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Quintero Ávila Cristina
National Technological Institute of Mexico /I.T. De Ciudad Juárez, Mexico
https://orcid.org/0009-0006-3553-5752
quinterocristina492@gmail.com

Poblano-Ojinaga Eduardo Rafael*
National Technological Institute of Mexico/I.T. De Ciudad Juárez, Mexico
https://orcid.org/0000-0003-3482-7252
sadministrativa@cdjuarez.tecnm.mx

Rodríguez Mejía Jeovany Rafael
National Technological Institute of Mexico/I.T. of Ciudad Juárez, Mexico
https://orcid.org/0009-0001-2238-3255
jrodriguez@itcj.edu.mx

Meléndez Pastrana Inocente Yuliana
National Technological Institute of Mexico/I.T. of Ciudad Juárez
https://orcid.org/0000-0002-5260-7977
yuliana.mp@cdjuarez.tecnm.mx

Valles Chávez Adán
National Technological Institute of Mexico / IT of Ciudad Juárez, Mexico
https://orcid.org/0000-0002-6559-0123
avalles@itcj.edu.mx

***Corresponding Author**

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Abstract: The design of monitoring, control, and optimization systems in an energy generation system represents a solution to current economic and environmental challenges. In particular, these systems allow us to achieve efficiencies and high yields in operation. However, the use of high technology in this type of system allows for the integration of artificial intelligence (AI), data science, and the management of depreciation data by combining traditional microelectronics with MEMS sensors (microelectromechanical systems) and legacy semiconductors. The research proposal seeks to effectively achieve the integration into a hybrid power generation system of monitoring, control, and optimization using MEMS and legacy-type semiconductors. The aim is to optimize hybrid energy generation systems. The use of legacy semiconductors and integrated circuits. This is done with the goal of integrating the use of monitoring, control, and high-end optimization systems into the Hybrid Energy Design Methodology to analyze environmental impact and energy sustainability. Thus, the initial stage is to design and conceptualize the use of monitoring systems by MEMS sensors for physical and non-quantifiable variables, the use of legacy semiconductor control and optimization systems, and integrated circuits. Subsequently, as stipulated in the Hybrid Methodology SCRUMM, research results will be published in academic scientific journals, in addition to contributing to the training of human resources through the participation of undergraduate and postgraduate students.

Keywords: Hybrid power generation systems, Monitoring and control systems, MEMS sensors, Legacy semiconductors.

Abstract: The design of monitoring, control, and optimization systems in a power generation system represents a solution to current readjustment and environmental challenges. In particular, these systems enable us to achieve efficiency and high performance in operation. However, the use of high technology in this type of system allows for the integration of artificial intelligence (AI), data science, and deterioration data management, combining traditional microelectronics with MEMS (microelectromechanical systems) sensors and legacy semiconductors. The research proposal seeks to effectively achieve the integration of monitoring, control, and optimization in a hybrid power generation system through the use of MEMS and legacy semiconductors. The aim is to optimize hybrid power generation systems through the use of legacy semiconductors and obsolete integrated circuits.

The goal is to integrate the use of high-level monitoring, control, and optimization systems into the hybrid energy design methodology to analyze environmental impact and energy sustainability. Thus, the initial stage is to design and conceptualize the use of monitoring systems using MEM sensors for physical and non-quantifiable variables, the use of semiconductor media and legacy control and optimization systems, and obsolete integrated circuits. Subsequently, as stipulated in the SCRUMM Hybrid Methodology, the research results will be published in academic scientific journals, in addition to contributing to human resources training through the participation of undergraduate and graduate students.

Keywords: Hybrid power generation systems, monitoring and control systems, MEMS sensors, traditional semiconductors.

INTRODUCTION

The design of monitoring, control, and optimization systems in an energy generation system represents a solution to current economic and environmental challenges. In particular, these systems allow us to achieve efficiencies and high yields in operation. However, the use of high technology in these types of systems allows for the integration of artificial intelligence (AI), data science, and data management by combining traditional microelectronics with MEMS sensors (microelectromechanical systems) and semiconductors.

Thus, the hybrid laboratory that combines renewable energy sources seeks efficiency in energy production, reducing costs and carbon dioxide emissions (CO2).

Each technology in this hybrid system offers advantages; however, the flow of energy varies in these systems. Therefore, the appropriate administration of available energy is of great importance and value. The optimization and integration of these technologies allow us to overcome the limitations of each individual system, such as specific climate dependence, achieving a balance between supply and energy demand.

