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Design and Performance Comparison of PI and PID Controllers For Half Bridge DC-DC Converter

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ABSTRACT -*Proportional Integral Derivative (PID) controller is the most widely used controller in the industries because of its simplicity and robustness. Different types of tuning are proposed for PID controllers[1]-[4]. This paper proposes a new technology, which utilizes the duty cycle signal to improve the light load efficiency with simple implementation. In this paper Ziegler-Nichols tuned PID scheme is developed for DC-DC converters where large load changes are expected or the need for fast response time[9]. The Ziegler-Nichols rule developed in this paper is used for tuning discrete PID controller to obtain its parameters with a minimum computing complexity and is applied to Half Bridge DC-DC converter to improve its performance. The transient response and settling time of the converter is improved and it is compared with the Ziegler-Nichols based PI controller.*

Keywords - Variable parameter PID, Ziegler-Nichols method,PI Controller .

1, INTRODUCTION

The switch-mode dc–dc converters are power electronic systems that convert one level of electrical voltage into another level by switching action. These converters are very popular because of their high efficiency and smaller size, and therefore are used extensively in personal computers, communication, medical electronics and adapters of consumer electronic devices to provide different level of dc voltages. The widespread use of switching dc–dc converters in many electronic systems makes a necessity for many electronic system design engineers to design and develop efficient and reliable supplies according to demand. Switching converters are in general, time-variant, nonlinear dynamic systems[13].

The non-linearity arises primarily due to switching, power devices, and passive components, such as inductors, and capacitors. As a result, the conventional linear control techniques can't be directly applied to analyze. To design the feedback compensation using linear control techniques, a dynamic model of the switching converter is needed. The dynamic system should model the low frequency behavior of the system, but should neglect the insignificant behavior at and beyond the switching frequency. Therefore modeling process should involve the approximation to neglect the high frequency phenomena.

The Z-N tuning process should satisfy two important requirements. First it should not affect converter operation under nominal condition and second it should be based on a simple and robust algorithm whose complexity should not significantly increase the silicon area of the IC controller[11]. A compressive study has been done and scheme is presented for Ziegler-Nichols tuned PI & PID controller to improve the transient response under set-point change and load disturbances.

2, PID CONTROLLER AND BUCK CONVERTER

A general body of a PID control system is shown in Fig.1, where it can be seen that in a PID controller, the error signal e(t) is used to generate the proportional, integral, and derivative actions, with the resulting signals weighted and summed to form the control signal u(t) applied to the plant model.

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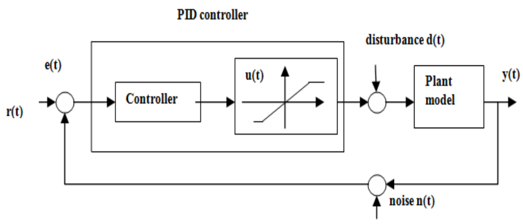

Figure .1 A typical PID control system

2.1 Different PID Controller Tuning Methods

Despite there are many design methods for PID controllers, the most widely used design methods in the literature are Ziegler-Nichols rules, Chien-Hrones-Reswick PID tuning algorithm, Cohen-Coon tuning algorithm, Wang-Juang-Chan tuning formulae[7].

The Ziegler-Nichols[3] design method which was presented in mid-20th century is the most popular methods used in process control to determine the parameters of a PID controller. One of the important specialties of this system guarantees the stabilities.

PID control consists of three types of control, Proportional, Integral and Derivative control[1].

Proportional Control:

The proportional controller output uses a 'proportion' of the system error to control the system. However, this introduces an offset error into the system.

$$P_{term} = K_P \times Error \qquad (1)$$

Integral Control:

The integral controller output is proportional to the amount of time there is an error present in the system. The integral action removes the offset introduced by the proportional control but introduces a phase lag into the system.

$$I_{term} = K_I \times \int Error \, dt \qquad (2)$$

Derivative Control:

The derivative controller output is proportional to the rate of change of the error. Derivative control is used to reduce/eliminate overshoot and introduces a phase lead action that removes the phase lag introduced by the integral action.

