



The Comparison Of PI Control Method And One Cycle Control Method For Buck Converter.

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Abstract: DC-DC converters, reducing or decreasing the input voltage at the output, are commonly used in many power electronics application. Generally, all types of converter are derived from Buck or Boost converter topology. 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 and PI Control Method for buck converter and its results are analyzing using MATLAB/SIMULINK. Buck converter is analyzed with two control methods, PI and One Cycle Control (OCC), have been applied to set the output voltage at desired voltage level with 100 W output power and 10 kHz switching frequency. The simulation results have been obtained by using Simulink/MATLAB and compared with each other. The results include the dynamic response of the suggested control methods with variation of reference, power at output and input voltages. And, the proposed OCC method has better results from the point of load and reference variation. For input voltage variation PI control method is superior.

Keywords: One cycle control, buck converter, PI Control, DC-DC converter

I. Introduction

Nowadays, widespread requirement of modern power electronic equipment and systems leads to common usage of DC-DC converters that are designed to be used in various power electronic applications. High frequency switching converters are significant power electronic devices commonly used in power electronic applications [1].

The DC-DC switching converters system has the nature of pulsed nonlinear 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 and PI Control is explained. Buck converter with one cycle control and PI 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 and PI Control

A. Theory of OCC

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

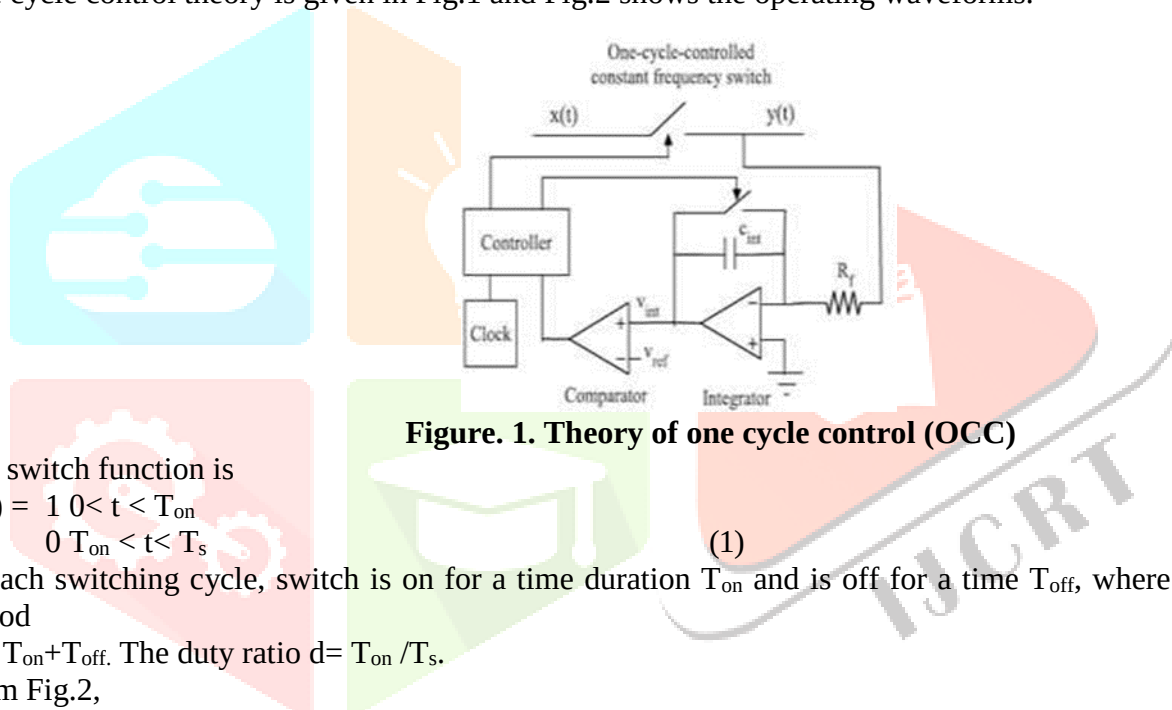


Figure. 1. Theory of one cycle control (OCC)

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 nonlinear.

