

## Implementation of One Cycle Control Method in Buck and Boost Converter

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**Abstract:** Conventional control methods has slow dynamic response to power source perturbation compared to one cycle control method. This paper demonstrates that switching converters based on One-Cycle Control strategy. One cycle control is a kind of nonlinear control technique. It is defined as the average value of the switched variable can follow its control reference within a switching cycle. In this paper presents one cycle control method for both buck and boost converter and its results are analyzing using MATLAB/SIMULINK.

**Keywords:** One cycle control, buck converter, boost converter, DC-DC converter

### I. Introduction

The DC-DC switching converters system has the nature of pulsed non linear dynamic characteristics. In conventional methods like pulse width modulation (PWM) and PI controller method has slow dynamic response to its input source perturbation. So to achieve robust performance with fast and excellent dynamic response, new method is introduced that is one cycle control technique [1]-[3]. By using one cycle control method (OCC), the result of the system become proper pulsed nonlinear characteristics which provides good rejection of source side and load side disturbance than the similar system with linear feedback control technique. To control switching converters for large-signal nonlinear schemes, power electronics community has been a continuous effort in the research [3]. The conventional feedback control technique responds to the disturbance occurs in source is slow. The number of switching cycles is required in larger count before it regains its steady-state. Thus, to overcome those problem so many method where taken to consideration [4]-[5].

One-cycle control (OCC) technique is a nonlinear control method, which takes advantage of the pulsed and non-linear nature of the switching converters and achieves fast dynamic control of the average value of the switched variable [6]-[7]. More specifically it takes only one switching cycle for the average value of the switched variable to reach a new steady-state after a transient. There is no steady-state or dynamic error between the reference signal and the average value of the switched variable. This technique provides fast dynamic response, excellent power source perturbation, robust performance, and automatic switching error correction. It has been widely applied in dc-dc conversion mainly in buck converter [8], power amplifier as a controlling method [9], power factor correction [10], active shunt power filter [11], multi-input DC-DC converters [12], and maximum power point tracking (MPPT) of PV solar energy onboard ship [13]-[14].

The paper divides in V sections. In section II, the basic concepts of once cycle control is explained. Buck converter and boost converter with one cycle control is explained in section III. The MATLAB/SIMULINK results are analyzed in section IV and conclusion in section V.

### II. Concept Of One Cycle Control

#### A. Theory of OCC

One cycle control theory is given in Fig.1 and Fig.2 shows the operating waveforms.

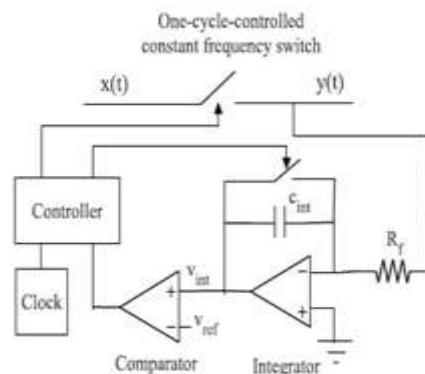


Figure. 1. Theory of one cycle control (OCC)

The switch function is

$$k(t) = \begin{cases} 1 & 0 < t < T_{on} \\ 0 & T_{on} < t < T_s \end{cases} \quad (1)$$

In each switching cycle, switch is on for a time duration  $T_{on}$  and is off for a time  $T_{off}$ , where switching period  $T_s = T_{on} + T_{off}$ . The duty ratio  $d = T_{on}/T_s$ .

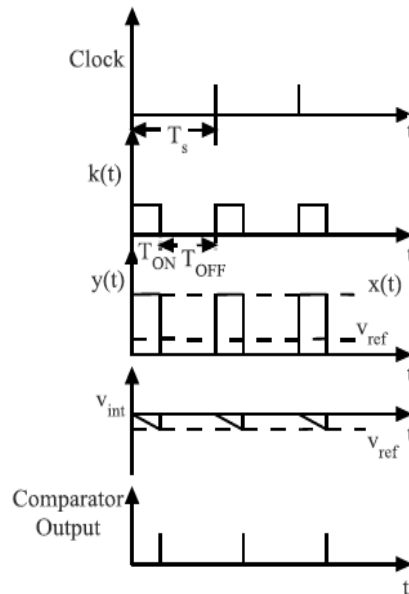
From Fig.2,

$$y(t) = k(t) * x(t) \quad (2)$$

The average of the switched variable is

$$y(t) = \frac{1}{T_s} \int_0^{T_{on}} x(t) dt \quad (3)$$

The output of the switch is the product of input signal and the duty ratio, hence the switch is non linear.



