An Approximate Short Circuit Strategy for Transient MPPT Performance of Uniformly Irradiated Photovoltaic Modules

M.E. BAŞOĞLU

***Abstract*—This paper presents an improved strategy to provide better maximum power point tracking (MPPT) performance and increase energy yield during transient state of MPPT process. This strategy is based on the estimation of short circuit current (SCC) of the photovoltaic (PV) system without short circuit. Besides that, this strategy aims to decrease convergence time to maximum power point (MPP) by preventing real short circuit of PV source and eliminating the additional switch requirement. To determine performance of the proposed strategy, simulation studies have been performed in MATLAB/Simulink and this strategy has been compared with fractional SCC (FSCC) technique and perturb and observe (P&O) algorithm. In addition, to make validation experimentally, a low powered single ended primary inductance converter (SEPIC) is realized. Both simulation and experimental results show that proposed strategy performs better transient MPPT performance than FSCC technique and P&O algorithm.**

Index Terms— **Fractional short circuit current, Maximum power point tracking, photovoltaic module, perturb and observe.**

I. INTRODUCTION

MAXIMUM power extraction of a PV system is an essential operation since PV systems have small power conversion efficiency. To obtain maximum efficiency, a power processing unit (PPU) is inserted between PV modules/array and load, battery and/or electrical grid. A PPU in a PV system should provide energy conversion with maximum efficiency. Lots of MPPT techniques have been presented to get the biggest efficiency and maximize energy from PV modules/arrays [1].

Among MPPT algorithms, P&O algorithm is widely used in industrial applications due to ease of implementation. However, its performance is poor in dynamic environmental conditions. Therefore, some parameters of P&O should be optimized [2]. For example, this algorithm has a paradigm about response time and fluctuation at steady state. Therefore, adaptive and variable duty step size approaches contribute performance of P&O [3]. In [4], in order to achieve fast MPPT operation, two step size incremental conductance (IC) is applied to boost converter. On the other hand, dynamic step size approach can be more useful compared with the fixed and/or two step sized technique. In [5], step size optimization on MPPT algorithm is studied deeply. Since P&O is easy to implement practically, its modification is very popular. In [6], changes in current, voltage and power are monitored and checked to make correct decision in rapid insolation variations. By additional checking of ΔI, failure operation in rapid insolation change is eliminated. IC is another popular algorithm. It also checks $\Delta I/\Delta V$ to track MPP. One advantage of this algorithm is the high correctness in MPPT under rapidly changing weather conditions [7]. A fixed step sized model predictive control (MPC) based MPPT algorithm including IC is proposed in [8]. Results show that it performs better than conventional IC under dynamic weather condition. A modified version of IC is proposed for partially shaded PV systems to track global MPP [9]. In order to increase the performance of the hill climbing type MPPT techniques, a design guide is proposed to determine perturbation time and perturbation frequency correctly in MPPT systems [10]. A two stage global MPPT algorithm, including variable step size P&O and segmentation rule search approach, is proposed. This algorithm is developed after extensive simulations of many PV module manufacturer datasheets [11]. The first $0.8V_{OC}$ based algorithm is proposed by [12]. It samples the power in every consecutive peaks and compares values of power at these peaks to determine the global MPP. Recently, a hybrid algorithm containing $0.8V_{OC}$ model and P&O has been proposed for distributed MPPT applications in which each module realizes its own MPPT operation [13]. In this algorithm, global MPP is tracked effectively in a short duration which improves the dynamic MPPT performance. In another study, typical voltage-current (V-I) characteristic feature is used to perform MPPT in a single ended primary inductance converter (SEPIC) to realize tracking in a partially shaded and uniform irradiation conditions [14]. With the help of a look-up table and converter based formulation, PV module is roughly operated at the vicinity of MPP. A modified IC algorithm is presented in [15] to increase tracking speed in

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uniform irradiance conditions. Even if this approach has a fast tracking capability, performance of this algorithm mainly depends on the PV parameters and loading conditions. A polynomial model of PV array is developed from a single diode circuit to determine MPP. Optimal selection of parameters is the main issue to be addressed in this study [16]. According to the results, this model is useful compared with the classical P&O. Because it has zero oscillation and no failure performance in rapidly changing weather conditions.

