COMPARISON AND ANALYSIS OF MPPT ALGORITHMS FOR KY CONVERTER

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Abstract

Renewable energy is the need of the hour in today's modern world. To convert the available solar energy into usable energy we need converters with better performances. KY converter has been chosen for this paper. KY converter is a type of boost converter which has non-pulsating O/P current, reduced current stress on the O/P capacitor, and also reduced O/P voltage ripple. The transient response of this converter is fast. The analysis of MPPT algorithms which best suited for solar-fed KY converter is done. Here fuzzy logic-based MPPT algorithm and P&O algorithm are used and analyzed for the operation of the KY converter. The MATLAB / Simulink program was used to develop and simulate the proposed work. The simulated outcomes were analyzed.

***Keywords*—**KY converter, MPPT, P & O algorithm, Fuzzy logic controller.

INTRODUCTION

In the modern world, the need for electricity is growing every day. The non-renewable energy resources is been depleted on a large scale. Hence the need of the hour is to use renewable energy resources. Solar, wind, and tidal are some of the examples of renewable energy resources. The use of solar energy has increased in the past decade. To condition, the output of solar panels DC to DC converters are employed.

DC-DC Converters are applied to step up or down the DC voltage depending on the necessity. Generally utilized DC to DC converters are Buck, Boost, as well as Buck-Boost converters. KY converter [5] is a kind of DC to DC step-up converter which has reduced fast transient response, voltage ripple, and non-pulsating O/P current. Two kinds of KY Buck-Boost converter [8] were proposed by the author. The converter has buck-like characteristics with synchronized rectification. The converter output is unlike the conventional Buck-Boost converter, where the output is positive. Later [8] to enhance the voltage gain KY Boost converter was introduced. Here the right half-plane of the bode plot does not have zeroes. So the system's transient response is faster than the Boost converter. [4] The integrated KY converter and its performance are analyzed under discontinuous conduction mode. [1] An Integrated KY converter is proposed herein when operated under discontinuous conduction mode, Constant on-time control is employed. It is used to enhance the system's efficacy. [2] For the fully-integrated KY converter, 220 MHz Pulse width modulation is employed with closed-loop mode. To activate the Discontinuous conduction mode controller zero crossing detector is been employed. [3] The integrated KY converter has been implemented in IC fabrication for small voltage levels with parasitic resistance in it. Many converters have been analyzed and compared with KY converters to show the KY converter's advantage.

As solar energy is employed, to detect the maximum power, MPPT techniques should be used. [10] For the KY Buck-Boost converter, the fuzzy logic controller is used, where the ripples are minimum. [11] The fuzzy logic control (FLC) is utilized for the hybrid solar and wind system. It is a grid-connected hybrid system. FLC is employed for extracting maximum power. [12] The controller is evaluated with the nominal PID controller, where the fuzzy logic controller is the best choice. Here the fuzzy logic-based algorithm and P&O algorithm are employed in simulation and the results are analyzed.

PROPOSED SYSTEM

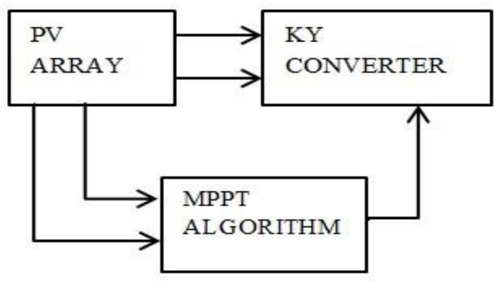

Figure1: Proposed system's block diagram

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The schematic design of the suggested system is shown in Fig. 1. To harvest the solar energy PV array is utilized. To track maximum power, the MPPT (Maximum Power Point Tracking) algorithm is used. KY converter is fed from the PV array.

OPERATION AND DESIGN OF KY CONVERTER

DC-DC converters need to be designed in such a way that the efficiency and transient response are better. Also, the output ripple should be minimized. The KY converter's operation in modes 1 & 2 is explained. The design of the converter is also explained.

