IMPLEMENTATION OF FUZZY-LOGIC MPPT CONTROLLER FOR GRID CONNECTED PV SYSTEMS

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ABSTRACT

Recently, solar energy has been extensively utilized in power systems, particularly photovoltaic (PV) generation units. In this context, this paper. presents a unique fuzzy logic-based approach for adjusting the step size of the incremental conductance (INC) maximum power point tracking (MPPT) method for PV. The proposed technique calculates a variable voltage step size based on the degree of climb or descent of the power-voltage relation. For this goal, a novel technique is presented that involves introducing five effective areas around the point of maximum PV power. To change the step size of the duty cycle, a fuzzy logic system is created based on the location of the fuzzy inputs in the five regions around the maximum PowerPoint of the PV array. The generated fuzzy inputs are inspired by the slope of the power-voltage relation, namely the current-voltage ratio and its derivatives, while appropriate membership functions and fuzzy rules are designed. The proposed method improves MPPT efficiency by adjusting the step size of the incremental conductance method, thanks to the effective coordination between the proposed fuzzy logic-based algorithm and the INC method. The PV array's output DC power and tracking speed are displayed as indices to demonstrate the improvement in MPPT. This study presents a power converter interface that connects a photovoltaic (PV) array to the utility grid using a simple boost converter (SBC) and a 12-pulse power inverter with maximum power point tracking (MPPT). Generally, a PV array has a lower and fluctuating dc voltage. It is increased to the desired amount before being converted to alternating current via the 12-pulse LCI. The proposed method has been validated and evaluated by simulating a grid-connected PV system with dynamically changing irradiance and temperature. The results showed a close agreement between analysis and simulation, demonstrating the usefulness and applicability of the approach. Furthermore, it increases output DC power and shortens convergence time to achieve steady-state conditions despite intermittent environmental changes. Additionally, Total Harmonic Distortion, being less than 15%, can be effectively filtered.

1. INTRODUCTION

1.1 Introduction

The rise in electric power demand, installation of thermal or nuclear-generating units, and usage of expensive fossil fuels or nuclear fuels has resulted in global emission. Hence, renewable energy sources play an active role in electrical energy production to meet the energy need of the future of various renewable sources, solar energy is an attractive option due to the availability of terawatts and decreasing cost of photovoltaic (PV) array. A PV panel generates electricity directly from the sunlight with less pollution. The I-V diagram of PV panels is non-linear and hence occurs only one point called maximum power point (MPP). To extract maximum possible power from PV panel, an MPPT control algorithm is used. Different techniques such as fuzzy logic, neural network techniques, pilot cells, incremental conductance (INC) techniques, perturb and observe (P&O) methods etc are used.

The tracking performances are similar under steady state and transient conditions for P&O and INC methods. Also, the INC method is a specific execution of the P&O algorithm. By using adjustable step size and perturbation frequency, the dynamic behaviour of P&O is improved. Various perturbation amplitude and frequencies of INC and P&O are compared, and the results are similar. It is therefore clear that each algorithm has its advantages and disadvantages. These algorithms can be implemented either in dc-dc converters or dc-ac converters or a combination of both; however, simplified control is to be ensured.

A grid-connected PV power system involving two converter stages (DC/DC/AC), an attractive control strategy has been presented. It includes a dc stage, an ac stage, and a transformer stage. A line commutated inverter (LCI) gives better efficiency than VSI. However, LCI is used at a moderate power level owing to large harmonics at high power. Maximum power can be extracted from the PV panels by adjusting the switching delay angle (α) of the LCI. In two-stage systems, it is also possible to deliver PV power to the grid with a constant firing angle. The controller is a feedback control system because it gives a better result as compared to the feed-forward system. The merits of a feedback control system are that it reduces sensitivity, reduces unwanted disturbance, and has a better frequency response. LCI is used in the proposed system because the total harmonic distortion (THD) of grid current is close to 15 % which can easily be filtered. The scheme has the advantage of flexibility in dc-link voltage, whereas in VSI, it should be greater than the peak inverter output voltage. In this scheme, a simple boost converter (SBC) and 12-pulse LCI are used for the grid interface of the PV array. A three-phase step-up transformer is linked to match the inverter voltage with the grid. The different sections of the proposed system are illustrated below.

