Experimental Approach of the Behavior of a Multiphase High Gain dc-dc Converter on a Photovoltaic System operating under Variable Irradiation

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Abstract

Background: The performance of a modified multiphase ultra-high gain converter for a solar PV system under variable irradiation conditions is investigated in this paper. The resultant voltage of the intended converter is extremely high, less power loss and low voltage stress. Low stress across the switches makes use of utilization of low rated components which makes the converter cost efficient and reliable. This paper mainly focuses on developing the geometrical model of a PV system using one diode model that depicts the real time PV array with various level of exposure to sunlight. The results of matlab simulation are compared with real time hardware results and validated. The study mainly helps in interpreting the results of any converter with variable insolation and under real time operating conditions.

1. Introduction

Among flow sources, PV systems has reached greater heights due to its excellent features like direct power conversion from sunlight to electricity, availability in abundant, clean source of energy without any byproduct, easy maintenance and many more (1). Though it has several advantages, output power or voltage fluctuation and low voltage output are some of the common problem that exists in solar pv systems. Hence a high voltage gain converter with interleaving architecture is projected here. The proposed converter achieves a maximum voltage gain, reduced voltage and current stress, reduced losses and higher power conversion efficiency. In the paper,[2] the author has describes the performance of the converter with solar radiation as input and the results were analyzed. Nevertheless it is known that PV produces a fluctuating output due to variation in the solar radiation and temperature. The performance of various inverter architectures for solar PV systems with variable irradiation has been investigated (3). The output power output of the

photovoltaic system is a nonlinear function that varies with respect to the irradiance, temperature and load parameters. To obtain a quality output from a PV source, a converter with best MPPT algorithm has been incorporated. To design a suitable MPPT for a converter, the performance of the converter with variable irradiance has to be studied and analyzed (4). The performance of the proposed converter with PV array as the source with variable irradiance conditions is mainly focused in the proposed paper. A novel modeling technique to accurately track the behavior of the system with respect to temperature variations and insolation variation. A new architecture that fuses Adaptive Network-Fuzzy Inference System (ANFIS) and Takagi-Sugeno for MPPT under variable irradiance conditions is discussed (5). Gray wolf optimization MPPT algorithm is adopted in this system (6) A hybrid system for micro grid applications that feed a nonlinear load is discussed in this paper (7). Stability in output under nonlinear load conditions and power quality improvement is achieved by a new filtering technique (6). A high accurate PSPICE model using diodes that exactly depicts the electrical behavior of the pv system under fluctuating temperature and insolation conditions is presented in (8-10). The losses that occurs due to recombination in diode is eliminated by adding a diode in parallel. Apart from load management in pv standalone systems using a novel MPPT technique, harmonic analysis using FFT tool is implemented (11). Comparative study of PV system under fluctuating irradiance conditions using different MPPT algorithms is investigated (12). In this paper, an extremely high gain converter with low voltage stress, low inductor ripple with maximum efficiency with PV array as a source is proposed. Radiation from sunlight is not a constant factor, it keeps fluctuating. Effect of variable irradiance on the behavior of the proposed converter with pv source is investigated.

