Implementation of Intelligent Controller for Maximum Power Point Tracking Control of Solar Power Generation System

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Abstract:
This paper presents the improved model of solar photovoltaic module and back propagation neural network based maximum power point tracking (MPPT) for boost converter in a standalone photovoltaic system under variable temperature and insulation in static and dynamic conditions. Solar panel is a power source having nonlinear internal resistance. As the intensity of light falling on the panel varies, its voltage as well as its internal resistance both varies. To extract maximum power from the panel, the load resistance should be equal to the internal resistance of the panel. Maximum power point trackers are used to operate a photovoltaic panel at its maximum power point in order to increase the system efficiency. This is done, with the aid of MATLAB and Artificial Neural Network (ANN).
Maximum Power Point Tracking (MPPT) algorithms is important in PV systems because it reduces the PV array cost by reducing the number of PV panels required to achieve the desired output power. This paper presents à comparative simulation study of two important MPPT algorithms specifically perturb and observe and incremental conductance. These algorithms are widely used because of its low-cost and ease of realization. Some important parameters such as voltage, current and power output for each different combination have been traced for both algorithms.

KEYWORDS: :- *Maximum Power Point Tracking (MPPT),* Solar Photovoltaic system (SPV), ANN, SNN, DNN, Boost converter, MATLAB.

1. INTRODUCTION

Photovoltaic (PV) generation represents currently one of the most promising sources of renewable green energy. Due to the environmental and economic benefits, PV generation is preferred over other renewable energy sources, since they are clean, inexhaustible and require little maintenance. PV cells generate electric power by directly converting solar energy to electrical energy. PV panels and arrays, generate DC power that has to be converted to AC at standard power frequency in order to feed the loads. Therefore, PV systems require interfacing power converters between the PV arrays and the grid.

Photovoltaic-generated energy can be delivered to power system networks through grid-connected inverters.

Renewable energy sources play an important role in electric power generation. Various renewable sources such as solar energy, wind energy, geothermal etc. are harness for electric power generation. Solar Energy good choice for electric power generation. The Earth receives 174 peta watts (PW) of incoming solar radiation (insulation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The solar energy is directly converted into electrical energy by solar photovoltaic module. The output power of a PV panel array depends on the PV voltage and umpire datable weather conditions. In order to optimize the ratio between output power and installation cost, DC/DC converters are used to draw maximum power from the PV panel array. Many approaches have been proposed to adjust the duty cycle of the converter for maximum power point.

2. Solar PV Array Modeling

Basic Principle of PV Cell

PV cells are essentially a very large area p-n junction diode where such a diode is created by forminga junction between the n-type and p-type regions. As sunlight strikes a PV cell, the incident energy is converted directly into electrical energy. Transmitted light is absorbed within the semiconductor by using the energy to excite free electrons from a low energy status to an unoccupied higher energy level. When a PV cell is illuminated, excess electron-hold pairs are generated by light throughout the material, hence the p-n junction is electrically shorted and current will flow Solar Photovoltaic system cell can be modeled as an ideal current source in parallel with an ideal diode. Fig.1 represents the simplified circuit mode l of a PV cell. The output of the current source is directly proportional to the light falling on the cell (photocurrent I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generated current I called diode(D) current or dark current. The diode determine the I-V characteristics of the cell.

Modelling of Photovoltaic Array

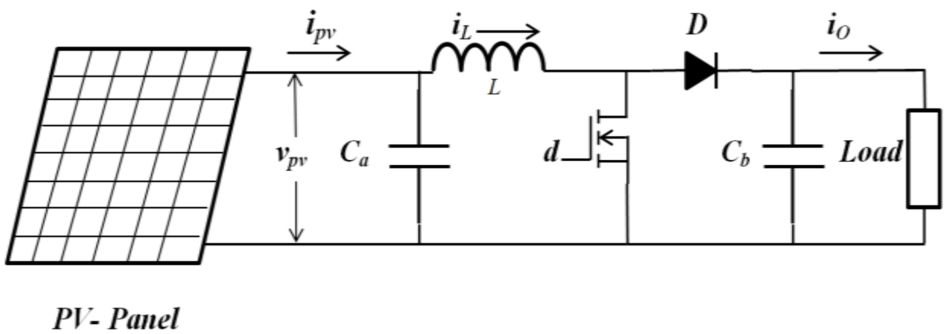

Fig.1Solarpowergenerationsystemwithdc/dc boost converter

Consider a PV panel array composed of solar cells arranged in an np-parallel, ns-series configuration. Let v_{pv} and i_{pv}, respectively, de note the output voltage and current of the PV array. The voltage/current characteristic equation of the PV array can be described by a light-generated current source and a diode .If the internal shunt and series resistances are neglected, the output current of the PV array is given by,

