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Comparative Analysis of Constant PV Generation Using Solar PV System Under Various Algorithms and Converter Topologies

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Abstract

PV solar output is optimized using a modified Maximum Power Point Tracking (MPPT) algorithm using Grey Wolf Optimization (GWO). However, the overvoltage can be caused by the maximum power that the PV generates. Used SEPIC converter for MPPT-CPG control. The simulation results of the proposed control method show that the output voltage response does not exceed the value of 24 V. The effectiveness and stability of the proposed control strategy are validated, particularly in terms of tracking speed under Partial Shading Conditions (PSCs). Simulation results indicate that the BFBIC topology, combined with the proposed Improved Grey Wolf Optimization (IGWO) algorithm, outperforms other algorithms in most cases. In this paper compares GWO algorithm with MPPT against the BFBIC Topology with IGWO algorithm.

Keywords: MPPT, Partial Shading Condition.

1. Introduction

The electrical energy produced by solar panels is influenced by the amount of solar irradiance they receive; higher irradiance results in greater output power. Additionally, photovoltaic systems generally have low efficiency. Grey Wolf Optimization (GWO) is an artificial intelligence method inspired by the hunting behavior of gray wolves.

When the PV output power (P_{PV}) is below or equal to the set point (P_{limit}), the MPPT mode is activated to maximize the power generated by the SEPIC converter. However, when P_{PV} reaches P_{limit}, the CPG mode is activated, maintaining the PV output power at a constant level of $P_{PV} = P_{limit}$.

A novel nature-inspired Improved Grey Wolf Optimization (IGWO) MPPT method is proposed for application in BFBIC topology to enhance response speed, system stability, and adaptability to changes in the external environment. This strategy integrates a nonlinear tangent trigonometric function as a convergence factor into the GWO algorithm.

2. Topology Structure

The topology structure of BFBIC is shown below. The BFBIC is adopted as the converter topology to realize MPPT and DC booster control of the PV arrays.

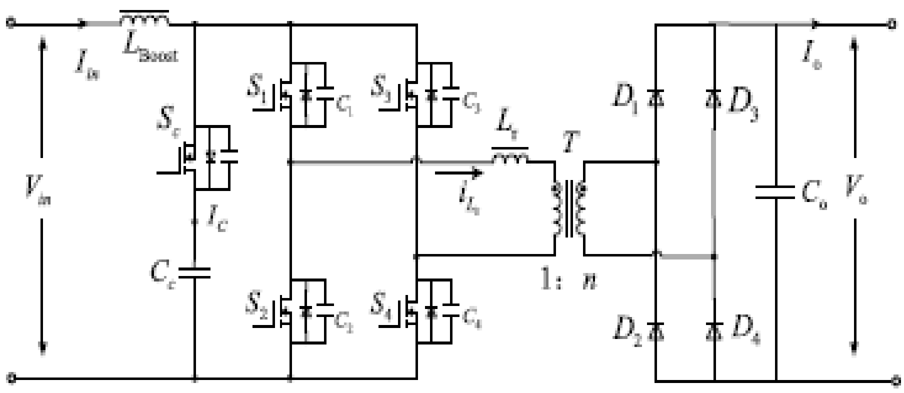

Figure 1. Topology Structure of BFBIC

2.1. Modes of Operation of BFBIC Structure

Stage 1 (<t1): All four switches (S1-S4) are turned on, and the circuit operates in boost mode.

Stage 2 (*t*1- *t*2): The switches *S*2, *S*3 are turned off. At this time, the active clamp switch *S*c is still turned off.

Stage 3 (*t*2- *t*4): At *t*2, due to the presence and conduction of the body diode of the active clamp switch *S*c, the voltage at both ends of the switch *S*c is approximately zero.

Stage 4 (*t*4- *t*5): at *t*4, the active clamp switch *S*c is turned off. Owing to the leakage current of the transformer is greater than the input inductor current, the excess current flows to the junction capacitance of *S*2 and *S*3, and the junction capacitance charge.

Stage 5 (*t*5- *t*6): The body diode is turned on to achieve ZVS of the switches *S*2, *S*3.