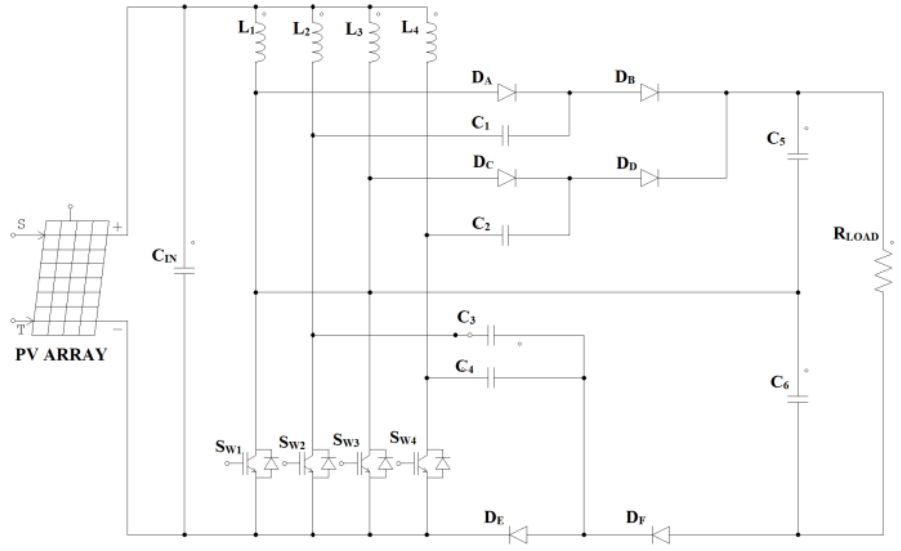

Fig. 1 Circuit diagram of a four phase high gain converter

2. Proposed Converter

The power circuit of a High gain converter fused with interleaving technique is shown in figure 1. The circuit is powered by a pv source which has a PV array. The PV array is constructed with 2 PV modules in series and 11 PV modules in parallel. The Matlab Simulink model to obtain the PV and VI characteristics is shown in figure 2.

