

Research on ripple rejection of DC power supply based on dual pulse width modulation

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Abstract: With the development of power electronics technology, how to improve the output quality of DC power supply has become an important subject of recent scholars' research. This paper put forward a new PWM control mode, the DC power supply output ripple is effectively suppressed. The theoretical basis is given by the principle analysis. Finally, the accuracy of the theoretical analysis is verified by simulation.

1. Introduction

With the development of power electronics technology, how to improve the output quality of DC power supply has become an important subject of recent scholars' research. DC power output ripple is too large mainly have the following effects: the capacitor load caused by resonance and harmonic current amplification, resulting in the capacitor due to overload or over-voltage damage; so that some electrical equipment, especially precision instruments and equipment work is not normal, or even damage; resulting in energy measurement and other detection instrument error.

Buck circuit as a research object, put forward a new PWM control mode, the DC power supply output ripple is effectively suppressed.

2. Principle of Dual Pulse Width Modulation

For the dual pulse width modulation scheme in Figure.1.

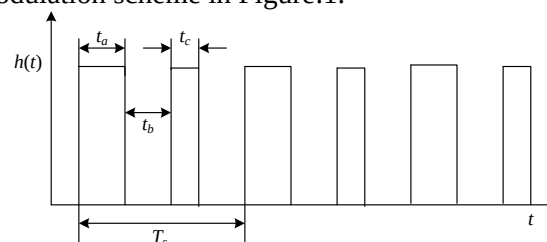


Fig.1 Dual pulse modulation

From figure1 we can see the first pulse on time is t_a , the second pulse on time is t_b , the time interval between the two pulses is t_c , and t_a , t_b , t_c satisfy the following relation:

$$\begin{cases} t_a = D_{on1} \times T_s \\ t_c = D_{on2} \times T_s \\ D_{on} = D_{on1} + D_{on2} \\ t_b = D_{int} \times T_s < (1 - D_{on}) T_s \end{cases} \quad (1)$$

D_{on1} is the duty cycle of the first pulse in the formula (1), D_{on2} is the duty cycle of the second pulse, D_{int1} is the ratio of the time between the two pulse intervals and the control signal period; here we define 2 function $H(n,D)$ and $G(n,D)$

$$H(n,D) = \frac{D_{on2}}{D_{on1}} \quad (2)$$

$$G(n,D) = \frac{D_{int1}}{D_{on1}} \quad (3)$$

Where $H(n,D)$ is the proportional coefficient of the duty cycle of the second pulse and the first pulse in the switching period, and $G(n,D)$ is the ratio of the two pulse interval to the duration of the first pulse (1), (2) and (3) we can get the mathematical expression of D_{on1} , D_{on2} , D_{int1} as formula(4):

$$\begin{cases} D_{on1} = \frac{D_{on}}{1 + H(n,D)} \\ D_{on2} = \frac{H(n,D) \times D_{on}}{1 + H(n,D)} \\ D_{int1} = \frac{D_{on} \times G(n,D)}{1 + H(n,D)} \end{cases} \quad (4)$$

3. Application of Dual Pulse Width Modulation in Buck Circuit

3.1 Principle analysis

In order to further study the dual pulse width modulation mode, this paper uses Buck circuit as an example to analyze the output current ripple; harmonics of Buck circuit in single pulse width and dual pulse width modulation mode.

From one paper[1] we can obtain the single-pulse mode current ripple as follows, in the formula, V_s is the input voltage size, T_s is the switching period, D_{on} is the switch-ing cycle duty cycle, F_s is the switching frequency.

$$\Delta I_{L-single} = \frac{V_s D_{on} (1 - D_{on})}{L f_s} \quad (5)$$

Figure 6 is the working waveform of the circuit in the dual pulse width modulation mode; in the figure, t_a is the first pulse on time, t_b is the two pulse time interval, t_c is the second pulse on time, t_d is the second pulse With the time interval of the first pulse of the next cycle.

