# Analysis of AI Used in Power Quality Improvement of MPPT Grid Connected PV System

**Laxman Kumar[1], Vivek Kumar Yadav[2], E Vijay Kumar[3]**

*[1]Electrical Engineering, RKDF IST College*
*[2]Electrical Engineering, RKDF IST College*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract -** This paper focuses on the modelling and simulation of Maximum Power Point algorithms to Improve Power Quality at different atmospheric condition and using AI Improve efficiency. Grid-connected output systems are made to convert as much solar energy as possible into usable electricity. Artificial intelligence, Artificial Neural Network (ANN) and the Incremental Conductance Technique method are two recommended techniques interface with DC link controller with the reference voltage in a variety of situations. The aim of this paper is to track MPPT from the solar PV array by the proposed AI controller for irradiation changes and comparing results with PO, A single phase grid connected with a photovoltaic (PV) power system wll provide high voltage gain with state model analysis for the control of the system has been presented. First the photovoltaic system is designed and simulated using MATLAB SIMULINK software. The output voltage of a PV array is comparatively low thus high voltage gain is necessary for grid-connection and synchronization. The PV system has been provided with a boost converter which will boost the low voltage of the PV array to high dc-voltage. A steady state model is obtained and is verified with the help of simulation. A full bridge inverter with bidirectional power flow is used as the second power processing stage, which stabilizes the dc voltage and the output current. Further, a maximum-power-point-tracking method is employed in the PV system to obtain a high performance.

***Key Words***: AI, Solar System, Maximum Power Point Tracking, Fuzzy logic Algorithm, Sinusoidal Pulse Width Modulation, Matlab.

## 1. INTRODUCTION

As many countries are dependent on nonrenewable resources such as coal, petroleum, and natural gas for electricity generation, there is an energy crisis and environmental problems. Clean electricity generation necessitates renewable energy sources such as solar PV and wind generation systems [1]. The power extracted from solar PV is controlled by implementing suitable algorithms to improve power electronic systems[12]. The essential function of the power electronic systems is to extract maximum power from solar and wind. The conversions of stages in single and double-power electronic system configurations are generally used for power transfer from solar or wind to the grid in applications of a three-phase system. The two steps of conversion in a power electronic system are the DC/DC converter and the DC-to-AC inverter [2]. Amongst the renewable source of energy, the photovoltaic power systems are gaining popularity, with heavy demand in energy sector and to reduce environmental pollution around caused due to excess use non-renewable source of energy. Several system structures are designed for main grid line connected PV systems. Four various types of system configure ration are used for main grid line connected PV power application: the centralized inverter system, string inverter system, and the multi- string type inverter system [3]. It is mandatory that the most of the solutions designed to attain the PV system tasks such as MPPT, in inverter and Power factor correction are employed at two different stages.

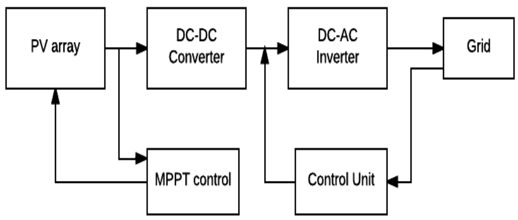


Fig-1: Block Diagram of Solar System with MPPT Based Inverter and Grid Synchronization

## 2. ARTIFICIAL INTELLIGENCE IN ELECTRICAL ENGINEERING

Artificial intelligence has provided a great potential and space for optimization in the field of electrical engineering. This can not only bring about a significant improvement not only with regards to the economic aspects but also in the safety and the actual control of the operation [7]. Ever since artificial intelligence reached a stage where it could be used in various fields in order to make work simpler, it has been used widely in various fields of life, primarily in robotics and computer programming [9]. Recent studies and investigations have shown that artificial intelligence can also be a viable option in the field of electrical engineering especially as a solution to some longstanding power system problems where conventional methods experience some difficulty.

