Journal of Electrical and Electronic Engineering
2022; 10(3): 80-85
http://www.sciencepublishinggroup.com/j/jeee
doi: 10.11648/j.jeee.20221003.12
ISSN: 2329-1613 (Print); ISSN: 2329-1605 (Online)

Implementation of Fractional Voltage and Current Based MPPT Techniques Using PLC and HMI

Maytham Ali Fadhil, Jawad Radhi Mahmood

Electrical Engineering Department, Basrah University, Basrah, Iraq

Email address:
Eng.maitham_ali@yahoo.com (M. A. Fadhil), Jawdradhi59@gmail.com (J. R. Mahmood)

To cite this article:
Maytham Ali Fadhil, Jawad Radhi Mahmood. Implementation of Fractional Voltage and Current Based MPPT Techniques Using PLC and HMI. *Journal of Electrical and Electronic Engineering*. Vol. 10, No. 3, 2022, pp. 80-85. doi: 10.11648/j.jeee.20221003.12

Received: October 26, 2021; **Accepted**: November 16, 2021; **Published**: May 31, 2022

Abstract: This paper presents the implementation of the two-famous maximum power point tracking (MPPT) techniques used in photovoltaic (PV) system, namely fractional open-circuit voltage (FOCV) and fractional short circuit current (FSCC) based on PLC and HMI in laboratory platform. The real-time operation of these two algorithms in the proposed platform has been done with the help of the DC-DC converter and other components. The main feature of this implementation is using all facilities of the PLC and HMI by the user to control all the essential keys of the two techniques like reference voltage and current sources, PID controller parameters, tracking speed, tracking accuracy, and power curve plotting utility. The purpose of this paper is to clear that, the user or researcher can be used the PLC and HMI to implement any topic related to the PV system such as the implementation of maximum power point tracking techniques or any other subject such as PV modeling or PV simulation even PV panels testing. PLC "programmable logic controller" is a special microprocessor-based controlled system, and it is a special type of computer capable of withstanding the industrial environment like vibration and high temperature. HMI "human interface machine" is used to create a user-friendly interface with the help of its base screens or popup screens. The combination of PLC and HMI is a powerful tool to use in PV system implementation.

Keywords: Fractional Open-Circuit Voltage, HMI, MPPT, PID, PLC, PV Module, Short-Circuit Current

1. Introduction

The electric generation sources are different and varied in the world. There are conventional or non-conventional types and environment-friendly or not types. The photovoltaic system is one of the non-conventional environment-friendly sources. In this type, the conversion between two types of energy has been done, from solar energy to electrical energy. The significant drawbacks of the photovoltaic systems are low efficiency of energy conversion and high manufacturing cost. The low efficiency caused by many reasons like PV module characteristics non-linearity and depends upon the irradiation and temperature levels [1, 2]. Therefore, it is essential to use one or more of maximum power point tracking algorithms as a searching process to get maximum energy from PV systems. There are many methods for maximum power point tracking of the PV system [3-6]. Fractional voltage-based and fractional current-based techniques are simple and fast techniques among them [7, 8].

Many researchers discuss the two MPPT algorithms which are the fractional open-circuit voltage and the fractional short-circuit current. The study of Nouguchi et al. [9] presented an adaptive FSCC algorithm to extract maximum power from the PV panel and also described some applications of this method. An adaptive FOCV algorithm have been developed [10] to improve the performance of fractional voltage-based technique under weather conditions changing. Shubham Negi et al. [11] introduced the method for adapting the voltage fraction constant (k) in the FOCV algorithm, and the circuit has been designed in a 180 nm CMOS process. The MPPT algorithm based by using FOCV, FSCC, and incremental conductance method for accurate extraction of maximum power point of PV panel, the result of the proposed method presented under MATLAB/Simulink environment [12]. A comparison between the numerical bisection method and fractional (voltage and current) based algorithms have been researched [13], the test of three algorithms has been done by the help of DC-DC boost converter and PI controller.