$$I = I_{pv,cell} - I_d \quad \text{.....................(1)}$$

$$I_d = I_{0,cell}[\exp(\frac{qv}{akT})-1] \quad \text{............... (2)}$$

$$I = I_{pv,cell} - I_{0,cell}[\exp(\frac{qv}{akT})-1] \quad \text{.........(3)}$$

A single PV cell produces an output voltage of less than 1 volt, it is necessary to string together a number of PV cells in series to achieve a desired output voltage. Solar panel is a power source having nonlinear internal resistance. As the intensity of light falling on the panel varies, its voltage as well as its internal resistance both varies. To exact maximum power from the panel the load resistance should be equal to the internal resistance of the panel. The solar panel module, whichcontain36cells in series 1sets.

According to this equation, Fig. 2 depicts the characteristics of the array power with respect to the PV voltage, the insulation, and cell temperature. It can be observed that the maximum power point is maximized by the PV voltage and is dependent on various insulation and temperature

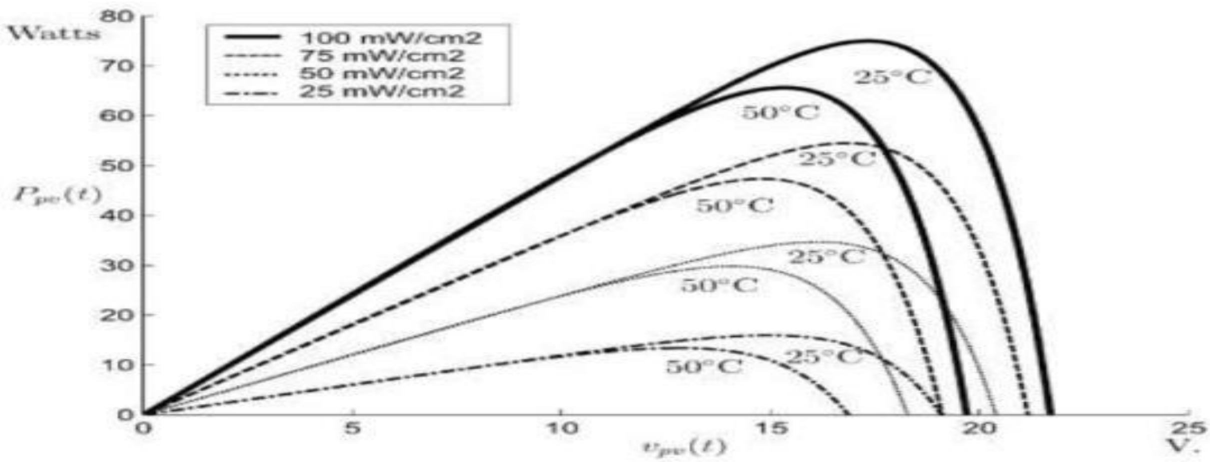

Fig.2Characteristicsofthearraypowerwith respect to the PV voltage

3. Maximum Power Point Tracking

The objective of MPPT is to extract maximum power from the solar panels. The I-V and P-V characteristics of the solar panels are affected by atmospheric changes such in solar irradiance (G),temperature(T)and diode ideality factor (n). Hence the MPPT should track the maximum power from the solar panel subject to these changes.