$$D_{term} = K_D \times d(Error)/dt \qquad (3)$$

2.2 Buck Converter

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The buck or step down converter regulates the average DC output voltage at a level lower than the input or source voltage. This is accomplished through controlled switching where the DC input voltage is turned on and off periodically, resulting in a lower average output voltage. The buck converter is commonly used in regulated DC power supplies like those in computers and instrumentation. The buck converter is also used to provide a variable DC voltage to the armature of a DC motor for variable speed drive applications

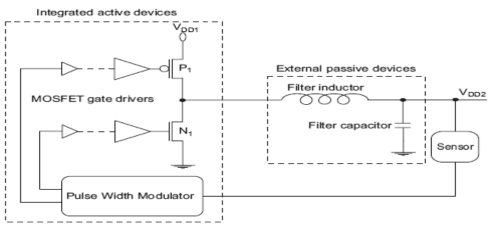

Figure.2 Block diagram of buck converter

3, PROPOSED METHOD

The demand for the high efficiency DC-DC converters is increase dramatically, especially for use in battery operated devices such as cellular phones and laptop computers. The switched mode power supply is called as the high efficiency power supply and buck converter is one of them therefore it is of great importance to research on buck converter. good performance. The output voltage is controlled by varying the duty cycle.

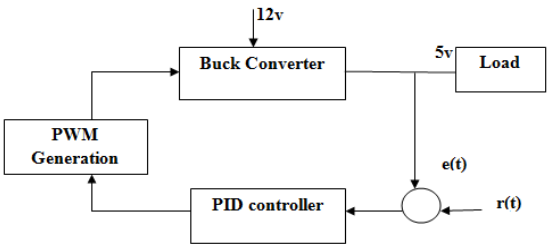

Figure .3 Block diagram of a proposed system

Proportional Integral Derivative (PID) controller is the most widely used controller in the industries because of its simplicity and robustness. Different types of tuning are proposed for PID controllers. This proposed system proposes a new technology, which utilizes the duty cycle signal to improve the light load efficiency with simple implementation. In this proposed system Ziegler-Nichols tuned PID scheme is developed for DC-DC converters where large load changes are expected or the need for fast response time.The transient response and settling time of the converter is improved.

4, DESIGN OF PID AND PI CONTROLLER

4.1 Ziegler-Nichols method-1

Controller	K_p	T_i	T_d
P	T/t_d		
PI	$0.9T/t_d$	$3.33t_d$	
PID	$1.2T/t_d$	$2t_d$	$.5t_d$

Table.1 Formula For Z-N Method 1

PID Controller:

Transfer function for PID Controller is

$$Kp(1 + \frac{1}{T_i S} + T_d S) \quad (4)$$

$K_p = 12$
$K_i = 10.4*e3$
$K_d = 3.42*e\text{-}3$.

PI Controller:

The transfer function for PI controller is

$$Kp(1 + \frac{1}{T_i S}) \quad (5)$$

$K_p = 9$
$K_i = 4.7*e\text{-}3$.

4.2 Ziegler-Nichols method-2

Controller	K_p	K_i	K_d
P	T/t_d		
PI	T/t_d	$t_d/0.3$	
PID	$1.2T/t_d$	$t_d/0.5$	$.5t_d$

Table 2. Formula for Z-N method-2

PID Controller:

$K_p = 12$
$K_i = 1.14*e\text{-}3$
$K_d = 2.85*e\text{-}4$.

PI Controller :

$Kp = 9$.
$K_i = 1.9 * e\text{-}3$.

