

Phase Shifting Control Soft Switch Analysis

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Abstract—This paper uses the soft switch technology, power devices under the condition of zero voltage or zero current conduction or shut off, it can effectively reduce the switching loss, and theoretically zero switching loss. Soft switch technology of switch power supply theory analysis, this paper analyzes the soft switch of the operational modal ZVZCS, lagging advanced arm and arm control mode as well as the advance, the problem such as lag bridge arm of the dead zone formation.

Keywords—soft switch; zero voltage; zero current; switching loss; zero switching

I. INTRODUCTION

In power system, DC system reliability, stability and technical performance directly affect the power grid operation and the security of equipment. In communication networks, communication power supply quality directly affects the quality and effect of all kinds of communication, so people are extremely attaches great importance to the power supply quality and technical performance. Simulation research and development of new type of power supply and power supply becomes a very important meaning righteousness. In the high power. C-DC commonly is used in a converter circuit structure of the whole bridge transformation, there are two kinds of typical bridge converter Control, PWM control and phase shift control, PWM control mode for application has many excellent performance is very common. This paper introduces the soft switch implementation.

II. THE PHASE SHIFT PWM SOFT SWITCH CONTROL IMPLEMENTATION

According to the four switch tube conduction, DC/DC full bridge converter is + 1, 0, 1 three kinds of working condition. Discuss the realization of the soft switch, it is necessary to explain three kinds of working state of the full bridge converter. (1) + 1 state, when the Q4 and Q1 at the same time conduction, add on the transformer primary side AB two input voltage with a positive voltage, namely the $V_{AB} = (+1)V_{in}$. (2) the zero state, when the Q1 (D1) and Q2 (D2) at the same time conduction or Q3 (D3) and Q4 (D4) at the same time conduction, $V_{AB} = 0 = (0)V_{in}$. (3) - 1 state, when Q2 and Q3 at the same time conduction $V_{AB} = (-1)V_{in}$. According to three kinds of working state of the switch tube, there are three kinds of full bridge converter switching mode (1) + 1/1 (or -1 / + 1) (2) +1/0 (or -1/0) (3) 0 / + 1 (or 0/1).

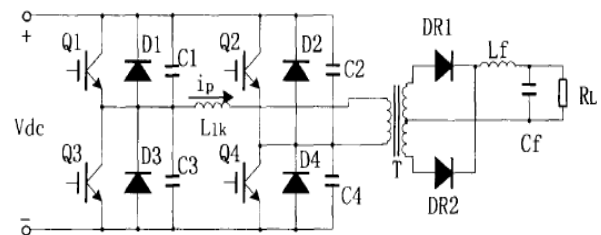


Figure 1. The phase shift control soft switch main circuit diagram

Fig .1, if switch bridge take diagonally two way switch tube shut off at the same time, in the figure Llk is the leakage inductance of main transformer. When Q1&Q 4 (or Q2&Q 3) shut off at the same time, because of the existence of Llk primary side current applied will not immediately reduce to zero, then Q1&Q 4 (or Q2&Q3) immediately transferred to the current D2&D3 (or D1&D4) $V_{AB}=(-1)V_{in}$. (or $V_{AB} = (+1)V_{in}$), +1/-1 switching (or -1/+1). The voltage causes the original edge current reduced to zero.

In order to achieve soft switch features of switch tube, we can give each parallel absorption capacity, as shown in fig.1 the C1 ~ C4. When the switch tube shut off, the original edge shut off the current pipe such as Q1 and Q4 shunt capacitance C1 and C4 charging, at the same time to C2 and C3 discharge. It limits the voltage build-up rate of Q1 and Q4, implements the Q1 and Q4 soft shut off. When the voltage rise to C1 and C4 V_{in} , C2 and C3 voltage drops to zero at the same time, Q2 and Q3 reverse conduction, and diode D2 and 3 provides a zero voltage Q2 and Q3 opening conditions. But if the open Q2 and Q3, transformer primary side with the duty ratio of 1 AC square wave voltage, cannot achieve PWM control.