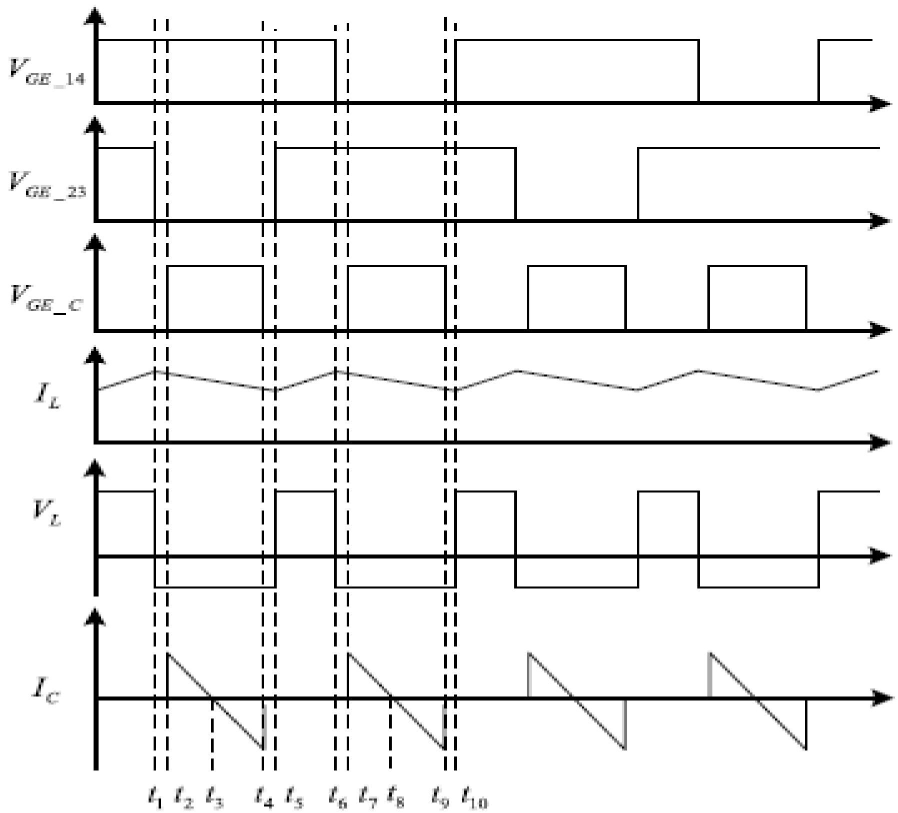

Figure.2. Timing diagram and waveform of BFBIC Converter

3. SEPIC Converter

SEPIC converter is developed from a Buck-Boost converter whose output signal polarity is not reversed and has a lower input current ripple so that this converter is suitable for MPPT [14],

[15]. The circuit of SEPIC converter is shown in Fig. 5. Input voltage (Vin), output voltage (Vout), SEPIC inductor (L1 and L2), filter capacitors (C1 and C2), diode output (D), and load resistor (R).

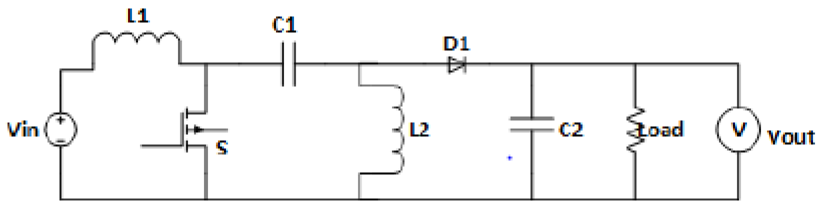

Figure.3. SEPIC Converter Circuit

3.1. Design of SEPIC Converter

Table.1. Specifications

Terms	Value
Input Voltgae	17.6 V
Input Current	11.4 A
Output Voltage	24 V
Output Current	6A
Size of capacitors	4700µF
Size of Inductors	111.2 µF

4. Simulation Results

To evaluate the performance of the proposed control strategy, a PV system comprising series-parallel PV arrays with a BFBIC converter was established as shown in Fig. 7. The PV array has a 3 × 3 structure, where the first and second column sub-arrays consist of 10 × 3 sub-modules, and the third column sub-array consists of 10 × 4 sub-modules.