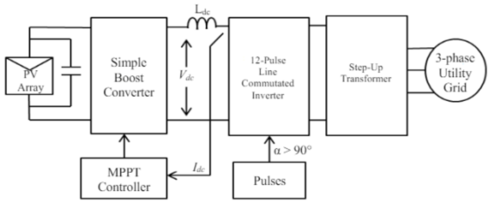


Fig. 1. The proposed power converter interface

1.2 Objectives

The objectives of this project

1. To interface a Fuzzy Logic based MPPT controller employing Incremental Conductance for grid connected PV systems to overcome the drifting of Maximum power point which occurs when a solar PV Array is subjected to rapid change in environmental conditions.

2. To interface a 12-Pulse Line commutated Inverter with grid connected PV systems and obtain Total Harmonic Distortion less than or equal to 15%.

2. LITERATUREREVIEW

[1] N. Priyadarshi, F. Azam, A. K. Bhoi, and A. K. Sharma, ''Dynamic operation of grid-connected photovoltaic power system,'' in Advances in Greener Energy Technologies. Singapore: Springer, 2020, pp. 211–218 gave info that deals with grid-connected photovoltaic power system that uses solar panels to convert sunlight into electricity and is connected to the local power grid. The dynamic operation of this system refers to its ability to adapt to changes in the electricity demand and supply, as well as the variations in solar radiation.

[2] H. Rezk, M. Aly, M. Al-Dhaifallah, and M. Shoyama, ''Design and hardware

implementation of new adaptive fuzzy logic-based MPPT control method for photovoltaic applications,'' IEEE Access, vol. 7, pp. 106427–106438, 2019 Gave the importance to optimize the power output of photovoltaic systems by continuously tracking the maximum power point (MPP) of the solar panel. By utilizing fuzzy logic, the control algorithm is able to adapt to changing environmental conditions and ensure the system operates at its peak efficiency.

[3] A. K. Podder, N. K. Roy, and H. R. Pota, ‘‘MPPT methods for solar PV systems: A critical review based on tracking nature,'' IET Renew. Power Gener., vol. 13, no. 10, pp. 1615–1632, Jul. 2019 provided an overview of the time-sharing switching strategy based on the concept of dividing the operating time into different intervals, during which different power electronic devices are activated. This strategy allows for the optimal utilization of the PV system's output power, ensuring maximum energy conversion and minimizing losses.

[4] H. Bounechba, A. Bouzid, K. Nabti, and H. Benalla, ‘‘Comparison of perturb & observe and fuzzy logic in maximum power point tracker for PV systems,'' Energy Procedia, vol. 50, pp. 677–684, Jan. 2014. It discusses the development of a fuzzy logic based MPPT controller for a boost converter, contrasting its performance with a traditional tracking algorithm known as perturb & observe (P&O). The paper outlines the design steps for both controllers and presents simulation results to compare their efficacy. The findings indicate that employing a fuzzy logic controller for MPPT enhances energy production efficiency from PV systems.

[5] Charles Maria Jenisha, Nanjappagounder Ammasaigounden, Dharmaian Retnam Binu Ben Jose, "Power electronic controller with time sharing switching strategy for grid connected PV systems", Turkish Journal of Electrical Engineering & Computer Science, Vol. 27, No. 1, pp. 243 – 257, Jan. 2019 provided an overview of the time sharing switching strategy based on the concept of dividing the operating time into different intervals, during which different power electronic devices are activated. This strategy allows for the optimal utilization of the PV system's output power, ensuring maximum energy conversion and minimizing losses.

3. METHODOLOGY

The project methodology encompasses several key steps. Firstly, it addresses the dynamic nature of environmental conditions, such as solar irradiation and cell temperature, which influence the optimal operating point of the system. Secondly, to maximize power output, adjustments are made to the PV array voltage, typically achieved through modifying the duty cycle of the boost converter. The system architecture comprises a PV array, boost converter, three-phase line-commutated inverter, and step-up transformer.