A. KY CONVERTER

The KY boost converter combination of the KY converter and the SR ("Synchronously Rectified") boost converter. It is a step-up converter that has an additional inductor and a capacitor [8].

Fig. 2 exhibits a schematic circuit illustration of a KY converter. The input, as well as O/P voltage, are represented with v_i & v_o. The voltage across energy transferring capacitors is denoted as v_{Cb} and v_{Cm}. The voltage across the output capacitor is denoted as v_{Co}. The I/P current is defined by i_{Li}. The currents passing across the capacitors C_b, C_o, and inductor L_o are signified by i_{Cb}, i_{Co}, and i_{Lo}. KY converter works in 2 modes. During mode 1 the switch S_2 is in ON condition. During mode 2 the switch S_1 is in ON condition.

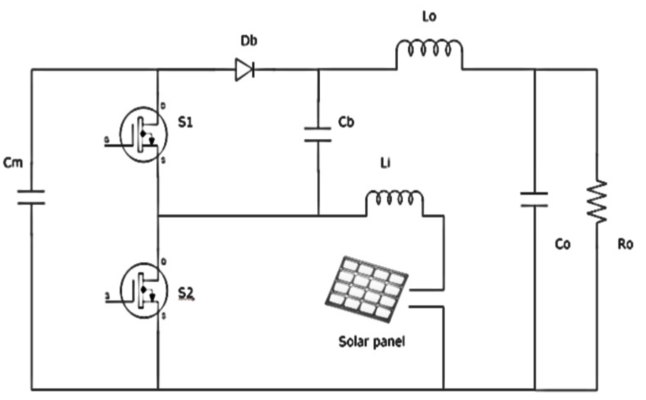

Figure 2: Circuit illustration of KY converter

B. KY CONVERTER'S OPERATION IN MODE 1

The KY converter's power flow throughout mode 1 is s demonstrated in Fig. 3. The switch (S_2) is in ON condition in this mode. When S_2 is turned ON the current flows through the input inductor (L_i), Switch 2(S_2), capacitor (C_m), output capacitor (C_o), output inductor (L_o), energy transferring capacitor (C_b), and Diode (D_b). The differential equations of mode 1 are given as

$$L_i \frac{di_{L_i}}{dt} = v_i \tag{1}$$

$$L_o \frac{di_{L_o}}{dt} = v_{Cb} - v_o \tag{2}$$

$$C_o \frac{dv_{Co}}{dt} = i_{Lo} - \frac{v_o}{R_o} \tag{3}$$

$$C_b \frac{dv_{Cb}}{dt} = -(i_{Cm} + i_{Lo}) \tag{4}$$

$$v_{Cm} = v_{Cb} \tag{5}$$

The equations (1) to (5) denote the differential equations of mode 1.

