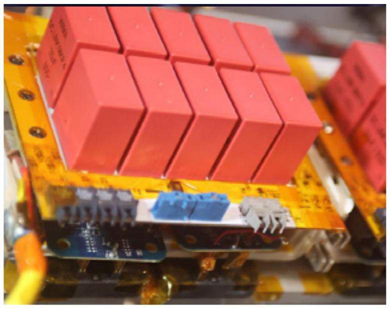
CIEES ANNUAL REPORT 2020-2022



CIEES
CENTER FOR INTEGRATED ELECTRIC ENERGY SYSTEMS
AT STONY BROOK UNIVERSITY

DIRECTOR'S MESSAGE

Dr. Vyacheslav Solovyov
Center Director

The Center for Integrated Electric Energy Systems (CIEES) is a part of the New York State network of Centers for Advanced Technology and is located at the Advanced Energy Research and Technology Center (AERTC).

The CIEES goal is to make New York a global leader in renewable energy technologies, and to foster the integration of renewable sources into the electric grid. CIEES supports collaborations with university experts and Brookhaven National Laboratories in the following thrust domains: electric grid technology, energy storage technology, and integrating storage in the grid.

Dear Colleagues,

It's been more than two years since the world first faced what would become the unprecedented challenge of the coronavirus pandemic. Today, as our nation and planet continue to recover, we resume our annual report, with a lot to share. The Center for Integrated Electric Energy Systems (CIEES) was not idle during that time.

While practicing safe protocols, CIEES maintained its ongoing effort to promote job creation and new businesses on Long Island and throughout downstate New York. During disruptions caused by COVID-19, CIEES clients quickly adapted to the new reality and continued to operate, and during 2019-2021 generated 57 new jobs while retaining 48. $17,689,773 of economic impact was recognized by CIEES industry partners between July 1, 2019, and June 30, 2021, aiding in the recovery process.

In addition, during the reporting period of July 1, 2020 and December 31, 2021, CIEES research programs generated 13 new technology disclosures, which were filed with the University Intellectual Property Partners office; and 7 new patent applications were filed by the University during the reporting period on CIEES research program technologies. Between 2020 and 2021, 13 new federal and non-profit grants totaling approximately $2,028,171 were received by CIEES faculty in support of CIEES research projects. Several companies, such as StorEn Technologies and ThermoLift, accomplished significant business expansion. After successful demonstration of the StorEn vanadium flow battery by the CIEES team, the company was able to raise $1,069,000 in private funding, which launched the development of a large-scale battery for telecommunication installations. This development is especially welcome on Long Island, which is experiencing unprecedented penetration of wind power from offshore wind farms in the Block Island area. And on May 18 2020, Thermolift Inc. received $426,500 for a demonstration program of their advanced natural gas-driven heat pump and air conditioner in Canada.

The Center also continued to expand its technical capabilities in microgrid and energy storage. Specifically, the Center secured two US NAVY projects, "Robust and Intelligent Integration of Micro-Grids to Improve Isolated Site Resilience" and "Management system for microgrid-tied kV-class supercapacitor units". Both projects are focused on the development of energy storage and energy management products for microgrids by utilizing the latest advances in broadband communication technologies. The projects involve New York companies, such as Unique Technical Services, Shirley, NY (battery and grid management), BrenTronics, Commack, NY (Li-ion grid-tied storage), and Ioxus Oneonta, NY (supercapacitive energy storage). The NAVY projects will also employ five SBU Ph.D. students who will receive hands-on training in microgrid development and operation. The CIEES team is in the process of installing the microgrid platform at the CIEES lab in the Advanced Energy Center.

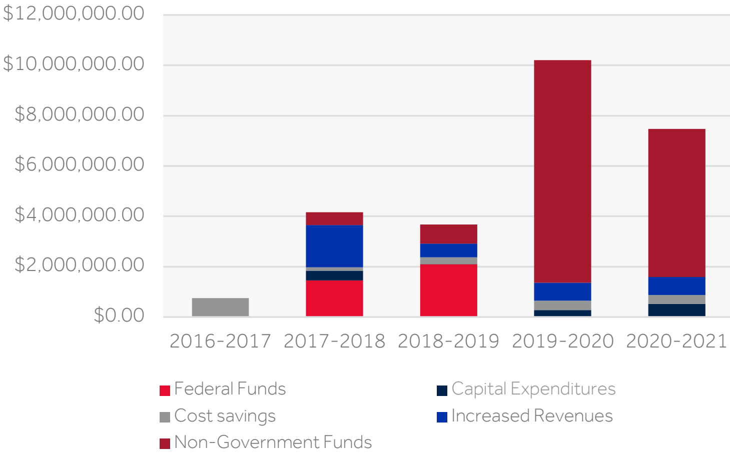
Also during this period, CIEES continued to support the New York State Climate Leadership and Community Protection Act (CLCPA), which envisions a transformation of the State's electricity grid to 70% renewable generation by 2030, zero-emission electricity by 2040, and an 85% economy-wide reduction in greenhouse gas emissions from 1990 levels by 2050. The Center's location on Long Island is strategic for utilizing 9 GW of offshore wind power for economic development opportunities for NY State. To this end, the Center's team won an award from the offshore wind power installer, Orsted Corp. to develop "Energy Storage Solutions for Transmission Planning and Grid Stability with Massive Offshore Wind Farms". This project will build a high-fidelity dynamic model and simulator of Zones K and I with offshore wind and storage, and comprehensively evaluate the benefit of storage control in improving the onshore grid stability.

Proudly, as part of the workforce development mission, CIEES continued to work with the Department of Electrical & Computer Engineering at Stony Brook University (SBU) on its outreach program during the academic year 2020-2021 as well as during the summer of 2021. This effort is committed to serve students in high needs schools and from underrepresented groups, meeting the requirements of the Next Generation Science Standards (NGSS)/New York State Science Learning Standards (NYSSLS). CIEES offered a virtual summer camp, 'Online Robotics Camp' for over 70 middle school students that had unprecedented success in attendance, in August 2020.

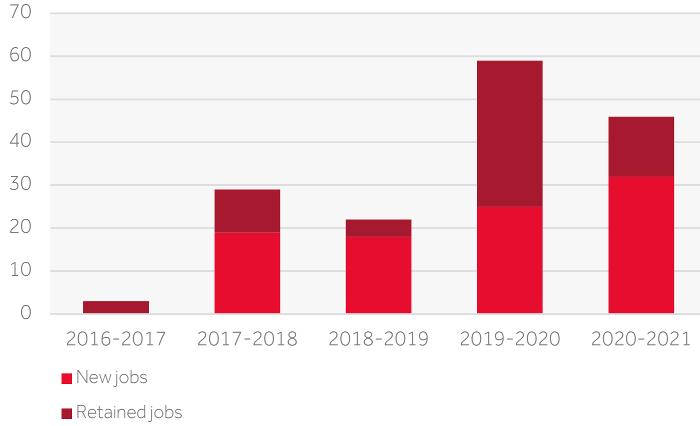
Moving Forward,
Slowa
Center Director, CIEES

CENTER IMPACT

ECONOMIC IMPACT



JOB CREATION



2020-2021 AT A GLANCE

MARCH 2020

Prof. Benjamin Hsiao, former Director of CIEES, receives the Prince Sultan bin Abdulaziz International Prize for Water - Creativity Prize

Benjamin S. Hsiao, distinguished professor, and Priyanka Sharma, research assistant professor, both from the Department of Chemistry at Stony Brook University, received the Creativity Prize — which is awarded to water-related interdisciplinary work — in the ninth Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW). The PSIPW is an internationally renowned scientific award established in 2002 by HRH Crown Prince Sultan Bin Abdulaziz. It recognizes innovative research aimed at finding solutions to today's global water-related challenges.

