



**UNIVERSITI PUTRA MALAYSIA**

**FUZZY LOGIC-BASED HILL CLIMBING TECHNIQUE FOR  
PHOTOVOLTAIC MAXIMUM POWER POINT TRACKING CONVERTER**

**MOHAMMAD HOSSEIN TAGHVAEE**

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**By**

**MOHAMMAD HOSSEIN TAGHVAEE**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirement for the Degree of Master of Science**

**May 2013**

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

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**May 2013**

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Photovoltaic (PV) is a fast growing segment among renewable energy systems, whose development is owed to depleting fossil fuel and climate-changing environmental pollution. Its weaknesses, however, are its variable generation and non-linear characteristic due to its intermittent nature. These disadvantages contribute to issues of high per-kW installation cost and further low efficiency in PV generators.

An important consideration for achieving high efficiency in PV operation is to match the PV source and load impedance properly for any weather condition. The maximum extractable power from PV panels depends not only to the strength of the solar irradiation but also to the operating point of the energy conversion system. Maximum power point tracking (MPPT) is of paramount importance to the system as it not only maximizes system efficiency but also minimizes the return of investment in the PV installation. The hill climbing algorithm is the most common

method of MPPT due to its simplicity, ease of implementation, and good performance. However, it has issue of perturbation step size and trade off between faster response and steady-state oscillations.

Therefore, in this research work, the hill climbing search method has been modified based on fuzzy logic control for improvement of MPPT operation. This proposed MPPT algorithm is named as fuzzy logic based hill climbing. The proposed MPPT was implemented by fuzzifying the rules of hill climbing search method to reduce its drawbacks, and with this technique, not only the real maximum power point can be readily tracked, but also fast dynamic response and small steady state error can be achieved.

In this study, the characteristics of a PV module (Kyocera KD210GH) were mathematically modeled and simulated using MATLAB simulation tool. Then, the proposed MPPT algorithm and dc-dc boost converter were designed and developed in the same tool. Simulation results are presented to validate performance of the algorithm under different irradiation schemes, and to compare with the results obtained from conventional algorithm. Further experimental setup was carried out for comparative evaluation and the MPPT algorithm was implemented to performance verification of the algorithm by using digital signal processor (TMS320F28335).

The results obtained clearly confirm the proposed MPPT exhibits at least two times faster converging speed than the conventional MPPT in optimum configuration, and

the oscillations around maximum power point under steady state condition show improvement up to 75%.



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

**TEKNIK LOGIK KABUR BERASASKAN MENDAKI BUKIT BAGI  
PENUKAR PENGESANAN TITIK KUASA MAKSIMUM FOTOVOLTA**

Oleh

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Fotovolta merupakan satu segmen yang berkembang pesat di kalangan sistem tenaga boleh diperbaharui, yang mana pembangunannya terjadi akibat semakin berkurangan bahan api fosil dan perubahan iklim kesan pencemaran alam sekitar. Kelemahannya, bagaimanapun, penjanaannya yang berubah-ubah dan ciri-ciri tidak linear yang disebabkan sifatnya yang tidak konsisten. Kelemahan ini menyumbang kepada isu-isu seperti kos pemasangan setiap kW yang tinggi dan seterusnya kecekapan yang rendah dalam penjana fotovolta.

Satu pertimbangan yang penting bagi mencapai kecekapan yang tinggi dalam operasi fotovolta adalah untuk memadankan sumber fotovolta dan galangan beban yang betul dalam sebarang keadaan cuaca. Kuasa maksimum yang diekstrak daripada panel fotovolta bergantung bukan sahaja kepada kekuatan sinaran suria tetapi juga kepada titik operasi sistem penukaran tenaga. Pengesanan titik kuasa maksimum adalah amat penting untuk sistem kerana ia bukan sahaja memaksimumkan kecekapan sistem tetapi juga meminimumkan pulangan pelaburan dalam pemasangan fotovolta. Algoritma mendaki bukit adalah kaedah paling biasa

pengesanan titik kuasa maksimum kerana sifatnya yang ringkas, mudah dilaksanakan, dan prestasi yang baik. Walau bagaimanapun, ia mempunyai isu berkaitan saiz langkah pengusikan dan pengimbangan antara tindak balas yang lebih cepat dan ayunan keadaan mantap.

Oleh yang demikian, dalam kerja penyelidikan ini, kaedah carian mendaki bukit telah diubahsuai berdasarkan kawalan logik kabur untuk memperbaiki operasi pengesanan titik kuasa maksimum. Algoritma pengesanan titik kuasa maksimum yang dicadangkan dinamakan sebagai logik kabur berasaskan mendaki bukit. Pengesanan titik kuasa maksimum yang dicadangkan telah dilaksanakan dengan mengaburkan aturan kaedah carian mendaki bukit untuk mengurangkan kelemahannya, dan dengan teknik ini, bukan sahaja kuasa maksimum sebenar titik sedia dikesan, tetapi juga tindak balas dinamik yang pantas dan ralat kecil keadaan mantap boleh dicapai.

Dalam kaedah kerja ini, ciri-ciri modul fotovolta (Kyocera KD210GH) secara matematik dimodelkan dan disimulasi menggunakan perkakasan perisian MATLAB. Kemudian, algoritma pengesanan titik kuasa maksimum dan penukar dc-dc penggalak telah direka dan dibangunkan dalam perkakasan yang sama. Keputusan simulasi dibentangkan untuk mengesahkan prestasi algoritma dalam skim penyinaran berbeza, and membandingkannya dengan keputusan yang diperolehi daripada algoritma konvensional. Persediaan eksperimen berikutnya dilakukan bagi penilaian secara bandingan dan algoritma pengesanan titik kuasa maksimum dilaksanakan untuk mengesahkan prestasi algoritma dengan menggunakan pemproses isyarat digital (TMS320F28335).



Keputusan yang diperolehi secara jelas menunjukkan pengesanan titik kuasa maksimum yang dicadangkan mempamerkan kelajuan menumpu yang lebih cepat daripada pengesanan titik kuasa maksimum konvensional dalam konfigurasi optimum, dan ayunan di sekitar titik kuasa maksimum di bawah keadaan mantap menunjukkan peningkatan kepada 75%.



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I certify that an Examination Committee has met on **May,14<sup>th</sup>, 2013** to conduct the final examination of Mohammad Hossein Taghvaei on his thesis entitled “**FUZZY LOGIC BASED HILL CLIMBING TECHNIQUE FOR PHOTOVOLTAIC MAXIMUM POWER POINT TRACKING (MPPT) CONVERTER**” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the (Master of Science).

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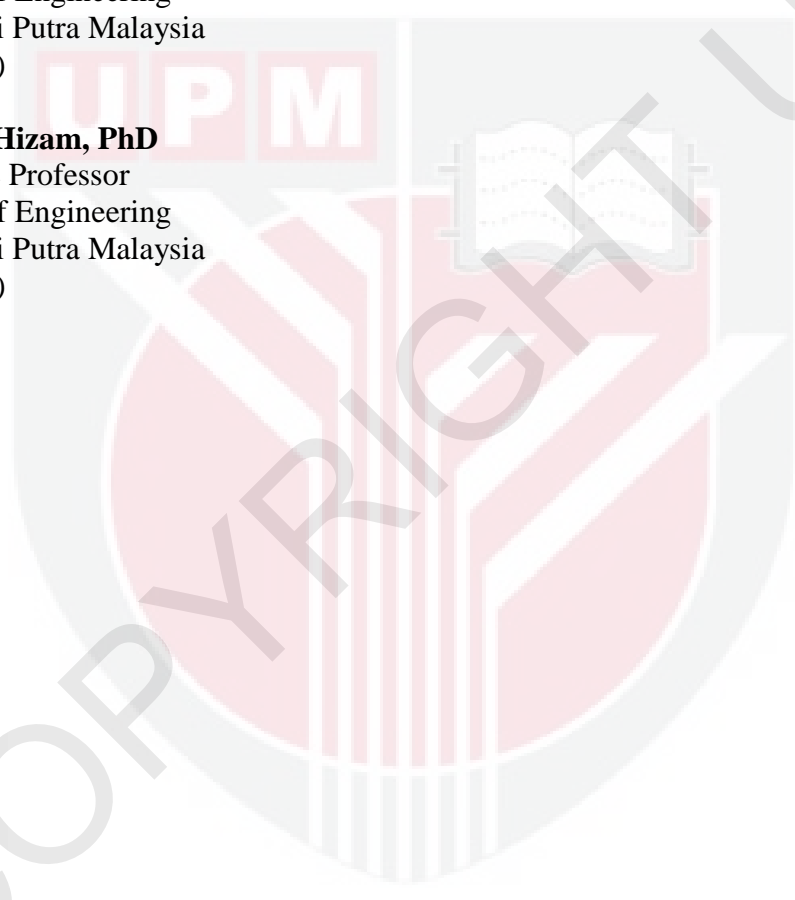
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## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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**MOHAMMAD HOSSEIN TAGHVAEE**

Date: 14 May 2013



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