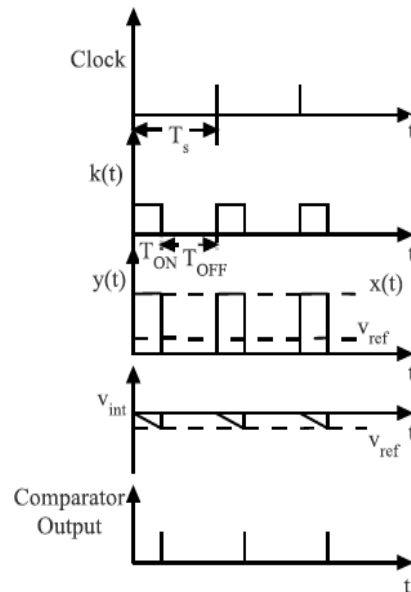


Figure. 2 waveforms of one cycle control

If the duty ratio of switch is modulated such that the integration of the switched variable at the switch

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

output is exactly equal to the integration of the control reference in each switching cycle.

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: $y(t) = V_{ref}(t)$.

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

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

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.

B.Theory of PI Control System

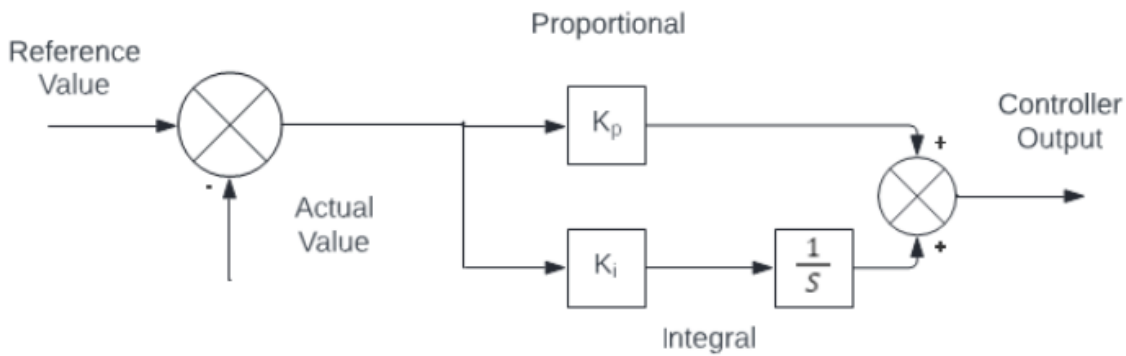


Figure. 3. Theory of PI Control System

A Proportional-Integral (PI) controller combines proportional and integral control actions to regulate a process variable. Proportional control adjusts the control signal based on the error between the set point and the process variable, while integral control eliminates steady-state errors by integrating the error over time.

Explanation of PI Control:

Proportional Control:

The proportional term (K_p) amplifies the error signal and provides the initial control action. The larger the K_p , the faster the response, but it can also lead to overshoot and instability.

Integral Control:

The integral term (K_i) integrates the error over time, accumulating the error. This term eliminates steady-state errors by gradually adjusting the control signal until the error is zero. However, it can also make the system slow to respond.