MAY 2020

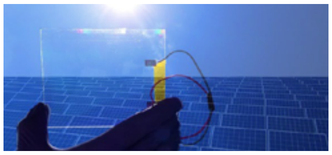
Dr. Priyanka Sharma, CIEES post-doc, is awarded the 2020 Young Academic Inventor's Award

Priyanka Sharma, a research scientist in the laboratory group of Distinguished Professor of Chemistry Benjamin Hsiao and CIEES, has been awarded the 2020 Young Academic Inventor's Award from the National Academy of Inventors, Stony Brook Chapter (NAI-SBU) for her inventions leading to the development of nitro-oxidation method to extract nanocellulose from raw biomass, which drastically decreases the consumption of energy, chemicals and water. The NAI-SBU was established in 2016 to recognize innovation and invention. Inventors are recognized for their imagination and accomplishments and called upon to share their special translational talents within the University and the wider community.

OCTOBER 2020

SuperClean Glass receives R&D 100 Award

Members of the Materials Science and Chemical Engineering Department together with SBU startup Superclean Glass Inc., a CIEES industry partner, have received the highly coveted R&D100 award from R&D World magazine, often referred to as the "Oscar of Innovation". Every year the magazine selects 100 most innovative products that exemplify revolutionary advances in science and innovation. The team included SBU Ph.D. candidate Shrish Patel and research professor Dr. Victor Veerasamy, together with the company-affiliated Dr. Alexander Orlov and Jim Smith. The electrostatic-based self-cleaning technology that promises to revolutionize solar plants deployment in desert regions was initially developed at Stony Brook at Prof. Orlov's Lab and won numerous business plan competitions before being licensed to SuperClean Glass Inc. for further commercial development.



R&D 100 AWARDS

APRIL 2021

Esther S. Takeuchi Elected to American Academy of Arts and Sciences

One of the world's leading energy storage researchers and a leader of CIEES energy storage thrust, Esther S. Takeuchi, the William and Jane Knapp Chair in Energy and the Environment at Stony Brook University, has been honored with membership to the elite American Academy of Arts and Sciences (AAAS), which recognizes the outstanding achievements of individuals in academia, the arts, business, government and public affairs.

2020-2021 AT A GLANCE

ThermoLift C.E.O. Paul Schwartz with the heat pump model

JULY 2021

ThermoLift received new investment from a Canadian venture fund

Canadian VC firm Natural Gas Innovation Fund is increasing its investment in Stony Brook-based ThermoLift, a CIEES industry partner – the first company in which NGIF Cleantech Ventures, the parent fund's $35 million seed fund for natural-gas innovations, has scaled up its capital outlay. ThermoLift's Thermal Compression Climate Control Device – a fuel-flexible heat pump that leverages a unique thermodynamic process called the Hofbauer Cycle to create both cost and energy efficiencies – is currently being tested in its first North American pilot program in concert with FortisBC Energy, an energy-solutions provider supplying natural gas, electricity and renewable energy to more than 1 million British Columbia customers.

Distinguished Professor Esther Takeuchi and David Brock, former SBU graduate student and BNL associate scientist, in the 'dry lab' in Brookhaven's Interdisciplinary Science Building.

AUGUST 2021

Dr. Takeuchi group receives $2.2 million DOE award on reducing carbon footprint of automotive sector

A research group led by Esther Takeuchi — distinguished professor in the Department of Materials Science and Chemical Engineering at Stony Brook and the William and Jane Knapp Endowed Chair in Energy and the Environment — has received an award of more than $2.2 million, part of a DOE initiative aimed at facilitating new technologies to reduce CO2 emissions from passenger cars and light- and heavy-duty trucks. In addition to Stony Brook researchers, the group will also include participants from Brookhaven National Laboratory (BNL) and Brown University. Fossil-fuel powered cars and trucks are a leading cause of air pollution and carbon emissions. According to the US Environmental Protection Agency, transportation is the biggest single contributor to greenhouse gas emissions. To help combat this, the US Department of Energy (DOE) is working to decarbonize the transportation sector.

The NSF DMREF Research team: Toshio Nakamura, Devinder Mahajan, T.A. Venkatesh and Clive Clayton

SEPTEMBER 2021

A team of SBU researchers receives $1.8 million DOE grant to develop future hydrogen technologies

A team of researchers in Stony Brook's Department of Materials Science and Chemical Engineering, led by professor T.A. Venkatesh, has been awarded $1.8 million from the National Science Foundation's (NSF) Designing Materials to Revolutionize and Engineer our Future (DMREF) program. The award will advance our hydrogen knowledge frontier and help enable a marketplace for a clean hydrogen economy. Stony Brook will lead the project in partnership with Stanford University, MIT and Sandia National Lab, in addition to industry partners National Grid and Exxon Mobil. CIEES is providing the team with access to analytical Facilties at the Advanced Energy Center.

StorEn 0.5 MWh flow battery prototype

OCTOBER 2021

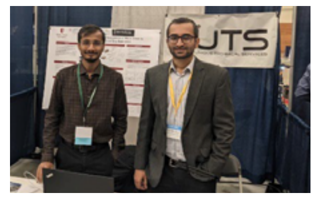
StorEn Technologies, CIEES industry partner, receives $6M investment for large-scale vanadium battery development

StorEn is developing rechargeable vanadium-flow batteries, which use vanadium ions in different oxidation states to store chemical potential energy. Vandium flow batteries have been proven to work: They already exist throughout major industry, used primarily as backup power sources. StorEn is focused on producing smaller, condensed prototypes suitable for smaller-load markets, including light commercial and residential applications. Currently, the company manually builds the stack – assembly, piled metal plates held together by metal bars – for each battery unit. It's a "very tedious job," according to Brovero, and "our next challenge is to complete an automatic assembly plant for the stack." Boosted by the crowdfunding windfall, that automation process will be a U.S.-based project, the CEO noted.

NOVEMBER 2021

CIEES team at NYSTAR Innovation Summit

CIEES team, for the first time in two years, presented at the New York State Innovation Summit on November 8-9, 2021 at the Turning Stone in Verona, NY. This multi-day event showcased emerging technologies that support innovation and drive business growth in NY State. The 2021 New York State Innovation Summit featured companies and researchers at the forefront of emerging technologies and new advancements in production capabilities. The CIEES team partnered wtih Unique Technical Services LLC, BAH Holdings LLC, ChemCubed LLC.



CIEES student team presenting industrial clients at the NYSTAR Innovation Summit

Professor Fang Luo, PhD, and Spellman C.E.O. Loren Skeist, MD, inspect a 3D integrated high-voltage GaN power module that Luo fabricated for electric vehicles.

DECEMBER 2021

LI-based Spellman High Voltage Electronics Corporation pledges a five-year support for the Spellman High Voltage Power Electronics Laboratory, Stony Brook University

SUNY Empire Innovation Associate Professor Fang Luo, PhD, in the Department of Electrical and Computer Engineering, and Spellman High-Voltage Electronics, establish Spellman High Voltage Power Electronics Laboratory (SHVPEL). SHVPEL, located in Hauppauge, NY, is the world's leading provider of custom-designed and standard AC-DC and DC-DC high voltage power converters and Monoblock® X-Ray sources for medical, industrial, semiconductor, security, analytical, laboratory, and under-sea cable power-feed applications. The laboratory will provide opportunities for cross-disciplinary collaboration at Stony Brook, from computer science and materials science to civil engineering and even the social sciences. Partnerships like the Spellman High Voltage Power Electronics Laboratory are critical to the success of Stony Brook's engineering programs as they integrate the University's commitment to experiential learning with real-time industry initiatives, standards and goals. The laboratory will train highly skilled workers for the power electronics industry. CIEES is currently working with Dr. Fang's lab on design and implementation of an exploratory microgrid.

