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Research on Passive Soft-switching Power Inverter with Energy Storage Capacitor Assisted Commutation

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Abstract

In this paper, the topology of an energy storage capacitor assisted commutation passive soft switching power inverter is analyzed, the working principle and working process of the topology are analyzed through each state of the switch, and the mathematical model is used to solve and set the main parameters.Through theoretical analysis, it is proved that this circuit can realize the soft switching of switching devices and the feedback of energy.By analyzing the working conditions of the soft switch of this circuit, the control strategy of SPWM is designed. As long as the modulation meets the conditions of zero voltage switching and zero current switching, the soft switching of the switch can be realized.Then the energy storage capacitor assisted commutation passive soft switching power inverter is simulated, the simulation results are compared with the traditional inverter simulation results, and the frequency spectrum of the structure is analyzed, and the correctness of the control strategy is verified by simulation. This paper also studies an absorption soft-switching topology, which realizes zero-current turn-on and zero-voltage turn-off of the main switch. the characteristic of this circuit topology is that the upper and lower tubes of the bridge arm share the same turn-on absorption inductor and turn-off absorption capacitor. on the basis of optimizing the main absorption structure, a small amount of inductors and diode elements are added to minimize the additional elements, and the voltage source is constructed with capacitors.The energy feedback and the reset of the absorbing element are realized.

Keywords

Passive lossless; soft switching; PWM control; inverter.

1. Introduction

This paper studies a main circuit topology of energy storage capacitor assisted commutation passive soft switching power inverter. compared with the traditional passive soft switching inverter, it avoids the use of two large capacitors and does not have the problem of voltage paranoia. Then one-phase circuit is selected to analyze its working principle, and the theoretical waveforms of each stage are given.The working mechanism of zero-voltage switching and zero-current switching, the critical conditions of soft-switching and the PWM control method satisfying the conditions of zero-voltage switching and zero-current switching are discussed, which lays a theoretical foundation for circuit simulation experiments.The main circuit topology of soft-switching three-phase PWM inverter is simulated and analyzed, and the simulation results are compared with those of traditional hard-switching three-phase PWM inverter. It is found that soft switching can be realized in a certain modulation range. Finally, the analysis results are summarized to verify the correctness of the control strategy.

2. Materials and Methods

2.1. Circuit Topology Analysis

According to the principle of passive lossless soft switching, a basic passive lossless soft switching circuit generally includes three functional circuits: turn-on buffer circuit (zero-current turn-on), turn-off buffer circuit (zero-voltage turn-off), and energy feed circuit (turn-on buffer and turn-off buffer reset).The half-bridge circuit topology of passive lossless PWM inverter analyzed in this section is shown in figure 1.

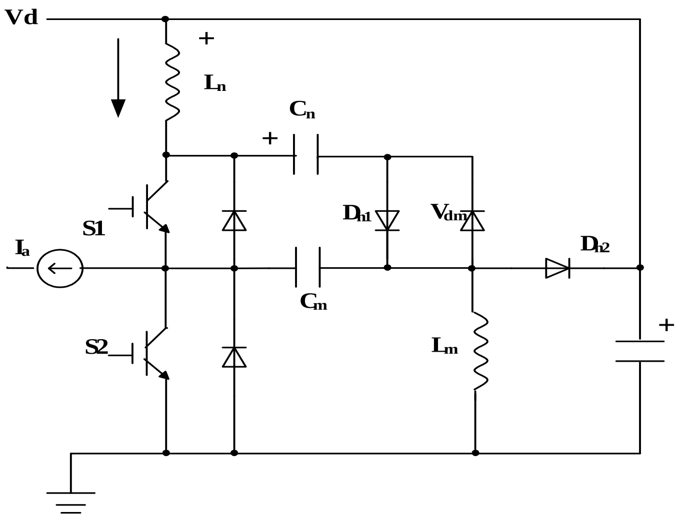

Fig 1. Half-bridge circuit topology of inverter

Open buffer circuit: Ln is a common open absorption inductor shared by the upper and lower tubes, which bears the power supply voltage when it is turned on, and realizes the zero current opening of the main power tube.Turn-off buffer circuit: Crn is a common turn-off absorption capacitor for two transistors. When turning off, the bypass load current achieves zero-voltage turn-off of the master.Energy feeding loop: the energy is transferred to the feedback branch inductor Lm through S1, and then fed back to the power supply. It makes use of the short interval between the inductive load and the absorption inductor when the power switch and the continuous current diode carry current at the same time, and the energy is transferred from the Cn to the Lm. In the steady state, the Cn energy is released by the Lm-Cn-Ln-Vd.

2.2. Analytical Assumption

(1) all components have ideal characteristics.