From previous statements, it is clear to say that the fractional voltage-based and Fractional current-based algorithms have been discussed and treated in a different way, but none of them presents the implementation of these methods of MPPT using the programmable logic controller (PLC).

The PLC is a specialized computer that has useful features and is used widely in industrial applications [14]. It is designed to work in a harsh environment such as high humidity, high temperature, and vibration. The user stores the application program into the PLC memory, and the PLC executes it. The PLC can receive user command through its input terminal or communication port. To dell with all memory locations of the PLC, the user should be using a PC or an HMI.

HMI (human-machine interface) is a special computer widely used in the industrial field. It allows the user to enter and update the PLC memory. The HMI has the facility to display and monitoring the PLC memory data. The HMI communicates with the PLC through one method of communication (serial communication, LAN port, etc.).

This paper aimed to present the implementation of the two algorithms (FOCV and FSCC) based on PLC-HMI in a laboratory platform that has many tasks related to the PV system concept.

2. Fractional Voltage and Current Based Mppt Techniques

The basic idea of these techniques based on the relationship between PV module parameters (voltage and current) and the environment conditions (irradiation and temperature). The maximum power point voltage and current are related to the PV module open-circuit voltage and short-circuit current as below

$$Vmp(G_i, T_i) = k_{vi}Voc(G_i, T_i) \quad (1)$$

$$Imp(G_i, T_i) = k_{ii}Isc(G_i, T_i) \quad (2)$$

Where Vmp and Imp are PV module maximum power point voltage and current respectively, Voc and Isc are PV module open circuit voltage and short circuit current, Kv and Ki are voltage and current fractional constant, G is irradiation level, and T is temperature level. The subscript (i) refers to the instant of measuring.

The variation range of the Kv and Ki is from 0.71 to 0.78 and from 0.78 to 0.92 respectively in the practical system [15]. This variation in the fractional factors are small and can be approximated to constant. Under such assumption, the equations (1) and (2) can be written as

$$Vmp = k_v Voc \quad (3)$$

$$Imp = k_i Isc \quad (4)$$

The Vmp and Imp represent the reference values fed to the tracking algorithm controller to force the PV module operation point to the maximum power one. Figure 1 and Figure 2 represent the schematic block diagram of a PID based controller in which the Vmp and Imp are the reference values, the I and V are the present values, and the duty cycle is the manipulated value.

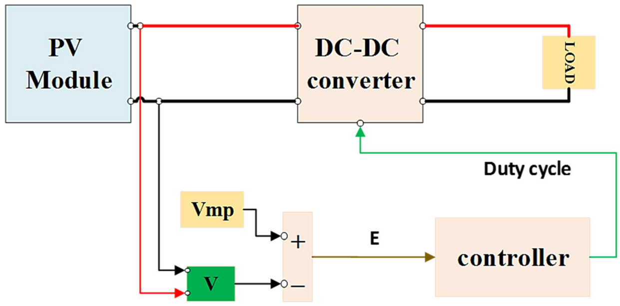


Figure 1. *Schematic block diagram of the FOCV MPPT.*

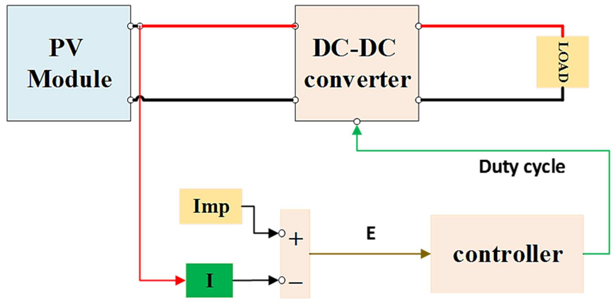


Figure 2. *Schematic block diagram of the FSCC MPPT.*

3. The Proposed Platform Hardware

The proposed laboratory platform has been designed to execute multi tasks related to the PV system, such as simulation of the PV cell/module, simulation of widely used PV array maximum power point tracking techniques, and operation of famous MPPT algorithms in real-time mode. This paper focuses on explaining the operation of two MPPT algorithms in real-time, which are fractional voltage-based and fractional current-based.