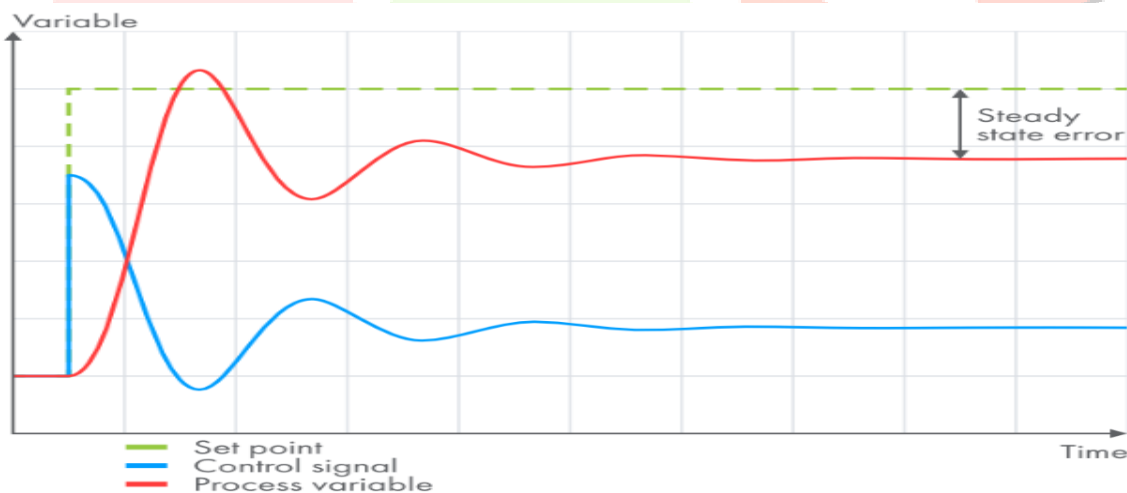


Figure. 4 waveforms PI control System

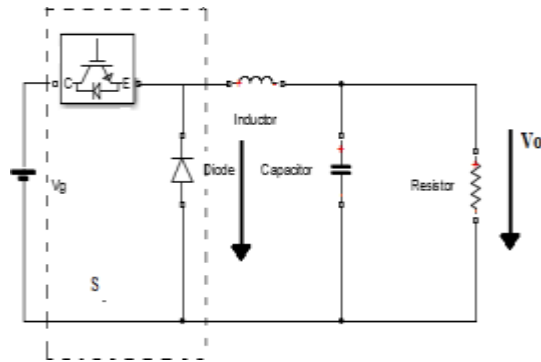
Combined Action:

PI control combines these two actions. The proportional term provides a fast initial response, and the integral term eliminates steady-state errors over time.

III. Buck Converter with OCC

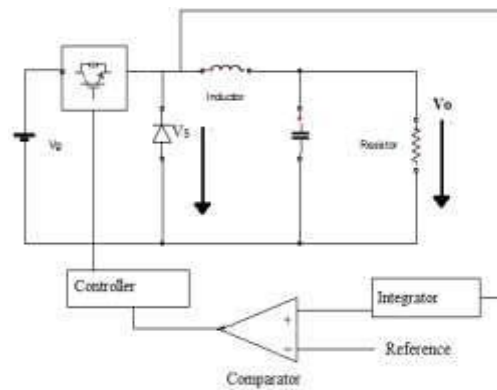
C. Buck converter

A buck converter is shown in Fig.5. 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. 5. Buck converter



D. Buck converter with OCC

Figure.6. 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

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

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.

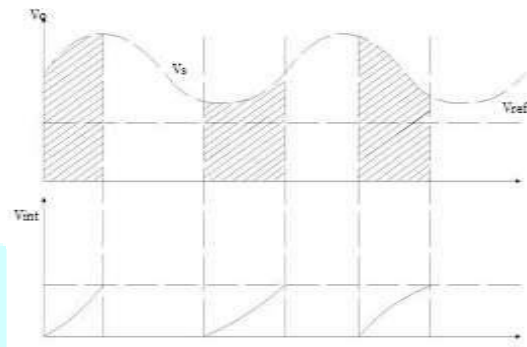


Figure.7 Constant control reference

E. Buck converter with PI Control

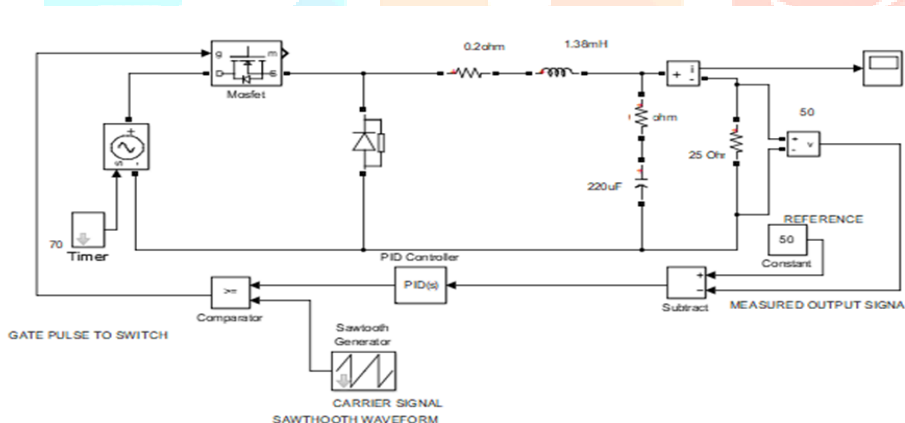


Figure.8.PI control of buck converter

A buck converter controlled by a PI controller uses a PI controller to regulate the output voltage by adjusting the duty cycle of the switching element. The PI controller compares the actual output voltage with a reference value, calculates the error, and then generates a control signal (duty cycle) to the buck converter. This control signal regulates the output voltage by adjusting the on-time of the switching element, effectively stepping down the input voltage to the desired output voltage.

