J. Inst. Eng. India Ser. B
https://doi.org/10.1007/s40031-025-01211-6

ORIGINAL CONTRIBUTION

Sovereign Butterfly Optimization and Flyback Converter Integration for Robust Photovoltaic Systems Under Partial Shading

Saqib Asgar Kanth[1,2] · **Baziga Youssuf**[1] · **Sheikh Javed Iqbal**[1]

Received: 22 January 2024 / Accepted: 20 February 2025

Abstract This paper presents an advanced approach to enhance the performance of grid-connected photovoltaic (PV) systems under partial shading conditions. The proposed method integrates a flyback converter with the Sovereign Butterfly Optimization Algorithm for Maximum Power Point Tracking. The flyback converter is rigorously analysed for reliability, performance, and grid compliance. To mitigate voltage harmonics and phase delays, a controller-based anomaly obliteration technique is employed, processing three-phase currents through dq0 frames. Additionally, a Subsystem Synchronization Control Strategy is applied to synchronize active and non-active currents injected into the grid. Simulation results demonstrate significant improvements, achieving 99.31% tracking accuracy, 2.60% minimum power oscillation around the maximum power point, and maintaining the Total Harmonic Distortion of grid current at 1.94%, meeting IEC 61727 standards. This innovative approach offers a robust solution for enhancing grid-connected PV systems' performance under partial shading conditions.

Keywords PV · MPPT · Partial shading · Flyback converter · Butterfly optimization algorithm · Grid connected

✉ Saqib Asgar Kanth
saqibasgarkanth@gmail.com

Baziga Youssuf
baazii007@gmail.com

Sheikh Javed Iqbal
jvd@nitsri.ac.in

1 Department of Electrical Engineering Jammu and Kashmir, NIT Srinagar, Srinagar, India

2 Srinagar, India

Introduction

The surge in Renewable Energy Resources (RER) capacity signals a transformative era in global energy, led by solar and wind energy. Yet, the inherent uncertainty of these intermittent resources poses a challenge to power grid stability, demanding efficient management during fault conditions for grid reliability [1]. Despite strides in grid integration, challenges persist due to RER intermittency, impacting power grid stability. Large-scale applications with high-power central inverters for renewable energy adopt control strategies akin to grid-side converters. As global integration of Photovoltaic (PV) systems expands, optimizing performance becomes pivotal for effective power generation [2]. A major hurdle to optimal performance is partial shading (PS), causing a substantial reduction in PV output power. Maximum Power Point Tracking (MPPT) is particularly challenging under PS, as the PV system exhibits multiple maximum points. Inadequate MPPT controllers may fail to identify the true maximum point, resulting in decreased output power [3]. The research community explores various AI-based MPPT algorithms, including Fuzzy Logic Control (FLC) [4–6]. While FLC-based algorithms show promise, their reliance on PV power-voltage (P–V) scan methods introduces computational complexity, cost, and slower tracking [7]. FLC algorithms may struggle to monitor global maxima under shaded conditions [8]. Recent AI-based MPPT advancements integrate FLC with differential flatness control [9], compare with Particle Swarm Optimization (PSO), and propose an adaptive neuro-fuzzy system-based MPPT [10]. Challenges persist, including computational complexity and longer convergence times [11–14].

The Photovoltaic (PV) system integrates into the utility grid at the Common Coupling Point (CPP), introducing active power filtering using an efficient signal generation

Published online: 08 March 2025