**Figure. 2** waveforms of one cycle control

If the duty ratio of switch is modulated such that the integration of the switched variable at the switch output is exactly equal to the integration of the control reference in each switching cycle.

$$\int_0^{T_{on}} x(t) dt = \int_0^{T_s} V_{ref}(t) dt \quad (4)$$

Then

$$y(t) = \frac{1}{T_s} \int_0^{T_{on}} x(t) dt = \frac{1}{T_s} \int_0^{T_s} V_{ref} dt = V_{ref}(t) \quad (5)$$

With one cycle control, the effective output signal of the switch is:  $y(t) = V_{ref}(t)$ .

The main components of one cycle control technique are the integrator and the reset switch. The integration starts at the moment when the switch is turned on by a fixed frequency clock pulse. Hence the integration value

$$V_{int} = k \int_0^t x(t) dt.$$

where  $k$  is a constant. The integration value grows from zero and reaches the control reference value. At that time controller sends a command to switch to change the state from on to off. Duty ratio of present cycle is determined by using the following equation:

$$k \int_0^{dT_s} x(t) dt = V_{ref}(t) \quad (6)$$

The average value of switched variable at the switch output is

$$y(t) = \frac{1}{T_s} \int_0^{dT_s} x(t) dt = \frac{1}{kT_s} V_{ref}(t) = K_c V_{ref} \quad (7)$$

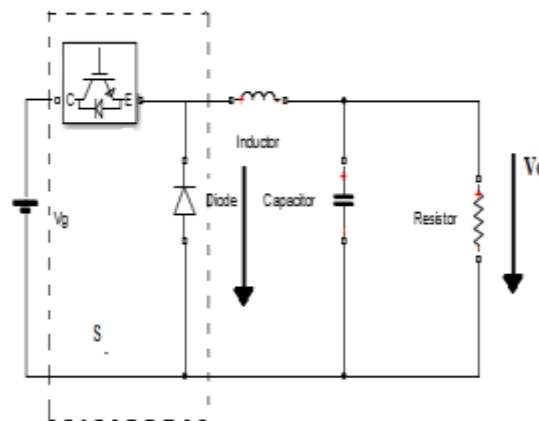
Where  $K_c = (kT_s)^{-1}$

That means in One Cycle Control, the duty ratio of the switch is modulated such that in each cycle the average value of the switched variable is exactly equal to control reference value in both steady state and transient condition.

### III. Buck And Boost Converter With OCC

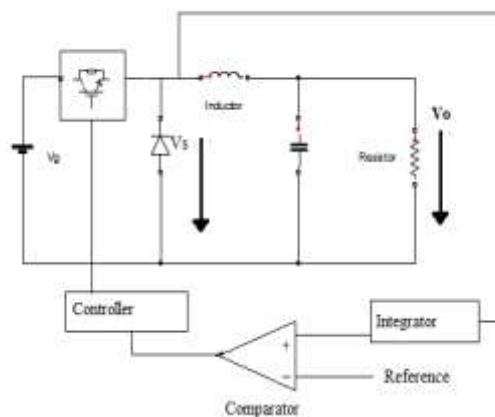
#### B. Buck converter

A buck converter is shown in Fig.3. The dc power source is  $V_g$  and the switch  $S$  operated with a constant frequency  $f_s$ . When the IGBT is on, the diode is off, and the diode voltage  $V_s$  equals the power source voltage  $V_g$ . When IGBT is off the diode is on and the diode voltage  $V_s$  is zero. The power source voltage is chopped by the switch resulting in switching variable  $V_s$ . Close observation of the switched variable leads to a simple fact. The output voltage of the buck converter is the average value of the switched variable.



**Figure. 3.**Buck converter

#### C. Buck converter with OCC



**Figure.4.**One cycle control of buck converter

A constant frequency clock turns on the IGBT at the beginning of each switching period. The diode voltage is integrated and compared with a control reference. When the integrated value reaches the reference value the comparator changes its state. As a result the IGBT is turned off and the integrator is reset to zero. If the control reference is constant, then the average diode voltage is constant and the output voltage is constant, as shown in Fig 5.

With this control scheme, the duty ratio  $d$  is determined by

$$\frac{1}{T_s} \int_0^{dT_s} V_g dt = V_{ref}$$

which is a non-linear function of the input voltage and the control reference. If this control concept is practically realizable, then transient of the average value of the diode voltage would be completed within one switching cycle. This control scheme is defined as one cycle control.