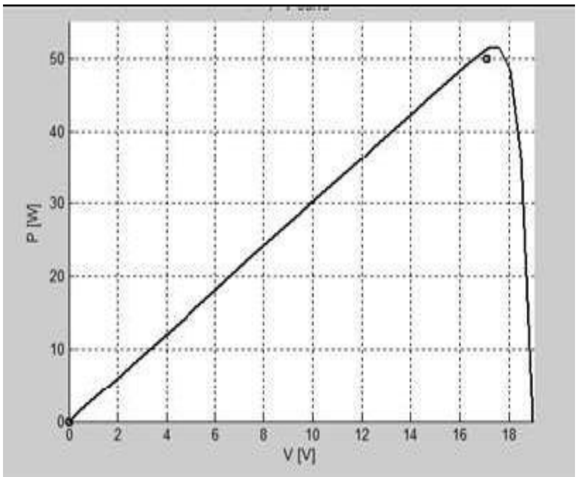

Fig.3PVarraycharacteristicswithMPPT

For a good solar cell, the series resistance (Rs), should be very small and the shunt (parallel) resistance (Rp), should be very large. For commercial solar cells (Rp) is much greater than the forward resistanceof a diode. The I-V curve is shown in Figure 4. The curve has three important parameters namely open circuit voltage (Voc), short circuit current (Isc) and maximum power point (MPP). In this model single diode equivalent circuit is considered. The I-V characteristic of the photovoltaic device depends on the internal characteristics of the device and on external influences such as irradiation level and the temperature characteristics of the PV cell are illustrated in figure 5. It depends on the open circuit voltage (Voc), the short circuit current (Isc) and the maximum power point (MPP).

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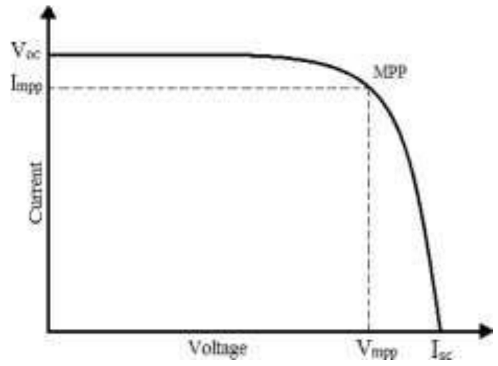

Figure 4.I-V characteristics of the PV cell

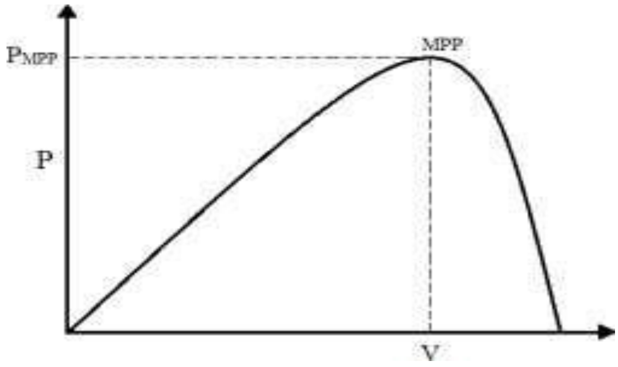

Figure 5.P-V characteristics of the PV cell

4. DC/DC Boost Converter

A step-up converter is used in this research to connect a PV panel with a load in order to adjust the operating voltage and current of the PV panel at optimal values. The boost converter contains an MOSFET and a diode which are represented as a dual ideal switch U in order to simplify the circuit analysis. If U is a state of 0, the diode is ON and the MOSFET is OFF and vice versa if U is a state of 1. The boost converter contains also passive components an inductor L, an capacitor C and a resistance R. The operation principle of the boost converter can be demonstrated for each switching period under the continuous conduction mode(CCM) into two modes, the first mode is an ON mode in the duration the period $0 \leq t \leq ton$.