In order to realize PWM control in Q2 and Q3 and diode D2 and D3 conduction, we cannot open Q2 and Q3. Because the $V_{AB} = (-1)V_{in}$, primary side current i_p will decrease under the action of the negative voltage and back to zero. Due to four switch tubes are in the off state, the shunt capacitance can produce resonance with the leakage inductance. The original i_p reverse side current increases, C1 and C4 discharge, C2 and C3 charging. So when Q2 and Q3 opened, the shunt capacitance C2 and C3 voltage is not zero, the charge is directly through the switch tube is released, all capacitance of energy consumption in Q2 and Q3 cause switch tube heating, and have opened in the switch tube current peak. They damage the switch tube, and can realize soft switch. From the

above analysis shows that in diagonal two switch tube shut off switch mode at the same time, +1/ -1 or -1/ +1 switch mode, unable to realize the switch tube of soft switch.

However, if the two diagonal of the switch tube conduction time relative stagger one time, that is a switch tube opening ahead of a period of time, the same cut-off time; The other switch tube opening time constant shut off the time delay for a period of time. The switch state switch tube will improve. Q1 and Q3 switch tube will open ahead of schedule, and definition of Q1 and Q3 bridge arm for bridge arm in advance; Switch off switch tube Q2 and lags in Q4, and definition of Q2 and Q4 bridge arm for lag bridge arm.

When we use phase-shift control mode, in the circuit shown in fig.1, when the Q1 and Q4 are conduction time, transformer voltage on the side of the original as (+1)Vdc, current i_p flows through the Q1, transformer primary side, Q4. When they shut off, the first shut off Q1, i_p to recharge, C1 to C3 discharge. As a result of the existence of C1 and C3, it limits the build-up rate of voltage of the Q1, and Q1 is zero voltage turn off. Due to the leakage inductance of the transformer and filter inductance existing i_p approximately is same. When C3 voltage drop to zero, and D3 natural conducts, it creates conditions for zero voltage of Q3 opened. when Q3 is ahead of opened, Q3 opening loss is near zero. In this state, the transformer primary side voltage is zero, the switching for switching (+ 1) / 0. In diagonal two switch tubes work, shut off of Q3 and Q1 opening, its working principle are exactly the same.

The next, if i_p is large enough, when Q4 is shut off, the i_p to recharge, and C4 to C2 discharge at the same time. Due to presence of C2 and C4, Q4 is zero voltage turn off. When C2 voltage drops to zero, D2 natural conduction, at this time Q2 can be opened in zero voltage. When high frequency transformer primary side voltage is as (+1)Vdc, the switch mode is 0/-1. Lag bridge arm realizing ZVS of the leakage inductance of the energy is energy. when the load is small, the leakage inductance energy enough reduce lag bridge arm to achieve zero voltage switching.

At this moment if i_p in gradually reduce to zero reset state, the primary current is zero, and Q4 is shut off to realize zero current turn off. Opening of Q2, due to the leakage inductance of the transformer, current rising rate of Q2, be suppressed to realize zero current opening of Q2. At this point, the voltage transformer primary side is (-1)Vdc, switching the switch mode 0 / - 1. This way of zero current switch, switch on both ends of the tube can't shunt capacitance. When a current reduced to zero, it does not increase in the opposite direction, or lose the zero current switch conditions. Known from the analysis of the above, DC full bridge converter under the phase shift PWM control mode, the advanced arm is easy to realize ZVS and rear axle arm can realize ZVS, also it can realize ZCS.

