Neural Network Based MPPT Controller for Solar Powered Induction Motor

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Abstract— *These This study uses a neural network controller to develop a maximum power point tracking controller (NNC). This controller will detect and control the speed of a solar-powered 3-phase induction motor. All photovoltaic systems must use the Maximum power point tracking (MPPT) method (PV) system, and to boost the system's effectiveness, incremental efficient conductance algorithm is utilized to obtain the solar panel's maximum output, which powers an induction motor with SEPIC Converter which boosts the solar panel's available voltage. It uses a dc converter. The converter's primary benefit is having non inverted output. Between the PV array and the converter, it serves as an interface motor strain. In order to monitor the maximum power point (MPP) of solar cell modules, an improved MPPT algorithm based on neural network (NN) approach is proposed after assessing the output characteristics of a solar cell. The Bayesian Regularization approach was selected as the training strategy to complete the assignment since it performs well even for smaller data, supporting the diverse train data set. Theoretical findings demonstrate that in the same environment, the Enhanced NN MPPT algorithm is more efficient than the Perturb and Observe technique. MATLAB/Simulink software is used for designing of proposed system.*

Index Terms—PV, ANN, MPPT, Induction Motor.

Table 1 List of abbreviations

NAME	ABBREVIATION
Neural Network Controller	NNC
Maximum Power Point Tracking	MPPT
Perturbation and Observation	P&O
Maximum Power Point	MPP
Neural Network	NN
Photovoltaic	PV
Buck Converter	BC
Buck Boost Converter	BBC
Cuk Converter	CC
Single-Ended Primary Inductance Converter	SEPIC

1. INTRODUCTION

With the advancement of modern technology, global energy challenges have elevated renewable energy to the top of the global agenda. As a result, our search for green energy has led us to a number of renewable energy sources that draw their energy directly from the sun or from heat created at deep. The concept covers electricity and heat from renewable energy sources, including solar, wind, hydro, biomass and geothermal, as well as biofuels and hydrogen.

Solar energy is the safest option among them as a dependable power source since it is plentiful in nature and does not provide any risk for environmental danger [1]. To maximize the electricity provided by PV solar systems, engineers creating solar inverters use MPPT algorithms [2]. The algorithms make sure that the PV system generates the most electricity possible at all times by taking into account variables like temperature and fluctuating irradiance (sunlight) [3-6]. There are several MPPT analysis methods, however they may all be classified according to the kind of control variable used: voltage, current, or duty cycle. The versatility and flexibility of these algorithms to address non-linear situations is their key benefit. They can also produce the perfect solution or multipacks MPPT for global maxima with acceptable efficiency. So, these approaches outperform traditional algorithms in terms of tracking performance [7] [8]. When discussing early research on MPPT algorithms, the Perturbation and Observation (P&O) technique first comes to mind. This approach is very simple and basic, but often imprecise [9] [10]. A persistent disturbance in a fixed direction, for example, will shift the operational point away from the actual MPP, since the system is assumed to oscillate around the MPP in the actual configuration. Nonetheless, the fractional open-circuit voltage and fractional short-circuit current methods are more prevalent than the P&O approach [12]. Although it can be difficult to implement, fuzzy logic has given satisfactory results [13] [14]. Fuzzy logic can help mitigate the P&O method's two key drawbacks: sluggish detection speed and ringing noise around the MPP. However, the application of machine learning can provide the most accurate results in the shortest time in the current era of artificial intelligence developments and NN design. Therefore, no other The MPPT algorithm can equal the level of efficiency provided by the MPPT solar controller's NN model. This study unequivocally confirms this assertion.