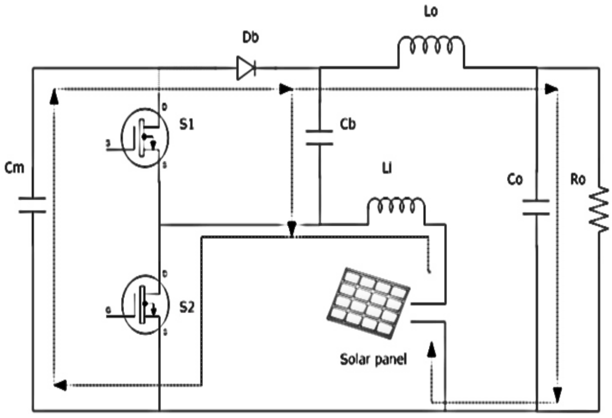

Figure 3: Circuit diagram represents the power flow via KY converter in mode 1

C. KY CONVERTER'S OPERATION IN MODE 2

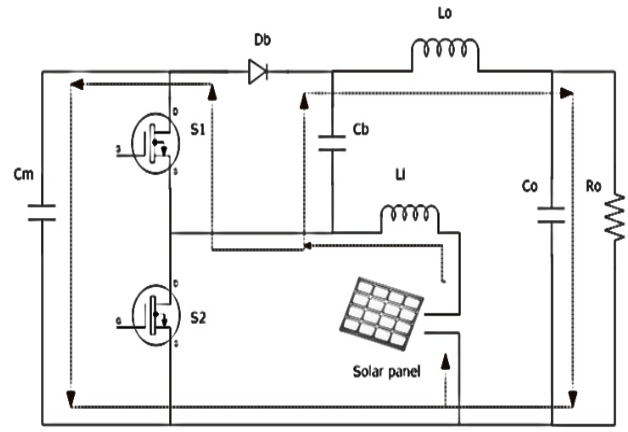

Figure 4:Circuit diagram represents the power flow viaKY converter in mode 2

Figure 4 depicts the power flow in the KY converter during mode 2. In this mode, the S_1 (switch) is in ON condition. When the S_1 is turned ON the current passes through the output capacitor (C_o), output inductor (L_o), energy transferring capacitor (C_b), capacitor (C_m), Switch 1(S_1), and input inductor (L_i). The differential equations of mode 2 are given as

$$L_i \frac{di_{L_i}}{dt} = v_i - v_{Cm} \tag{6}$$

$$L_o \frac{di_{L_o}}{dt} = v_{Cm} + v_{Cb} - v_o \tag{7}$$

$$C_o \frac{dv_{Co}}{dt} = i_{Lo} - \frac{v_o}{R_o} \tag{8}$$

$$C_b \frac{dv_{Cb}}{dt} = -i_{Lo} \tag{9}$$

$$i_{Cm} = i_{Li} - i_{Lo} \tag{10}$$

The equations (6) to (10) denote the differential equations of mode 2.

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From equations 1 to 10 the average equations (11 to 14) are obtained as,

$$L_i \frac{d(i_{L_i})}{dt} = (v_i) - (v_{Cm})(1-d) \quad (11)$$

$$L_o \frac{d(i_{Lo})}{dt} = (1-d)(v_{Cm}) + (v_{Cb}) - (L_o) \quad (12)$$

$$C_o \frac{d(v_o)}{dt} = (i_{Lo}) - \frac{(v_o)}{R_o} \quad (13)$$

$$C_b \frac{d(v_{Cb})}{dt} = -(i_{Cm} + i_{Lo})d - (i_{Lo})(1-d) \quad (14)$$

The equations of v_{Cm} and i_{Cm} can be shown in terms of v_{Cb}, $i_{Lo,}$ and i_{Li}. The following shows the derivation steps.

During ON time (d), the voltages of v_{Cm} and v_{Cb} are equivalent. To calculate the average of v_{Cm} and v_{Cb} over a single switching cycle the following procedure is used.

$$(v_{Cm})T_s = \frac{v_a+v_b}{2}(1-d)T_s + \frac{v_c+v_a}{2}dT_s \quad (15)$$

$$(v_{Cb})T_s = \frac{v_a+v_d}{2}(1-d)T_s + \frac{v_c+v_a}{2}dT_s \quad (16)$$

During the period (1-d), the voltage across energy transferring C_m (v_{Cm}) is increasing and the voltage across C_b (v_{Cb}) is falling. As a result, the voltages v_b and v_d maybe represented as

$$v_b = v_a + \frac{(i_{L_i})+(i_{Lo})}{C_m}(1-d)T_s \quad (17)$$

$$v_d = v_a - \frac{(i_{Lo})}{C_m}(1-d)T_s \quad (18)$$

Based on equations (15) to (18) v_{Cm} can be represented as,

$$v_{Cm} = \frac{1}{2}(1-d)^2 T_s \left[\frac{C_b}{C_m C_b}\left(i_{L_i}\right) + \frac{C_m - C_b}{C_m C_b}\left(i_{L_o}\right)\right] + v_{Cb} \quad (19)$$

Equation 19 is rearranged as,

$$v_{Cm} = \alpha\left(i_{L_o}\right)(1-d)^2 + \beta(i_{L_i})(1-d)^2 + v_{Cb} \quad (20)$$

Where, $\alpha = \frac{C_m - C_b}{2C_m C_b}$ and $\beta = \frac{T}{2C_m}$

According to the ampere-second balance, i_{C_m} is represented as

$$i_{C_m} = \frac{(1-d)}{d}\left[(i_{Lo}) - (i_{Li})\right] \quad (21)$$

By substituting (20) & (21) into (11 to 14), the following expressions may be achieved:

$$L_i \frac{d(i_{L_i})}{dt} = (v_i) - (v_{Cb})(1-d) - \alpha\left(i_{L_o}\right)(1-d)^3 - \beta(i_{L_i})(1-d)^3 \quad (22)$$

$$L_o \frac{d(i_{Lo})}{dt} = -(v_o) + (v_{Cb})(2-d) + \alpha\left(i_{L_o}\right)(1-d)^2 + \beta(i_{L_i})(1-d)^3 \quad (23)$$

$$C_o \frac{d(v_o)}{dt} = (i_{Lo}) - \frac{(v_o)}{R_o} \quad (24)$$

$$C_b \frac{d(v_{Cb})}{dt} = (i_{Li})(1-d) - (i_{Lo})(2-d) \quad (25)$$

Based on the equations (22) to (25) the inductance and capacitance values are calculated.

D. DESIGN VALUES

The table shows the design values for the parameters used in KY converters. The design values of the KY converter are provided in Table I.

TABLE I. KY CONVERTER DESIGN VALUES

S.NO	PARAMETERS	VALUES
1	R_o	90 Ω
2	f_s	50 kHz
3	C_m	100 µF
4	C_b	100 µF
5	C_o	150 µF
6	L_o	100 µH
7	L_i	100 µH

The suggested converter's simulation is based on the design parameters provided in the tables.

MPPT ALGORITHMS

MPPT is a method commonly used with renewable energies like solar panels and wind turbines to extract maximum power. The commonly used algorithms are a differential method, perturbation & Observation (P and O), Incremental and Conductance (I and C), etc. are some of the basic MPPT algorithms used widely.

In this paper as said earlier two types of MPPT algorithms are used for the KY converter. Conventional P and O algorithms and the emerging fuzzy logic-based algorithm are used.

A.FUZZY LOGIC CONTROLLER

Fuzzy-based MPPT algorithm works based on the crisp inputs received from the fuzzifier. The crisp inputs here are voltage and current. The stored membership function converts the crisp input into fuzzy input. Based on the fuzzy inputs received the rule evaluation and control action is made. It produces fuzzy output. This output is sent to the defuzzifier. The defuzzifier gives crisp output based on the provided membership function. The crisp output here is the duty cycle. Figure5(a) shows the flow of fuzzy logic controller 5(b) shows the rule viewer 5(c) shows surface view of the fuzzy logic used for the simulation.

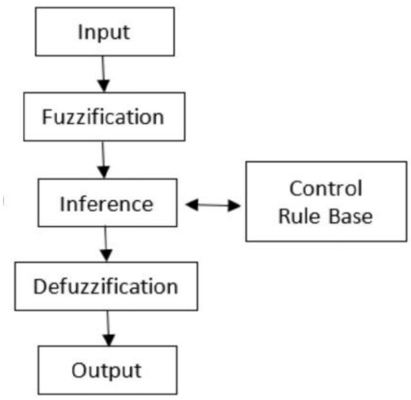

Figure5(a)Flow of Fuzzy-Logic controller

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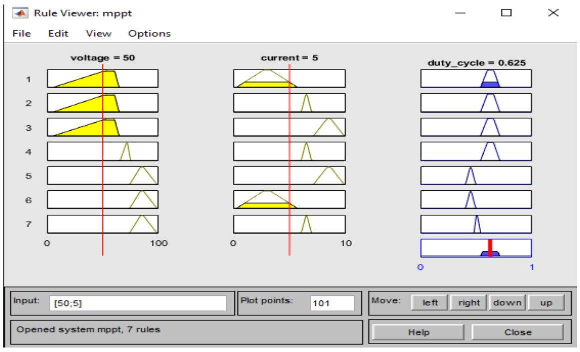

Figure 5(b). Rule viewer of the fuzzy logic controller for KY converter

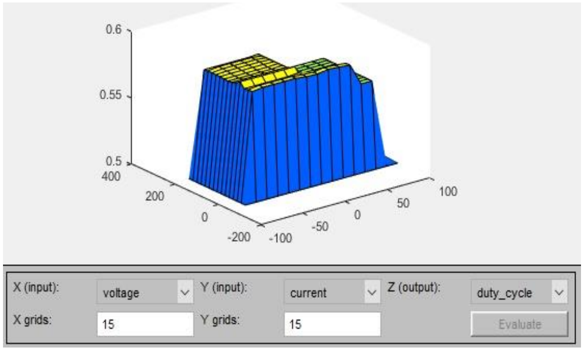

Figure 5(c): Surface viewer of the fuzzy logic controller for KY converter

B. PERTURBATION & OBSERVATION ALGORITHM

P&O algorithm abbreviated as perturbation and observation algorithm works based on the disturbance (perturbation) introduced in the system. So, the minor perturbation introduced causes the power fluctuation of the PV module. The PV module’s O/P is determined and compared with the previous power continuously. Based on the error difference the duty cycle is generated. Figure 6 depicts the algorithm flow chart.

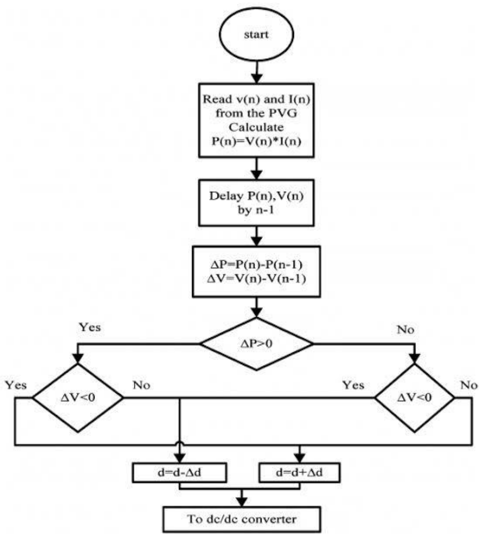

Figure 6: P&O algorithm used for KY converter

SIMULATION & ANALYSIS

The suggested block diagram is simulated with the support of MATLAB/Simulink. A simulation of a KY converter is performed using the parameters indicated in Table I. A PWM generator (DC to DC) is used to create the MOSFET's gating signal. The duty cycle for the MOSFETs is generated using a P&O algorithm and fuzzy logic controller. Figures 7 and 8 show the simulation of the KY converter with the “fuzzy logic controller” and the P & O algorithm.

