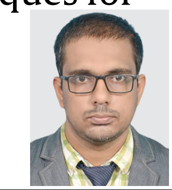
Sustainable Energy, Grids and Networks 29 (2022) 100582

Contents lists available at ScienceDirect

Sustainable Energy, Grids and Networks

journal homepage: www.elsevier.com/locate/segan

Performance assessment of selective machine learning techniques for improved PV array fault diagnosis



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ARTICLE INFO

Article history:
Received 1 September 2021
Received in revised form 17 November 2021
Accepted 28 November 2021
Available online 16 December 2021

Keywords:
PV arrays
Machine learning
Fault diagnosis and classification
XGBoost
CatBoost
Light gradient boosting machine

ABSTRACT

Solar photovoltaics (SPV) are susceptible to various kinds of faults which can diminish overall performance of the system. Proper fault diagnosis strategy needs to be developed to accurately identify the faults for smooth operation of the photovoltaic (PV) systems. Machine learning (ML) can be used to diagnose the faults in PV arrays. In this paper, three powerful machine learning algorithms i.e., categorical boosting (CatBoost), light gradient boosting method (LGBM), and extreme gradient boosting (XGBoost) have been selected for investigating their efficacy to diagnose different PV array faults. A PV system has been designed in MATLAB/Simulink environment using real time irradiance and temperature data acquired from grid connected PV System of National Institute of Technology Agartala. The constructed dataset is used to extract features including one new index to train these algorithms in Python 3.7. Promising results have been achieved using these algorithms as average detection and classification accuracy of 99.996% and 99.745% has been noted by implementing LGBM, followed by CatBoost, and XGBoost respectively. Moreover, these algorithms reduce the computational time significantly with LGBM leading the chart with training time of 0.053 and 0.375 s for fault detection and classification. These algorithms have been compared with random forest (RF) technique to exhibit their proficiency in fault diagnosis of PV arrays.

1. Introduction

1.1. Motivation and incitement

There is a perceptible paradigm shift in power and energy sector since last few decades through conventional to renewable energy sources (RES). The fundamental causes behind this can be identified as — environmental concerns as well as rapid depletion of conventional energy sources. Solar and wind energy are the main contributors of RES. As per the report of International Renewable Energy Agency [1], the renewable energy production has increased from 1227 to 2537 GW during 2010 to 2019, which accounts to a staggering 106.78% growth in renewable power production. In the meantime, power generation from SPV has increased from 40 GW to 580 GW, emanating a 1350% growth in capacity. The significance of SPVs among RESs is further established as power generated from SPV constitutes approximately 23% of total renewable power production. The advantages of using solar energy are — abundantly available, sustainable in nature with almost zero carbon footprints [2].

Faults are still mostly detected using manual techniques throughout the world. These manual techniques require human intervention which often can analyze the external parts and bears the possibility of inefficient fault detection. Moreover, the faults can only be diagnosed post incident [3]. Hence, accurate and fault diagnosis is essential to maintain the performance of the system. PV systems are designed to withstand harsh operating conditions. However, continuous operation of PV systems under such conditions may result in deficient performance of the system. Moreover, PV systems are considered as expensive energy producing source due to its high operating cost and low energy conversion capabilities [4]. Hence, fault free operation of PV system must be ensured to prevent the further escalation of the operating cost. Additionally, continuous monitoring is required to identify the causes which may potentially harm the system [5]. Fault detection algorithms are essentially employed to identify the faults occurred in the PV system, which eventually permits the operator to implement corrective actions for smoother operation of the PV system [5]. Undetected faults may cause lifetime reduction, decrement in power generation, and even result in fire hazards [6]. Hence, accurate examination, smart monitoring of system, and prompt fault detection are necessary in PV system to ensure smooth operation of the plant [7,8]. Faults in PV array can primarily be classified as — short circuit, open

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https://doi.org/10.1016/j.segan.2021.100582
2352-4677/