# Soft Computing Based Hybrid MPPT Controller Using ANN And INC Method

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***Abstract*—The growing worldwide need for clean and renewable energy sources has significantly increased the adoption of photovoltaic (PV) systems. However, the nonlinear behaviour of PV modules and their sensitivity to environmental conditions such as solar irradiance and temperature create major difficulties in extracting maximum available power. As a result, Maximum Power Point Tracking (MPPT) techniques play a vital role in improving the efficiency and performance of PV energy conversion systems. Traditional MPPT methods, including the Incremental Conductance (INC) algorithm, are widely used due to their simple implementation, stable operation, and acceptable tracking performance under uniform environmental conditions. However, these conventional techniques often experience reduced effectiveness during rapidly changing weather conditions and partial shading situations because of increased oscillations around the maximum power point and slower response characteristics. To address these challenges, soft computing techniques, particularly Artificial Neural Networks (ANN), have gained attention as intelligent alternatives capable of learning complex nonlinear behaviours and providing adaptive control strategies. This work introduces a soft-computing-based hybrid MPPT controller that combines the forecasting capability of ANN with the reliability of the INC method. In the proposed system, the ANN is trained using extensive PV data, including voltage, current, irradiance, and temperature, to estimate the optimal duty cycle corresponding to the maximum power point. During real-time operation, the ANN acts as the primary estimator, enabling fast convergence and reducing steady-state oscillations. Meanwhile, the INC algorithm serves as a secondary correction mechanism to fine-tune the operating point whenever sudden or unexpected environmental variations cause deviations in the ANN prediction.***

*Index Terms*—**Maximum Power Point Tracking (MPPT), Artificial Neutral Networks (ANN), Incremental Conductance (INC), Soft Computing, PV system, Solar Energy, Hybrid MPPT Controller, DC-DC converter, Intelligent Control Techniques.**

## I.INTRODUCTION

The worldwide shift toward renewable and sustainable energy resources has made photovoltaic (PV) systems one of the leading technologies for clean electricity generation. Although PV systems offer several benefits, including abundant energy availability, low maintenance cost, and eco-friendly operation, their efficiency is greatly influenced by environmental conditions such as solar irradiance and temperature. Variations in these factors introduce nonlinear changes in the current–voltage (I–V) and power–voltage (P–V) characteristics of PV modules, causing the Maximum Power Point (MPP) to vary continuously. Therefore, Maximum Power Point Tracking (MPPT) algorithms are crucial for ensuring maximum energy extraction under different operating conditions.

Traditional MPPT techniques, including Perturb and Observe (P&O) and Incremental Conductance (INC), are commonly used because of their simple structure, easy implementation, and reliable performance under stable atmospheric conditions. Among these methods, the INC algorithm provides better accuracy by comparing incremental conductance with instantaneous conductance to identify the MPP. However, conventional MPPT algorithms still face several drawbacks, such as slower dynamic response, steady-state oscillations, and reduced tracking efficiency during rapid irradiance changes or partial shading conditions. These limitations emphasize the necessity for more adaptive, intelligent, and robust MPPT approaches capable of handling diverse environmental variations effectively.

In recent years, soft-computing techniques such as Artificial Neural Networks (ANN), fuzzy logic, and evolutionary optimization methods have emerged as effective solutions for managing the nonlinear and uncertain behaviour of PV systems. ANN techniques, in particular, possess strong learning and generalization abilities, allowing them to model complex nonlinear relationships and estimate optimal operating points with high accuracy. However, standalone ANN-based MPPT methods may depend heavily on the quality of training data and can produce less accurate results when exposed to operating conditions outside the trained dataset.

## II.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.
2. Analyze conventional MPPT techniques, especially the Incremental Conductance (INC) method.
3. Develop an Artificial Neural Network (ANN) model for predicting the maximum power point (MPP) of the PV system
4. Integrate ANN with the Incremental Conductance algorithm to form a hybrid MPPT controller.

## III.METHODOLOGY

1. Photovoltaic (PV) System Modelling

A photovoltaic array is modelled 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 analyse 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

## IV. SIGNIFICANCE

A Soft Computing Based Hybrid MPPT Controller using ANN and INC Method is a photovoltaic (PV) power optimization technique that combines the strengths of:
- Artificial Neural Network (ANN) — intelligent prediction and adaptive learning
- Incremental Conductance (INC) — accurate real-time tracking of Maximum Power Point (MPP)

The significance of this hybrid approach lies in improving the efficiency, speed, and reliability of solar energy systems under changing environmental conditions.