IV.Simulation Results

F.Buck converter with OCC

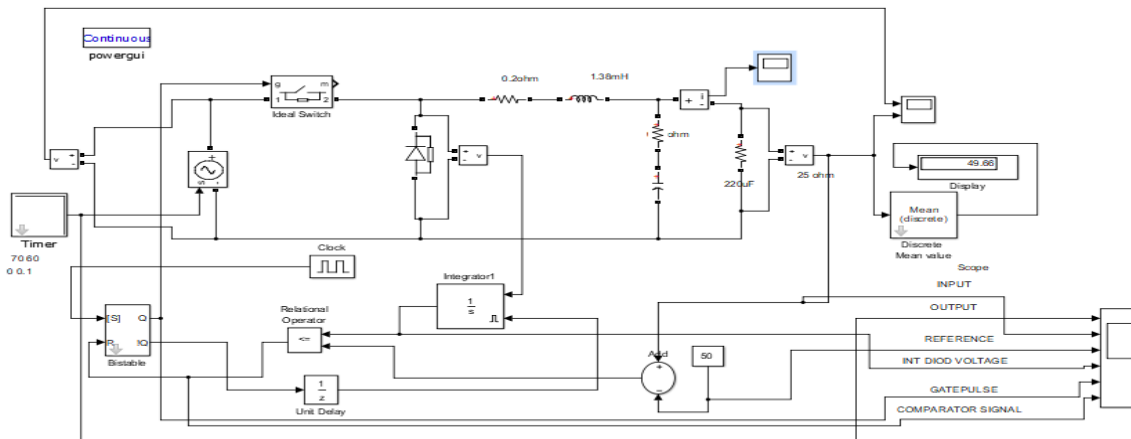


Figure.9 One cycle control of buck converter

Fig 9 shows the simulation circuit for buck converter with one cycle control. The main parameters used are as follows:

$$R_1 = 0.2 \, \Omega$$

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

$$R_2 = 0.29 \, \Omega$$

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

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

Input voltage= varying from 70 V DC to 60 V DC

Control Reference voltage (desired output) =50 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.

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 7 at instant 0.1sec.of buck converter