TABLE I
LIST OF ABBREVIATIONS AND NOMENCLATURE

Abbreviations		Definitions
MPPT	:	Maximum power point tracking
SCC	:	Short circuit current
PV	:	Photovoltaic
MPP	:	Maximum power point
FSCC	:	Fractional short circuit current
PPU	:	Power processing unit
SEPIC	:	Single ended primary inductance converter
DC	:	Direct current
P&O	:	Perturb and observe
IC	:	Incremental conductance
STC	:	Standard test condition
PWM	:	Pulse width modulation
RMS	:	Root mean square
I_{PH} / I_{SC}	:	Photo current / Short circuit current
Q_A / Q_R	:	Ambient irradiance / Reference irradiance
T_J / T_R	:	Junction / Reference temperature
V_{PV} / I_{PV}	:	Voltage and current of PV module
V_O / V_{IN}	:	Output and input of SEPIC voltage
K_I	:	Temperature coefficient
q / k	:	Electron charge / Boltzmann constant
A	:	Diode ideality factor
R_S / R_P	:	Series and parallel resistor
R_L / R_{PV}	:	Load resistor / Equivalent resistance of PV
I_O	:	Output current of SEPIC
L_P / L_S	:	Primary and secondary inductance
C_O / C_S	:	Output capacitor / AC capacitor
ΔV_{IN} / ΔV_O	:	Ripple on input voltage / output voltage
f_P	:	Switching frequency
ΔI_{Lp} / ΔI_{Ls}	:	Current ripples of inductors

FSCC is one of the conventional MPPT techniques using linear relationship between SCC and maximum power current [17]. It is generally accepted that ratio of SCC and maximum power current is a constant since variations in solar irradiance and temperature does not affect this ratio significantly. On the other hand, FSCC requires additional semiconducting switch and integrated circuit for gate driving, resulting low tracking speed and small tracking efficiency because of the periodical disconnection between PV module/array and load, battery and/or electrical grid. The main idea behind this research is to improve transient MPPT performance of PV systems in uniform irradiance condition. A strategy is proposed for the purpose of estimation the value of SCC without additional switch. Thanks to this estimation, PV system is not short circuited and more energy can be transferred from PV sources to the output of the PPU. To determine performance of this strategy, one of the advanced buck-boost converter topology, low power SEPIC has been designed and realized. Remains of the paper continue as follows. Theory of the proposed strategy is presented in the next section. In Section III, design steps of the SEPIC and simulation results are given. Experimental results are presented in the Section IV. Finally, main outcomes of the proposed strategy is summarized in Section V.

II. Theory Of The Proposed Strategy

PV modules are nonlinear power sources having exponential I-V characteristic. They are combined with many PV cells connected in series and/or parallel. Nonlinearity of the PV cell is come from its p-n structure which is similar to basic diode. A typical PV cell can be modelled by a controlled current source, a diode, and two resistors. [18]. A common type of equivalent circuit of a PV cell is presented in Fig. 1.

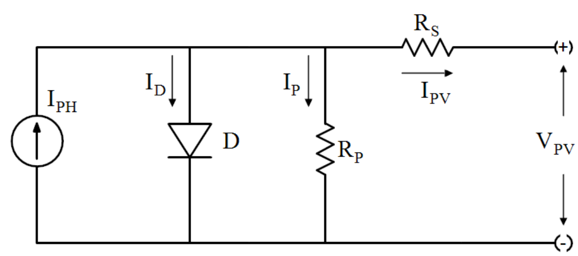

Fig.1. One diode electrical model of a typical PV cell

PV cells can be considered as controlled direct current (DC) source. The electrical current generated from the PV cell mainly depends on the irradiance received by the PV cell. In addition, temperature and coefficients have minor effect on the changes in PV power/current. Photo/light current of a PV cell can be calculated as in (1) [18].

$$I_{PH} = I_{SC}\,\frac{Q_A}{Q_R} - K_I\,(T_J - T_R) \qquad (1)$$

In (1), I_{PH} is the photo current of the cell, Q_A is the ambient irradiance, Q_R is the reference irradiance, K_I is the temperature coefficient of the current, T_J and T_R are the junction temperature and reference temperature, respectively.