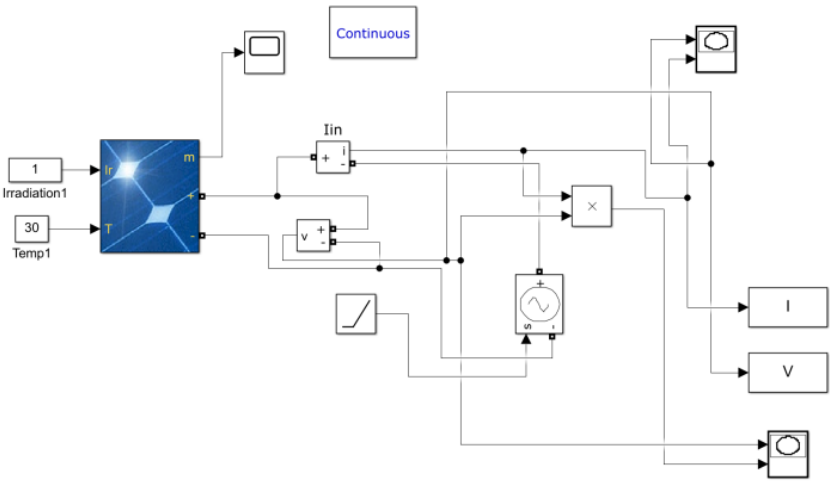

Fig. 2 Circuit diagram of a four phase high gain converter

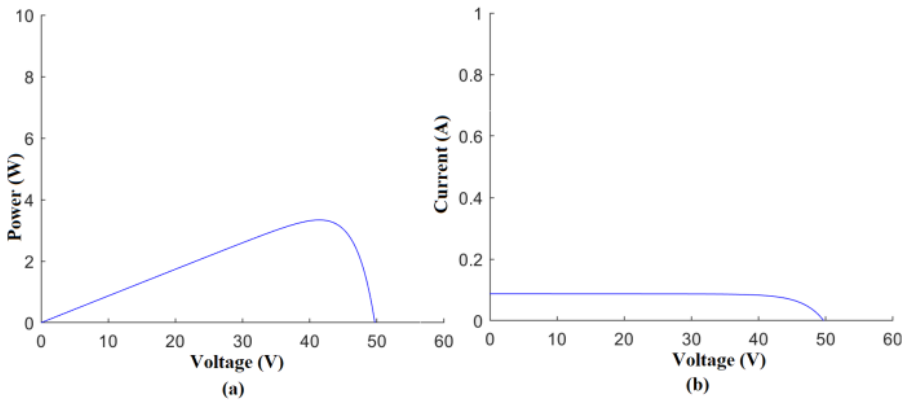

Fig. 3 a. Electrical Characteristics of the PV array

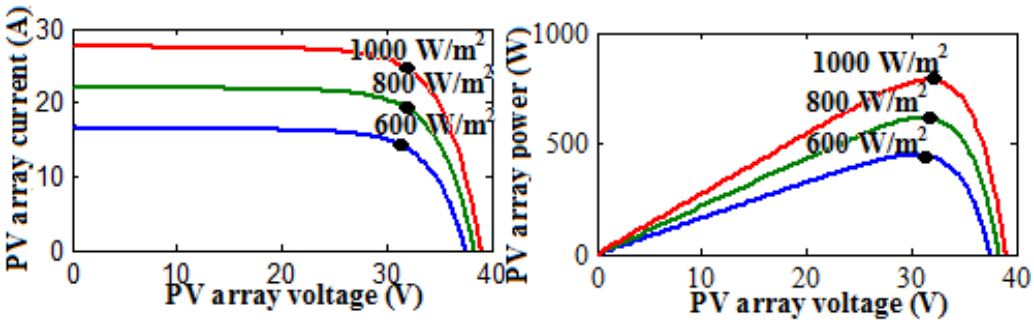

Fig. 4 a. I Electrical Characteristics of PV array under variable insolation

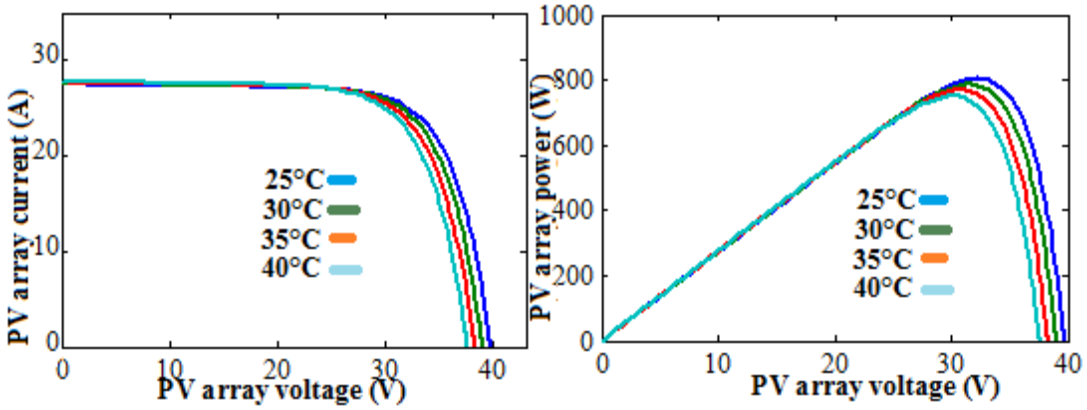

Fig. 5 a. I-V Characteristics b. P-V Characteristics of the PV array under variable temperature

Figure 3 show the electrical characteristics of the PV array. The electrical characteristics of the PV array under variable insolation values are shown in Figure 4. Figure 5 shows the electrical characteristics under variable temperature values. Figure 5 shows the modes of operation of the proposed converter. It operates in four modes. In each mode two MOSFETs are under conduction. Each switch stays in ON condition for 180º.