A DC-DC converter is required to enhance the voltage of a PV panel. Boost, buck converters (BC), buck-boost converters (BBC), Cuk converters (CC), and SEPIC are all popular converters [7-8]. A single-ended primary inductance

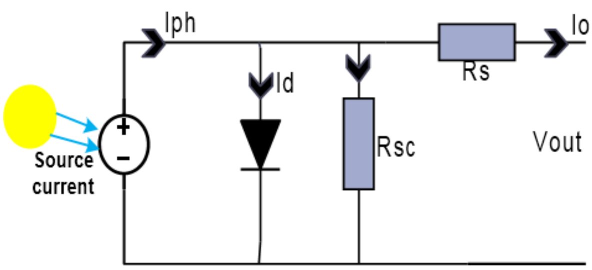
(SEPIC) converter is a DC/DC converter that has a positive regulated output and a non-inverting output. The fact that BBC only require an inductor and a capacitor makes them more affordable. However, the downside is that the high input current ripple creates harmonics and, in many cases, requires the use of large capacitors or LC filters. The fact that BBC convert the output voltage can reduce their efficiency or increase their cost, which can complicate their use.

2. PROPOSED METHODOLOGY

2.1 PV PANEL

Through the photovoltaic (PV) effect, solar panels utilize the sun's light energy photon to produce electricity. The majority of modules employ wafer-based cells or thin-film cells made of silicon or a non-magnetic transition metal. With little ongoing expense and almost little emissions, it can almost always supply electricity. Less than 3 watts are typically produced by a common PV cell at about 0.5 V dc. Many PV cells can be linked in series or parallel to form a PV module. The increase in voltage is caused by series connections, whereas the increase in current is caused by parallel connections. The block diagram of the suggested system is shown in Figure 2.

The solar panel single unit is solar cell. When the number of solar cells is connected then the solar panel is built. The connection of solar cell in solar panel is both series and parallel. For the modeling purpose we consider equivalent circuit diagram of solar cell which is consist of a diode, a current source and two resistances. This model is also described as single diode circuit of PV cell shown in Figure 1. In these two resistances one connected in series with current source and another connected in parallel.



Figuure 1 PV cell Equivalent circuit

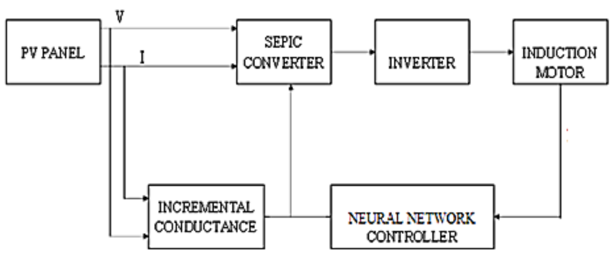


Figure 2 Block Diagram of Proposed Model

$$I = I_{ph} - I_0\left[\exp^{\frac{ev_d}{KFT_C}} - 1\right] - \frac{V_d}{R_{sh}} \quad (1)$$

$$I_{ph} = \left[\mu_{sc}(T_c - T_r) + I_{SC}\right] + G \quad (2)$$

$$I_0 = I_{0\alpha}\left(\frac{T_C}{T_r}\right)^3 \exp\left[\frac{eV_g}{KF}\left(\frac{1}{T_r} - \frac{1}{T_C}\right)\right] \quad (3)$$

Where

I_{ph}	Photo current
I_0	Dark saturation current
e	Electric charge (1.6×10^{-19} C)
K	Boltzmann's constant (1.38×10^{-23})
F	cell idealizing factor
T_c	Absolute temperature
T_r	cell's Reference temperature
V_d	Diode voltage
R_{sh}	Parallel resistance
R_s	Series resistance
$I_{o\alpha}$	Cell saturation current
V_{oc}	Open circuit voltage
μ_{sc}	Temperature coefficient cell's short circuit current
V	Output voltage of solar cell
I	Output current of solar cell
G	solar irradiation in kw/m2