Improved Maximum Power Extraction
The primary goal of MPPT (Maximum Power Point Tracking) is to extract the maximum possible power from a solar PV panel.
The hybrid ANN–INC controller:
- Predicts the approximate MPP quickly using ANN
- Fine-tunes the operating point accurately using INC

Faster Tracking Speed
Traditional MPPT methods may respond slowly to:
- Sudden irradiance variations
- Cloud shading
- Temperature fluctuations

ANN provides:
- Fast estimation of the MPP
- Reduced convergence time

INC then refines the operating point precisely.

## V. WORKING

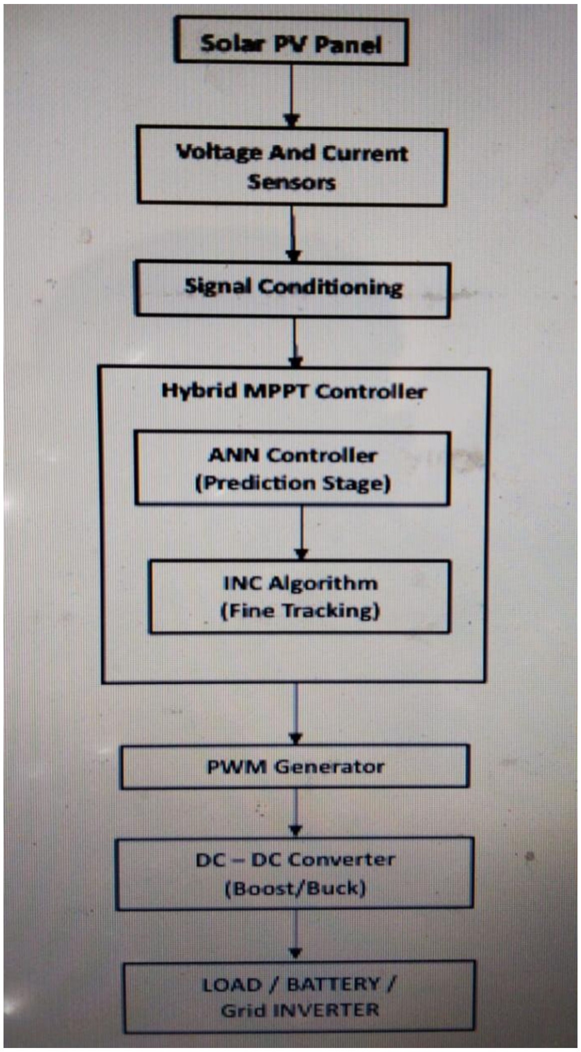


Fig.01 Block Diagram of Soft Computing Based Hybrid MPPT Controller using ANN and INC Method

A Soft Computing Based Hybrid MPPT Controller using Artificial Neural Network (ANN) and Incremental Conductance (INC) is designed to extract the maximum available power from a photovoltaic (PV) system under varying environmental conditions such as irradiance and temperature.

The hybrid method combines:
- ANN for fast prediction of the Maximum Power Point (MPP)
- INC for accurate fine-tuning and stable tracking

This improves efficiency, tracking speed, and system reliability.

Step 1: Solar PV Power Generation
The solar photovoltaic panel converts sunlight into electrical energy.
The output power depends on:
- Solar irradiance
- Temperature
- Load conditions

The generated power is:
$P = V \times I$
where:
- $P$= Power
- $V$= Voltage
- $I$= Current

$P = VI$

Step 2: Measurement of PV Parameters
Sensors continuously measure:
- PV voltage
- PV current

Additional parameters may include:
- Irradiance
- Temperature

These measured signals are sent to the hybrid MPPT controller.

Step 3: ANN-Based Prediction Stage
The Artificial Neural Network (ANN) acts as an intelligent estimator.
ANN Operation
The ANN is trained using historical PV data under different environmental conditions.
Inputs to ANN
- Voltage
- Current
- Irradiance
- Temperature
- Output from ANN
- Estimated MPP voltage or Duty cycle for converter control

Role of ANN
The ANN:
- Predicts the approximate maximum power point rapidly
- Reduces tracking time
- Provides fast response to sudden weather changes

This stage gives an initial estimate very close to the actual MPP.