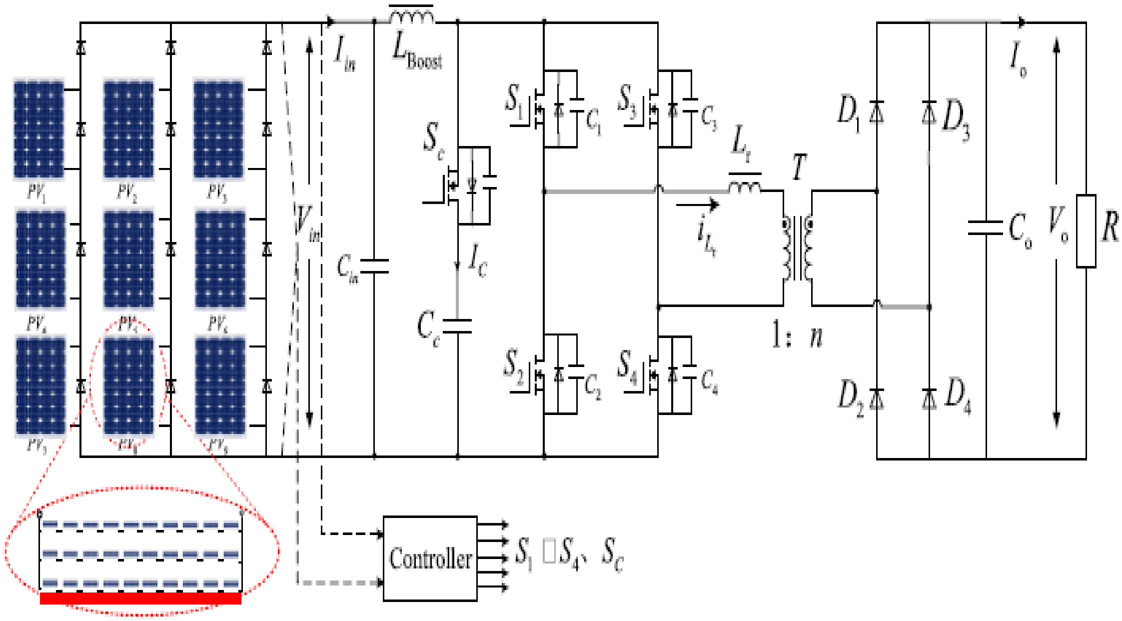

Figure.4. PV System with BFBIC Converter

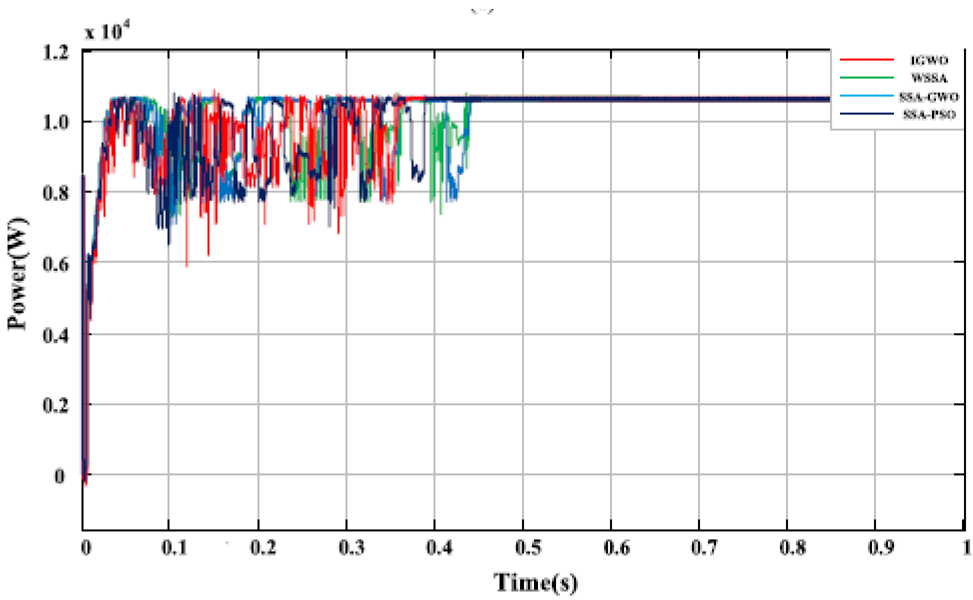

Figure.5 Output waveforms of the Improved MPPT algorithm.

