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Hybrid Optimized Fuzzy Logic Controller for Standalone Photovoltaic Systems with Two-Stage Converter

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Abstract

Standalone solar PV systems have emerged as potential alternatives to electricity problems in areas where a grid is unavailable. Obtaining full power from a photoelectric system, DC-DC inverter, DC-AC converter, and control system presents great difficulties when building these devices. In this paper, Hybrid optimization (Chaotic Hybrid Butterfly Optimization Algorithm with Particle Swarm Optimization) based fuzzy logic controller for standalone PV battery system with two-stage converter. The power of PV systems may be decreased by the oscillation, random fluctuation, and slow speed of their power tracking. To tackle these issues, a novel Fuzzy logic with Particle Swarm Optimization technique is implemented to the MPPT controller under fast varying irradiance and PS conditions. The fuzzy logic controller (FLC) is proposed in this paper as a Maximum Power Point Tracking (MPPT) system to get maximum power from photovoltaic with changes in irradiation and temperature. Fuzzy logic naturally provides a superior controller for this type of nonlinear application. The new control strategy design was evaluated and validated using extensive MATLAB simulations under different scenarios, including load variations. The system output was evaluated using extensive MATLAB simulations.

Introduction

In a stand-alone system, the system is designed to operate independent of the electric utility grid and is generally designed and sized to supply certain dc and/or ac electrical loads. The dc output of the batteries can be used immediately to run certain low dc voltage loads such as lighting bulbs or refrigerators or it can be converted by an inverter to ac voltage to run ac loads that constitute most appliances. The PV signals can be fed to the output load or linked to the grid power, they require DC-DC or DC-AC conversions. However, since PV power is unstable, standalone PV units need an energy power storage component, usually implemented by a battery bank. PV supplies change over time because of the source and condition's variable nature under the load or grid specification demand.

The techno-economic feasibility of solar systems in the form of photovoltaic (PV) generation is highly dependent upon its operating conditions. (PS) environment causing major power losses. In comparison with other renewable sources like geothermal, wind, tidal and biomass, solar energy is the most effective source. Solar energy is usually harvested by photovoltaics (PV) systems. The DC-DC converter is used to transfer regulated DC Electric Power to load according to utilization. The control action is provided by pulse signal, i.e. duty cycle. The controller is designed to optimize the duty cycle to achieve the

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desired optimization. techniques, in literature, exhibit some major common drawbacks. The types of the load for a standalone PV system may be DC and/or AC loads. The performance of a stand-alone PV system with battery storage is discussed. The output of the boost converter in current and voltage is changed according to the changes of weather conditions Hashim Hasabelrasul and zhenjiang cai, lei sun, etal (2022), have proposed "Two-Stage Converter Standalone PV-Battery System Based on VSG Control" Xiaonan, and Josep M. Guerrero, (2014), have proposed "State-of-Charge Balance Using Adaptive Droop Control for Distributed Energy Storage Systems in DC Microgrid Applications"Syed Bilal Qaiser Naqvi and Bhim Singh (2020) have proposed "Grid Connected Two Stage PV-Battery System with PV Intermittency Mitigation and Improved Power Quality" In order to improve the ability of the algorithm for high-dimensional optimization problems that we proposed, the method for hybrid the meta-heuristic algorithms, which combines the basic PSO and BOA, and the chaotic theory, is also used in the improved method.The objectives of this paper,

- To adjust the inverter the fuzzy logic controller with Particle swarm optimization is developed.
- To improve the level of voltage the boost converter is used.
- To get maximum power from photovoltaic with changes in irradiation and temperature the MPPT is used.

Proposed System

A commonly used PV generation system takes a two-stage topology, where, normally the first stage is typically a DC/DC converter performing the power extraction from PV arrays.This fig depicts a schematic diagram of a proposed block diagram for two-stage converter with PSO based fuzzy logic controller. A DC-DC, DC-AC, and a storage unit through a bidirectional converter via the PV power source to supply the load are observed.