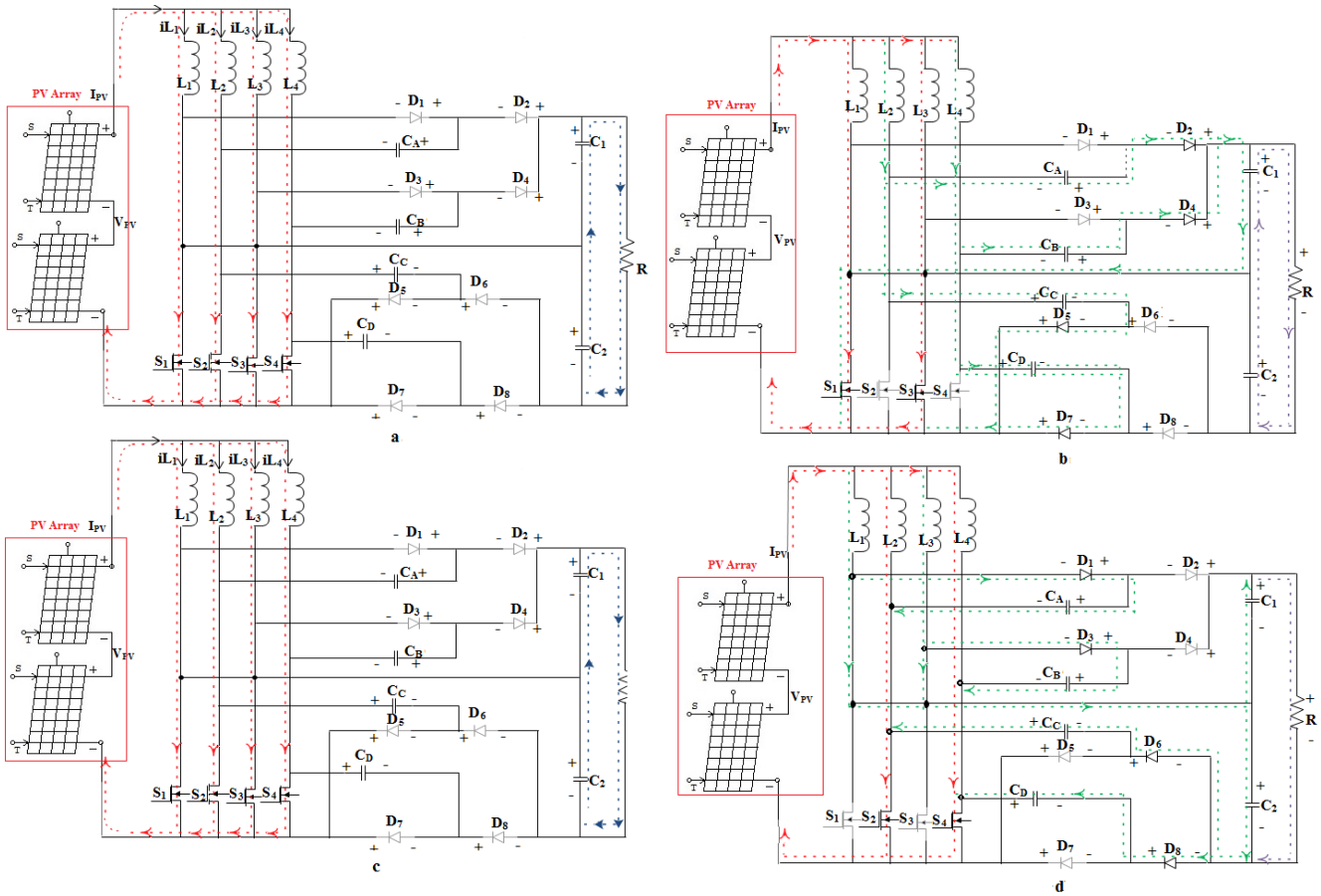

Fig. 6 Four modes of operation of the proposed converter

A multiphase high gain dc-dc converter that achieves maximum voltage gain about 24 times of the input supply is proposed here. The proposed topology consists of four switches and works in four modes of operation. Each switch operates with an angle of 180º. Under each mode of different combinations of switches are under conduction. The four modes of operation of the proposed circuit is shown in figure.. In mode 1, all the four switches S_1, S_2, S_3 and S_4 conducts and all the four inductors gets charged. In Mode 2, S_2 and S_4 are turned off maintaining S_1 and S3 to be in on state. L_1 and L_3gets charged. Part of energy deposited in the inductor L_2 and L_4 is discharged. In mode 3, again all the four switches conducts and the inductors gets charged. In mode 4, S_2 and S_4 are turned on and S_1 and S_3 are turned off. The Part of energy deposited in the inductor L_1 and L_3 is discharged to the load.

3. Simulation results

The behaviour of the converter under real time conditions can be well understood only after investigating the converter performance under variable temperature and irradiation. Proper control methods can be developed only after the voltage, current and power waveforms are observed for variable temperature and irradiation conditions as the irradiation and temperature of the sunlight is not a constant function, it keeps changing. The simulation results of the in and out voltage under variable insolation for a open loop system are observed in figure 7a and b respectively. Figure 8 a and b shows the current entering from the source and leaving to the load under variable insolation for a open loop system. Figure 9 a and b shows the supply power and output power under variable insolation for a open loop system.

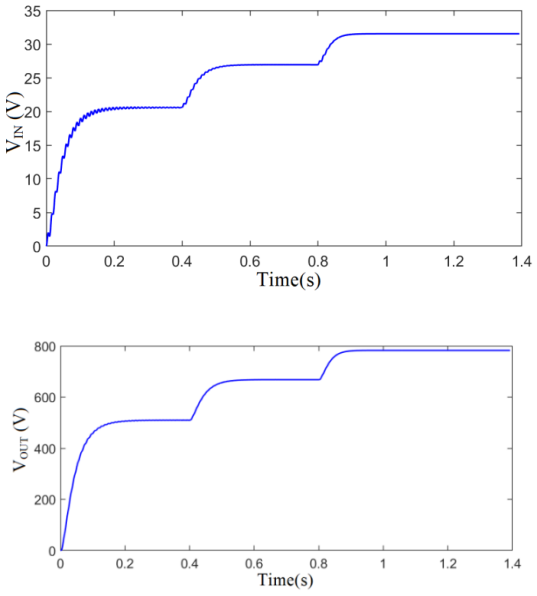

Fig. 7. (a) Input voltage under variable insolation (b) Output voltage under variable insolation

