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PERFORMANCE IMPROVEMENT OF FUZZY LOGIC CONTROLLER BASED CUK CONVERTER FOR MAXIMUM POWER POINT TRACKING

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Abstract*— This paper introduced a fuzzy logic controller (FLC) based CUK converter for maximum power point tracking (MPPT) of a photovoltaic(PV) system. The FLC projected that the Unsymmetrical membership function gives faster response than the symmetrically distributed membership functions. The fuzzy logic controller for the CUK MPPT scheme shows smooth change of current and no change (Constant) of Voltage in variable-load, represented in little steady state error and overshoot. As the inverter is used in a PV system, Fuzzy logic controller is employed forgetting sinusoidal wave output, higher dynamic performance under fast varying atmospheric conditions and reduced total harmonic distortion. The proposed scheme guarantee optimal use of photovoltaic (PV) array and proves its effectiveness invariable load conditions, at the load (Inverter) side. The performance of the converter is tested in MATLAB/Simulink.

Keywords*— Maximum power point tracking (MPPT), Fuzzy logic controller (FLC), Perturb and observe (P&O), DC/DC CUK converter, Single phase H-bridge inverter.

I. INTRODUCTION

Solar energy is one of the major important renewable energy sources. Compared to other non-renewable resources. Solar energy is clean and emission free. Photovoltaic (PV) has come out as a major one for meeting the energy demand. It is a pollution free resources, with less running and maintenance cost. Now days, solar power generation system has attracted more attention due to the energy crisis and environment pollution problem. Photovoltaic power generation systems can effectively resolve environmental issues such as the green house effect and air pollution. PV power generation systems have one big problem that the amount of electric power generated by PV module is always changing with weather conditions. i.e., irradiation. Therefore, a Maximum Power Point Tracking (MPPT) method to achieve maximum power (MP) output at real time becomes necessary in PV generation systems. The amount of power generated by a PV depends on the operating voltage of the array. A PV's maximum power is reached. At the Maximum Power point, the PV operates at maximum efficiency. Therefore, many methods have been introduced to determine MPPT for a particular value. The conventional MPPT methods are generally classified into the following groups such as Perturbation and observation (P&O) methods, Incremental conductance methods, Constant current or constant voltage etc. Among them the P &O method has drawn much attention due to its simplicity.

The selection of suitable DC-DC converter plays an major role for maximum power point tracking (MPPT)operation. There are many factors to be considered for proposing the DC-DC converters such as input/output energy flow, flexibility, cost and PV array effect. The Buck and buck-boost converters have discontinuous input current, which causes more power loss due to input switching and low efficiency. The SEPIC and the CUK converters provides the choice to have either higher or lower output voltage compared to the input voltage. Furthermore, they have continuous input current and better efficiency compared to other converters. There is no general agreement in the literature on which one of the two converters is best; the SEPIC or the CUK[4]-[5].This paper seeks to use the CUK converter because it provides high efficiency and low switching losses.

The traditional PI controllers to apply for DC-DC converters as in literature [6]-[9]. Rahim et al. [6] used a five-level inverter to reduce the THD level of the output wave employing the PI controller. However, the cost of the system increased and the control of the inverter became complicated. Furthermore, the THD level did not decrease that much at the expected level. Femia and Fortunato et al., in [7] and [8], respectively, used OCC for MPPT and single-stage inverter, the above authors used conventional PI controllers along with

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MPPT scheme. The limitations of PI controller are well known as it is sensitive to parameter variations, weather conditions and uncertainties. Therefore, there is a need to apply additional efficient controller which can handle the uncertainties like unpredictable weather for the PV system. Among different intelligent controllers, fuzzy logic is the easiest to integrate with the system. Recently, Fuzzy Logic Controller (FLC) has received an increasing attention to researchers for converter control, motor drives, and other process control as it gives better responses than other conventional controllers [9]-[10]. The imprecision of the weather variations that can be reflected by PV arrays can be addressed perfectly using fuzzy controller. In order to get the advantages of fuzzy logic algorithm, the MPPT algorithm is integrated with the FLC so that the overall control system can always provide maximum power transfer from PV array to the inverter side in spite of the changeable weather conditions. This paper presents an FLC based MPPT operation of CUK converter for PV inverter applications. As the proposed method always transfers maximum power from PV arrays to the inverter load side, it optimizes the number of PV modules. The fuzzy controller for the CUK MPPT scheme shows a high-precision in current transition and no change in voltage, in variable-load conditions, represented in little state error and overshoot. As the inverter is used in a PV system, FLC is employed for more-accurate output sine wave, higher dynamic performance under rapidly varying atmospheric conditions to track maximum power effectively, and reduced total harmonic distortion.