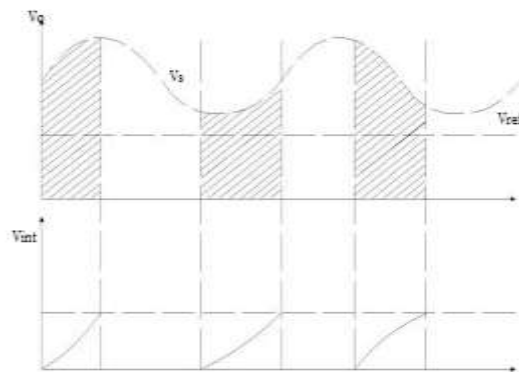


Figure.5 Constant control reference

#### D. Boost converter

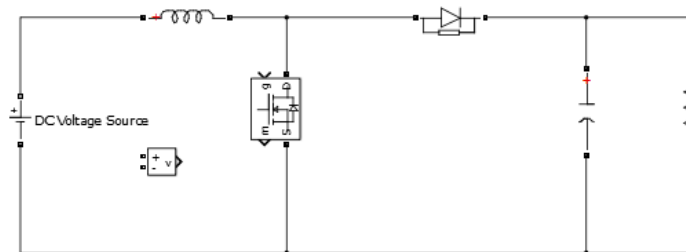


Figure.6 Boost converter

Fig 6 shows a boost converter. In boost converter the output voltage is always higher than the input voltages. It is otherwise known as step up DC-DC converter. The DC input power is  $V_s$  and the switch is MOSFET which is operated at a frequency of  $f_s$ . When the switch is OFF, the diode is ON, the diode voltage is equal to the difference between input and output voltage. When switch is ON, the diode is reverse biased and current flows through the switch and no output voltage.

#### E. Boost converter with OCC

For buck converters the integral of the diode voltage is used as a measure for the operation of the controller. In boost converters, it is possible to compare the integral of the diode voltage with a reference signal as is shown in Fig. 7. The control law in this case is as follows [15]: Fig.7 shows the general idea. In practice this circuit cannot start from the zero condition.

At the beginning when the output voltage and the diode voltage are zero, the integral of this voltage will never exceed the value of the reference and consequently the switch is always on. To solve this problem in the implementation of a one-cycle controller for boost converters, the output of the RS flip-flop should be AND ed with a square wave with a maximum practical duty cycle. Therefore at the beginning when the diode voltage is less than the reference voltage, the switch works with a maximum duty cycle.

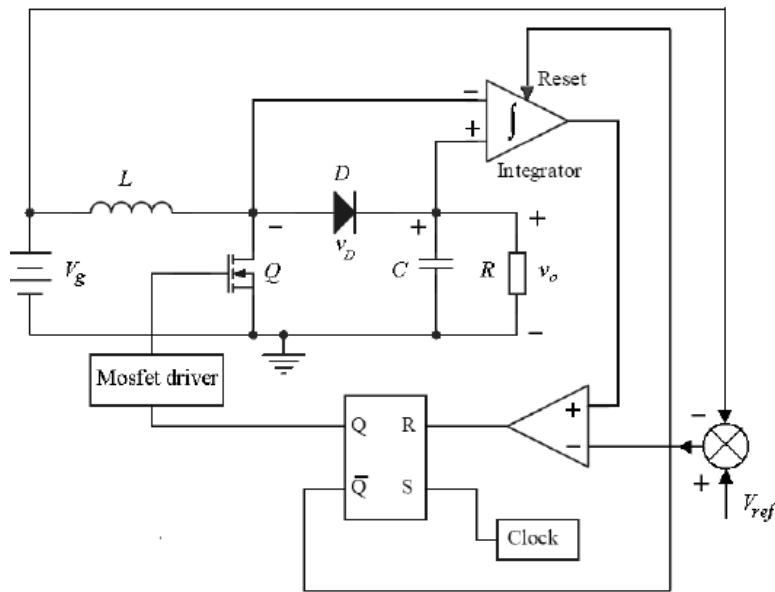


Figure.7. Boost converter with OCC

It can be seen that in OCC of a buck converter, when there is no line variation, the duty cycles at the transient and steady state are the same. This is not the case in one-cycle controlled boost converters. However, because in both cases it is the output voltage which limits the inductor current, at transient time when the output voltage is lower than the input, the inductor current has an overshoot. The overshoot of the inductor current influences the transient behavior of the output voltage; consequently, by eliminating the inductor current, the transient response of the controller can be improved.

#### IV. Simulation Results

##### F. Buck converter with OCC

Fig 8 shows the simulation circuit for buck converter with one cycle control. The main parameters used are as follows:

$$R_1 = 0.2 \Omega$$

$$L_1 = 1.38 \text{ e-}3 \text{ H}$$

$$R_2 = 0.39 \Omega$$

$$C = 220 \text{ e-}6 \text{ F}$$

$$R_{\text{load}} = 25 \Omega$$

Input voltage= varying from 50 V DC to 60 V DC

Control Reference voltage (desired output) =40 V

Switching frequency(One-Cycle Control)=10 kHz

A constant frequency clock turns on the MOSFET at the beginning of each switching period. The diode voltage is integrated and compared with a control reference.

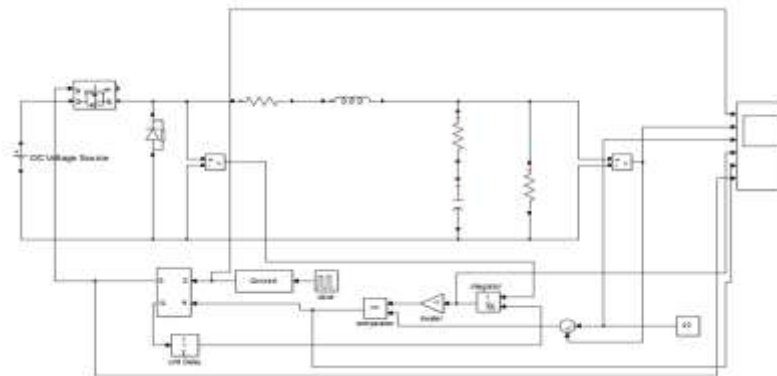


Figure.8 One cycle control of buck converter

When the integrated value reaches the reference value the comparator changes its state. As a result the MOSFET is turned off and the integrator is reset to zero. If the control reference is constant, then the average diode voltage is constant and the output voltage is constant, as shown in Fig 9.

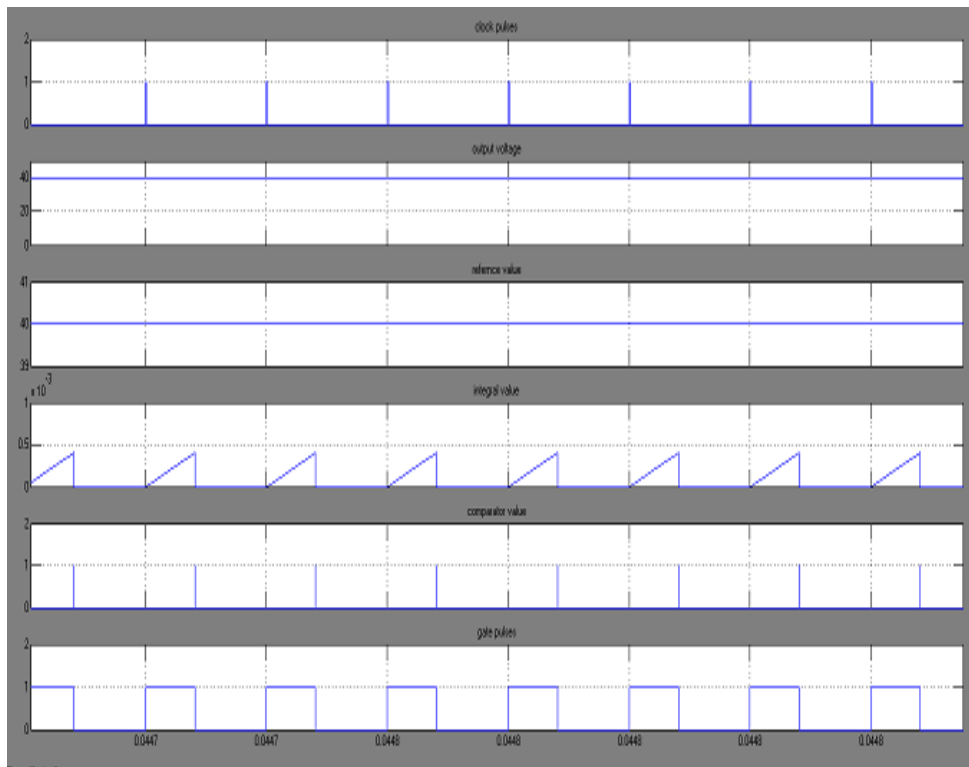


Figure.9 Waveform for OCC of buck converter

Fig 10 shows the output voltage perturbations and output voltage using OCC. As compared to PWM and PI controller it is having fast dynamic response.