III. FULL BRIDGE CONVERTER

Full bridge converter duty cycle loss analysis of phase shift duty cycle loss is a unique phenomenon in the PWM converter control. Duty ratio loss refers to the duty ratio, on the edge of transformer vice Dsec compared is less than the original edge of Dp, the difference between them is the deputy duty ratio loss DloSS; Because in the actual application of power semiconductor switch itself is not ideal, it has a certain opened and shut off time, at the same

bridge arm up and down two switch tube guide communication, there must be a dead zone between time, in order to prevent the same bridge arm through a short circuit. Work in the converter zero state, there must be a resonance time make the switch tube to achieve soft switch. Because of high frequency leakage inductance of the transformer can also make the transformer vice edge produced relative to the edge of the original voltage pulse width decreases. Duty cycle loss and efficiency by the great influence on the performance of the converter, analysis and research on switch dead zone, the cause of the duty ratio and its influence is the study of soft switch is the important content of the phase shift PwM control.

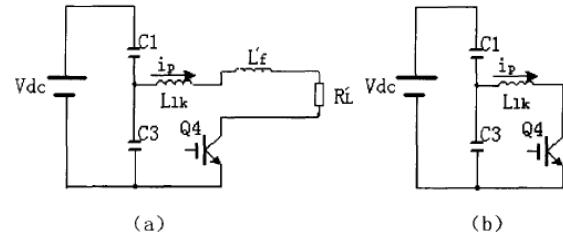


Figure 2. The lead arm switch schematic diagram

As shown in Fig .2, represents a full bridge converter switch tube Q1 shut off the switch tube Q3 opened this time switch.(a) figure is Q1 just shut off when the voltage on the capacitor C1 basic is zero, the voltage on the C3 to Vdc, still to the vice transformer original side provide energy, according to the analysis method of the transformer in electrical machinery, transformer secondary side load conversion to a side, the filter inductor Lf being very high, can be thought of primary side current i_p approximate constant. When transformer primary side voltage drop to cannot provide vice edge energy, rectifier diode DR1 and DR2 conduction at the same time, the transformer primary side voltage clamping at 0 v, state as shown in (b), at this time due to shunt capacitance is very small, approximate think i_p remains unchanged, in the whole process is similar to a constant current source, the voltage on the C3 as follows:

$$V(t) = V_{dc} - \frac{i_p}{2C_3}t$$

The voltage drops to zero on the C3 need time for:

$$t_1 = \frac{2C_3V_{dc}}{i_p}$$

t_1 , switch tube is a dead zone between Q1 and Q3 driving signals, can be seen from the type, when the load is small, the i_p is small, t_1 is bigger, so to ensure that the opening of the bridge arm zero voltage in advance, the Q1 and Q3 drive signals between the calculated value of delay time should be in small load.

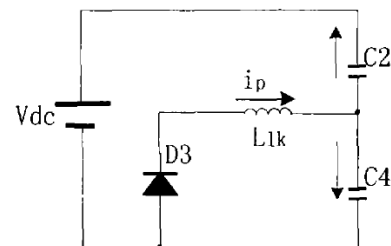


Figure 3. Lag arm switch schematic diagram

Fig .3 depicts the phase-shifting control full bridge converter switch tube Q4 shut off to Q2 opened the status of the converter work this time.Q4 just shut off when the voltage on the C4 basic is zero, C2 on voltage of Vdc, primary side current IP is provided by C2 and C4 two paths, namely the primary side current IP used to take the charge on the C2, and recharge C4.As a result of the existence of C2 and C4, Q4 realize zero voltage turn off. Transformer winding is still clamp in 0 v, this paragraph of time is actually a capacitance C2 and C4 and inductance LLK work in resonance, the voltage on the C2 is:

$$V(t) = V_{dc} - i_p \sqrt{\frac{L_{LK}}{2C_2}} \sin \frac{1}{\sqrt{2C_2 L_{LK}}} t$$

C2 reduced to 0 voltage on the time required to:

$$t_2 = \sqrt{2C_2 L_{LK}} \sin^{-1} \left(\frac{V_{dc}}{i_p} \sqrt{\frac{2C_2}{L_{LK}}} \right)$$

