Design of Grid Connected Photovoltaic System Employing Increamental Conductance MPPT Algotithm

Jitendra Kasera
Deptt. Of Electrical Engg.
CTAE, Udaipur (Raj.)
jitendrakasera@yahoo.com

Vinod Kumar
Deptt. Of Electrical Engg.
CTAE, Udaipur (Raj.)
vinod.cte@yahoo.com

Dr. R.R. Joshi
Deptt. Of Electrical Engg.
CTAE, Udaipur (Raj.)
rrjoshi_iitd@yahoo.com

Jai Kumar Maherchandani
Deptt. Of Electrical Engg.
BIT, Mesra,Ranchi (Raj.)
jkm2000@rediffmail.com

***Abstract* – This paper is mainly to develop a grid-connected photovoltaic simulation system with Incremental conductance maximum power point tracking (MPPT) function using MATLAB. By this simulation we predict the behaviors of the real photovoltaic system. A PV model is first developed and then combined with an MPPT algorithm and a DC-DC converter, in order to verify the correctness of MPPT controller. This system is followed by DC-AC inverter and the output is connected to the grid. The results are output voltage and current of PV model, output AC voltage, current and real power to the system.**

Keywords-PV Model, MPPT Algorithm, DC-Dc Converter, DC-AC Inverter, System Control.

I. INTRODUCTION

The decrease of conventional energy sources and the growing problem of environmental pollution, the research and utilization about the renewable energy, such as solar energy, wind energy as so on, have been concerned with more and more attention [1]-[2]. The Distributed generation headed by the photovoltaic (PV) generation can solve well the electrical power requirement in remote areas. In addition, the photovoltaic grid-connected system greatly eases the problem that the existing electricity supply system is often unable to meet peak demand, and then it has become an important supplement of the electricity supply in many countries. Regarding the endless aspect of solar energy, it is worth saying that solar energy is a unique prospective solution for energy crisis. However, despite all the afore mentioned advantages of solar power systems, they do not present desirable efficiency [3]-[4]. The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on. Changes in insolation on panels due to fast climatic changes such as cloudy weather and increase in ambient temperature can reduce the photovoltaic (PV) array output power. In other words, each PV cell produces energy pertaining to its operational and environmental conditions [5]-[6]. The poor efficiency of solar cell causes us to employ the MPPT algorithm to improve the efficiency of solar cell.

II. MPPT ALGORITHM

There are a large number of algorithms that are able to track MPPs. An improved method for INC on the basis of variable step is presented [7].Some of them are simple, such as those based on voltage and current feedback, and some are more complicated, such as perturbation and observation (P&O) or the incremental conductance (IncCond) method. They also vary in complexity, sensor requirement, speed of convergence, cost, range of operation, popularity, ability to detect multiple local maxima, and their applications [8]–[10].

Having a curious look at the recommended methods, hill climbing and P&O [11]–[16] are the algorithms that were in the center of consideration because of their simplicity and ease of implementation. Hill climbing [14], [17] is perturbation in the duty ratio of the power converter, and the P&O method [15], [18] is perturbation in the operating voltage of the PV array. However, the P&O algorithm cannot compare the array terminal voltage with the actual MPP voltage, since the change in power is only considered to be a result of the array terminal voltage perturbation. As a result, they are not accurate enough because they perform steady-state oscillations, which consequently waste the energy [8]. By minimizing the perturbation step size, oscillation can be reduced, but a smaller perturbation size slows down the speed of tracking MPPs. Thus, there are some disadvantages with these methods, where they fail under rapidly changing atmospheric conditions [19].

On the other hand, some MPPTs are more rapid and accurate and, thus, more impressive, which need special design and familiarity with specific subjects such as fuzzy logic [20] or neural network [21] methods. MPPT fuzzy logic controllers have good performance under varying atmospheric conditions and exhibit better performance

than the P&O control method [8]; however, the main disadvantage of this method is that its effectiveness is highly dependent on the technical knowledge of the engineer in computing the error and coming up with the rule-based table. It is greatly dependent on how a designer arranges the system that requires skill and experience.

MPPT technique	Speed	Complexity	Reliability	Implementation
Fractional I_{sc}	Medium	Medium	Low	Digital/Analog
Fractional V_{oc}	Medium	Low	Low	Digital/Analog
IncCond	Varies	Medium	Medium	Digital
Hill climbing	Varies	Low	Medium	Digital/Analog
Fuzzy logic	Fast	High	Medium	Digital
Neural network	Fast	High	Medium	Digital

TABLE 1 COMPARISION OF VARIOUS MPPT ALGORITHMS

III INCREMENTAL CONDUCTANCE ALGORITHM

Incremental conductance (INC) method is a type of MPPT algorithm. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV). INC method provides rapid MPP tracking even in rapidly changing irradiation conditions with higher accuracy than the Perturb and observe method.

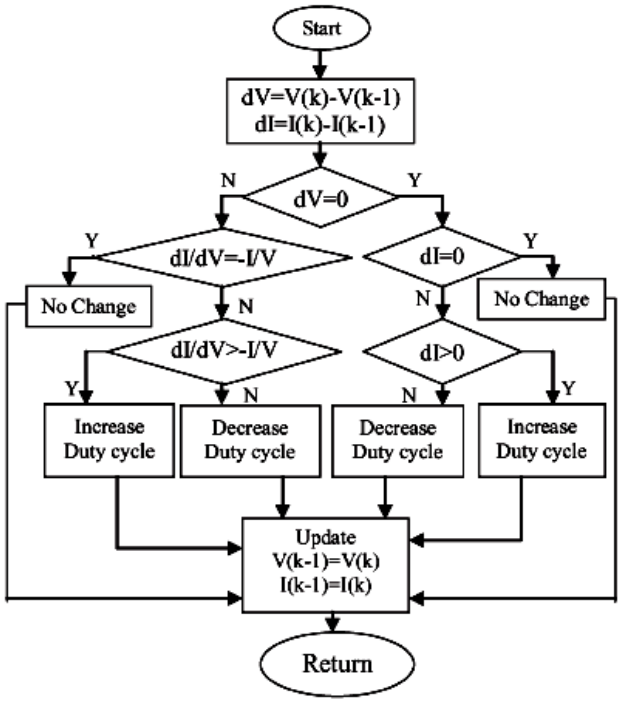

Fig.1 Flow Chart of Incremental Conductance Algorithm

IV GRID CONNECTED PHOTOVOLTAIC SYSTEM

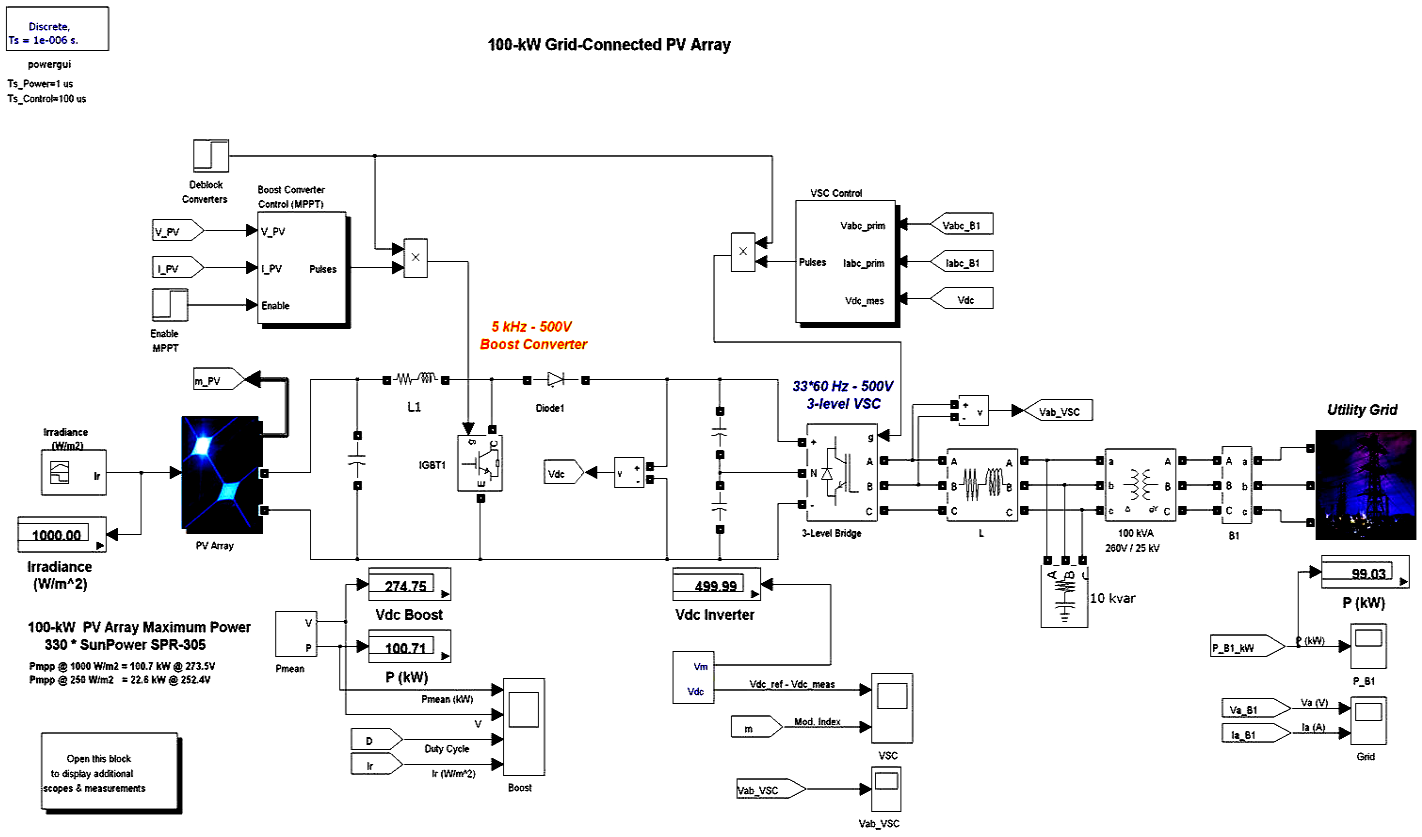

Fig.2 : Model of Grid connected PV system

The model contains:

- PV array delivering a maximum of 100 kW at 1000 W/m2 sun irradiance.
- 5-kHz boost converter (orange blocks) increasing voltage from PV natural voltage (272 V DC at maximum power) to 500 V DC. Switching duty cycle is optimized by the MPPT controller that uses the "Incremental Conductance + Integral Regulator" technique.
- 1980-Hz (33*60) 3-level 3-phase VSC (blue blocks). The VSC converts the 500 V DC to 260 V AC and keeps unity power factor.
- 10-kvar capacitor bank filtering harmonics produced by VSC.
- 100-kVA 260V/25kV three-phase coupling transformer.
- Utility grid model (25-kV distribution feeder + 120 kV equivalent transmission system).

VSC converter

The three-level VSC (blue blocks) regulates DC bus voltage at 500 V and keeps unity power factor.

The control system uses two control loops: an external control loop which regulates DC link voltage to +/- 250 V and an internal control loop which regulates Id and Iq grid currents (active and reactive current components).

Id current reference is the output of the DC voltage external controller. Iq current reference is set to zero in order to maintain unity power factor. Vd and Vq voltage outputs of the current controller are converted to three modulating signals Uref_abc used by the PWM three-level pulse generator.

The control system uses a sample time of 100 µs for voltage and current controllers as well as for the PLL synchronization unit. In the detailed model, pulse generators of Boost and VSC converters use a fast sample time of 1µs in order to get an appropriate resolution of PWM waveforms.

IV. SIMULATION RESULTS:

1. PV ARRAY:-

The PV array results show the output voltage and current as the output from the PV array. By the output we find that the value of voltage and current are varying with the change in value of irradiance.

