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Renewables energy source remote laboratory at CUJAE. Development and Perspectives

Laboratorio remoto sobre fuentes renovables de energía en la Universidad Tecnológica de La Habana José Antonio Echeverria (CUJAE). Desarrollo y Perspectivas

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ABSTRACT/ RESUMEN
The integration of remote labs in renewable energy education is not yet common in Cuba due to material and knowledge limitations. The Erasmus+ project "EUBBC-Digital" has enabled their introduction in CUJAE's Electrical Engineering program. This work addresses the generalities of the proposal and the objectives pursued by the presence of an installation of this type within the curriculum of the degree. The CUJAE Renewables energy source remote laboratory should be up and running in September this year. Having a remote laboratory will allow students to reach a new stage in their training, offering them the possibility of applying information and communication technologies to solve real problems and improve collaboration with other institutions. The paper identifies the intentions, goals and expectations of the remote lab and offers the opportunity for teachers and students from other countries to collaborate.
Key words: renewable energy sources, remote laboratory, flipped learning, micro grid, hybrid system.

La integración de laboratorios remotos en la educación sobre energías renovables aún no es común en Cuba, debido a limitaciones materiales y de conocimiento. El proyecto Erasmus+ "EUBBC-Digital" ha permitido su introducción en la carrera de Ingeniería Eléctrica de la CUJAE. Este trabajo aborda las generalidades de la propuesta y los objetivos de incluir este tipo de instalación en el plan de estudios. El laboratorio remoto de la CUJAE para energías renovables entrará en funcionamiento en septiembre. Este recurso permitirá a los estudiantes alcanzar un nuevo nivel en su formación, brindándoles la posibilidad de aplicar tecnologías de la información para resolver problemas reales y mejorar la colaboración con otras instituciones. El artículo detalla las intenciones, metas y expectativas del laboratorio, además de ofrecer oportunidades de colaboración internacional para docentes y estudiantes.
***Palabras clave:** fuentes renovables de energía, laboratorio remoto, aula invertida, micro red, sistema hibrido.*

INTRODUCTION
The landscape of higher education in renewable energy is rapidly evolving, driven by advancements in technology and the urgent need for sustainable energy solutions. Traditional methods of teaching and learning, while still valuable, are being complemented and, in some cases, transformed by innovative approaches that leverage digital technologies [1-3].

One such innovation is the remote laboratory, a platform that allows students to conduct experiments and engage in practical learning experiences from any location with internet access [4-5].Remote laboratories represent a significant leap forward in educational methodologies [6-7], particularly in fields such as renewable energy [8-10]. The integration of remote laboratories into renewable energy education offers numerous advantages. It enhances learning outcomes by providing students with continuous access to experimental setups, fosters collaboration across different institutions and countries, and allows for a more scalable and inclusive educational model [11-12].

Students can gain practical experience with solar panels, wind turbines, bioenergy systems, and other renewable technologies without the constraints of physical presence or time-bound laboratory sessions [13-14]. More specifically, they will also have access to such learning resources that their home universities might not be able to offer them.Moreover, remote laboratories are particularly pertinent in the context of renewable energy education due to the field's inherently interdisciplinary nature. They facilitate the blending of theoretical knowledge with practical application, enabling students to better understand the complexities and real-world challenges of renewable energy systems. Through remote labs, students can simulate and analyze energy generation, storage, and distribution processes, experiment with various scenarios, and develop innovative solutions to current energy problems [15,16].

Remote laboratories in renewable energy higher education represent a transformative approach that enhances the accessibility, flexibility, and quality of practical education. They prepare students to become skilled professionals capable of addressing the global energy challenges of the future, thereby contributing to the advancement of sustainable energy technologies and the broader goal of environmental stewardship.As part of this experience and solutions, five related projects[1] (EUSL-Energy, EUBBC Digital, EU-BEGP, EDU-ABCM and EEU-ZW) under the overall Explore Energy Digital Academy (EEDA) concept [17], work collaboratively to advance sustainable practices and innovative solutions across various areas of expertise related with renewable energy.