Traditional Fuzzy Logic MPPT control is employed to extract available power from the PV array effectively. This control mechanism utilizes feedback from the sensed dc-link current to adjust the duty ratio of the boost converter, ensuring optimal power extraction. The closed-loop control system continually updates the duty ratio to maximize the dc link current, thereby directing maximum power to the inverter. The boost converter plays a pivotal role in elevating the PV voltage to the required level at the dc bus, facilitating efficient power transfer.

Finally, the output voltage from the line-commutated inverter undergoes a step-up transformation before interfacing with the grid. This process ensures compatibility with grid requirements and enhances the efficiency of power transmission. The firing angle of the 12-pulse LCI is set at 135°, optimizing its performance within the system. Overall, this methodology integrates various components and control strategies to achieve efficient power extraction and grid integration from the photovoltaic array.

4. SOLAR CELLS

Basics of Solar Cells

Photovoltaics utilize solar cells to convert sunlight into electricity through the photovoltaic effect, discovered by Alexandre-Edmond Becquerel in 1839. This effect relies on photons exciting electrons to generate an electric current.

Solar power is environmentally friendly and sustainable, with minimal emissions and manageable waste. Recycling technologies are being developed to address end-of-use concerns, promoting a greener energy cycle.Solar installations boast longevity and low maintenance requirements, lasting over a century after initial setup. Once established, operating costs are significantly lower compared to conventional power sources.

Solar cells exhibit two distinct regions in their operating characteristics: the current source region and the voltage source region. These regions define the behavior of the cell concerning output current and terminal voltage, facilitating efficient energy conversion.

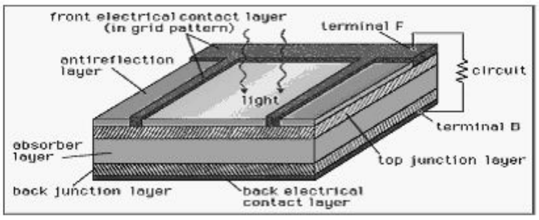


Fig.2.2: Solar cell

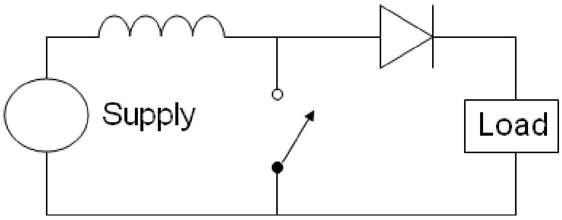
5.CONVERTERS

5.1 DC-DC CONVERTER

A DC-to-DC converter transforms an input DC voltage into a different DC output voltage level. It is commonly employed to achieve voltage conversion and fulfill tasks like noise isolation and power bus regulation.

5.2 BOOST CONVERTER:

A boost converter, also known as a step-up converter, elevates the output DC voltage above its input level. Belonging to the category of switching-mode power supplies (SMPS), it incorporates multiple semiconductor switches and energy storage components, such as diodes and transistors. Additionally, output voltage ripple is commonly mitigated through the inclusion of capacitive filters, sometimes in conjunction with inductors, at the converter's output.



Electric power can be derived from various DC sources like batteries, solar panels, rectifiers, and DC generators. The conversion of one DC voltage to another is termed DC to DC conversion. Specifically, a boost converter achieves this with an output voltage surpassing the source voltage, hence it's also referred to as a step-up converter. As power must remain conserved (P = VI or P = UI in Europe), the output current is correspondingly lower than the source current.

6. INVERTERS

5.1 DC- AC CONVERTER (INVERTER)

An inverter is an electrical apparatus that transforms direct current (DC) into alternating current (AC), offering flexibility in voltage and frequency through suitable transformers, switches, and control circuits. Solid-state inverters, devoid of moving components, find application across various domains, ranging from small-scale computer power supplies to large-scale electric utility systems for high-voltage direct current transmission. They are commonly employed to deliver AC power from DC sources like solar panels or batteries.