Photo current of a PV cell is the maximum available current generally defined as short circuit current. By extracting the diode current from the photo current, PV current feeding to the load can be found as in (2) [19].

$$I_{PV} = I_{PH} - I_S\left(e^{\frac{\left[q(V_{PV} - I_{PV}R_S)\right]}{kT_J A}} - 1\right) - \frac{V_{PV} - I_{PV}R_S}{R_P} \qquad (2)$$

In (2), I_{PV} and V_{PV} are the current and voltage of PV module, I_S is the diode saturation current, q is the electron charge, k is the Boltzmann constant, R_S is the series resistor, R_P is the parallel resistor and A is the ideality factor of diode.

Conventional MPPT algorithms have some disabilities such as low response time causing small tracking efficiency and big power fluctuation at steady state condition. Therefore, modern MPPT techniques have two stages at least. In the first stage, operation in vicinity of MPP is aimed. Then, a typical MPPT technique such as P&O, IC and constant voltage algorithm are used. In this study, performance improvement in the first stage is focused.

In order to estimate SCC of the PV module/array, first, power-voltage (P-V) characteristic curves of the PV system are analyzed. Number of P-V curves is determined by the value of solar irradiance step which is $100W/m^2$ [12]. Minimum and maximum values of irradiance are $100W/m^2$ and $1000W/m^2$ [12]. Number of these curves is calculated by the combination of C(10,1)=10. According to these P-V curves, equivalent resistances seen by the PV module for all irradiances are determined by (3) [14]. P-V and I-V curves of the PV module used in this study are presented in Fig. 2.

$$R_{PV(n)} = \frac{V_{MPP(n)}}{I_{MPP(n)}} = \frac{V^2_{MPP(n)}}{P_{MPP(n)}} \tag{3}$$

In (3), $V_{MPP(n)}$ and $I_{MPP(n)}$ are the nth voltage and current of the PV module, respectively. $R_{PV(n)}$ is the nth average value of resistance seen from output of the PV module.

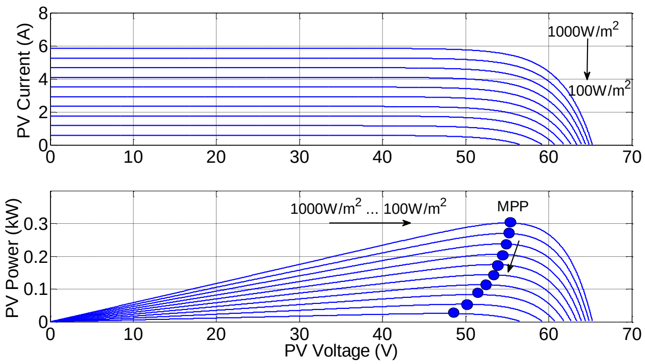

Fig.2. I-V and P-V characteristic curves of selected PV module

Specifications of the PV module at standard test conditions (STC) used in this study are listed in Table II. Type of PV cell used in this module is monocrystal. Characteristic curves given in Fig. 2 corresponds to the PV system in which three PV modules are connected in series to form a small PV array. To simplify the validation of the proposed strategy, resistive load is selected which is connected to the output of the SEPIC. As known, SEPIC is a kind of buck-boost converter. Its voltage gain can be formulated as in (4) [20].

