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DC-DC Converter with Active Switched LC Network for PV System Along with MPPT

Kalarathi M[1*] and Gnanavadivel J[2]

[1]*Associate Professor, Mepco Schlenk Engineering College, Sivakasi, India; rathigkl@mepcoeng.ac.in*
[2]*Associate Professor, Mepco Schlenk Engineering College, Sivakasi, India; gvadivel@mepcoeng.ac.in*

***Correspondence:** Kalarathi M; rathigkl@mepcoeng.ac.in

ABSTRACT- To get maximum power from Photo Voltaic (PV) panel, a DC-DC converter is operated with an active switched LC-network and a fuzzy controller, which boosts the output voltage by utilizing Maximum Power Point Tracking (MPPT). In areas where solar energy is abundant, PV systems offer a low-cost source of electricity. Non-Polluting and low maintenance are two advantages of a PV system. There are several factors that can reduce the output of solar energy, including irradiance, temperature, and partial shading in the cells. A DC-DC converter with active switched LC networks can be used to provide constant output voltage. As the power outcome of the PV system is variable, Perturb and Observe (P and O) MPPT procedure obtains maximum output power. The output of P and O MPPT is compared with Fuzzy Logic Controller (FLC) MPPT and the results are presented.

Keywords: Active switched-inductor; Active switched-capacitor; Maximum Power Point Tracking.

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1. INTRODUCTION

Rising electricity demand, forces us to find a new and efficient ways of power production. The drawbacks of conventional way of electricity generating techniques such as pollution, high cost and extinction makes us to find renewable source of energy. The renewable energy source is cost efficient, non-polluting, and available in large amount. But they are non-reliable. Solar energy is vital one among the non-conventional resources. Its output varies due to the changing weather condition. The energy for sun rays can be extracted in two ways. One of the ways is heating the water by concentrating the solar rays in one particular point. Another one is using PV cell to convert it into electricity. But due the weather condition the output voltage and power will be varied.

The two variable parameters are solar irradiance and temperature. It is mentioned in the literature [1,2] the characteristics of the PV system as a function of temperature and irradiance. Accordingly, PV systems can provide maximum output during low temperatures and high solar irradiance. But variable output from PV system will affect the reliability of the system. Many researchers came forward to find the solution to make the output of the PV system as constant. As a result, they found that using a DC-DC converter and an analysis circuit, the output can be maintained as constant and the maximum output power possible can be obtained. DC-DC converter should be chosen such that the loss should be less, provides high gain and could be able to obtain maximum power with high efficiency.

Several high step up DC-DC converters are mentioned in the literature [3 -10]. There are various algorithms to track maximum power such as incremental conductance [11], model based rapid tracking [12], neural network method [13], genetic algorithm approach [14] and P and O technique [15]. Here, P and O method is implemented based on its advantages such as cost efficient, good performance and easy implementation. In [16], modified incremental conductance method is employed as MPPT algorithm. DC-DC converter used is boost converter and they have improved the efficiency and reduced the ripple content in the output.

In the paper [17], the P and O MPPT algorithm is used with boost converter connected to the grid. With large step times, the model in the paper [18] runs faster. In [19], P and O method and boost converter is used, and the converter's duty cycle value is controlled by the aforesaid algorithm. A comparison of the P and O method and the incremental conductance method in MATLAB is performed in [20] and it is determined that the P and O method improved the oscillation number, but Incremental conductance maintained accuracy. A DC-DC converter is used in tandem with a fuzzy controller in [21]. There is a combination of DC-DC Boost converters and P and O methods used in [22].

The DC-DC converter is used here with an active switched LC network in order to obtain high gain and efficiency. The MPPT is used as an analysis circuit. It takes output power and voltage of the PV system and calculates the duty ratio value for the switches in the DC-DC converter. It monitors the output of the PV system and for even a small change in the output and duty ratio value will be changed.