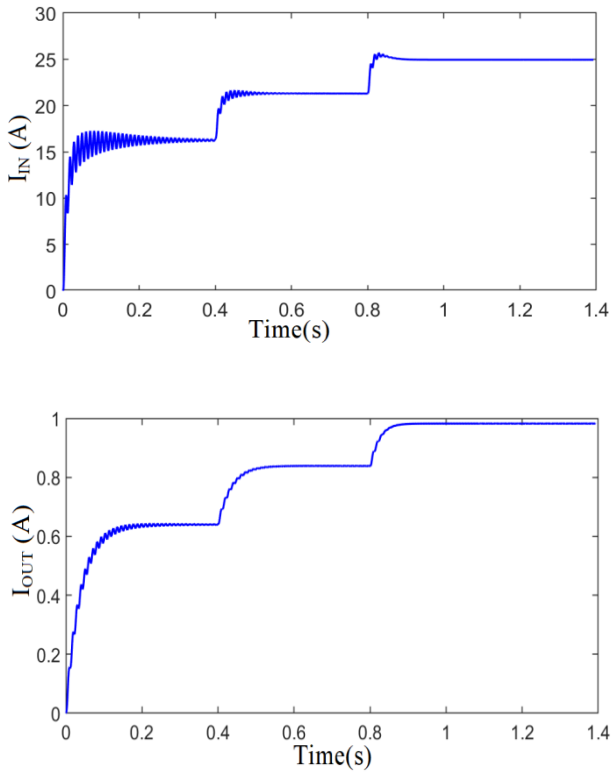

Fig. 8. (a) Input current under variable insolation (b) Output current under variable insolation

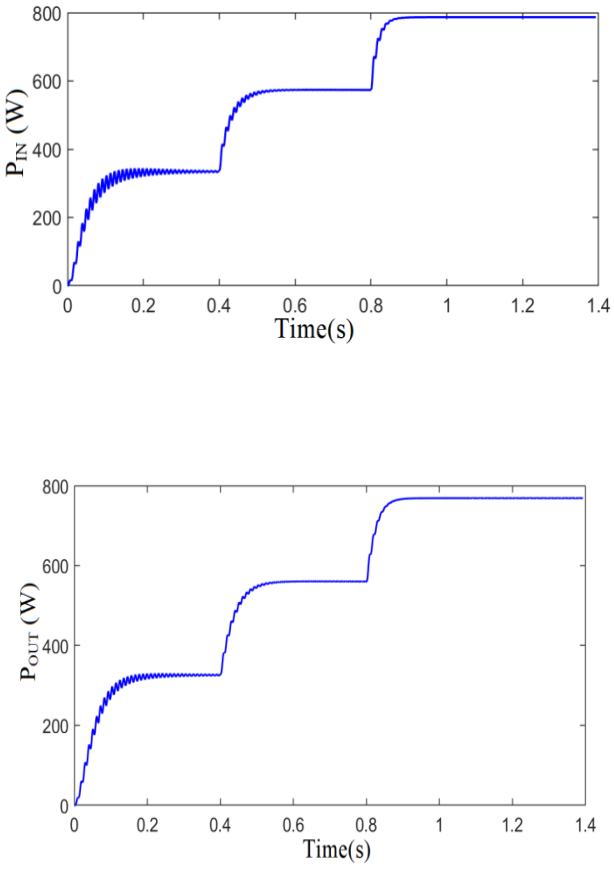

Fig. 9. (a) Input power under variable insolation (b) Output power under variable insolation

4. Hardware results

The source voltage, output voltage of the real time proposed converter under variable insolation for a open loop system are observed in figure 11 a and b respectively. Figure 12 a and b shows the input current and output current under fluctuating insolation for a open loop system.

Fig. 10. (a) Hardware setup of the proposed converter

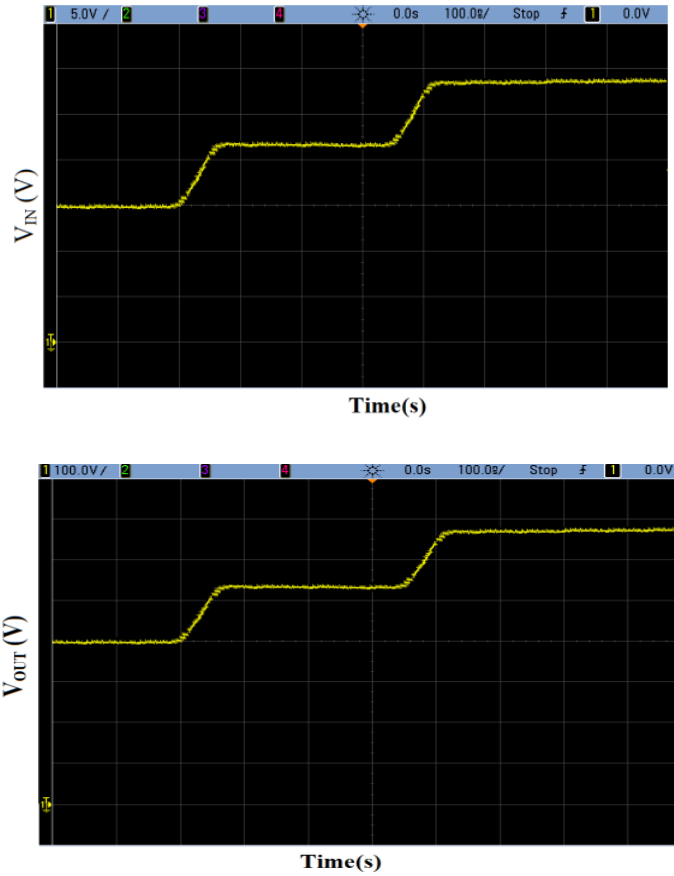

Fig. 11. (a) Hardware results of input and output voltage of the proposed converter

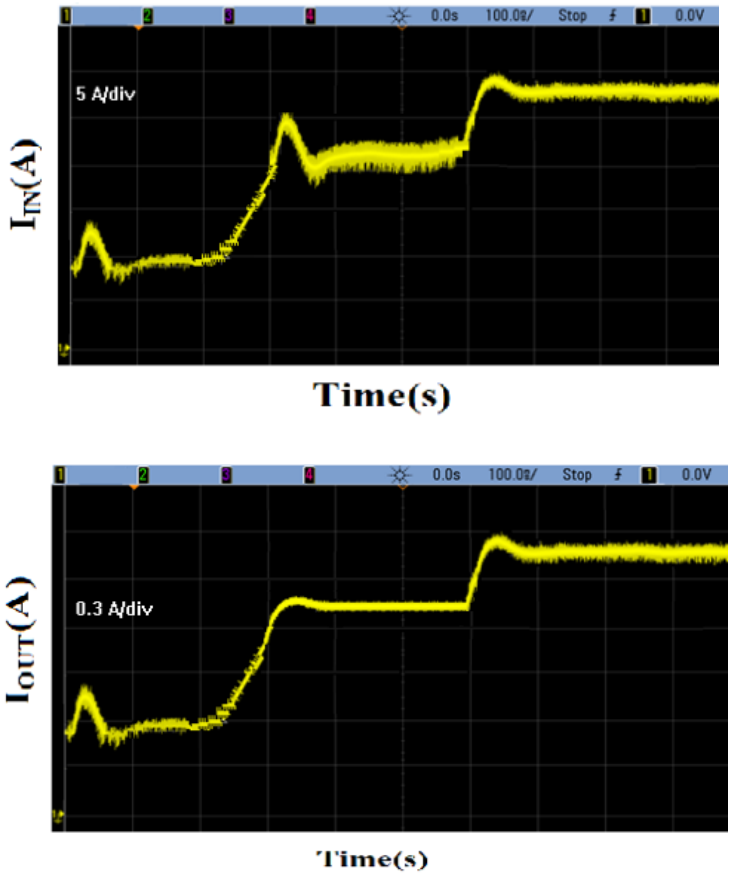

Fig. 11. (a) Hardware results of input and output current of the proposed converter

5. Conclusion

The performance of the multiphase high gain converter with PV as the source under variable insolation and variable temperature are analyzed. With the performed analysis, researcher can easily develop suitable control algorithm for the proposed converter under variable insolation and temperature conditions. In real time PV produces the output based on insolation and temperature. This paper also enumerated the characteristics of the proposed PV array under variable solar radiation and fluctuating temperature conditions.

Refrences

[1]. N. Nordin, S. I. Sulaiman and A. M. Omar, "Prediction of AC power output in grid-connected photovoltaic system using Artificial Neural Network with multi-variable inputs," 2016 IEEE Conference on Systems, Process and Control (ICSPC), 2016, pp. 192-195, doi: 10.1109/SPC.2016.7920728

[2]. Lakshmi S, Ramaprabha R “A novel multiphase interleaved quadrupler circuit with reduced voltage stress and ripples for photovoltaic applications”. International Transactions on Electrical Energy Systems, Jan 2020; https://doi.org/10.1002/2050-7038.12317

[3]. T. T. Thong, T. T. Huan, C. Van Kien and H. P. H. Anh, "An Advanced Fuzzy Control for Maximum Power Point Tracking PV System Optimized with Modified MDE Algorithm," 2021 International Conference on System Science and Engineering (ICSSE), 2021, pp. 69-76, doi: 10.1109/ICSSE52999.2021.9538458.

[4]. M. V. M. Kumar, R. S. Kumar, G. V. Prajwal and S. B. Ramakrishna, "A study on development of PV cell/module and output power variation based on two-diode model," 2017 International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 2017, pp. 587-592, doi: 10.1109/ICIMIA.2017.7975528.

[5]. M. T. A. Khan, T. Tanaka, B. Tan, R. Dagstanyan and J. Borland, "Hybrid String Inverter with Energy Storage for Grid Independent Power System," 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC) (A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC), 2018, pp. 0573-0578, doi: 10.1109/PVSC.2018.8547655.

[6]. M. M. Eshak, M. A. Khafagy, P. Makeen and S. O. Abdellatif, "Optimizing the performance of a stand-alone PV system under non-uniform irradiance using Gray-Wolf and hybrid neural network AI-MPPT algorithms," 2020 2nd Novel Intelligent and Leading Emerging Sciences Conference (NILES), 2020, pp. 600-605, doi: 10.1109/NILES50944.2020.9257965.

[7]. S. Murshid, B. Singh, H. B. Gooi and Y. S. Eddy Foo, "Implementation of Frequency Adaptive Damped SOGI Based Control for Power Quality Improvement in Wind-Solar-BES Based AC Microgrids," 2021 IEEE Power & Energy Society General Meeting (PESGM), 2021, pp. 1-5, doi: 10.1109/PESGM46819.2021.9637979.

[8]. M. E. Elnagi Mahmoud, A. A. ZakiDiab and D. A. Kotin, "Simulation and Experimental Validation of Two-Diode Model of Photovoltaic (PV) Modules," 2018 XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), 2018, pp. 244-251, doi: 10.1109/APEIE.2018.8546293.

[9]. X. Ma, S. Bader and B. Oelmann, "On the Performance of the Two-Diode Model for Photovoltaic Cells Under Indoor Artificial Lighting," in IEEE Access, vol. 9, pp. 1350-1361, 2021, doi: 10.1109/ACCESS.2020.3047158.

[10]. J. Xue et al., "Low-Voltage, High-Brightness Silicon Micro-LEDs for CMOS Photonics," in IEEE Transactions on Electron Devices, vol. 68, no. 8, pp. 3870-3875, Aug. 2021, doi: 10.1109/TED.2021.3085541.

[11].] K. S. Prakash Oruganti, C. A. Vaithilingam, G. Rajendran, A. Ramasamy and R. A. Gamboa, "Performance Evaluation of Maximum Power Point Algorithms for Annulling the Effect of Irradiance and Temperature for Standalone Electric Vehicle Charger," 2021 Innovations in Power and Advanced Computing Technologies (i-PACT), 2021, pp. 1-6, doi: 10.1109/i-PACT52855.2021.9696741.

[12].] K. W. Hugues and S. P. Daniel Chowdhury, "An African solution for water and electricity supply, using a standalone photovoltaic based Quasi Z Source Inverter," 2016 IEEE PES Power Africa, 2016, pp. 291-295, doi: 10.110