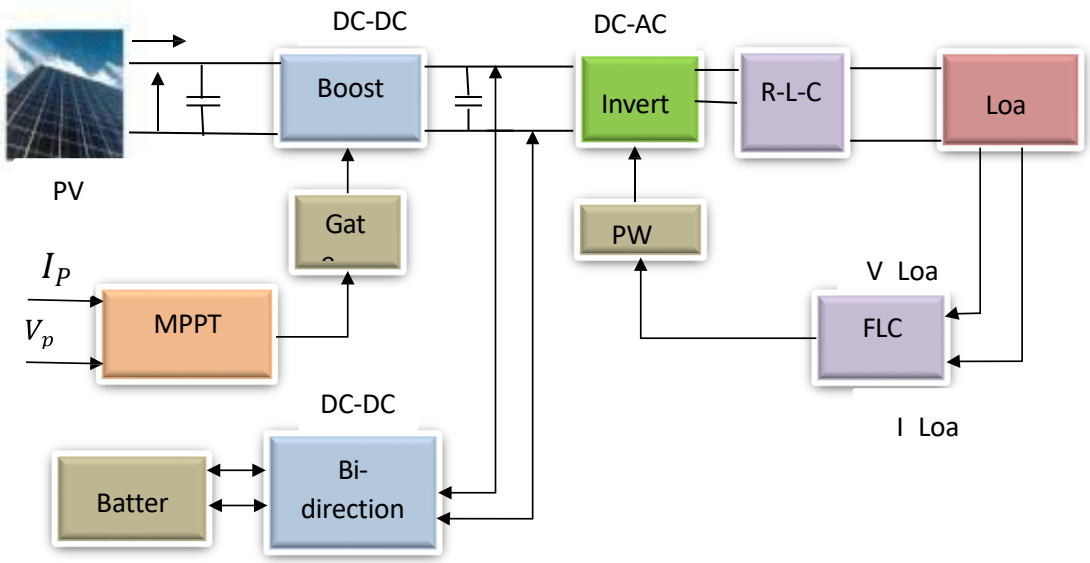


Fig 1: Proposed Block Diagram For Two-Stage Converter With Pso Based Fuzzy Logic Coller

The Basic Butterfly Optimization Algorithm (BOA)

The nature-inspired meta-heuristic algorithm is proposed, named BOA, which simulates the foraging and mating behavior of the butterfly. The fragrance can be formulated as

$$fi = cI^a \quad (1)$$

The mathematical model of the butterflies' global search movements can be formulated as follows

$$x_i^t + 1 = x_i^t + \left(r^2 \times x_i^k - x_j^t\right) \times fi \quad (2)$$

PSO algorithm is based on the swarm of birds moving for searching food in a multidimensional search space, The position of the best global particle in the optimal solution is as

$$w(t) = (w^{max} - w^{min}).T \quad (3)$$

In order to combine the advantages of the two algorithms, we combine the functionality of both algorithms and do not use both algorithm one after another. In other words, it is heterogeneous because of the method involved to produce the final results of the two algorithms. The hybrid is proposed as follows

$$X_i^{t+1} = X_i^t + V^{t+1} \quad (4)$$

$$X_i^{t+1} = w.X_i^t + \left(r^2 \times X_i^k - w.X_j^t\right) \times f_i \qquad (5)$$

Fuzzy Logic Control Structure

Fuzzy logic controller structure is based on fuzzy sets where a variable is a member of one or more sets with a specified degree of membership. Benefits of using Fuzzy logic are; it allows us to emulate the human reasoning process in computers, quantify imprecise information, make decision based on vague information such as resistive load is connected to the PV module through the buck boost dc-dc converter.

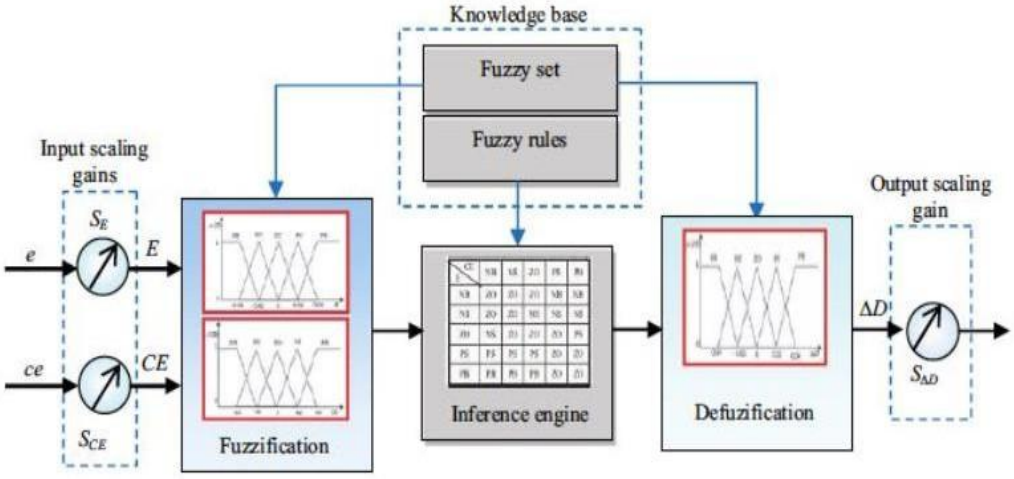


Fig 2: Structure Of Fuzzy Logic Control

Membership Functions Of the Proposed Fuzzy System

Fuzzy sets for each input and output variable. The range of the inputs memberships which are PV voltage and PV current were modified according to the characteristics of
proposed PV module (Voc @ 22 V, Isc = 15 A) and buck-boost converter. The tracking process is started with an initial duty cycle, D= 0. The converter input current *Im* and voltage *Vm* are then measured and sense the duty cycle that can give maximum power output of the converter at that time based on predicted values that have already been entered into fuzzy system. This operation repeats itself continuously until the power reaches the maximum value and the system becomes stable.The fig 3 represents the output duty cycle for fuzzy controller