FEATURED CIEES PARTNER PROGRAMS

INSTITUTE OF GAS INNOVATION AND TECHNOLOGY (IGIT)

MISSION

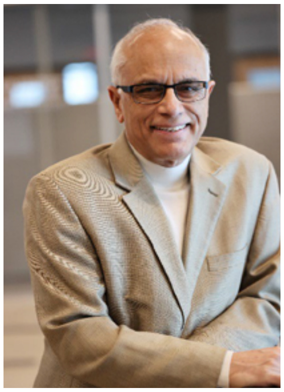
Use Academic-Industry platform to accelerate deployment of advanced energy technologies and infrastructure for gas to provide community residents and businesses with value-added services accomplished through innovative energy research, analysis, and education. CIEES works with IGIT on a variety of industrial applications of renewable hydrogen: efficient electrolysis, Hydrogen storage, permeability of pipe materials to high-pressure Hydrogen. The projects involve NY utilities, such as National Grid, ConEdison and small businesses.

RESEARCH

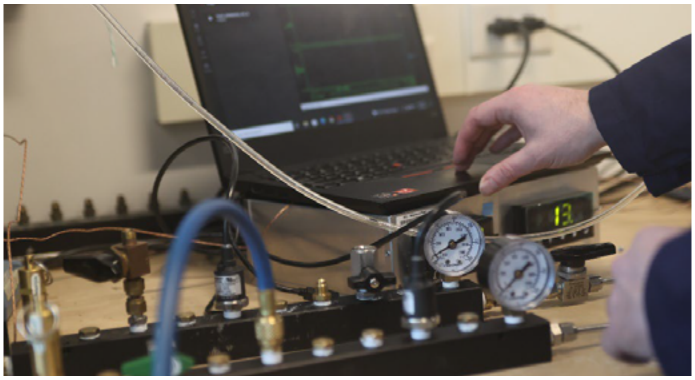
Carbon-based energy consumption and its environmental impact from released greenhouse gases (GHGs), such as carbon dioxide (CO2) and leaked methane (CH4), is now of immediate concern. In 2020, the recorded atmospheric concentrations of CO2 and CH4 were 416 and 1.89 ppm, respectively. However, CH4 is 84 times more potent than CO2, over a 20-year period, its CO2 equivalency calculates to 158.7 ppm, a rather serious number that cannot be ignored. About 2.5 million miles of pipelines transport natural gas, accounting for about 25 percent of all the energy consumed in the US each year. If the fossil-based natural gas is replaced with a greener substitute such as Hydrogen, there is an increased opportunity to deliver a transformative impact in the clean energy space and reduce GHG emissions.

The IGIT team studies the impact of partially replacing natural gas with renewable natural gas (RNG) and "green" Hydrogen. The benefits of utilizing RNG are that it has no climate change impact when combusted and utilized in the same applications as fossil natural gas. RNG can be injected into the gas grid, used as a transportation fuel, or used for heating and electricity generation. Less common applications include utilizing RNG to produce chemicals, such as methanol, dimethyl ether, and ammonia. For example, an IGIT assessment of the biogas potential on Long Island, based on the review of local landfills, wastewater treatment plants, solid waste generation and management, and agricultural waste, found that 234 x 106 m3 of methane (CH(4)) from biogas might be harvestable. However, currently, only about 10% of the State's resources are used to generate biogas, of which a small fraction is processed to RNG on the only two operational RNG facilities in the NY state. This is why "green" Hydrogen is essential in reducing NY state carbon footprint. Injecting RNG and "green" hydrogen gas into the pipeline system can reduce up to 20% of the State's carbon emissions resulting from fossil natural gas usage, which is a significant greenhouse gas reduction.

The team is working on a concept of storing intermittent electricity produced from renewables such as Hydrogen or RNG, an option formally known as power-to-gas, or P2G. This concept could deliver storage potential two orders of magnitude higher than batteries and would ensure a sustainable future for gas in coming decades.



Prof. Devinder Mahajan, Director of the Institute of Gas Innovation and Technology



Hydrogen storage experiment at IGIT facility

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FEATURED CIEES PARTNER PROGRAMS

SPELLMAN HIGH VOLTAGE POWER ELECTRONICS LABORATORY

MISSION

Utilize the advances in Wide Bandgap semiconductors to enable efficient and compact high power density electronics for automotive, grid and aerospace applications. The Spellmann Lab and CIEES are setting a test microgrid at the Advanced Energy Center. The demonstration grid will include intelligent energy dispatch and connected sensing technologies. The project will develop a universal management system for the rapid deployment of diverse energy storage assets (such as batteries, supercapacitors, flow batteries and generators) and loads (resistive, inductive and capacitive) to the microgrid. The demonstration uses energy storage products from NY companies, BrenTronics LLC and Ioxus Corp.

Dr. Fang Luo, The Spellman High-Voltage Lab Director

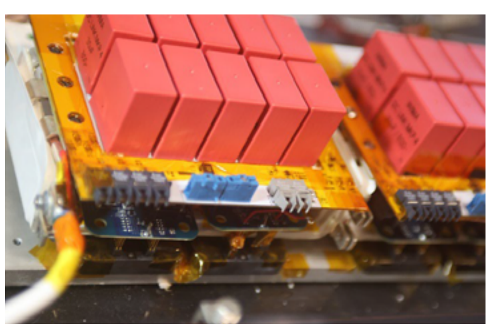
RESEARCH

Wide-bandgap devices (WBG), such as Silicon-carbide (SiC) Metal–Oxide–Semiconductor Field-effect Transistor (MOSFET) and Gallium-Nitride (GaN) High-Electron Mobility Transistor (HEMT) have been popular in recent years because of improved switching performance, which enables higher switching frequencies with limited switching loss, reduces current ripples and size of passive components and increases converter power density and efficiency. These are highly desirable features for electric vehicles, microgrids and future electric airplanes. The tendency in the modern power-electronic application is the ever-increasing operating voltage of the systems. The higher voltage allows reducing the size and weight of conductors.

In 2021, a regional manufacturer of custom high-voltage power systems, Spellman High-Voltage Corp. and Dr. Fang's group teamed up to advance the next generation of power electronics by setting up a Spellman High-Voltage Lab at CIEES. While medium voltage to low voltage power conversion is a much larger market – e.g., low voltage power is used by all consumer electronics, computers, cell phones – it is high voltage power (1,000 – 500,000 volts) that is required for the systems manufactured by Spellman's clients in medical imaging, security screening, industrial quality control, food inspection, semiconductor manufacturing, underwater data transmission, nanotechnology, analytical instrumentation and many other applications. WBG devices are ideally suited for the next generation of high-voltage, high-power systems.

Advanced high-power inverters based on wide-band devices

High switching speeds of Wide Bandgap devices makes filtering the parasitic electromagnetic emission more challenging. Among the passive components in particular, passive filters are still a major bottleneck to enabling higher power density.



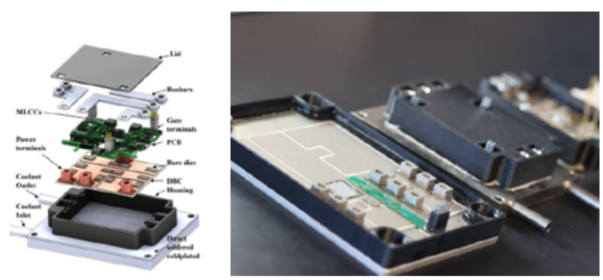
Inverters with advanced digital filters developed by Dr. Fang's team.

Conventionally, a second-order passive filter is used to mitigate the parasitic emission. These passive filters tend to be bulky and could occupy up to 30% of the system volume.

Dr. Fang's team developed zero-phase filtering, which is a method to implement filtering without any phase distortion. This methodology was applied in an active digital filter to compensate the phase distortion introduced by the noise-sensing passive high pass filter. The concept was demonstrated using a simple feed-forward voltage-sense voltage-cancellation filter for differential mode noise attenuation. Converter test results show attenuation of 46 dB attenuation around 120 kHz. This is the highest attenuation reported with a single order filter around 150 kHz with analog or active digital filters.

Packaging of power modules

WBG module packaging is another research direction of the Lab. WBG devices are especially sensitive to parasitic inductances in interconnections. Optimizing the power loop at the packaging level is one of the optimal solutions for inductance minimization. Aligned with this concept, emerging packaging technologies are being developed, such as direct-lead-bonding structures, structures based on flexible PCB, and PCB embedded packaging. Dr. Fang's group is working on hybrid packaging structures that can reduce stray inductance and enhance gate drive synchronization. As a result, faster-switching speed and lower switching loss can be achieved. The modules utilize a direct-soldered coldplate, which reduces the junction-to-coolant thermal resistance because of eliminated thermal grease resistance.



Packaging of wide-band semiconductor inverters developed at Spellman High Voltage Power Electronics Laboratory

Power electronics for all-electric aircraft

The future aviation industry faces numerous challenges, including improved overall efficiency and volumetric density, reduced emissions, and lowered dependence on carbon-based fuels. The aviation industry emitted 905 million tonnes of CO_2 in 2019. This number is expected to substantially increase as the global aviation industry demand grows in the future. In response to the forecasted situation, the international civil aviation organization (ICAO) set goals

FEATURED CIEES PARTNER PROGRAMS

of not only keeping CO2 emissions at the 2020 level, but also targeting a 50 % reduction in net CO2 emissions by 2050, as of 2005 levels of 650 tonnes of CO2. In order to realize low carbon propulsion targets, the National Aeronautics and Space Administration (NASA) has adopted two primary paths: enabling the use of alternative fuels and shifting to innovative propulsion systems, such as fully electric aircraft. In order to address the long term challenges associated with fully electric aircrafts, NASA has funded exploring the usage of liquid Hydrogen (LH2) energy storage. The project, "Cryogenic High Efficiency Electrical Technologies for Aircraft" (CHEETA) aims at developing a fully electric aircraft that has an on-board cryogenic system to store LH2, which will be used for fuel cell energy conversion.

As part of the cryogenic converter development, Dr. Fang's team developed numerous cryogenic subsystems, including driver boards and double pulse test platforms using off-shelf components. Both the boards were integrated and their performance was successfully tested at room temperature and inside Liquid Nitrogen, 77 K environment. Using the designed subsystems, dynamic characterization of GaN switching module was performed for the first time. Overall switching loss reduction of as much as 62 % was observed at device-rated current. The team developed a complete list of off-shelf components which were utilized in the design. As part of future work, converter testing under rated conditions is on-going, delivering results with superconducting inductor at temperatures such as ~ 20 K.

SELECTED PUBLICATIONS

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ADVANCED COMBUSTION AND ALTERNATIVE FUELS LABORATORY

Dr. Dimitris Assanis, Director of the Advanced Combustion and Alternative Fuels Laboratory

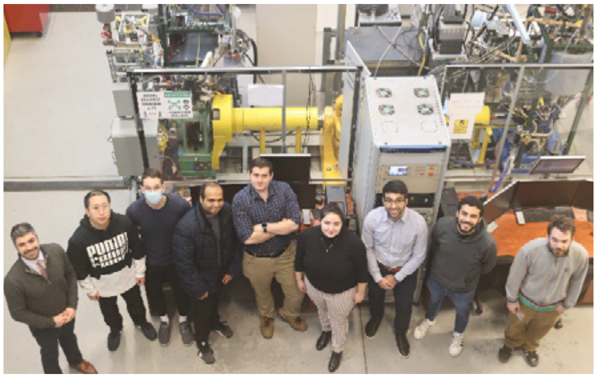
MISSION

Development of power generation and propulsion systems with an emphasis on advanced combustion modes and alternative fuels for internal combustion engines. CIEES team works with the Advanced Combustion and Alternative Fuels Laboratory on development of alternative carbon-neutral fuels for retrofit of existing internal combustion engines.

RESEARCH

Solid oxide fuel cell – gas turbine energy systems

Among various environmentally sustainable solutions for the production of electrical energy, solid oxide fuel cells (SOFCs) can generate electricity with a high conversion efficiency while emitting relatively low emissions of pollutants. This is attributed to the inherent theoretical conversion efficiency advantage of SOFCs, since electricity is generated directly from oxidizing the fuel instead of converting it to electricity by means of combustion.



Advanced Combustion and Alternative Fuels Laboratory team.

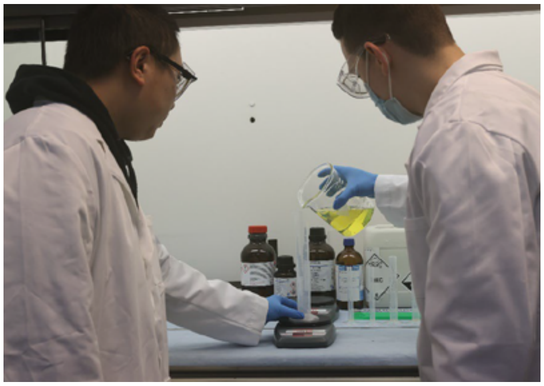
A promising approach to increase electrical conversion efficiency and reduce emissions is the integration of SOFCs with downstream energy conversion devices such as gas turbines and internal combustion engines. In a solid oxide fuel cell – gas turbine energy system, the combustor is used to burn the high-energy anode off-gas from the SOFC to produce extra shaft work for the hybrid system that is converted to electrical power.

FEATURED CIEES PARTNER PROGRAMS

Dr. Assanis's team is exploring the feasibility of a realistic SOFC anode off-gas as a potential alternative fuel under SI combustion conditions over a range of compression ratios, as well as to determine the fuel's compositional effects on engine thermodynamics, combustion characteristics, and emissions levels. The experimental results reveal that the conventional spark-ignition engine can be used downstream of a SOFC stack to generate additional power, thus confirming the feasibility of a fuel cell- internal combustion engine hybrid power plant to improve the combined electrical efficiency.

Alternative fuels for internal combustion engines

The Assanis team is actively studying alternatives to gasoline for internal combustion engines. Natural gas is a gaseous fuel, which has been extensively used and investigated in spark-ignition automotive engines. Combining it with lean combustion has shown the potential to reduce emissions and improve efficiency compared to stoichiometric gasoline engines. The main limitations of lean Natural gas combustion are instability and ignitability. Supplementing Natural gas with Hydrogen is considered a solution to lean Natural gas combustion limitations, and it has been studied extensively. The research has demonstrated that Hydrogen addition accelerates combustion, extends the lean ignition limit, and improves combustion efficiency. The lean ignition limit extension offered by Hydrogen enables increased efficiency and NOx reduction.

