UNIVERSITI PUTRA MALAYSIA

COMBINATION OF PERTURB AND OBSERVE WITH ONLINE SEQUENTIAL EXTREME LEARNING MACHINE FOR PHOTOVOLTAIC SYSTEM MAXIMUM POWER POINT TRACKING

YASIR SABAH DIRA

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By

YASIR SABAH DIRA

Thesis Submitted to the School of Graduated Studies, University Putra Malaysia,In Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

The efforts spent on this work are dedicated to all family members including father, mother, and to all friends who gave a full support. Their moral support and professional guidance were a source of inspiration, in the fulfillment of this project.

Abstract of a thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman : Mohammad Hamiruce Marhaban, PhD
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Photovoltaic energy is one of the most renowned sources of renewable energy. Its major drawback, however, is the low efficiency of ultra-violet to electrical energy conversion. Irradiance and temperature are the major factors that determine its ability to achieve maximum power output. Maximum power point tracking (MPPT) is developed in photovoltaic systems to maintain the maximum power output produced by its source. A boost DC-DC converter with maximum power point tracking algorithm aids in operating at the desired voltage level. From different MPPT techniques previously proposed, the online sequential extreme learning machine algorithm and conventional perturb and observe are combined together as a proposed MPPT algorithm. This combination is capable of extracting energy at the maximum operating level of a photovoltaic module.

The simulation work covers modelling of the photovoltaic module, and the boost DC-DC converter and power LED light as a load, with maximum power point tracking algorithm to form a photovoltaic system. This system was evaluated under the actual environmental data based on location and dynamic MPPT efficiency tests. For comparison purpose, the conventional extreme learning machine and modified P&O were modelled as well.

Several factors will be triggered on the solar module performance, and the PV module will be degraded over time. In this thesis, the proposed method will be emulated under the degradation of maximum output PV current. The diode ideality factor was chosen to evaluate the PV output current degradation.

System elements are individually modelled in MATLAB/M-File and then connected to assess performance under different environmental conditions. The simulated results of the complete PV system show that the performances of the PV module using the proposed MPPT technique provide better output power when compared with the conventional ELM and modified P&O. It yields not only a reduction in convergence time to track the maximum power point but also significant output power when subjected to slow and rapid solar irradiance changes.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

GABUNGAN KACAUAN DAN PERHATIAN DENGAN MESIN PEMBELAJARAN EKSTREM TURUTAN DALAM TALIAN UNTUK SISTEM JEJAK TITIK KUASA MAKSIMUM FOTOVOLTAIK

Oleh

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Tenaga fotovoltan merupakan salah satu sumber tenaga boleh pulih yang paling terkenal. Walau bagaimanapun, kekurangan utamanya adalah kecekapan rendah ultra violet kepada penukaran tenaga elektrik. Kesinaran dan suhu adalah faktor utama yang menentukan keupayaannya untuk mencapai output kuasa maksima. Penjejakan titik kuasa maksimum (MPPT) dibangunkan dalam sistem fotovoltan untuk mengekalkan output kuasa maksimum yang dihasilkan oleh sumbernya. Rangsangan penukar DC-DC dengan algoritma pengesanan titik kuasa maksimum dalam beroperasi pada tahap voltan yang dikehendaki. Daripada teknik MPPT berbeza yang dicadangkan sebelum ini, algoritma mesin pembelajaran secara beransur-ansur dalam talian dan perturb konvensional dan pemerhatian digabungkan bersama sebagai cadangan algoritma MPPT. Gabungan ini mampu mengekstrak tenaga pada tahap operasi maksimum modul fotovoltan.

Kerja simulasi merangkumi pemodelan modul fotovoltan, dan merangsang penukar DC-DC dan kuasa LED cahaya sebagai beban, dengan algoritma pengesanan titik kuasa maksimum untuk membentuk sistem fotovoltan. Sistem ini dinilai di bawah data persekitaran sebenar berdasarkan lokasi dan ujian kecekapan MPPT dinamik. Untuk tujuan perbandingan, mesin pembelajaran konvensional maksimum dan P&O yang diubah suai juga dimodelkan.

