International Journal of Engineering Research ISSN: 2319-6890 (online),2347-5013(print)
Volume No.9, Issue No.1, pp: 17-20 1 Jan. 2020

A Novel Global Maximum Power Point (GMPP) Tracking for Non Uniform Illumination Conditions

Gunavardhan Reddy B., P. Murari, Vijay kumar K., Chakradhar P., S. Roop Kumar S.
Electrical and Electronics Engineering Department,
Sanketika Vidya Parishad Engineering College, Visakhapatnam, A.P., India

Abstract : Characteristic curves of Photo-voltaic (PV) cells depend on physical conditions like solar irradiation, temperature and Non-Uniform Illumination (NUI). In rapidly changing NUI conditions, the PV array output contains multiple power peaks. The standard power extraction techniques are insufficient in tracing the global peaks in such multiple peak scenarios. Global Maximum Power Point (GMPP) tracking techniques involving Artificial Intelligence (AI) techniques are required to utilize the power generated efficiently. In this work, an algorithm is proposed which makes use of the irradiation and temperature data from respective sensors and converges the output to the global peak with least array scanning and hardware equipment. Based on the sensor data, the algorithm uses a narrow region to scan the maximum power peak. The global power point will be tracked by adjusting the duty cycle of PWM power converter in a predetermined range of outputs.

Index Terms — Global Maximum Power Point, Non-Uniform Illumination, Photo voltaic.

I. INTRODUCTION

Conventional Maximum Power Extraction (MPE) techniques like Perturb and Observe (P&O), Incremental Conductance (IC) algorithms holds good under uniform illumination conditions but are inept in dynamic NUI conditions due to number of power peaks [i]. Artificial Intelligence (AI) techniques operate well in dynamic NUI conditions but it is difficult to use practically. The pertinence of an MPE algorithm depends on conditions such as: speed of convergence, hardware requirements (including suitable sensors), local or global peak traceability, implementation intricacy, and overall cost. The algorithms such as modified P&O, IC are comparatively easy to implement practically but have the disadvantage of scanning the characteristics of the entire array. In modified P&O, the complete P-V characteristics of array are scanned and the instantaneous power values are saved in the memory of the processor and after completing scanning. For every iteration the GMPP tracking starts. This gradually reduces the tracking speed to small values. Whereas in modified IC technique [ii], the GMPP is tracked by modification of conventional IC algorithm but fails to work operate in rapidly changing environment conditions. However, a Modified HC technique needs an array scanning about 80% of the P-V array [4]. AI techniques such as Artificial Neural Network (ANN), Fuzzy Logic Control (FLC) etc., are apt under changing NUI conditions but they require inspection practically [5]-[8].

In this article, an MPE technique has been developed which is easy for practical execution. The algorithm instantaneously predicts a voltage range for GMPP and converges it to the desired operating point. This technique requires less hardware and time to converge compared to other MPE techniques. Initially, the proposed algorithm has been verified experimentally by simulation studies on an M×N PV array for NUI conditions. An experimental set- up consisting of a 2×2 photovoltaic array, power converter, sensor network and processor board is developed. The algorithm has been verified experimentally in real time. This algorithm is generic in construction and can be implemented for experimentally verifying any M×N SPV array. Microchip dsPIC30F6014A micro-controller is used for the purpose of execution and real time verification of the proposed algorithm.

Section-I gives the background of this article and shows the curves for GMPP and local MPP. Section-II consists of Sensor scanning, methodologies involved in the technique and the flowchart of the present technique. Section-III shows the results after implementing the present algorithm and also the practical NUI conditions. Section-IV gives the conclusion of this article and also the drawbacks in it.

The P-V characteristics of an SPV array with bypass diodes exhibits multiple power peaks under NUI conditions [9]. It cannot be achieved by conventional MPE techniques to trace the GMPP in such scenarios. In order to understand the problems due to NUI, a simulation model has been developed with each SPV module in it of Short-Circuit Current (SCC) 1.1A and Open-Circuit Voltage (OCV) of 23V. This developed simulation model comprises the effect of temperature and irradiation on the OCV and the SCC [10]. The NUI consists of local power peaks due to the bypass diodes present in the power converter module. Fig.1. shows the schematic of SPV array also known as block diagram of the SPV array.

II. METHODOLOGY

A. Sensor Array

For an M×N array, the number of modules connected in series in each string is 'M' whereas 'N' indicates the total number of such strings. Each SPV module in the array is indicated as 'Module xy' where 'y' indicates the string number and 'x' indicates the module number in the string. Illumination sensors are arranged in a 2x2 array. The illumination sensor array is arranged in such a way that the irradiation falling on each module is represented by four sensors. Every two adjacent modules in the array shares two common sensors. Temperature sensors are assembled at the bottom of every SPV module. Photo diodes or light dependent resistors (LDRs) can be used to sense effective illumination associated with each SPV module in the array.

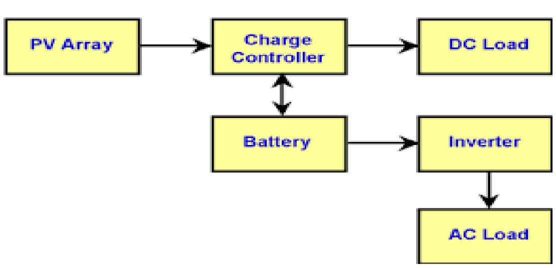
B. MPE Technique

The dynamic NUI on the SPV array is detected by a sensor network as discussed. The instantaneous dynamic NUI information is given to the digital processor based controller board which in turn implements the proposed fast predicting algorithm to trace the GMPP. The PWM output of the controller controls the power converter in order to operate the SPV array at its GMPP. The power converter in turn feeds electrical power to the load (R_0).

C. Flowchart of the Algorithm

Fig. 2 describes the flowchart of the proposed algorithm for M×N SPV array. The irradiation (G) information of all SPV modules in M×N array is measured by the illumination sensor network which is an input to the proposed algorithm. The boundaries of the I-V curve for each string in the M×N SPV array is predicted by the proposed algorithm using the real time irradiation readings from the illumination sensors. The sensors are calibrated and arranged in such a way that their output values define the corresponding light intensity of all the respective SPV modules.

Fig.1. Schematic representation of proposed MPE technique



The I_M and V_M are calculated by considering the relation

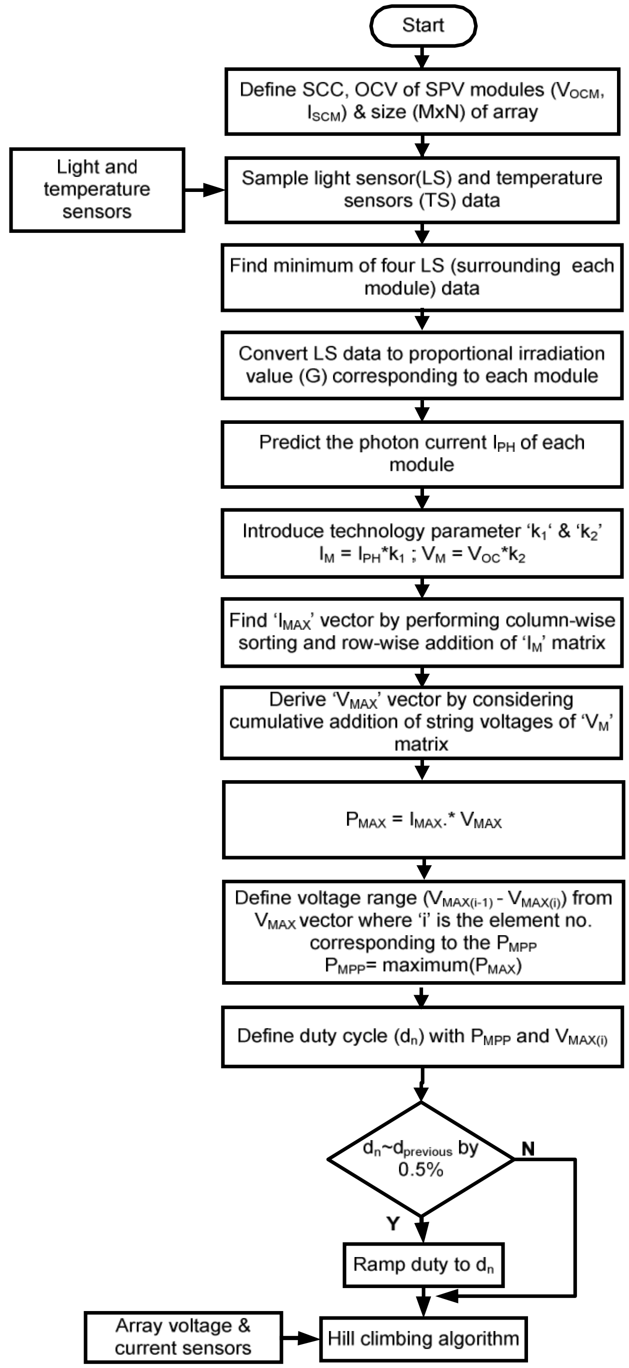


Fig.2. Flowchart of the algorithm

The photon current of the module is predicted at the given light or irradiation value (G) using (1).