II. SOLAR CELL MODELING

Solar cells consist of a p-n junction fabricated in thin wafer or layer of semiconductors. Its electrical characteristics differ very little from a diode represented by the equation of Shockley [1], [2] and [3]. The simplest equivalent circuit of a solar cell is a current source in parallel with a diode as shown in Fig. 1. The current source output is directly proportional to the light falling on the cell. So the modeling of this solar cell can be developed based on equation (1).

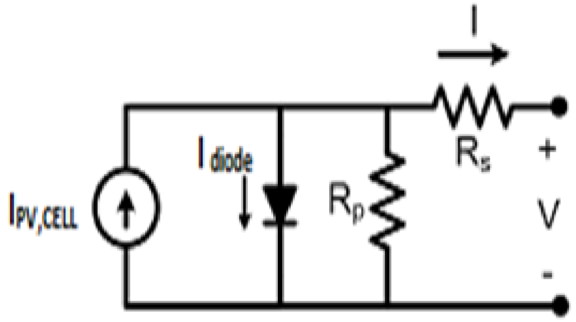

Fig 1 : Equivalent Model of a Photovoltaic Cell.

$$I = I_{PV,CELL} - I_{diode} = I_{PV,CELL} - I_{0,CELL}\left[EXP\left(\frac{q*V}{\propto*k*T}\right)-1\right] \quad (1)$$

Where,
I_{PV}, cell is the generated Current by the incident light.
I_{diode} is the diode current of schockley equation.
I_0,cell [A] is the reverse saturation current of the diode [A].
q is the electron charge [1.60217646 ・10-19C].
k is the Boltzmann constant [1.3806503 ・10-3J/K]. T [K] is the p-n junction temperature.
α is the ideality constant of the diode which lies between 1 and 2 for mono crystalline silicon.

Practical PV modules are composed of several connected PV cells, it requires the additional parameters Rs and Rp, with these parameters (1) becomes (2)

$$I = I_{PV} - I_0\left[EXP\left(\frac{V+R_S*I}{V_t*\propto}\right)-1\right]-\frac{V+R_S*I}{R_p} \quad (2)$$

The current generated by the light of the module depends linearly on solar irradiation and is also influenced by temperature according to (3).

$$I_{PV} = \left(I_{PV,n}+K_I\Delta T\right)\frac{G}{G_n} \quad (3)$$

Where K_I is the Temperature coefficient of I_{SC}, G is the irradiance (W/m²) and Gn is the irradiance at standard operating conditions. The diode saturation current I_0 dependence on temperature can be expressed as shown in (4).

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 EXP\left[\frac{q*E_g}{\propto*k\left(\frac{1}{T_n}-\frac{1}{T}\right)}\right] \quad (4)$$

Eg is the band gap energy of the semiconductor and I0,nis the nominal saturation current expressed by (5)

$$I_{0,n} = \frac{I_{SC,n}}{\left[EXP\left(\frac{V_{OC,n}}{V_{t,n}*\propto}\right)-1\right]} \quad (5)$$

From (4) and (5) I0 can be expressed as shown in (6).

$$I_0 = \frac{I_{SC,n}+K_I\Delta T}{EXP\left(\frac{V_{OC,n}+K_V\Delta T}{V_t*\propto}\right)-1} \quad (6)$$

Where, $V_{OC,n}$ is open circuit voltage ,$I_{SC,n}$ is the short circuit current , $V_{t,n}$is the thermal voltage , T_n is the temperature at standard operating conditions. V_t = Ns*kT/q is the thermal voltage of the module with Ns cells connected in series.

2.1 Photovoltaic Module Simulation

Fig.2 shows the modeling circuit diagram of the Photovoltaic module by Matlab/Simulink tool. The modeling of the PV is done applying the equations seen before, (1), (2), (3),(4),(5)

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and (6) Irradiance and temperature are the inputs of the system. In Fig 3 & 4 the three remarkable points V_{oc}=21.1V, I_{sc}=3.8A and maximum power point (P_{max}=60W, Voltage at Maximum Power V_{mp}=17.5V, Current at Maximum Power I_{mp} =3.5A) are shown.

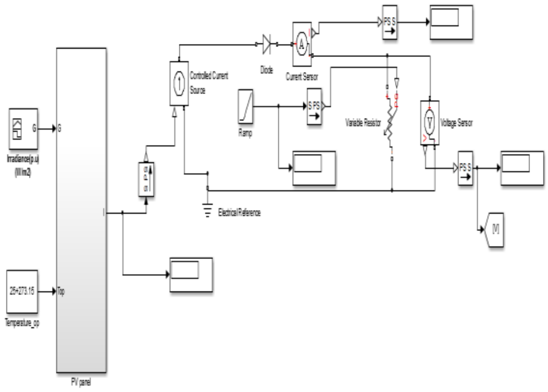

Fig 2 : PV Module Model in Simulink

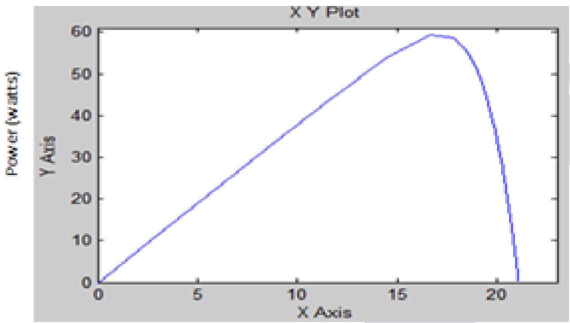

Fig 3. P-V Characteristics at T=25° C, Irradiance 1000W/M²by Simulink

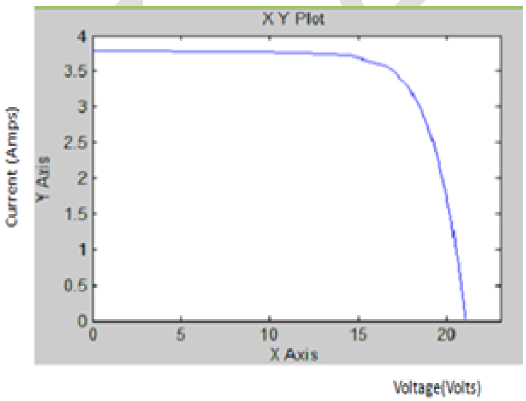

Fig 4 : I-V Characteristics at T=25° C, Irradiance 1000W/M² by Simulink

2.2 Perturb and Observe Algorithm

In this method a small perturbation is introduced to the system. Due to this perturbation the module power changes. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the maximum power is reached the power at the next instant decreases and hence after that the perturbation is reversed. When the steady state is reached the above algorithm oscillates around the maximum point. In order to keep the variation of power is small the perturbation size should be kept very small as shown in Fig.5.

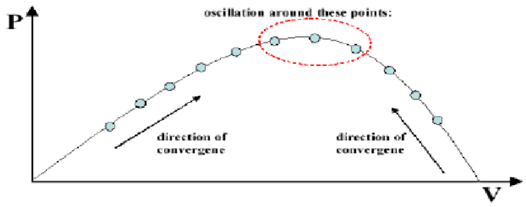

Fig 5 : Perturb and Observe Algorithm

The flow chart of the above algorithm is shown in the Fig. 6. The algorithm measures the value of current and voltage from the solar photovoltaic module. Power is calculated from the PV current and Voltage. The value of power and voltage at k^{th} instant are stored. Then next values at $(k+1)^{th}$ instant are measured again and power is calculated from measured values. The voltage and power at $(k+1)^{th}$ instant are subtracted with the values from k^{th} instant. If we monitor the power voltage curve of the solar pv module we observe that in the right hand side of the curve where the voltage is almost constant and the slope of power voltage is negative (dP/dV<0) whereas in the left hand side of the slope is positive.(dP/dV>0). The right hand side curve is for the lower duty cycle (nearer to zero) where as the left hand side curve is for the higher duty cycle (nearer to unity). Depending on the sign of dP (P (k+1) - P (k)) and dV (V (k+1) -V (k)) after subtraction the algorithm decides whether to increase the module voltage or to reduce it [1].