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2. MATERIALS AND METHODS

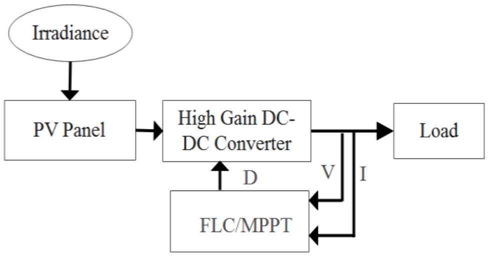

Figure 1: Block Diagram

A DC load is supplied by a solar generator via an adaptation stage consisting of a DC-DC converter operated based on the P and O MPPT charge controller that assumes maximum energy transfer efficiency. This flow is shown in the *figure 1*.

2.1 DC-DC Converter

A variety of applications require high-gain voltage conversion, particularly in grid-connected systems for power processing of low- voltage renewable sources. ASC is used in this suggested converter, while the voltage gain is boosted by a combined ASL and ASC networks. The suggested converter has a basic construction with low voltage strains on the extra diode and capacitor. *Figure 2* shows DC-DC converter circuit.

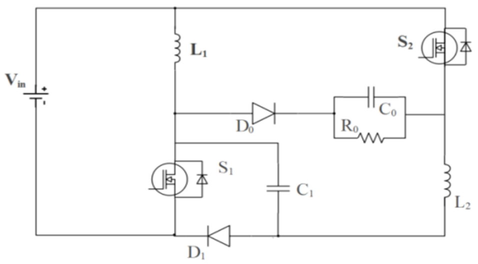

Figure 2: DC-DC Converter

The suggested converter includes two Continuous Conduction Modes (CCM) identified based on the currents of capacitor C_1, inductor L_1, and inductor L_2. To obtain the gain equation, we are considering only the CCM only. There are two time period Ton and Toff. During Ton, the gate signal will be given to the MOSFET switches. Both the inductors will become parallel to the source. In Toff period, the switches will act open switch. The inductor (L_1) will be connected with the capacitor (C_1). The capacitor will store the energy during period. The circuits during the on mode and off mode are shown in the *figures 3* and *4*.

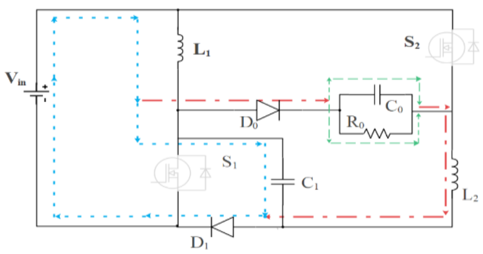

Figure 3: ON Mode Circuit

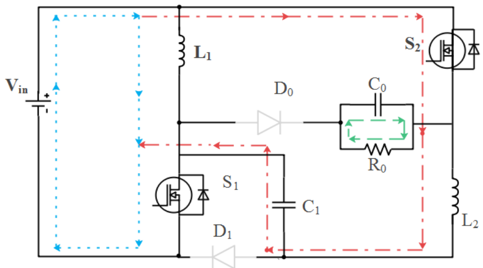

Figure 4: OFF Mode circuit

The current and voltage equations are given in (1) to (8).

During ON mode:

$$V_{L_1} = V_{in} \tag{1}$$
$$V_{L_2} = V_{in} + V_{C_1} \tag{2}$$
$$i_{C_1} = -i_{L_2} \tag{3}$$
$$i_{C_0} = -I_0 \tag{4}$$

During Off mode:

$$V_{L_1} = V_{in} - V_{C_1} \tag{5}$$
$$V_{L_2} = V_{C_1} - V_o \tag{6}$$
$$i_{C_1} = i_{L_1} - i_{L_2} \tag{7}$$
$$i_{C_0} = i_{L_2} - I_0 \tag{8}$$

The gain equation of the converter is obtained as mentioned below.

$$G = \frac{V_o}{V_{in}} = \frac{(1+D-D^2)}{(1-D)^2} \tag{9}$$

Figure 5 reveals the switching waveform of the DC-DC converter where the inductors will charge during ON mode and discharge during OFF mode. The capacitors will also charge during on mode and discharge during OFF mode. *Figure 6* portrays the plot between gain and duty ratio for different converters.

