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Design of PSO Based KY Boost Converter to Reduce Output Ripple Voltage

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ABSTRACT

Intend of the paper is to improve the time response and to minimize the ripples of the output voltage in KY converter. Converter exhibit fast settling time, low voltage ripples and better transient response under continuous conduction mode, if KY converter is triggered with PI controller tuned by PSO algorithm. Simulation of the above work is carried out using Mat Lab simulink and a comparative study is made between PID, PI and PSO based PI controller and the finding clearly visualize that PSO based PI controller exhibit a superior characteristics.

Keywords: Boost converter, KY converter, Output Voltage Ripple, Particle Swarm Optimization (PSO), PI controller.

1. INTRODUCTION

For the access of low power, electronic device such as MP3 player, Bluetooth devices, amplifier etc., it is necessary to boost up voltage to the required level. For that we should concentrate on the ripple of output voltage, settling time and transient response of the converter. Voltage ripples are large in the case of non-isolated step up DC-DC voltage. This can be reduced by adding an inductance – capacitance (LC) filter [2] Equivalent Series Resistant (ESR) Capacitor [1]. Though these methods have good load transient response but it is difficult to achieve right-hand zero under Continuous Conduction Mode (CCM) [3]–[9] practically. The established control techniques for DC-DC converter are loop bandwidth control for the reduction of output voltage ripples [11] coupling inductors [3], sliding mode converter [10] and voltage control techniques [4]–[9]. we can infer that the system have one right – half plane zero with CCM which produces good transient response but achieving this in practice is difficult [3]–[9].

Time domain parameter are observed to analysis the performance of KY converter in reducing the ripples by a converter [13] based on Particle Swarm Optimization technique (PSO) is represented in MATLAB simulink model and the results obtained from simulation evince that there is a reduction in output voltage ripple with quick settling time compared to existing system.

2. PROPOSED SYSTEM

In this proposed system PSO [11] is implemented in the controller to select the firing angle of KY converter switches for decreasing the ripples in voltage.

Figure 1 display the basic model of KY converter, comparator, PWM generator, and controller tuned by particle swarm optimization (PSO) algorithm. Error signal is generated by comparator after comparing output signal with reference. The error signal is fed into PSO based PI controller and switching pulse for driving the converter are generated by PWM generator as per the controller Output.

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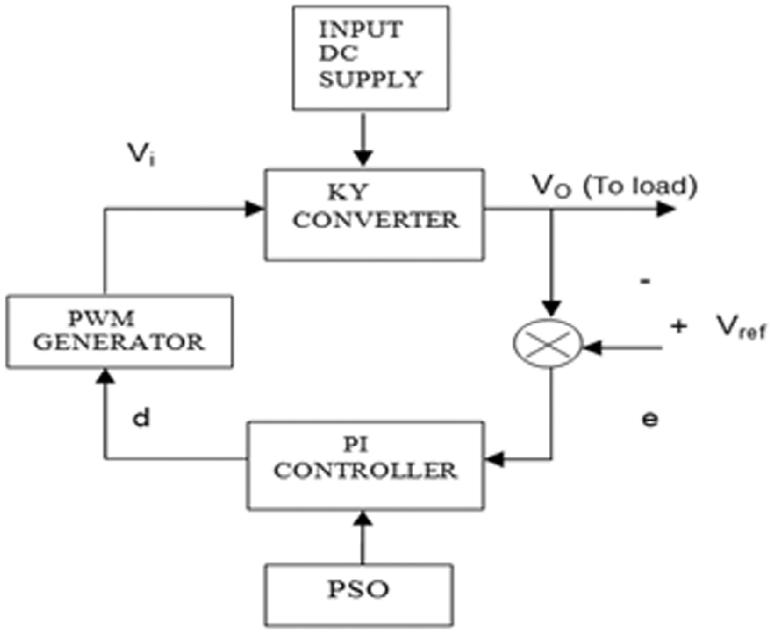

Figure 1: Block Diagram

3. BASIC OPERATION OF KY BOOST (POSITIVE OUTPUT VOLTAGE) CONVERTER

3.1. Circuit Description

Figure 2 display the circuit which is the combined form of KY converter and SR boost converter [4] [5] which operates in two modes based on the switching sequence.