There are two primary types of inverters. Modified sine wave inverters produce an output akin to a square wave but with brief intervals of zero voltage before switching polarity. They are cost-effective and straightforward, yet may not be suitable for sensitive equipment like certain printers. Conversely, pure sine wave inverters yield an output closely resembling a sine wave, with minimal harmonic distortion (<3%), rendering them compatible with all AC electronic devices, including those requiring precise power quality. Although more complex in design, they are commonly utilized in grid-tie applications, albeit at a higher cost per unit power.

The electrical inverter, functioning as a high-power electronic oscillator, derives its name from its reverse operation compared to early mechanical AC to DC converters. It essentially reverses the functionality of a rectifier, converting DC to AC.

6. MATLAB SIMULATION

6.1 SIMULATION CIRCUITS:

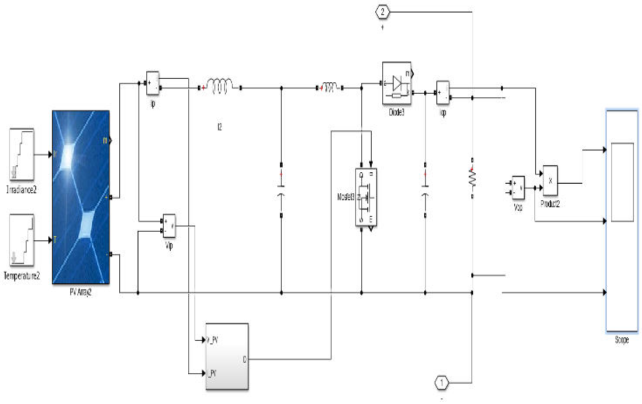
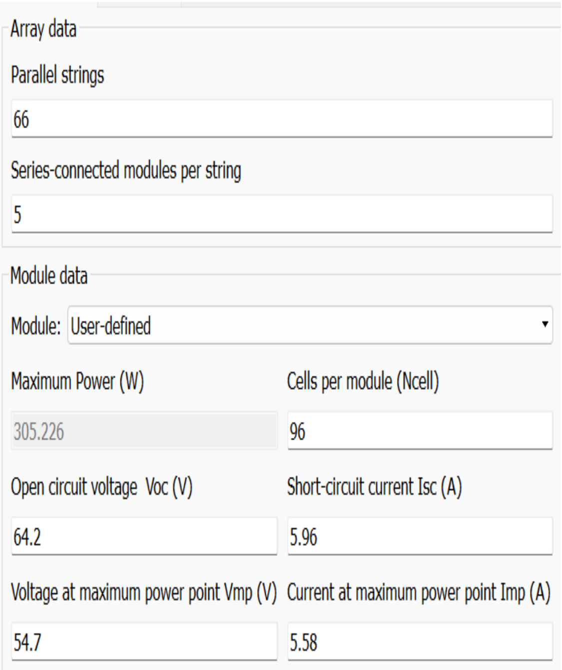


Fig. PV array connected to Simple Boost Converter



Array data

Parallel strings: 66

Series-connected modules per string: 5

Module data

Module: User-defined

Maximum Power (W): 305.226

Cells per module (Ncell): 96

Open circuit voltage Voc (V): 64.2

Short-circuit current Isc (A): 5.96

Voltage at maximum power point Vmp (V): 54.7

Current at maximum power point Imp (A): 5.58

Fig. Parameters of the PV array implemented in the simulation.