Beberapa faktor akan dicetuskan pada prestasi modul solar, dan modul PV akan degradasi dari masa ke semasa. Dalam tesis ini, kaedah yang dicadangkan akan dicontohi di bawah degradasi output maksimum PV semasa. Faktor kesamaan diod dipilih untuk menilai keluaran semasa output PV.

Elemen-elemen sistem dimodelkan secara individu dalam MATLAB/M-File dan kemudian disambungkan untuk menilai prestasi di bawah keadaan persekitaran yang berbeza. Hasil simulasi sistem PV yang lengkap menunjukkan bahawa prestasi modul PV menggunakan teknik MPPT yang dicadangkan memberikan kuasa output yang lebih baik jika dibandingkan dengan ELM konvensional dan P&O yang diubah suai. Ia bukan sahaja menghasilkan pengurangan masa penumpuan untuk menjejaki titik kuasa maksimum tetapi juga kuasa output yang ketara apabila tertakluk kepada perubahan sinar matahari yang perlahan dan pantas.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
T	Temperature
Ir	Sun Irradiance
DC	Direct Current
AC	Alternating Current
PV	Photovoltaic
P&O	Perturb and Observe
ELM	Extreme Learning Machine
OS-ELM	Online Sequential Extreme Learning Machine
Isc	Short Circuit Current
Voc	Open Circuit Current
V	Voltage
I	Current
P	Power
STC	Standard Test Conditions
D	Duty Cycle
Vs	Ideal Switch Voltage
Vo	Output Voltage
Vi	Input Voltage
L	Inductor
C	Capacitor
R	Resistor
RTDs	Real Time Digital Simulation
PWM	Pulse with Modulation
ANN	Artificial Neural Network
DE	Differential Evolution
PSO	Particle Swarm Optimization
ANFIS	Adaptive Neuro-Fuzzy Inference System
dv	Changing Voltage
dt	Changing Time

dp	Changing Power
HFC	Hierarchical Fuzzy Logic
MPV	Voltage-Based Control
DMP	Direct Maximum Power
Vref	Reference Voltage
RBF	Radial Basis Function
n	Diode Ideality Factor
Sig	Sigmoid Activation Function
Vmpp	Voltage at Maximum Power Point

CHAPTER 1

INTRODUCTION

1.1 Background

The rapidly growing demand for power and its limitation regarding available sources to harness energy has now become a key problem for industries. Conventional energy sources do not suffice to match with the rising demand for power. A key concern at this age is the search for alternative energy sources. Renewable energy has now gradually gained much popularity, and is constantly being used globally along with conventional systems to address the issue of energy demand. Just few years back, the use of alternative renewable sources such as solar, wind, water and geothermal energy became more common (Eltawil & Zhao, 2010).

The most widely used renewable energy source is solar energy due to ease of its availability everywhere, which allows proper utilisation. Environmentally, photovoltaic systems are noiseless and produce negligible pollution. Economically, these systems do not require much maintenance and can sustain for a long time (over 20 years). These photovoltaic systems are known for their flexibility; they can not only be installed on rooftops but also in rural areas that have limited availability of grid. However, currently, these systems are very costly and do not deliver much efficiency.

In a photovoltaic system, electrical energy is generated by each solar cell directly from the sun in the form of solar energy. Although relatively low voltage is produced individually, a fair amount of power can be generated by combining numerous solar cells together in parallel or series to form a photovoltaic module. It is thus crucial to harness maximum power from a PV system. At a particular operating point known as the maximum power point (MPP), a certain maximum power is supplied by each PV cell. It is thus beneficial when the PV system operates at its maximum power point to maximise the PV generated power (Illanes, De Francisco, Torres, De Blas, & Appelbaum, 2003) (Ahmed & Salam, 2016) (Jie Wang, 2013) (Maghami, Hizam, & Gomes, 2014).

PV energy is categorised under nonlinear source of energy as it relies on environmental conditions. However, with numerous research studies, the PV technology has now become more feasible and delivers better performance (Salam, 2014).