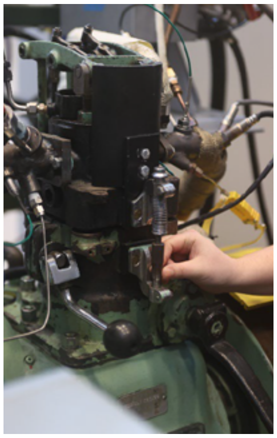


Another promising research area is renewable fuels from biomass. Biomass catalytic fast pyrolysis integrated with hydrotreating produces advanced biofuels that could be used as bio-blendstocks to improve the properties of petroleum diesel fuels and enhance their combustion in compression ignition engines. The biofuels produced are rich in naphthenes (cycloalkanes) that could improve cold-weather behavior and reduce the sooting propensity of blended diesel fuels. Dr. Assanis's team research indicates that based on the present surrogate fuel formulation representing a low-oxygenated naphthenic bio-blendstock produced from the fast catalytic pyrolysis, such biofuels have the potential to be a viable drop-in fuel for compression ignition engines at moderate blend ratios without compromising engine performance and impacting exhaust emissions.

Advanced combustion strategies for gasoline engines

Advanced combustion strategies employing highly dilute and low-temperature combustion modes promise significant improvements in efficiency and emissions of internal combustion engines. For spark-ignited engines, advanced ignition systems, stratified charge operation, and exhaust gas recirculation with enhanced reactivity are some of the most promising near-term solutions for increasing dilution tolerance. Mixture dilution with air and exhaust gas is a key enabler of high thermal efficiency through direct thermodynamic benefits, as well as indirectly by allowing engine boosting and downsizing, higher compression ratios and reducing the need for airflow throttling.

Dr. Assanis's team works on strategies based on controlled auto-ignition driven by chemical kinetics, such as homogeneous charge compression ignition, that have demonstrated great efficiency benefits. Controlled auto-ignition driven by chemical kinetics considerably extends the lean operating limit while still maintaining fast combustion. The reduced residence time, in addition to the inherently lower combustion temperatures, further reduces efficiency losses due to heat transfer. The advanced combustion strategies revealed potential improvements in net thermal efficiency up to 30%, with an additional 12.5% possible.



A test internal combustion engine at Advanced Combustion and Alternative Fuels Laboratory.

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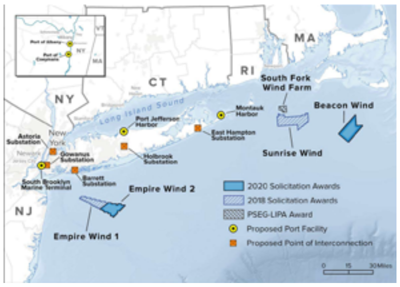
INDUSTRY PROJECTS

ENERGY STORAGE SOLUTIONS FOR TRANSMISSION PLANNING AND GRID STABILITY WITH MASSIVE OFFSHORE WIND FARMS

Stony Brook PI: Dr. Yue Zhang
Industrial partner: Sunrise Wind L.L.C. and Orsted Corporation

This project addresses two of the most important challenges in offshore wind (OSW) energy integration into NYISO Zone K and I – onshore transmission upgrade and onshore grid stability – by developing comprehensive energy storage solutions.



Wind farm leases off the Long Island coast

Rendering of the proposed wind farm

Onshore grid transmission upgrade has been identified as the most challenging issue in OSW integration, not only for achieving the current OSW integration target but also even more so for the greater OSW goals in the long run. Existing studies on transmission upgrades in the NYISO territory have been simplified as wind energy forecast errors and system contingencies are ignored, whereas real-world power system operations in the presence of forecast errors and contingencies will encounter much more complex scenarios and potentially require a significantly higher need for transmission upgrade. In this project, the flexibility of energy storage will be exploited to absorb the OSW forecast errors and the system shocks due to contingencies and ultimately significantly reduce the need for transmission upgrade and the barrier to massive OSW integration in NYISO Zone K and I. The CIEES team investigates optimal energy storage placement, sizing, and operation strategies under realistic power system operation settings with massive OSW, and evaluates the value of storage in reducing the need for transmission upgrade and OSW curtailment. Another challenging issue with massive OSW is grid stability in the presence of a) rapid fluctuations of wind energy and b) reduced system inertia as fewer conventional synchronous generators are present. The team utilizes the fast control of energy storage, inverters and OSW wind turbines for stabilizing the voltage and frequency of the onshore grid. The deliverable is a hi-fidelity dynamic model and simulator of the Zone K and I with OSW and storage, and comprehensively evaluate the benefit of storage control in improving the onshore grid stability.

PREDICTING FREQUENCY MODELS BY INCORPORATING A LOSSY REPRESENTATION

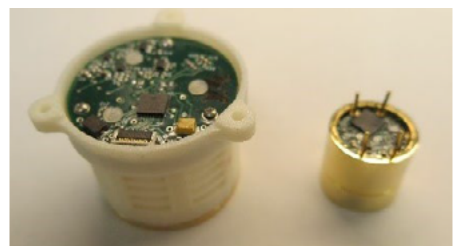
Stony Brook PI: Dr. Fang Luo
Industrial partner: Raytheon Technologies

The project's goal is to predict frequency responses of cable characteristic and load input impedances. Numeric models are developed to match the experimental results. Several lumped segments incorporating a lossy representation of the line were used to model the cable. The cable and induction models were implemented using a computational tool such as MATLAB, thereby providing a convenient method to analyze the overvoltage phenomena. CIEES supplied power equipment and assisted the SBU team in evaluation.

ENVIRONMENTAL TESTING OF OPTICAL GAS SENSORS

Stony Brook PI: Prof. Ben Hsiao
Industrial partner: BAH Holdings LLC

BAH Holdings is a startup developing optical sensing solutions for the petrochemical industry. The company is interested in developing a new generation of gas sensors using the mid-IR lasers and LED that are being researched in SBU's Electrical Engineering Department. The company extensively used CIEES facilities for testing the infrared methane sensor. BAH is entering a testing agreement with ConEd for pilot testing of 200 sensors in the New York City service area. CIEES team is assisting BAH with preparing sensor samples for the Gas Technology Institute validation, and in finding vendors for the pilot production of the 200 sensor units for the ConEd Field trials.



Optical methane sensors developed by BAH Holdings

LIGHTWEIGHT POWER CONVERTER COOLING WITH ENHANCED EMI. CHARACTERISTICS

Stony Brook PI: Dr. Fang Luo
Industrial partner: JetCool L.L.C.

The project develops microconvective liquid cooling technology that uses arrays of fluid jets to cool the industry's highest power devices. Unlike typical heat sinks or cold plates that pass fluid over a surface, our cooling jets route fluid directly at the surface, creating an order-of-magnitude improvement in heat transfer. CIEES assisted the SBU team in setting up the experiment in the Advanced Energy Center.

INDUSTRY PROJECTS

NANOENGINEERED SOFT MAGNETS FOR POWER ELECTRONICS

Stony Brook PI: Dr. Fang Luo
Industrial partner: PowderMet Inc

These projects develop high resistance, high permeability and saturation, low coercivity magnetic cores for power conversion systems. The developed soft magnetic will benefit the current state-of-art of soft magnetic to allow designers to increase system power at high frequency while reducing the weight and size, also reducing (or, in some cases, even eliminating) the need for costly, large, and heavy cooling systems. CIEES team assisted in calorimetric measuremnents of the magnetic alloys.