5, SIMULATION RESULTS

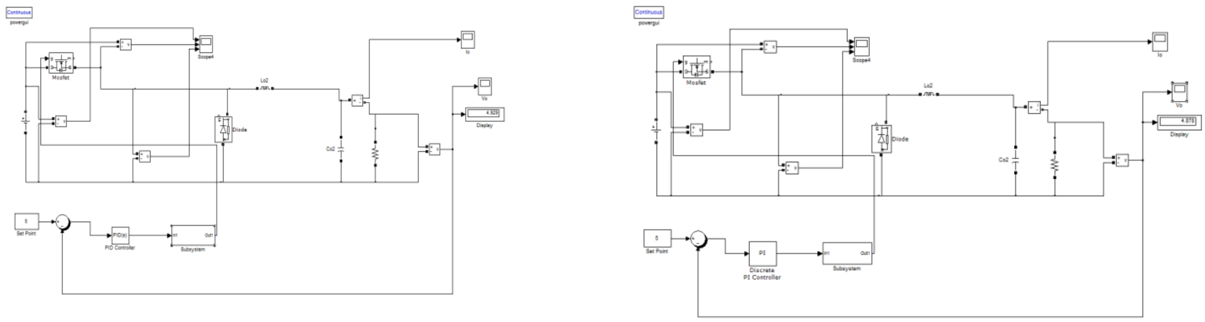

Figure.4 Closed Loop Simulation Circuit for Z-N PID 1 and Z-N PI 1

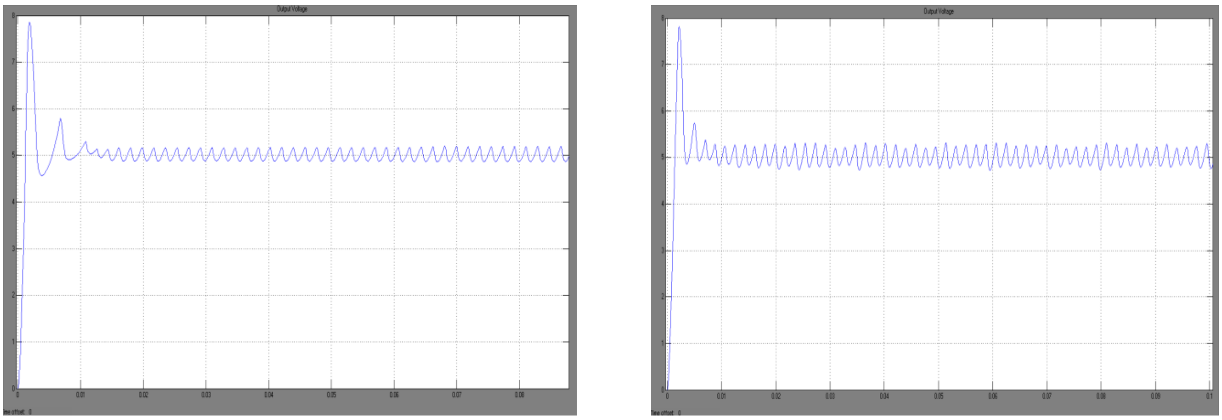

Figure .5 Simulation Waveform of Output Voltage for ZN-PID 1 and ZN-PI 1

6,SIMULATION ANALYSIS

6.1 Ziegler – Nichols Method 1 and Method 2

Parameters	**PI**	**PID**
Maximum peak overshoot (Mp)	3.02v	2.95v
Rise time (tr)	1.04 * e-3 s	1.22 * e-3 s
Peaktime (tp)	2.2 * e-3 s	1.9 * e-3 s
Delay time (td)	8.56 * e-4 s	8.2 * e-4 s

Parameters	**PI**	**PID**
Maximum peak overshoot (Mp)	1.03v	0.9v
Rise time (tr)	1.42 * e-3 s	1.4 * e-3 s
Peaktime (tp)	1.778 * e-3 s	1.67 * e-3 s
Delay time (td)	8.65 * e-4 s	8.6 * e-3 s

Settling time (ts)	3.33 ms	3.1 ms
Steady state error (ess)	12.2 %	7.1 %

Settling time (ts)	3.48 ms	3.4 ms
Steady state error (ess)	15.4 %	12.6 %

Table .3 Simulation analysis using Ziegler-Nichols method 1 and method 2

VII. CONCLUSION

In spite of the fact that controllers designed by the Ziegler-Nichols rules give a good performance. In this paper, the control technique applicable for a buck converter is proposed and the analysis of its operating principles was discussed. In this paper, a Ziegler-Nichols tuned PID scheme has been presented for DC-DC converter It is concluded that with the use of voltage feedback loop constant output voltage is obtained.The proposed scheme continuously adjusts the controller gains through Ziegler-Nichols rules defined on the instantaneous process states. It can be easily applied to an existing controller.

The effectiveness of the proposed controller has been tested through simulation experiments on Half Bridge DC-DC converter. The performance of the converter is compared with ZN tune PI controller is applied with initial parameters. The Ziegler-Nichols tuned PID has shown consistently enhanced performance both in transient and steady state conditions. In the proposed scheme transient response and settling time of the converter has been improved.

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