$$V_O = V_{IN}\frac{D}{1-D} \tag{4}$$

In (4), V_O and V_{IN} are the output and input voltage of converter, respectively. D is the duty ratio of the pulse width modulation (PWM). Since input port of the converter is connected to the PV module, $V_{IN}=V_{PV}$. V_O and V_{PV} can be formulated as in (5) and (6), respectively.

$$V_O = I_O R_L \tag{5}$$

$$V_{PV} = I_{PV} R_{PV} \tag{6}$$

TABLE II
SPECIFICATION OF THE PV MODULE at STC

Specification	**Value**
Maximum power	101W
Maximum power voltage	18.4V
Maximum power current	5.51A
Open circuit voltage	21.7
Short circuit current	5.85
Type of cell used in the module	Monocrystal

In (5), I_O is the output current of the converter, R_L is the load resistance. By combining (4), (5) and (6), duty ratio of PWM for irradiance conditions providing MPPT operation is specified as in (7) [14]. Number of duty ratio is n.

$$D(n) = \frac{1}{1+\sqrt{\frac{R_{PV(n)}}{R_L}}} \tag{7}$$

It is easily said that value of D(n) is the biggest for highest irradiance condition since $R_{PV(n)}$ is smaller in $1000W/m^2$ than that of the other irradiance conditions. So, to guarantee the operation in the constant current region which represents the left region of the MPP, the biggest value of duty ratio for a specified load is applied to the converter. In this way, vicinity of short circuit operation is provided without the need of real short circuit. Illustration of this operation is presented for ten different irradiance conditions in Fig. 3. For example, first, PV module is operated at the vicinity of MPP where red circles are located. Then P&O is activated to finely tune the operation point at MPP.

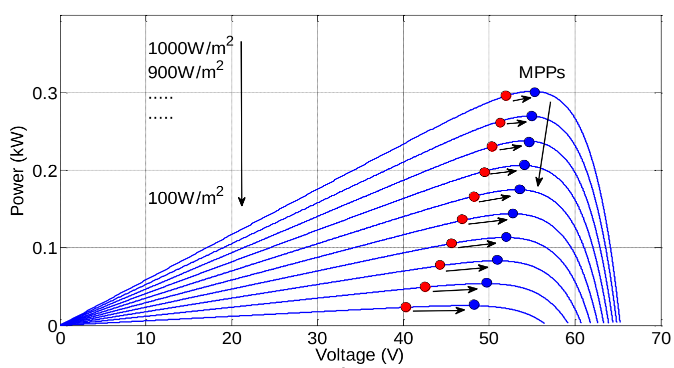

Fig.3. Illustration of the proposed strategy

III. Design Of The Power Stage Of The Sepic

In order to validate the proposed strategy, SEPIC is selected as a PPU since it is one of the buck-boost converters. It can increase or decrease the voltage which is a typical requirement

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in a MPPT application. Typical SEPIC converter consists of two inductors, three capacitors, a power switch and a power diode as shown in Fig. 4. For a typical MPPT application, a current transducer and voltage dividing resistors are also used to sense current and voltage of PV module for MPPT operation. When power switch is turned on primary inductance is energized by the PV source and current of primary inductance increases linearly and saves energy. Voltage of primary inductance, V_{Lp} is equal to input voltage and voltage of PV module (V_{Lp}=V_{IN}=V_{PV}). Besides, secondary inductance has same voltage while the power switch is conducting. Current change in these inductances are formulated as in (8). Since voltages of these inductances are same, they can be wound on the same core and values of inductances are halved [21].

$$\Delta I_{Lp} = \Delta I_{Ls} = \frac{1}{2}\frac{V_{IN}t_{ON}}{L_P} \quad (8)$$

In (8), ΔI_{Lp} and ΔI_{Ls} are the current ripples of coupled inductor, t_{on} is the conducting time of switch and L_p is the primary inductance value.