INTEGRATION OF THE 5KW P2S DEMONSTRATION UNIT

Stony Brook PI: Dr. Devinder Mahajan
Industrial partner: Danskammer Energy

The project will realize the integration of the 5kW power demonstration unit. The CIEES team will determine additional markets and demand for Hydrogen supplies in the region/state that could be applicable to all parts of the nation. The team will identify, assess and evaluate the feasibility of Hydrogen suppliers for New York State to deliver fuel to transition from fossil fuels.

Development of prototype gas negation unit at IGIT facility

MINIMIZING ENVIRONMENTAL IMPACT OF PEM FUEL CELL ASSEMBLY

Stony Brook PI: Dr. Simon Marcia
Industrial partner: MEAN Technology LLC

The CIEES team will perform an environmental assessment of a recycling process for the platinum catalyst contained in the Membrane Electrode Assemblies of a polymer electrolyte membrane fuel cell. During this study, four hydrometallurgical platinum recovery processes from cathode will be analyzed at a laboratory scale.

COUPLING HYDROGEN VALUE CHAIN IN THE POWER TO GAS DEMONSTRATION UNIT

Stony Brook PI: Dr. Devinder Mahajan
Industrial partner: Consolidated Edison Company

Hydrogen storage units in Prof. Mahajan's lab

The project studies the Hydrogen absorption/desorption kinetics in mixed metal hydrides on the Power to Gas unit. It is known that hydrogen storage in metal hydrides is one of the attractive approaches for storing gaseous hydrogen. One attractive class of metal hydride system, mixed metal alloys, shows high hydrogen storage capacity, rapid kinetics and a relatively long electrochemical charge-discharge cycle life. The excellent properties of alloy type hydrides alloys makes them promising for stationary hydrogen storage. CIIES team assisted IGIT in assembly and provided gas analysis equipment.

OFF-GRID POWER PRODUCTION FROM RENEWABLE GAS SOURCE

Stony Brook PI: Dr. Devinder Mahajan
Industrial partner: National Grid

The Institute of Gas Innovation and Technology (I-GIT) is a partnership between Advanced Energy Research and Technology Center (AERTC) and National Grid-USA. The IGIT team will demonstrate a power-to-gas (P2G) concept that will produce Hydrogen, store it in a 14-cylinder metal hydride rack and feed to run a 5kW fuel cell unit. The unit will be sited at AERTC as a demonstration unit to validate the P2G concept. CIEES assisted IGIT in assembly and evaluation of Fe-Ti hydrogen storage units.

THERMOLIFT NATURAL GAS FIRED HEAT PUMP FOR BUILDING HEATING AND COOLING

Stony Brook PI: Dr. Anurag Purwar
Industrial partner: ThermoLift, Inc.

ThermoLift, based in Stony Brook, NY is developing a cold-climate, natural gas air-conditioner and heat pump technology that combines heating, air-conditioning, and water heating into a single appliance. It can provide a 30-50% reduction in building HVAC costs as well as associated reductions in greenhouse gas emissions. Currently, Thermo Lift heat pumps are undergoing pilot testing in British Columbia, Canada, by the local utility, Fortis BC. Ten customers, five residential and five small commercial buildings, are testing a new natural gas heat pump technology for space and water heating. The Thermo-Lift heat pump provides space and water heating in one system and is reported to offer efficiencies as high as 160 percent. This pilot, the first in North America, will test the efficiency, reliability and customer acceptance of the technology. Thermo-Lift C.E.O., Paul Swartz, credits CIEES for providing expertise and assistance during the critical stages of technology development. The CIEES put together a team of scientists who performed thermodynamic analysis of the ThermoLift engine.

INDUSTRY PROJECTS

REDESIGN OF MILITARY-GRADE 5 K WH INTEGRATED LI-ION ENERGY STORAGE FOR BEHIND THE METER APPLICATIONS

Stony Brook PI: Dr. Vyacheslav Solovyov
Industrial partner: Bren-Tronics, Inc.

Long Island (LI) is a high-density residential area where a large number of renewable energy generation systems have been installed or are at the planning stage. Several Eastern LI load pockets: South Hampton, East Hampton and Montauk are facing summer power shortages due a high seasonal demand. For example, the average annual demand of the South Hampton load pocket is 55 MW, however the summer months can be as high as 140 MW for 10-20 hrs. Behind-the-meter energy storage, which we believe does not require a lengthy and expensive permitting process, can be rapidly deployed and help alleviate this demand with renewables.

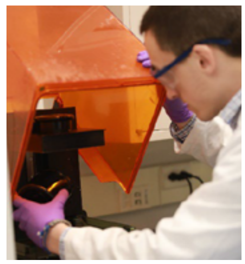
BrenTronics energy storage units

Bren-Tronics and the CIEES team developed behind-the-meter energy storage solution by re-designing an existing 5 kWh, 48 V battery, currently offered by Bren-Tronics to DoD customers. The unit complies with rigid MIL-Spec safety standards, thus this solution is a good fit for residential behind-the-meter, on-premises installation where fire, flood and electrical safety are very important. The flood safety is especially relevant for neighborhoods in flood-prone coastal areas, such as South Shore of LI (as witnessed during Super Storm Sandy). The market opportunity is estimated at $20M annually, the main source of revenue being the installation and service of the battery storage systems.

EVALUATION OF ADDITIVE MANUFACTURED NANOCOMPOSITE MATERIALS FOR FLEXIBLE ELECTRONICS

Stony Brook PI: Dr. Vyacheslav Solovyov
Industrial partner: ChemCubed L.L.C.

ChemCubed L.L.C. is a small business in the field of flexible electronics that finds multiple uses in energy, aerospace and automotive products. The company utilizes methods of additive manufacturing to manufacture composite materials with precisely controlled properties, such as hardness, tensile strength, elongation at break, Young's modulus, electrical conductivity, thermal conductivity, flame retardancy, security (tagging), or a combination thereof. In various aspects, the methods can include printing amounts of two or more curable liquids from a multichannel piezo head device to form a layer that can be cured by applying a wavelength of light from a light source.

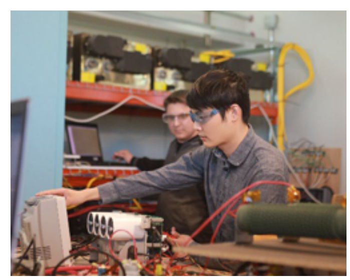

ChemCubed scientist operating an ink-jet printer

The CIEES team performed mechanical and structural tests of composite samples provided by ChemCubed, currently residing in AERTC, Stony Brook's R&D Park. Flexible electronics is a fast-growing area where Chem Cubed is well-positioned to take a lead. CIEES employed a post-doctoral research associate who performed the sample analysis using the equipment available at CIEES.

EVALUATION OF STOREN VANADIUM FLOW BATTERY TECHNOLOGY

Stony Brook PI: Dr. Vyacheslav Solovyov
Industrial partner: StorEn Technologies

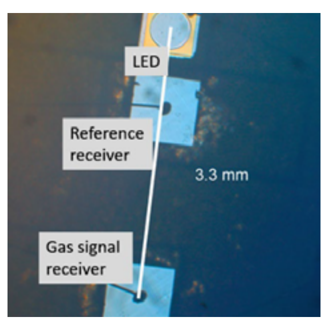
StorEn is commercializing the vanadium flow battery (VFB) which is a rechargeable flow battery that employs vanadium ions in different oxidation states to store chemical potential energy. During this period, the CIEES team concluded testing of the unit. The unit was charged up to 100% of the stored energy capacity, 20 kWh, more than 100 times. The CIEES team confirmed the high roundtrip efficiency and charge retention of the battery. The battery demonstrated stable operation up to the maximum 5 kWh power.