3.1. Hardware Component of the Platform

Figure 3 shows the proposed platform block diagram. Figure 4 shows the whole proposed laboratory platform and the components involved in this work described below:

XEC-DR28UA/DC: programmable logic controller to implement the MPPT algorithms.

XBF-AH08E: analog module used to convert signals from analog form to digital form and verse Versa in this work two input channels (A/D) were used, and one output channel (D/A) was used.

XP30-TTA/DC: human-machine interface to allow the user to input and control the different activities such as start or stop the process and choosing step size.

MIMI DC DRIVE: (DC-DC converter), DC 6-60V, 30 A support PLC analog control.

ABL8REM24050: 24V, 5A DC power supply used to power the PLC, HMI, and other components in the platform.

RMCA61BD: analog current converter used to convert the drawn current from PV module (0-15A) into a suitable signal (0-10V) to analog module.

RMCV60BD: analog voltage converter used to convert the measured voltage of the PV module (0-50V) into a suitable signal (0-10V) to analog module.

LC1D09BD: magnetic contactor to connect the PV module with the load on the platform.

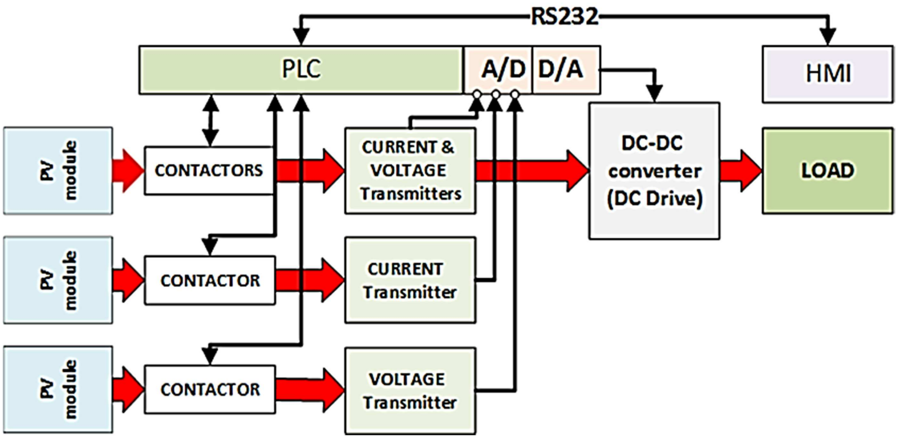


Figure 3. *The proposed platform diagram.*

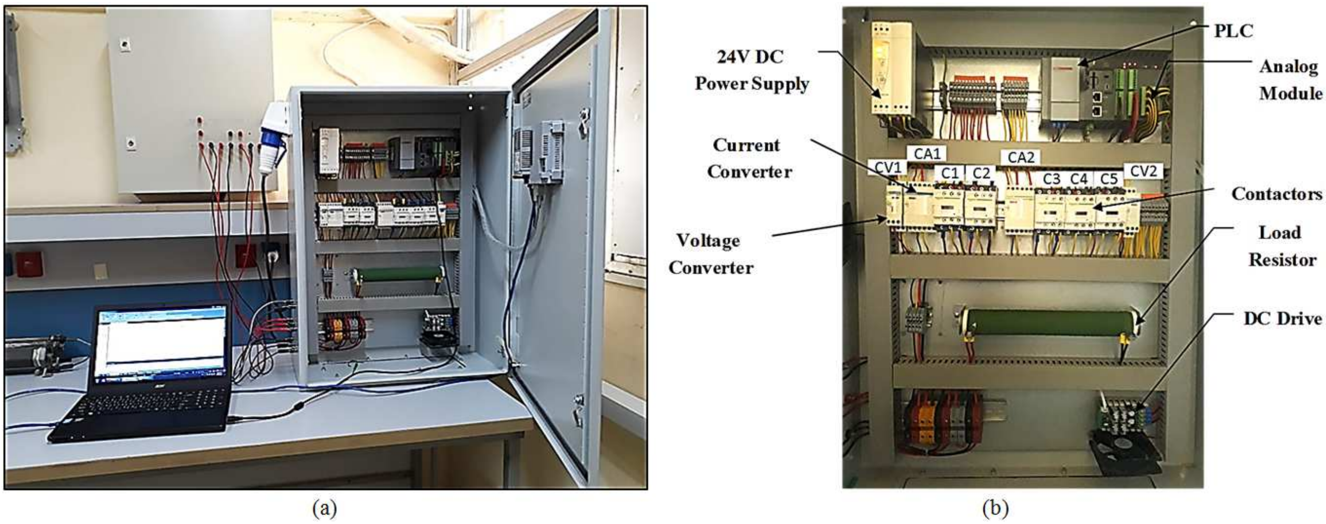


Figure 4. *Proposed platform a) front view b) inside view.*

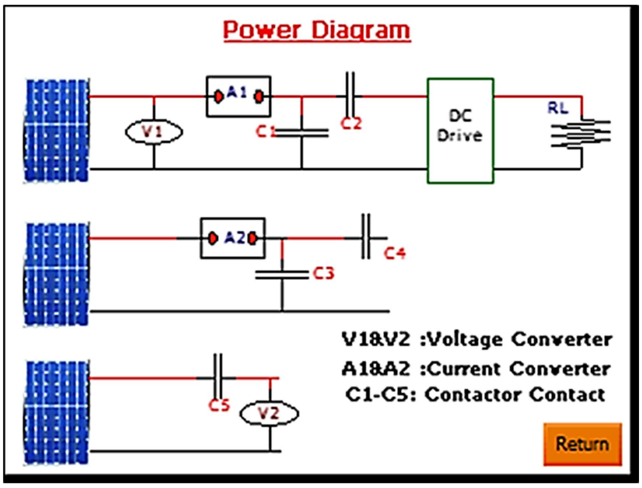


Figure 5. *Power configuration of the proposed system.*

3.2. Power Configuration