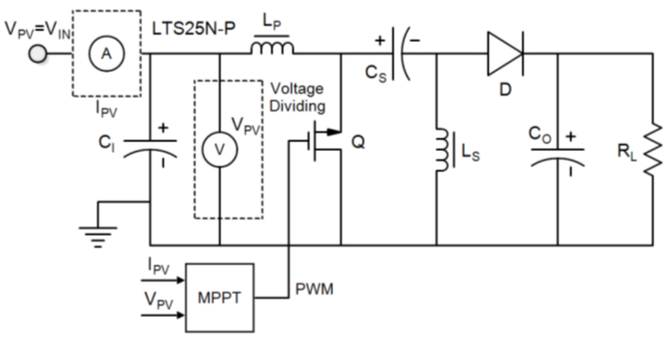

Fig.4. Electrical scheme of the MPPT system

Peak to peak voltage ripple and root mean square (RMS) current rating are the main parameters for capacitor selection [21]. Output voltage of the SEPIC is calculated as in (9). D_{crt} is critical duty ratio corresponding to maximum value of D_{crt} and output current multiplication. In (9), f_P is the switching frequency. Voltage value across the output capacitor and its equivalent series resistance are the significant parameters [20].

$$C_O = \frac{D_{crt}I_O}{\Delta V_O f_P} \quad (9)$$

Calculation of coupled capacitor is made similarly. Voltage of C_S is equal to input voltage in steady state condition. This capacitor is calculated as following equation [20].

$$C_S = \frac{D_{crt}I_O}{\Delta V_{IN} f_P} \quad (10)$$

A. Simulation Results

In order to observe the performance of the proposed MPPT strategy, some simulation studies have been performed in MATLAB/Simulink. Furthermore, proposed strategy has been compared with FSCC approach and P&O algorithm. Fig. 5 presents the simulation results the case of irradiance change. In this simulation case, irradiance is changed from 1000W/m^2 to 500W/m^2 at t=2s. Duty ratio is updated in proposed strategy and new MPP is tracked a few milliseconds. Although FSCC performs better than P&O, it has performed worse than proposed SCC strategy. According to the result of FSCC seen in Fig. 5, voltage and power of PV module decreases to zero since PV module is short circuited. In this results, energy discontinuity and additional switch are the prominent drawbacks.

IV. Prototype Circuit and Experimental Results

In this section, prototype of SEPIC converter, sensing and measurement circuits for MPPT operation, the other hardware requirements and results of experimental studies are presented. A low power SEPIC which consists of a coupled inductor, input, output and coupled capacitor, a semiconducting switch (MOSFET) from International Rectifier, IRFP450 and a fast diode named as MUR860. Primary and secondary inductance values are 569uH. To stabilize the voltage of PV module two parallel capacitors are used. Their values are 470uF. In the output of the SEPIC, a 150 electrolytic capacitor is used. In order to realize MPPT operation, voltage and current of PV module are sensed by a voltage dividing circuit and LTS25NP current transducer. Voltage dividing circuits contain two resistor and a capacitor. Their values are 33k, 2,7k and 10nF, respectively. So as to generate PWM for MOSFET switching, a microprocessor from Microchip, PIC18F452, has been used. However, PWM signal obtained from this component does not provide enough current to drive MOSFET's gate. Therefore, a gate driver integrated circuit from International Rectifier, IR2118 is used. All components used in this prototype circuit, measurement devices and model of PV emulator are listed in Table III.