(2) the load is a strong inductive load in which the time constant is much larger than the switching period, that is, the load current remains constant during the change of the switching state.

(3) the two switches as the same bridge arm cannot be turned on at the same time, and this "common" will short-circuit the input DC power supply.When the switch tube of the same bridge arm makes a state transition, it always turns off the on switch first, and then turns on the other off switch.The lag interval between turn-off and turn-on is called "dead zone" time.The dead time is ignored in the process of circuit analysis.

(4) the reference direction of voltage and current is shown in figure 3-1, and the one not given is determined according to the direction of the series diode.

(5) the capacitor Cn chooses a larger capacitance value, the voltage fluctuation is small, and its voltage is always equal to E ~ (E), which is much less than Vd.

(6) it is assumed that Ln = Lm,Ln and Lm act together in the turn-on process of power-on.

2.3. Circuit Parameter Settin

The design process of the loop parameters is as follows: the specified critical modulation mL, the maximum voltage of the switch tube in state 3 and the maximum current in state 6, the rated voltage and rated current of the component, and then according to the zero current turn-on condition and zero voltage turn-off condition, the appropriate absorbing inductance and absorbing capacitance are selected to ensure that the circuit can realize the soft switching function.The control object of the project is the permanent magnet synchronous motor (PMSM) of 22KW. According to the actual situation of the project and the summary of voltage and current stress, the simulation parameters are designed as follows:

Ia=15A, Ln=Lm=50μH, Cm=1.5μF, Cn=10000μF

2.4. Modulation Strategy of Energy Storage Capacitor assisted commutation passive soft switching Power Inverter

The inverter adopts bipolar SPWM modulation mode, and the PWM signal is generated by triangular wave comparison method as shown in figures 2 and 3.

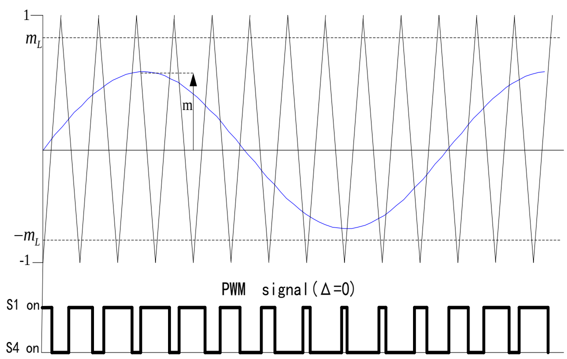

Fig 2. $m < m_L$

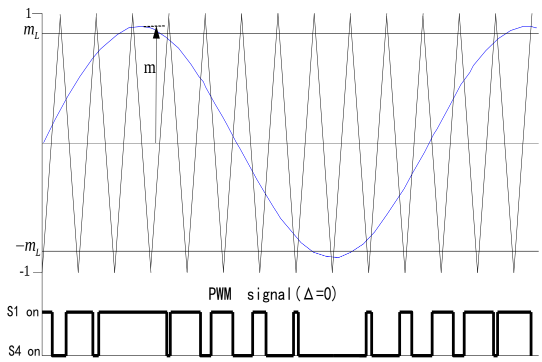

Fig 3. $m > m_L$

The modulation system is that the amplitude of the sine wave is higher than that of the upper triangular wave, the amplitude of the triangular wave is set to 1, and the amplitude of the sine wave is.When the instantaneous value of the sine wave of phase An is greater than that of the triangle wave, S1 is turned on and S2 is turned off, and the other two phases adopt the same control method.

Let fc be the switching frequency and T the minimum pulse width of the switching device.In order to turn on zero voltage, it is necessary to ensure that the capacitor charging time is not less than the capacitor charging time, such as the mL in the figure is the critical modulation.Fig. 2 the minimum pulse width is not less than T, which ensures that the switching device can achieve ZVS,. Therefore, the usual SPWM modulation can be used.Fig. 3 when using the usual SPWM modulation, the minimum pulse width is smaller than T at the point where the absolute value of the sine wave exceeds the mL.Therefore, when the instantaneous value of sine wave is larger than + mL, the upper switch is always on, and when the instantaneous value of sine wave is smaller than-mL, the lower switch is always on.When switching, the inverter sets a dead time Δ to prevent short circuit.

3. Results and Discussion

3.1. Simulation Results of Soft Switching Circuit Operation

Figure 4 shows the voltage and current waveform of the switch tube. Taking the above switch

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tube as an example, the zero voltage switch of the upper tube is realized, and the buffer of the lower tube is turned on to realize zero current switching, which completely realizes zero loss in the whole operation cycle of the switch. Moreover, the rate of change of current and voltage at the moment of the action of the switch tube is very small, which can restrain the generation of electromagnetic interference.It is verified that the main circuit of the inverter can realize the soft switching of the switch.

