SOLAR PHOTOVOLTAIC (PV) MAXIMUM POWER POINT TRACKER (MPPT)USING VARIABLE STEP SIZE PERTURB AND OBSERVE (P&O) ALGORITHM

OMER JAMAL ELDIN IBRAHIM MOHAMMED

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2014

This project report is dedicated to my parents for their endless support and encouragement.

ACKNOWLEDGEMENT

First and foremost, I would like to express heartfelt gratitude to my supervisor **Assos**. **Prof. Dr. Awang Bin Jusoh** for his constant support during my study at UTM. He inspired me greatly to work in this project. His willingness to motivate me contributed tremendously to this project. I have learned a lot from him and I am fortunate to have him as my mentor and supervisor.

Besides, I would like to thank the authority of Universiti Teknologi Malaysia (UTM) for providing me with a good environment and facilities.

ABSTRACT

Photovoltaic PV solar known for the low energy convergence efficiency when compared to other types of energy sources. Since PV Solar have nonlinear characteristic, it gives its maximum output at the Maximum Power Point MPP. This point affected by sun irradiation, temperature and the degree of the sun irradiance. It economically essential to utilize the maximum output of PV solar. Hence, a proper Maximum Power Point Tracking (MPPT) can achieve this task under fast weather variation. In this project, modified Perturb and Observe (P&O) or more commonly known as variable step size P&O method was introduced and implemented throughout the project to overcome the common drawbacks of conventional P&O method as solar irradiation changes. The operation of the entire solar MPPT system was observed through theoretical approaches using MATLAB/Simulink simulation. The system was further explored with the inclusion of surrounding temperature. Double diode modeling circuit will be used for higher accuracy and efficiency.

ABSTRAK

Tenaga solar fotovoltan (PV) dikenali mempunyai kecekapan penukaran tenaga yang rendah berbanding dengan sumber tenaga yang lain. Fotovoltan solar mempunyai cirian tidak linar, di mana ia boleh membekalkan kuasa maksima, bilamana ia beroperasi pada satu titik kuasa maksima (MPP). Titik ini dipengaruhi oleh kadar sinaran matahari, suhu dan juga darjah terjahan matahari. Oleh sebab itu, kajian ini telah dilaksanakan bagi merekabentuk sebuah litar pengesan titik kuasa maksima terhadap sumber tenaga fotovoltan bagi keadaan sinaran matahari dan juga perubahan suhu yang tidak tetap. Kajian ini menggunakan kaedah ubahsuai P&O atau P&O langkah saiz boleh ubah bagi mengatasi kelemahan kaedah lazim P&O bila mana berlaku perubahan pada sinaran matahari dan perubahan suhu. Operasi keseluruhan dan prestasi rekabentuk sistem P&O telah dikaji menggunakan pendekatan teori serta simulasi MATLAB/Simulink. Sumber fotovoltan solar telah dimodelkan secara diod kembar bagi tujuan ketepatan dan kecekapan yang lebih baik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RE	Renewable Energy
PV	Photovoltaic
P&O	Perturb and Observe
MPPT	Maximum Power Point Tracking
MPPT	Maximum Power Point
STD	Standard Test Condition
A.M	Atmosphere
CdTe	Cadmium Telluride
LCD	Liquid Crystal Display
CIGS	Copper Indium Gallium Selenide
CdS	Cadmium Sulphide
GaAs	Gallium Arsenide
DC	Direct Current
AC	Alternative Current
D	Diode
OCV	Open Circuit Voltage
SCC	Short Circuit Current
InCond	Incremental Conductance
ANN	Artificial Neural Network
FLC	Fuzzy Logic Control
E	Error
CE	Change in Error
D	Duty
HC	Hill Climbing

CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to the significant rise of electrical energy demand and the high rise of fossil fuels and their environmental effects, such as global warming, greenhouse gases and acidic rain, renewable energies (RE) are becoming more popular than they were many decades ago. Renewable energies are sustainable, environment friendly and inexpensive compared to fossil fuel. However, they have higher initial cost [1-3].

Among the various forms of renewable energy, the importance of solar energy is growing day by day because of the great advance in Photovoltaic (PV) cell technologies, making it economically feasible [1,3].