A typical PV system is geared with either DC–AC or DC–DC converters, which employs the maximum power point tracking (MPPT). Amongst DC–DC converters, buck, boost and buck-boost DC–DC converters are the most common configurations, and they are built to deliver specific conversions of DC voltage. In this study, a boost DC–DC converter was selected since it can be employed to carry out step up of the PV output voltage. There are basically three types of PV systems: grid connected, standalone and hybrid. The standalone PV system makes use of a DC–DC converter limited to specific load for systems like water pump, DC motor, lighting and many more applications. The grid connected PV system employs DC–DC converters and DC–AC converters that are directly connected to the power grid system. In case of the hybrid PV system, it is generally combined with other types of electrical energy sources like wind system, diesel generator and others (Kashif Ishaque Z. S., 2013). In this study, a standalone PV system has been designed specifically as presented in Figure 1.1. The boost DC–DC converter is used to increase PV's output voltage to supply voltage to the load that can be power LED, resistor or battery. A controller is included in this PV system to apply MPPT algorithm by keeping in mind environmental conditions (sun irradiance and temperature). An elaborate detail of this algorithm is shown in the later section. The DC–DC converter is controlled by production of the duty cycle. In recent years, various MPPT methods have been put forward concerning PV power systems, which help in locating MPP and improve the efficiency of the system. The most popularly employed MPPT algorithm amongst other techniques is the perturb and observe algorithm due to its ease of implementation and simple structure. There are two major drawbacks associated with this technique. The first and the important one is when the irradiation changes quickly, it easily loses track of MPP. The other drawback is oscillations of the current and voltage around MPP.

To resolve these drawbacks, in recent years, certain solutions addressing these issues have been published. Considering the rapid changes in irradiation conditions, in (Eltawil & Zhao, 2010), the enhanced P&O method, also known as "dP-P&O", uses an additional measurement without perturbation in the current and voltage.

With regards to the oscillations around MPP in steady state, in (Illanes, De Francisco, Torres, De Blas, & Appelbaum, 2003), a variable perturbation step is employed for the P&O algorithm to decrease the surrounding oscillation. This modified P&O method can also help in finding out whether the operating point is far from or near to MPP and adjust the perturbation's size accordingly. Neural networks are another MPPT method, where NN's performance relies on the functions of the hidden layer and how well the training of the neural network was.

The main drawback of this MPPT technique is the need for specific data for the training process for every PV module and locations, since the PV module's characteristics differ with change in model and the atmospheric conditions, which again relies on the location. Since these characteristics change with time, periodic training should be conducted for the neural network.

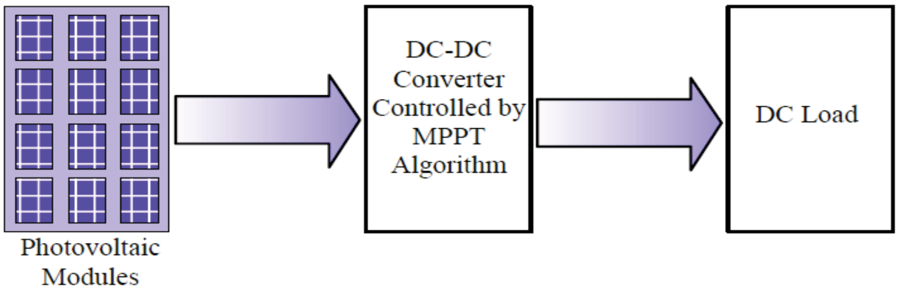

Figure 1.1 : Block diagram of standalone MPPT-PV system

1.2 Motivation and Problem Statement

Two negative problems can be associated with the PV systems' power generation. These issues are related to PV modules' amount of generated power, which changes continuously with differing atmospheric conditions. The *P–V* and *I–V* characteristics, which are nonlinear in nature, can also influence the conversion efficiency and these change based on solar radiation and cell temperature. However, a unique point can be associated with the *P–V* and *I–V* curves, also known as the maximum power point (MPP). At this point, maximum efficiency is achieved by the PV module, which is also its maximum power. Therefore, various research studies have been focusing on maximising the power conversion to enable an increase in the overall efficiency.

