Chapter 14
Optimization of MPPT Controller for Standalone Photovoltaic Systems

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ABSTRACT

A photovoltaic (PV) system uses the maximum power point tracking (MPPT) controller used in a photovoltaic (PV) system to get the maximum power operating point at different temperatures and irradiance conditions. Several optimization methods from conventional to soft computing methods have been applied to software and hardware platforms to generate duty cycles and optimize fuzzy membership functions. The PV system with partial shading condition is also considered for better tracking of power peaks. Merits and demerits of different MPPT optimization methods have been discussed to conclude better. The results obtained by recently developed algorithms in the MPPT controller have been compared to show better performance and effectiveness of the algorithm. This chapter references undertaking research work to optimize MPPT controllers in PV systems under partial shading conditions.

1. INTRODUCTION

In recent years, researchers have shown significant interest in renewable energy sources due to their abundant availability across a broad spectrum (Shah et al., 2023). The photovoltaic (PV) system's power generation has no impact on pollution, has no moving components, and doesn't deplete materials (Shah et al., 2023; J. Soni & Bhattacharjee, 2023). The ambient temperature and solar irradiation have an impact on the performance of the PV system. Furthermore, the PV system achieves its highest output power at a specific operating point (Bhattacharjee et al., 2021). Clouds, vegetation, structures, and birds

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all have an impact on how much electricity a PV system can produce. Consequently, the PV system's efficiency and dependability are reduced (Bhattacharjee et al., 2021; J. Soni & Bhattacharjee, 2022). Many tracking techniques have been devised to get the most out of the solar panels (Verma et al., 2022). Some of the commonly used techniques include hill-climbing approaches, perturb and observe (P&O), and incremental conductance (INC) (J. M. Soni et al., 2020; Verma et al., 2022).

Because they are straightforward, inexpensive, and simple to apply, traditional methods are more suited for practical applications (Ferreira & van Wyk, n.d.; J. M. Soni et al., 2020; Verma et al., 2022). When power monitoring is being done, it is difficult to get to the precise tracking location. Following each sample period, these techniques are utilized to monitor the output voltage and current of the PV system (Hattu, 2019). The settings will provide incorrect tracking directions if the atmospheric conditions change (Hattu, 2019; Reay, 2004). To address the shortcomings of conventional approaches, optimization techniques and soft computing machine intelligence (AI) tools have been created. Without obtaining a perfect mathematical model, AI techniques can determine the PV unit's precise functioning point. As a result, these techniques rely on the PV system's features and behaviour. However, in shadowed situations, the PV module's output power is impacted (Syafaruddin et al., 2010). Evolutionary optimization methods like 'Genetic Algorithm' (GA), 'Particle Swarm Optimization (PSO), 'Cuckoo Search' (CS), and 'Firefly Algorithm' (FA) have been used to get global maxima point. However, the algorithm's efficiency decreases after using random variables in algorithms. The desired optimum solution cannot be obtained due to an increment in uncertainty (Kosgi & Kulkarni, 2022; Syafaruddin et al., 2010). By adjusting the control parameters of the power converter, such as voltage, current, and duty cycle, the algorithms' parameters can influence and modify them. MPPT techniques monitor the PV system's characteristics, and the DC-DC converter receives the resulting control signal (Ayad et al., 2021; Kosgi & Kulkarni, 2022; Syafaruddin et al., 2010). Given in 1.1 is the system chart of the PV unit with a DC load.

The ambient temperature and solar irradiation have a direct impact on the output power of the PV module (Bayeh & Moubayed, 2014). To achieve the maximum power point, it is necessary to modify the duty cycle of the converter, similar to how the maximum power point tracker operates (Waghmare-Ujgare et al., 2022). Because of this, the MPPT point may be attained gradually. The point of operation for a PV system directly connected to a load is determined by the intersection of the I-V characteristics. Therefore, the most possible power cannot be generated. The MPP alters when climatic conditions vary, increasing unit oversizing and expense (Lee & Sohn, 2011; Waghmare-Ujgare et al., 2022). By integrating power converters like buck, boost, buck-boost, and SEPIC converters, the PV system can be effectively enhanced in its performance. Incorporating a DC-DC converter enables the PV system to operate with improved efficiency (Hegazy et al., 2020; Lee & Sohn, 2011; Waghmare-Ujgare et al., 2022).

The single-phase PWM converters may change the frequency at which DC input voltage is converted to AC output voltage. The ON and OFF times of switching devices determine the AC voltage's output frequency (Yamamoto & Shinohara, 1996). The H-bridge inverter gives the non-sinusoidal output voltage suitable for the low and medium voltage levels. The unwanted signals available in the voltage waveform are called harmonics (Georgakopoulos et al., 2018). The electrical equipment becomes overheated due to excessive harmonics. Therefore, the high power system requires the sinusoidal voltage with fewer harmonics. The multi-level inverter can get smooth output voltage (Hosseini et al., 2015).