The Photovoltaic (PV) cell is a way of converting sun radiation into electricity. The amount of converted energy depends on several factors, such as solar irradiation on PV cell surface, angle of solar radiation, PV cell temperature, solar cell efficiency, dust and humidity [6, 9, 12].

The advantages of solar PV cells can be listed as below:

1- Ease of use where can generate electricity once they installed and connected.
2- Can be mounted on a roof of existing structure or be integrated into a building.
3- Silent and emissions free.
4- Energy can be stored in batteries to be used later.
5- Generated energy can be fed into a grid after some electrical process.

In spite of its advantages, PV cells suffer from

1- The high initial cost.
2- The low efficiency.
3- The requirement of larger surface per kW than the conventional source of energy.

It is vital for PV system to produce maximum output power at any time. However, PV systems are significantly influenced by weather variations such as solar radiation, temperature, shading, etc. Therefore, achieving the operation at maximum power point under weather changing with rapid response is economically essential.

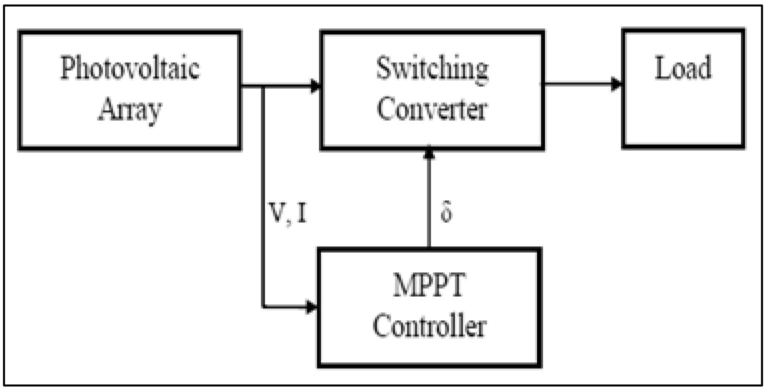

Figure 1.1: Solar MPPT System

1.2 Objective

In this project, modified Perturb and Observe (P&O) or more commonly known as variable step size P&O method was introduced and implemented throughout the project to overcome the common drawbacks of conventional P&O method as solar irradiation changes, as well as temperature changes.

1.3 Scope of the Work

The operation of the entire solar MPPT system will be observed through theoretical approaches using MATLAB/Simulink simulation.

The system will be further explored with the inclusion of surrounding temperature. Double diode modeling circuit will be used for higher accuracy and efficiency.

1.4 The Importance of the Research

The conventional Perturb and Observe (P&O) method has two main disadvantages. Firstly, in this algorithm the amplitude of the perturbations applied to the system is the main factor determining the amplitude of oscillations as well as the convergence rate of the output power to the Maximum Power Point (MPP). The larger the perturbations the faster the algorithm will find the MPP. However, a larger perturbation will lead to a higher value of oscillation amplitude. If the applied perturbations are too small, on the other hand, the oscillations around the MPP will be reduced, but the rate of convergence will decrease as well. In other words, in this algorithm there is a trade-off between the rate of response and the amount of oscillations under steady state conditions. To overcome this disadvantage, use of a variable perturbation size that gets smaller as MPP is approached was proposed. In this approach large perturbations are applied when the output power is far from the MPP, whereas smaller steps are adopted as the output power oscillates around the MPP.

REFERENCES

[1] Chihchiang Hua, Jongrong Lin, Chihming Shen. Implementation of a DSP-controlled photovoltaic system with peak power tracking, Industrial Electronics, IEEE Transactions (1998); Volume: 45 , Issue: 1, pp. 99- 107.

[2] Johari, A., Hafshar, S.S., Ramli, M., Hashim, H. Potential use of solar photovoltaic in Peninsular Malaysia, Clean Energy and Technology (CET), IEEE First Conference (2011) , pp. 110- 114.

[3] Chian-Song Chiu. T-S Fuzzy Maximum Power Point Tracking Control of Solar Power Generation Systems Energy Conversion, IEEE Transactions (2010), Volume:25, Issue: 4, pp. 112- 1132.

[4] B. Parida, S. Iniya, R. Goic. A review of solar photovoltaic technologies. Renewable and Sustainable Energy Reviews, 15 (2011), pp. 1625–1636.