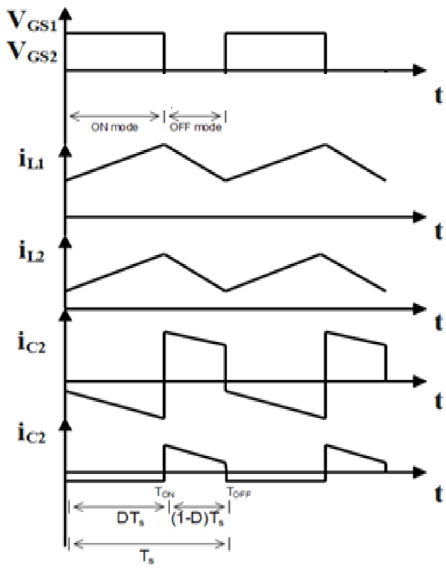

Figure 5: Switching Waveform of DC-DC Converter

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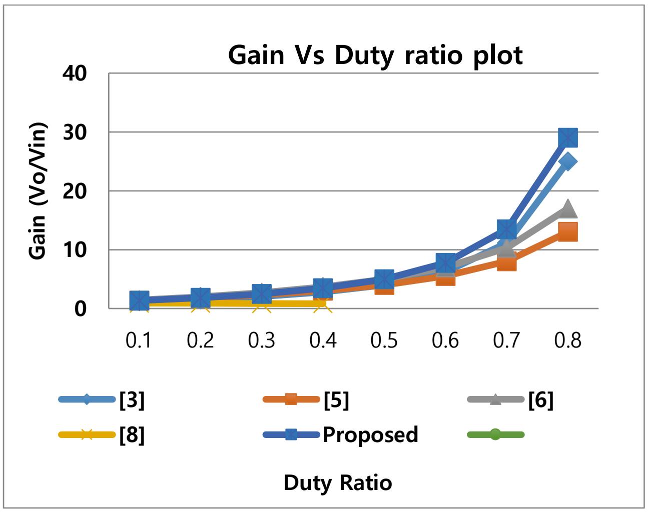

Figure 6: Gain Vs Duty ratio curve for different converters

2.2 Maximum Power Point Tracking

Because power output from the panel is reduced during rainy, gloomy weather, MPPT is employed to extract the maximum power from converter. PV system electrical properties affect maximum power point tracking.

2.2.1 P and O MPPT

The P&O MPPT algorithm is unaffected by environmental circumstances. With this approach, only a few parameters are controllable in a closed-loop regulator. This method is widely used in commercial systems because it is simple and involves only a few measured parameters. This method evaluates the output voltage, current, and power of a PV array's output and adjusts the duty cycle value in accordance with the maximum power point.

2.2.2 Fuzzy Controller Based MPPT

The FLC is an easy method to carry logical operations on the inputs. The process of converting input of the fuzzy logic control into fuzzy set based on the membership function of the input is known as fuzzification. Then based on the rules given, the output fuzzy set will be generated. Based on membership function of the output and defuzzification method, the output fuzzy set in converted into an integer value. There are various defuzzification methods. In this paper, we used centroid method.

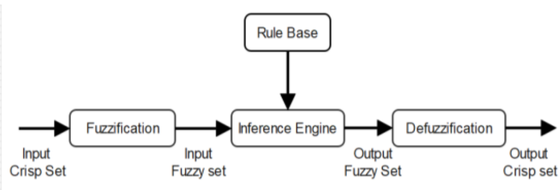

Figure 7: Control flow diagram of FLC

Figure 7 shows the control flow of the FLC which explain the conversion and comparison stages. The inputs of FLC are

$$E_n = \frac{dP}{dV} = \frac{(P_n - P_o)}{(V_n - V_o)} \quad (10)$$

$$CE = E_n - E_o \quad (11)$$

Where P_n denotes the output power from PV panel. E_n is the deviation in power with respect to deviation in voltage (error). CE denotes change in error. The output of the FLC is variation in duty cycle (*ΔD*). The input crisp set and output fuzzy set are converter into fuzzy set and crisp set based on the membership function.