EEDA is an overarching initiative designed to foster collaboration among universities and institutions around the world. It aims to create a comprehensive digital ecosystem that integrates educationacross renewable energy. By leveraging digital technologies, flipped learning, the academy seeks to support the transition to a sustainable and resilient future.An essential component of EEDA is its repository, which have dataand educational resources developed by EUBBC Digital and the other related projects. This repository ensures that valuable information is accessible to learners, professors, and public in general.Additionally, a set of remote labs has been developed within EEDA [18], facilitating hands-on research and experimentation in various fields. These remote labs enable users to conduct experiments and gather data from anywhere, promoting collaborative research and innovation across geographical boundaries.

MATERIALS AND METHODS

Electrical Engineering Faculty Background Inside EUBBC Project

The Republic of Cuba is a country with limited generation supply. Because of this, the government has set a strategic focus on two main directions: energy saving and efficiency, and the efficient supply of energy using renewable resources to ensure future economic development. To achieve the above-mentioned goals, Cuban institutions have developed activities in the following areas [19]:

1) Use of renewable energy sources as one of the main priorities for the country.
2) Modification of the energy matrix of generation and consumption of electricity.
3) Decreasing the inefficiencies of the equipment of the electrical system.
4) Reduction of the dependence on fossil fuels.
5) Contribution to environmental sustainability.
6) Increasing competitiveness of the economy as a whole.
7) Decreasing the high cost of energy delivered to consumers due to fuel prices.

The role of Cuban's Universities is to contribute, from science perspective, to progress in all the areas mentioned above. With research papers, doctoral and master's thesis, publications, conferences papers, among others. Teamwork between areas of the same university and between universities is a fundamental aspect to achieve these objectives, as well as work with universities and research centers in other countries, allowing exchange experiences and personal, use of equipment and facilities, dissemination and internationalization. The Technological University José Antonio Echeverría (CUJAE) is the Technical University of Havana, and the only technological university of Cuba. The Faculty of Electrical Engineering at CUJAE is the leading institution for electrical engineering studies in the country. The main research topics are linked to Cuba's national power producer Unión Eléctrica. This company generates, transmits and distributes electricity in Cuba. The Faculty is also responsible for the continuous development of the curriculum for electrical engineers in the Western part of the country.

[1] EUSL-Energy: https://eusl-energy.firebaseapp.com/
EUBBC Digital:https://www.eubbcdigital.com/
EU-BEGP: https://eu-begp.org/es/
EDU-ABCM: https://tpg.unige.eu/edu-abcm-capacity-building-on-student-centered-energy-education-in-cameroon-ethiopia-mauritius-and-mozambique/
EEU-ZW: https://euzw.managewe.com/euzwweb/index.php

Moreover, the center offers courses for postgraduate studies, such as the Master of Electrical Engineering and a PhD program. For achieve this, a participation in national and international projects are essential. One of these projects is EUBBC-Digital. The EUBBC-Digital project (Europe, Brazil, Bolivia and Cuba) aims to promote the development of capacities to create digital learning modules available globally, to collaboratively implement postgraduate programs in Latin America. As part of the project, one of the main goals is the development of a remote laboratory and remote laboratory exercises that could be used by the teachers inside the project and students globally. This remote laboratory will be the first of its kind at CUJAE. Besides the remote laboratories at the University of Havana[2] and the University of Villa Clara[3] (as part of the EUBBC project), there is no other laboratory of this type reported in Cuba.

Remote Laboratory Proposal

The renewable energy sources (RES) laboratory will allow to carry out experiments regarding the control and operation of hybrid systems, isolated systems and systems with high penetration of renewable sources. It will allow students to become familiar with the use of RES, understand their characteristics, operation and integration to grid, on the one hand, understand renewable technology and on the other, how to operate to maintain efficient energy consumption.

This laboratory will serve not only for educational purposes, but also for research. In addition, once it is in operation, a service will be offered not only to university students, but it will also serve as vocational training for students of previous educations, guided tours for children and the rest of the community to understand the need for renewable sources within the energy mix of a country or region. The intent is to use the lab in several environments while creating specific Intended Learning Outcomes (ILOs) for each case, ranging from overall demonstrations for citizens to “hard-core” engineering exercises for MSc level students, passing via ILOs where vocational training by practicing technicians is performed. This will be performed through the use of specifically adapted “learning modules” (via the system used in EEDA) where the base material is used but adapted to the intended target groups (figura 1), [20].

Fig.1. Example of how a lab description is identified for different target groups (from Universidad PrivadaBoliviana)

RESULTS AND DISCUSSION

Development of the Remote Laboratory

The Laboratory will have the following equipment and capabilities. In the first stage, the equipment is from EDIBON[4]:

•Conventional Energy Power Plant (figure 2). Its purpose is, as in a real microgrid, to create the bases of the structure of the electrical microgrid and determine its frequency and voltage parameters. The rest of the plants will be synchronized to this thanks to the stability produced. In addition, this application acts as a base generation in the microgrid, providing electric power at a constant rate. As in real microgrids, this application represents diesel or gas generation, typically used on islands or other microgrid-based systems.

[2]The PV remote lab is under development at University of Havana as part of EUBBC-Digital
[3]The Solar concentration remote laboratory is presently under procurement of UCLV
[4] https://www.edibon.com/en/

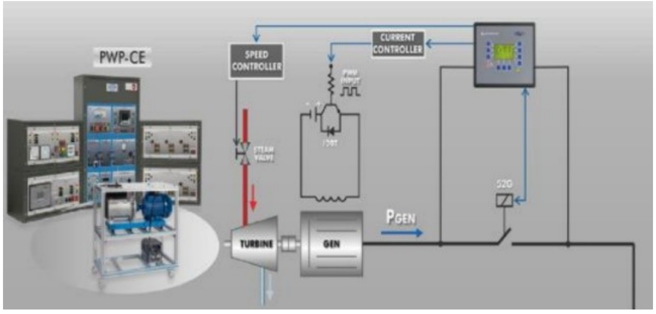

Fig.2. Conventional Energy Power Plant, Model PWP-CE

•Wind Energy Power Plant. The purpose of this application is the study of wind power plants in the context of microgrids. It is made up of an induction turbine-generator group whose purpose is to supply energy to the micro-grid by distributing intelligent energy based on the decisions of the operator (user). For this, the application includes a network analyzer to measure in real time the energy produced by the wind power plant. To control the turbine-generator group, a multifunction digital controller (AVR and ASC) is included that will allow optimal regulation of all its electrical and mechanical parameters. Among many parameters, it is possible to control the active power "set point" to automatically select how much power we want to inject into the microgrid. The multifunction controller is of vital importance, since it is the one in charge of managing the power distribution between the different energy sources. See figure 3.

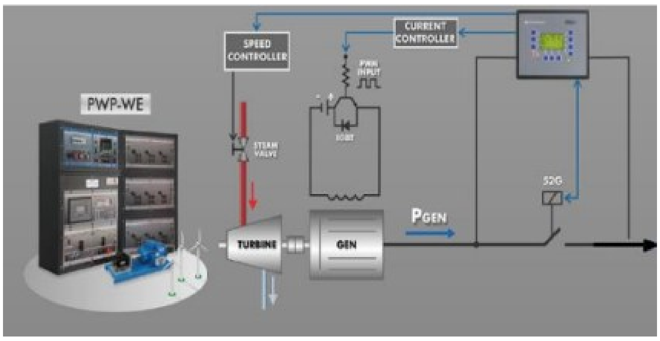

Fig.3. Wind Power Plant, Model PWP-WE

•Photovoltaic Power Plant (figure 4). The purpose of this application is the study of photovoltaic power plants in the context of microgrids. It has a three-phase inverter powered by a photovoltaic panel array simulator. The parameters and generation functions of the photovoltaic simulator may be configured by the user according to the situations and conditions to be studied. At the same time, the user will be able to study important concepts on photovoltaic installations such as the MPPT characteristic (maximum power point monitoring), the limitation of the power of an inverter (derating), the efficiency of an inverter or the generation of reactive energy.