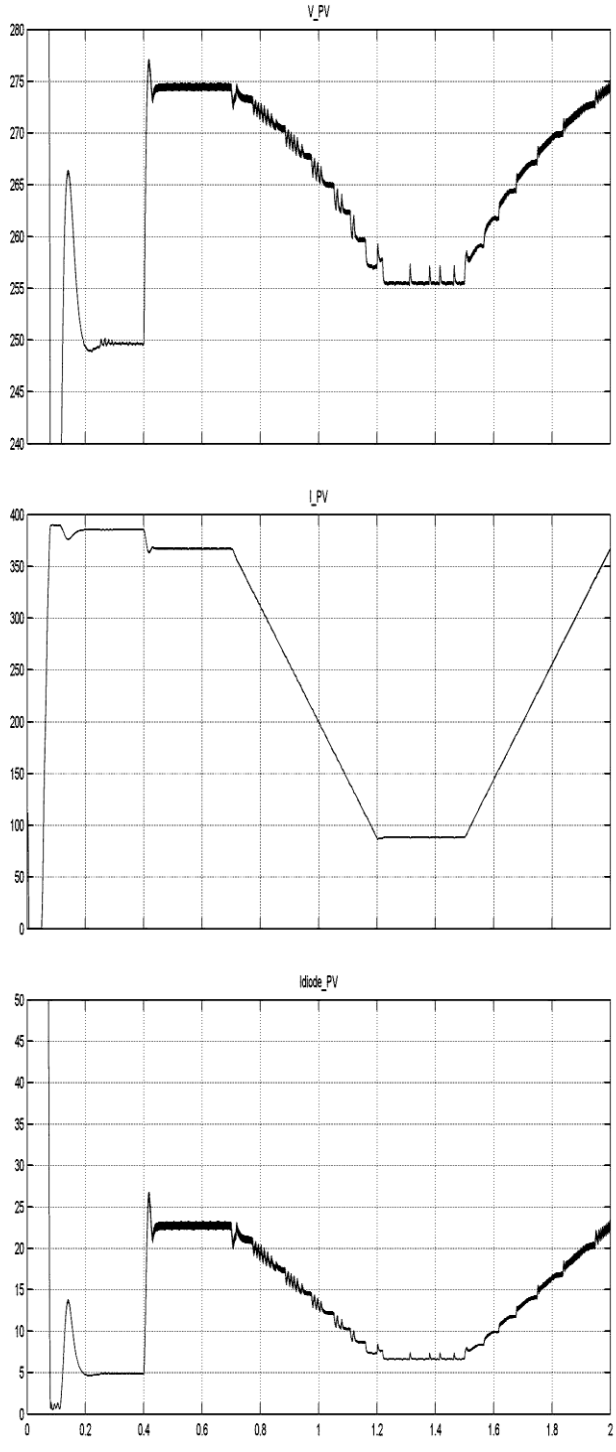

Fig.3 PV Array output voltage, Current and Diode Current Waveform.

2. DC-DC CONVERTER

In the detailed model, the boost converter boosts DC voltage from 273.5 V to 500V. This converter uses a MPPT system which automatically varies the duty cycle in order to generate the required voltage to extract maximum power.

By seeing the output waveform it's clear that the measured or output voltage from the Boost converter always hang near its reference value as set. For this operation the modulation index of the DC-DC converter control keep on changing so that output voltage can track the desired voltage. Initially the control is blocked, we can see the effects of this on waveform, after sometime it's blocking is removed from it and result are appreciable.

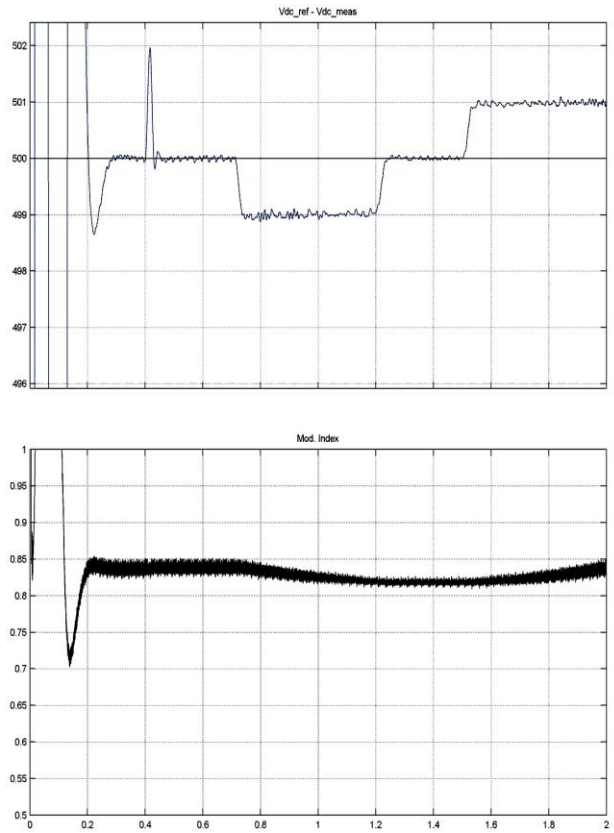

Fig.4. Reference voltage-Measured Voltage and Modulation Index Waveform.