3. RESULTS

3.1 Simulation Results

3.1.1 Simulation with P and O MPPT

The simulation of DC-DC converter with MPPT is done where input for the DC-DC converter is given from the PV panel and the voltage and current are measured and given to the MPPT tracking block in order to calculate the duty ratio. *Table 1* denotes the simulation parameters used.

Table 1: Converter Specifications

Parameters	Value
Supply Voltage	20 V
Output Voltage	200 V
Output Power	100 W
Switching Frequency(f_s)	50 kHz
Duty Ratio	0.65
Inductor value	L_1: 200 µH, L_2:800 µH
Capacitor value	C_1 : 22 µF,C_0 : 100 µF
Load Resistor	400 Ω

The *figure 8* shows the PV and IV curve of the PV panel for the irradiance value is fixed as 250W/m^2 and the temperature as 25°Celsius. The *figure 9* shows input power waveform along with MPPT that tracks the maximum power. Output waveform of DC-DC Converter along with the P and O MPPT is shown in the *figure 10*. The efficiency of the circuit is 74%. The *figure 11* illustrates the output power for variable irradiance.

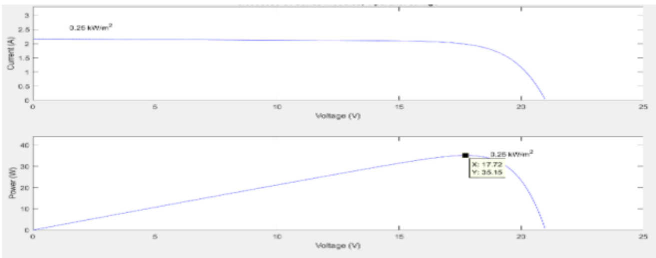

Figure 8: PV and VI curve for the PV panel

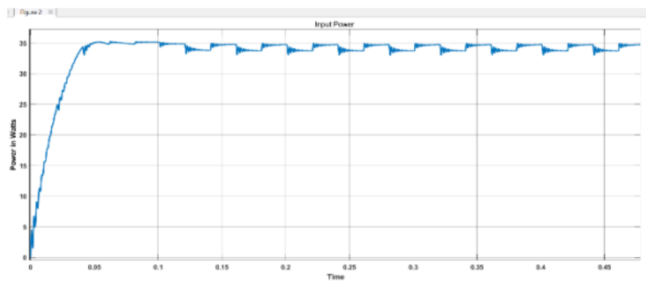

Figure 9: Power from the PV module

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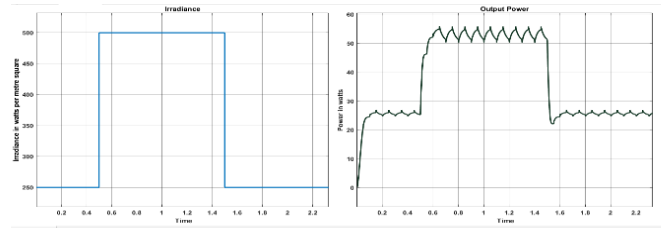

Figure 10: Output power of MPPT

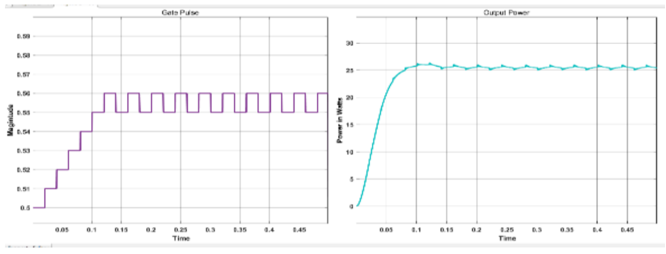

Figure 11: Output power of MPPT with different Irradiance level

3.1.2 Simulation with Fuzzy Controller MPPT

The simulation of DC-DC converter along with FLC is carried out where the input for the DC-DC converter is given from the PV panel and the voltage and current are measured and given to a function to calculate the slope and change in slope and this value will be given to the FLC in order to calculate the change in duty ratio. This value will be added to the previous duty ratio value.