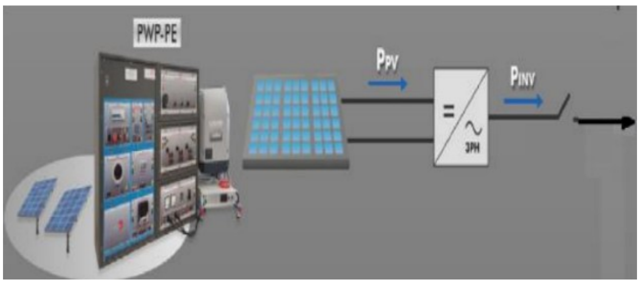

Fig.4. Photovoltaic Power Plant, Model PWP-PE

•Data Acquisition and Power Management Software. Represents the control and operation center of a microgrid. From with this software the user will be able to plan wind, and photovoltaic energy resources. Based on this predefined plan, Renewable energy generation sources will inject available energy into the microgrid to meet demand needs.

Metodologycal aspects

Clear intended learning outcomes are a key component of good program and unit planning and assessment for students. Intended Learning Outcomes (ILOs) define what a learner will have acquired and will be able to do upon successfully completing their studies.

In the EEDA the Intended Learning Outcomes are all established as per the European Qualification Framework (EQF) 2017[5], separated into "Knowledge", "Skills" and "Responsibility & Autonomy". The first intended stakeholders of the lab will be students at MSc level as well as practicing engineers on Master level, The main ILOs, of the lab are that the learners shall be able to:

- Simulate and operate hybrid system with renewable energy, understand their characteristics, operation and integration to grid, on the one hand, understand renewable technology and on the other, how to operate to maintain efficient energy consumption.
- Analize the behavior of wind power (second stage) and photovoltaics plants (first stage) in the context of microgrids.
- Increase the knowledge and ability of teachers and the institution itself about the use and possibilities of the presence of not only virtual, but also remote laboratories, within the educational teaching process that takes place in our University.

This application can work together with other energy generation equipment to study the energy mix, its advantages and the problems that arise when alternative sources are interconnected in the same electrical system. This application can be combined with other generation, transmission/distribution and load applications. The intending date for have the laboratory ready, and offer the first experiments is September 2024. The laboratory can be used by Cuban students directly, physically in the laboratory facilities. It can also be used by Cuban students in other provinces of the country (different from Havana), as well as by students from other universities and institutions outside of Cuba through the booking system.

As part of our master's program, more than 60% of the students in our program are from the productive sector, these students will also have access to the laboratory. In the near future, a business model will be established for the promotion and use of the laboratory in the productive sector.Some of the practical exercises that can be carried out with this laboratory equipment:

- Basic concepts of isolated networks.
- Automatic control of the voltage and frequency of the synchronous generator in an island network.
- Study of energy demand and generation in isolated networks.
- Maximum production of photovoltaic power with grid injection through the grid inverter.
- Maximum photovoltaic power production with grid injection through the grid inverter and local energy consumption.
- Remote control of the voltage and power setpoints of the synchronous generator in the microgrid.
- Remote synchronization operation with synchronous generator and grid.
- Visualization of the power curve for the pre-configured solar irradiation values.
- Real-time monitoring of frequency, current and voltage values and waveforms.
- Real-time monitoring of the active, reactive and apparent powers generated.

All of these exercises all related with real problems and case scenarios from Cuba. The learning from old cases and experience from professors and teachers form de Industry allow to understood and analyze the operation and design of hybrid systems and microgrid. In the other hand, these exercises allow to teachers an students analyze new scenarios and new hybrid system and microgrids, in cooperation with National Electric Company, with hug impact on the decision making and training of the personnel involved.

CONCLUSIONS

Having a remote laboratory will allow teachers and students to reach a new stage in their training, offering them the possibility of applying information and communication technologies to solve problems that, previously, required their physical presence in the laboratory, as well as supporting compliance of the objectives of the Computerization Program of Cuban society. It also allows us to offer a laboratory service, once the first phase is completed, to expand its use which will increase the efficiency of the installation.Teachers and students at other universities will be welcome (by contacting the main author of the paper) to use the facility.

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[5]https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017H0615(01)

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

CONTRIBUTION OF THE AUTHORS

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Diseño y programación de software empleados en la investigación. Participó en revisión del estado del arte, diseño y validación de modelo teórico, recolección de datos, realización de aplicaciones, trabajo estadístico, análisis de los resultados, redacción del borrador del artículo, revisión crítica de su contenido y aprobación final.

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