$$I_{PH} = (G/G_{REF}) \times I_{SCM} \quad (1)$$

Where I_{SCM} is the short circuit current of the module used in the array at G_{REF} (reference irradiation).

$I_M = K_1 * I_{PH}$ where K_1 depends on the physical parameters of the solar module like irradiation, technology and degradation etc. and $V_M = K_2 * V_{OC}$ where K_2 depends on temperature and technology of SPV module [2].The experimental observation of temperature shows dependence of OCV for a mono-crystalline SPV module at a particular irradiation.

After predicting module boundaries I_M and V_M of all the modules, the boundaries of the array (I_{MAX}, V_{MAX}) required for the algorithm are predicted. An example case of three peaks scenario for a 3×3 array. The technology dependent factors, K_1 and K_2 have to be derived experimentally for the modules used in the SPV array. In this paper, the mono-crystalline SPV modules used for experimental validation of algorithm are characterized at different irradiations to find K_1 using a solar simulator setup. The corresponding P-V and the irradiation (G) versus I_{MPP}/I_{SC} (K_1) characteristics of the mono-crystalline module. Similarly, K_2 is derived by observing module P-V characteristics at different temperatures and at constant irradiation. After predicting the overall array boundaries as described in the flowchart, the proposed algorithm instantaneously predicts the power at all the possible peaks for the given NUI scenario, and in turn derives the voltage range ($V_{MAX(i-1)}$ to $V_{MAX(i)}$) in which GMPP exists. Once the proposed algorithm predicts the GMPP range, any hill climbing algorithm can be used to track the MPP. This means a very narrow zone of the SPV array‘s P-V characteristics has to be scanned.

The PWM switching duty cycle of the boost power converter connected to the SPV array will be continuously updated by the processor board as per the above described algorithm in order to operate the SPV array always at GMPP in real time. In the proposed MPE algorithm, the duty cycle of the boost converter will be initialized to a value corresponding to the predicted GMPP point using (2).

$$d = 1 - \sqrt{\frac{V_i}{I_i R_O}} \qquad (2)$$

‘V_i’ is the voltage derived from the algorithm corresponding to GMPP ($V_{MAX(i)}$) and ‘I_i’ is calculated from the ratio P_{MPP}/V_i where P_{MPP} is the maximum power at GMPP predicted by the algorithm.

III.RESULTS

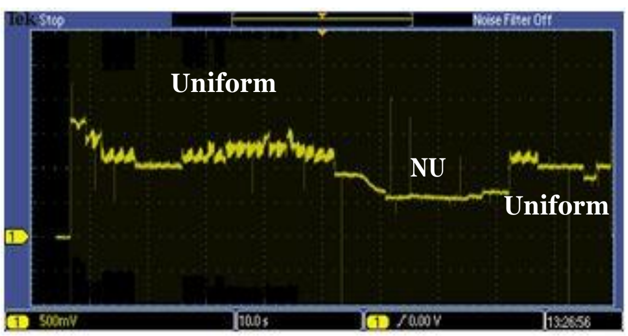
The proposed MPE algorithm has been validated by means of simulation studies using SIMULINK and also by experimental validation using the hardware developed for the case of a 2x2 SPV array. Mono-crystalline SPV modules of SCC 0.9A and OCV 24V are considered for validation of the proposed algorithm. Fig. 8(a) shows the test cases of the 2x2 SPV array for both uniform illumination and NUI conditions whereas Fig. 8(b) shows the corresponding P-V characteristics obtained by simulations. Fig.4. shows the simulation result of the proposed algorithm for voltage output of the 2x2 SPV array. At 0.3 seconds, the illumination input to the array changes to the given NUI scenario and at 0.6 second, the illumination input again alters back to the uniform illumination condition. It can be observed from that the MPE algorithm has automatically driven the 2x2 SPV array to an array voltage corresponding to the GMPP.

