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Ph.D. Dissertation Defense

Entitled

CAPTURING MAXIMUM PV POWER WITH MACHINE LEARNING: MAXIMUM CURRENT PREDICTION, MPPT METHODOLOGY, AND ADJUSTABLE ML-BASED CONTROLLER

by

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Abstract

The primary aim of this doctoral thesis is to investigate the potential application of machine learning (ML) in optimizing Maximum Power Point Tracking (MPPT) and developing an adaptable ML-based controller for photovoltaic (PV) systems. The absence of MPPT mechanisms results in fixed voltage and current points for PV modules, leading to significant power loss when environmental conditions fluctuate. The limitations of conventional and improved conventional MPPT methods, as well as classical Proportional-Integral (PI) controllers, have motivated the exploration of alternative methods to maximize PV power. To address these limitations, this thesis proposes the use of ensemble ML methods, specifically the CatBoost algorithm, as a viable alternative to conventional MPPT methods. The proposed methodology incorporates the ability of ML models to learn from data and adapt to varying environmental conditions. The CatBoost method was found to outperform other methods in predicting the maximum current, with mean and standard deviation of absolute error of almost 9000 samples of 0.0025% and 0.0084, respectively. Additionally, this thesis proposes an adjustable ML-based controller for PV systems that addresses the limitations of PI controllers by leveraging the learning ability of ML models. The controller uses feature engineering and SHapley Additive exPlanations (SHAP) values for feature analysis, enabling the identification of the features that have the most significant impact on system performance and adjusting the controller's parameters accordingly. Results showed that almost 75% of the model output is highly correlated to the reference current and the error signal, with feature importance of 45% and 30%, respectively. The proposed methodology was verified experimentally, and the results showed that the proposed gradient boosting based controller had an overall minimum mean error of 3.06E-03. In transient response analysis, the proposed controller was associated with the lowest rise and fall times of 2.148 ms and 2.456 ms, respectively. In summary, the proposed methodology demonstrates the potential of ML to improve the performance of PV systems and provides a promising direction for future research in the field. The work presented in this thesis is a significant contribution to the development of efficient and adaptable MPPT mechanisms and adjustable ML-based controllers for PV systems.

Keywords: Adjustable ML-based controller, CatBoost algorithm, Maximum Power Point Tracking, Photovoltaic systems, Machine learning