Figure 5 shows the Power configuration of the proposed platform to operate the FOCV and FSCC techniques in real-time mode. From this figure, the open-circuit voltage can be measured from PV module under test (open the contactors C1 & C2) or from a pilot module (close C5), and the short-circuit current can be measured from the PV module under test (close C1 & open C2) or from a pilot module (Close C3).

4. The Proposed Platform Software

Two software will be discussed in the next section, one for PLC utility, and another for HMI utility.

4.1. PLC Utility

The PLC utility related to the fractional voltage-based and fractional current-based techniques does three functions. The first is reading the PV module voltage, current, and calculate the output power. The second one deals with the parameter setting of the PID controller. The third one outputs the control signal to the DC-DC converter.

PV module parameter (voltage and current) reading and power calculation

VI1:=WORD_TO_INT(IN:=%UW0.1.3); //READ VOLTAGE 1

VI2:=WORD_TO_INT(IN:=%UW0.1.5); //READ VOC

II1:=WORD_TO_INT(IN:=%UW0.1.4); //READ I

II2:=WORD_TO_INT(IN:=%UW0.1.6); // READ ISC

V:=(VI/VSCALE);// NORM V1 AND SCALING

I:=II/ISCALE; // NORM I AND SCALING

P:=V*I; // POWER CALCULATION

PID parameter setting

// FRACTIONAL VOC-BACED

%KD629:=%KD25; // KP FOR PID

%KD630:=%KD26; // TI FOR PID

%KD631:=%KD27; // TD FOR PID

%KX19249:=1; //ANTI WIND (0 ENABLE)

%KX19201:=%MW275.4;//PID A/MANUAL SELECT

MVV:=WORD_TO_INT(IN:=%MW287);

