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Research Experiences for Undergraduates (REU) Site
Integrating Research in Sustainable Energy and the Environment across Disciplines (IR-SEED)

Texas A&M University-Kingsville

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Research Project List

Project #1: Assessment on the Use of Electric Vehicles to Reduce Renewable Energy Variability

By Dr. Francisco Haces Fernandez, Assistant Professor, Dept. of Management, Marketing and Information Systems

i. Motivation: Variability is one of the main challenges for renewable energy penetration to the electric grid. In many locations of the United States onshore wind energy reaches high generation levels during the middle of the night while solar energy peaks at midday. As such, these renewable generation patterns normally do not coincide with general top consumption periods. Therefore, grid operators need to supplement electricity shortages, caused by renewables' variability, applying natural gas or coal, that can be quickly ramped up as needed. However, using natural gas or coal as reserve resources for electricity generation hinders environmental benefits from renewable energy and prevent further reductions on electricity prices.

ii. *Project Description*: As wind and solar energy continue to grow it is important to assess methods to compensate for its variability. This research will investigate energy storage applying electric vehicles (EV), to be supplied to the grid on high consumption, low generation periods. The US has one of the highest levels of vehicles per capita in the world and exponential growth of EVs is expected in the near future. Therefore, synergistic opportunities between renewables and EV are very promising. The main research objective of this project is the assessment of electricity consumption and generation to evaluate the use of EV for energy storage to ameliorate renewable intermittency. Data analytics and Geographic Information Systems (GIS) methodologies will be applied to assess these factors as well as wind and solar electricity generation across hourly periods and seasons. Publicly available databases from federal and state agencies, as well as from national laboratories, will be collected during the research. The data will be assessed applying computational modeling tools, including GIS, to evaluate the project feasibility, as renewable energy and EVs continue to growth in the near future.

iii. *Undergraduate Research Opportunities*: Two undergraduate students will participate in this project to conduct different research activities. Both students will work together to 1) collect and analyze data required for the project, 2) train on GIS and data analytics to assess the potential to use EV as reserve capacity to compensate for renewables intermittency. One student will focus on assessing the potential storage and electricity usage from domestic passenger cars, pickups and vans. Activities will include 1) modeling the diverse battery storage capacities for these vehicles 2) Model potential to provide power to the grid to supplement renewables variability from these vehicles. The second student will focus on commercial vehicles, including delivery trucks and bans, buses, and trucks with three or more axles. Activities will include 1) modeling the diverse battery storage capacities for these vehicles 2) Model potential to provide power to the grid to supplement renewables variability from these vehicles.

Project #2: Improving the Solar Cell Efficiency through Surface Texturing

By Dr. Mohammad Motaher Hossain, Associate Professor, Dept. of Mechanical and Industrial Engineering

i. Motivation: Applications of solar technologies have been significantly growing over the years in residential, commercial, agricultural, and industrial sectors. Organic or Polymer Solar Cells (PSCs) have attracted considerable attention in recent years as a promising alternative to conventional silicon-based solar cells due to their cost effectiveness and potential applications where flexibility, light weight, and transparency are desired. Although significant progress has been made in recent years, the power conversion efficiency of PSCs is still low compared to conventional solar cells. One way to further improve the efficiency is to provide a texture/pattern on the surface that would minimize reflection and maximize absorption of incident sunlight. The research question is "Can the sunlight absorption be increased by introducing textures on polymer surfaces?".

ii. Project Description: The research objective is to improve the solar cell efficiency of PSCs by reducing reflection and maximizing absorption through introduction of texture on the surface. A MATLAB based Graphical User Interface (GUI) will be developed to calculate the quantity of sunlight absorption based on material and optical properties, 3D texture geometries, incident wavelengths, multiple reflectance-incidence (i.e., reflected light from one surface feature can impinge onto another surface feature and get absorbed), etc., and determine the optimal surface texture for a material system that will maximize sunlight absorption. Based on the findings, micro-textured polymer surfaces will be fabricated using laser engraving and/or hot embossing or 3D printing processes. Sunlight absorption on these micro-textured surfaces will be measured to validate the simulation findings. How the transparency of the polymeric material is impacted by the introduction of textures will also be investigated.

iii. Undergraduate Research Opportunities: Two undergraduate students will work together in this project to develop MATLAB GUI for estimating the sunlight absorption for various surface texture geometries and designing an optimal surface texture geometry. They will fabricate micro-textured polymer samples to investigate the effect of texturing on the transparency of polymers, measure the increase in sunlight absorption and, thereby study the improvement in solar cell efficiency.