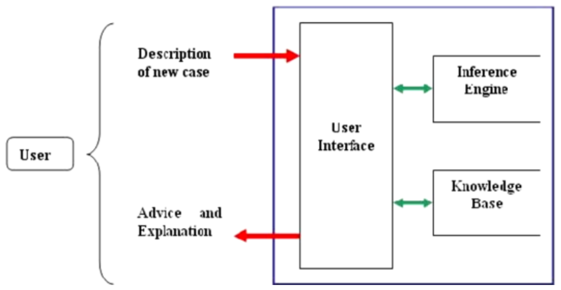


Fig-2: Block diagram of expert system

**Pros and Cons of Artificial Intelligence**

As an emerging technology, artificial intelligence has its fair share of advantages and disadvantages. By studying more about the pros and cons of artificial intelligence, we can decide on how artificial intelligence can be integrated with electrical engineering and power systems in order to facilitate a smarter system.

**A. Pros of artificial intelligence:**

• First, Reduction in human error: With the increase in amount of data being supplied, artificial intelligence can completely nullify human error and thereby give a much more accurate result when compared to the results provided by humans. This is a huge advantage as accuracy is very important in the field of electrical engineering as one single mistake can not only disrupt the power system but also lead to catastrophic results.

• Safety of human labor: Another major advantage of artificial intelligence is the fact that human beings do not have to directly interact with scenarios that can be risky or pose a threat to the labor. In case of a fire in an apartment, robots powered by AI can be used to navigate through the building and put out the fire, thereby nullifying the risk to human life as well as accomplishing the task with a satisfactory outcome.

• Repetition: There are a lot of tasks that need to be repeated in order to be completed. Tasks such as sending the same email to a group of people or installing particular software on the system of each and every employee's computer system are considered to be boring and tedious. Artificial intelligence can be used in order to tackle such tasks with ease, thereby not only completing the task but also ensuring that human labor is not wasted on such tasks. A possible area of application can be in the manufacturing and automation of various electrical components.

• Speed of decision making: Since artificial intelligence is ultimately carried out by machines, it is generally faster. The main difference between artificial intelligence and human intelligence is that human beings analyze all the factors pragmatically as well as emotionally and then come to a decision based on what that person feels is right [13]. Therefore, the decision can vary wildly from person to person. Artificial intelligence on the other hand gives an output considering all the factors based on how it has been programmed. This approach significantly speeds up the problem solving and decision making. power outages and disruptions in the power delivery to the consumers.

• Availability: Problems can occur without a warning. It is imperative for a system to be able to tackle any issue that can crop up at any time.

**B. Cons of artificial intelligence:**

• The Unemployment: This is one of the most controversial points of focus when it comes to whether artificial intelligence must be implemented in various industries [4].

• Propagation of laziness: Artificial intelligence is not only available 24x7 but also does not tire and perform at peak efficiency all day. As discussed above, this eliminates the need for human supervision as well, thereby making us complacent and lazy as we feel that the artificial intelligence can deal with the problems at hand.

• Lack of emotional intelligence: As discussed earlier, artificial intelligence solves problems and makes decisions much faster than human beings but this comes at a cost [12].

• Cost: Integrating artificial intelligence into an already existing system not only consumes a lot of time and effort but also costs a lot of money.

• Time of implementation: Due to a lack of extremely skilled programmers and the difficulty in the development of a satisfactory model, developing the suitable artificial intelligence in order to tackle real life situations will take a lot of time to develop and test [6].

## 3. SOLAR PV POWER SYSTEM

PV stands for 'Photo voltaic' and means converting light into electricity (as opposed to Solar Thermal which is heating water). The solar panels generate DC electricity from sunlight which is fed through an inverter to convert it into AC electricity. The inverter is connected to your consumer unit (fuse board) so the electricity can be used in your home. A photovoltaic (PV) cell is a particular electrical device that can change over sun oriented vitality into direct current by photovoltaic impact. It is coordinated piece of sun oriented[4], PV systems can be broadly classified in two major groups:

a) Stand- Alone b) Grid Tied

These systems are isolated from the electric distribution grid. Fig-3 describes the most common system configuration. The system described in Fig-3 is actually one of the most complexes; and includes all the elements necessary to serve AC appliances in a common household or commercial application[5]. Vitality framework and is an imperative wellspring of option wellspring of vitality.