%KW1268:=INT_TO_WORD(IN:=MVV); // MV MANUAL INPUT

%KW1266:=100; //PID MAXIMUM MV

%KW1267:=0; // PID MIN MV

%KW1264:=%KW56; // PID PV CHANGE MAX

%KW1265:=%KW57; // PID MV CHANGE MAX

%KX19233:=1;//PID DIRECTION (1 REVERSE)

%KW1287:=%MW293; // PV MAX LIMIT

%KW1256:=INT_TO_WORD(IN:=VSV); // SV INPUT TO PID

%KW1269:=%MW288; // PV FOR PID

CONTROLLER1(REQ:=%MW275.0 AND %KW0.0, BLOCK:=0, LOOP:=1);

%KD669:=%KD41; // KP FOR PID

%KD670:=%KD42; // TI FOR PID

%KD671:=%KD43; // TD FOR PID

%KX19203:=%MW401.1; //PID A/MANUAL SELECT

MVV:=WORD_TO_INT(IN:=%MW412);

%KW1348:=INT_TO_WORD(IN:=MVV); // MV MANUAL INPUT

%KW1346:=100; //PID MAXIMUM MV

%KW1347:=0; // PID MIN MV

%KW1344:=%KW88; // PID PV CHANGE MAX

%KW1345:=%KW89;// PID MV CHANGE MAX

%KX19235:=0; //PID DIRECTION (1 REVERSE)

%KW1367:=INT_TO_WORD(IN:=ISC1); // PV MAX LIMIT

%KW1336:=INT_TO_WORD(IN:=ISV); // SV INPUT TO PID AND HMI

%KW1349:=INT_TO_WORD(IN:=I1); // CALCULATE PV FOR PID

CONTROLLER2(REQ:=%MW400.0, BLOCK:=0, LOOP:=3);

Control signal output

D:=WORD_TO_INT(IN:=%KW1271);// OUTPUT OF PID FOR VOC-BASED

D:=WORD_TO_INT(IN:=%KW1351);// OUTPUT OF PID FOR ISC-BASED

4.2. HMI Graphical Interface

To operate the FOCV and FSCC techniques in real-time, many HMI screens have been introduced. Each screen has its function. These screens and its service are listed below.

MPPT technique navigation screen (Figure 6): this base screen used to select which algorithm the user wants to run.

FOCV technique screen (Figure 7): in this base screen, the user can navigate to the PID parameters setting popup window, enable or disable the controller contributor (P, I, D), observe the PV module voltage, current, power, and DC-DC converter duty cycle, and open the P-V curve plotting popup window.

FSCC technique screen (Figure 8): this base screen helps the user to open the PID parameters and P-V curve plotting popup windows. Also, this screen supports the monitoring of the PV module voltage, current, power, and DC-DC converter duty cycle.

PID parameters screens (Figure 9): these screens introduced to help the user to allow the user to enter the different values of the PID parameters as sampling time (Ts), integration time constant (Ti), and the differential time constant (Td). It also provides a facility to set the current factor, voltage factor, and set the maximum change of the present and manipulated values.