T2 is a dead zone between switch tube drive signal of time. By the advanced bridge arm and the lag bridge arm of dead zone, switch tube can achieve the maximum duty cycle is:

$$D_{mi} = \frac{0.5T - t_1 - t_2}{0.5T}$$

Vice side and transformer due to the loss of duty cycle, duty ratio is less than the original vice side duty ratio; Causes of duty cycle loss is: when the opening of the lag bridge arm switch tube, there is the original and current changes from positive (or negative) to negative (or positive) load current of the time, during this time, although the original edge has positive voltage square wave (or negative voltage square wave), but the original edge is not enough to provide the load current, vice side of two rectifier diode conduction, all fly-wheel diode, transformer primary side voltage clamping at 0 v, until after the primary side current is added to the greater than I_t/K , the original began to vice and provides energy.This period of time working condition in Q2 opened, for example, described in Fig .4.

Q2 has just opened, the leakage inductance of the current work for I_1 , flows through the D2, use the reduce to zero, then reverse increase, for I_2 , flows through the Vdc, Vde, D3 to LLK. The leakage inductance of the current in the Vde QZ, LLK, and Q3 back to Vdc. Until after I_2 to I_1 / K , the end of the period of time.

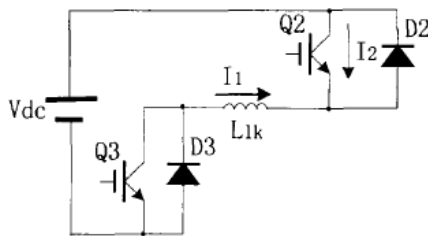


Figure 4. Q2 just opened when working state diagram

This period of time as follows:

$$t_3 = L_{lk} \frac{L_f / K + I_1}{V_{dc}}$$

Vice side duty cycle loss is plenteous Dloss as follows:

$$D_{loss} = \frac{2t_3}{T} = 2L_{lk} \frac{I_f / K + I_1}{T \cdot V_{dc}}$$

On the type, the greater the LLK, the bigger the Dloss; The greater the load, the greater the Dloss; The lower the input voltage, the bigger the Dloss.

IV. THE PHASE-SHIFTING CONTROL ZVZCS FULL BRIDGE CONVERTER CURRENT RESTORATION MEASURES

Phase shifting control full bridge converter advanced arm can achieve zero voltage switching (ZVS), the lagging arm can achieve zero voltage switching (ZVS) or zero current switching (ZCS); So the way of soft switch of the converter is divided into two categories: (1) way of ZVS, O state work in constant current mode, advanced bridge arm and lag bridge arm all realize ZVS; Reset (ZVZCS, O state work in current mode, bridge arm realizing ZVS in advance, the lag bridge arm realize ZCS; Because when IGBT turn-off current trailing phenomenon, so it is suitable for work in ZCS mode, in the high-power switching power supply module ZVZCS works phase-shifting control PWM converter has been widely used.

In the working process of the ZVZCS converter, when the arm to complete the zero voltage turn off in advance and after opening, how to realize the current IP reset to zero is zero lag bridge arm current switch. Complete advanced arm zero voltage turn off and the opening, zero voltage on both ends of the high-frequency transformer, in order to make the primary side current reduce to zero, it must be in the current loop (D3 a transformer primary side winding a Q4, D3 or D1 a Q2 a transformer primary side winding a D1) take measures to add a reverse in the leakage inductance of the voltage. So long as in the transformer primary side add a blocking voltage source Vanti, its circuit structure as shown in Fig .5:

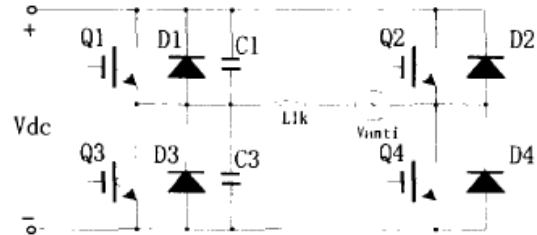


Figure 5. Join the blocking voltage source of the full bridge converter

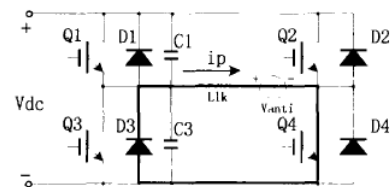


Figure 6. The current $I_P > 0$ when the reset circuit

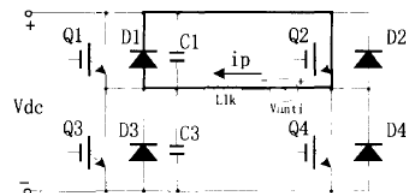


Figure 7. $I_P < 0$ when the current reset circuit

When i_P for the timing, after loop D3 a transformer primary side, Q4 D3; The polarity of the voltage source block as shown in Fig .6.

When i_P is negative, after loop D1 Q2 one transformer winding a D1, the polarity of the voltage source block as shown in Fig .7.

By the polarity of the voltage source block can be seen, when i_P is through the primary side current, breaking the power supply voltage is positive; When the primary side current is negative, the power supply voltage is negative. Implement this blocking power the simplest method is to use a capacitance C, as shown in Fig.8. When the two diagonal switch tube Q1 and Q4 conduction at the same time, the IP recharge C; When the two diagonal switch tube Q2 and Q3 conduction at the same time, the IP to discharge capacitance C. In zero state, capacitance C voltage remains constant, the polarity is just the opposite with the flow direction of the current IP, the IP reduce to zero, have the effect of IP to reset.

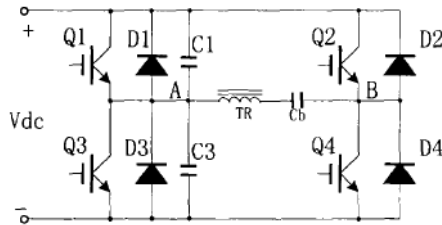


Figure 8. blocking voltage source

While blocking voltage source have played an important role in current reset, but when the zero state, when i_P reset to zero does not allow its continues to grow back, so in the current reset must be cut off after the i_P reverse channel. Throughout the year. State, advance bridge arm of Q1 and Q3 has opened, therefore cannot implement blocking function in advanced arm. In AB can implement i_P reverse blocking, the typical method are as follows:

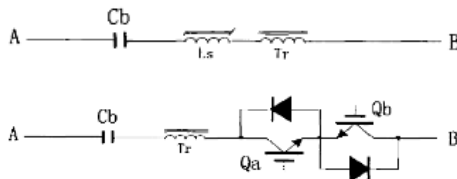


Figure 9. IP reverse blocking circuit

Series a saturation inductance side, as shown in Fig .9 (a), when the zero state, saturated inductor in linear L, value is very big, can prevent reverse flow of IP. In a state and a 1 + 1, it works in saturated form 2. Add a pair of reverse series switch tube, as shown in Fig .9 (b). the switch tube working at ZCS condition, toggle switch tube during zero state, each switch tube conduction half cycle in

turn. When IP from A to B Qa conduction, Qb shut off, after IP reduce to zero, shut off the Qa open Qb, prevent reverse flow of IP; Second half of the cycle of i_P from the Qb to A, B when i_P reduce to zero, shut off the Qb open Qa.

V. CONCLUSIONS

Though the above two methods can complete blocking the function of the current i_P reverse flow, but there are a lot of disadvantages., in the first way to 0 to 1 or + 1 state switch, string into the saturation inductance will make i_P rose at a slower pace, resulting in lost duty ratio increasing, bring a series of problems affect the performance of the switch power supply. Second way, increased the two switch tube, you need to add two way control and drive circuit, reduces the reliability of the system and raise the cost of the system. To improve the lag bridge arm, two diodes in series with lag bridge arm. Unidirectional conductivity of natural block i_P reverse flow, thus for lag bridge arm switch tube Q2 and Q4 ZCS is an effective and practical way.

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