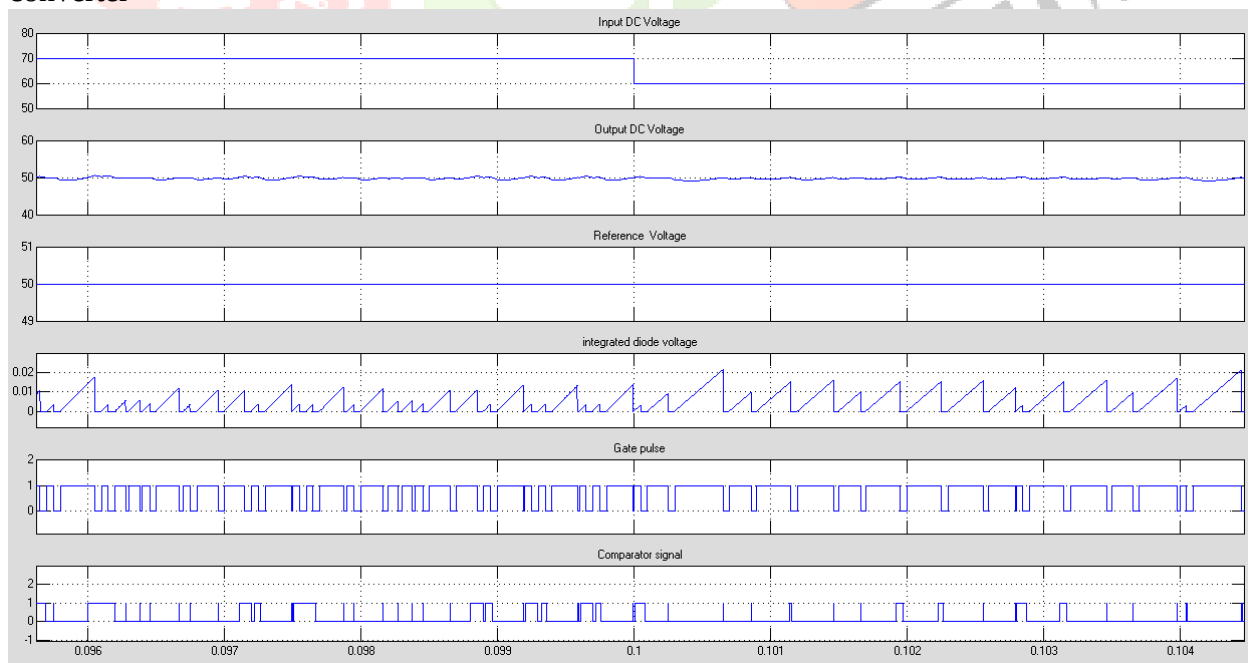


Figure.10 Waveform for buck converter with OCC

Fig 8 shows the input voltage perturbations and output voltage using OCC. As compared to PWM and PI controller it is having fast dynamic response.

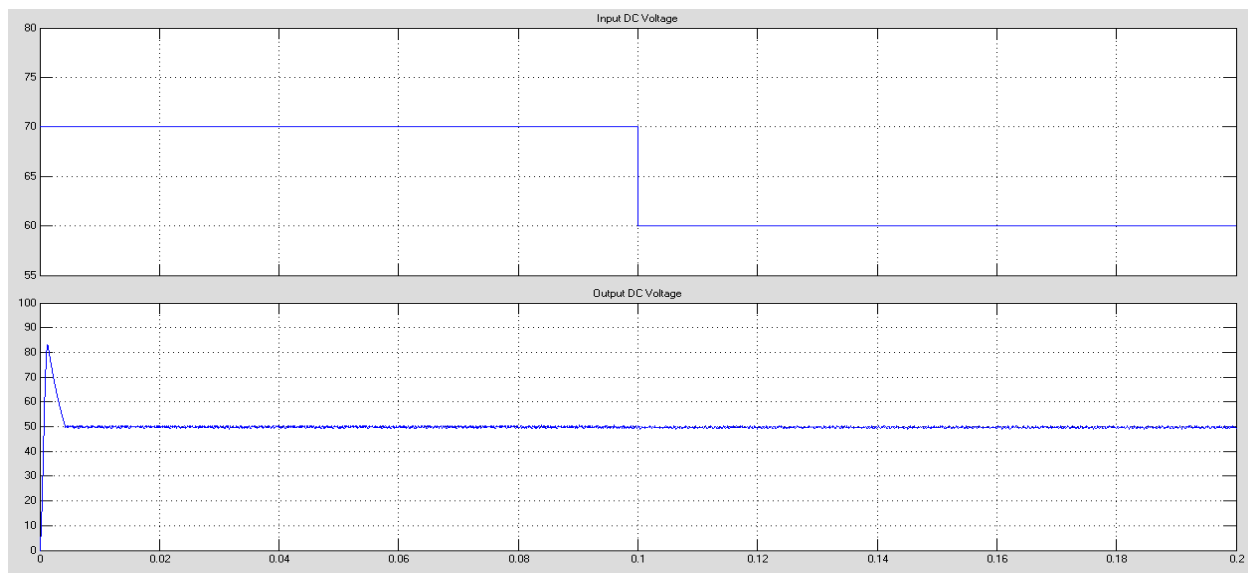


Figure 11. (a) Input voltage step change- perturbation (b) Output voltage using OCC