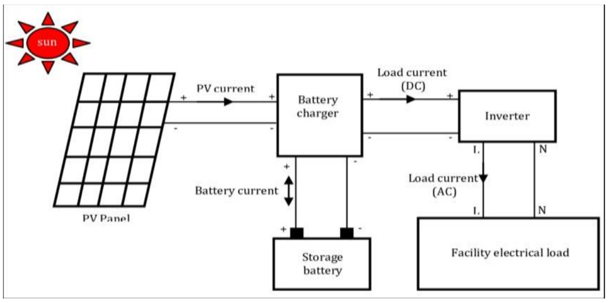


Fig-3: Configuration of the Stand-Alone PV System

b) Grid Tied

These systems are directly coupled to the electric distribution network and do not require battery storage. Fig-2 describes the basic system configuration. Electric energy is either sold or bought from the local electric utility depending on the local energy load patterns and the solar resource variation during the day, this operation mode requires an inverter to convert DC currents to AC currents. There are many benefits that could be obtained from using grid-tied PV systems instead of the traditional stand-alone schemes.

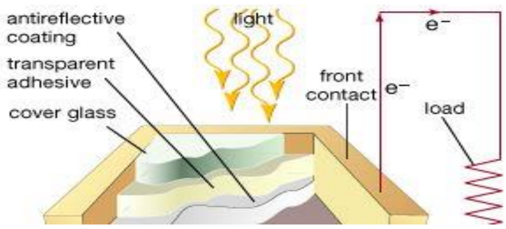


Fig-4: Summary on how solar cells work

Photovoltaic (PV) systems have become a popular choice for renewable energy generation due to their ability to convert sunlight directly into electrical energy[6]. The heart of a PV system is the solar panel, which consists of a collection of photovoltaic cells that generate direct current (DC) electricity when exposed to sunlight.

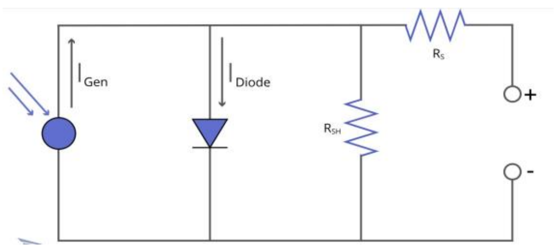


Fig-5: Equivalent Circuit for Solar Cell

Solar Cell and its Characteristic

This subtopic will be discussing in depth about the solar cell and its characteristics. The current-voltage curve, crucial parameters from manufacturer's datasheet, effect on the current-voltage curve when there's change on solar radiation and temperature as well the mathematical equation used for modeling in this project shall be discussed in this subtopic which will help to have deeper understanding in verifying the solar modeling later part of the project.

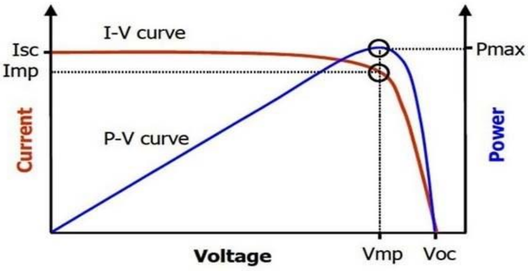


Fig-6: Characteristic I-V curve of a practical photovoltaic device

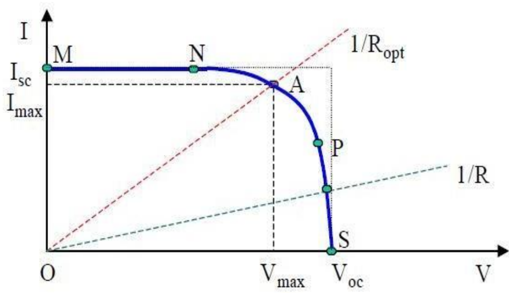


Fig-7: A typical current-voltage (I-V) curve for a solar cell.

## 4. MAXIMUM POWER POINT TRACKING (MPPT)

Maximum Power Point Tracking (MPPT) is an essential feature in solar photovoltaic systems that ensures maximum utilization of solar energy by maintaining the output voltage and current of the solar panel at the point of maximum power. MPPT algorithms are responsible for continuously monitoring the solar panel voltage and current, and adjusting the duty cycle of the converter to maintain maximum power transfer. In the proposed system, an MPPT-based inverter is used to efficiently convert the DC output of the solar panel to AC power.

The MPPT-based inverter also features a switching strategy known as sinusoidal pulse width modulation (SPWM), which is used to convert the DC input to a sinusoidal waveform output. The inverter is designed to operate in synchronization with the grid, which means that it is able to inject power into the grid without causing any disturbances. The synchronization is achieved using a phase-locked loop (PLL) circuit, which is responsible for locking the inverter output frequency to the grid frequency.

