A Review Paper on Soft Computing Based Hybrid MPPT Controller Using ANN And INC Method

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***Abstract*—The increasing global demand for clean and sustainable energy has accelerated the deployment of photovoltaic (PV) systems. However, the inherently nonlinear characteristics of PV modules and their strong dependency on environmental factors such as irradiance and temperature pose significant challenges for achieving maximum power extraction. Maximum Power Point Tracking (MPPT) techniques are therefore critical for enhancing the overall efficiency and reliability of PV power conversion. Conventional MPPT algorithms, such as the Incremental Conductance (INC) method, offer simplicity, good stability, and satisfactory tracking under uniform conditions. Nevertheless, their performance tends to degrade under rapidly changing weather and partial shading scenarios due to oscillations around the maximum power point and slower dynamic response. To overcome these limitations, soft-computing approaches, especially Artificial Neural Networks (ANN) have emerged as advanced alternatives capable of learning nonlinear system behavior and providing adaptive control. This paper presents a soft-computing-based hybrid MPPT controller that strategically combines the predictive capabilities of an ANN with the robustness of the INC algorithm. The proposed ANN model is trained using a comprehensive dataset comprising PV voltage, current, irradiance, and temperature to predict the optimal duty cycle corresponding to the maximum power point. During real-time operation, the ANN serves as the primary estimator, offering rapid convergence and minimizing steady-state oscillations. The INC algorithm functions as a secondary corrective mechanism, ensuring accurate fine-tuning whenever the ANN output deviates due to unforeseen or abrupt environmental changes. This hybrid configuration leverages the strengths of both methods: the adaptability and fast response of ANN with the reliability and error-checking capability of INC.**

***Index Terms*—MPPT, ANN, INC, Soft Computing, PV system, Solar Energy, Hybrid MPPT Controller, DC-DC converter, Intelligent Control Techniques.**

I. INTRODUCTION

The global transition toward sustainable and renewable energy sources has positioned photovoltaic (PV) systems as one of the most promising solutions for clean power generation. Despite their numerous advantages. such as abundance, low operating cost, and environmental friendliness. The efficiency of PV systems remains highly dependent on external factors, particularly solar irradiance and temperature. These environmental variations cause nonlinear changes in the PV module’s current voltage (I–V) and power–voltage (P–V) characteristics, resulting in a continuously shifting Maximum Power Point (MPP). To ensure optimal energy extraction under all conditions, Maximum Power Point Tracking (MPPT) algorithms are essential components of modern PV power converters.

Conventional MPPT techniques such as Perturb and Observe (P&O) and Incremental Conductance (INC) have been widely adopted due to their simplicity, ease of implementation, and satisfactory performance under stable weather conditions. Among these, the INC method offers improved accuracy by comparing instantaneous conductance with incremental conductance to detect the MPP. However, classical algorithms often suffer from limitations including slow dynamic response, steady-state oscillations, and reduced tracking capability under rapidly changing irradiance or partial shading conditions. These challenges highlight the need for more intelligent, adaptive, and robust MPPT strategies that can respond effectively to varying environmental scenarios.

Soft-computing techniques such as Artificial Neural Networks (ANN), fuzzy logic, and evolutionary algorithms—have emerged as promising solutions for addressing the nonlinear and uncertain behavior of PV systems. ANNs possess strong learning and generalization capabilities, enabling them to approximate complex functions and predict optimal operating points with high precision. Nevertheless, ANN-based MPPT alone can be sensitive to training quality and may exhibit inaccuracies when encountering operating conditions not represented in the training dataset.

II. LITERATURE SURVEY

1. Adaptive Hybrid ANN and Incremental Conductance Approach for Maximum Power Point Tracking in Solar PV Systems.

- Authors: Rahul Kumar Rai, Umesh Kumar Sinha.
- Publication: Indian Journal of Pure & Applied Physics
- Published Year: 2025
- Findings:

Proposed ANN-INC hybrid MPPT achieved nearly 99% efficiency, reduced oscillations, and faster convergence under changing irradiance condition.

2. Solar Power System Assessments Using ANN and Hybrid Boost Converter Based MPPT Algorithm.

- Authors: Imran Haseeb
- Publication: Applied Sciences
- Published Year: 2021
- Findings:

ANN with hybrid boost converter improved PV power extraction, reduced oscillations, and enhanced system stability under variable atmospheric conditions.

3. An Enhanced MPPT Method based on ANN-assisted Sequential Monte Carlo and Quickest Change Detection.

- Authors: Leian Chen, Xiaodong Wang
- Publication: arXiv
- Published Year: 2018
- Findings:

ANN-assisted Incremental Conductance improved global MPP estimation and tracking efficiency during partial shading and rapid irradiance changes.

4. PSO and ANN Based Hybrid MPPT Algorithm for Photovoltaic Array under Partial Shading Condition.

- Authors: Md. Motakabbir Rahman, Md. Shahidul Islam
- Publication: Engineering International
- Published Year: 2020
- Findings:

Hybrid ANN-PSO method successfully tracked global maximum power under partial shading where conventional MPPT methods failed.

III. OBJECTIVE

To design and implement a soft computing-based hybrid Maximum Power Point Tracking (MPPT) controller using Artificial Neural Network (ANN) and Incremental Conductance (INC) methods for improving the efficiency and dynamic performance of photovoltaic (PV) systems under varying environmental conditions.

1. The characteristics and operation of photovoltaic (PV) systems under varying irradiance and temperature conditions.

Photovoltaic (PV) systems convert solar energy into electrical energy using semiconductor solar cells. The performance of a PV system mainly depends on environmental factors such as solar irradiance and temperature.