SBU interns testing the StorEn battery

DEVELOPMENT OF FABRICATION PROCESS FOR OPTICAL METHANE SENSOR

Stony Brook PI: Dr. Sergey Suchalkin
Industrial partner: BAH Holdings LLC

A team of scientists and engineers at Stony Brook University is developing novel mid-IR optical elements for methane sensing. The sensing elements are manufactured by the advanced molecular beam epitaxy and tuned to optical absorption lines of methane. The technology enables sensors with ultra-low power consumption. Such sensors can operate on a single battery for 10 years. CIEES team assisted BAH in testing the emitter efficiency at high temperatures using the environmental chamber at the Advanced Energy Center.



Optical sensing package designed for BAH Holdings methane sensors by SBU team.


Graduate students of Electrical Engineering Department testing mid-IR optical elements.

FEDERAL AND NOT-FOR-PROFIT GRANTS

ASYNCHRONOUS DISTRIBUTED AND ADAPTIVE PARAMETER TUNING (ADAPT) FOR HYBRID PV PLANTS

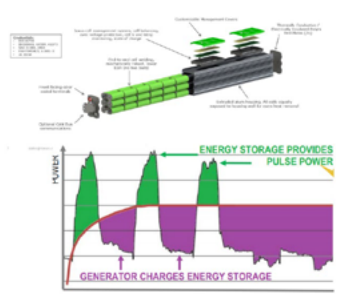
Stony Brook PI: Dr. Peng Zhang
Funding agency: US Department of Energy

This work will help communities maintain power during man-made or natural disasters and restore power after them, improve cybersecurity for PV inverters and power systems, and develop advanced hybrid plants that operate collaboratively with other resources for improved reliability and resilience. It will advance grid operations technologies and enable solar to provide more grid services—or enable grid operators to maintain system-wide balance and manage electricity transmission. In addition, it will advance the cybersecurity of solar technologies to better detect disturbances and develop strategies to survive a cyberattack.

MANAGEMENT SYSTEM FOR MICROGRID-TIED KV-CLASS SUPERCAPACITOR UNITS

Stony Brook PI: Dr. Vyacheslav Solovyov
Funding agency: US Navy Office of Naval Research

The project addresses the need for effective management of high-voltage supercapacitive energy storage that would significantly improve resilience in a high-voltage microgrid subjected to pulsed loads and disruptions. The project will advance the high-voltage supercapacitor storage as a part of Fully Integrated Power and Energy Systems (IPES) of the near-future NAVY grids. The SBU team will work with the leading manufacturer of the state-of-the-art high voltage supercapacitor storage, Ioxus Inc. and the energy storage integrator, Unique Technical Services LLC (UTS), to evaluate the feasibility of achieving the NAVY target of 1 MW/m3 power density in the Energy Storage Cabinet geometry using Ioxus iMOD-series product.



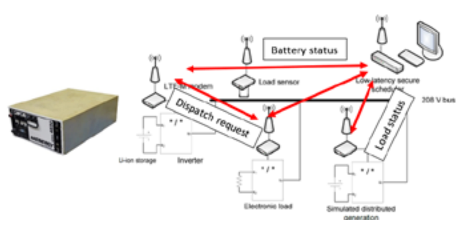
Application of high-voltage supercapacitors in microgrid

ROBUST AND INTELLIGENT INTEGRATION OF MICRO-GRIDS TO IMPROVE ISOLATED SITE RESILIENCE

Stony Brook PI: Dr. Benjamin Hsiao
Funding agency: US Navy Office of Naval Research

Remote military bases or communities can have a wide range of systems, spanning from the kW to GW, with different complexity and maturity. There is a lack of integrated "plug-and-play" mobile energy storage solutions that can be seamlessly integrated into a microgrid without compromising the grid power quality.

The popular microgrid management approach is droop control-based; the strategy inherited from the traditional electric grid, where stability is ensured by multiple synchronous generators operating at a 4-5% frequency droop. Absent inertia of large generators in an islanded microgrid requires intermediate energy storage systems to absorb or inject power through pre-determined or adaptably adjusted droop curves. However, under large load variations, such as shipboard electromagnetic weapon platforms and high-power electric vehicle chargers on forward bases, droop controllers are known to demonstrate poor damping performance.



Layout if the microgrid prototype. The arrows show dispatch communications. The left panel show the BRENERGY 4850 Li-ion battery used in this study.

The project uses a communication-based multi-agent approach using secure wired communication, CAN and RS-485. By interconnecting the loads and generators within the microgrid, optimal energy dispatch can be realized through a look-ahead load prediction strategy. Under this scenario, a load controller will communicate the anticipated energy dispatch to the distributed energy resource (DER) and the energy storage unit. Here we use the most advanced in the internet of things (IoT) communication to demonstrate predictive energy dispatch of a Mil-spec energy storage (Bren-Tronics BRENERGY TM 4850 Li-ion storage), commercial out-of-shelf (COTS) inverter, under a variety of loads. The proposal team fully utilizes synergy between SBU's expertise in wireless communication and Bren-Tronics experience in supporting US warfighters with state-of-the-art energy solutions.

LEARNING DISTRIBUTION GRIDS (LEAD): MACHINE LEARNING ALGORITHMS FOR HI-FIDELITY MODELING, MONITORING, AND FORECASTING OF DISTRIBUTION SYSTEMS AND DISTRIBUTED ENERGY RESOURCES

Stony Brook PI: Dr. Yue Zhao
Funding agency: National Science Foundation

The innovation of the project lies in integrating Internet of Things technologies, software-defined networking and real-time computing to establish a scalable SD2N architecture.

SEMICONDUCTOR-BASED EMI MITIGATION ARCHITECTURE FOR FUTURE POWER ELECTRONICS SYSTEMS

Stony Brook PI: Dr. Fang Luo
Funding agency: National Science Foundation

The project provides a disruptive semiconductor-based active filtering method which could essentially replace passive filtering solutions that have been used for decades. The success of this project will not only significantly improve the power density and efficiency of future power electronic systems, but also change the design philosophy for electromagnetic emission mitigation in such systems. The proposed program integrates cutting-edge research with education, and thus, provides a platform to integrate STEM interdisciplinary knowledge together with hands-on activities with the focus on establishing a pipeline of STEM students in electrical engineering from pre-college to graduate level.

ENABLING SELF-PROTECTING, ULTRA-CYBER-PHYSICAL-RESILIENT MICROGRIDS

Stony Brook PI: Dr. Peng Zhang
Funding agency: US Navy Office of Naval Research

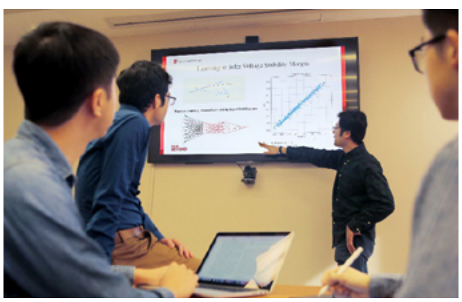
This project develops a deployable Three Lines of Defense model that integrates three of SBU's unique techniques – programmable active security scanning, encrypted control, software-defined microgrid controls (including push-sum-enabled distributed algorithms to enable unprecedentedly self-protecting, ultra-cyber-physical-resilient, and cognitive microgrids.