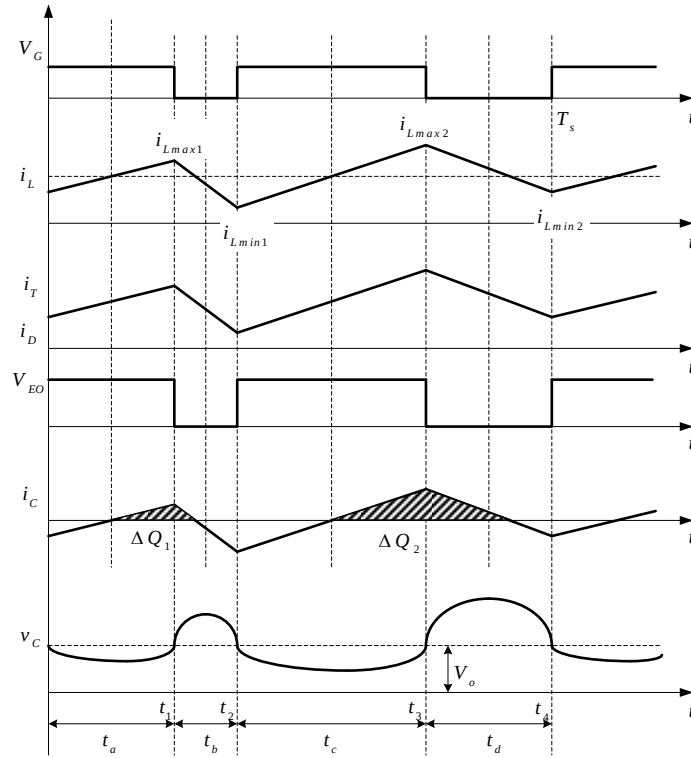


Fig.2 Working principle diagram of double pulse modulation mode

From the principle of the buck circuit we can obtain the following formula:

$$\Delta i_{L1+} = \frac{V_s - V_o}{L} t_a = \frac{V_s - V_o}{L} D_{on1} T_s = \frac{V_s - V_o}{L f_s} D_{on1} \quad (6)$$

$$\Delta i_{L1-} = \frac{V_o}{L} t_b = \frac{V_o}{L} D_{int1} T_s = \frac{V_o}{L f_s} D_{int1} \quad (7)$$

$$\Delta i_{L2+} = \frac{V_s - V_o}{L} t_c = \frac{V_s - V_o}{L} D_{on2} T_s = \frac{V_s - V_o}{L f_s} D_{on2} \quad (8)$$

$$\Delta i_{L2-} = \frac{V_o}{L} t_d = \frac{V_o}{L} D_{int2} T_s = \frac{V_o}{L f_s} D_{int2} \quad (9)$$

The duty cycle of the two pulses in the dual pulse width modulation mode has the following relationship with the duty cycle of the whole cycle:

$$D_{on1} + D_{on2} = D_{on} \quad (10)$$

The relationship between the interval and the ratio of the pulse is as follows:

$$D_{int1} + D_{int2} = D_{off} = 1 - D_{on} \quad (11)$$

From Figure2 we can obtain the maximum value of the inductor current minimum expression within the pulse width modulation period:

$$\begin{cases} I_{Lmax1} = i_L(0) + \Delta i_{L1+} \\ I_{Lmin1} = I_{Lmax1} - \Delta i_{L1-} \\ I_{Lmax2} = I_{Lmin1} + \Delta i_{L2+} \\ I_{Lmin2} = I_{Lmax2} - \Delta i_{L2-} = i_L(0) \end{cases} \quad (12)$$

From Figure2 we can see that, at that time, at that time;

In the following equation (2.3.14), we obtain the following inequality group:

$$\begin{cases} I_{Lmax1} > I_{Lmax2}, D_{off} D_{on1} > D_{on} D_{off2} \\ I_{Lmax1} < I_{Lmax2}, D_{off} D_{on1} < D_{on} D_{off2} \\ I_{Lmin1} > I_{Lmin2}, D_{off} D_{on2} > D_{on} D_{off2} \\ I_{Lmin1} < I_{Lmin2}, D_{off} D_{on2} < D_{on} D_{off2} \end{cases} \quad (13)$$