PROBLEM STATEMENT:

The design of monitoring, control, and optimization systems in hybrid power generation represents a solution to current environmental and energy challenges. However, the integration of high technology, such as artificial intelligence (AI), data science, MEMS sensors (microelectromechanical systems), and legacy semiconductors, is essential to enhance efficiency and sustainability. This research aims to develop a hybrid energy system that incorporates monitoring, control, and optimization through the use of MEMS and legacy semiconductors. The goal is to analyze the environmental impact and improve energy sustainability by integrating advanced monitoring and control methodologies into the hybrid energy design process.

OBJECTIVES:

General Objective

Integrate a hybrid energy generation system with a monitoring, control, and optimization system using MEMS and legacy-type semiconductors.

Specific Objectives

1. Integrate condition monitoring systems for hybrid energy generation systems into the infrastructure of the Alternative Energy Laboratory using MEMS sensors.
2. Incorporate control and optimization systems for hybrid energy generation into the laboratory infrastructure using legacy semiconductors and dedicated integrated circuits.
3. Integrate high-end monitoring, control, and optimization systems into the design methodology of hybrid energy systems to analyze environmental impact and energy sustainability.
4. Design and conceptualize the use of monitoring systems with MEMS sensors for physical and non-quantifiable variables.
5. Design and conceptualize control and optimization systems using legacy semiconductors and dedicated integrated circuits.
6. Publish research results in scientific journals and academic books.
7. Contribute to human resource development by involving undergraduate and graduate students.
8. Promote project dissemination through participation in conferences, seminars, and the National Laboratory of Microelectronics and Semiconductors.
9. Join the National Network of Alternative Energies.

THEORETICAL FRAMEWORK:

This research explores the integration of various systems related to energy generation, sustainability, and technology. The objective of the is to incorporate monitoring and control systems using MEMS

(Microelectromechanical Systems) and legacy semiconductors within a hybrid energy generation laboratory. As modern industry advances, global energy shortages and air pollution have become major issues, driving the world to accelerate the development of alternative energy resources. Solar energy, for instance, is widely available and has significant potential to replace fossil fuels. Photovoltaic technology demonstrates great promise in harnessing solar energy. Based on the photovoltaic effect, solar cells directly convert sunlight into electricity through a pollution-free process (Ruhang, 2016).

Photovoltaic Systems

A photovoltaic system is an electrical system that generates energy from sunlight. These systems rely on the ability of photovoltaic cells to convert sunlight into electrical energy. They are a widely used technology for generating renewable electricity in a decentralized manner, reducing greenhouse gas emissions and relying on abundant natural resources such as sunlight.

Wind Systems

A wind system is a form of renewable energy that converts the kinetic energy of the wind into electrical energy. It utilizes wind turbines, also known as aerogenerators, which consist of blades mounted on a tall mast. These turbines capture wind energy and convert it into mechanical energy, which is then transformed into electricity. Groups of wind turbines are known as wind farms. These farms, which can be located on land or offshore, can generate energy continuously depending on the availability of wind resources in the region. Wind energy is one of the most efficient forms of renewable energy.

Green Hydrogen

Green hydrogen is produced from renewable energy sources, such as solar or wind power, through the electrolysis of water—a process that separates water into hydrogen and oxygen without generating carbon dioxide (CO_2) emissions. This makes green hydrogen an option for decarbonizing sectors that traditionally rely on fossil fuels. It can serve as a clean alternative to conventional fossil fuels. During this process, the resulting hydrogen is stored and can be used as a clean fuel in various applications, including electricity generation, transportation, and industry.

Smart Grid

Smart grids are advanced electrical networks capable of monitoring and controlling consumption. They are installations in which consumption is visible at all times, and not only through the electricity bill.

They make it possible to monitor and measure the electrical behavior of each of the devices connected to the infrastructure.

To carry out these functions, smart grids incorporate an automated computer system, capable of automatically responding to variations in energy production and demand. Thus, both the end user and the distributor have more information about consumption, allowing for a more responsible use of energy throughout the cycle, from the generating plants to the domestic system.

These systems represent solutions for a shift towards a more sustainable energy system, reducing dependence on fossil fuels and reducing the environmental impacts associated with conventional energy generation.