Project #3: Digital Twin for Power and Energy Systems

By Dr. Taesic Kim, Associate Professor, Dept. of Electrical Engineering and Computer Science

i. Motivation: A digital twin (DT) is a virtual representation that serves as the real-time digital counterpart of a physical object or process. The DT has been considered as a key component of The Industry 4.0, specifically for smart manufacturing. It is also expected that the conventional physical power and energy system can be further advanced as a result of adopting the emerging digital twin frameworks utilizing cyber-physical systems (CPS) technologies such as Internet of Things (IoT), cloud/edge computing services, artificial intelligence (AI), and blockchain.

ii. Project Description: The objective of the proposed project is to investigate a digital twin framework for battery energy systems (BESSs) such as grid-connected BESS and electric vehicles (EV) considering both battery health conditions and grid services. The approach is to: 1) investigate key technologies of DT using IoT and cloud system; 2) study and implement a machine learning (ML)-based battery cell/pack digital twin; 3) study charging control to adapt optimal charge voltage and current profiles based on the battery DT and grid situations; 4) implement and testing a DT system using a real-time hardware-in-the-loop testbed.

iii. Undergraduate Research Opportunities: Two undergraduate students will have an extensive experience in the state-of-the-art DT technologies and power and energy system research by participating in specific research tasks selected by students among the research activities under the guidance of Dr.

Kim and Kim's research team including graduate students. Students will: 1) learn knowledge of digital twin technologies and tools, ML, power and energy systems, and programming languages such as MATLAB/Simulink, Java and Python; 2) have a hand-on experience in laboratory techniques such as utilizing IoT devices and a hardware-in-the-loop (HIL) testing using a real-time grid simulator and a cloud server; and 3) participate in the dissemination activities.

Project #4: Design and Optimization of a Self-Adjustable Wave Energy Converter

By Dr. Hua Li, Professor, Dept. of Mechanical and Industrial Engineering

i. Motivation: Ocean wave energy resource potential is vast, and it can significantly contribute to the human energy needs if efficiently explored. However, the commercial harvesting of wave energy is still at infancy when compared to wind and solar energy. A wave energy converter (WEC) needs to be able to optimally harvest wave energy and survive the harsh ocean environment at the same time. Of the different types of available wave energy harvesting methods, one promising concept is the heaving point absorber where the heave motion due to the interaction between ocean wave and absorber's body generates power. To harvest more energy, the heaving point absorber needs to operate at the resonance region during its interaction with the ocean waves to achieve the optimum oscillation, which is the main challenge with this concept due to the irregular frequencies of the real ocean waves.

ii. Project Description: This research seeks to design and optimize a self-adjusted wave energy converter based on heaving point absorber concept that is capable of harvesting wave energy optimally at multiple frequencies and is able to survive the ocean environment during its operating and design life at the same time. Theoretical hydrodynamic and diffraction of floating bodies, computational fluid dynamics, and finite element analysis tools as well as relevant design codes of practice will be applied to determine the device power capture rate, stability, static, and its fatigue responses using real ocean wave data from the Gulf of Mexico. There are three main tasks: 1) Improve an existing conceptual design of a self-adjusted WEC based on heaving point absorber concept through the optimization of its working mechanism, 2) Simulation and estimation of the energy capture of the self-adjusted WEC through the use of computational fluid dynamics and finite element analysis tools, and 3) Perform a structural reliability analysis of the self-adjusted WEC to ascertain its survivability in the ocean environment.

iii. Undergraduate Research Opportunities: Two undergraduate students will participate in this project to conduct different but related research activities. Both students will first work together to improve the existing design of a self-adjustable WEC. One student will focus on simulation and estimation of the energy capture of the new WEC. The other student will focus on structural reliability analysis of the new WEC.