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

F. Buck converter with PI Control

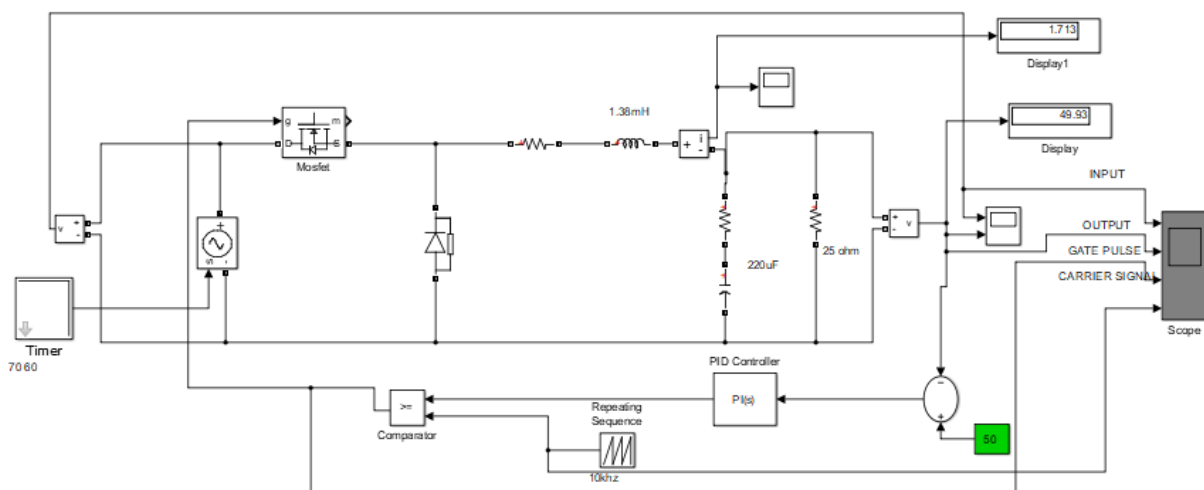


Figure.12 One cycle control of buck converter

Fig 12 shows the simulation circuit for buck converter with one cycle control. The main parameters used are as follows:

$$R_1 = 0.2 \, \Omega$$

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

$$R_2 = 0.29 \, \Omega$$

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

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

Input voltage= varying from 70 V DC to 60 V DC

Control Reference voltage (desired output) =50 V

Switching frequency (One-Cycle Control)=10 kHz

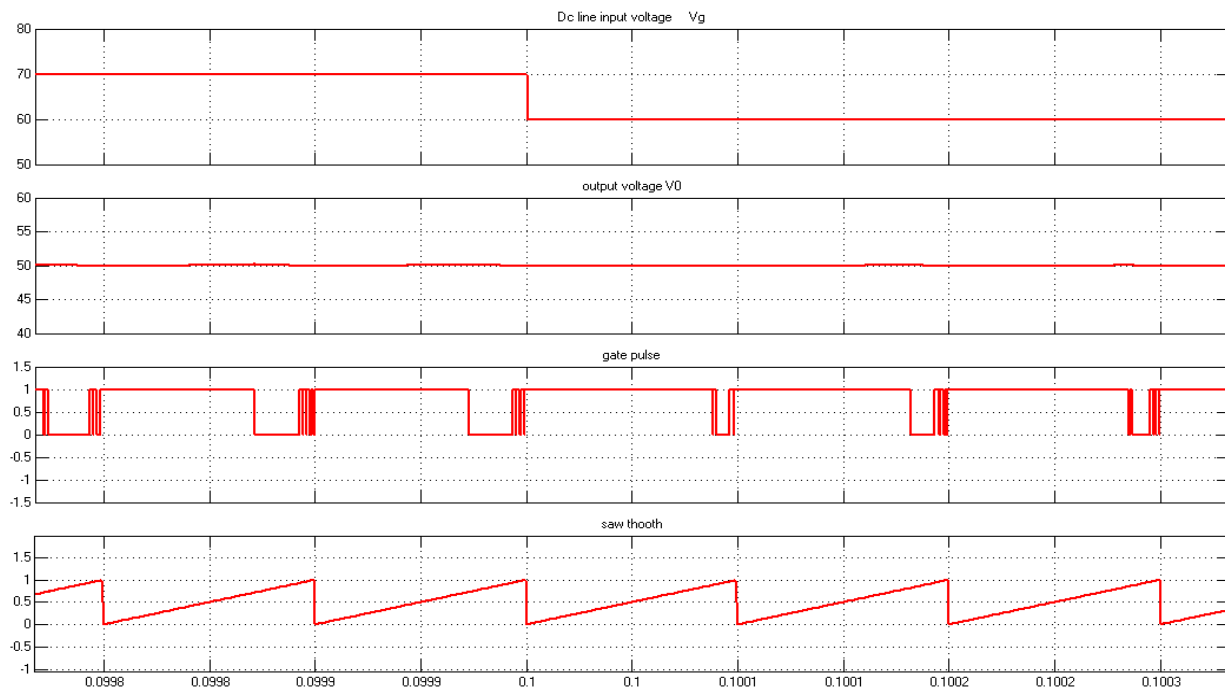


Figure.13 Waveform for buck converter with PI control-1

A buck converter controlled by a PI controller uses a PI controller to regulate the output voltage by adjusting the duty cycle of the switching element. The PI controller compares the actual output voltage 50v with a reference value 50v, calculates the error, and then generates a control signal (duty cycle) to the buck converter. This control signal regulates the output voltage by adjusting the on-time of the switching element when input voltage change from 70v to 60v , effectively stepping up the input voltage to the desired output voltage.

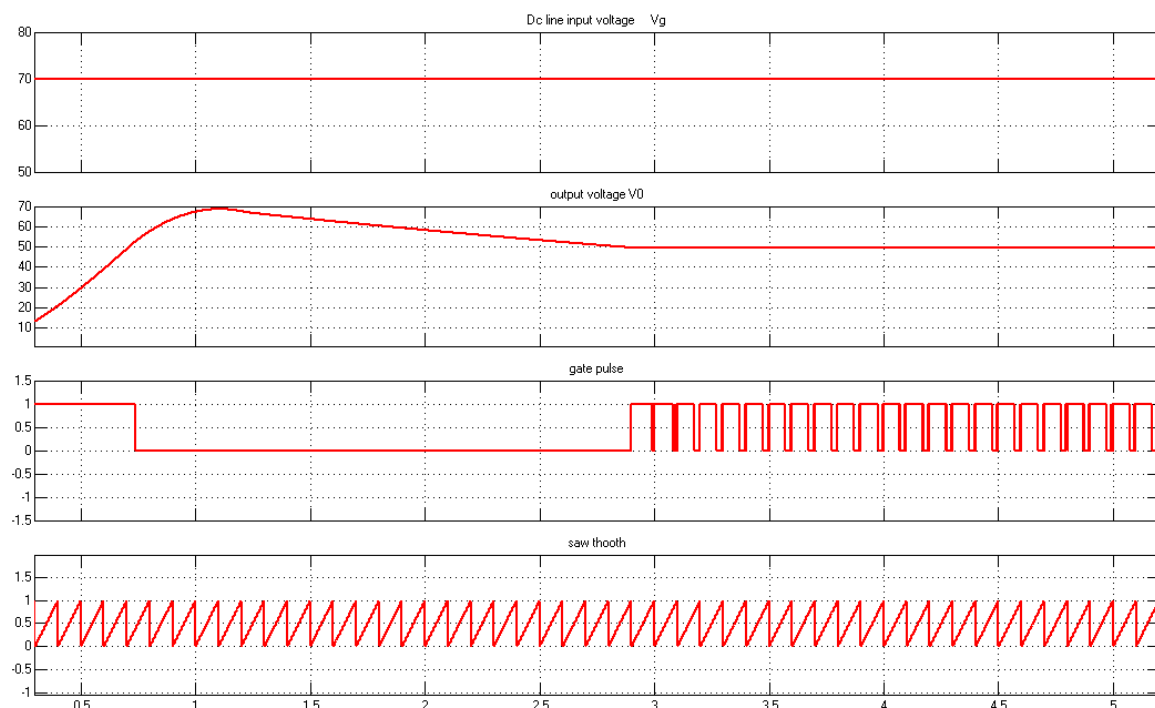


Figure.14 Waveform for buck converter with PI control-2

IV. 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 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 converter.

If we compare both control technic on some common parameters starting overshoot is more in OCC compare to PI control but time is less in OCC. Secondly Steady state Error and time is less in OCC compare to PI Control method.

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