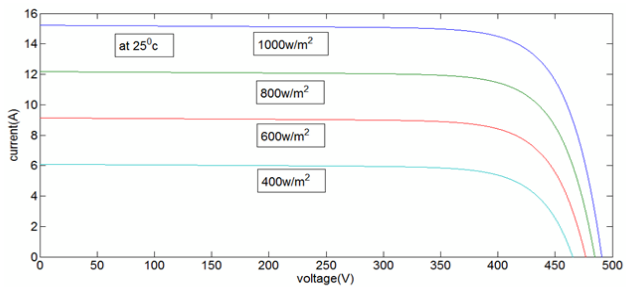


Figure 3 V-I curve of PV module

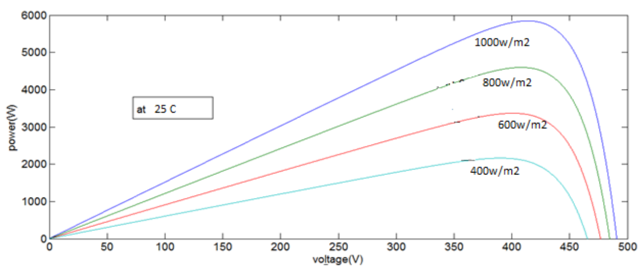


Figure 4 P-V curve of PV module

2.2 MACHINE LEARNING

2.2.1 DIFFERENT TECHNIQUE USE IN MACHINE LEARNING.

There are different types of machine learning approaches available for different application shown in figure 5 such as: Supervised learning is carried out under supervision. Supervised learning is also called "learning with a teacher. "In this system, we know the output. It contains a model that can be predicted with the help of labelled datasets. In labelled data sets, the target answer is already known. Basically, it is used for diagnostics, image processing, fore- casting, process optimization prediction, and risk assessment The algorithms used in it are decision trees, discriminant analysis, linear regression, logistic regression, nearest neighbor, random forest, etc. Unsupervised learning, also known as learning without a teacher, in unsupervised learning, machines use unknown data sets to learn, and the machine tries to find the data pattern from unknown datasets and gives a response to it. The applications of unsupervised learning is segmentation, big data visualizations, face recognition, planning, etc. The algorithms used in it are fuzzy C-means, principal component analysis, cluster analysis, and K-means. Reinforcement learning is a technique in which systems learn from their surroundings by interacting with them. It is different from supervised learning in that it does not need label-data pairs. Reinforcement learning (RL) is the main thing to do, balanced be- tween the environment and existing knowledge. Real-time choices, skill development, learning tasks, robot navigation, gaming, and resource management are all uses of real reinforcement learning. It is basically based on the reward and penalty principle. For each correct move, a point is awarded to the machine, and each incorrect move results in a penalty. In this manner, the machine learns for itself. Mostly, it is used in games for passing different levels. The algorithms used in it are control theory, game theory, genetic algorithms, multi-agent systems, simulation-based optimization, static swarm intelligence, Q-learning etc.

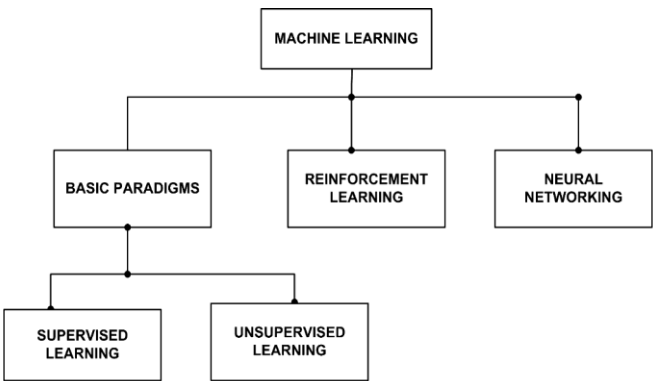


Figure 5 Classification of machine learning

2.2.2 ARTIFICIAL NEURAL NETWORK MPPT

In this solar energy system, an MPPT controller based on RBFN is employed to monitor the MPP of PV. Figure 6 depicts the fundamental architecture of an RBFN-based network. The performance of an RBFN network is determined by the interconnected architecture, weights, and system activation functions. These necessitates a different MPPT controller for each solar energy source, increasing the system's size and complexity.

Figure 7 shows MPPT algorithm for proposed model.