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller is used to move the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation and it also fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular because of its simplicity

The design ofa boost converter for a PV system is a complex task which involves many factors. In general, the input and output voltages of the boost converter are varied with the solar irradiances and load variations. The output voltage is also varied which follows the reference voltage generated from an MPPT controller. Thus the selection of boost converter components (the input inductor and the output capacitor) is a compromise between dynamic responses and the MPPT algorithm trigger time. The maximum value of the state variables should be calculated to estimate the value of the boost converter

5. Artificial neural networks (ANNs)

Artificial neural networks (ANNs) have been proven to be universal approximate or non-linear dynamic systems. They emulate nonlinear systems using a multilevel neural network Neural network has the potential to provide an improved method of deriving non linear models which is complementary to conventional techniques. This work deals with the application of an artificial neural networks based

MPPT of PV systems. Back propagation neural network are utilized as pattern classifier. Back propagation neural network is an example of non- linear layered feed-forward networks. Back propagation constructs global approximations to non-linear input-output mapping. There are capable of generalizations in regions of the input space where little or no training data area available In the proposed work, we develop an MPPT method for stand-alone solar power generation systems via the neural network approach. Here, the output power of the PV array is adjusted by a DC/DC boost converter. Then the system is represented in the neural network model, where the partial derivative of the PV power with respect to the PV voltage is taken as the control output. With this neural network is been trained for the desired response

Dynamic neural network (DNN)

A Dynamic Neural Network (DNN) is a neural network that can alter its own topology to accept perpetual novelty. Perpetual novelty is data that is always changing. A DNN never finishes learning. ADNN always accepts the data shown to it. To achieve this, the DNN needs to not only change its knowledge, but the topology that stores it. A purely dynamic neural network never stops learning or changing its topology. The field of DNNs is in its infancy. Most DNN examples are only partially dynamic that is that they are dynamic during a particular phase of their use

The three variable inputs are given insulation (sun) temperature and duty ratio (for controlling the MOSFET switch) and these values are trained using Feed Forward Back Propagation network by giving different delay as feedback till achieving maximum voltage. There response for the following input of [90, 319, and 0.55] in dynamic characteristics is as follows

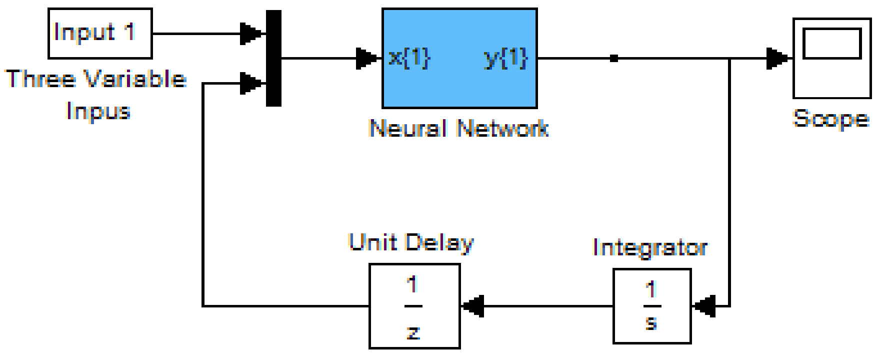

Fig.6 simulations for DNN

Static neural network (SNN)

A Static Neural Network (SNN) is a neural network in which desired output is obtained from desired input. A SNN is the one in which the output produced will be same for the particular range of inputs.