3. DC-AC INVERTER

The control system uses two control loops: an external control loop which regulates DC link voltage to +/- 250 V and an internal control loop which regulates Id and Iq grid currents.

The output waveform shows us that with such a control loop we get perfectly sinusoidal waveform. Also with this with MPPT enabling after some instance we find that the system power keep on tracking maximum power so as to supply the grid.

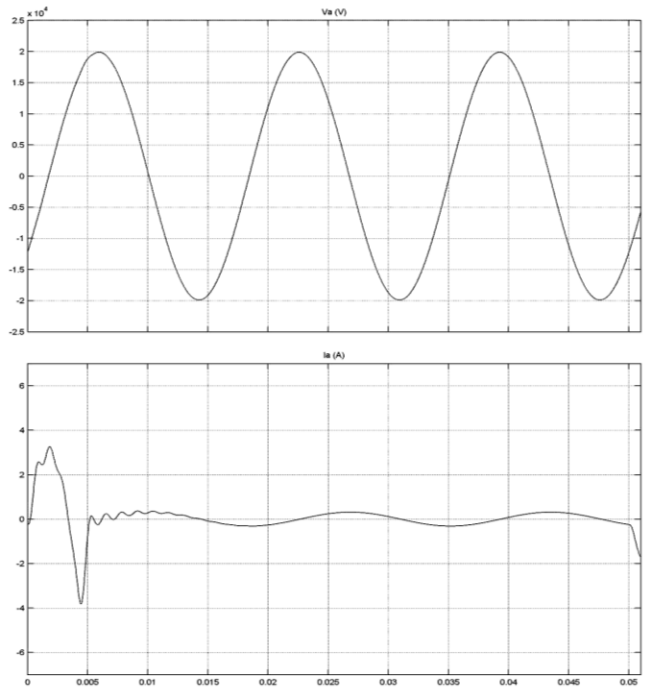

Fig.5 Ac Output Voltage and Current Waveform with Grid Connection.

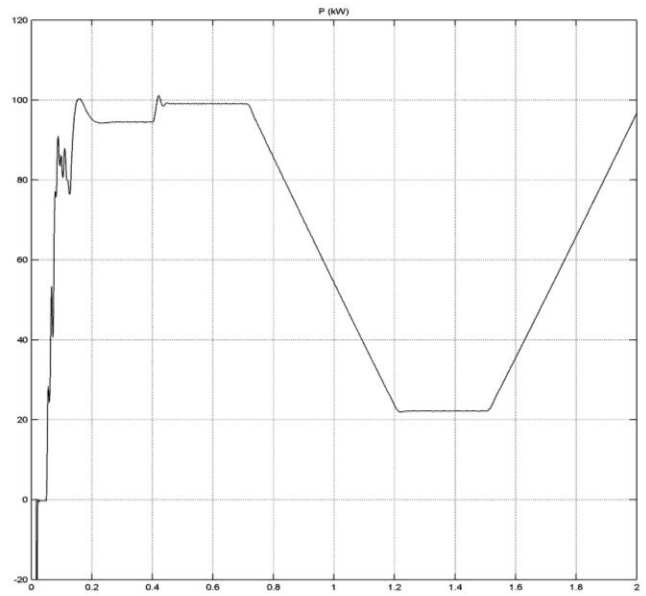

Fig.6 AC Real Power Waveform with Grid Connection.

V.CONCLUSION

In this paper modelling and simulation of PV system with Incremental Conductance MPPT Algorithm on Grid Connected Photovoltaic System is performed on MATLAB/SIMULINK. We discuss in breif about various MPPT Algorithm and we perform sil\mulation with incremental conductance algorithm. By this algorithm we keep on tracking the maximum power from the PV System that can be supplied to the grid. The various waveform that obtains in simulation are presented wjich proves the result of getting MPPT.