[5] M.E Meral, F. Dincer. A review of the factors affecting operation and efficiency of photovoltaic based electricity generation systems. Renewable and Sustainable Energy Reviews, 15 (2011), pp. 2176–2184.

[6] Long Shi, Michael Yit Lin Chew. A review on sustainable design of renewable energy systems Review Article. Renewable and Sustainable Energy Reviews, Volume 16, Issue 1, January (2012), pp. 192-207.

[7] Y. Hamakawa. Recent advances in solar photovoltaic technology and its new role for environmental issue. Renewable Energy, 5 (1994), pp. 34–43.

[8] M. Ohnishi, A. Takeoka, S. Nakano, Y. Kuwano. Advanced photovoltaic technologies and residential application. Renewable Energy, (1995), pp. 275–282.

[9] K.E. Park, G.H. Kang, H.I. Kim, G.J. Yu, J.T. Kim. Analysis of thermal and electrical performance of semi-transparent photovoltaic (PV) module. Energy, 35 (2010), pp. 2681–2687.

[10] Bhubaneswari Parida, S. Iniyan, Ranko Goic. A review of solar photovoltaic technologies Review Article. Renewable and Sustainable Energy Reviews, Volume 15, Issue 3, April (2011), pp. 1625-1636.

[11] L. El Chaar, L.A. lamont, N. El Zein. Review of photovoltaic technologies Review Article. Renewable and Sustainable Energy Reviews, Volume 15, Issue 5, June (2011), pp. 2165-2175.

[12] S. Mekhilef, R. Saidur, M. Kamalisarvestani. Effect of dust, humidity and air velocity on efficiency of photovoltaic cells Review Article. Renewable and Sustainable Energy Reviews, Volume 16, Issue 5, June (2012), pp. 2920-2925.

[13] AmirHosein GhaffarianHoseini, Nur Dalilah Dahlan, Umberto Berardi, Ali GhaffarianHoseini, Nastaran Makaremi, Mahdiar GhaffarianHoseini, Sustainable energy performances of green buildings: A review of current theories, implementations and challenges Review Article Renewable and Sustainable Energy Reviews, Volume 25, September (2013), pp. 1-17

[14] Alon Kuperman, Moshe Averbukh, Simon Lineykin. Maximum power point matching versus maximum power point tracking for solar generators Review Article. Renewable and Sustainable Energy Reviews, Volume 19, March 2013, pp. 11-17.

[15] Anbarasi Jebaselvi, S. Paramasivam. Analysis on renewable energy systems Review Article Renewable and Sustainable Energy Reviews, Volume 28, December (2013), pp. 625-634.

[16] Ravinder Kumar Kharb, S.L. Shimi, S. Chatterji, Md. Fahim Ansari. Modeling of solar PV module and maximum power point tracking using ANFIS Review Article. Renewable and Sustainable Energy Reviews, Volume 33, May (2014), pp.602-612.

[17] MPPT techniques for photovoltaic applications Review Article, Mohamed A. Eltawil, Zhengming Zhao, Renewable and Sustainable Energy Reviews, Volume 25, September (2013), Pages 793-813.

[18] Classification and comparison of maximum power point tracking techniques for photovoltaic system: A review Review Article, Ali Reza Reisi, Mohammad Hassan Moradi, Shahriar Jamasb, Renewable and Sustainable Energy Reviews, Volume 19, March (2013), pp. 433-443.

[19] Maximum power point tracking control techniques: State-of-the-art in photovoltaic applications Review Article, Pallavee Bhatnagar, R.K. Nema, Renewable and Sustainable Energy Reviews, Volume 23, July (2013), pp.224-241.

[20] A maximum power point tracker for PV systems using a high performance boost converter, Jancarle L. Santos, Fernando Antunes, Anis Chehab, Cícero Cruz Solar Energy, Volume 80, Issue 7, July (2006), pp. 772-778.

[21] A high performance maximum power point tracker for PV systems Original Research Article, Ali Akbar Ghassami, Seyed Mohammad Sadeghzadeh, Asma Soleimani, International Journal of Electrical Power & Energy Systems, Volume 53, December (2013), pp. 237-243.

[22] two-steps algorithm improving the P&O steady state MPPT efficiency Original Research Article, Emilio Mamarelis, Giovanni Petrone, Giovanni Spagnuolo Applied Energy, Volume 113, January (2014),pp. 414-42.