Project #5: Understanding the Climate Change Resilience of Earth's Surface Water Storage Using Satellite Observations, Computer Simulations, and Geographical Information System

By Dr. Adnan Rajib, Assistant Professor, Dept. of Environmental Engineering

i. Motivation: Climate change is causing deep uncertainties in freshwater availability on Earth's surface, with increased frequencies of extreme events like floods and droughts. Against this trend, small waterbodies present in abundance across the Earth's surface can offer significant storage functions to reduce the impacts of floods and droughts and serve as water sources. This project aims at providing undergraduate students with hands-on skill-development opportunities to accomplish two objectives: (i) high-resolution mapping of small surface waterbodies for any given location and estimating their water storage capacities using new-generation satellite Earth observations, and (ii) incorporate projections of future climate change in a computer model and simulate how small waterbodies can reduce the impacts of future floods and droughts.

ii. Project Description: This project will use satellite Earth observations, computer simulations, and Geographical Information System (GIS) under three thematic areas: Theme 1 – Discovery, processing, and analysis of satellite Earth observations, Theme 2 – Integration of Earth observations in a hydrological model to simulate how numerous small surface waterbodies can reduce future climate change impacts; and Theme 3 – Use of GIS to create dynamic maps demonstrating the scientific findings of the project via user-friendly interactive online platforms.

iii. Undergraduate Research Opportunities: Two undergraduate students will work together in this project. One student will work independently on Theme 1 (Earth observations) while maintaining close collaboration with the other student who will be working on Theme 2 (Computer simulations). Both students will work collaboratively on Theme 3. Such a collaborative effort will be logical because the proposed task under Theme 3 is partially dependent on those under Themes 1 and 2. The technical learning outcomes include managing "big data", state-of-the science hydrological model, and GIS-based online data visualization. The conceptual learning outcomes include the applications of Earth observations to estimate surface water storage, value of surface waterbodies in sustaining the Earth's resilience to climate change, and in-depth understanding of the hydrologic cycle.

Project #6: Role of Soil Moisture and its Assimilation on Streamflow Forecasting using Hydrologic Modeling and Remote Sensing

By Dr. Tushar Sinha, Associate Professor, Dept. of Environmental Engineering

i. Motivation: Several studies have shown that skillful streamflow forecasts can improve management of water and agricultural operations. Monthly to seasonal streamflow forecasts skills are primarily dependent on atmospheric conditions, Sea Surface Temperatures (SSTs) and initial hydrologic conditions such as soil moisture. Soil moisture data assimilation has proven to enhance streamflow forecasting skills using hydrologic modeling. Nevertheless, streamflow forecasting skills can vary due to multiple factors such as seasons, climate variability (e.g., El Nino Southern Oscillations – ENSO conditions), and geographic locations. Therefore, there is a need to understand how soil moisture data assimilation can improve seasonal streamflow forecasts in rainfall-runoff regimes in different hydroclimatic settings.

ii. ***Project Description***: The overall objectives of this project are to develop monthly updated streamflow forecasts and quantify the role of soil moisture on streamflow forecasting skill in two selected watersheds located in different hydroclimatic settings. To accomplish this objective, climate forecasts (precipitation and air temperature from multiple General Circulation Models - GCMs) will be used to implement a widely used hydrologic model (Variable Infiltration Capacity - VIC) to develop monthly updated streamflow forecasts. Soil moisture data will be estimated based on the European Space Agency - Climate Change Initiative (ESA CCI SM v04.5) satellite data, which has shown to outperform other satellite-based products. The near-surface soil moisture from ESA CCI SM v04.5 will be used to implement the VIC model to evaluate skills of updated streamflow forecasts. Specifically, four major research activities will include: 1) Calibrate the VIC model for selected watersheds, 2) Statistically downscale climate forecasts from GCMs to the scale of VIC model to develop streamflow forecasts, 3) Estimate soil moisture based on ESA CCI SM V04.5 satellite data, and 4) Estimate the role of near-surface soil moisture on seasonal streamflow forecasts developed using the VIC model in different months and seasons.

iii. ***Undergraduate Research Opportunities***: Two undergraduate students will participate in this project to conduct different research activities. One student will focus on: 1) Learning Linux and 2) Setting up and implementing the VIC model. The other student will focus on: 1) Statistically downscaling GCM climate forecasts at a finer-resolution, and 2) Estimating soil moisture from satellite data using remote sensing. Both the students will also receive training in handling and analyzing big data.