Fig. 3(a) and 3(b) shows the experimental set-up for validating the proposed MPE algorithm. LDRs are used as illumination sensors and LM35 IC is used to measure the temperature of the SPV modules. For the proof of concept the 2x2 Mono-crystalline SPV array is configured with only four light sensors at the four corners. Microchip DSPIC30F6014A micro-controller, current sensor (ACS712), an op-amp based voltage sensor and the boost power converter circuit are configured on a single electronic board.

The algorithm was developed using MPLAB IDE. dsPIC30F6014A micro-controller has internal 12-bit ADC and PWM modules. The light sensor, temperature sensor, current & voltage sensor data are fed to the micro-controller/processor ADC channels. The processor executes the proposed MPE algorithm as per sensor information and changes the PWM duty cycle accordingly. The PWM signal generated by the processor goes to the opto-coupler driver IC VO3120. This drives the gate of MOSFET switch of the power converter. The algorithm samples the sensor data at predetermined intervals and determines the converter’s PWM duty cycle of operation thereby maintaining the 2x2 SPV array at its GMPP. The conducted experiment has three stages. Initially, the Mono-crystalline 2x2 SPV array was maintained at uniform illumination (740W/m^2). After 40 seconds, artificial shading (NUI) was created and followed by that the shading was removed after 20 seconds back to the uniform illumination condition (740W/m^2). Fig. 10 shows the oscilloscope recording of the voltage sensor i.e. the SPV array output voltage. The voltage sensor converts the array voltage with a gain factor of thirty in order to provide a compatible voltage to the processor’s ADC channel. It can be observed that the proposed MPE algorithm has driven the 2x2 SPV array to approximately 30V and 15V respectively during the uniform illumination and NUI conditions respectively. This is similar to the results obtained by SIMULINK simulation. The algorithm has tracked the GMPP dynamically in the real time by instantaneously sensing the illumination pattern change and by converging to the GMPP.

Fig. 3(a). Experimental setup with 2x2 mono-crystalline SPV array at uniform irradiation (740W/m^2)

Fig. 3(b). Experimental setup with 2x2 mono-crystalline SPV



array at NUI.

Fig. 4. Oscilloscope recording of array voltage sensor

IV. CONCLUSION

Artificial techniques are easy for NUI conditions it becomes difficult to implement them practically. The MPE technique discussed in this article requires minimum hardware and is easy for practical implementation. This algorithm is suitable for both uniform illumination and NUI conditions and can be implemented using analog as well as digital electronics. The MPE technique in the present article has been studied during different NUI conditions. The algorithm converges very quickly to the GMPP in real time implementation whereas other MPE techniques require complete/more array scanning. The proposed algorithm includes technology dependent factors while predicting the GMPP. The proposed MPE technique has been verified by simulation using SIMULINK and also by experimental studies on a 2x2 mono-crystalline PV array.

REFERENCES

i. *Ishaque, K. and Z. Salam, "A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition", Energy Reviews on Renewable & Sustainable, pp. 475-488, 2013.*

ii. *M. A. Elgendy, B. Zahawiand, D.J.Atkinson, "Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications", IEEE Transactions on Sustainable Energy, Vol.3, Issue.1, Pages.21-33, January 2012*

iii. *Patel, H. and V. Agarwal, "Maximum Power Point Tracking Scheme for PV Systems Operating Under Partially Shaded Conditions" IEEE Transactions on Industrial Electronics, Vol.55, Issue.4, pp.1689-1698, 2008.*

iv. *T. Esram, P. L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques", IEEE Transactions on Energy Conversion, Vol.22, Issue.2, Pages.439- 449, 2007.*

v. *B. Subudhi, R. Pradhan, "A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems", IEEE Transactions on Sustainable Energy, Vol.4, Issue.1, Pages.89-98, 2013.*

vi. *S. Bal, B. C. Babu, "Comparative study between P&O and Current Compensation method for MPPT of PV energy system", Students Conference on Engineering and Systems (SCES), 2012.*

vii. *H. Ziar, S. Mansourpour, E. Afjei, M. Kazemi, "Bypass diode characteristic effect on the behavior of solar PV array at shadow condition", 3rd conference on Power Electronics and Drive Systems Technology (PEDSTC), Pages.229-233, 15-16th Feb 2012, doi: 10.1109/PEDSTC.2012.6183331.*

viii. *G. Bhuvaneswari, R. Annamalai, "Development of a solar cell model in MATLAB for PV based generation system" Annual IEEE INDICON, 2011.*