[23] A maximum power point tracker for PV systems using a high performance boost converter, Jancarle L. Santos, Fernando Antunes, Anis Chehab, Cícero Cruz Solar Energy, Volume 80, Issue 7, July (2006), pp.772-778.

[24] A high performance maximum power point tracker for PV systems Original Research Article, Ali Akbar Ghassami, Seyed Mohammad Sadeghzadeh, Asma Soleimani, International Journal of Electrical Power & Energy Systems, Volume 53, December (2013), pp. 237-243.

[25] two-steps algorithm improving the P&O steady state MPPT efficiency Original Research Article, Emilio Mamarelis, Giovanni Petrone, Giovanni Spagnuolo Applied Energy, Volume 113, January (2014), pp. 414-42.

[26] An improved perturbation and observation maximum power point tracking algorithm for PV arrays Liu, X.; Lopes, L.A.C. Power Electronics Specialists Conference, (2004). PESC 04.

[27] Improved perturbation and observation method (IP&O) of MPPT control for photovoltaic power systems, Youngseok Jung; Junghun So; Gwonjong Yu; Choi, J., Photovoltaic Specialists Conference, (2005). Conference.

[28] A Method for MPPT Control While Searching for Parameters Corresponding to Weather Conditions for PV Generation Systems, Mutoh, N.; Ohno, M.; Inoue, T., Industrial Electronics, IEEE Transactions on, Volume: 53, Issue: 4.

[29] Predictive & Adaptive MPPT Perturb and Observe Method, Fermia, N.; Granozio, D.; Petrone, G.; Vitelli, M., Aerospace and Electronic Systems, IEEE Transactions on, Volume: 43, Issue: 3.

[30] An Improved Perturbation and Observation Maximum Power Point Tracking Algorithm for PV Arrays, Liu, X.; Lopes, L.A.C. Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual Volume: 3, Publication Year: (2004), 2005 - 2010 Vol.3.

[31]Improved perturbation and observation method (IP&O) of MPPT control for photovoltaic power systems, Youngseok Jung; Junghun So; Gwonjong Yu; Choi, J., Photovoltaic Specialists Conference, 2005. Conference Record of the Thirty-first IEEE, Publication Year: (2005), pp. 1788- 1791.

[32] Perturb and observe MPPT technique robustness improved,Femia, N. ; Petrone, G. ; Spagnuolo, G. ; Vitelli, M. Industrial Electronics, 2004 IEEE International Symposium on Volume:2, Publication Year: 2004 , pp. 845- 850 vol. 2.

[33] Increasing the efficiency of P&O MPPT by converter dynamic matching Femia, N. ; Petrone, G. ; Spagnuolo, G. ; Vitelli, M. Industrial Electronics, 2004 IEEE International Symposium, Publication Year: (2004), pp. 1017- 1021 vol. 2.

[34] A Method for MPPT Control While Searching for Parameters Corresponding to Weather Conditions for PV Generation Systems Mutoh, N. ; Ohno, M. ; Inoue, T.

Industrial Electronics, IEEE Transactions on Volume: 53, Issue: 4, Publication Year: (2006), pp. 1055- 1065.

[35] FPGA Implementation of MPPT Using Variable Step-Size P&O Algorithm for PV Applications Khaehintung, N.; Wiangtong, T.; Sirisuk, P. Communications and Information Technologies,. ISCIT '06. International Symposium on Publication Year: (2006), pp. 212- 215.

[36] Predictive & Adaptive MPPT Perturb and Observe Method Fermia, N.; Granozio, D.; Petrone, G.; Vitelli, M. Aerospace and Electronic Systems, IEEE Transactions on Volume: 43, Issue: 3, Publication Year: (2007), pp. 934- 950.

[37] A Technique for Improving P&O MPPT Performances of Double-Stage Grid-Connected Photovoltaic Systems Femia, N. ; Petrone, G. ; Spagnuolo, G. ; Vitelli, M. Industrial Electronics, IEEE Transactions on Volume: 56, Issue: 11, Publication Year: (2009), pp. 4473- 4482.

[38] Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking Piegari, L.; Rizzo, R. Renewable Power Generation, IET Volume: 4, Issue: 4, Publication Year: (2010), pp. 317- 328.

