Mismatch Mitigation Techniques for Solar PV Modules

Submitted by

Hanan Farid Gul

12113

Supervised by

Engr. Imranzeb Durrani

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Department of Electrical Engineering

City University of Science & Information Technology, Peshawar.

Table of contents:

Introduction:

Coal is a major source of energy worldwide, but it is limited and environmentally pollutant. To address this, there's a growing shift towards replacing coal with renewable sources like solar and wind energy, which have become increasingly popular in recent years [1]. Apart from other renewable energy sources, solar PV technology has experienced consistent growth over the years and is now recognized as a key contributor to clean and sustainable energy [2].

The operation of a solar PV module is based on the photovoltaic effect, which is the process of converting sunlight into electricity. The solar cells convert sunlight directly into electricity. A solar PV system consists of a solar PV array, PV converters, batteries, a PV inverter and an inductor-capacitor-inductor (LCL) filter to remove harmonics after the DC-AC inversion. A PV array is a group of solar panels connected in series. These panels are like special plates that catch sunlight and turn it into electricity. PV converters perform DC-DC operation, there is a buck-boost converter inside which can increase or decrease the DC voltage according to the connected load. Battery is used for energy storage when there is no sunlight in the daytime or when used at night. An inverter is used for DC-AC inversion [3]. The power from the PV array can be processed by power electronic converters and the maximum power is extracted by means of maximum power point tracking (MPPT) control. This ensures the system operates at peak performance, delivering maximum power to the load based on sunlight and temperature conditions [4]. The main energy source of the PV system is its PV panels (i.e. PV array), grouped into PV modules that can be connected in series and/or parallel to achieve the needed voltage and current. The performance of both series- and parallel-connected PV modules can be affected by various faults that may occur in practice [5].

Apart from being a clean and green energy source, PV technology has other advantages as well. Like, the availability of primary energy resources i.e. sunlight is in abundance. Also, the material required to manufacture the PV cells i.e. sand is in abundance and easily accessible. Due to its various advantages photovoltaic energy has attracted many people across the world to invest and manufacture. The efficiency of PV modules is about 26.7% [6]. Solar PV modules have some drawbacks as well. Firstly, it requires large-scale battery-based energy storage because the energy produced by solar PV modules is intermittent. Secondly, solar PV modules are highly sensitive to the environment/operating conditions. The output of PV modules varies with wind speed, amount of dust in the air, size of dust, and humidity as well. To keep the solar PV modules productive, the solar panels are required to be cleaned with fresh water, which is a scarce source in many parts of the world [7].

In various faults, the mismatch faults are the most commonly observed ones in PV systems, which usually occur due to the partial shading on PV modules [8]. Under partial shading conditions, the cells become non-productive or underproductive, depending upon the intensity of shade and its nature [5]. The shading may be a result of dust, birds dropping, wildlife, or passing clouds which can reduce the output current of the PV modules. This reduced current due to mismatch condition causes power losses which are dissipated within the solar module or solar cells. The power that is dissipated in the solar cells increases the cell temperature and creates a hotspot [9]. So, in this case, the cell is reverse-biased and acts as a load instead of a generator, and hence it results in the aging of the solar PV modules and reduces the power generation of the PV module. It means that the mismatch faults not only reduce the power output but also decrease the lifespan and reliability of the PV module. And also the cost will be affected eventually [10].

The mismatch faults can be divided into two types i.e. temporary and permanent faults. The temporary can be partial shading or temperature variation. The shading may be in result of bird dropping, dust accumulation, or snow covering, and the dust accumulation on the PV module glass degrades the glass transmittance which can affect the output of the PV module. The temperature has also a direct effect on PV modules. In industry, the standard test condition for PV modules is 25°C but the PV modules are operated at lower or higher outdoor temperatures [11]. The permanent faults include soldering and hotspots. In a PV module different materials are soldered together. Due to the degradation of solder joints failure may occur in the entire PV module. The degraded joints are normally operated at a high temperature, which can weaken the connection between materials and cause deformation in the PV modules. The deformation will result in mismatching in the system and increase the series resistance. The increased resistance further consumes power, leading to hot spots, and possibly arcing at the joints, and consequently, it can affect the overall PV performance. As discussed above hotspots are caused due to the shading on the PV module which increases the cell temperature and the cell acts as a load instead of a generator.

In order to improve the lifetime of PV modules and improve energy generation in solar PV systems, various mismatch mitigation techniques will be studied from the literature which will overcome the mismatch effects.

Problem Statement:

Solar system faces mismatch conditions due to partial shading which results in module efficiency degradation and reduces life span. To overcome this issue solar module/cell having hotspot should be bypassed to remove the faulty portion from the system.

Objective:

- To study different mitigation techniques in literature to overcome the mismatch effect and maintain the efficiency of solar PV modules.
- To increase lifespan of PV module.

Methodology:

First of all different mitigating techniques and topologies will be studied from the present literature. Those techniques and topologies will be designed in MATLAB Simulink for further analysis to overcome the mismatch losses. At the end all the findings from this study will be documented.

Applications:

This study will provide solutions to;

- Improve life of PV system.
- Avoid degradation in PV system.

Time Line:

Work Schedule per weeks	Sep-NoV	Dec- Jan	Jan-Feb	Mar-Apr	May	June
Literature Survey	18-09-2023 4-10-2023					
Data Collection	05-10-2023 01-11-2023	02-11-2023 03-12-2023	05-01-2024 31-01-2024			
Software Implementation		02-12-2023 29-12-2023	02-02-2024 27-02-2024	01-03-2024 29-04-2024		
Result Compilation & Thesis Writing					02-05-2024 29-05-2024	01-06-2024 15-06-2024

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