

AVIS DE SOUTENANCE D'UNE THESE DE DOCTORAT

Le Directeur de l'Ecole Nationale des Sciences Appliquées a le plaisir d'informer le public

qu'une soutenance de thèse de Doctorat en

«**Sciences et ingénierie**»

aura lieu le 18/04/2026 à 15H à l'ENSA, Kénitra

La Thèse sera présentée par Mr BENZZINE HAMZA

Sous le thème :

Intelligent Greenhouse Energy and Climate Management: Data-Driven Forecasting and AHP-Prioritized MPC with Hybrid Renewable Microgrid Integration

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Sujet de thèse :

Intelligent Greenhouse Energy and Climate Management: Data-Driven Forecasting and AHP-Prioritized MPC with Hybrid Renewable Microgrid Integration

Abstract:

Greenhouse production is increasingly constrained by energy cost, water scarcity, and climate variability, making conventional rule-based control and grid-dependent operation difficult to sustain, particularly in warm and semi-arid regions. This thesis proposes an integrated framework for intelligent greenhouse energy and microclimate management that combines (i) thermal/energy modeling, (ii) data-driven forecasting of weather disturbances, (iii) AHP-based agronomic prioritization, and (iv) Data-Enhanced Model Predictive Control (DE-MPC) coupled with a hybrid renewable microgrid.

The work first establishes the scientific positioning through a review of greenhouse energy efficiency, renewable integration, and predictive control, then develops a greenhouse energy balance to quantify heat exchanges through the envelope and ventilation. Passive cooling options are synthesized, and a case study on ventilation/window positioning under Moroccan conditions illustrates how architectural choices can reduce cooling demand while maintaining indoor stability.

A hybrid energy supply architecture integrating PV/wind generation and battery storage is then designed and evaluated. A MATLAB-TRNSYS co-simulation environment with closed-loop optimization, enabling an MPC-based Energy Management System to coordinate power flows under operational constraints and maximize renewable utilization.

For climate operation, external disturbances (temperature, humidity, solar irradiance, wind) are forecast using deep learning models (e.g., LSTM/PLSTM), and the predictions are embedded in the MPC horizon for anticipatory control. Agronomic expertise is incorporated via the Analytic Hierarchy Process, converting expert priorities (temperature, humidity, irrigation/fertigation, lighting, CO₂) into weights in the MPC objective to achieve transparent trade-offs between crop-oriented performance and energy consumption.

Seasonal simulations indicate improved microclimate tracking, reduced unnecessary actuator usage, and higher renewable penetration compared with baseline strategies while satisfying system constraints. Finally, the thesis outlines translation toward practice through the SCAISAR pilot deployment, a 50 m² research greenhouse integrating sensors, actuators, centralized management, and a hybrid microgrid with grid-compliant coupling and commissioning requirements. The pilot serves as a platform to validate the proposed methodology, refine models with field data, and support scalable deployment.

Keywords: Greenhouse; controlled environment agriculture (CEA); Model Predictive Control; forecasting; multi-objective optimization; AHP; hybrid microgrid; energy management; co-simulation; food–water–energy (FWE) nexus