The conventional MPPT methods have gained much popularity owing to their structural simplicity and ease of implementation. However, these methods suffer from some drawbacks involving P&O algorithms, like slow response speed and oscillation around the MPP. Numerous works, reviews and analyses have been carried out to provide more details on the drawbacks, which are summarised below:

- Poor tracking, not sufficiently intelligent, and rapid change of the irradiance causes drops the efficiency as it deviates from the real maximum power point (MPP) (Kashif Ishaque Z. S., 2011).
- Inability to confirm whether the higher new output power value was due to the new duty cycle value or the new irradiation amount (Mahmoud A. YOUNIS, 2012).
- At the optimal operating point, continuous oscillations deviate the average power level from the MPP, especially during low irradiance (H S Sudhakar, 2013).
- It goes back and forth near the MPP and is not able to stick exactly (Nguyen, 2015).
- Slow time response (Nguyen, 2015).

Many works have been proposed to improve the conventional P&O MPPT method in order to eliminate its drawbacks. Modified P&O method was proposed to in order to reduce the oscillation around the MPP caused by conventional P&O (Ahmed & Salam, 2016). The objective of the modified P&O is to ensure that steady state oscillation and the deviation from the tracking locus is minimized. It was obvious that the modified P&O algorithm has been achieved a better perfromance than the conventional P&O, on other hand, the output of this method has minimized the oscillation but at the same time the output power does not meet the maximum operating point of solar module, which is lead to reduce the output efficiecny of the PV system.

On other hand, soft computing based MPPT such as extreme learning machine (Jie Wang, 2013), was proposed, in this method the MPPT technique has a good tracking performance with the changing of atmospheric conditions. Since ELM has been trained once when the network established. The limitation of this method is the network need to train periodically based on the characteristics of PV module which is based on the weather conditions. in this manner, the tracking perfromance of ELM MPPT does not update while the envirmental conditions changing for time to time.

Many parameters from the environment affect the solar photovoltaic module such as shadow, air pollution and dust which is lead to reduce the energy yield (Maghami, Hizam, & Gomes, 2014). In this work, the reduction of maximum output current (I-max) will be considered, since the maximum output current has a reverse proportional with the diode current, when the diode current increases the maximum output current of PV module decreased. On other hand, the output current of solar module will be decreased when the ideality factor (n) of PV's diode increased. Thus, the diode ideality factor (n) will be used as a parameter to simulate the maximum output current's reduction. This issue was put under consideration in this research to evaluate the performance of the proposed method under the maximum PV output current degradation.

In this work, the OS-ELM algorithm will be combined with P&O as a MPPT method to track the maximum power output of PV module with updating feature to achieve a better tracking performance of MPP. The issue of maximum output current degradation was put under consideration in this research to evaluate the performance of the proposed method under that degradation. Where, the proposed method will be updated every time based on the characteristics of solar module and the enviromental conditions.

1.3 Research Objective

This research focuses on the modeling of a PV system by improving the MPPT controller using OS-ELM and P&O, the main objectives of this work can be summarized as follows:

1. To develop circuit topology of PV boost DC-DC converter.
2. To design, develop and integrate P&O and OS-ELM MPPT algorithm in the PV boost DC-DC converter with varying diode ideality factor.
3. To compare and evaluate performance of the proposed MPPT method with the conventional ELM MPPT algorithm and modified P&O method at various environmental conditions.
4. To test the proposed MPPT technique's performance under the static and dynamic MPPT test and under the degradation of PV output current.

1.4 Research Scope

A MPPT-PV stand-alone power system comprises photovoltaic module, power LED light as a load and step-up (Boost) switching DC-DC converter, acting as the power interface between the PV module and the load. The system will be used to test the performance of proposed MPPT technique under the static and dynamic efficiency test of MPPT (EN 50530) (Salam, 2014). Two algorithms have been combined together designed and simulated in MATLAB software.