Including the tracking efficiency (η) and tracking time (T). Although the P&O algorithm can stabilize in 0.3 seconds, its GMPPT efficiency is only 73.93%. Several intelligent algorithms demonstrate better performance, with tracking efficiencies exceeding 99.50%. Additionally, the proposed IGWO algorithm reduces the tracking time by approximately 30%, indicating that IGWO has a faster tracking speed compared to the other algorithms.

4. Simulation Results of GWO MPPT-CPG

The simulation results compare the GWO MPPT method with the GWO MPPT-CPG method, which uses a limited power of 100W, under radiation variations of 350W/m², 500W/m², and 1000W/m².

The GWO MPPT-CPG method is able to produce a power of 57.253W, compared to 57.05W generated by the GWO MPPT method. Additionally, the voltage generated by the GWO MPPT-CPG method, when the limited power is 100W under an irradiation of 1000W/m², has an error of 1.48%.

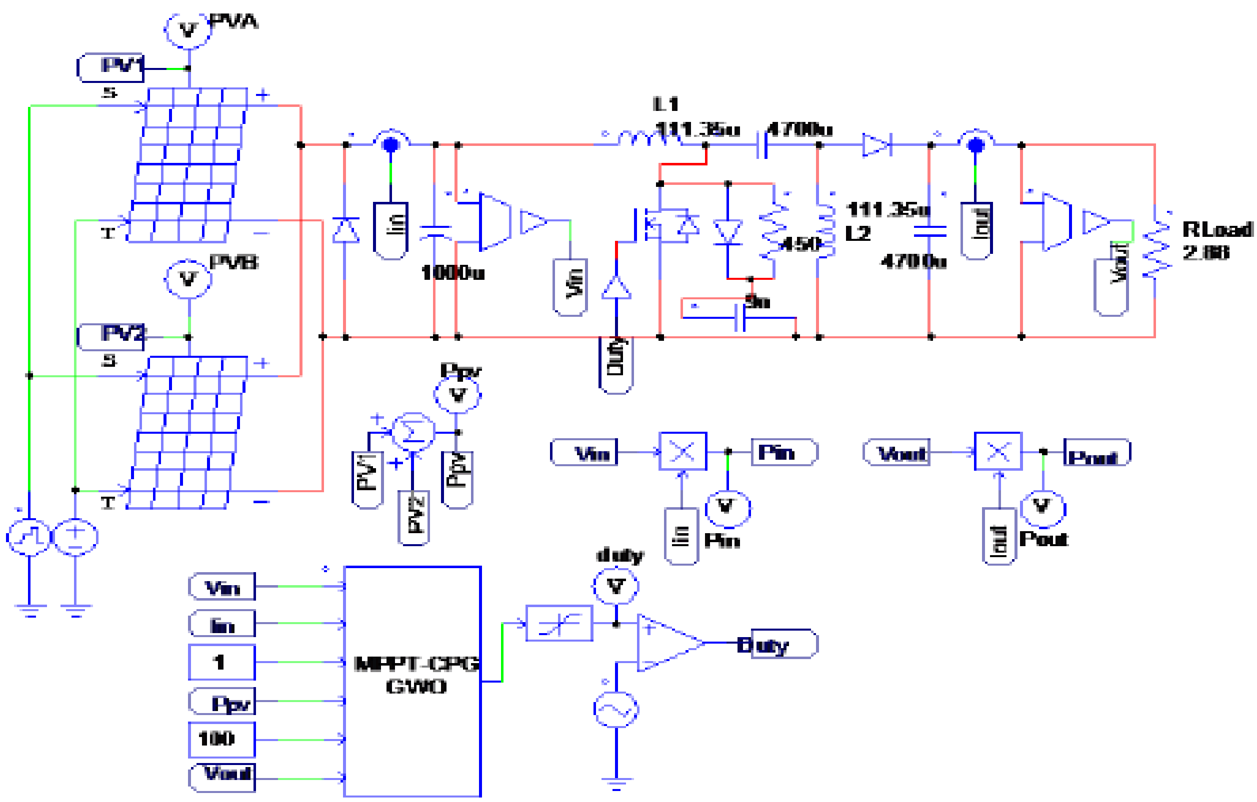

Figure.6 - Simulation Circuit with MPPT GWO-CPG

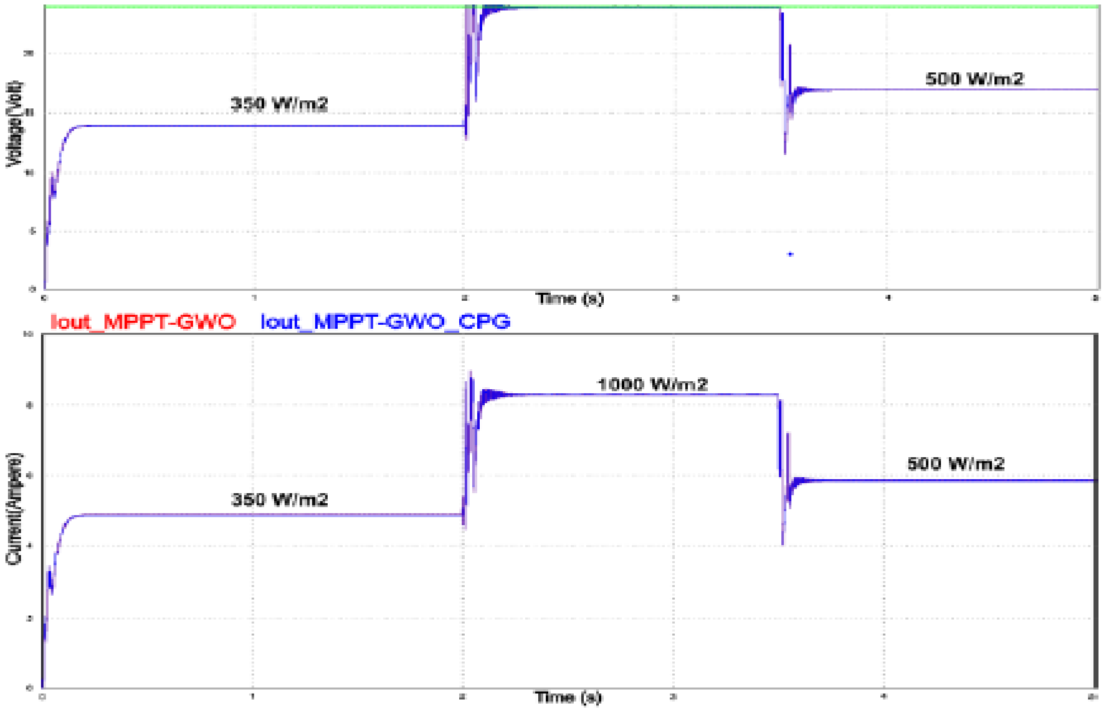

Figure.7. GWO MPPT-CPG with limited power 200 Watt

5. Conclusion

GWO MPPT-CPG method proposed in this paper aims to control the solar panel to avoid the occurrence of overvoltage in the load. The simulation results show that the GWO MPPT-CPG method can produce more optimum power than the GWO MPPT method.

The convergence of IGWO is analyzed by using Markov process and convergence in probability. Furthermore, the MPPT results tested on the PV system simulation platform validated the effectiveness and superiority of the proposed IGWO MPPT algorithm. The causes of tracking failure of SSA-GWO algorithm in Pattern 5 are further compared and analyzed.

It is concluded that IGWO has the following advantages:

1) The MPP can be tracked stably and effectively under different PSCs;

2) Compared with other algorithms, the proposed control method based on IGWO is equipped with faster tracking speed and high reliability;

3) The proposed IGWO MPPT method can effectively realize ZVS of active clamp switch and bridge switch.

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