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Realized by

Mr. Smail MANSOURI
Ms. Sarra MADI

Enhanced Real-Time Monitoring System for Photovoltaic (PV) Systems: Integration of I-V Curve Analysis

Supervised by

Associate Professor	Dr. Azzeddine DEKHANE	NHSTE
Assistant Professor	Dr. Abdallah BOUZITOUNA	NHSTE

Thesis defended before a jury composed of :

Grade	Full Name	President	Institutional Affiliation
Grade	Full Name	Examiner	Institutional Affiliation
Grade	Full Name	Examiner	Institutional Affiliation
Grade	Full Name	Guest	Institutional Affiliation

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"يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ ۚ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ ﴿١١﴾" سورة المجادلة

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Smail Mansouri & Sarra Madi

Dedication

“

I dedicate this work to

My dear parents, whose love, sacrifice, and encouragement have been the guiding light of my academic journey.

To my beloved brothers, Ayoub and Mohamed, your support means the world to me.

In loving memory of my grandmother, whose presence I dearly miss, yet whose teachings and love continue to resonate within me every day. " اللَّهُمَّ ارْحَمْ جَدَّتِي وَاغْفِرْ لَهَا "

To all my best friends, DRIHEM Youcef Rami, BELHACINI Lina, MANAA Assil, SELMANE Anouar and all my beloved companions, your support has been invaluable.

”

Smail Mansouri

Dedication

“

I dedicate this work to

You, my steadfast pillars, my source of strength and support along the way, my parents. Every step of the way has been guided by your values and your inspiring example.

To my beloved sister Fairouz and my dear grandmother.

To my sister and best friend, the one who has supported me through all these years, in the good times as well as the most difficult, to the person dearest to my heart, my sister Hiba.

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”

Sarra Madi

Abstract

The increasing adoption of photovoltaic (PV) systems Requires advanced monitoring solutions to ensure optimal performance and reliability. This thesis presents the development and implementation of a real-time PV system monitoring system, incorporating an I-V tracer to enhance the accuracy and efficiency of performance assessments. Two distinct approaches were explored to achieve this goal.

The first approach follows the IEC 60891 standard, which facilitates the conversion of measured I-V characteristics in operating conditions (OPC) to Standard Test Conditions (STC). The correction under STC conditions allows the estimation of the deviation between the tested module's power and the maximum power specified by the manufacturer.

The second approach involves the estimation of the single diode model (SDM) parameters using a metaheuristic optimization algorithm known as Teaching-Learning-Based Optimization (TLBO). This algorithm effectively estimates the parameters by mimicking the pedagogical process of teaching and learning, thereby providing a robust solution for parameter extraction under varying environmental conditions.

Keywords: PV panels, solar cell modeling, monitoring and data acquisition, fault detection and identification, solar performance analysis, I-V curves, Teaching-Learning-based Optimization algorithm, Procedures for temperature and irradiance corrections.

ملخص

يتطلب الانتشار المتزايد لأنظمة الطاقة الكهروضوئية (PV) تطبيق حلول مراقبة متقدمة لضمان الأداء الأمثل والموثوقية العالية. تستعرض هذه الأطروحة عملية تطوير وتنفيذ نظام مراقبة في الوقت الفعلي لأنظمة الطاقة الكهروضوئية، بما في ذلك دمج جهاز تتبع التيار-الجهد (I-V) لتعزيز دقة وكفاءة تقييمات الأداء. تم تحليل واستكشاف نهجين لتحقيق هذا الهدف بنجاح.

النهج الأول يستند إلى معيار IEC 60891، الذي يسهل تحويل خصائص التيار-الجهد (I-V) المقاسة في ظروف التشغيل (OPC) إلى ظروف الاختبار القياسية (STC). يتيح إجراء التصحيح تحت ظروف الاختبار القياسية تقدير الفروق بين القدرة الفعلية للوحدة المختبرة والقدرة القصوى المحددة من قبل الشركة المصنعة.

النهج الثاني يشمل تقدير معلمات نموذج الصمام الثنائي الواحد (SDM) باستخدام خوارزمية تحسين ميتاهوريستية تُعرف باسم تحسين القائم على التعليم والتعلم (TLBO). تُقدر هذه الخوارزمية المعلمات بشكل فعال من خلال محاكاة عملية التدريس والتعلم، مما يوفر حلاً قوياً لاستخراج المعلمات تحت ظروف بيئية متغيرة.

الكلمات المفتاحية: لوحات الطاقة الشمسية، نمذجة الخلايا الشمسية، المراقبة وجمع البيانات، كشف الأعطال والتعرف عليها، تحليل أداء الطاقة الشمسية، منحنيات I-V، خوارزمية التحسين المعتمدة على التعليم والتعلم، إجراءات تصحيح درجة الحرارة والإشعاع.

Résumé

L'adoption croissante des systèmes photovoltaïques (PV) nécessite des solutions de surveillance avancées pour garantir des performances et une fiabilité optimales. Cette thèse présente le développement et la mise en œuvre d'un système de surveillance en temps réel des systèmes PV, intégrant un traceur I-V pour améliorer la précision et l'efficacité des évaluations de performance. Deux approches distinctes ont été explorées pour atteindre cet objectif.

La première approche suit la norme IEC 60891, qui facilite la conversion des caractéristiques I-V mesurées en conditions de fonctionnement (OPC) en conditions de test standard (STC). La correction sous conditions STC permet d'estimer la déviation entre la puissance du module testé et la puissance maximale spécifiée par le fabricant.

La deuxième approche implique l'estimation des paramètres du modèle à diode unique (SDM) en utilisant un algorithme d'optimisation métaheuristique connu sous le nom d'optimisation basée sur l'apprentissage et l'enseignement (TLBO). Cet algorithme estime efficacement les paramètres en imitant le processus pédagogique, fournissant ainsi une solution robuste pour l'extraction des paramètres dans des conditions environnementales variées.

Mots-clés: panneaux photovoltaïques, modélisation des cellules solaires, surveillance et acquisition de données, détection et identification des défauts, analyse des performances solaires, courbes I-V, algorithme d'optimisation basé sur l'apprentissage, procédures de correction de la température et de l'irradiance.

List of Abbreviations and Acronyms

PV	Photovoltaic
MENA	Middle East And North Africa
EBMs	Electrical-based methods
VTMs	Visual and thermal methods
SPDT	single-pole double-throw
IEC	International Electrotechnical Commission
OPC	Operating Conditions
STC	Standard Test Conditions
DUT	Device Under Test
SDM	Single Diode Model
CEC	California Energy Commission
SAM	System Advisor Model
TLBO	Teaching-Learning-Based Optimization
ADC	Analogue-Digital Converter
FET	Field-Effect Transistor

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