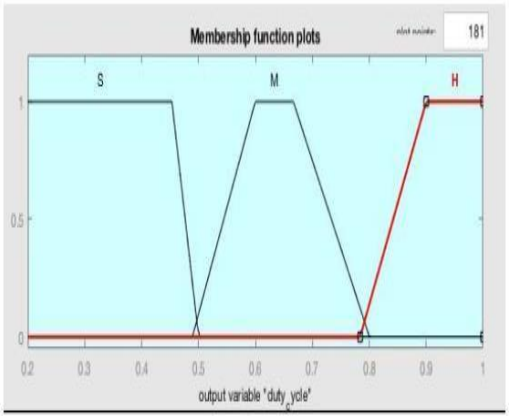


Fig 3: Output Duty Cycle for Fuzzy Controller

Simulation Result And Analysis

The I-V and P-V characteristics are illustrated in Figure.4.The settling time, rise time, delay time and oscillation of output responses (power, voltage and current) of PV module with fuzzy logic based MPPT controller are lower than the PSO based MPPT technique. Overshoot evaluated by considering the difference between steady state maximum power and maximum power

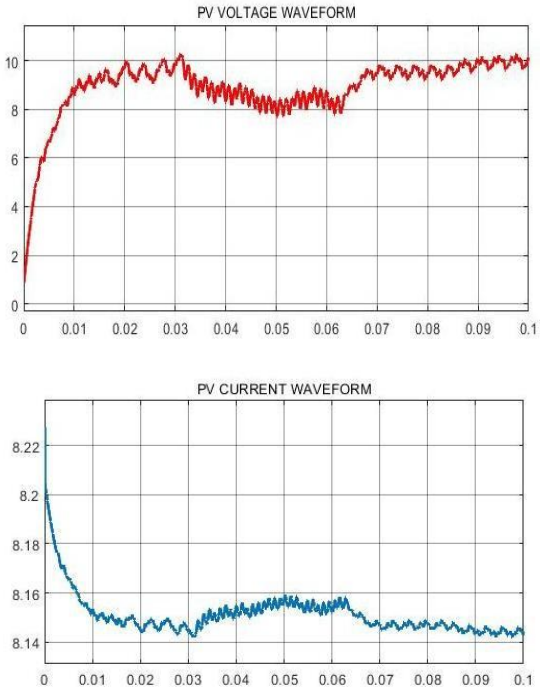
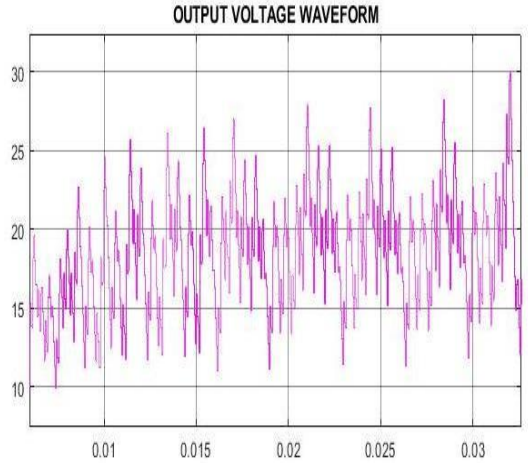


Fig 4: PV Voltage and PV Current Waveform

Input And Outputwaveform

The output voltage of converter connected to PV array, the control voltage used as the reference for the switching, the output voltage and current of the inverter. It is found that even after a long interval of time there is very much instabilities in the system for which the output does not comes to a constant value. Since the PV output is not constant and distorted, corresponding output waveform (current, voltage as well as controller voltage) of the inverter circuit is also not sinusoidal and full of distortion.



The output voltage and current waveform are represented in fig 5

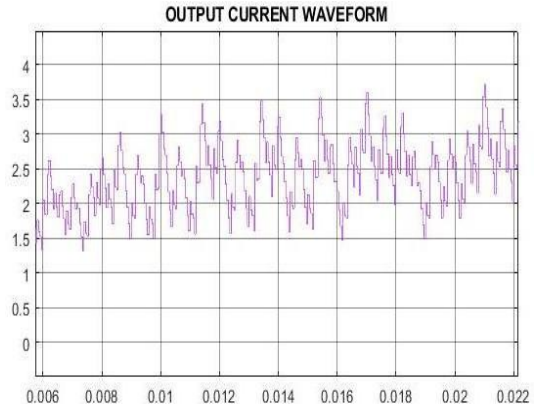


Fig 5: Output Voltage and Current Waveform

Conclusion

The combined control provided successful tracking under various irradiation scenarios thanks to the proposed method's quick and responsive control capability. In addition to the combined control performance tests and the favorable effects on the whole system, it is seen from the bidirectional battery method that the control of battery modes also has superior control capacity. The MPPT system has a 9.5% control efficiency. The experiment proved that the inertia increase greatly improves the frequency dynamics. This means that FLC can truly and very precisely Simulink model of Two-Stage Converter Therefore, it is considered a good controller for this system, a novel hybrid algorithm was compared with other swarm algorithms, and two experiments were designed. . To deal with 26 high-dimensional optimization problems, a cubic map was employed for the initial population of HPSOBOA, and the experimental results show that the initial fitness value is superior to the BOA and other algorithms. In addition, the experimental results show that the dimensional chaotic maps may also have a good performance for improving the basic BOA.

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