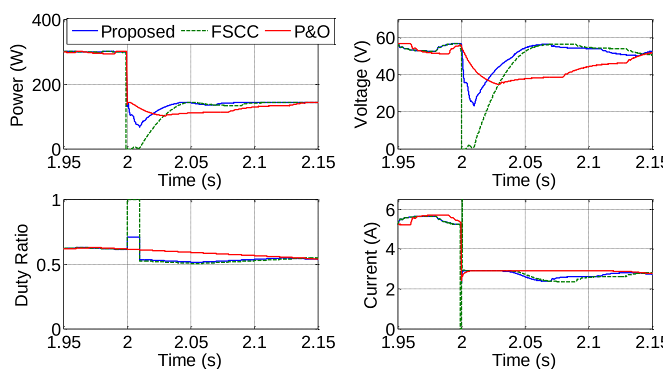

Fig.5. Simulation results of proposed strategy, FSCC and P&O algorithm

In experimental validation, specifications of the PV module given in Table I are used. As a PV source, three PV modules are connected in series to form a PV array. This array is irradiated by 700W/m^2 which is set through interface program of the PV emulator. Experimental test platform is shown in Fig. 6. As listed in Table I, parameters of monocrystalline type PV module is used in the PV emulator. If another type of cell is used, performance of the proposed strategy is not affected since approximate short circuit and its duration time is related to the power stage of the system.

TABLE III
SPECIFICATIONS OF THE SEPIC AND MEASUREMENT DEVICES

Components / Measurement	**Value / Brand / Model**
Input capacitor	2//470µF, 100V
Output capacitor	150µF, 200V
Coupled inductance (L_P / L_S)	569µH / 569µH
Coupled capacitor	220µF, 100V
MOSFET	IRFP450
Diode	MUR860
Current transducer	LTS25NP
Voltage dividing resistors / capacitor	33k/2,7k – 10nF
Microprocessor	PIC18F452
Switching frequency	20kHz
Current probe	Fluke 80i-110s
Oscilloscope	GW Instek -GDS3254
PV emulator	CHROMA 62050-600S
Resistive Load	24Ω – 200W

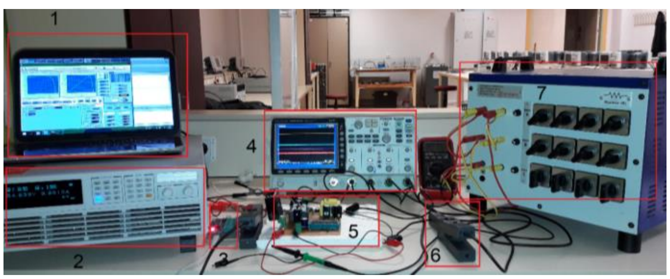

Fig.6. Test platform 1: Computer for PV emulator programming and PIC18F452 programming, 2: PV emulator, 3: PICKIT2, 4: Oscilloscope, 5: Prototype SEPIC, 6: Current Probe, 7: Resistive loading bank)

A. *Experimental Results*

As explained in the Section II, proposed strategy provides proper initialization without short circuit and an operation point near exact MPP is tracked. Then, P&O algorithm completes the tracking. Fig. 7 presents the result of the proposed strategy. When zooming the region presented in rectangle, proposed strategy tracks the MPP in a few hundred milliseconds. In this figure, voltage, current and power of the PV module and duty ratio are presented.

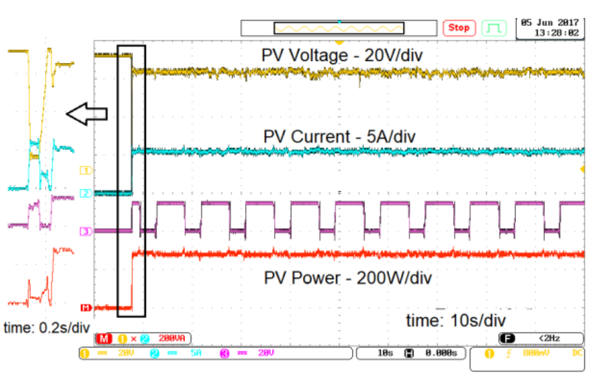

Fig.7. Experimental results of the proposed strategy

Experimental results of the proposed strategy and FSCC are presented in Fig. 8. In this case, first, solar irradiance is set to 1000W/m^2 and MPP is tracked. After thirty seconds, solar irradiance decreases to 500W/m^2 by emulator. In this condition, approximate short circuit is realized. The result of the proposed strategy can be seen in the first circle in Fig. 8. In the proposed strategy, PV array is not short circuited completely. It can be easily understood by the variations of PV module voltage. Normally, if PV array is completely short circuited, voltage sharply decreases to zero immediately. However, voltage of PV array decreases to half of the first value. To observe the difference between the proposed strategy and FSCC, twenty seconds later, PV array is short circuited. With full short circuit condition, shown in the second circle in Fig. 8, voltage of PV module converges to zero. Therefore, proposed strategy collects more energy during initialization interval compared with the FSCC approach.