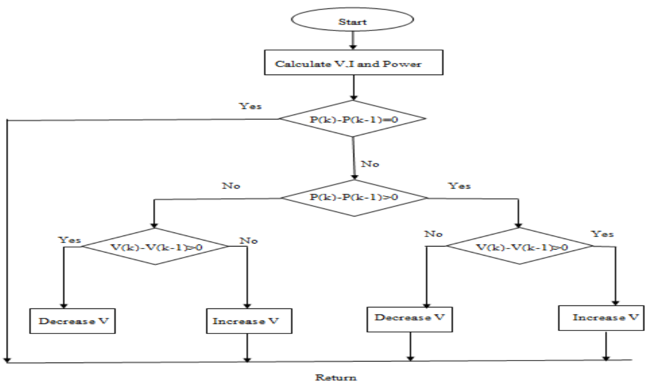

Fig 6 : Flow Chart of Perturb and Observe.

III. THE PROPOSED SYSTEM

DC-DC converter's main function is to increase the level of voltage fed to the inverter. In this work, voltage level

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increases or decreases according to MPPT. The controller, moreover, changes the voltage level by changing the duty cycle of the Pulse Width Modulation (PWM) signal Fig. 7 shows the proposed system implementation, where a sinusoidal reference-signal is compared with the output signal of inverter to produce a nearly zero error signal. The other reference signal is used to compare the CUK output, to achieve maximum power. This signal is adaptive, changing its shape according to weather conditions. The converter output is fed to inverter. The inverter's input signal should be as smooth as possible, but the CUK MPPT generates a non-smooth signal, due to its tracking of maximum power. This problem is not as big in the design, as the non smooth signal Can be enhanced by the inverter's Fuzzy controller and the low-pass filter connected after the inverter. The two enhance the output signal, so even if the input signal is not smooth, extraction of maximum power is possible.

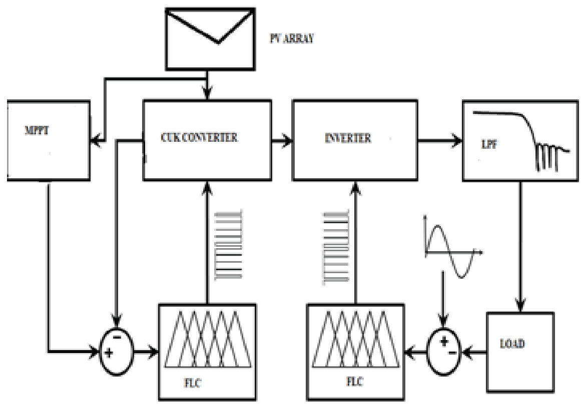


Fig 7 : Circuit diagram of the CUK converter for FLC based MPPT scheme.

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems [11]. They have the advantage to be robust and relatively simple to design as they do not require the knowledge of the accurate model. They do require in the other hand the complete knowledge of the operation of the PV system by the designer. The design of fuzzy controller was done using Mamdani method for both the converter and the single-phase inverter. The structure of proposed FLC is shown in Fig.8