Step 4: Incremental Conductance (INC) Fine Tracking
After ANN prediction, the INC algorithm performs accurate tracking of the exact MPP.

Step 5: PWM Signal Generation
The controller generates a PWM (Pulse Width Modulation) signal.
The PWM:
- Controls switching operation
- Adjusts converter duty cycle

This helps maintain operation at MPP.

Step 6: DC-DC Converter Operation
The PWM signal drives a:
- Boost converter
- Buck converter
- Buck-boost converter

The converter:
- Adjusts PV voltage/current
- Transfers maximum power to the load

Step 7: Power Delivery to Load
The extracted maximum power is supplied to:
- Battery systems
- DC loads
- Grid-connected inverter
- Microgrid systems

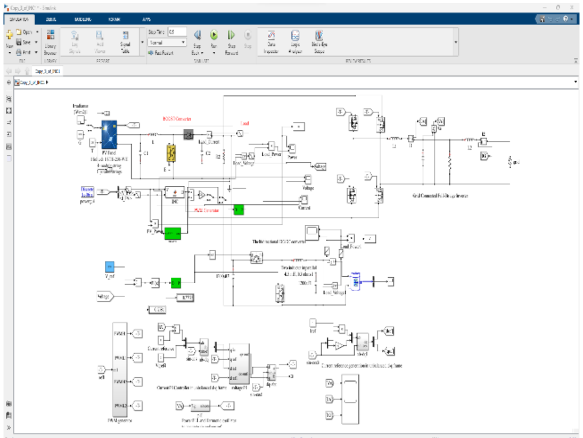
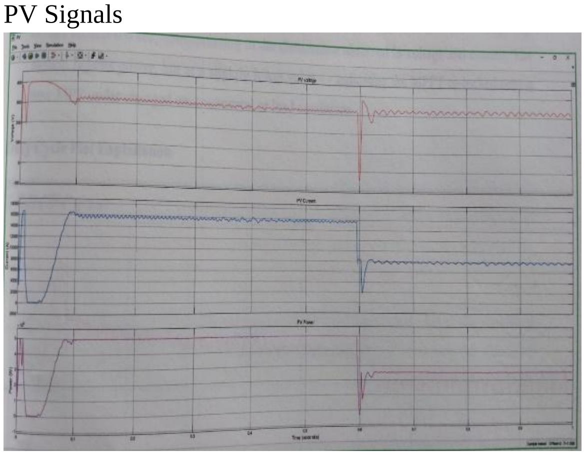


Fig.02 Matlab Simulation Model of Soft Computing Based Hybrid MPPT Controller using ANN and INC Method

## VI. RESULTS

PV Signals



Result & Analysis

1. Improved Maximum Power Extraction

The hybrid ANN–INC controller successfully tracks the Maximum Power Point (MPP) and extracts higher power from the PV panel under varying environmental conditions.

2. Faster Tracking Speed

The ANN predicts the approximate MPP quickly, while the INC algorithm fine-tunes the operating point accurately.

3. Higher Conversion Efficiency

The combined ANN–INC approach increases the efficiency of the overall PV system.

| Parameter | P&O Method | Conventional INC | Hybrid ANN–INC |
|---|---|---|---|
| Tracking Speed | Moderate | Good | Very High |
| Oscillation | High | Moderate | Very Low |
| Stability | Moderate | Good | Excellent |

## VII. CONCLUSION

The Soft Computing Based Hybrid MPPT Controller utilizing Artificial Neural Network (ANN) and Incremental Conductance (INC) techniques offers an effective and intelligent approach for enhancing power extraction in photovoltaic (PV) systems under changing environmental conditions. This hybrid method integrates the rapid prediction capability of ANN with the precise tracking ability of the Incremental Conductance algorithm.

Compared to traditional MPPT approaches such as Perturb and Observe (P&O) and standard INC methods, the hybrid ANN–INC controller provides superior tracking speed, improved efficiency, enhanced dynamic response, and greater system stability. Additionally, it performs efficiently under partial shading conditions and nonlinear operating environments.

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