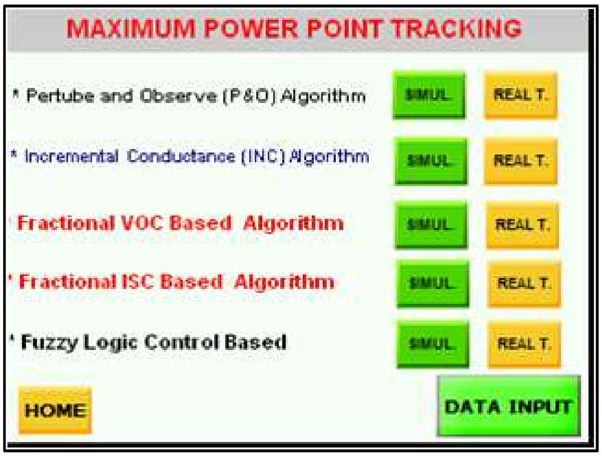


Figure 6. *The MPPT algorithm navigation screen.*

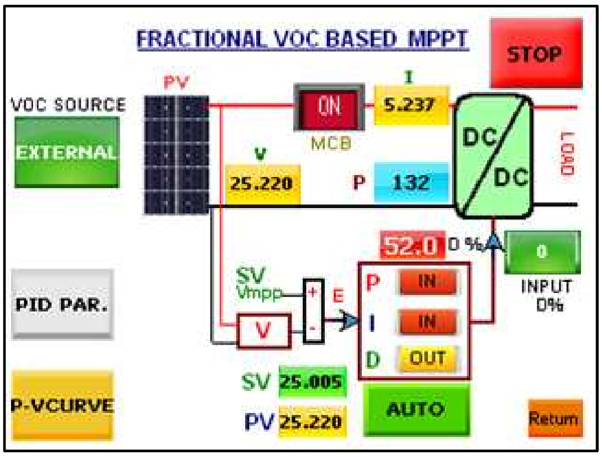


Figure 7. *The FOCV technique screen.*

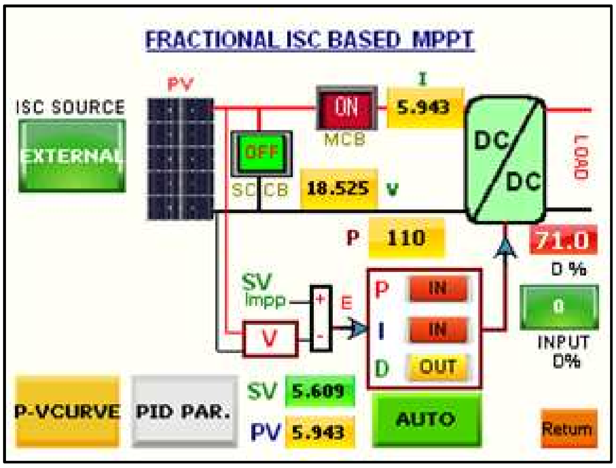
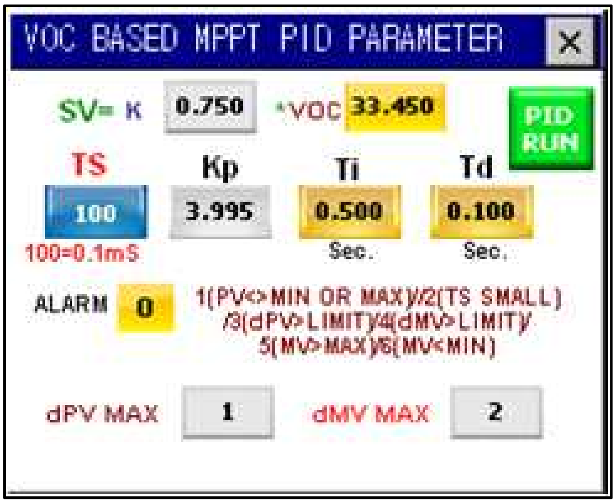


Figure 8. The FSCC technique screen.

(a)



(b)

Figure 9. The PID parameter popup window a) for FOCV technique b) for the FSCC technique.

5. The Experimental Examples

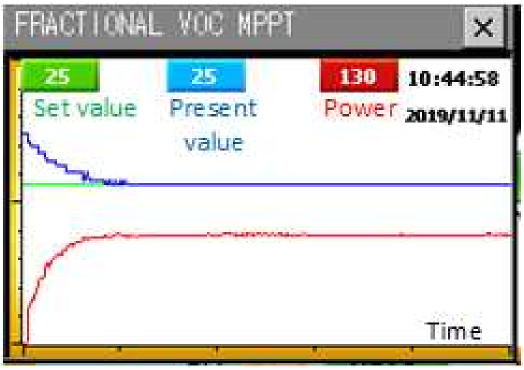
To test the fractional voltage-based and fractional current-based techniques under the different set of the PID controller parameters, the PRO SOLAR PS-660250 module has been used. The PRO SOLAR PS-660250 electrical parameters are illustrated in Table 1.