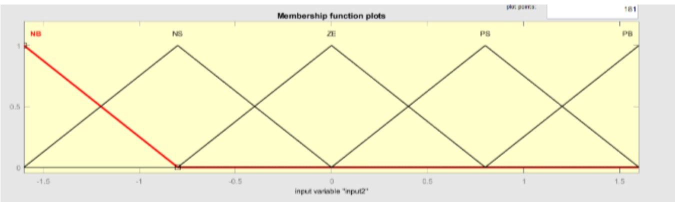

Figure 12: Input1 Membership function (Error)

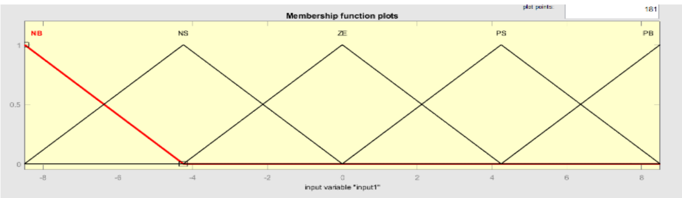

Figure 13: Input2 Membership function (change in Error)

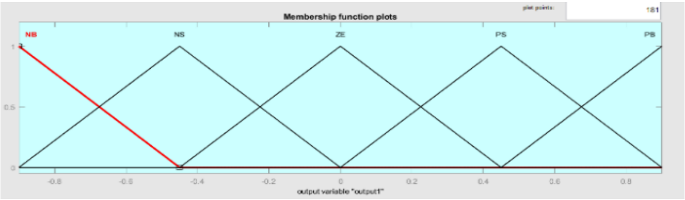

Figure 14: Output Membership function (change in Duty Ratio)

Figures 12 and *13* portrays the membership function for the inputs of the FLC and the *figure 14* shows the membership function for the output of the FLC. The inputs of the FLC are compared based on the fuzzy rues shown in the *table 2.*

Table 2: The rules for FLC

NB	PoS	PoB	NeB	NeS	NeS
NS	PoS	PoS	NeS	NeS	NeS
ZE	ZE	ZE	ZE	ZE	ZE
PS	NeS	NeS	PoS	PoS	PoS
PB	NeS	NeB	PoB	PoB	PoS

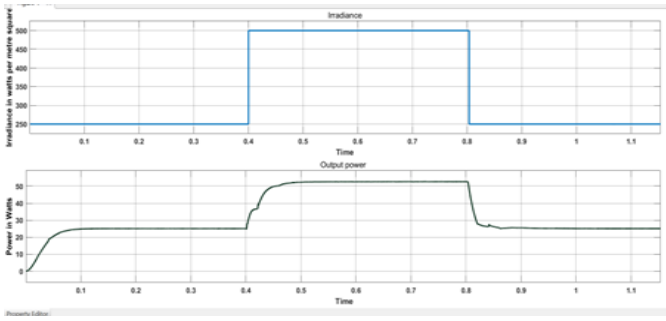

Figure 15: Output waveform of PV system along with FLC

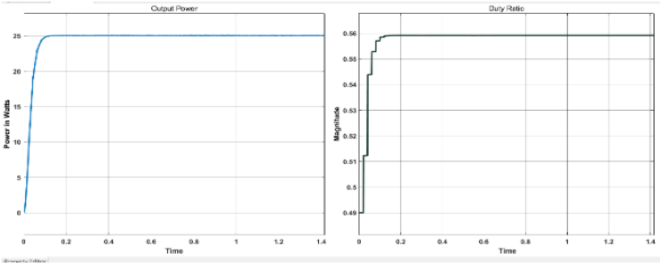

Figure 16: Output waveform of PV system for different irradiance along with FLC

The *figure 15* shows the waveform that represents the output power waveform for fuzzy logic controller for the irradiance value 250W/m^2 and the temperature as 25˚C. *Figure 16* represents the output waveform for different irradiance value (250, 500 and again 250 W/m^2) at 25˚Celsius temperature.

3.2 Experimental Results

The hardware for the converter used is designed and the experimental result are obtained for input voltage (Vin) 5V and duty ratio of 0.65. As per the gain equation for duty ratio, the voltage gain should be 10. Thus, the obtained voltage is also 50V and the waveform of the output voltage is portrayed in *figure 17*. *Figures 18 and 19* show current through inductors L_1 and L_2. *Figures 20 and 21* show current through diodes D_0 and D_1. *Figures 22 and 23* show the voltage across MOSFETs S_1 and S_2.

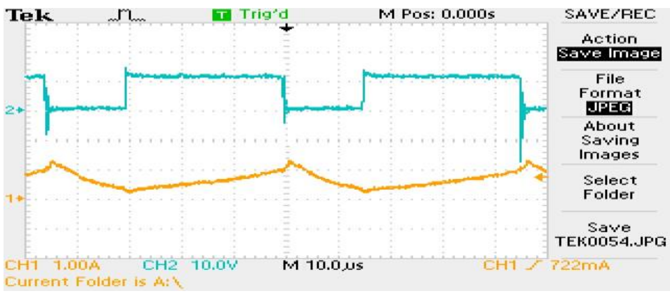

Figure 17: Hardware Output voltage waveform

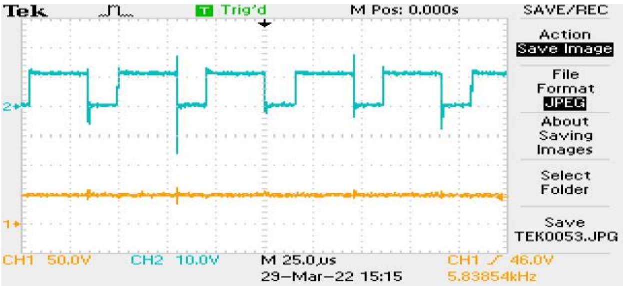

Figure 18: Inductor Current (L1)

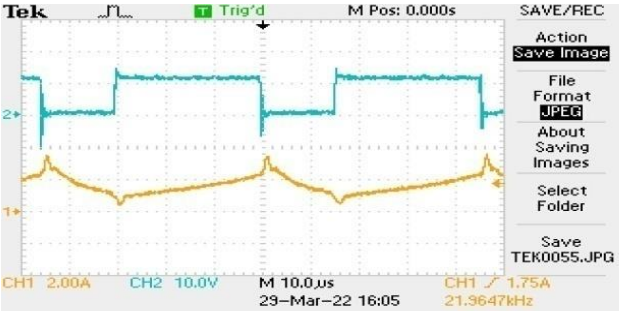

Figure 19: Current through Inductor (L2)

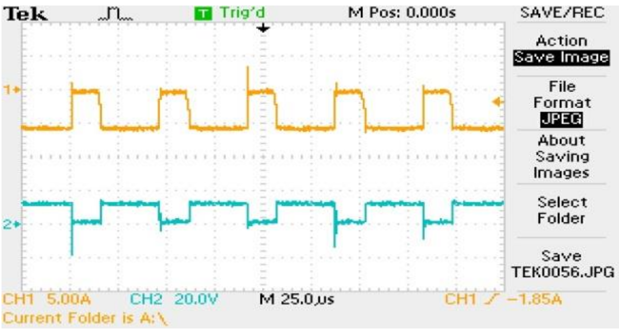

Figure 20: Current through Diode (D0)

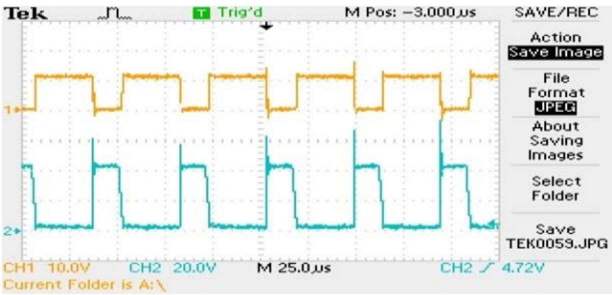

Figure 21: Current through Diode (D1)