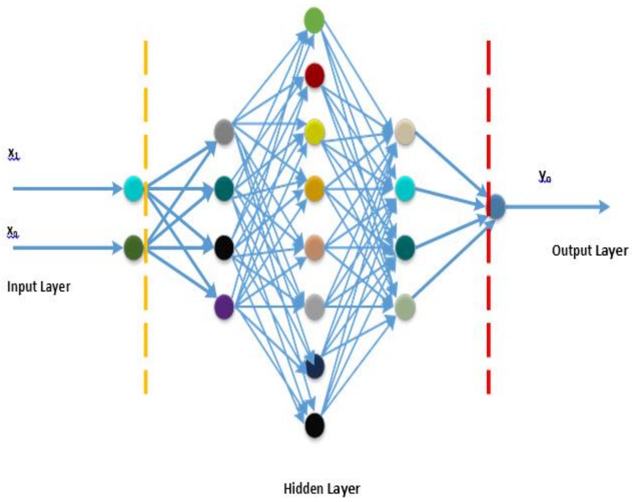


Figure 6 ANN internal structure

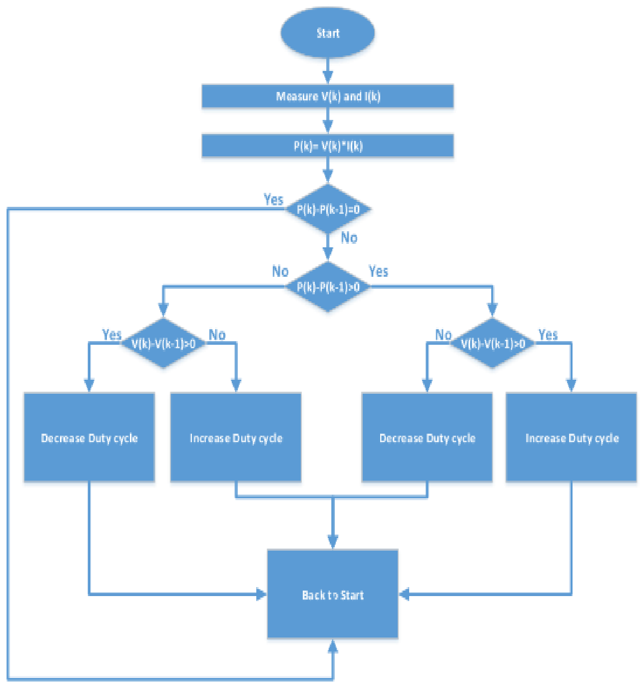


Figure 7 Proposed MPPT algorithm

2.3 SEPIC CONVERTER

The SEPIC (Single Ended Primary Inductance Converter) is a type of DC-DC converter. It begins with a boost converter and progresses to a BBC. The main advantage of this inverter is its ability to provide a non-inverted output, which means it has the same polarity as the input. It is frequently employed in battery-powered systems where the output voltage must be larger, less, or equal to the input voltage. Change the duty cycle of the control switch to regulate the output voltage. Because of their much greater input impedance, low voltage drop, and low switching losses, MOSFETs are frequently utilized as control switches.

Change the duty cycle of the control switch to regulate the output voltage. MOSFETs are often used as control switches due to their significantly higher input impedance, low voltage drop, and low switching losses. The SEPIC converter is a fourth-order converter, which means it transfers energy from the input side to the output side using two inductors and two capacitors as its four energy storage components. The input inductor L is placed similarly to a BBC topology and is coupled to a MOSFET-controlled switch similarly to a boost topology.

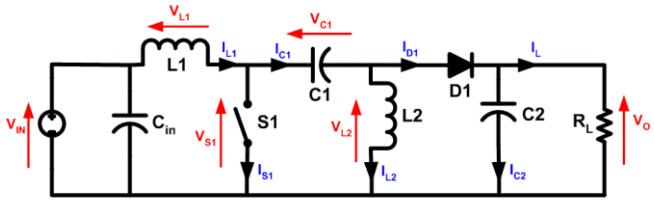


Figure 8 SEPIC Converter

3. MATLAB SIMULATION DIAGRAM

Figure 9 shows a simulation diagram of the proposed system. The model is created using the MATLAB/Simulink tools. The Sim Power system toolbox is used to create the suggested system.