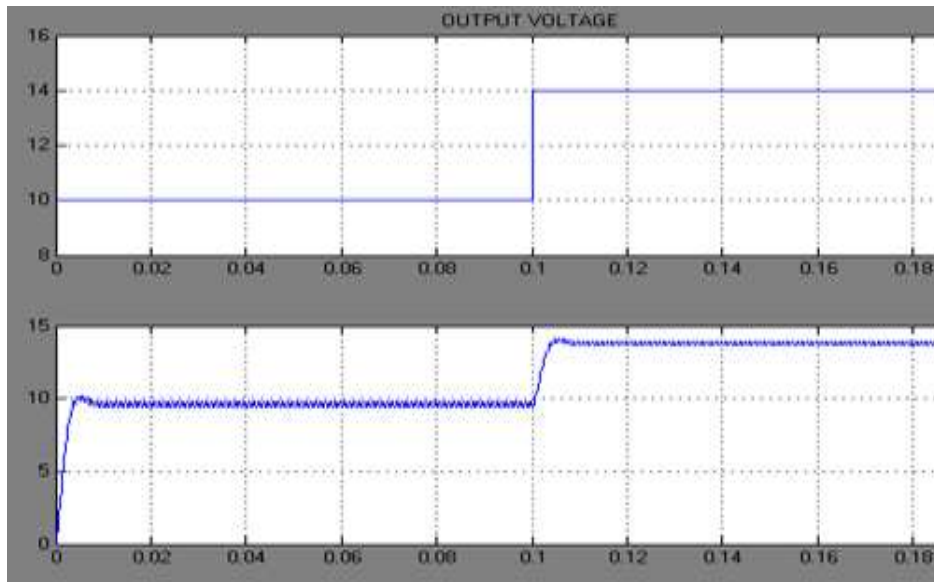


Figure 10.(a)output reference perturbation (b) Output voltage using OCC

The One-Cycle Controller rejects the input voltage perturbation and follow the control reference in one cycle and gives desired output 40 V.

G. Boost converter with OCC

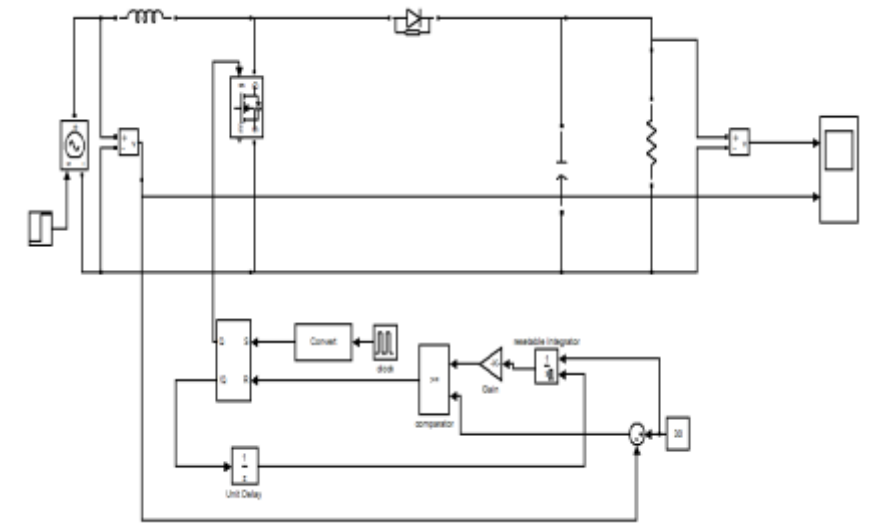


Figure.11. One cycle control of boost converter

Fig 11 shows the circuit diagram for boost converter with one cycle control. The DC input power is  $V_s$  and the switch is MOSFET which is operated at a frequency of  $f_s$ . When the switch is OFF, the diode is ON, the diode voltage is equal to the difference between input and output voltage. When switch is ON, the diode is reverse biased and current flows through the switch and no output voltage.

At the beginning when the output voltage and the diode voltage are zero, the integral of this voltage will never exceed the value of the reference and consequently the switch is always on. To solve this problem in the implementation of a one-cycle controller for boost converters, the output of the RS flip-flop should be AND ed with a square wave with a maximum practical duty cycle. Therefore at the beginning when the diode voltage is less than the reference voltage, the switch works with a maximum duty cycle.

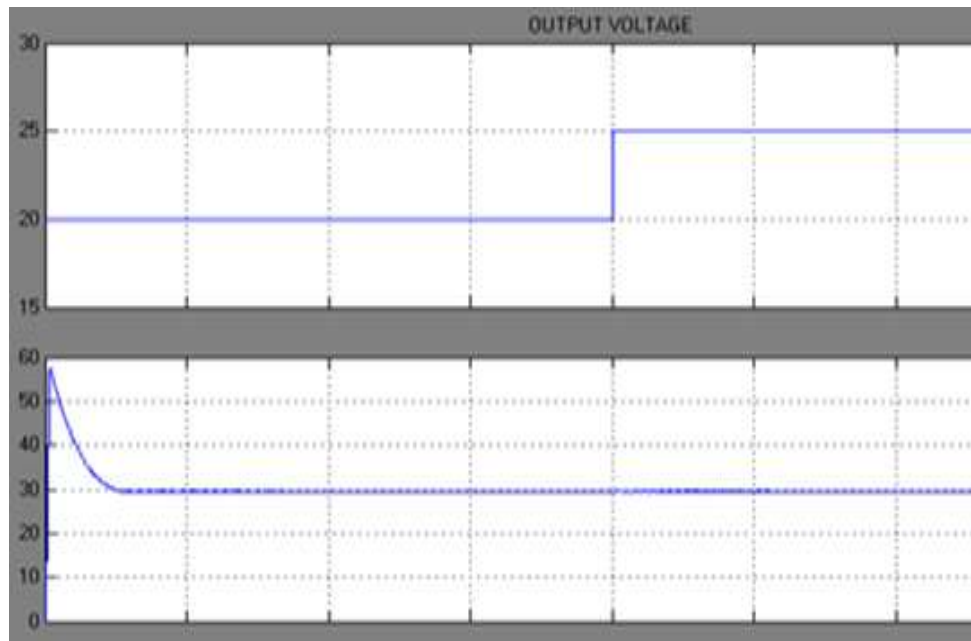


Fig.12.(a) Input voltage perturbation (b) output voltage perturbation during occ

From fig 12 and 13, Output voltage is changed due to input voltage perturbation. But under one-cycle control, the output voltage is not change even if the power source having a disturbance. So one-cycle control technique is excellent to reject the power source disturbance.

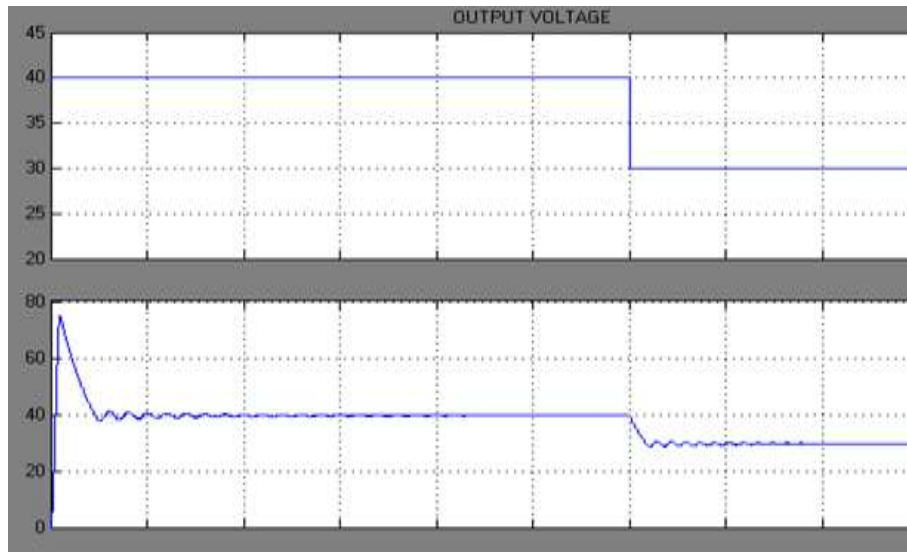


Fig 13.(a)Output reference perturbation (b) output voltage using occ

### V. Conclusion

The most important feature of one cycle control is its line disturbance rejection capability which in this matter is more powerful than conventional methods. The simulations of this buck converter and boost converter with this one cycle control-technique have demonstrated that it has fast dynamic response, excellent robust performance, control current is simple and so on and this improved technique can be implemented in others type of switching converters.

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