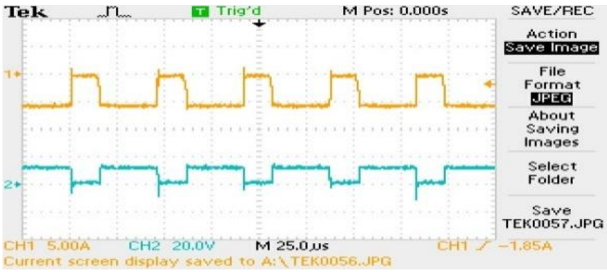

Figure 22: Voltage across MOSFET (S1)

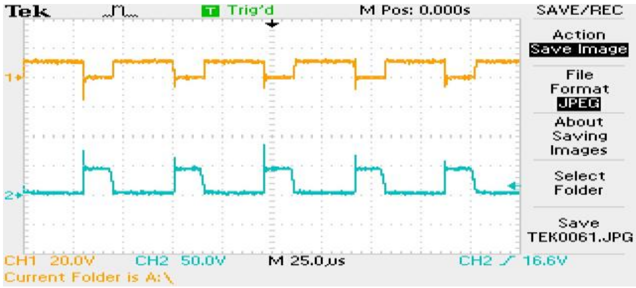

Figure 23: Voltage across MOSFET (S2)

4. DISCUSSION

The proposed converter model is first developed in MATLAB and the results are presented. The P and O based MPPT results are portrayed in *figures 9, 10 and 11* under closed loop condition. The simulations are then carried out with fuzzy controller based MPPT under different irradiances and its outputs are shown in *figures 15 and 16*. From the *figure 15*, we can say that the output of the FLC based MPPT is more stable than the P and O MPPT and from the *figure 16*, we can say that the FLC tracks the maximum power value even the irradiance value changes. A hardware prototype model is developed, and results are presented in *figures 19 to 25*. *Figure 17* shows an output voltage of 50 V for an input voltage of 5 V and a gain of 0.65.

5. CONCLUSION

The DC-DC converter used has more advantages such as high gain, high voltage efficiency, simple circuit and minimum voltage stress on the devices used. The output of the P and O MPPT and FLC are compared, and we can conclude that the output obtained by the FLC is more stable and efficient. The output is obtained with FLC for different level of irradiance and the FLC tracks the maximum power point.

REFERENCES

[1] Marcelo Gradella Villalva; Jonas Rafael Gazoli; Ernesto Ruppert Filho. Comprehensive approach to modeling and simulation of photovoltaic arrays. IEEE Trans. Power Electron.2009; vol. 24, no 5, pp. 157-168.

[2] Bal, S.; Anurag, A.; Babu B.C.; Comparative analysis of mathematical modeling of the photovoltaic array. In proceedings of Annual IEEE India Conference (INDICON), 2012, pp. 269-274, doi: 10.1109/INDCON.2012.6420627.

[3] Narthana, S; Muthu Thiruvengadam, P; Gnanavadivel, J. Adaptive neuro-fuzzy approach for maximum power point tracking with high gain converter for photo voltaic applications -International Journal of Advanced Technology and Engineering Exploration, 2022; vol. 9, no.93, pp-1168-1182.

[4] Abinayalakshmi, B; Muralidharan, S; Gnanavadivel, J. Design of Quadratic Boost Converter for Renewable Applications, Lecture Notes in Electrical Engineering, 2021; vol.795, pp.1-13.

[5] Jayanthi, K; Senthil Kumar, N; Gnanavadivel, J. Design and implementation of modified SEPIC high gain DC-DC converter for DC microgrid applications, International Transactions on Electrical Energy System, 2021; vol.13, no.8,pp. 2100-2118.

[6] Gnanavadivel, J; Shunmathi, M; Muthu Thiruvengadam, P; Narthana, S. Analysis of DC-DC Converter with High Step -up Gain for Alternative Energy Sources, International Journal of Engineering Trends and Technology, 2021; vol.69, no.4,pp. 162-168.

[7] Kala Rathi, M; Jayanthi, K. A Solar PV Fed Switched Capacitor Boost Circuit for DC Microgrid, International Journal of Engineering Trends and Technology, 2021; vol.69, no.3,pp. 127-132.