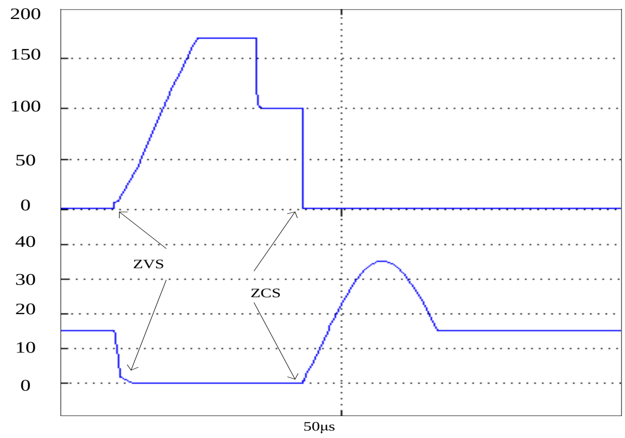

Fig 4. Voltage and current waveforms of soft switching transistors

3.2. Soft Switching Circuit Output Simulation Result

Figure 5 shows the output current waveform of the soft-switching inverter controlled by PWM when the output frequency is 60Hz and the modulation m is 0.6. figure 6 shows the output line voltage waveform. Through the simulation, we can see that the hard-switching inverter is well controlled under the modulation of 0.6 output frequency 60HZ, the current and voltage are not distorted, and the output current and voltage of the soft-switching inverter are ideal under this modulation.

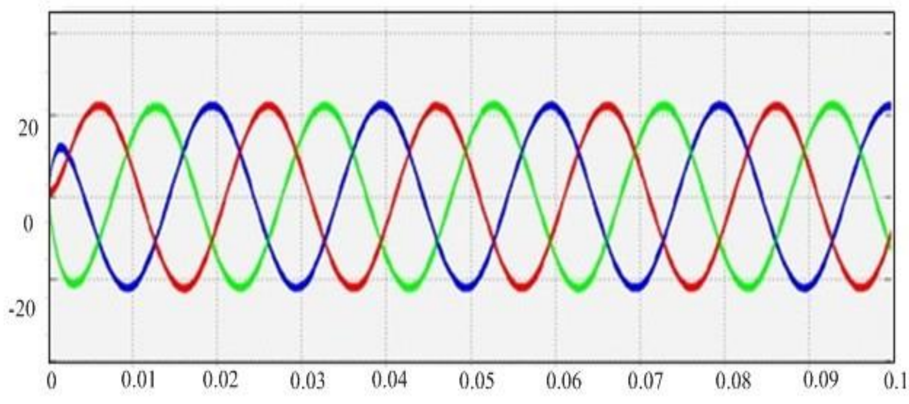

Fig 5. Output current of soft-switching inverter(m=0.6,f=60HZ)

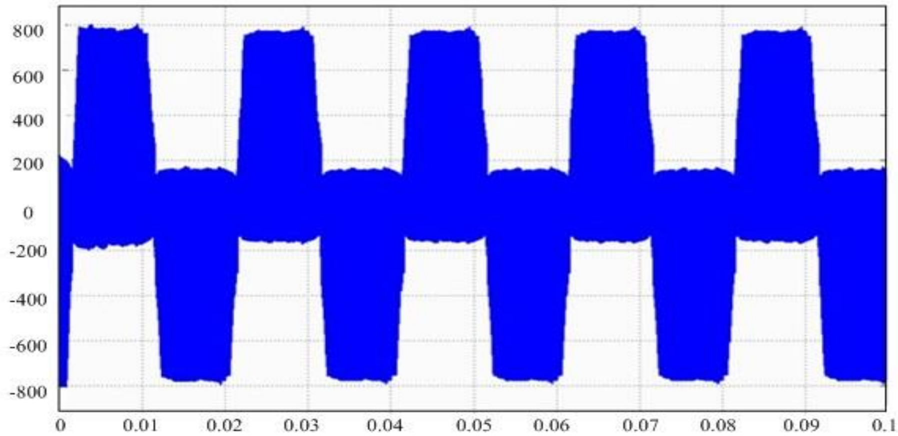

Fig 6. Output line voltage of soft-switching inverter(m=0.6,f=60HZ)

3.3. Analysis of Output Current of Inverter

Below is the output current waveform of the soft-switching PWM inverter under the same conditions, the switching loop can output a good sine wave, which verifies the correctness of the control strategy, and the circuit can better achieve soft switching.The curve of the relationship between the distortion rate of phase current, line voltage and modulation m is shown in figure 7 and figure 8.When the modulation is below the critical modulation, the distortion rate of the output phase current and line voltage of the passive lossless soft-switching inverter circuit is obviously smaller than that of the corresponding hard-switching inverter circuit.However, when the modulation is above the critical modulation, the distortion rate of the output phase current and line voltage of the passive lossless soft-switching inverter is obviously higher than that of the corresponding hard-switching inverter circuit.Therefore, in order to expand the modulation range of soft-switching inverter in normal SPWM modulation, the mL should be as large as possible.