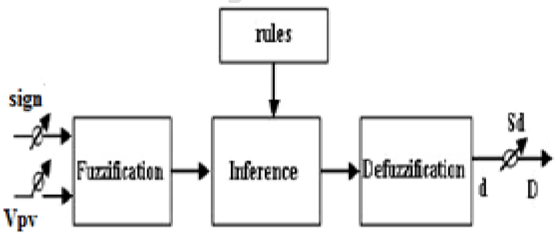


Fig 8 : Structure of proposed Fuzzy logic controller

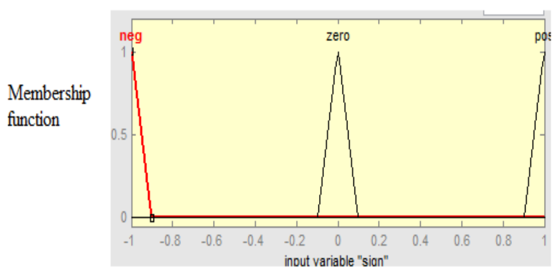
4.1 FLC for CUK Converter

The input variables of the FLC are the sign error and the voltage V_{pv}. The output of the FLC is the duty cycled (n), of the PWM signal, which regulates the output voltage. Fig.9 shows the membership functions of the inputs and the outputs of the CUK side FLCs. The triangular membership functions are used for the FLC for easier computation. The universe of discourse for input variable 1 (sign) is divided into three Fuzzy sets Negative (n), Zero (z), Positive(p).The universe of discourse for input variable 2 (Vpv) is divided into 3 Fuzzy sets Low (l), Optimum (o) and high (h) is defined to describe each linguistic variable. The universe of discourse for the output variable (d) is divided into 5 Fuzzy sets: Low negative(ln), High optimum negative(hon), Zero(z), Low optimum positive (lop) and High positive(hp).

The fuzzy rules of the proposed PV CUK DC-DC converter can be represented in an un symmetric form as shown in TABLE I. Unsymmetrical membership function offers faster response than the symmetrical membership function. Furthermore, as in Fig.9 and 10, the Mamdani fuzzy inference method is used for the proposed FLC, where the maximum of minimum composition technique is used for the inference and the center-of-gravity method is used for the defuzzification method. For example, IF (Sign is neg) and (V_{pv} is low) THEN (output is ln).

TABLE I - Fuzzy Rule-Based Matrix

Sign / Vpv	Negative n	Zero z	Positive p
Low l	ln	z	lop
Optimum o	hon	z	lop
High h	hon	z	hp



(a)

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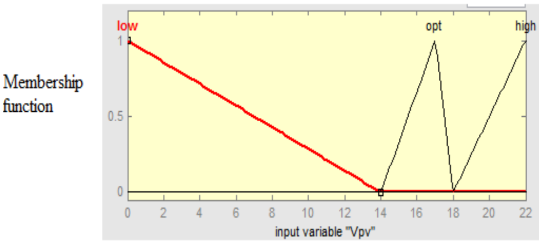
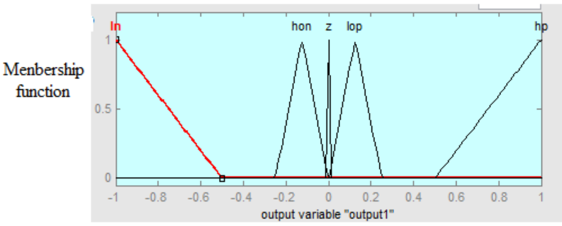


(b)

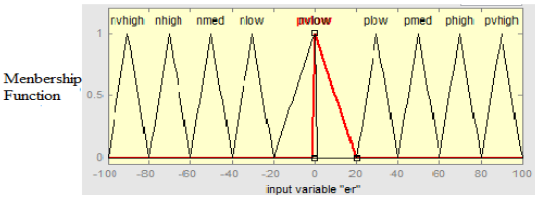


(c)

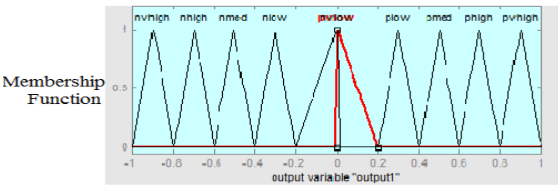
Fig 9: Unsymmetrical membership function of the proposed FLC (a) sign (b) Vpv (c) Output

4.2 FLC for Inverter

The controlled FLC PWM signal can attain two advantages to the inverter; first, it produces a smooth output sine-wave, second, it attain a smooth transition for the current signal and constant transition for the voltage signal in variable-load conditions. The input variables of the FLC are the error, and the output of the FLC is the duty cycle d(n) of the PWM signal, which regulates the output voltage. Fig.10 shows the membership functions of the input and the output of the Inverter side FLCs. For example, IF (error is pvlow) THEN (output is pvlow)



(a)



(b)

Fig 10 : Membership function of the proposed FLC (a) error (b) output

V. SIMULATION RESULTS

The simulation of the proposed system was carried out in MATLAB/Simulink Power Systems environment.