From (12) and (13) we can conclude that the output current ripple expression of the circuit in the dual pulse width modulation mode is:

$$\Delta i_{L-dual} = \begin{cases} I_{Lmax1} - I_{Lmin2}; (I_{Lmax1} > I_{Lmax2}, I_{Lmin1} > I_{Lmin2}) \\ I_{Lmax1} - I_{Lmin1}; (I_{Lmax1} > I_{Lmax2}, I_{Lmin1} < I_{Lmin2}) \\ I_{Lmax2} - I_{Lmin1}; (I_{Lmax1} < I_{Lmax2}, I_{Lmin1} < I_{Lmin2}) \\ I_{Lmax2} - I_{Lmin2}; (I_{Lmax1} < I_{Lmax2}, I_{Lmin1} > I_{Lmin2}) \end{cases} \quad (14)$$

Substituting the constraints in (13) into equation (14) we can obtain the following formula:

$$\Delta I_{L-dual} = \begin{cases} \frac{V_s - V_o}{L} t_a; (D_{off} D_{on1} > D_{on} D_{int1} \&\& D_{off} D_{on2} > D_{on} D_{int2}) \\ \frac{V_o}{L} t_b; (D_{off} D_{on1} > D_{on} D_{int2} \&\& D_{off} D_{on2} < D_{on} D_{int2}) \\ \frac{V_s - V_o}{L} t_c; (D_{off} D_{on1} < D_{on} D_{int2} \&\& D_{off} D_{on2} < D_{on} D_{int2}) \\ \frac{V_s - V_o}{L} t_a - \frac{V_o}{L} t_b + \frac{V_s - V_o}{L} t_c; (D_{off} D_{on1} < D_{on} D_{int2} \&\& D_{off} D_{on2} > D_{on} D_{int2}) \end{cases} \quad (15)$$

From (12) and (13) we can conclude the following formula:

$$\Delta I_{L-dual} = \begin{cases} \frac{V_s - V_o}{L} t_a; (\frac{G(n,D)}{H(n,D)} D_{on} > D_{off} \&\& D_{off} < G(n,D) D_{on}) \\ \frac{V_o}{L} t_b; (\frac{G(n,D)}{H(n,D)} D_{on} > D_{off} > G(n,D) D_{on}) \\ \frac{V_s - V_o}{L} t_c; (D_{off} > \frac{G(n,D)}{H(n,D)} D_{on} \&\& D_{off} > G(n,D) D_{on}) \\ \frac{V_s - V_o}{L} t_a - \frac{V_o}{L} t_b + \frac{V_s - V_o}{L} t_c; (\frac{G(n,D)}{H(n,D)} D_{on} < D_{off} < G(n,D) D_{on}) \end{cases} \quad (16)$$

And the single pulse modulation current ripple can be described as:

$$\Delta I_{L-single} = \frac{V_s D_{on} (1 - D_{on})}{L f_s} = \frac{V_s - V_o}{L} (t_a + t_c) = \frac{V_o}{L} (t_b + t_d) \quad (17)$$

Comparing the formula (16) with the formula (17), it can be seen that the output current of the circuit in the dual pulse width modulation mode regardless of the value of the function H (n, D) and G (n,D) , the ripple of the dual-pulse modulation mode is less than the single-pulse modulation mode output current ripple:

$$\Delta I_{L-single} > \Delta I_{L-dual} \quad (18)$$

3.2 Simulation Result

In order to verify the principle of the previous analysis, this paper uses MATLAB to use the dual pulse width modulation mode Buck circuit simulation analysis, the specific simulation results shown in Table 1.

Table1 Double pulse modulation mode current

	Ripple1	Ripple 2	Ripple 3	Ripple 4	Single Pulse
Simulation Current Ripple(mA)	121	149	125	123	316
Experiment Current Ripple(mA)	156	186	153	159	353

Through the simulation results we can see that the use of dual pulse width modulation method can effectively suppress the output current ripple to prove the accuracy of this analysis.

4. Conclusion

In this paper, Buck circuit is used as a model to propose a dual pulse width modulation method which can suppress the output current ripple. The theoretical basis is given by the principle analysis. Finally, the accuracy of the theoretical analysis is verified by simulation.

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