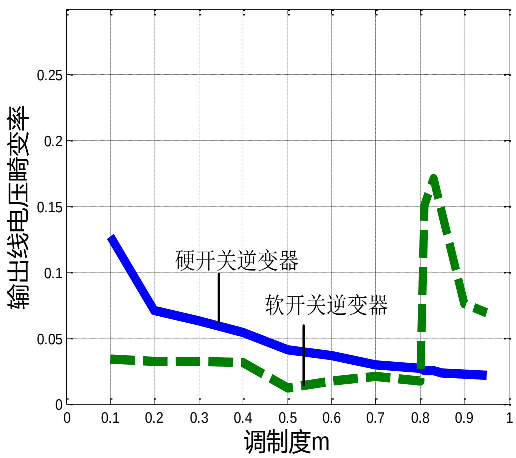

Fig 7. The curve of the relationship between the line voltage distortion rate and the modulation m

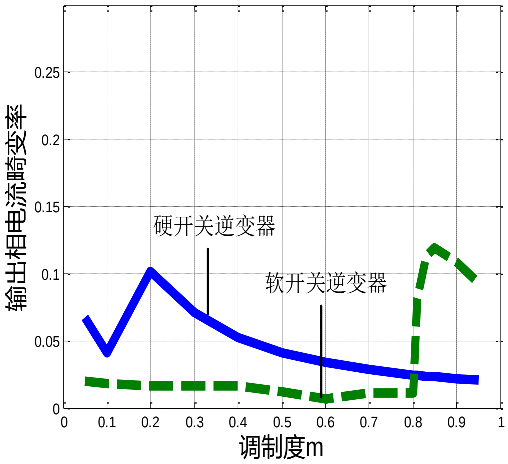

Fig 8. The relation curve between the output phase current distortion rate and the modulation m

Figure 9 shows that the waveform of the soft-switching circuit is distorted when the modulation is 0.9.It shows that when SPWM is used to control the soft-switching inverter, the control is not very good when the modulation is greater than 0.9, and the output current and voltage are seriously distorted. Therefore, in order to control the soft-switching inverter with SPWM, the modulation must be set below 0.9. the clear modulation exceeds the critical modulation is not very good.

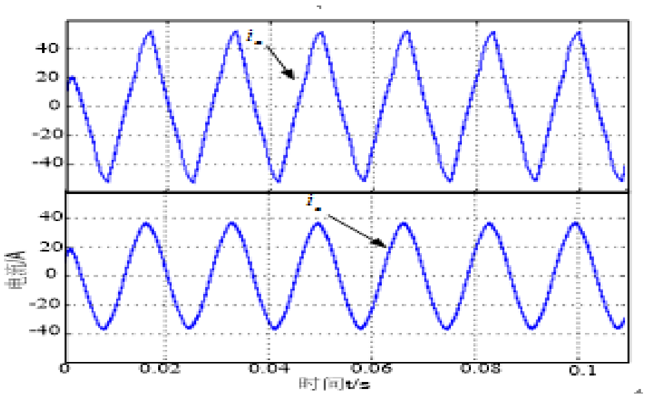

Fig 9. Output current of soft-switching inverter

4. Conclusion

The topology of an energy storage capacitor assisted commutation passive soft switching power inverter is analyzed in this paper. the characteristic of this circuit topology is that the upper and lower tubes of the bridge arm share the same turn-on absorption inductor and turn-off absorption capacitor. On the basis of optimizing the main absorption structure, a small amount of inductors and diodes are added to minimize the additional components, and the capacitor is used to construct the voltage source to realize the energy feedback and the reset of the absorption elements.The main parameter values are set according to the mathematical model, and the circuit is analyzed and summarized.Through theoretical analysis, it is proved that this circuit can realize the soft switching of switching devices and the feedback of energy.Secondly, the control strategy of SPWM is designed according to the working conditions of the soft switch of the circuit. As long as the modulation meets the conditions of zero voltage switching and zero current switching, the soft switching of the switch can be realized. The energy storage capacitor assisted commutation passive soft switching power inverter is simulated, and the correctness of the control strategy is verified.

Passive lossless technology does have the performance of reducing the switching loss, reducing the instantaneous du/dt and di/dt of the switch and the EMI of electromagnetic interference. Compared with active soft switching technology, passive lossless soft switching technology has the advantages of low cost, simple principle, high reliability and no control. