Solar Future 2010

11-12 Şubat-February, 2010
İstanbul

BİLDİRİLER KİTABI
PROCEEDINGS BOOK

Sun as main energy, from vision to reality

Destekleyen Kurumlar / Supporting Organizations

Bu kitapta yayınlanan yazı ve grafiklerin her hakkı mahfuzdur. Sektörel Fuarcılık Ltd. Şti'nin yazılı izni alınmadan, kaynak gösterilerek de olsa iktibas edilemez. Bildirilerin bütün sorumluluğu yazarlarına aittir.

All rights reserved. No parts of this publication may be reproduces in any form or by any means,whether as a source without the consent of the Sektörel Fuarcılık Ltd. Şti. The responsibility of all presentations and ads belong to their authors and owners.

Sektörel Fuarcılık Ltd. Şti.
Balmumcu Bahar Sok. No: 2/13
Beşiktaş/İstanbul
Tel : (0212) 275 83 59
Faks : (0212) 211 38 50
web sitesi : www.sektorelfuarcilik.com

Baskı ve Cilt
Özgün Ofset
4. Levent
Tel: (0212) 280 00 09

ÖNSÖZ

Bilindiği üzere enerji, hayat kalitesini iyileştiren, ekonomik ve sosyal ilerlemeyi sağlayan en önemli faktördür. Ancak, artan enerji fiyatları, küresel ısınma ve iklim değişikliği, dünya enerji talebindeki artış, hızla tükenmekte olan fosil yakıtlara bağımlılığın yakın gelecekte devam edecek olması, yeni enerji teknolojileri alanındaki gelişmeler, ülkeleri yeni arayışlara götürmektedir. Dünya'nın enerji geleceği ile ilgili raporlara bakıldığında; 2000-2100 yılları arasında enerji ihtiyaçları ve kaynaklarındaki dağılımda, 2100 yılında petrolun iyice azalacağı, kömürün nerdeyse hiç kalmayacağı, güneş enerjisi kullanımının ise çok artacağı görülmektedir.

2009 yılında başlatılan, 2050 yılına kadar 554 Milyar USD bütçesi olan DESERTEC projesi ile birlikte, Türkiye'nin alternatif enerji kaynakları koridoru-hub'ı üzerinde olması önemini daha da arttırmıştır. Türkiye; ekonomik güneş enerjisi potansiyeli bakımından; Orta Doğu ve Kuzey Avrupa ülkeleri hariç, AB ülkeleri içerisinde İtalya ve Yunanistan'ı geçmekte ve Portekiz ile eşdeğer durumda değerlendirilmektedir. Dünya Enerji senaryolarında enerji talebi 2006-2030 yılları arasında her yıl %1,6 büyümekte ve sonuçta bu güne göre %45 artışa ulaşmaktadır. Bu talep enerji arzı yatırımlarını da 2030 da 26.3 Trilyon USD' a ulaştıracağını göstermektedir. Dünya elektrik enerjisi üretiminde güneş enerjisinin kullanımı 2007 yılına göre 80 kat artarak 5 TWh den 402 TWh a çıkmaktadır.

Güneş enerjisi uygulamalarının, Amerika Birleşik Devletleri, Japonya ve Almanya gibi gelişmiş ülkelerde hızla artmasının sebeplerinin başında destekleyici mekanizmalar gelmektedir. Bu mekanizmalar içerisinde sadece Feed-in Tariff bulunmamakta, vergi indirimleri, yatırım garantileri v.b ilave destekler de yer almaktadır. 2009 yılı itibariyle 73 ülke yenilenebilir enerji politika hedeflerini belirlemiş, 64 ülke yenilenebilir enerjiden elektirik üretimi konusunda politikalar üretmiş, 45 ülke ve 18 eyalet-bölge ise Feed-in Tariff denilen destekleme mekanizmaları oluşturmuştur.

Solar Future 2010 konferansı için ilgili sektörün önde gelen temsilcileri ile birlikte hazırladığımız Yol Haritası raporunda; 2020 yılı için elektrik üretiminde kurulu güç hedefi yoğunlaştırılmış güneş enerjisi güç sistemleri (CSP) teknolojisi ile 200 MWp ve fotovoltaik (PV) teknolojisi ile 4800 MWp olarak belirlenmiştir. 2020 yılında Yol Haritası'nda hedeflenen güneş enerjisi elektirik üretim santralleri için ayrılacak 13-20 Milyar USD lik yatırım ile, yaklaşık 200.000-500.000 kişiye direkt olarak üretim, satış, proje, kurulum,servis alanlarında istihdam olanağı sağlanmış olacaktır.

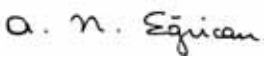
Güneş enerjisinin geleceğini tartıştığımız SOLAR FUTURE 2010 Konferansında dört ana konuşmacımız (Keynote Speaker) Dr. Frederick Morse, Prof. Dr. Yogi Goswami, Mr. Jerry Stokes ve Mr. David Johnston, panel ve oturumlarda yer alan diğer yerli ve yabancı davetli konuşmacılar, akademi ve sektörden araştırmacılar , uygulamacılar, bidirileri ile değerli katkılarda bulunmuşlardır. Her birine ayrı ayrı teşekkür ediyorum.

Kongre öncesi hazırlanan ve panel sırasında sunulan ve tartısılan ''Solar Future Road Map''önerisinin faydalı olacagının umuyorum.

Toplantının düzenlenmesi Yeditepe Üniversitesi bünyesinde yer alan International Centre for applied Thermodynamics (ICAT) tarafından Sektörel Fuarcılık ile işbirliği içinde gerçekleştirilmiştir. Yeditepe Üniversitesi Mütevelli Heyeti Başkanı Sn.Ülker Turgut'a, Rektör Prof.Dr.Ahmet Serpil'e, Sektörel Fuarcılık adına Sn.Süleyman Bulak'a ve emeği geçen herkese teşekkürü bir borç biliyorum. Şüphesiz, onların yardımları olmadan böyle bir toplantı gerçekleştirilemezdi.

SOLAR FUTURE 2010 Konferansında sunulan tüm calısmaların ülkemizde günes enerjisi strateji ve politikalarının olusturulmasında yararlı olmasını temenni ediyorum.

Saygılarımla,



Prof. Dr. Nilüfer EĞRİCAN
President, International Center For Applied Thermodynamics (ICAT)
Conference Chair, Solar Future 2010
11-12 Şubat 2010 - İstanbul

İÇİNDEKİLER / INDEX

KONFERANS PROGRAMI
CONFERENCE PROGRAM

11 Şubat / February, 2010

www.solarfutureconference.com

APOLLON SALONU

08:30 - 10:00 KAYIT

10:00 - 11:00 **AÇILIŞ KONUŞMALARI**

Prof. Dr. Nilüfer Eğrican - Organizasyon ve Danışma Kurulu Başkanı / ICAT Başkanı

Prof. Dr. Ahmet Serpil - Yeditepe Üniversitesi Rektörü

Doç. Dr. Hasan Ali Çelik - TBMM Sanayi Enerji Tabi Kay. ve Bilgi Teknolojileri Kom. Başk.

Mahmut Küçük - Bayındırlık ve İskan Bakanlığı Müsteşar Yrd.

Mustafa Demir - Bayındırlık ve İskan Bakanı

Prof. Dr. Veysel Eroğlu - Çevre ve Orman Bakanı

11:00 - 13:00 **ÖZEL OTURUM : Davetli Konuşmacılar**

OTURUM BAŞKANI : Prof. Dr. Sadık Kakaç

11:00 - 12:00 **KEYNOTE: Dr. Frederick Morse** Yoğunlaştırılmış Güneş Enerjisi Üretim Sistemleri

12:00 - 13:00 **KEYNOTE: Prof. Dr. Yogi Goswami** Güneş Enerjisi Teknolojilerinde Yenilikler ve Gelişmeler

13:00 - 14:00 Öğle Yemeği

14:00 - 15:30 **OTURUM 1 : Uygulamalar I**

OTURUM BAŞKANI : Doç. Dr. Mustafa Tınıs

Ahmet Lokurlu Parabolik Oluk Tipi Kollektör Sistemleri İle Soğutma

Olof Andersson Sığ Kotlardaki Jeotermal Uygulamalarda Güneşin Bir Kaynak Olarak Değerlendirilmesi

Pınar M. Mengüç Yakın-Alan Işınımlı Isı Transferi Kavramlarinin Termo/Fotovoltaik Güç Jeneratörleri Gelişimine Katkisi

İsmail Hakkı Karaca Verimi Artırılmış Fotovoltaik Paneller: Hibrid Panel (PV/T) Teknolojisi İle Elektrik ve Isı Enerjisi Üretimi

Birol Kılkış Isıtma, Soğutma ve Enerji Üretimi için Güneş Trijenerasyon Modülü

Sıddık İçli Yeni Gelişen PV Teknolojileri

15:30 - 16:00 SORU - CEVAP

16:00 - 16:30 Çay - Kahve Arası

16:30 - 18:30 **PANEL: "Güneş Enerjisi Sektörünün Mevcut Durumu, Potansiyeli, Gelecekteki Fırsatlar ve Beklentiler"**

Moderatör: Prof. Dr. Necdet Altuntop (Erciyes Üniversitesi)

Panelistler:

Rıza Durdu (İstek Solar Güneş Enerjisi Sistemleri A.Ş.) Güneş enerjisi sektörünün sorunları nelerdir,mevcut sıkıntılara sebeb olan engellerin örneklerle ortaya konulması

Hakan Çelik (Feniş-Fentek A.Ş.) Türkiye'de Güneş Enerjisinin Isıl Uygulamalarının Yaygınlaştırılmasına Yönelik Öneriler

Hakan Alaş (Ezinç A.Ş.) Sektörümüz ve Dünya'daki Yerimiz

Halil İbrahim Dağ (Solimpeks) Türkiye'de güneş enerjisi sektörünün gelişimindeki bir takım engeller ve bunların aşılmasında kullanılabilecek bazı metotlar

Sencer Erten (Vaillant Grup) Güneş Enerjisi Sektörünün Mevcut Durumu, Potansiyeli, Gelecekteki Fırsatlar ve Beklentiler

ZEUS (BC) SALONU

13:00 - 14:00 Öğle Yemeği

14:00 - 15:30 **OTURUM 2 : Elektrik Eldesi ve Elemanları**

OTURUM BAŞKANI : Dr. Baha Kuban

Cem Kaypmaz Pv Üretim Teknikleri - Temel Bileşenler

Deniz Selkan Polatkan Güneş Elektriği Sistemlerinde Türkiye İçin Öncelikler

Erkan Elcik Güneş İzleyen Sistemler ve Bileşenleri

Emir Aydar Yoğunlaştırmalı Güneş Enerjisi Teknolojileri

Ateş Uğurel 10 Adımda Güneş Santrali

Şölen Kınayyiğit Boya Esaslı Güneş Gözelerinde Rutenyum(II) Polipiridil Komplekslerinin Duyarlaştırıcı Olarak Kullanımı

ZEUS (A) SALONU

13:00 - 14:00 Öğle Yemeği

14:00 - 15:30 **OTURUM 3 : Uygulamalar II**

OTURUM BAŞKANI : Prof. Dr. A. Yalçın Göğüş

Zeynep Elvan Yıldırım Güneş Enerjisi Destekli Adsorpsiyonlu Isı Pompaları İçin Uygun Akışkan Çifti Seçimi

Nikolai Dobrott Türkiye'de Güneş Enerjisi

Pelin Karaçar Ercoşkun Güneş Enerjisi Teknolojileri İçin Benimseme Modeli

Hakan Öztop İçerisinde Faz Değiştiren Madde Bulunan Güneş Enerjili Su Isıtma Sisteminin Tasarımı ve Isıl Performansının İncelenmesi

Burcu Reisli Solar Hücreler ve Solar Tekstil Teknolojileri

Çelik Erengezgin Enerji Mimarlığı

APOLLON HALL

08:30 - 10:00 REGISTRATION

10:00 - 11:00 **OPENING CEREMONY AND OPENING SPEECHES**

Prof. Dr. Nilüfer Eğrican - President of Organisation and Consultation / President of ICAT

Prof. Dr. Ahmet Serpil - President Yeditepe University

Assoc. Prof. Hasan Ali Çelik - President of Turkish Grand National Assambly (TGNA) Industry, Commerce, Energy, Natural Resources, Information and Technology Commission

Mahmut Küçük - Undersecretary of Ministry of Public Works and Settlement

Mustafa Demir - Ministry of Public Works and Settlement

Prof. Dr. Veysel Eroğlu - Minister of Environment and Forestry

11:00 - 13:00 **KEYNOTE SPEECH : Keynote Speakers**

CHAIRMAN : Prof. Dr. Sadık Kakaç

11:00 - 12:00 **KEYNOTE: Dr. Frederick Morse** Concentrating Solar Power

12:00 - 13:00 **KEYNOTE: Prof. Dr. Yogi Goswami** New and Emerging Developments in Solar Energy

13:00 - 14:00 Lunch

14:00 - 15:30 **SESSION 1 : Implementation I**

SESSION CHAIRMAN : Doç. Dr. Mustafa Tıns

Ahmet Lokurlu Advanced Solar Cooling System Based on a Novel Technological Development - 'Solitem Parabolic Through Collector PTC'

Olof Andersson Solar As A Source For Shallow Geothermal Applications

Pınar M. Mengüç Effect Of Near - Field Radiative Transfer on Development of Thermophotovoltaic Power

İsmail Hakkı Karaca Enhanced Efficiency Photovoltaic Panels: Electricity & Heat Production By Hybrid Panel Technology (PV/T)

Birol Kılkış Solar Trigeneration Module For Heating Cooling And Power

Sıddık İçli New Developing PV Technologies

15:30 - 16:00 Question - Answer

16:00 - 16:30 Coffee Break

16:30 - 18:30 **PANEL: "Solar Energy Industry, Its Potential, Opportunities and Expectations For The Future"**

CHAIRMAN: Prof. Dr. Necdet Altuntop (Erciyes University)

Panelists:

Rıza Durdu (İstek Solar Güneş Enerjisi Sistemleri A.Ş.) What are the problems of the Thermal Solar Energy Sector in Turkey and the presentation of obstructions that caused to the problems axisted by axamples.

Hakan Çelik (Feniş-Fentek A.Ş.) Recommendations concerning to deployment of solar thermal applications in Turkey

Hakan Alaş (Ezinç A.Ş.) Turkish Solar Industry And It's Position In The World.

Halil İbrahim Dağ (Solimpeks) Numerous frustrations in the development of solar business in turkey and some methods to exceed such barriers

Sencer Erten (Vaillant Grup) Current potential of solar thermal energy sector, future opportunities and expectations

ZEUS (BC) HALL

13:00 - 14:00 Lunch

14:00 - 15:30 **SESSION 2 : Electricity Generation and Equipment**

SESSION CHAIRMAN : Dr. Baha Kuban

Cem Kaypmaz PV Production Techniques - Main Components

Deniz Selkan Polatkan Priorities For Turkey On Sun Electricity Systems

Erkan Elcik Sun Tracking Systems and Subcomponents

Emir Aydar Concentrated Solar Thermal Power Technologies

Ateş Uğurel Establishing Solar Plant In 10 Steps

Şölen Kınayyiğit Ruthenium(II) Polypyridyl Complexes As Sensitizers In Dye Sensitized Solar Cells

ZEUS (A) HALL

13:00 - 14:00 Lunch

14:00 - 15:30 **SESSION 3 : Implementation II**

SESSION CHAIRMAN : Prof. Dr. A. Yalçın Göğüş

Zeynep Elvan Yıldırım A Review On Proper Working Pairs For Solar Adsorption Heat Pumps

Nikolai Dobrott Solar Energy in Turkey

Pelin Karaçar Ercoşkun Adoption Model for Solar Technologies

Hakan Öztop Design and Thermal Performance of Solar Water Heating System Which Contains Phase Changing Material

Burcu Reisli Solar Cells and Solar Textiles Teknologies

Çelik Erengezgin Energy Architecture

APOLLON SALONU

08:30 - 09:00 Çay - Kahve Arası

09:00 -10:00 **OTURUM 4 : Toplayıcılar Ve Kontrol**
OTURUM BAŞKANI : Deniz Selkan Polatkan
Hakan Öztop PV Destekli Hibrid Bir Güneş Kollektörünün Isıl Performansının Araştırılması
Peter Omojaro Kanatlı ve Çelik Hasırlı, Absorberlı, Tek Geçişli, Güneş Enerjili Hava Isıtıcılarının Deneysel Performansı
Abdulmajeed Mohamad Parabolik Oluk Tipi Kollektörlerin Termal Performans Analizi
Ali Eltamaly Fotovoltaik Maksimum Güç Noktası İzleyicisi İçin Bulanık Mantık Kontrol Ünitesi Modellemesi

10:00 - 10:30 Çay - Kahve Arası

10:30 - 12:30 **ÖZEL OTURUM : Davetli Konuşmacılar**
OTURUM BAŞKANI : Prof. Dr. Abdulmajeed Mohamad

10:30 - 11:30 **KEYNOTE: David Johnston** Biyoklimatik Konutlarda Yaratıcı ve Yenilikçi Tasarım

11:30 - 12:30 **KEYNOTE: Jerry Stokes** Şebeke Paritesi İçin Belirlenen Rota ve Ulaşmada Temel Gereksinmeler

12:30 - 13:30 Öğle Yemeği

13:30 - 15:30 **PANEL : Fotovoltaik Teknolojilerinde Küresel Yol Haritaları ve Türkiye Fotovoltaik Sektöründe Oluşan Fırsatlar**
Moderatör : Prof. Dr.Şener Oktik (Muğla Üniversitesi Rektörü)
Panelist : Dr. Jinsoo Song (Kore Enerji Araştırmaları Enst.)

15:30 - 16:00 **SUNUM: SOLAR FUTURE TÜRKİYE YOL HARİTASI**
Levent Gülbahar -GENSED, ICAT - Yol Haritası Hazırlık Grubu Adına

16:00 - 16:30 Çay - Kahve Arası

16:30 - 18:15 **OTURUM 7 : Politikalar ve Stratejiler - Finans**
OTURUM BAŞKANI : Prof. Dr. Çiğdem Erçelebi
Berat Pehlivanoğlu Türkiye'de Overseas Private Investment Corporation (OPIC) Mevcudiyeti
Burak Ömer Saraçoğlu Güneş Enerjisi Elektrik Üretim Sistemlerinde Türkiye İçin Teknoloji Transfer Stratejisinin Geliştirilmesi
Süleyman Boşça Güneş Enerjisi için bir Politika Tasarımı
Recep Soyalp Enerji Sektörünün Stratejik Pazarlama Yöntemlerinin Eksiklikleri
Müjgan Çetin Güneş Enerjisi: Ekonomiye ve İstihdama Katkıları
Tuğrul Görgün Uluslar arası Ticaret Çerçevesinde Güneş Enerjisi Teknolojileri, Önemli Ülkeler ve Türkiye'nin Durumu

ZEUS (BC) SALONU

08:30 - 09:00 Çay - Kahve Arası

09:00 -10:00 **OTURUM 5 : Güneş Işınımı**
OTURUM BAŞKANI: Prof. Dr. Pınar Mengüç
Şaban Pusat Ölçülmüş Toplam Güneş Işınımı Ve Güneşlenme Süresi Verileri Üzerine Bir Çalışma: İstanbul İçin Örnek Bir Çalışma
Şaban Pusat Ölçülen Ve Hesaplanan Güneş Radyasyonu Verilerinin Karşılaştırılması: İstanbul İçin Örnek Bir Çalışma
Taner Yıldırım Güneş Enerjisi Potansiyeli Belirleme Ölçümleri
Bekir Yelmen Akdeniz Bölgesi İçin Yatay Düzleme Gelen Aylık Ortalama Tüm Güneş Işınımının Tespiti

ZEUS (A) SALONU

08:30 - 09:00 Çay - Kahve Arası

09:00 - 10:00 **OTURUM 6 : Sürdürülebilir Yapılar**
OTURUM BAŞKANI : Prof.Dr.Birol Kılkış
Erol İnelmen Bir Ev Isıtıcı Uygulama Ve Bakımı İle İlgili Tecrübelerin Paylaşımı
Emine Yetişkul Şenbil Güneş Panelleri Yaygınlaştırma Önerileri
Engin Erarslan Güneşkent Antalya'ya Doğru
Zümrüt Kaynak Planlamada ve Yapılaşmada Yenilenebilir Enerji Kullanımı ve Güneş Enerjisi: Mevcut Yasal Düzenlemeler, ilave Tedbirler

APOLLON HALL

08:30 - 09:00 Coffee Break

09:00 -10:00 **SESSION 4 : Collectors And Control**
SESSION CHAIRMAN : Deniz Selkan Polatkan
Hakan Öztop Thermal Performance Of PV Assisted Hybrid Solar Collector
Peter Omojaro Experimental Performance of Single Pass Solar Air Heater With Fins And Steel Wire Mesh As An Absorber
Abdulmajeed Mohamad Thermal Performance Analysis of Parabolic Trough Solar Collector
Ali Eltamaly Modelling Of Fuzzy Logic Controller For Photovoltaic Maximum Power Point Tracker

10:00 - 10:30 Coffee Break

10:30 - 12:30 **KEYNOTE SPEECH : Keynote Speakers**
CHAIRMAN : Prof. Dr. Abdulmajeed Mohamad

10:30 - 11:30 **KEYNOTE: David Johnston** Innovative Design for Bioclimatic Housing

11:30 - 12:30 **KEYNOTE: Jerry Stokes** Solar PV: The Route to Grid Parity and Key Requirements for the Journey

12:30 - 13:30 Lunch

13:30 - 15:30 **PANEL : Global Photovoltaic Road-maps and Opportunities for Turkish Industries in the PV Sector**
Moderatör : Prof. Dr.Şener Oktik (President Muğla University)
Panelist : Dr. Jinsoo Song (Korea Institute Of Energy Research)

15:30 - 16:00 **SUNUM: SOLAR FUTURE ROAD MAP FOR TURKEY**
Levent Gülbahar - GENSED(Solar Energy Industry Association of Turkey), On Behalf of ICAT - Roadmap Preparatory Group "

16:00 - 16:30 Coffee Break

16:30 - 18:15 **SESSION 7 : Policies and Strategies - Finance**
SESSION CHAIRMAN : Prof. Dr. Çiğdem Erçelebi
Berat Pehlivanoğlu Local Presence For OPIC in Turkey
Burak Ömer Saraçoğlu Developing Solar Power Generation Technology Transfer Strategy For Turkish Electricity Generation Market
Süleyman Boşça Political Design For Solar Energy
Recep Soyalp Lack Of Strategic Marketing Methods In Energy Sector
Müjgan Çetin Contribution of Solar Energy to Economy and Employment
Tuğrul Görgün Solar Energy Technologies, Leading Countries and Turkey's Position In Terms Of International Trade

ZEUS (BC) HALL

08:30 - 09:00 Coffee Break

09:00 -10:00 **SESSION 5 : Solar Radiation**
SESSION CHAIRMAN : Prof. Dr. Pınar Mengüç
Şaban Pusat A study on Global Solar Radiation and Sunshine Duration Measured Data: A case study for İstanbul
Şaban Pusat Comparison of Measured and Estimated Solar Radiation Data: A case study for İstanbul
Taner Yıldırım Measurements for Determining Solar Energy Potential
Bekir Yelmen Determining Average Monthly Total Solar Radiation Striking Onto Horizontal Plane For Mediterranean Region

16:00 - 16:30 Coffee Break

16:30 - 18:15 **SESSION 8 : Various Concepts and Implementation**
SESSION CHAIRMAN : Assoc. Prof. Hussain Noor al-Madani
İlker Ongun Studies of National Photovoltaic Technology Platform (NPTP) on Education, Standard and Determining Photovoltaic Roadmap for Turkey
Nilüfer İlhan Hydepark A Standalone Renewable Hydrojen Demonstration Park in Turkey
Pınar Mengüç Radiative Transfer and Global Climate Change
Özge Yalçıner Ercoşkun Transitioning to an Ecological and Technological Campus
Menderes Üstüner Using Renewable Energy Resources In Agriculture
Güven Çankaya Optical Constants of Optical Titanium Oxide Thin Films Derived from Sol - Gel Process

ZEUS (A) HALL

08:30 - 09:00 Coffee Break

09:00 -10:00 **SESSION 6 : Sustainable Buildings**
SESSION CHAIRMAN : Prof.Dr.Birol Kılkış
Erol İnelmen Sharing experiences gained while installing and operating a "Home Solar Heater"
Emine Yetişkul Şenbil Solar Panel Project Proposals
Engin Erarslan Vision of Güneşkent Antalya
Zümrüt Kaynak Usage of Renewable Energy and Solar Energy in Planning and Constructing:Existing Legal arrangements, Additional Actions

16:00 - 16:30 Coffee Break

16:30 - 18:15 **SESSION 9 : Storage**
SESSION CHAIRMAN : Prof. Dr. Halime Paksoy
Halime Paksoy Thermal Energy Storage Technologies for Solar Applications
Yusuf Tekin A numerical investigation of the obstacle geometry effect on thermal stratification in hot water storage tanks
Muhsin Mazman Electrical Energy Storage Techniques for Solar Energy
Şevki Dükkancılar Electricity Storage and Wellknown Conceptions
Sevinç Mantar Theoretical Investigation Storing of Solar Light In A Solar Pond
Bünyamin Yağcıtekin Solar Cars In Sustainable Transportation

MODELING OF FUZZY LOGIC CONTROLLER FOR PHOTOVOLTAIC MAXIMUM POWER POINT TRACKER

Ali. M. ELTAMALY
Electrical Engineering Dept., King Saud University,
Riyadh, Saudi Arabia

Abstract—In this paper a fuzzy logic controller for maximum power point tracker of photovoltaic energy system is introduced. This controller uses boost converter to control the terminal voltage of PV system to work at the maximum power point. The load side is consists of battery and control switches to control the power flow from the PV system to the battery and the load. The system is modeled using Matlab/Simulink program. The output power from PV system in case of using fuzzy controller is compared with the theoretical maximum power from the same system and the power output in case of using best constant output voltage. The fuzzy controller shows stable operation for different data introduced to the system. It also restrains any overshooting in input or output systems and increases a considerable amount of the energy captured.

I. Introduction

The production of electric energy from PV has a lot of applications. PV is environmental friendly and has no emission of harmful gasses as the emission associated with conventional electricity generation.

The power generated from PV is variable with its terminal voltage for each value of radiation and temperature as shown in **Fig.1**. There is one Maximum Power Point, MPP associated with each radiation and temperature. Tracking this point to force the PV system to work around it will substantially increase the energy produced. That shows the importance of MPP Tracker, MPPT. MPPT needs fast and smart controller to counteract the fast change in weather data or load changes. MPPT consists of two basic components, dc-dc converter and its controller which is shown in **Fig.2.** Many techniques have been introduced to catch the MPP. A survey showing comparison of PV MPPT techniques is shown in [1,2].

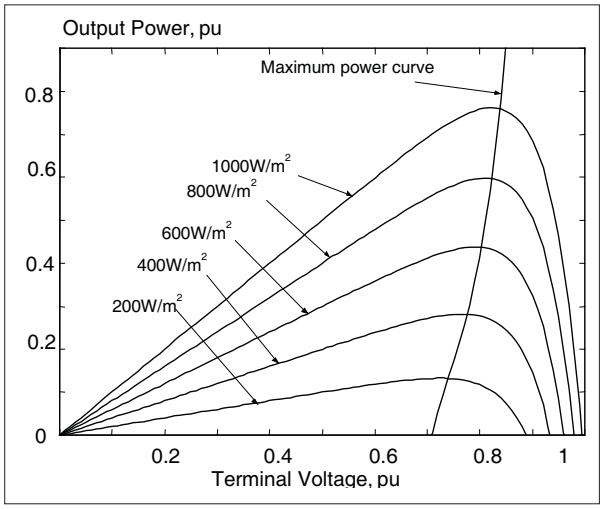


Fig 1. P-V characteristics of PV module.

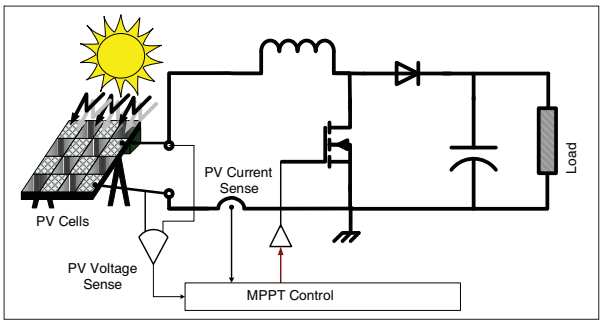


Fig 2. PV energy system with MPPT

In the direct coupled method [3,4], PV array is connected directly to the loads without power modifier. To match the MPPs of the solar array as closely as possible, it is important to choose the solar array characteristics according to the characteristics of the load. The direct-coupled method cannot automatically track the MPPs of the solar array when the insulation, temperature, or, load changed.

It is clear from the P-V curve of **Fig.1** that, the ratio of the array's maximum power voltage, V_{mp}, to its open-circuit voltage, V_{oc}, is approximately constant. So, PV array can be forced to work as a ratio of its open circuit voltage. The literature reports success with 73 to 80% from V_{oc} [5-8]. It is also observed that the relation between the short circuit current and the current associated with the maximum power is approximately constant. So it is possible to use a constant current MPPT algorithm that approximates the MPP current as a constant ratio of the short-circuit current [9,10]. The momentary interruption in the constant voltage or current can be avoided by using a pilot cell [11].

Another technique called perturb-and-observe (P&O), this process works by perturbing the system by incrementing the array operating voltage and observing its impact on the array output power. Due to constant step-width the system will face high oscillation especially under unstable environmental conditions. This technique suffers from wrong operation especially in case of multiple local maxima. A lot of modifications for this technique have been presented in literature [12-20].

The incremental conductance (IncCond) method [21-25] is based on comparing the instantaneous panel conductance with the incremental panel conductance. The input impedance of the dc-dc converter is matched with optimum impedance of PV panel. As noted in literatures, this method has a good performance under rapidly changing conditions. But this technique requires sophisticated control system. The parasitic capacitance algorithm [23] is similar to IncCond technique except that the effect of the solar cells' parasitic junction capacitance Cp, which models charge storage in the p–n junctions of the solar cells, is included.

Ripple correlation control (RCC) [26] makes use of ripple to perform MPPT. RCC correlates the time derivative of the time-varying PV power with the time derivative of the time-varying PV array current or voltage to drive the power gradient to zero, thus reaching the MPP. Simple and inexpensive analog circuits can be used to implement RCC. An example is given in [30]. RCC quickly tracks the MPP, even under varying irradiance levels. Another advantage of RCC is that it does not require any prior information about the PV array characteristics, making its adaptation to different PV systems straightforward.

The hill climbing technique [26-29] uses a perturbation in the duty ratio of the dc chopper and determine the change in power until the change of power reach its almost zero value which is the MPP. Hill climbing technique can be implemented by using PID controller or by fuzzy logic controller, FLC.

FLC has been introduced in many researches as in [31]–[36] to force the PV to work around MPP. FLCs have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity.

II. Model Of The Proposed System

In the proposed system, the simulation has been carried out using three different techniques for comparison. In the first technique, a Matlab file has been used to calculate the theoretical MPP. In the second technique a constant terminal voltage of the PV is adjusted. In the last technique, a fuzzy controller has been used as a MPPT. The simulation of the proposed system has been implemented using Matlab/Simulink program as shown in **Fig 3**. The simulation of the proposed system contains sub-models that explained in the following:

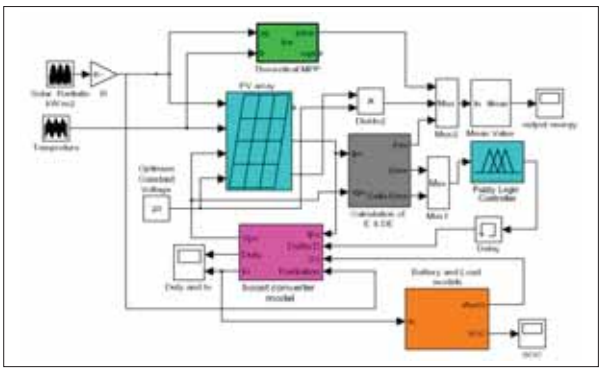


Fig 3. Simulink simulation model of the proposed system.

A. Photovoltaic Cell Model

The PV cell model is based on the single-diode representation of a silicon photovoltaic cell as illustrated in **Fig 4.** [37]. The governing equations, which describes the I-V characteristics of a crystalline silicon photovoltaic cell as described in [37] which solved conveniently using SIMULINK as shown in **Fig 5**.

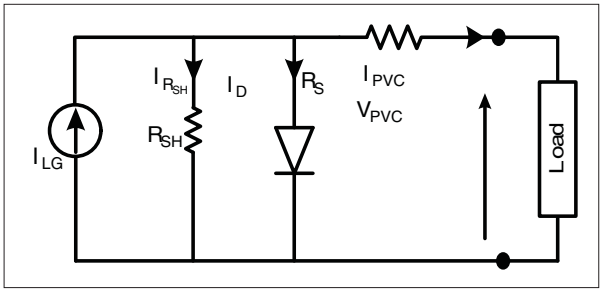


Fig 4. Equivalent circuit of photovoltaic cell.

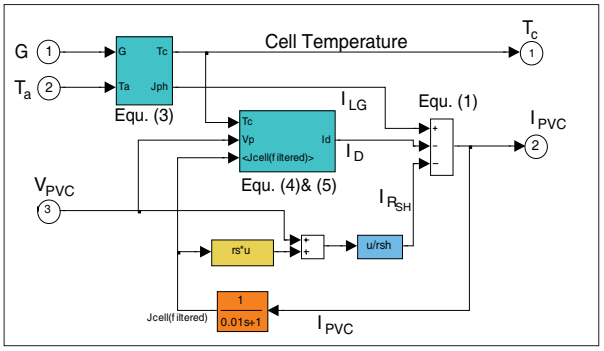


Fig 5. Simulink model of PV cell.

B. Battery and Load Model

The battery model is shown in many literatures and explained in details in [38]. The accuracy of this model data is very important in the whole system. The battery model has the following input parameters,

1. Initial state of charge (SOC_i), indicating available charge,
2. Highest and lowest state of charge, SOC_H , SOC_L (Wh).
3. Number of 2V cells in series.
4. Charge and discharge battery efficiency; K.
5. Battery self-discharge rate.

A control switches are necessary to control the charging and discharging the battery. These switches are necessary to keep the battery from being overcharged or undercharged which significantly reduce the battery's life. The control switches are shown in **Fig 6**.

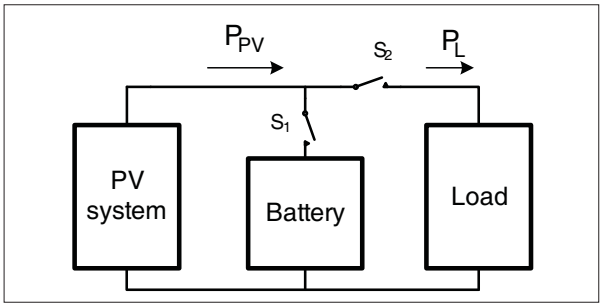


Fig 6. Block diagram of charging control.

The operating logic used in the control switches is shown in **Table (1)** Switch S_1 will stay ON unless SOC reaches its maximum value, SOC_H. Switch S_2 will stay ON unless SOC its minimum value, SOC_L.

Table 1. The operating logic used in the control switches.

Mode	S_1	S_2	SOC
1	OFF	ON	SOC= SOC_H
2	ON	OFF	SOC= SOC_L
3	ON	ON	SOCL < SOC< SOC_H

C. Boost converter Model

Boost converter model has been designed as shown in **Fig 7**. The inputs of this model are the change required in duty ratio, ΔD, Radiation, and PV current, I_{PV}. The outputs of this model are the PV output voltage, V_{PV}. duty ratio, D and output current. The value of ΔD is subtracted from D to get the new value of D depending on the following equation

$$D(k+1)=D(k)\ \Delta D(k) \quad (1)$$

The value of D is used to determine V_{PV} as shown in (2).

$$V_{PV}= V_o\ (1-D) \quad (2)$$

where, Vo is the boost converter output voltage

PV voltage, VPV obtained from (2) and IPV used to obtain Vo. The output current that feeds the battery and load can be obtained from dividing the output power on V_o.

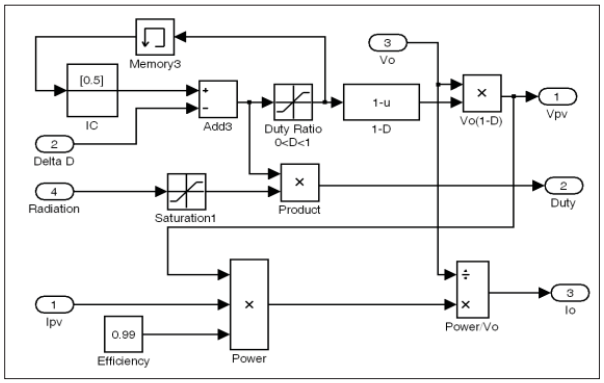


Fig 7. Simulink model of the boost converter used in the simulation.

D. Model of calculating Error and its variation, E and ΔE

The Simulink model of calculating E and ΔE is shown in **Fig 8**. The input values of this module are I_{PV} and V_{PV}. These values are used to calculate the power from PV array. Then the error signal can be calculated depending on (3). The value of ΔE is calculated as shown in (4).

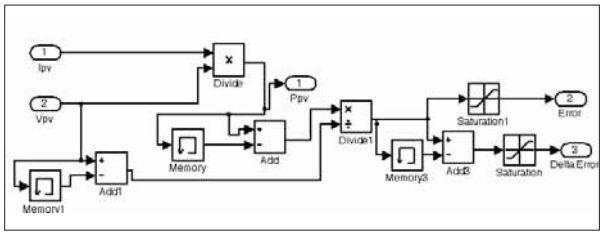


Fig 8. Simulink model of calculating E and ΔE.

$$E(n)=\frac{P(n)-p(n-1)}{V(n)-V(n-1)} \quad (3)$$

$$\Delta E(n)=E(n)-E(n-1) \quad (4)$$

E. Fuzzy Logic Controller Model

The FIS editor is an effective Graphical User Interface (GUI) tool provided with the fuzzy logic toolbox in Matlab to simplify the design of the FLC which are used in this system. The output power from the PV system and the voltage are used to determine the E and ΔE based on (3) and (4). Predicting the range of E and ΔE depends on the experience of the system designer. These variables are expressed in terms of linguistic variables or labels such as PB (Positive Big), PM (Positive Medium), PS (Positive Small), ZE (Zero), NS (Negative Small), NM (Negative Medium),NB (Negative Big) using basic fuzzy subset. Each of these acronyms is described by a given mathematical membership functions, MF as shown in **Fig 9**. MF is sometimes made less symmetric to give more importance to specific fuzzy levels as in [35] or it can be symmetric as shown in [39] and used here in this paper. The inputs to a FLC are usually E and ΔE. Once E and ΔE calculated and converted to the linguistic variables based on MF, the FLC output, which is typically a change in duty ratio, ΔD of the power converter, can be looked up in a rule base **Table 2**. FLC membership functions for both inputs and output variables can be used as triangle-shaped function which is easiest way to be implemented on the digital control system. The linguistic variables assigned to ΔD for the different combinations of E and ΔE are based on the power converter being used and also on the knowledge of the user.

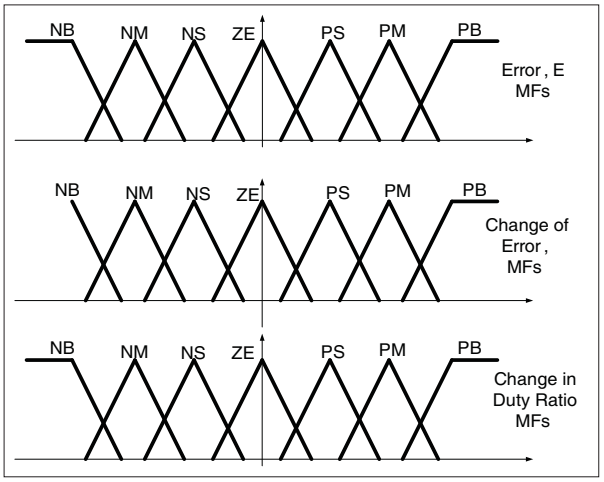


Fig.9 A fuzzy system with two inputs, 1 output and 7 MFs each.

Table (2) Rules for a fuzzy system with 2-inputs and 1 output with 7-membership functions.

E \ ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

These linguistic variables of input and output MFs are then compared to a set of pre-designed values during aggregation stage. The accurate choose the relation between input and output function determine the appropriate response of the FLC system. The relation between them depends on the experience of the system designer. These relations can be tabulated as shown in **Table 2** [40,41]. Some researches proportionate these variables to only five fuzzy subset functions as in [33]. **Table 2** can be translated into 49 fuzzy rules IF-THEN rules to describe the knowledge of control as follows;

R_{25}: *If E is NM and ΔE is PS then ΔD is NS*
R_{63}: *If E is PM and ΔE is NS then ΔD is PS*
.....
R_{31}: *If E is PS and ΔE is NB then ΔD is NM*

In the defuzzification stage, FLC output is converted from a linguistic variable to a numerical variable by using MF. This provides an analog signal which is ΔD of the boost converter. This value is subtracted from previous value of D to get its new value as shown in (1).

Defuzzification is for converting the fuzzy subset of control form inference back to values. As the plant usually required a nonfuzzy value of control, a defuzzification stage is needed. Defuzzificaion for this system is the height method. The height method is both very simple and very fast method. The height defuzzification method in a system of rules by formally given by (5):

$$\Delta D = \left(\sum_{k=1}^{m} c(k) * W_k \right) / \sum_{k=1}^{n} W_K \qquad (5)$$

where ΔD = change of control output
c(k) = peak value of each output
W_k = height of rule k.

The relation between the inputs and the output of the fuzzy controller can be represented as a 3-D drawing which called surface function, is shown in **Fig 10**. It is clear that the surface function is approximately smooth which enhance the stability of the fuzzy system.

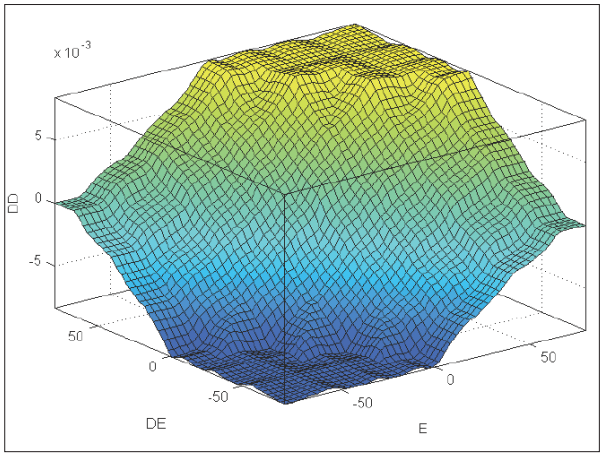


Fig 10. Surface function of the proposed FLC

III. Simulation Results

The radiation and temperature data which used in simulation are from realistic hourly data of the Riyadh city of Saudi Arabia. These data is concentrated in narrow range of time (4sec.) which approves the *rob*ustness of the FLC. 500 Watts PV array is used in simulation. The simulation is carried out with FLC and constant voltage technique for the purpose of comparisons.

These two MPPT techniques have been compared with theoretical MPP from PV module which can be calculated using a Matlab file. The load is connected with a PV array through a battery. **Fig 11** shows in the first trace the solar radiation used in the simulation. In the second trace of **Fig 11**, the output power for FLC and constant voltage MPPT technique compared with the theoretical value of MPPT. It is clear from second trace that, the power output with FLC is following the theoretical MPP exactly but the output power with constant voltage control is considerably lower than that associated with FLC. Moreover FLC can restrain any overshooting in the input or output variables. Third trace of **Fig 11** shows the value of ΔD which is the output from FLC. This value can be used to modulate the value of the duty ratio. Fourth trace of **Fig 11**, shows the duty ratio of the boost converter. Fifth and sixth trace of **Fig 11**, show the error function, E and the change of error, ΔE.

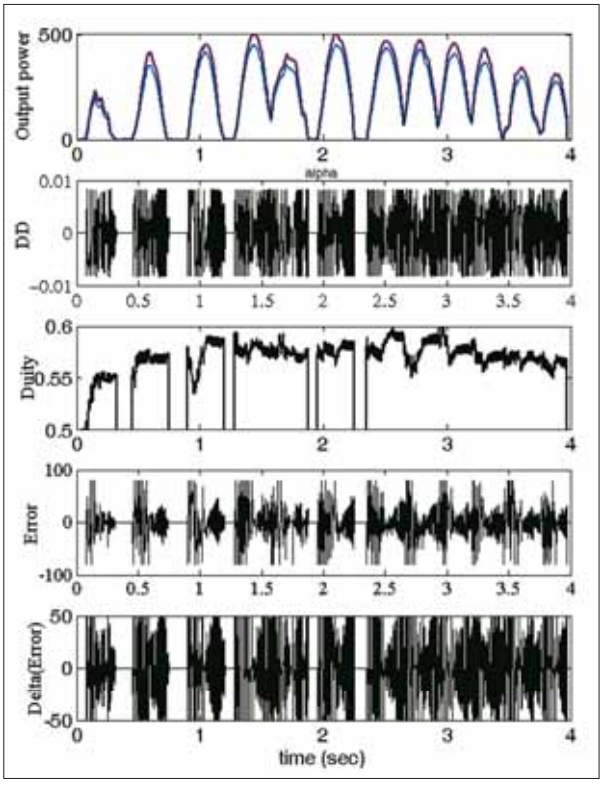


Fig.11 Simulation results of the propose FLC system.

Output power from PV system using FLC and constant voltage along with the theoretical MPPT are shown in **Fig 12** for the purpose of comparison. It is clear from **Fig 12** that the output power associated with FLC system follows exactly the theoretical MPPPT which proves the superiority of the system.

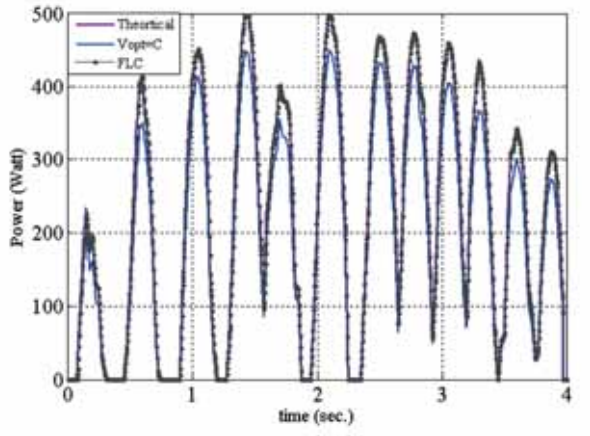


Fig.12 The output power from PV system using FLC and constant voltage along with the theoretical MPPT.

References

[1] T. Esram, and P. L. Chapman " Comparison of Photovoltaic Array Maximum PowerPoint Tracking Techniques" IEEE Trans. on EC, Vol. 22, # 2, June 2007, pp. 439-449.

[2] V. Salas, E. Olías, A. Barrado, A. Lázaro" Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems" Solar Energy Materials and Solar Cells, Volume 90, Issue 11, 6 July 2006, PP. 1555-1578.

[3] A. Balouktsis, T. D. Karapantsios, K. Anastasiou, A. Antoniadis, and I. Balouktsis "Load Matching in a Direct-Coupled Photovoltaic System-Application to Thevenin's Equivalent Loads" International Journal of Photoenergy, Hindawi Publishing, Vol. 2006, # 27274, Pages 1–7.

[4] W. R. Anis, and H. M. B. Metwally, 1994, "Dynamic Performance of a Directly Coupled PV Pumping System," Solar Energy, Vol. 53, No. 4, pp. 369-377.

[5] M. A. S. Masoum, H. Dehbonei, and E. F. Fuchs, "Theoretical and experimental analyses of photovoltaic systems with voltage and current-based maximum power-point tracking," IEEE Trans. Energy Convers., vol. 17, no. 4, pp. 514–522, Dec. 2002.

[6] H.-J. Noh, D.-Y. Lee, and D.-S. Hyun, "An improved MPPT converter with current compensation method for small scaled PV-applications," inProc. 28th Annu. Conf. Ind. Electron. Soc., 2002, pp. 1113–1118.

[7] K. Kobayashi, H. Matsuo, and Y. Sekine, "A novel optimum operating point tracker of the solar cell power supply system," in Proc. 35th Annu.IEEE Power Electron. Spec. Conf., 2004, pp. 2147–2151.

[8] B. Bekker and H. J. Beukes, "Finding an optimal PV panel maximum power point tracking method" 7th AFRICON Conference in Africa, 2004, Vol., pp. 1125- 1129.

[9] N. Mutoh, T. Matuo, K. Okada, and M. Sakai, "Prediction-data-based maximum – power - point-tracking method for photovoltaic power generation systems," in Proc. 33rd Annu. IEEE Power Electron. Spec. Conf., 2002, pp. 1489–1494.

[10] S. Yuvarajan and S. Xu, "Photo-voltaic power converter with a simple maximum-power-point-tracker," in Proc. 2003 Int. Symp. Circuits Syst., 2003, pp. III-399–III-402.

[11] M. Veerachary, T. Senjyu, K. Uezato " Voltage-Based Maximum Power Point Tracking Control of PV System" IEEE Trans. On Aerospace and Electronic Systems Vol. 38, No. 1, pp.262-270, Jan. 2002.

[12] Fermia, N. Granozio, D. Petrone, G. Vitelli, M. "Predictive & Adaptive MPPT Perturb and Observe Method", IEEE Transactions on Aerospace and Electronic Systems, Vol.43, No.3, July 2007, PP. 934-950,

[13] M.-L. Chiang, C.-C. Hua, and J.-R. Lin, "Direct power control for distributed PV power system," in Proc. Power Convers. Conf., 2002, pp. 311– 315.