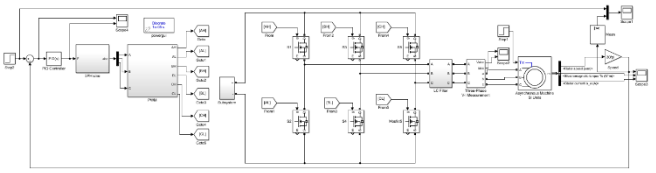


Figure 9 Simulation Circuit

4. RESULTS

Figure 10 shows the 290 Volts generated by the PV module. Solar irradiance and temperature are fed into the PV module to generate dc voltage. The boost converter output voltage 780 Volts is depicted in Figure 11. The ANN approach is used to manage the duty cycle of the boost converter. The duty cycle will alter based on the proposed MPPT method.

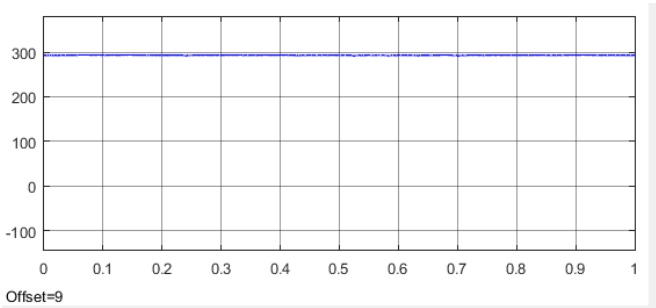


Figure 10 PV generated voltage

The output voltage of the boost converter is then linked to a three-phase inverter, which converts dc power to alternating current electricity. Figure 12 depicts the inverter Current 7 A, which is coupled to the filter. The filter's function is to reduce the harmonics in the inverter output voltage.

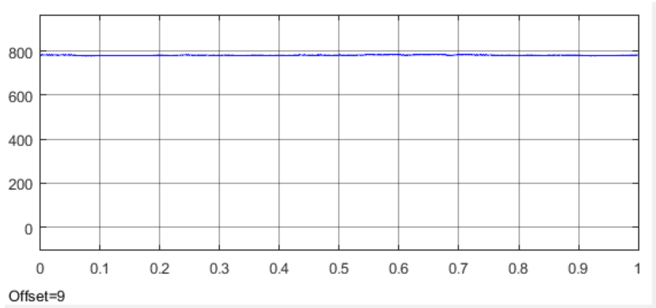


Figure 11 Boost Converter output voltage

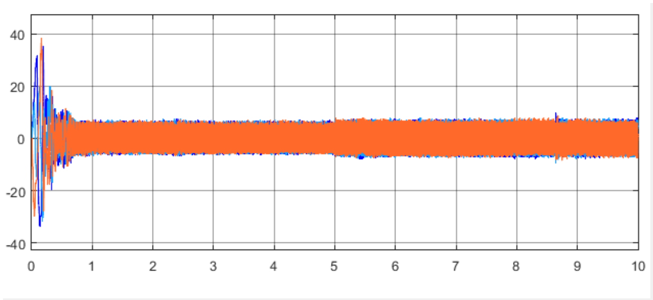


Figure 12 Inverter Current

Figure 13 depicts the inverter's Vab voltage, which is applied to an induction motor.

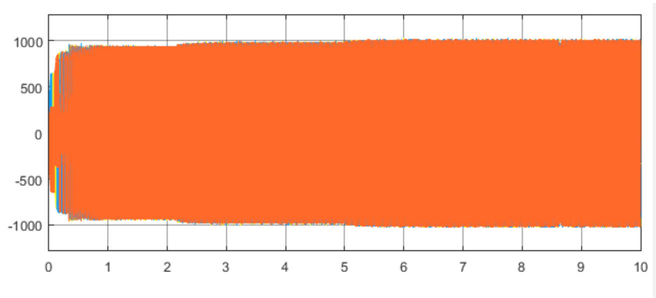


Figure 13 Inverter o/p after filter

Figure 14 depicts the speed of the motor. The reference speed is 1440 rpm, which is represented in red, and the motor output speed is shown in blue. As shown in the graph below, the motor quickly hit 1440 rpm.