The first algorithm is called On-line sequential extreme learning machine which is online training algorithm of extreme learning machine, used to predict the voltage at maximum power point based on the temperature and sun irradiance. The second algorithm is conventional perturb and observe algorithm which is used to measure the PV terminal voltage and current every specific time and working together with OS-ELM which is suitable with the changing of atmospheric conditions. The diode ideality factor was chosen as a parameter of solar module to emulate the reduction of PV output current. Moreover, a comparison has been carried out between the proposed MPPT technique with extreme learning machine and modified P&O MPPT techniques under different value of envirmental conditions.

1.5 Thesis Layout

This thesis consist of 5 chapters, the introduction, literature review, methodology, results and discussion and lastly the conclusion with future recommendations.

Chapter 1 describes the general background of this research, the overview of the thesis, the problem statement as well, proposed solution, and research objectives, have been described.

Chapter 2 presents the critical review of relevant literature for PV system, also the techniques of maximum power point tracking (MPPT).

Chapter 3 outlines the details and simulation of the proposed method, with all procedure of the system.

Chapter 4 shows and discusses the results obtained by the simulated PV system with the proposed method. As well as it is comparative with other MPPT technique.

Chapter 5 concludes this thesis and draws the recommendations; finally, this chapter states the future work direction.

REFERENCES

A. Durgadevi, S. A. (2011). Photovoltaic Modeling and Its Characteristics. *PROCEEDINGS OF ICETECT*, 469-475.

A. Yafaoui, B. W. (June 2007). IMPLEMENTATION OF MAXIMUM POWER POINT TRACKING ALGORITHM FOR RESIDENTAL PHOTOVOLTAIC SYSTEMS. *Second Canadian Solar Buildings Conference*, 1-6.

Adly, M., Ibrahim, M., & Sherif, H. (2012). Comparative Study of Improved Energy Generation Maximization Techniques for Photovoltaic Systems. 2-6.

Afghoul, H., Krim, F., & Chikouche, D. (2013). Increase the photovoltaic conversion efficiency using Neuro-fuzzy control applied to MPPT. *Proceedings of 2013 International Renewable and Sustainable Energy Conference, IRSEC 2013*, 348-353.

Ahmed, J., & Salam, Z. (2016). A Modified P and O Maximum Power Point Tracking Method with Reduced Steady-State Oscillation and Improved Tracking Efficiency. *IEEE Transactions on Sustainable Energy, 7*(4), 1506-1515.

Ashoor, F. A. (May 2015). *Maximum power point tracking techniques for photovoltaic water pumping system.* University of Bath.

Bataineh, K., & Hamzeh, A. (2014). Efficient Maximum Power Point Tracking Algorithm for PV Application under Rapid Changing Weather Condition. *ISRN Renewable Energy, 2014*, 1-13.

C. Liu, B. Wu, R. (2004). Advanced Algorithm for MPPT control of Photovoltaic Systems. *Canadian Solar Buildings Conference*, 20-24.

Chen, P., Liu, Y., Yau, Y., & Lee, H. (2008). Development of an energy efficient street light driving system. *2008 IEEE International Conference on Sustainable Energy Technologies, ICSET 2008*, 761-764.

Chin, C., Chin, Y., Chua, B., Kiring, A., & Teo, K. (2013). Fuzzy logic based MPPT for pv array under partially shaded conditions. *Proceedings - 2012 International Conference on Advanced Computer Science Applications and Technologies, ACSAT 2012*, 133-138.

Chunhua Liu, K. T. (2010). An Efficient Wind-Photovoltaic Hybrid Generation System Using Doubly Excited Permanent-Magnet Brushless Machine. *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 57*, 831-839.

Ciabattoni, L., Grisostomi, M., Ippoliti, G., & Longhi, S. (2013). Neural Networks Based Home Energy Management System in Residential PV Scenario. *2013 IEEE 39th Photovoltaic Specialists Conference*, 1721-1726.

Cooper, T. (2013). DIY DC/DC Boost Calculator. *adafruit learning system* .

Diab, H., El-Helw, H., & Talaat, H. (2012). Intelligent maximum power tracking and inverter hysteresis current control of grid-connected PV systems. *2012 International*

Conference on Advances in Power Conversion and Energy Technologies (APCET), 1-5.