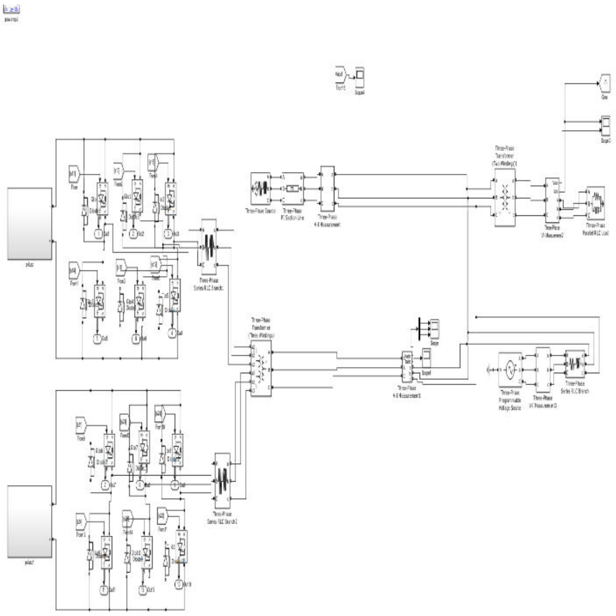


Fig. Interfacing the PV module with 12-Pulse LCI

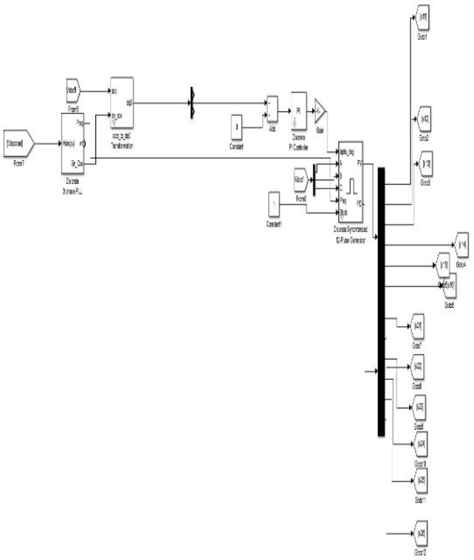


Fig. Firing Pulses for the Line Commutated Inverter.

6.2 RESULTS

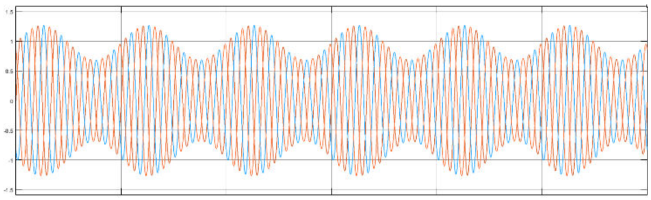


Fig. Load Current

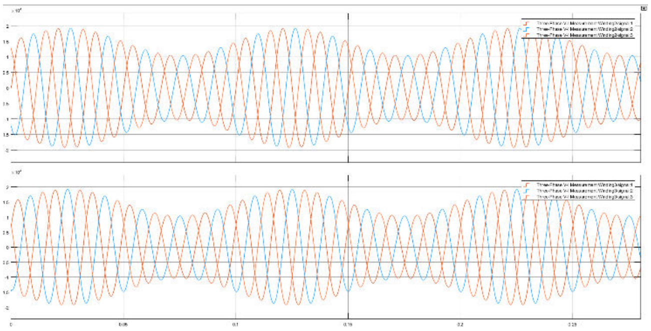


Fig. Load Voltage

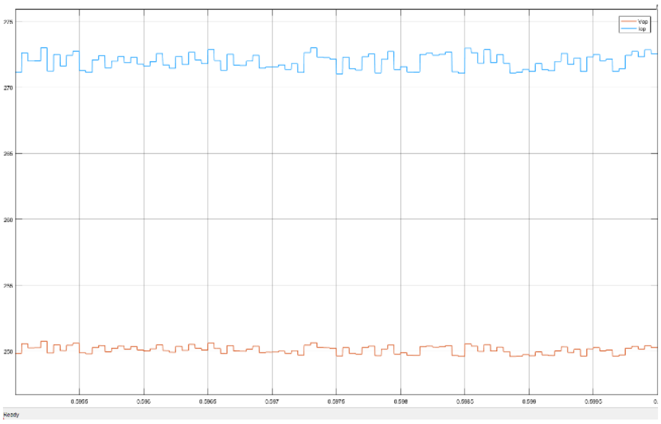


Fig. Output Voltage and Current from the PV array using Fuzzy logic-based controller.