FPGA and Semiconductors

Field-Programmable Gate Arrays (FPGAs) are semiconductor-based devices structured as matrices of configurable logic blocks interconnected through programmable connections. Their main advantage lies in their ability to be reprogrammed for specific tasks or adapted to new requirements even after manufacturing. Xilinx pioneered this technology, which has since evolved to be integrated into various applications across aerospace, automotive, electronics, and high-performance computing industries.

FPGAs are commonly used for hardware-level functionality testing before implementation in a processor. Their functionality is written in hardware description languages such as Verilog or VHDL. Additionally, simulation tools allow programs to run as if they were on the final hardware, ensuring proper interconnections and facilitating error detection and correction.

Today, real-time image processing tasks demand high computing power and efficient data management. FPGA technology offers both flexibility and computational performance at lower design costs. As a result, FPGAs have been widely adopted for robotic vision applications, signal processing systems, and FPGA-based control systems (Tessier, 2001).

Educational platforms incorporating FPGAs enable real-time linear and morphological image analysis. These platforms demonstrate image filtering using Xilinx Spartan FPGAs. They connect to personal computers, forming cost-effective yet powerful design workstations for educational purposes. Some FPGA-based systems feature a graphical user interface to manage communication, configuration, and data transfer (Ramirez, 2013).

DEVELOPMENT

For the development of the project, a hybrid methodology is proposed that integrates the particularities of traditional methodologies, mainly the incremental and design methodologies, while also having enough flexibility, similar to Scrum. Therefore, five macro modules are designated to represent the sequence of the incremental methodology primarily to achieve the set objectives. However, within each macro module, the Scrum methodology will be applied to allow sufficient flexibility and obtain results in each planned iteration.

In the first macro module, an analysis of the state of the art in hybrid energy generation systems laboratories and the use of monitoring, control, and optimization systems will be conducted. Additionally, specifications for the design and construction of the infrastructure will be defined based on existing topologies and possible configurations within educational and industrial environments for teaching and training purposes.

In the second module, the design and integration of monitoring, control, and optimization systems will be implemented within the hybrid energy generation systems laboratory infrastructure. Furthermore, indicators will be determined to validate the operation and interconnection capacity of the control, monitoring, and optimization systems, and assess the effectiveness of the open-access platforms.

In the third module, the methodology for the use of monitoring, control, and optimization systems in hybrid energy generation laboratories will be established. Additionally, evaluation methods for the efficiency and effectiveness of the developed infrastructure will be defined. In the fourth module, the impact of using control and optimization systems in hybrid energy generation laboratories on undergraduate and graduate students will be evaluated. In the fifth module, the most relevant results of the project will be published.

Furthermore, the results of the project, integrating control and optimization systems in the hybrid energy generation laboratory, will be presented at conferences, and efforts will be made to participate in thematic conferences within the academic units of engineering and graduate programs. However, it is important to note that the documentation of the project and the development of publications are worked on in parallel. For this reason, the hybrid methodology needs to be applied, as it allows for obtaining significant results during the development of the project, thus expanding the number of impactful published works.

Linking

This project aims to generate impact in urban and educational areas through the implementation of hybrid energy generation systems and the set of monitoring, control, and optimization systems designed using emerging technologies such as MEMS and Legacy Semiconductors. Therefore, by integrating technologies such as photovoltaics, wind, and green hydrogen, the goal is to provide sustainable and efficient solutions that address the energy needs of today's society.

This project requires the participation of students from various academic programs at the Institute, both at the undergraduate and graduate levels, who will be carrying out their professional residencies or thesis research. Through their collaboration, they will apply the methodology for the efficient use of infrastructure to develop monitoring, control, and optimization systems designed with emerging technologies such as MEMS and Legacy Semiconductors, along with energy and energy efficiency evaluation methods.

Collaboration from the linking departments will be requested for the validity of agreements or for the establishment of new linkage-collaboration agreements with industrial transformation chambers if necessary. Linkage and collaboration in the training of human resources to strengthen the National CONACYT Laboratory of Microtechnology and Semiconductors.

The results obtained, as well as the strategies and conclusions, will be published in scientific and outreach articles.

Proposed Method

This research proposes the design and characterization of a hybrid energy generation system with monitoring, control, and optimization capabilities. It integrates AI, data science, MEMS sensors, and legacy semiconductors to enhance efficiency, reduce costs, and minimize CO2 emissions through real-time energy management and optimization.

