting to learn about NETL R&IC core mission areas.

- Interested applicants should complete the online application at <http://www.ornl.gov/netl/>.
- In the online application **list David Tucker as your requested mentor**. This will associate your application with this job posting. Please send a CV to [David.Tucker@netl.doe.gov](mailto:David.Tucker@netl.doe.gov) and [Nana.Zhou@netl.doe.gov](mailto:Nana.Zhou@netl.doe.gov).
- If you have additional questions please contact Patricia Adkins-Coliane, [Patricia.adkins-coliane@netl.doe.gov](mailto:Patricia.adkins-coliane@netl.doe.gov), who is the NETL Graduate Education Program Manager.