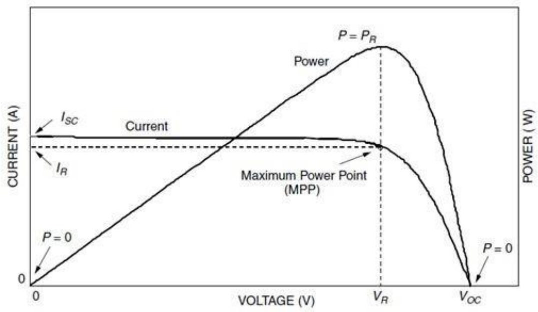


Fig-8: MPPT in I-V Curve and P-V Curve

## 5. CONVERTER AND INVERTER

As the output of the PV panel is very low and in order to connect it to the grid, its voltage has to be increased. The output of the solar panel is a DC voltage of very low magnitude. Hence a boost converter is required for boosting the voltage to higher level without use of the transformer. The primary parts of a support converter are an inductor, a diode and a high recurrence switch. These in a composed way supply energy to the heap at a voltage more prominent than the information voltage extent [7]. One capacitor is joined over the heap end to keep up the heap voltage consistent. In a boost converter, the output voltage is greater than the input voltage – hence the name is “boost”. A boost converter using a power MOSFET is shown below.

**Boost Converter -** The boost converter is an essential component of the proposed solar PV system in this study. The main function of the boost converter is to increase the voltage of the solar panel output to a level suitable for the inverter. The boost converter topology is chosen for its ability to handle high voltage and power levels efficiently [8]. The boost converter operates by converting the low voltage and high current output of the solar panels into high voltage and low current output. This is achieved by switching the DC input through an inductor and a diode, and storing the energy in the inductor during the "on" state of the switch. The stored energy is then released to the output during the "off" state of the switch.

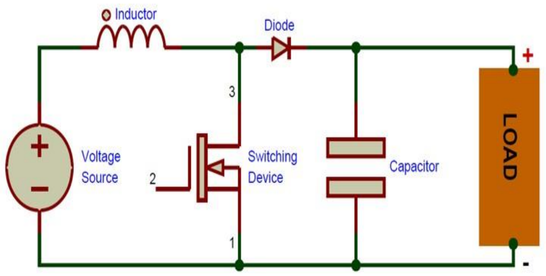


Fig-9: A boost Converter

Modes of Operation

Two methods of operation are there in a boost converter. a) Charging Mode

c) Discharging Mode

## 6. DC TO AC CONVERTER / INVERTER

In the proposed system of Modeling and Simulation of Solar System with MPPT Based Inverter and Grid Synchronization, a DC to AC converter is utilized to convert the DC power generated by the PV panels to AC power that can be used by the loads or fed back to the grid[10]. The DC to AC converter is an essential component of the system, as it enables the utilization of the DC power generated by the PV panels for practical applications.

**Operation of Inverter -** Not ideal for inductive AC and motor loads; sensitive electronic devices can be damaged by poor waveforms by low batteries. Voltage from direct current (DC) to alternating current (AC). Square wave inverter Quasi wave or Modified square wave inverter True/Pure Sine wave inverters Convert DC electricity from solar panels, batteries or fuel cells to AC; micro-inverters for converting DC power from solar panels to AC for the electric grid; UPS uses inverter to supply AC power when main power is unavailable; induction heating.

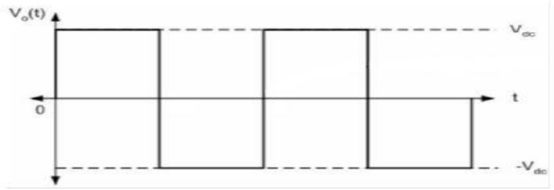


Fig-10: Square wave output of Inverter

The DC to AC converter is implemented using Pulse Width Modulation (PWM) techniques to generate a high-quality AC voltage with a frequency that matches the grid frequency. A Proportional Integral (PI) controller is used to regulate the DC link voltage and maintain a constant

DC voltage for the inverter- The PI controller adjusts the duty cycle of the PWM signal based on the difference between the desired DC voltage and the measured DC voltage.

## 7. MATLAB SIMULATION MODEL AND RESULT

The MPPT efficiency is observed at 90%. The simulation for solar PV with MPPT has demonstrated, that maximum power is tracked with different atmospheric conditions and observing MPPT efficiency at various radiation levels taking current as perturbing variable.

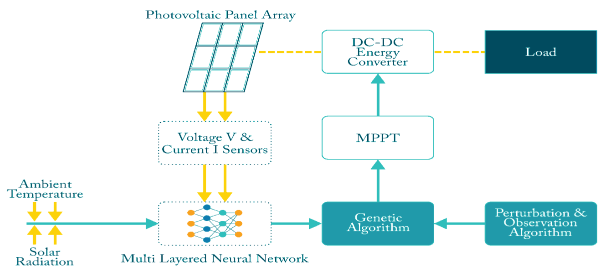


Fig-11: Block Diagram of proposed Neural Network (AI) system

A 100-kW PV array is connected to a 25-kV grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of a Simulink model using the 'Incremental Conductance + Integral Regulator' technique. Another example (see PV Array Grid Average model) uses average models for the DC_DC and VSC converters. In this average model the MPPT controller is based on the 'Perturb and Observe' technique. The detailed model contains the following components: **PV**

**array** delivering a maximum of 100 kW at 1000 W/m^2 sun irradiance.

- **5-kHz DC-DC boost converter** increasing voltage from PV natural voltage (273 V DC at maximum power) to 500 V DC. Switching duty cycle is optimized by a MPPT controller that uses the 'Incremental Conductance + Integral Regulator' technique. This MPPT system [11].
- The VSC converts the 500 V DC link voltage to 260 V AC and keeps unity power factor. The VSC control system uses two control loops: an external control loop which regulates DC link voltage to +/- 250 V and an internal control loop which regulates Id and Iq grid currents (active and reactive current components).
- **10-kvar capacitor bank** filtering harmonics produced by VSC.
- **100-kVA 260V/25kV three-phase coupling transformer**.
- **Utility grid** (25-kV distribution feeder + 120 kV equivalent transmission systems).

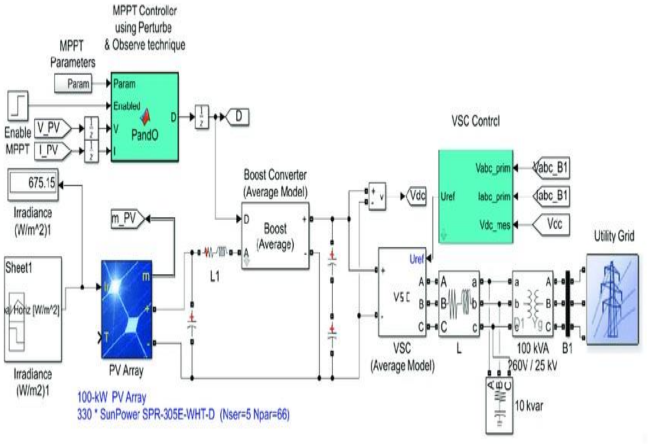

Fig-12: Modeling and Simulation of Solar System with MPPT Based Inverter and Grid Synchronization

Simulation Model Result of PV panel array

Fig. shows the out of the simulation model for designed PV array which is shown in fig-13. Where applied parameters for the simulation are:

Irradiance = 1000

Ambient Temperature Tamb = 25o C

Short Circuit current Isc = 2.02

A Maximum Current Im = 1.93

A Open Circuit Voltage Voc = 86.8 V

Maximum voltage Vm = 70.4 V

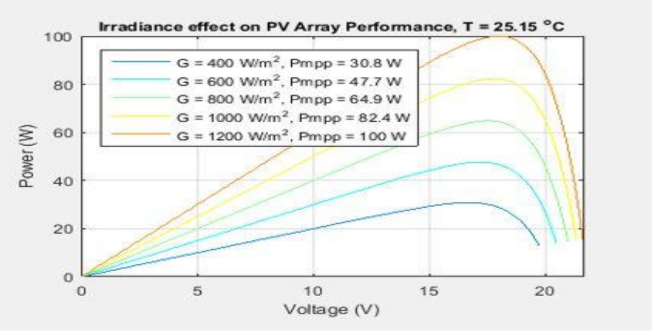


Fig-13: Output Voltage Power Waveform

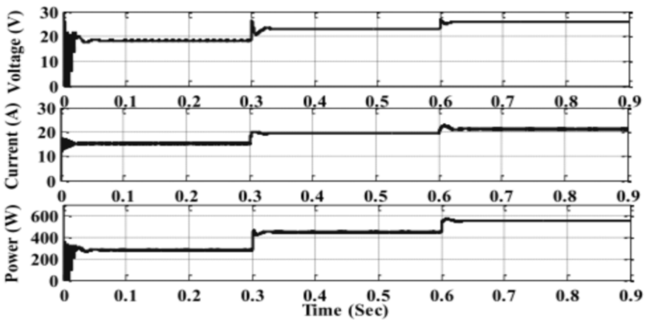


Fig-14: waveform of PV output

## 8. CONCLUSION

Artificial intelligence is an emerging field and the applications of AI in various fields of study only keeps growing day by day. Electrical power systems require a lot of deliberation when it comes to manufacturing, maintenance and security and this is where artificial intelligence comes into the picture. Artificial intelligence has its fair share of advantages and disadvantages but the impact that the advantages have on electrical systems as a whole far outweighs the disadvantages. A PWM generator was utilized for generating the pulse signal that was compared with the signal generated from the MPPT unit to give out the gating signal to the switch. If MPPT had not been used, then the user would have had to input the duty cycle to the system. When there is change in the solar irradiation the maximum power point changes and thus the required duty cycle for the operation of the model also changes. But if constant duty cycle is used then maximum power point cannot be tracked and thus the system is less efficient. The different waveforms were obtained by using the plot mechanism in MATLAB.

## 9. REFERENCES

1) Analysis of Artificial Intelligence Based MPPT in PV Grid Connected System J. Electrical Systems 20-7s (2024): 1016-1023

2) S. Sathyanarayanan, K. Sivakumar, and K. Thanushkodi. "Modeling and simulation of a solar PV system with a maximum power point tracking based inverter synchronized with the grid." Renewable Energy, vol. 93, pp. 15-24, 2016.

3) Bhagath Sivadasan, “Application of artificial

intelligence in electrical engineering", GRDJE, National conference on Emerging Trend in Electrical and Electronics Engineering, March 2018

4) P. Kumar, P. Srivastava, and S. Kumar. "Design and implementation of a fuzzy logic controller based MPPT algorithm for grid connected solar PV system." Sustainable Energy Technologies and Assessments, vol. 41, pp. 31-41, 2020.

5) S. Subramani, K. Thanushkodi, and K. Sivakumar. "Design and simulation of a maximum power point tracking controller for a solar PV system using a CUK converter." Journal of Renewable and Sustainable Energy, vol. 7, no. 5, pp. 053118, 2015.

6) S. Sathyanarayanan, K. Sivakumar, and K. Thanushkodi. "Implementation of a fuzzy logic controller based MPPT algorithm for a solar PV system connected to the grid." International Journal of Electrical Power and Energy Systems, vol. 84, pp. 142-150, 2017.

7) M. R. Khan, M. R. Islam, M. J. Hossain, and A. M. A. Haque. "Design and simulation of a grid connected solar photovoltaic system with MPPT and active power filter." International Journal of Renewable Energy Research, vol. 7, no. 3, pp. 1075-1082, 2017.

8) Santosh S. Raghuwanshi , Kamlesh Gupta," Modeling of a Single-Phase Grid-Connected Photovoltaic System Using MATLAB/Simulink", IEEE International Conference on Computer, Communication and Control -2015.

9) R. Kaur, J. Singh, and A. Gupta. "Design and simulation of a grid-tied solar PV system with a fuzzy logic controlled MPPT algorithm." Journal of Renewable and Sustainable Energy, vol. 10, no. 2, pp. 023703, 2018.

10) Y. Zhang, X. Ma, and W. Qiao. "Design and simulation of a grid-connected solar photovoltaic system with active power filter." Energy and Power Engineering, vol. 5, no. 4, pp. 294-300, 2013.

11) S. Khan, F. Ahmed, M. Akhtaruzzaman, and M. R. Islam. "Modeling and simulation of a grid-connected solar photovoltaic system with a modified perturb and observe maximum power point tracking algorithm." International Journal of Renewable Energy Research, vol. 9, no. 3, pp. 1267-1276, 2019.

12) M. A. Tariq, N. Abbas, and N. Naseer. "Grid integration of a solar photovoltaic system with maximum power point tracking and reactive power control." Journal of Solar Energy Engineering, vol. 142, no. 3, pp. 031013, 2020.