Elobaid, L. (2012). Artificial neural network based maximum power point tracking technique for PV systems. *IECON 2012-38th …*, 937-942.

Eltawil, M., & Zhao, Z. (2010). Grid-connected photovoltaic power systems: Technical and potential problems-A review. *Renewable and Sustainable Energy Reviews, 14*(1), 112-129.

F.Bouchafaa, I. A. (2011). Fuzzy Logic Control for the tracking of maximum power point of a PV system . *Energy Procedia, 6*, 633-642.

H S Sudhakar, G. B. (2013). Modeling, Control and Maximum Power Point Tracking (MPPT) for optimal Battery charging from Solar Photovoltaic (SPV) system. *The Jorunal of CPRI, 9*(3), 393-398.

Hiren Patel, V. A. (2009). MPPT Scheme for a PV-Fed Single-Phase Single-Stage Grid-Connected Inverter Operating in CCM With Only One Current Sensor. *IEEE TRANSACTIONS ON ENERGY CONVERSION, 24*(1), 256-263.

Horng, R. (2005). High-Power GaN – Mirror – Cu Light-Emitting Diodes for Vertical Current Injection Using Laser Liftoff and Electroplating Techniques. *Technology, 17*(9), 1809-1811.

Huang, G., Zhu, Q., & Siew, C. (2006). Extreme learning machine: Theory and applications. *Neurocomputing, 70*(1-3), 489-501.

Huang, G.-B. (2003). Learning Capability and Storage Capacity of Two-Hidden-Layer Feedforward Networks. *IEEE TRANSACTIONS ON NEURAL NETWORKS, 14*(2), 274-281.

Huang, G.-b., Zhu, Q.-y., & Siew, C.-k. (2004). Extreme Learning Machine : A New Learning Scheme of Feedforward Neural Networks. *IEEE International Joint Conference on Neural Networks, 2*, 985-990.

Illanes, R., De Francisco, A., Torres, J., De Blas, M., & Appelbaum, J. (2003). Comparative Study by Simulation of Photovoltaic Pumping Systems with Stationary and Polar Tracking Arrays. *Progress in Photovoltaics: Research and Applications, 11*(7), 453-465.

Iqbal, A., Abu-Rub, H., & Ahmed, S. (2010). Adaptive neuro-fuzzy inference system based maximum power point tracking of a solar PV module. *2010 IEEE International Energy Conference*, 51-56.

J.SUGANYA, D. M. (2012). MAXIMUM POWER POINT TRACKER FOR A PHOTOVOLTAIC SYSTEM. *International Conference on Computing, Electronics and Electrical Technologies [ICCEET], 12*, 463-465.

Jiang, L., Nayanasiri, D., Maskell, D., & Vilathgamuwa, D. (2013). A simple and efficient hybrid maximum power point tracking method for PV systems under partially shaded condition. *IEEE Industrial Electronics Society*, 1513-1518.

Jie Wang, K. Z. (2013). A MPPT Control Algorithm Based on Extreme Learning Machine in PV System. *Advanced Materials Research, 791-793*, 1214-1219.

Jong-Pil Lee, B.-D. M.-W. (2013). Implementation of High Efficiency Grid-tied Multi-level Photovoltaic Power Conditioning System Using Phase Shifted H-bridge Modules. *Journal of Power Electronics*.

Junsangsri, P., & Lombardi, F. (2010). Time/temperature degradation of solar cells under the single diode model. *Proceedings - IEEE International Symposium on Defect and Fault Tolerance in VLSI Systems*, 240-248.

Kalogirou, S. (2003). *Artificial intelligence for the modeling and control of combustion processes: A review* (Vol. 29).

Kashif Ishaque, Z. S. (2011). A comprehensive MATLAB Simulink PV system simulator with partial shading capability based on two-diode model. *Solar Energy, 85*, 2217–2227.

Kashif Ishaque, Z. S. (2013). A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition . *RenewableandSustainableEnergyReviews, 19*, 475-488.

Kulaksız, A., & Aydoğdu, Ö. (2012). ANN-based Maximum Power Point Tracking of Photovoltaic System using Fuzzy Controller. *International Symposium on Innovations in Intelligent Systems and Applications (INISTA), July*.