As is verified in the last two results presented in Fig. 7 and Fig. 8, proposed strategy initiates the operation point near the MPP, providing fast tracking. For comparison the other approach, P&O algorithm is used in same power level. As it is clear in Fig. 9 that tracking of MPP is very slow compared with the proposed strategy and FSCC algorithm. Tracking is completed in 1 second in Fig. 9. On the other hand, proposed strategy tracks the MPP in about 100 milliseconds. Normally, transient process of the MPPT is very small compared with the steady state condition. However, in a cloudy day, MPP changes frequently and number of transient processes increases. Prominence of the proposed strategy in such cases can be better understood.

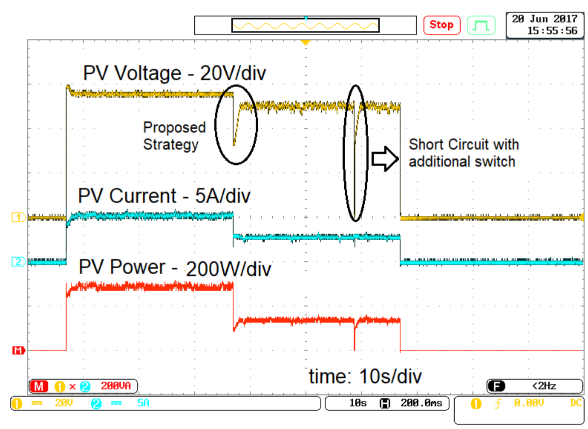

Fig.8. Comparison of the proposed strategy and FSCC

V. Conclusions And Future Work

In this study, an approximate short circuit strategy improving the transient process of MPPT is introduced. Proposed strategy uses ratio of maximum power current and short circuit current and initiates the operation point near the MPP. One advantage of this strategy compared with classical FSCC, additional switch is not required and PV module is not short circuited. So, more energy can be collected in the proposed strategy. Simulation and experimental results show that proposed strategy outperforms than FSCC and P&O

algorithm. In the future study, this strategy will be used in a commercially available power optimizer and/or micro inverter circuits with different power ratings.