DISCUSSION AND ANALYSIS OF EXPECTED RESULTS

The proposed hybrid energy generation system is expected to increase efficiency and reliability by integrating AI-driven optimization, MEMS sensors, and legacy semiconductors. By combining multiple renewable sources, the system aims to reduce dependence on specific weather conditions, achieving a more stable and consistent energy output. Real-time monitoring and control will enable dynamic adjustments, leading to higher energy output and lower operational costs.

Furthermore, the optimization algorithms are anticipated to minimize CO_2 emissions by efficiently managing energy storage, promoting greener energy production. The integration of data science techniques will improve resources, allowing for better resource allocation and demand forecasting. All in all, the system is expected to demonstrate improved performance, cost-effectiveness, and sustainability, making it a viable solution for future energy challenges.

The literature review conducted provided new insights into the importance of integrating advanced monitoring, control, and optimization systems within hybrid energy generation setups. By exploring various renewable energy sources such as solar, wind, and hydrogen technologies, it became evident that combining these systems not only improves energy efficiency but also enhances sustainability by reducing carbon emissions. The review highlighted how technologies like MEMS sensors and legacy semiconductors play a crucial role in real-time data acquisition and optimization, enabling better resource management. These findings underscore the significant potential of such hybrid systems to address both operational and environmental challenges in energy production.

CONCLUSIONS

Based on the literature review, the design and integration of monitoring, control, and optimization systems within hybrid energy generation systems presents a promising solution to current energy and environmental challenges. By combining various renewable energy sources like solar, wind, and green hydrogen with advanced technologies such as MEMS sensors, legacy semiconductors, and artificial intelligence, these systems can achieve greater operational efficiency, reduce energy costs, and minimize environmental impact. The research demonstrates that real-time monitoring and dynamic control enable optimal energy management, ensuring a more stable and reliable energy output. Moreover, this integration not only enhances the sustainability of energy production but also contributes to lowering CO_2 emissions, thus aligning with global efforts towards cleaner, more sustainable energy solutions. The successful implementation of these systems can serve as a model for future energy infrastructures, promoting both environmental stewardship and energy security.

FUTURE WORK

Building on the current research, future work will focus on further improving the integration of monitoring, control, and optimization systems within hybrid energy generation setups. One key area for development is the expansion of the system's scalability, enabling it to integrate a wider variety of renewable energy sources and adapt to different geographical and environmental conditions. Future efforts will also explore the continuous improvement of AI-driven optimization algorithms, incorporating machine learning techniques to predict energy demand more accurately and enhance real-time decision-making processes. Also, more in-depth testing of the system's performance under various operational conditions will be conducted to refine energy storage management and improve the overall reliability and efficiency of the system. Besides, further collaboration with industrial partners and stakeholders in the energy sector will be requested to validate the system in real-world applications, ensuring its viability for large-scale deployment. Finally, additional research will focus on the long-term environmental impact of hybrid systems, with an emphasis on minimizing waste, optimizing resource use, and improving the overall sustainability of energy production.

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COLLABORATIVE WORK TABLE

Role	Author(s)
Conceptualization	Rodriguez Mejia Jeovany Rafael, Quintero Avila Cristina, Poblano Eduardo
Methodology	Rodriguez Mejia Jeovany Rafael, Pinto Santos Jorge, Poblano Eduardo
Software	Pinto Santos Jorge, Poblano Eduardo, Rodriguez Mejia Jeovany Rafael
Validation	Pinto Santos Jorge, Rodriguez Mejia Jeovany Rafael, Poblano Eduardo
Formal Analysis	Quintero Avila Cristina, Pinto Santos Jorge, Poblano Eduardo
Investigation	Quintero Avila Cristina, Pinto Santos Jorge, Rodriguez Mejia Jeovany Rafael
Resources	Rodriguez Mejia Jeovany Rafael, Poblano Eduardo
Data	Rodriguez Mejia Jeovany Rafael, Poblano Eduardo, Pinto Santos Jorge
Writing – Original Draft Preparation	Quintero Avila Cristina, Pinto Santos Jorge
Writing – Review & Editing	Pinto Jorge, Cristina Quintero Avila, Poblano Eduardo
Visualization	Pinto Jorge, Poblano Eduardo, Cristina Quintero Avila
Supervision	Pinto Jorge, Rodriguez Mejia Jeovany Rafael, Poblano Eduardo
Project Administration	Cristina Quintero Avila, Valles Chavez Adan, Eduardo Poblano
Funding Acquisition	Pinto Jorge, Cristina Quintero Avila, Poblano Eduardo