Kumar, H., & Tripathi, R. (2012). Simulation of variable incremental conductance method with direct control method using boost converter. *2012 Students Conference on Engineering and Systems, SCES 2012*.

Lee, H. (2010). The new maximum power point tracking algorithm using ANN-based solar PV systems. *TENCON 2010 - 2010 IEEE Region 10 Conference*(3), 2179-2184.

Li, Z., Zang, C., Zeng, P., Yu, H., & Li, H. (2015). Day-ahead Hourly Photovoltaic Generation Forecasting using Extreme Learning Machine. *The 5th Annual IEEE International Conference on Cyber Technology in Automation, Control and Intelligent Systems*, 779-783.

M. Quamruzzaman, K. M. (2014). A Modified Perturb and Observe Maximum Power Point Tracking Technique for Signal-Stage Grid-Connected Photovoltaic Inverter. *WSEAS TRANSACTIONS on POWER SYSTEMS, 9*, 111-118.

Maghami, M., Hizam, H., & Gomes, C. (2014). Impact of dust on solar energy generation based on actual performance. *Conference Proceeding - 2014 IEEE International Conference on Power and Energy, PECon 2014*, 388-393.

Maghami, M., Hizam, H., Gomes, C., Hajighorbani, S., & Rezaei, N. (2015). Evaluation of the 2013 southeast Asian haze on solar generation performance. *PLoS ONE, 10*(8), 1-19.

Mahmoud A. YOUNIS, T. K. (2012). An Improved Maximum Power Point Tracking Controller for PV Systems Using Artificial Neural Network . *PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), R. 88 NR 3b*, 116-121.

Md. Ismail Hossain, S. A. (2011). Design and Implementation of MPPT Controlled Grid Connected Photovoltaic System . *IEEE Symposium on Computer & Informatics, 11*, 284-289.

Mellit, a., & Kalogirou, S. (2006). Neuro-Fuzzy Based Modeling for Photovoltaic Power Supply System. *2006 IEEE International Power and Energy Conference*, 88-93.

Mellit, A., Arab, A., Khorissi, N., & Salhi, H. (2007). An ANFIS-based forecasting for solar radiation data from sunshine duration and ambient temperature. *2007 IEEE Power Engineering Society General Meeting, PES*.

Meyer, E., & Van Dyk, E. (2004). Assessing the reliability and degradation of photovoltaic module performance parameters. *IEEE Transactions on Reliability, 53*(1), 83-92.

Muriel Gevrey, I. D. (2003). Review and comparison of methods to study the contribution of variables in artificial neural network models. *Ecological Modelling, 160*, 249-264.

Nabulsi, A., Dhaouadi, R., & Rehman, H.-u. (2011). Single Input Fuzzy Controller (SFLC) Based Maximum Power Point Tracking. (2009), 0-4.

Nan-Ying Liang, G.-B. H. (2006). A Fast and Accurate Online Sequential Learning Algorithm for Feedforward Networks. *IEEE TRANSACTIONS ON NEURAL NETWORKS, 17*(6), 1411-1423.

NAOUFEL KHALDI, H. M. (2014). Modelling and Analysis of Neural Network and Incremental Conductance MPPT Algorithm for PV Array Using Boost Converter. *Advances in Environmental Technology and Biotechnology*, 148-153.

Nguyen, X. H. (2015). Mathematical modeling of photovoltaic cell/module/arrays with tags in Matlab/Simulink. *Environmental Systems Research, 4:24*, 1-13.

Phan, Q., Le, D., Hong, H., Le, M., & Vu, N. (2010). The new MPPT algorithm using ANN-based PV. *2010 International Forum on Strategic Technology, IFOST 2010*, 402-407.

Radwan, H., Abdelkarem, E., Ahmed, M., & Orabi, M. (2011). The non ideality effect of optimizing the P&O MPPT algorithm for PV battery charger applications. *INTELEC, International Telecommunications Energy Conference (Proceedings)*.