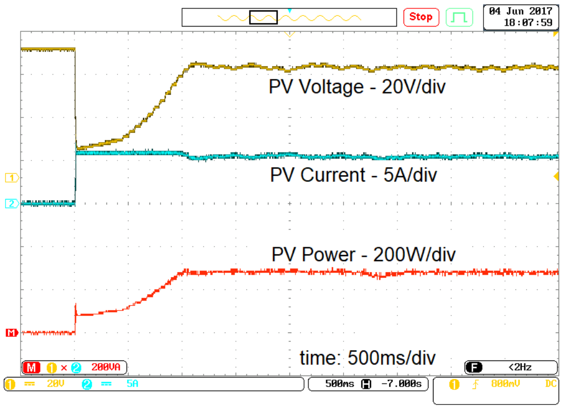

Fig.9. Experimental result of P&O algorithm

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REFERENCES

[1] Esram T., Chapman P.L., Comparison of photovoltaic array maximum power point tracking techniques, IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439-449, 2007.
[2] Fernia N., Petrone G., Spagnuolo G., Vitelli M., Optimization of perturb and observe maximum power point tracking method, IEEE Transactions on Power Electronics, vol. 20, no.4, pp. 963-973, 2005.
[3] Liu F., Duan S., Liu F., Liu B. Kang Y., A variable step size INC MPPT method for PV systems, IEEE Transactions on Industrial Electronics, vol. 55, no. 7, pp. 2622-2628, 2008.
[4] Belkaid A. Gaubert J. Gherbi A., Design and implementation of a high-performance technique for tracking PV peak power, IET Renewable Power Generation, vol. 11, no. 1, pp. 92-99, 2017.
[5] Tang L., Xu W. Mu C., Analysis for step-size optimization on MPPT algorithm for photovoltaic systems, IET Power Electronics, vol. 10, no. 13, pp. 1647-1654, 2017.
[6] Killi M., Samanta S., Modified perturb and observe MPPT algorithm for drift avoidance in photovoltaic systems, IEEE Transactions on Industrial Electronics, vol. 62, no. 9, pp. 5549-5559, 2015.
[7] Safari A., Mekhilef S., Simulation and hardware implementation of incremental conductance MPPT with direct control method using cúk converter, IEEE Transactions on Industrial Electronics, vol. 58, no. 4, pp. 1154-1161, 2011.
[8] Mosa M. Shadmand M.B., Balog R.S., Rub H.A., Efficient maximum power point tracking using model predictive control for photovoltaic systems under dynamic weather conditions, IET Renewable Power Generation, vol. 11, no. 1, pp. 1401-1409, 2017.
[9] Tey K.S., Mekhilef S., Modified incremental conductance algorithm for photovoltaic system under partial shading conditions and load variation, IEEE Transactions on Industrial Electronics, vol. 61, no. 10, pp. 5384-5392, 2014.
[10] Kivimäki J., Kolesnik S., Sitbon M., Suntio T. Kuperman A., Design guidelines for multiloop perturbative maximum power point tracking algorithms, IEEE Transactions on Power Electronics, vol. 33, no.2, pp. 1284-1293, 2018.
[11] Liu Y., Chen J., Huang J., Global maximum power point tracking algorithm for PV systems operating under partial shading conditions using segmentation search method, Solar Energy, vol. 103, pp. 350-363, 2014.
[12] Patel H. Agarwal V., Maximum power point tracking scheme for PV systems operating under partially shaded conditions, IEEE Transactions on Industrial Electronics, vol. 55, no. 4 pp. 1689-1698, 2008.
[13] Başoğlu M.E., Çakır B., Hybrid global maximum power point tracking approach for photovoltaic power optimisers, IET Renewable Power Generation, vol. 12, no. 8, pp. 875-882, 2018.
[14] Başoğlu M.E., Çakır B., A novel voltage-current characteristic based global maximum power point tracking algorithm in photovoltaic systems, Energy, vol. 112, pp. 153-163, 2016.
[15] Başoğlu M.E., Çakır B., An improved incremental conductance based MPPT approach for PV modules, Turkish Journal of Electrical Engineering & Computer Sciences, vol. 23, pp. 1687-1697-2015.
[16] Zadeh M.J.Z., Fathi S. H., A new approach for photovoltaic arrays modeling and maximum power point estimation in real operating conditions, IEEE Transactions on Industrial Electronics, vol. 64, no. 12, pp. 9334-9343, 2017.
[17] Noguchi T. Togashi S., Nakamoto R., Short current pulse based maximum power point tracking method for multiple photovoltaic and converter module system, IEEE Transactions on Industrial Electronics, vol. 49, no.1, pp. 217-223, 2002.
[18] Jiang L.L., Nayanasiri D.R., Maskell D.L., Vilathgamuwa D.M., A hybrid maximum power point tracking for partially shaded photovoltaic systems in the tropics, Renewable Energy, vol. 76, pp. 53-65, 2015.
[19] Nguyen T.L., Low K., A global maximum power point tracking scheme employing direct search algorithm for photovoltaic systems, IEEE Transactions on Industrial Electronics, vol. 57, no. 10, pp. 3456-3467, 2010.
[20] Mohan N., Undeland T.M., and Robbins W.P., Power Electronics: Converter, Applications, and Design, Wiley, 1995, p. 315.
[21] Falin J., Designing DC/DC converters based on SEPIC topology, Texas Instruments, 2008.

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