2. Analyze conventional MPPT techniques, especially the Incremental Conductance (INC) method.

- Maximum Power Point Tracking (MPPT) techniques are used in photovoltaic (PV) systems to extract maximum available power from solar panels under varying environmental conditions such as irradiance and temperature.
- Since the operating point of a PV system changes continuously, MPPT controllers are essential for improving efficiency and reducing power losses.

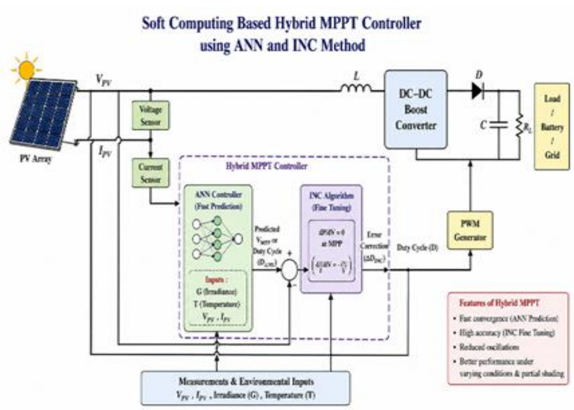
3. Develop an Artificial Neural Network (ANN) model for predicting the maximum power point (MPP) of the PV system.

- Artificial Neural Network (ANN) is a soft computing technique used in photovoltaic (PV) systems to predict the Maximum Power Point (MPP) accurately under varying environmental conditions such as irradiance and temperature.
- The ANN-based MPPT controller learns the

nonlinear relationship between PV parameters and the optimal operating point through training data.

4. Integrate ANN with the Incremental Conductance algorithm to form a hybrid MPPT controller.
- The integration of Artificial Neural Network (ANN) with the Incremental Conductance (INC) algorithm forms an intelligent hybrid Maximum Power Point Tracking (MPPT) controller for photovoltaic (PV) systems. The hybrid approach combines the fast prediction capability of ANN with the accurate tracking performance of the INC method.
- This integration improves the efficiency, speed, and stability of MPPT under rapidly changing environmental conditions and partial shading.

IV. METHODOLOGY



Block Diagram for Soft Computing based Hybrid MPPT Controller using ANN and INC Method

1. Photovoltaic (PV) System Modeling

A photovoltaic array is modeled to generate electrical power from solar energy.

Inputs to PV System

Solar irradiance (G)

Temperature (T)

Outputs of PV System

PV voltage (V_{pv})

PV current (I_{pv})

Output power (P_{pv})

The output power of the PV system is:

Ppv=Vpv X Ipv

The PV model is simulated under varying atmospheric conditions to analyze its nonlinear characteristics.

2. Design of DC–DC Boost Converter

A boost converter is used to regulate the PV output voltage and transfer maximum power to the load.

Components of Boost Converter
- Inductor
- Capacitor
- MOSFET switch
- Diode

The duty cycle of the converter is controlled by the MPPT controller.

Voltage Conversion Relation

V0=Vin/1-D

Where:

V0=Output voltage

Vin= Input voltage

D= Duty cycle

3. Development of ANN-Based MPPT Controller

The ANN model is developed to predict the approximate Maximum Power Point (MPP).
- ANN Inputs
- Irradiance
- Temperature
- PV voltage
- PV current
- ANN Outputs
- Reference voltage
- Duty cycle
- Predicted MPP
- ANN Neuron Equation
  $y = f(\sum_{i=1}^{n} w_i\, x_i + b)$

4. ANN Training Procedure

Step 1: Data Collection

Training data is collected from:
- Experimental PV data
- MATLAB simulations
- Different irradiance and temperature levels

Step 2: Training

The ANN is trained using:
- Backpropagation algorithm
- Levenberg–Marquardt optimization

Step 3: Validation

The trained ANN is validated for prediction accuracy.

5. Integration of ANN and INC Techniques

The ANN and INC methods are integrated to form a hybrid MPPT controller.

Hybrid Operation

ANN Stage

- Predicts approximate MPP rapidly
- Provides initial duty cycle/reference voltage

INC Stage

- Refines operating point precisely
- Eliminates steady-state oscillations

This hybrid structure combines:

- Fast prediction capability
- High tracking accuracy

6. MATLAB/Simulink Simulation

The complete system is simulated using MATLAB/Simulink.

Simulation Blocks

- PV Array
- ANN Controller
- INC Controller
- Boost Converter
- PWM Generator
- Load
- Scope/Measurement blocks

7. Performance Evaluation

The proposed hybrid MPPT controller is evaluated under:

- Variable irradiance
- Temperature variations
- Partial shading conditions

Performance Parameters

- Tracking efficiency
- Response time
- Power oscillations
- Converter output voltage

System stability

V. CONCLUSION

The Soft Computing Based Hybrid MPPT Controller using Artificial Neural Network (ANN) and Incremental Conductance (INC) Method provides an efficient and intelligent solution for maximizing power extraction in photovoltaic (PV) systems under varying environmental conditions. The proposed hybrid approach combines the fast prediction capability of ANN with the accurate tracking performance of the Incremental Conductance algorithm.

The ANN controller effectively predicts the approximate Maximum Power Point (MPP) using environmental and PV parameters such as irradiance, temperature, voltage, and current. The Incremental Conductance method then fine-tunes the operating point to achieve precise MPP tracking with reduced steady-state oscillations. This integration overcomes the limitations of conventional MPPT techniques such as slow response, oscillations, and reduced efficiency under rapidly changing weather conditions.

The hybrid ANN–INC controller demonstrates improved tracking speed, higher efficiency, better dynamic response, and enhanced stability compared to traditional MPPT methods like Perturb and Observe (P&O) and conventional INC. The system also performs effectively under partial shading conditions and nonlinear operating environments.

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