Ramaprabha, R., Mathur, B., & Sharanya, M. (2009). Solar array modeling and simulation of {MPPT} using neural network. *2009 {International} {Conference} on {Control}, {Automation}, {Communication} and {Energy} {Conservation} ({INCACEC})*(1), 5 pp. --.

Rifa'i, R. I. (2012). Maximum Power Point Tracking Control for Photovoltaic System Using Neural Fuzzy. *International Journal of Computer and Electrical Engineering, 4*(1), 75-81.

Rizzo, L. P. (2010). Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking. *IET Renewable Power Generation, 4*(4), 317-328.

Salam, K. I. (2014). Dynamic Efficiency of Direct Control Based Maximum Power Point Trackers. *Fifth International Conference on Intelligent Systems, Modelling and Simulation.*

Satapathy, P. (2015). A Hybrid Functional Link Extreme Learning Machine for Maximum Power Point Tracking of Partially Shaded Photovoltaic Array. *Power, Communication and Information Technology Conference*.

Satpathy, S. (2012). Photovoltaic power control using mppt and boost converter, Bachelor's thesis. (May), 36.

Seok-II Go, S.-J. A.-H.-W.-Y. (2011). Simulation and Analysis of Existing MPPT Control Methods in a PV Generation Systems. *Journal of International Council on Electrical Engineering, 1*(4), 446-451.

Sheraz, M., & Abido, M. (2012). An efficient MPPT controller using differential evolution and neural network. *Power and Energy (PECon), 2012 IEEE* ...(December), 2-5.

Subiyanto, Mohamed, A., & Hannan, M. (2009). Maximum power point tracking in grid connected PV system using a novel fuzzy logic controller. *2009 IEEE Student Conference on Research and Development (SCOReD)*(SCOReD), 349-352.

Sukumar, B. P. (2016). Research Survey on Various MPPT Performance ISSues to Improve the Solar PV System Efficiency. *Journal of Solar Energy*, 1-20.

Tuffaha, T., Babar, M., Khan, Y., & Malik, N. (2014). Comparative study of different hill climbing MPPT through simulation and experimental test bed. *Research Journal of Applied Sciences, Engineering and Technology, 7*(20), 4258-4263.

V.Rajasekaran, M. K. (2011). A novel MPPT scheme for solar powered boost inverter using evolutionary programming. *International Conference on Recent Advancements in Electrical, Electronic and Control Engineering, IConRAEeCE'11-Proceedings*, 346-351.

Villalva, M., Gazoli, J., & Filho, E. (2009). Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays. *IEEE Transactions on Power Electronics, 24*(5), 1198-1208.

Weiding Xiao, N. O. (2007). Topology Study of Photovoltaic Interface for Maximum Power Point Tracking. *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, 54*(3), 1696-1704.

Wu, X., Cheng, Z., & Wei, X. (2009). A study of maximum power point tracking in novel small-scale photovoltaic LED lighting systems. *2009 International Conference on Artificial Intelligence and Computational Intelligence, AICI 2009, 2*, 40-43.

Xu, J., Shen, A., Yang, C., Rao, W., & Yang, X. (2011). ANN based on IncCond algorithm for MPP tracker. *Proceedings - 2011 6th International Conference on Bio-Inspired Computing: Theories and Applications, BIC-TA 2011, 3*, 129-134.

Yamauchi, K. (2012). Incremental learning on a budget and its application to quick maximum power point tracking of photovoltaic systems.

Youngseok Jung. Junghun So, G. Y. (2005). IMPROVED PERTURBATION AND OBSERVATION METHOD (IP&O) OF MPPT CONRTOL FOR PHOTOVOLTAIC POWER SYSTEMS. *IEEE, 5*, 1788-1791.

Zhang, N., Behera, P., & Williams, C. (2013). Solar radiation prediction based on particle swarm optimization and evolutionary algorithm using recurrent neural networks. ... *Conference (SysCon), 2013 …*.

Zhao Yong, L. H. (2012). THE MPPT CONTROL METHOD BY USING BP NEURAL NETWORKS IN PV GENERATING SYSTEM. *International Conference on Industrial Control and Electronics Engineering, 12*, 1639-1642.