FEDERAL AND NOT-FOR-PROFIT GRANTS

LEARNING DISTRIBUTION GRIDS (LEAD): MACHINE LEARNING ALGORITHMS FOR HI-FIDELITY MODELING, MONITORING, AND FORECASTING OF DISTRIBUTION SYSTEMS AND DISTRIBUTED ENERGY RESOURCES

Stony Brook PI: Dr. Yue Zhao
Funding agency: NYS. Energy Research and Development Authority

The projects will develop an integrated suite of grid modernization metrics that leverage current industry practice and emerging industry additions (e.g. extreme event metrics from NERC) to develop new metrics that reflect emerging grid attributes and architectures, conduct baseline modernization assessments and provide ongoing dashboard for policy makers, regulators and industry stakeholders.



Dr. Yue Zhao team

LEARNING FOR FASTER COMPUTATIONS TO ENHANCE EFFICIENCY AND SECURITY OF POWER SYSTEM OPERATIONS

Stony Brook PI: Dr. Yue Zhao
Funding agency: National Science Foundation

This project will develop new machine learning algorithms, both leveraging and integrating with existing computational tools, to greatly improve the computational efficiency of solving challenging power system operation problems. We accomplish this by designing algorithms that use data to replace some of the existing heuristics based on human experience. We use a bottom-up approach by carefully formulating the problems to determine the best interface between the physical system and machine learning. This allows us to design algorithms that are aware of the physics of the problems and complement existing tools in the field.

ENABLING RELIABLE NETWORKED MICROGRIDS FOR DISTRIBUTION GRID RESILIENCY

Stony Brook PI: Dr. Peng Zhang
Funding agency: National Science Foundation

The research project creates and implements networked microgrids solutions on a novel cyberinfrastructure to ensure distribution grid resiliency. This cyber infrastructure is based on Software-Defined Networking. Specifically, the project has three main objectives: (1) To establish a formal analysis method to tractably assess networked microgrid stability; (2) To devise a new concept of microgrid active fault management (AFM) enabled through online distributed optimization; and (3) To build a Software-Defined Networking (SDN) based architecture to enable highly resilient networked microgrids.

DEVELOPMENT OF THE CRYOGENIC HYDROGEN-ENERGY ELECTRIC TRANSPORT AIRCRAFT (CHEETA) DESIGN CONCEPT

Stony Brook PI: Dr. Fang Luo
Funding agency: Board of Trustees of the University of Illinois

The project will develop a cryogenic hydrogen fuel cell system for powering all-electric aircraft. The team will investigate the technology needed to produce a practical all-electric design to replace conventional fossil fuel propulsion systems.

Cryogenic testing of GaN modules

EMPOWERING SMART AND CONNECTED COMMUNITIES THROUGH PROGRAMMABLE COMMUNITY MICROGRIDS

Stony Brook PI: Dr. Peng Zhang
Funding agency: National Science Foundation

The main objective of this project is to create smart programmable microgrids (SPMs). Our key innovation is to virtualize microgrid functions, making them software-defined and hardware-independent, so that converting distributed energy resources (DERs) to community microgrids becomes affordable, autonomic, and secure. To achieve our main objective, our team will: 1) Architect a programmable microgrid platform for virtualizing traditionally hardware-dependent microgrid functions as flexible software services, fully resolving hardware dependence issues and enabling unprecedented low costs; 2) Pioneer a concept of software-defined operation optimization for microgrids, where operation objectives, grid connection, and DER participations will be defined by software and plug-and-play, and can be quickly reconfigured, based on the development of modularized and tightened models and a novel asynchronous price-based decomposition-and-coordination method; 3) Devise a software-defined distributed formal analysis for online stability assessment under heterogeneous uncertainties and plug-and-play of microgrid components or microgrids; 4) Develop a real-time-learning-based cybersecurity function to protect SPMs against power bot attacks; and 5) Enable anaerobic-biomass-digesters (ADs) as environmentally friendly and dispatchable DERs by virtualizing the dispatch and control of ADs in SPM. The proposed SPM will be demonstrated on a Connecticut community microgrid through a recently built cyber-physical testbed.

SOFTWARE-DEFINED URBAN DISTRIBUTION NETWORK FOR SMART CITIES

Stony Brook PI: Dr. Peng Zhang
Funding agency: National Science Foundation

The innovation of the project lies in integrating Internet of Things technologies, software-defined networking and real-time computing to establish a scalable SD2N architecture.

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GRID-INTEGRATED RENEWABLES

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Professor,
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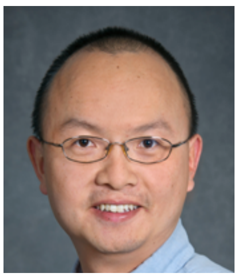
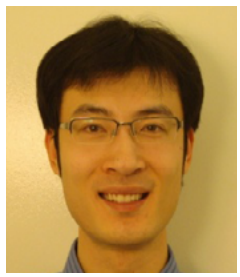
DEVINDER MAHAJAN
Professor,
Chemical Engineering

FANG LUO
Associate Professor,
Electrical and
Computer Engineering

DIMITRIS ASSANIS
Assistant Professor,
Mechanical Engineering



GANG HE
Assistant Professor,
Technology and Society



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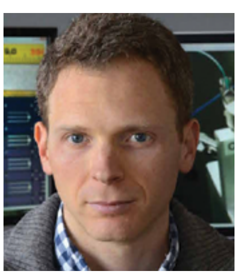
Computer Engineering

AUXILIARY GRID TECHNOLOGIES

JAMES MISEWICH
Associate Director,
Brookhaven National
Laboratory

GREGORY BELENKY
Distinguished Professor,
Electrical and Computer
Engineering

SERGEY SUCHALKIN
Assistant Professor,
Electrical Engineering



MATTHEW EISAMAN
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Assistant Professor,
Electrical Engineering

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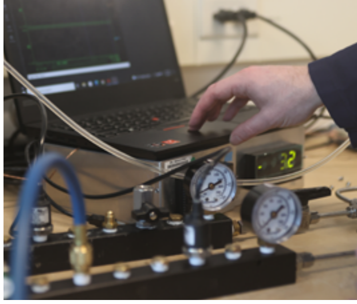
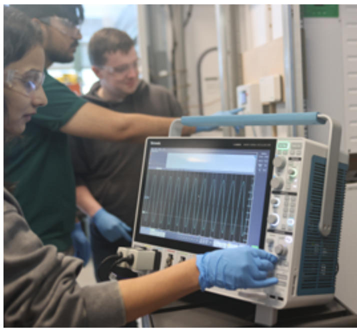
Assistant Professor,
Electrical Engineering

The CIEES goal is to make New York a global leader in technologies that will accelerate the progress of renewable energy as one of the mainstream resources displacing fossil fuel-based electric power worldwide by facilitating the integration of renewable sources into the electric grid.

CIEES will promote industry growth in New York by supporting industry collaborations with university experts in the following domains:

CHEMISTRY AND MATERIALS | Materials for energy storage
IT AND BIG DATA | Grid resiliency and analytics
ENERGY GENERATION AND ENERGY POLICY | Grid-integrated renewables
SEMICONDUCTORS and ELECTRONICS | Auxiliary grid technologies





CIEES
CENTER FOR INTEGRATED ELECTRIC ENERGY SYSTEMS
AT STONY BROOK UNIVERSITY

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