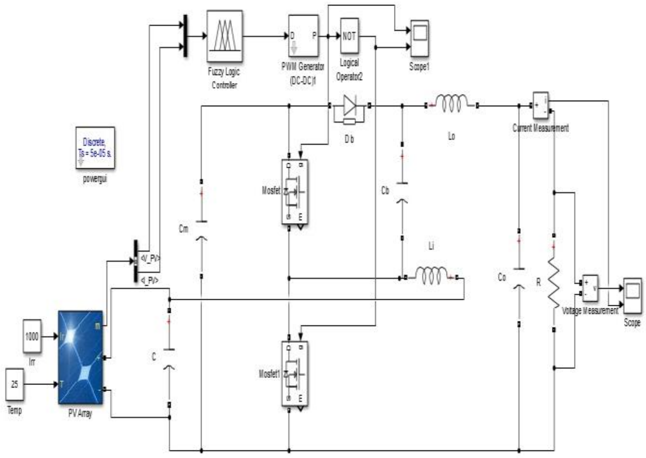

Figure 7: KY converter simulation with fuzzy logic controller

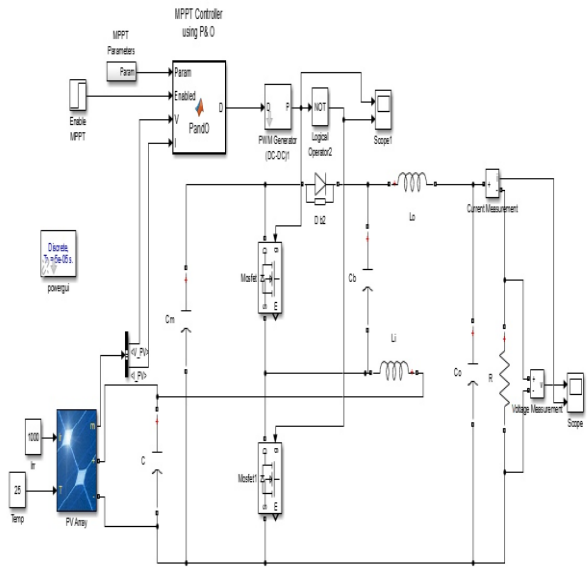

Figure 8. Simulation of KY converter with P&O algorithm

Figure 9 shows the output waveform for the KY converter simulation using a fuzzy logic controller. From this diagram it is concluded that the current is 2.795A, the O/P voltage is 251.5V, and the power is 702.94W.

The output waveform for the simulation of the KY converter utilizing a fuzzy logic controller is revealed in Figure 10. From this diagram it is inferred that the current is 2.647A, the O/P voltage is 238.2 V, and the power is 630.515 W. In the waveforms, X-axis represents time (sec) and the Y-axis indicates voltage (V) and Current (A) respectively.

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Figures 11 and 12 demonstrate the output voltage ripple for the P&O algorithm and fuzzy logic controller.