[8] Kala Rathi, M; Jayanthi, K. Dual State DC-DC Converter with PI and Fuzzy PI Controller for LED Drivers, International Journal of Engineering Trends and Technology, 2021; vol.69, no.3,pp. 180-184.

[9] Jayanthi, K; Kala Rathi, M. A High Gain DC-DC Converter Fed from Fuel Cell for DC Microgrid Application, Journal of Green Engineering, 2020; vol.9, no.9,pp. 4763-4772.

[10] Kala Rathi, M; Gnanavadivel, J; Jayanthi, K. Augmented ASC Network for Photo Voltaic Applications, International Journal of Electrical and Electronics Research, 2022; vol.10, no.3,pp. 544-549.

[11] Ishaque, Kashif; Zainal Salam; George Lauss; The performance of perturb and observe and incremental conductance maximum power point tracking method under dynamic weather conditions. Applied Energy. 2014; vol. 119, pp. 228-236.

[12] Tsang, K. M.; Chan W. L.; Model based rapid maximum power point tracking for photovoltaic systems. Energy conversion and management. 2013; vol. 70, pp. 83-89.

[13] Salam; Zainal; Jubaer Ahmed; Benny S.Merugu; The application of soft computing methods for MPPT of PV system: A technological and status review. Applied Energy. 2013; vol. 107, pp. 135-148.

[14] YousraShaiek; Mouna Ben Smida; Anis Sakly; Mohamed Faouzi Mimouni; Comparison between conventional methods and GA approach for maximum power point tracking of shaded solar PV generators. Solar energy. 2013; vol. 90, pp. 107-122.

[15] Yali Liu, Ming Li, Xu Ji, Xi Luo, Meidi Wang, Ying Zhang. A comparative study of the maximum power point tracking methods for PV systems. Energy Conversion and Management. 2014; vol. 85, pp. 809-816.

[16] Shahrukh Khan; Arshad Mahmood;Mohd Tariq; Mohammad Zaid; Irfan Khan; Syed Rahman; Improved Dual Switch Non-Isolated High Gain Boost Converter for DC microgrid Application. In proceedings of IEEE Texas Power and Energy Conference (TPEC). 2021; pp. 1-6.

[17] Marcos Paulo Hirth, Roger Gules, Carlos Henrique Illa Font. A Wide Conversion Ratio Bidirectional Modified SEPIC Converter with Nondissipative Current Snubber. IEEE Journal of Emerging and Selected Topics in Power Electronics. 2021; vol. 9, no. 2, pp. 1350-1360.

[18] Hasanpour, S.;Forouzesh, M.;Siwakoti, Y.P;Blaabjerg F.;New High Gain, High-Efficiency SEPIC Based DC-DC Converter for Renewable Energy Applications. IEEE Journal of Emerging and Selected Topics in Industrial Electronics. 2018; vol. 2, no. 4, pp. 567-578.

[19] Omar Abdel-Rahim;Haoyu Wang; A New High Gain DC-DC Converter with Model Predictive-Control Based MPPT Technique for Photovoltaic Systems. CPSS Transaction on Power Electronics and Applications. 2020; vol. 5, no. 2, pp. 191-200, doi: 10.24295/CPSSTPEA.2020.00016.

[20] Mahsa Ahmadi; Majid Hosseinpour;Seyed Reza Mousavi-Aghdam; Farzad Sedaghati. A High Conversion Ratio Transformerless Buck Boost Converter with Continuous Input Current. In proceedings of 12th Power Electronics, Drive Systems, and Technologies Conference (PEDSTC). 2021; pp. 1-7.

[21] Harini, K.;Syama, S.; Simulation and Analysis of Incremental Conductance and Perturb and Observe MPPT with DC-DC Converter Topology for PV Array. In proceedings of IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT). 2015; pp. 1-5.

[22] Ambikapathy, A.; Singh, G.; Shrivastava, A.; Efficient Soft-Switching DC-DC converter for MPPT of a Grid Connected PV System. In Proceedings of International Conference on Computing, Communication and Automation (ICCCA). 2016, pp. 934-938.