6. The Proposed MPPT model

6.1 Perturb and Observe (P&O) Algorithm

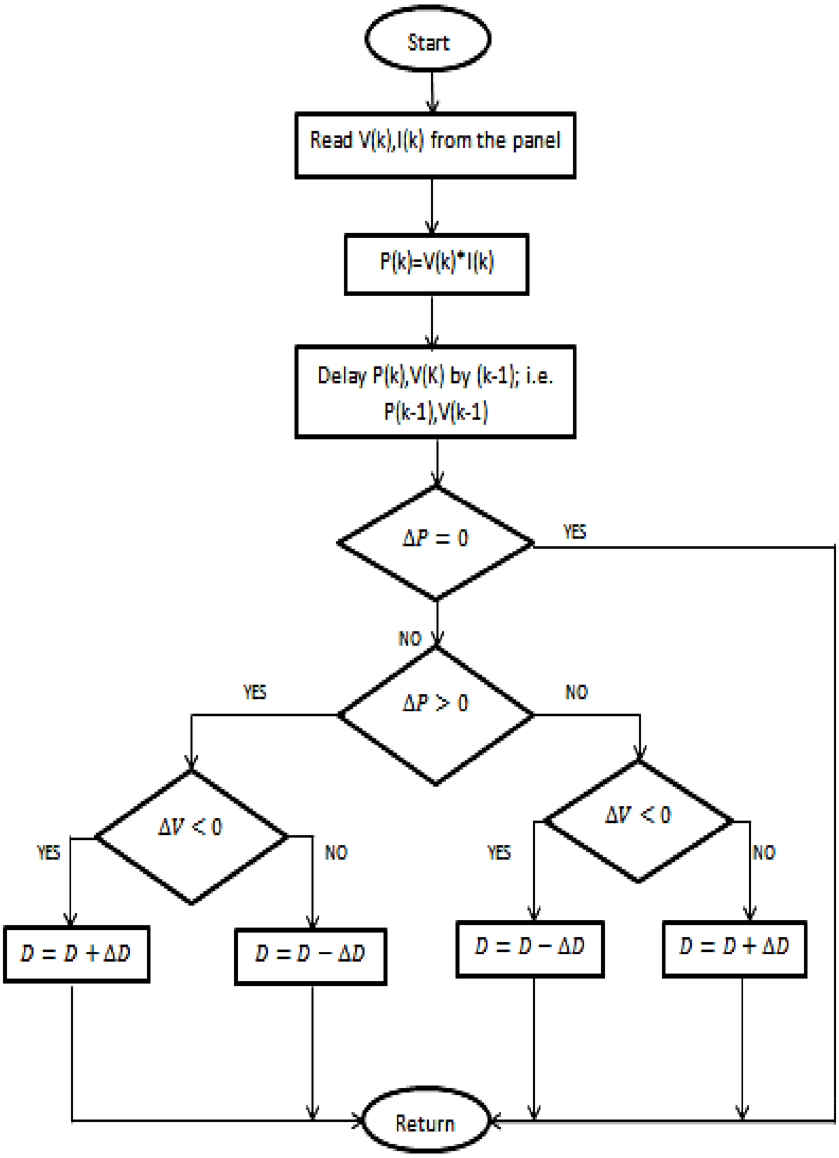

Figure 7 Perturb and Observe Algorithm

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller is used to move the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation and it also fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular because of its simplicity

A slight perturbation is introduced in this algorithm. The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same direction. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the steady state is reached.

6.2 Incremental conduction Algorithm

Incremental Conductance (IC) method overcomes the disadvantage of the perturb and observe method in tracking the peak power under fast varying atmospheric condition. This method can determine whether the MPPT has reached the MPP and also stops perturbing the operating point. If this conditionis not met, the direction in which the MPPT operating point must be perturbed can be calculated usingthe relationship between dl/dV and –I/V.

This relationship is derived from the fact that dP dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm determines when the MPPT has reached the MPP, whereas P&O oscillates around the MPP. This is clearly an advantage over P&O. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method [4]. The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart

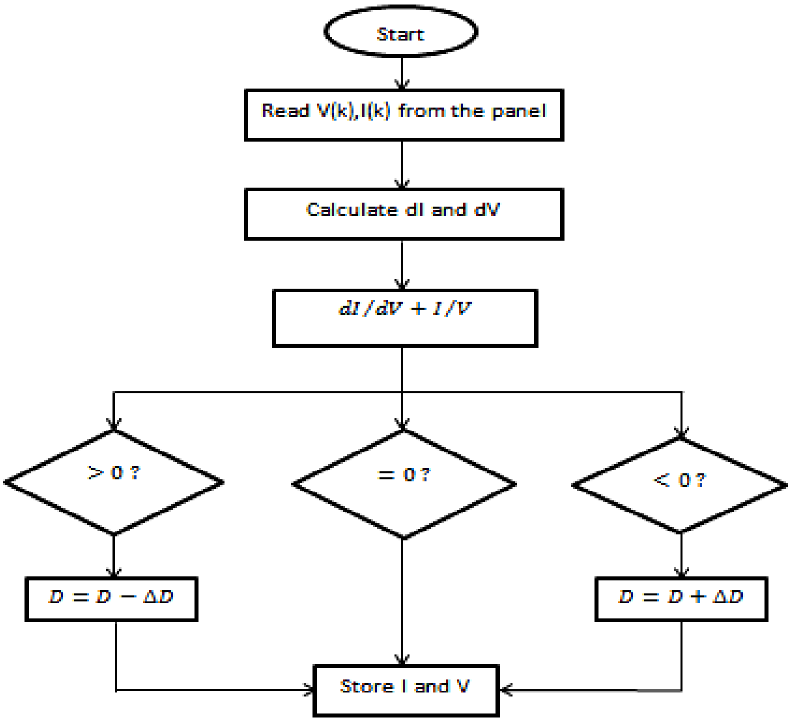

Figure 8 Incremental Conductance Algorithm

7. Conclusion

Interfacing an MPPT chopper between SPV and the load can maximize the power input to the load at all levels of insulation. This paper has presented the application of feed forward back propagation neural networks for maximum power point tracking of solar array. The back propagation neural network was modeled and simulated. The simulation results have shown that training of back propagation neural networks gives closer maximum power point. As the developed model takes care about the variations of all the parameters with respect to environmental conditions, it can be used to predetermine the SPV characteristics. The electronic load is useful for observing panel characteristics in the field conditions .In this paper a mathematical model of a photovoltaic panel has been developed using MATLAB Semulink This model is used for the maximum power point tracking algorithms. The P&O and Incremental conductance MPPT algorithms are discussed and their simulation results are presented. It is proved that Incremental conductance method has better performance than P&O algorithm. These algorithms improve the dynamics and steady state performance of the photovoltaic system as well as it improves the efficiency of the dc-dc converter system. The outcome shows that INC strategy gives preferred outcomes over P&O technique and INC technique gives better execution under shifting environmental condition. Henceforth INC strategy can be utilized for MPPT of sunlight-based PV applications.

8. Reference

1 D. P. Hohm, M. E. Ropp, “Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed”, 0-7803-5772-8/00,IEEE, 2000, 1699-1702.`

2 N. Pongratananukul and T. Kasparis, “Tool for Automated Simulation of Solar Arrays Using General-Purpose Simulators,” in IEEE Conference Proceedings, (0-7803-8502-0/04), 2004, 10-14.

3 Trishan Esram, andPatrick L. Chapman, „Comparison of Photovoltaic Array Maximum PowerPoint TrackingTechniques,‟ IEEETransactions on Energy Conversion, 22 (2), 2007, 439-449
.

4. Hairul Nissah Zainudin, Saad Mekhilef, „Comparison Study of Maximum Power Point Tracker Techniques for PV Systems,‟ Proc. 14th International Middle East Power Systems Conference (MEPCON‟10), Cairo University, Egypt, 2010, 750-755.

5. Ahmed G. Abdullah. “Comparison between neural network and P&O method in optimizing MPPT control for photovoltaic cell”. International Journal of Electrical and Computer Engineering (IJECE) Vol. 10, No. 5, October 2020

6 .D. Selvabharathi, Vishwas. “Design of standalone photovoltaic system using three port dc - dc converter”. International Journal of Electrical Engineering and Technology (IJEET) Volume 11,

7. H.M.A. Maamary, H.A. Kazem, M.T. Chaichan, Renewable energy and GCC States energy challenges in the 21st century: A review, International Journal of Computation and Applied Sciences. 2 (2017) 11-18. https://doi.org/10.24842/1611/0018

8. M.A. Hannan, Z.A. Ghani, M.M. Hoque, M.S.H. Lipu, A fuzzy-rule-based PV inverter controller to enhance the quality of solar power supply: Experimental test and validation, Electronics 8 (2019) 1335. https://doi.org/10.3390/electronics8111335

9. IEA, "World Energy Outlook 2015," 2015. https://www.iea.org/reports/world-energy-outlook-2015

10. R. Belu, Artificial intelligence techniques for solar energy and photovoltaic applications, in: M.K. Pour, S. Clarke, M.E. Jennex, A.V. Anttiroiko, S. Kamel, I. Lee, J. Kisielnicki, A. Gupta, C.V. Slyke, J. Wang, V. Weerakkody (Eds.), Robotics: Concepts, methodologies, tools, and applications, IGI Global., 2014, pp. 1662-1720.https://doi.org/10.4018/978-1-4666-4607-0.ch081