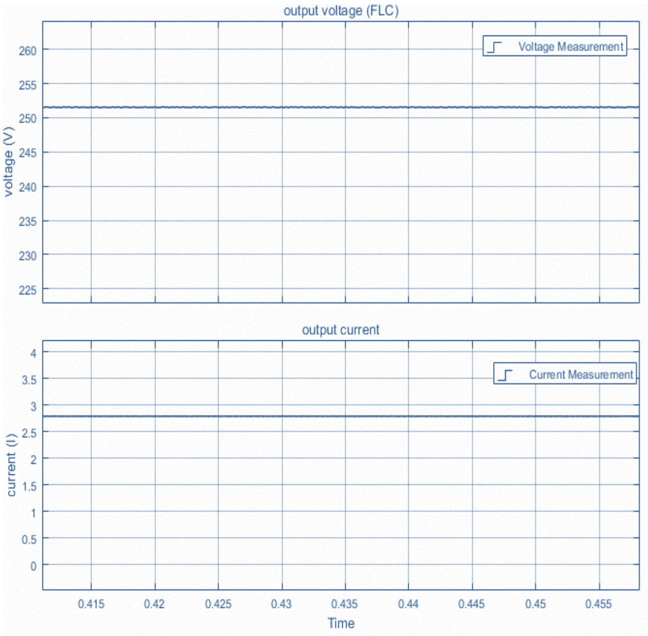

Figure 9: O/P of KY converter with fuzzy logic controller

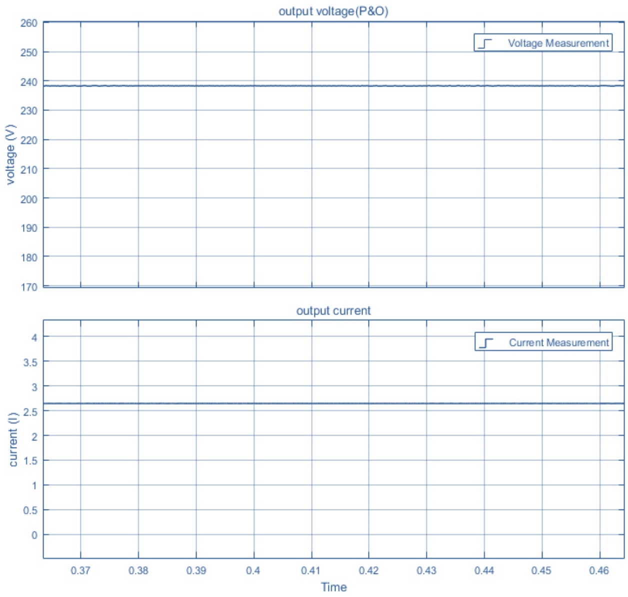

Figure 10: O/P of KY converter with P&O algorithm

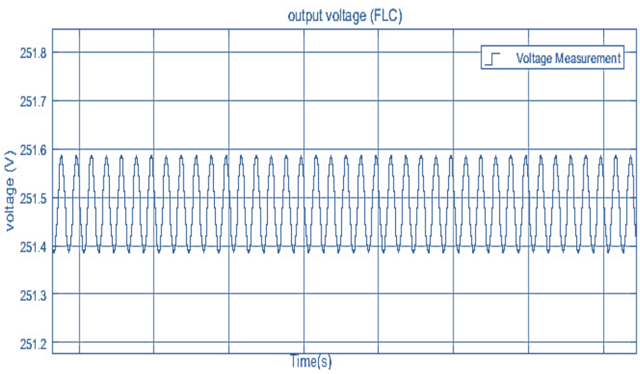

Fig.11: O/P voltage ripple of KY converter with a fuzzy logic controller

From the Fig. 11, it is concluded that the O/P voltage ripple for the simulation of the KY converter for the fuzzy-based algorithm is 0.2 V

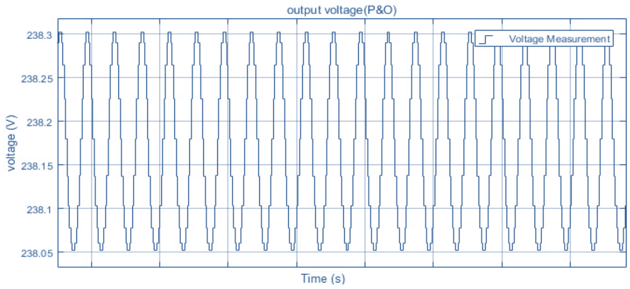

Figure 12: O/P voltage ripple of KY converter with P&O algorithm

From the fig. 12, it is concluded that the O/P voltage ripple for the simulation of the KY converter for the P and O algorithm is 0.25 V

The analysis of KY converter for fuzzy logic-based algorithm and P & O algorithm are listed in Table II.

TABLE II. ANALYSIS OF ALGORITHMS

PARAMETERS	FUZZY LOGIC BASED ALGORITHM	P & O ALGORITHM
OUTPUT VOLTAGE	251.5 V	238.2 V
INPUT VOLTAGE	90.5 V	90.5 V
OUTPUT POWER	702.94 W	630.515 W
OUTPUT CURRENT	2.795 A	2.647A

CONCLUSION

The KY converter is simulated using MATLAB/Simulink for both the fuzzy logic-based and P&O algorithms. The outcomes are examined and tabulated. It is concluded that the O/P voltage ripple for FLC is 0.2 V and for the P&O algorithm, the ripple is 0.25 V. Hence from the simulation it could be proved that the fuzzy-based approach is best suited for the KY converter. Moreover, the KY converter's O/P current is non-pulsating and has a good transient response. KY converter may be employed rather than conventional Boost converter wherever necessary. The KY converter prototype for a fuzzy-based algorithm may be implemented.

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