[39] Research on MPPT control of PV system based on PSO algorithm, Ze Cheng ; Hang Zhou ; Hongzhi Yang , Control and Decision Conference (CCDC), 2010 Chinese , Publication Year: (2010) , pp. 887- 892

[40] High-Performance Adaptive Perturb and Observe MPPT Technique for Photovoltaic-Based Microgrids Abdelsalam, A.K. ; Massoud, A.M. ; Ahmed, S. ; Enjeti, P. Power Electronics, IEEE Transactions on Volume:26 , Issue: 4 Publication Year: (2011) , pp. 1010- 1021.

[41] A genetic algorithm optimized ANN-based MPPT algorithm for a stand-alone PV system with induction motor drive, Ahmet Afşin Kulaksız, Ramazan Akkaya, Solar Energy, Volume 86, Issue 9, September (2012), pp. 2366-2375.

[42] Neural-network-based maximum power point tracking methods for photovoltaic systems operating under fast changing environments, K. Punitha, D. Devaraj, S. Sakthivel, Energy, Volume 62, 1 December (2013), pp. 330-340.

[43] Maximum power point tracking using fuzzy logic control, Mohamed M. Algazar, Hamdy AL-monier, Hamdy Abd EL-halim, Mohamed Ezzat El Kotb Salem, International Journal of Electrical Power & Energy Systems, Volume 39, Issue 1, July (2012), pp. 21-28.

[44] FPGA-based implementation of a fuzzy controller (MPPT) for photovoltaic module, A. Messai, A. Mellit, A. Massi Pavan, A. Guessoum, H. Mekki, Energy Conversion and Management, Volume 52, Issue 7, July (2011),pp. 2695-2704.

[45] Comparison of fuzzy logic and neural network in maximum power point tracker for PV systems, Chokri Ben Salah, Mohamed Ouali, Electric Power Systems Research, Volume 81, Issue 1, January (2011), Pages 43-50.

[46] Maximum power point tracking controller for PV systems using neural networks, A.B.G. Bahgat, N.H. Helwa, G.E. Ahmad, E.T. El Shenawy, Renewable Energy, Volume 30, Issue 8, July (2005), pp.1257-1268.

[47] Maximum power point tracking using P&O control optimized by a neural network approach: a good compromise between accuracy and complexity, Mohamed Aymen Sahnoun, Hector M. Romero Ugalde, Jean-Claude Carmona, Julien Gomand, Energy Procedia, Volume 42, (2013), pp. 650-659.

[48] A Neural Fuzzy Based Maximum Power Point Tracker for a Photovoltaic System, Otieno, C.A. ; Nyakoe, G.N. ; Wekesa, C.W. AFRICON, (2009). AFRICON '09.

[49] Maximum Power Point Tracking for Photovoltaic Systems Using, Fuzzy Logic and Artificial Neural Networks, Alabedin, A.M.Z. ; El-Saadany, E.F. ; Salama, M.M.A. Power and Energy Society General Meeting, (2011) IEEE.

[50] Neural Network Based Maximum Power Point Tracking of Photovoltaic Arrays, Islam, M.A.; Kabir, M.A. TENCON 2011 - 2011 IEEE Region 10 Conference, pp. 79- 82.

[51] ANN-based maximum power point tracking of photovoltaic system using fuzzy controller Kulaksiz, A.A. ; Aydogdu, O. , Innovations in Intelligent Systems and Applications (INISTA), 2012 International Symposium on , Publication Year: (2012), pp. 1- 5.

[52] Optimization of solar power by azimuthal angle and neural network control of a PV module Dubey, R.; Joshi, D., Power Electronics (IICPE), 2012 IEEE 5th India International Conference, Publication Year: (2012), pp. 1- 6.

[53] Maximum Power Point Tracking of Photovoltaic Generation Based on the Type 2 Fuzzy Logic Control Method, Amir Gheibi, S.M.A. Mohammadi, M. maghfoori, nergy Procedia, Volume 12, (2011), pp.538-546.

[54] Polar coordinated fuzzy controller based real-time maximum-power point control of photovoltaic system, Syafaruddin, Engin Karatepe, Takashi Hiyama, Renewable Energy, Volume 34, Issue 12, December (2009), pp. 2597-2606.