The KY converter consists of two switches S_1 and S_2 with protective diode D_1 and D_2 respectively, one capacitor C_b for transferring energy, one output inductor Lo, and one output Capacitor C_0, and one buffer capacitor Cm. It has inductance at both input and output side so output current ripple is low which tends to low output voltage ripple around 200mv. It is a non-isolated converter works in continues conduction mode with conversion voltage ratio of 1plus d, where d is a duty cycle of the controller. Based on the mode of operation the firing pulse of the corresponding switches was given by the PSO based controller with response to the error signal.

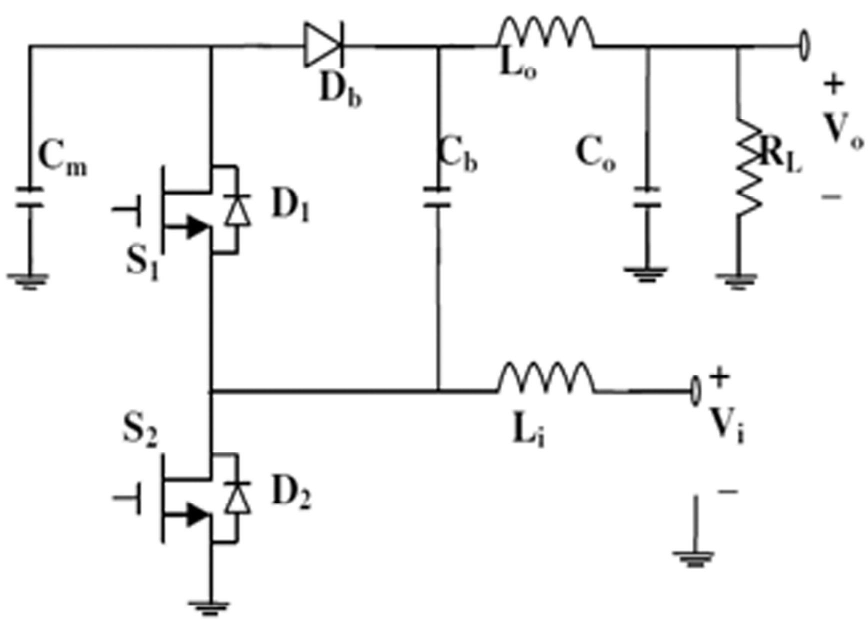

Figure 2: Positive KY Boost Converter

3.2. Modes of operation

KY converters has two modes of operation based on switching sequence

Mode 1: if the switch s_1 turned OFF and s_2 turned ON, the capacitor C_m discharged and the capacitor C_b is charged the voltage across L_i is V_I there by L_I is magnetized and Lo is demagnetized, the current flows through the L_O is the difference between the current through C_m and current through $R_{L,}$ the current through C_O is the different between current through L_O and current through R_L and the current through capacitor C_m is the sum of current through energy transfer capacitor C_b output inductor L_O which is represented in differential equation (1).

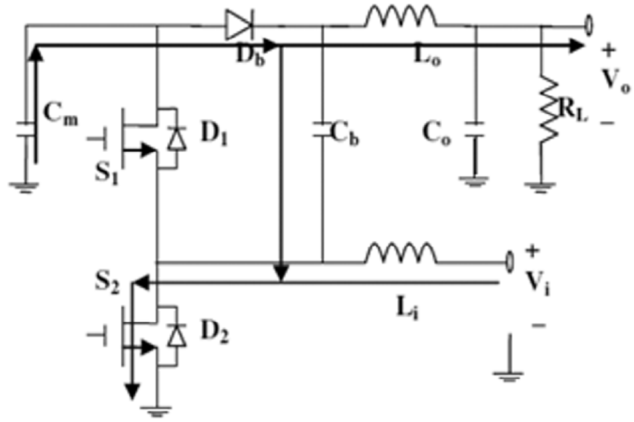

Figure 3: Mode 1 Operation

$$\begin{cases} Li\dfrac{\partial iLi}{\partial t} = vi, \\ Lo\dfrac{\partial iLo}{\partial t} = vcm - vo, \\ Co\dfrac{\partial vo}{\partial t} = iLo - \dfrac{vo}{RL}, \\ Cm\dfrac{\partial vcm}{\partial t} = -icb - iLo. \end{cases} \quad (1)$$

Mode 2: when the switch S_1 turned OFF and S_2 turned ON the capacitor C_b is discharged and the capacitor C_m is charged and voltage across L_i is calculated by the difference between V_I and V_{cm}, thereby magnetizing

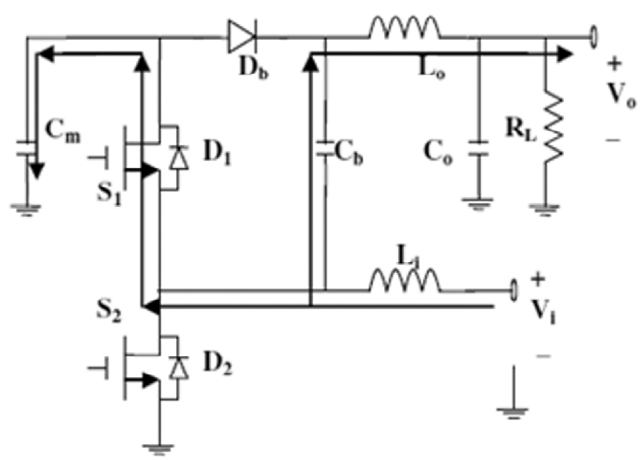

Figure 4: Mode 2 Operation

Lo and L_i is demagnetized. The voltage across L_O is the difference between voltage $2V_{cm}$ and V_O. The current through C_O is the difference between current through L_O and current through R_L, and the current through capacitor C_m is the difference between the current through output inductor L_O and input inductor L_i respectively which is represented in differential equation (2).

$$\begin{cases} Li\dfrac{\partial iLi}{\partial t} = vi - vcm, \\ Lo\dfrac{\partial iLo}{\partial t} = 2vcm - vo, \\ Co\dfrac{\partial vo}{\partial t} = iLo - \dfrac{vo}{RL}, \\ Cm\dfrac{\partial vcm}{\partial t} = -iLi - iLo. \end{cases} \tag{2}$$

From equation (3), we can obtain the average value of voltage and current, which is represented as *x*

$$\langle x \rangle = \frac{1}{Ts}\int_0^{Ts} x d\tau \tag{3}$$

The averaged inducutance and capcitance from equation (1)-(3) represented in equation (4):

$$\begin{cases} Li\dfrac{\partial \langle iLi \rangle}{\partial t} = \langle vi \rangle - (1-d)\langle vcm \rangle, \\ Lo\dfrac{\partial \langle iLo \rangle}{\partial t} = (2-d)\langle vcm \rangle - \langle vo \rangle, \\ Co\dfrac{\partial \langle vo \rangle}{\partial t} = \langle iLo \rangle - \dfrac{\langle vo \rangle}{RL}, \\ Cm\dfrac{\partial \langle vcm \rangle}{\partial t} = -\langle iLo \rangle + (1-d)\langle iLi \rangle - d\langle icb \rangle, \end{cases} \tag{4}$$

d-is the PWM generator duty cycle. The voltage ratio conversion can be obtained by following equation (5).

$$V_0 / V_i = 2 - d / 1 - d \tag{5}$$

KY boost converter design parameter is given in following table-1.

4. PARTICLE SWARM OPTIMIZATION

In recent years, the research community is paying more attention towards PSO for research purposes.

Optimum solution is found by the movement of number of particle in swarm in the search space. Each particle is constantly searching for the optimum solution which has a velocity because of the movement of particle and it memorize the its and neighbour optimum solution. There will be better co-operation and data exchange among the particle about the searched places. A particle finds the finesses of those in its neighbourhood and choose the best fitness position for particles. This position leads to adjust the particle's velocity. To get the new particle's velocity, the following calculation is used.

Table 1
KY Boost Converter Design Parameter

Parameter	*Symbol*	*Value*	*Unit*
Input voltage	V_i	12	V
Rated output voltage	V_0	36	V
Rated load current	I_0	2.5	A
Buffer capacitance	C_m	1000	µF
Output capacitor	C_0	470	µF
Output and input inductor	$L_{0,}$ L_i	15	µH
Energy transfer capacitor	C_b	680	µF
Output capacitor	C_0	470	µF
Load resistor	R_L	14.4	Ω
Switching frequency	F_S	195	kHz

New particle velocity = personel best direction randomly weighted portion + neighbourhood best direction randomly weighted portion + velocity of current

There are two types of neighbours.

They are,

1. Geographical neighbours
2. Social neighbours

Particles tune their positions according to a "Psychosocial compromise" between what an individual is comfortable with, and what society expect.

Position of the particle are modified by them with below mentioned datas

- velocity of current,
- the space between the xbest and present position,
- the present positions,
- the distance between the current position and the zbest.

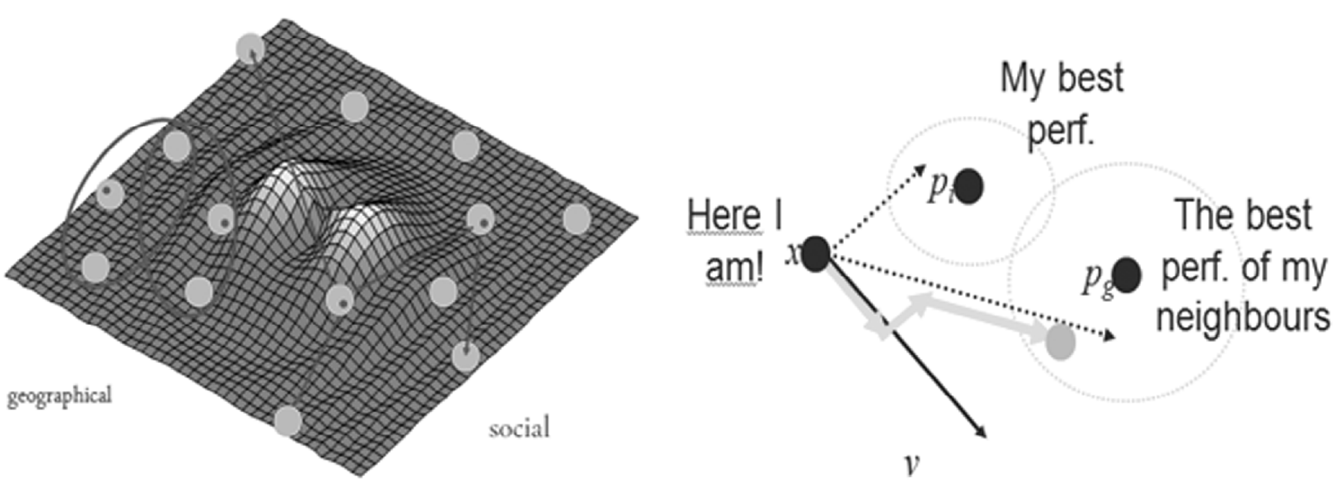

Figure 5: Neighbourhoods

equation gives the mathematical model for particle position modification (6)

$$V_i^{n+1} = m\, V_i^n + c_1\, \text{rand}_1(\ldots)\; x\; (x\text{best}_i - s_i^n) + c_2\, \text{rand}_2(\ldots)\; x\; (z\text{best} - s_i^n) \quad (6)$$

where,

v_i^n : velocity of agent i at iteration k,

m : weightingfunction,

c_j : weightingfactor,

rand : uniformly distributed random number between 0 and 1

s_i^n : current position of agent i at iteration k,

$xbest_i$: pbest of agent i,

zbest : gbest of the group.

for tuning PI controller particle swarm optimization algorithm is adapoted for decrease the output voltge ripple of KY converter.

The PSO tunes the PI controller with the error singal generated after comparing referance signal and output voltage. PSO algorithm is used to select the optimized $K_{P,}$ K_I value and this gives corresponding dutycycle[d] at the output side of the controller. The dutycycle[d] is fed into PWM generator working at the frequency of 195 KHZ, KY converter switches are tiggered with the firing angle given by PWM.

5. SIMULATION RESULT

The MATLAB SIMULINK for the proposed KY converter was shown in the figure from 6 to 10.

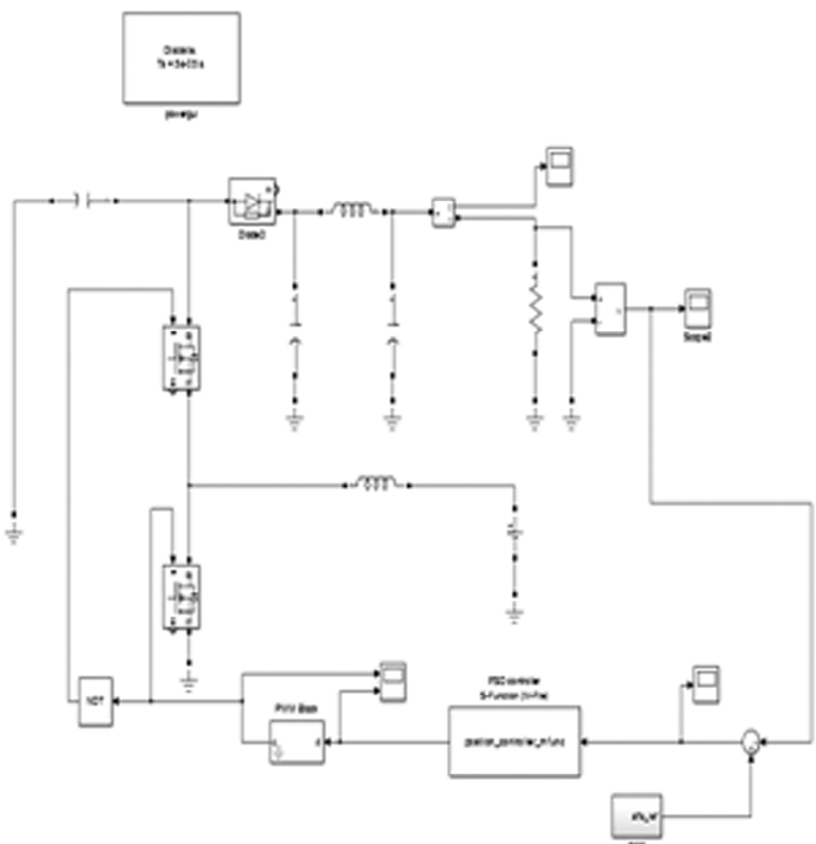

Figure 6: Simulink Model of Proposed PSO Based KY Converter

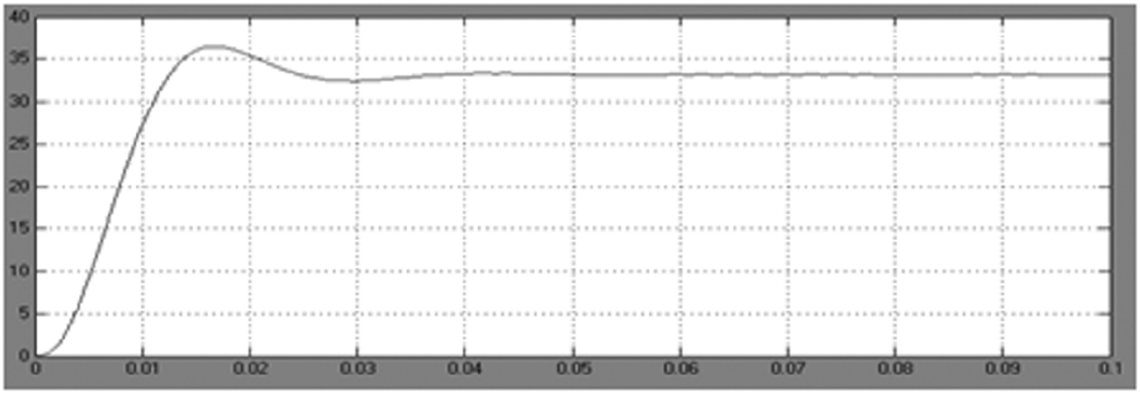

Figure 7: Output Voltage Waveform of PSO Based KY Converter

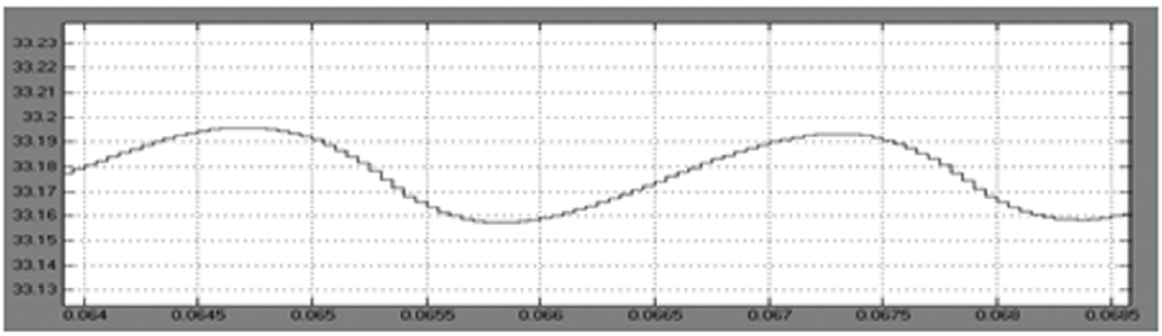

Figure 8: Output voltage ripple waveform of PSO based KY boost converter

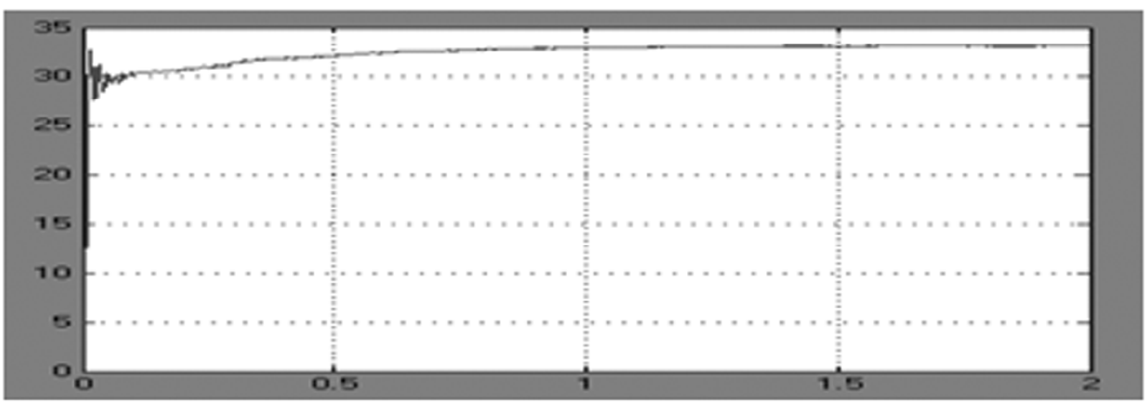

Figure 9: Output Voltage Waveform of PI controlled KY boost Converter

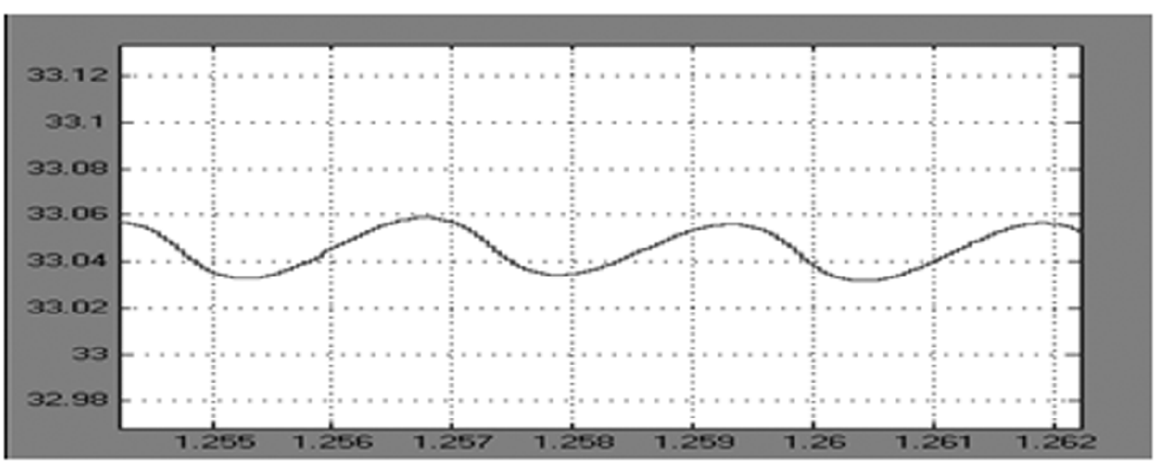

Figure 10: Output ripple Voltage Waveform of PI controlled KY boost Converter

Simulation was performed for both PI controlled KY boost converter and PSO tuned PI controlled KY converter. When compared to the existing system, PARTICLE SWARM OPTIMIZATION (PSO) tuned PI controller works more efficient then PI and PID controllers.

Table 2
Comparison of Existing Controller and Proposed Controller Output

Parameter	*PID*	*PI*	*PSO Based PI*
Output Ripple Voltage	200 mv	40 mv	20 mv
Settling time (ts)	65 ms	1 s	28 ms

6. CONCLUSION

Simulation result clearly visualize that PSO based PI controller for KY converter minimize the ripples in the output voltage 10 times compared to PID controller, provide a better time response characteristic by improving the transient response and reducing the time taken for settling compared to both PI, PID controller.

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