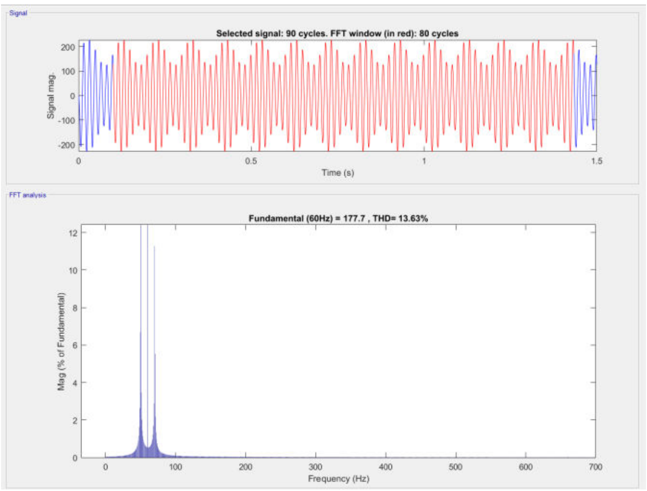
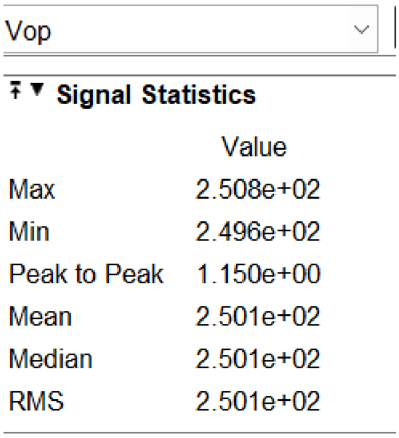


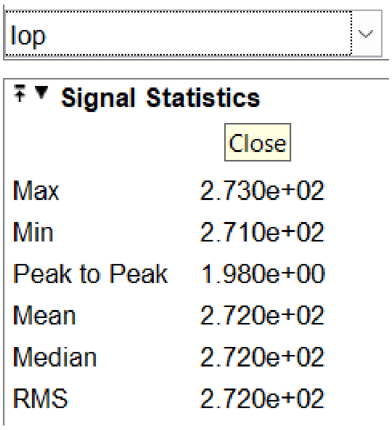
Fig. Total Harmonic Distortion (THD) in Grid Current



Signal Statistics

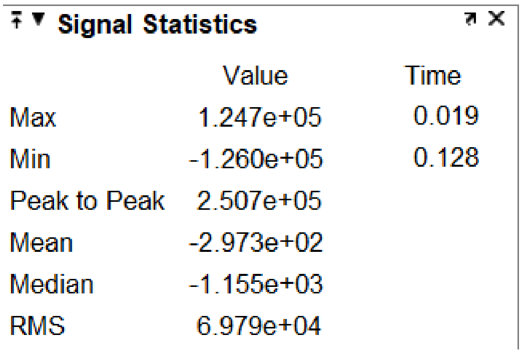
	Value
Max	2.508e+02
Min	2.496e+02
Peak to Peak	1.150e+00
Mean	2.501e+02
Median	2.501e+02
RMS	2.501e+02

Fig. PV output voltage



Max	2.730e+02
Min	2.710e+02
Peak to Peak	1.980e+00
Mean	2.720e+02
Median	2.720e+02
RMS	2.720e+02

Fig. PV output current



	Value	Time
Max	1.247e+05	0.019
Min	-1.260e+05	0.128
Peak to Peak	2.507e+05	
Mean	-2.973e+02	
Median	-1.155e+03	
RMS	6.979e+04	

Fig. Grid Voltage

7.CONCLUSION:

The fuzzy inputs are developed based on the power-voltage relation's slope, including the current-voltage ratio and its derivatives. This method enhances MPPT efficiency by effectively coordinating with the incremental conductance method, particularly in adjusting step sizes. Improved MPPT is demonstrated through increased output DC power and tracking speed indices. The paper introduces a power converter interface using a simple boost converter (SBC) and a 12-pulse power inverter for PV array-grid integration. Simulations validate the method's effectiveness in achieving steady-state conditions amidst varying environmental factors, with Total Harmonic Distortion below 15% for efficient filtering.

8.REFERENCES

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