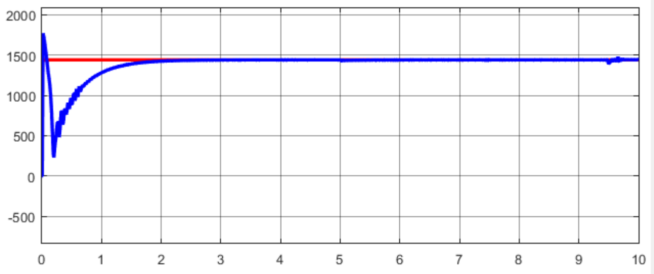


Figure 14 Motor speed with no variation

When the reference speed changes with regard to time, the motor speed follows, as illustrated in figure 15. Initially, the reference speed is 1440 for 5 seconds before changing to 1500 rpm. The motor attained the desired speed quite rapidly, as illustrated in Figure 15. Figure 16 depicts the torque curve. This value is also modified after 5 seconds and returned to the prior value. Figure 17 depicts the stator current of a motor.

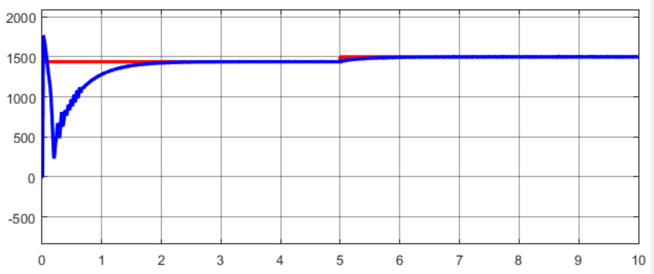


Figure 15 Motor speed with speed variation

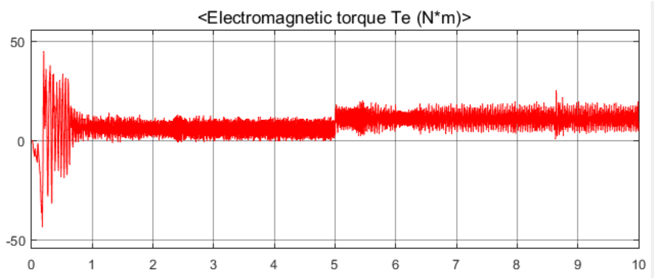


Figure 16 Motor electromagnetic Torque

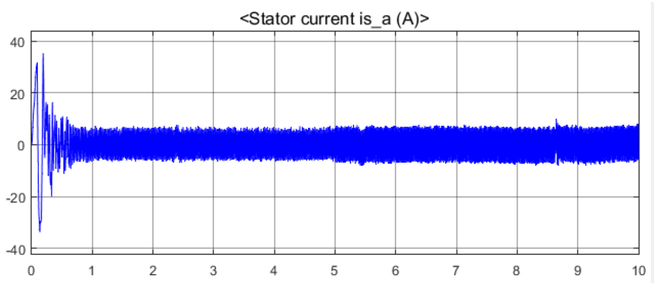


Figure 17 IM Stator Current

5. CONCLUSION

The suggested ANN-based MPPT algorithm was tested on a prototype system that used only an inverter stage to drive a direct-coupled induction motor. According to the simulation results, the suggested technique has several advantages over the usual MPPT algorithm with constant step size. Because of the variable step size, the response time was lowered, and oscillations around the MPP were reduced to achieve maximum power production in the steady state. The suggested system beats the current P&O method in this regard, which is strongly reliant on a compromise between tracking speed and oscillations around the MPP. Because the MPP is known ahead of time, there is no need for a search for MPPT in the suggested approach, and the results show that the MPP may be obtained rapidly.
This method is very reliable and gives better results as compared to other different techniques.

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