***Table 1.** Electrical data for PROPSOLAR PS-P660250 module.*

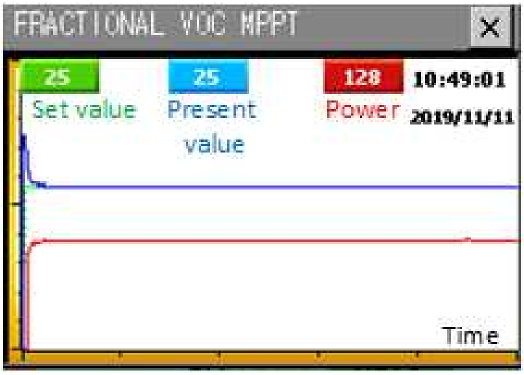
Parameter	Value
Maximum power (P_{mp}) [Watt]	250 W
Voltage at MPP (V_{mp}) [Volt]	30.8 V
Current at MPP (I_{mp}) [Ampere]	8.14 A
Open-circuit voltage (V_{oc}) [Volt]	38.2 V
Short-circuit current (I_{sc}) [Ampere]	9 A
Maximum power tolerance	+3%
Temperature coefficient of open circuit voltage (K_V)	-0.33%/°C
Temperature coefficient of short circuit current (K_I)	+0.058%/ °C

5.1. FOCV Technique Controller Response

To test the validity and effectiveness of this approach under the different settings of the PID controller parameters. Here two cases have been drawn, one for the (Kp=2.09, Ti=1.2, Td=0.1), which shown in Figure 10-a, and the second for (Kp=3.99, Ti=0.5, Td=0.2) which shown in Figure 10-b.



(a)

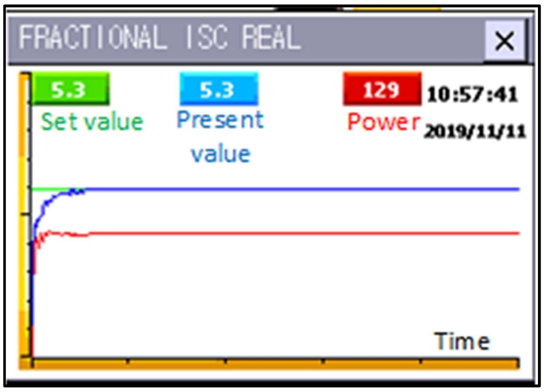


(b)

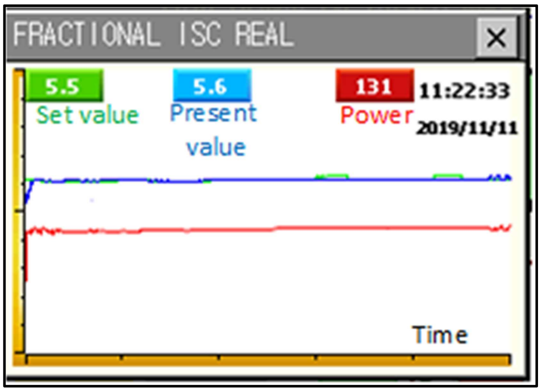
Figure 10. Output power response for Fractional Voc based MPPT a) For Kp=2.09, Ti=1.2, Td=0.1 b) For Kp=3.99, Ti=0.5, Td=0.2.

5.2. FSCC Technique Controller Response

To test this approach under the different settings of the PID controller parameters. Here two cases have been drawn, one for the (Kp=3, Ti=1.2, Td=0.8), which shown in Figure 11-a, and the second for (Kp=4, Ti=0.9, Td=0.1) which shown in Figure 11-b.