[14] W. Wu, N. Pongratananukul, W. Qiu, K. Rustom, T. Kasparis, and I. Batarseh,"DSP-based multiple peak power tracking for expandable power system," Applied Power Electronics Conference and Exposition, 2003.

[15] Y.-T. Hsiao and C.-H. Chen, "Maximum power tracking for photovoltaic power system," in Conf. Record 37th IAS Annu. Meeting Ind. Appl. Conf., 2002, pp. 1035–1040.

[16] Y. Jung, G. Yu, J. Choi, and J. Choi, "High-frequency DC link inverter for grid-connected photovoltaic system," in Conf. Record Twenty-Ninth IEEE Photovoltaic Spec. Conf., 2002, pp. 1410–1413.

[17] S. Jain andV.Agarwal, "A newalgorithm for rapid tracking of approximate maximum power point in photovoltaic systems," IEEE Power Electron. Lett., vol. 2, no. 1, pp. 16–19, Mar. 2004.

[18] T. Tafticht and K. Agbossou, "Development of a MPPT method for photovoltaic systems," in Canadian Conf. Elect. Comput. Eng., 2004, pp. 1123– 1126.

[19] N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point trackingmethod," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963–973, Jul. 2005.

[20] P. J. Wolfs and L. Tang, "A single cell maximum power point tracking converter without a current sensor for high performance vehicle solar arrays," in Proc. 36th Annu. IEEE Power Electron. Spec. Conf., 2005, pp. 165–171.

[21] K.Kobayashi, I. Takano, andY. Sawada, "A study on a two stage maximum power point tracking control of a photovoltaic system under partially shaded insolation conditions," in IEEE Power Eng. Soc. Gen.Meet., 2003, pp. 2612–2617.

[22] W. Wu, N. Pongratananukul, W. Qiu, K. Rustom, T. Kasparis, and I. Batarseh, "DSP-based multiple peak power tracking for expandable power system," in Eighteenth Annu. IEEE Appl. Power Electron. Conf. Expo., 2003, pp. 525–530.

[23] Jae Ho Lee , HyunSu Bae and Bo Hyung Cho" "Advanced Incremental Conductance MPPT Algorithm with a Variable Step Size", Power Electronics and Motion Control Conference, 2006. EPE-PEMC 2006. 12th International at Portoroz, Aug.2006, pp. 603-607

[24] J. Kouta, A. El-Ali, N. Moubayed and R. Outbib "Improving the incremental conductance control method of a solar energy conversion system"

[25] Ali M. Eltamaly, H. H. El-Tamaly and P. Enjeti, "An Improved Maximum Power Point Tracker for Photovoltaic Energy Systems" 2nd Minia International Conference for Advanced

Trends in Engineering, (MICATE'2002) Elminia, Egypt,16-18, March 2002.

[26] Kimball, J.W. Krein, P.T. "Digital Ripple Correlation Control for Photovoltaic Applications", Power Electronics Specialists Conference, 2007. PESC 2007. IEEE, June 2007, Orlando, FL, pp. 1690-1694.

[27] M.Veerachary, T. Senjyu, andK.Uezato, "Maximum power point tracking control of IDB converter supplied PV system," in IEE Proc. Elect. Power Applicat., 2001, pp. 494–502.

[28] W. Xiao and W. G. Dunford, "A modified adaptive hill climbing MPPT method for photovoltaic power systems," in Proc. 35th Annu. IEEE Power Electron. Spec. Conf., 2004, pp. 1957–1963.

[29] Fangrui Liu Yong Kang Yu Zhang Shanxu Duan "Comparison of P&O and hill climbing MPPT methods for grid-connected PV converter", 3rd IEEE Conference on Industrial Electronics and Applications, 2008, Singapore, ICIEA 2008, pp. 804-807

[30] S. Lalounia, D. Rekiouaa,*, T. Rekiouaa, E. Matagneb " Fuzzy logic control of stand-alone photovoltaic system with battery storage" Journal of Power Sources, Vol. 193 (2009), pp. 899–907.

[31] N. Ammasai Gounden, Sabitha Ann Peter, Himaja Nallandula, S. Krithiga " Fuzzy logic controller with MPPT using line-commutated inverter for three-phase grid-connected photovoltaic systems", Renewable Energy Journal, Vol. 34, 2009, pp. 909–915.

[32] Chokri Ben Salah, Maher Chaabenea, Mohsen Ben Ammara "Multi-criteria fuzzy algorithm for energy management of a domestic photovoltaic panel", Renewable Energy, Vol. 33, 2008, pp. 993–1001.

[33] I.H. Altasa, A.M. Sharaf" A novel maximum power fuzzy logic controller for photovoltaic solar energy systems" Renewable Energy, Vol. 33, 2008, pp.388–399.

[34] N. Khaehintung, K. Pramotung, B. Tuvirat, and P. Sirisuk, "RISCmicrocontroller built-in fuzzy logic controller of maximum power point tracking for solar-powered light-flasher applications," in Proc. 30th Annu. Conf. IEEE Ind. Electron. Soc., 2004, pp. 2673–2678.

[35] A.D. Karlis, T.L. Kottas, and Y.S. Boutalisb, " A novel maximum power point tracking method for PV systems using fuzzy cognitive networks (FCN)" Electric Power Systems Research, Vol., No. 3-4, March 2007, pp. 315-327.

[36] M. Veerachary, T. Senjyu, and K. Uezato, "Neural-network-based maximum-power-point tracking of coupled-inductor interleaved-boostconverter- supplied PV system using fuzzy controller," IEEE Trans. Ind. Electron., vol. 50, no. 4, pp. 749–758, Aug. 2003.

[37] Tom Markvart and Luis Castafier "Solar Cells: Materials, Manufacture and Operation", book, Elsevier publishing co., ISBN-13:978-1-85617-457-1, 2005.

[38] Luis Castan¨er and Santiago Silvestre "Modelling Photovoltaic Systems using PSpice", book, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, UK, ISBN 0-470-845279, 2002.

[39] C. Larbes, S.M. Aı¨t Cheikh*, T. Obeidi, A. Zerguerras" Genetic algorithms optimized fuzzy logic control for the maximum power point tracking in photovoltaic system" Renewable Energy, Vol.34, 2009, pp. 2093–2100.

[40] Manoj Datta, Tomonobu Senjyu, Atsushi Yona, Toshihisa Funabashi, and Chul-Hwan Kim "A Fuzzy Based Control Method for Isolated Power Utility Connected PV-diesel Hybrid System to Reduce Frequency Deviation" 2nd IEEE International Conference on Power and Energy (PECon 08), December 1-3, 2008, Johor Baharu, Malaysia

[41] Yiwang Wang, Fengwen Cao "Implementation of a Novel Fuzzy Controller for Grid-Connected Photovoltaic System", Power and Energy Engineering Conf., 2009. APPEEC 2009. Asia-Pacific, Wuhan, pp. 1-4.

IV. Summary

The generated power from the photovoltaic cell is changing with the operating voltage of the PV cell for each value of radiation and temperature. There is a maximum power point, MPP at certain voltage of the PV cells. Maximum power point tracker, MPPT is used to track this point. Simulation results reveals that, tracking the MPP by using the fuzzy logic control, FLC proves an exact tracking for the maximum power point even in highly changing weather conditions. Also, FLC has a very fast and accurate response for any fast change in the weather or load variations. FLC system restrains any overshooting in input or output systems and increases a considerable amount of the energy captured.