Two types of simulation carried out,

(i) Simulation diagram and results of FLC based CUK converter for MPPT shown in Fig.11 and 12. The output Voltage of CUK converter is 120V and Inductor current is 0.6A respectively.

(ii)

(ii) Simulation and results of Inverter using FLC shown in Fig.13 and 14. The CUK converter output voltage is fed to the inverter using sinusoidal PWM along with FLC. The output voltage of inverter is 110V A.C and current is 5A. From this result, the converter and inverter output voltage is maintained constant under change in load conditions and Total Harmonic Distortion (THD) is reduced around 4% shown in Fig.15. so, the performance of the whole system is improved.

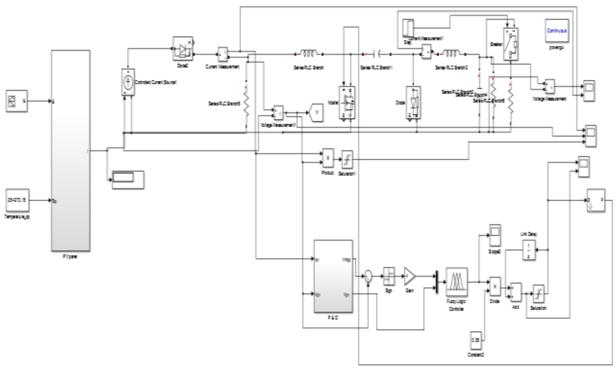


Fig 11 : Simulation diagram of FLC based CUK converter for MPPT

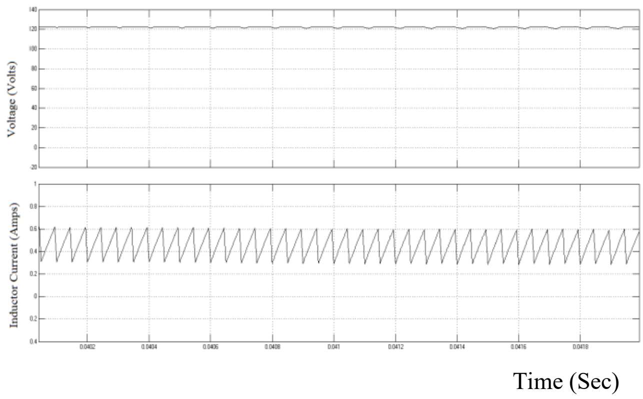


Fig 12 : CUK converter output voltage and Inductor current

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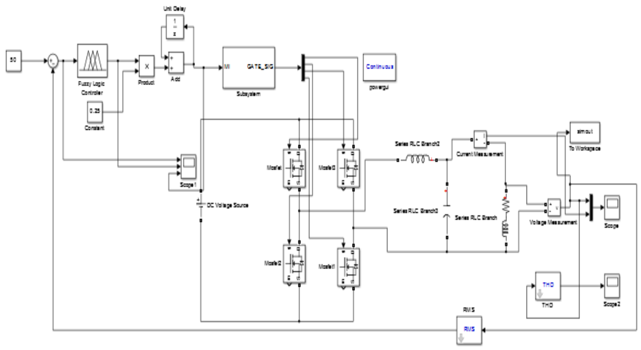