(a)



(b)

Figure 11. *Output power response for Fractional Isc based MPPT a) For Kp=3, Ti=1.2, Td=0.8 b) For Kp=4, Ti=0.9, Td=0.1.*

6. Conclusion

The proposed implementation of the fractional voltage and current based MPPT techniques by using PLC and HMI in a laboratory platform can be considered as user-friendly and convenient for educational and practical purposes. The user can test and experiment with many factors influence the MPPT techniques under consideration like the effects of changing PID contributors and parameters and the closeness of extracted power from the PV module to its maximum one when changing the fractional voltage and current factors.

References

[1] 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 Transaction on Energy Conversion, vol. 17, no. 4, pp. 514–522, (2002).

[2] M. A. Fadhil and J. R. Mahmood, "PLC-HMI based simulation of PV cell and array behavior"; Iraqi Journal of Electrical and Electronic Engineering, vol. 15, No 2, (2019).

[3] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Transaction on Energy Conversion, vol. 22, no. 2, pp. 439–449, (2007).

[4] U. Chauhan, V. singh, B. Kumar, and A. rani, "An improved MVO assisted global MPPT algorithm for Partially shaded PV system", Journal of Intelligent & Fuzzy Systems Preprint: 1-12, (2020).

[5] U. Chauhan, V. singh, B. Kumar, and A. rani," A Modified Incremental Conductance MPPT method for Standalone PV System", International Conference on Signal Processing and Integrated Networks, pp. 61-64, (2020).

[6] B. Y. Zhao, Z. G Zhao, Y. LI, R. Z Wang, R. a. Taylor, "An adaptive PID control method to improve the power tracking performance of solar photovoltaic air-conditioning system", Renewable and Sustainable Energy Reviews, 113, 109250, (2019).

[7] G. Remy, O. Bethoux, C. Marchand, and H. Dogan, "Review of MPPT Techniques for Photovoltaic Systems," IEEE Transactions on Industrial Electronics, no. June 2016, (2009).

[8] U. Chauhan, V. singh, B. Kumar, and A. rani, " An Improved Fractional Voltage based Mppt technique for PV Generation System", International Conference on Advances in Computing, Communication& Materials, pp. 267-271, (2020).

[9] T. Noguchi, S. Togashi, and R. Nakamoto, "Short-Current Pulse-Based Maximum-Power-Point," IEEE Transaction on Energy Conversion, vol. 49, no. 1, pp. 217–223, (2002).

[10] M. Lasheen, A. K. A. Rahman, M. Abdel-Salam, and S. Ookawara, "Adaptive reference voltage-based MPPT technique for PV applications," IET Renewable Power Generation., vol. 11, no. 5, pp. 715–722, (2017).

[11] S. Negi, A. Maity, A. Patra, and M. Sharad, "Adaptive fractional open circuit voltage method for maximum power point tracking in a photovoltaic panel," Proceedings - 32nd International Conference on VLSI Design, VLSID 2019 - Held concurrently with 18th International Conference on Embedded Systems, ES 2019, pp. 482–487, (2019).

[12] D. P. Quoc et al., "The new combined maximum power point tracking algorithm using fractional estimation in photovoltaic systems," Proceedings of the International Conference on Power Electronics and Drive Systems, no. December, pp. 919–923, (2011).

[13] M. M. Shebani, T. Iqbal, and J. E. Quaicoe, "Comparing bisection numerical algorithm with fractional short circuit current and open circuit voltage methods for MPPT photovoltaic systems," 2016 IEEE Electrical Power and Energy Conference, EPEC 2016, (2016).

[14] J. R. Mahmood, R. S. Ali, H. Migdadi, R. A. Abd-Alhameed, and E. M. Ibrahim, "Development of educational Fuzzy control laboratory using PLC and HMI," 2015 Internet Technologies and Applications, ITA 2015 - Proceedings of the 6th International Conference, no. October 2016, pp. 383–387, (2015).

[15] T. W. Hsu, H. H. Wu, D. L. Tsai, and C. L. Wei, "Photovoltaic Energy Harvester With Fractional Open-Circuit Voltage Based Maximum Power Point Tracking Circuit," IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 66, no. 2, pp. 257–261, (2019).