VII.REFERENCES :

[1] B. K. Bose, "Energy, environment, and advances in power electronics," *IEEE Trans. Power Electron.*, vol. 15, no. 4, pp. 688-701, Jul. 2000.

[2] F. Blaabjerg, C. Zhe, and S. B. Kjaer, "Power electronics as efficient interface in dispersed power generation systems," *IEEE Trans. Power Electron.*, vol. 19, no. 5, pp. 1184-1194, Sep. 2004.

[3] R. Faranda, S. Leva, and V. Maugeri, *MPPT Techniques for PV Systems: Energetic and Cost Comparison*. Milano, Italy: Elect. Eng. Dept. Politecnico di Milano, 2008, pp. 16.

[4] Z. Yan, L. Fei, Y. Jinjun, and D. Shanxu, "Study on realizing MPPT by improved incremental conductance method with variable step-size," in *Proc. IEEE ICIEA*, Jun. 2008, pp. 547–550.

[5] F. Liu, S. Duan, F. Liu, B. Liu, and Y. Kang, "A variable step size INC MPPT method for PV systems," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2622–2628, Jul. 2008.

[6] F. M. González-Longatt, "Model of photovoltaic module in Matlab," in *2do congreso iberoamericano de estudiantes de ingenieriacute;a eléctrica, electrónica y computación, ii cibelec*, 2005, pp. 1–5.

[7] Ma Xiujuan, WU Jiayu, Li Yanmei and Zhang Lanhui,"The Research on the Algorithm of Maximum Power Point Tracking in Photovoltaic Array",The World of Power Supply, Vol.6,2009,pp.36-38,51

[8] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Trans. Energy Convers.*, vol. 22, no. 2, pp. 439–449, Jun. 2007.

[9] V. Salas, E. Olias, A. Barrado, and A. Lazaro, "Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems," *Sol. Energy Mater. Sol. Cells*, vol. 90, no. 11, pp. 1555–1578, Jul. 2006.

[10] G. Petrone, G. Spagnuolo, R. Teodorescu, M. Veerachary, and M. Vitelli, "Reliability issues in photovoltaic power processing systems," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2569–2580, Jul. 2008.

[11] C. Hua, J. Lin, and C. Shen, "Implementation of a DSP-controlled photovoltaic system with peak power tracking," *IEEE Trans. Ind. Electron.*, vol. 45, no. 1, pp. 99–107, Feb. 1998.

[12] T. Noguchi, S. Togashi, and R. Nakamoto, "Short-current pulse-based maximum-power-point tracking method for multiple photovoltaic-and converter module system," *IEEE Trans. Ind. Electron.*, vol. 49, no. 1, pp. 217–223, Feb. 2002.

[13] N. Mutoh, M. Ohno, and T. Inoue, "A method for MPPT control while searching for parameters corresponding to weather conditions for PV generation systems," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1055– 1065, Jun. 2006.

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

[15] N. Femia, D. Granozio, G. Petrone, G. Spagnuolo, andM. Vitelli, "Predictive & adaptive MPPT perturb and observe method," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 43, no. 3, pp. 934–950, Jul. 2007.

[16] E. Koutroulis, K. Kalaitzakis, and N. C. Voulgaris, "Development of a microcontroller-based, photovoltaic maximum power point tracking control system," *IEEE Trans. Power Electron.*, vol. 16, no. 1, pp. 46–54, Jan. 2001.

[17] S. Jain and V. Agarwal, "A new algorithm 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] A. Pandey, N. Dasgupta, and A. K. Mukerjee, "Design issues in implementing MPPT for improved tracking and

dynamic performance," in *Proc. 32nd IECON*, Nov. 2006, pp. 4387–4391.

[19] K. H. Hussein, I. Muta, T. Hoshino, and M. Osakada, "Maximum photovoltaic power tracking: An algorithm for rapidly changing atmospheric conditions," *Proc. Inst. Elect. Eng.—Gener., Transmiss. Distrib.*, vol. 142, no. 1, pp. 59–64, Jan. 1995.

[20] T.-F.Wu, C.-H. Chang, and Y.-H. Chen, "A fuzzy-logic-controlled singlestage converter for PV-powered lighting system applications," *IEEE Trans. Ind. Electron.*, vol. 47, no. 2, pp. 287–296, Apr. 2000.

[21] 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.