Fig 13 : Simulation diagram of Inverter using FLC

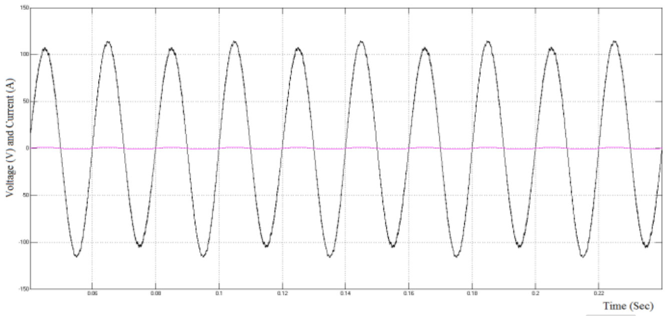

Fig 14 : Inverter output voltage and current

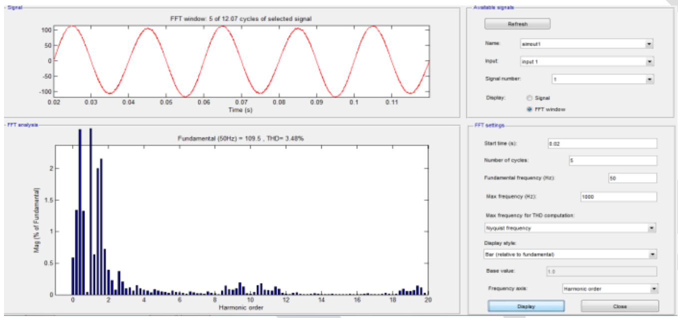

Fig.15 THD of Inverter

VI. CONCLUSION

This paper presented an optimized FLC controller that controlled CUK MPPT converter and single-phase inverter. The proposed Fuzzy Logic MPPT system to track the voltage with respective to the maximum power output. It results shows in increasing the efficiency of the PV panel and reducing the effects of weather changing as much as possible. So, the controller's performance can be improved both the converter and inverter side, i.e constant voltage and smooth current transition. The controller was able to control the duty cycle of the PWM signal by tracking un predictable MPPT signal. This type of control suitable for variable-load systems as it not only addressed steady-state response, but also improved transient response.

References

[1] Manoj Kumar, F. Ansari, A.K. Jha"Maximum power point tracking using perturbation and observation as well as incremental conductance algorithm",IJREASISSN 2294-3905, Vol.1,issue 4 (2011), pp.19-31.

[2] Ramos Hernanz, JA. Campayo Martin, JJ. Zamora Belver,I., Larranga Lesaka,J.Zulueta Guerrero,"Modeling of photovoltaic module" International conference on Renewable Engineering and Power Quality (ICREPQ'10) Granada (Spain), 23th to 25th March, 2010

[3] Francisco M. González-Longatt, —Model of photovoltaic Module in Matlab™,(II IBELEC 2005).

[4] D.Hyun-Lark,"Soft-Switching SEPIC Converter with Ripple Free Input Current,"IEEE Trans. Power Electronics,vol. 27, pp.2879- 2887,2012.

[5] C. Zengshi, "PI and Sliding Mode Control of a Cuk Converter," IEEE Trans. PowerElectronics,vol. 27, pp. 3695-3703, 2012.

[6] N.A. Rahim, J. Selvaraj, and C.Krismadenata, "Five-level inverter with dual reference modulation technique for grid-connected PV system" Elsevier, Renewable Energy, vol. 35 no. 3,pp. 712-720,March 2010

[7] N. Femia, D. Granozio, G. Petrone, G. Spagnuolo, M. Vitelli," Optimized One-Cycle Control in Photovoltaic Grid Connected Applications" IEEE Trans.Aerospace and Electronic Systems,vol. 42, no. 3, pp.954- 972, Feb 2006.

[8] M. Fortunato, A. Giustiniani, G. Petrone,G. Spagnuolo, M. Vitelli, "Maximum Power Point Tracking in a One-Cycle-Controlled Single-Stage Photovoltaic Inverter" IEEE Trans. Industrial Electronics, vol. 55, no. 7, pp. 2684-2693, Jul 2008.

[9] B.N. Alajmi, K.H. Ahmed, S.J. Finney, and B.W.Williams,"Fuzzy-Logic-Control Approach of a Modified Hill-Climbing Method for Maximum Power Point in Micro grid Standalone Photovoltaic System" IEEE Trans. Power Electronics, vol. 26 no. 4, pp. 1022-1030, April 2011.

[10] M.F. Naguib, and L.A.C. Lopes,"Harmonics Reduction in Current Source Converters Using Fuzzy Logic" IEEE Trans. Power Electronics, vol. 25 no. 1, pp. 158-167, Jan 2010.

[11] ElKhateb, A.; Rahim, N.A.; Selvaraj,J.,"Fuzzy Logic Controller for MPPT SEPIC converter and PV single-phase inverter," Industrial Electronics and Applications (ISIEA), IEEE Symposium on 25-28, pp.182- 187, Sept. 2011.

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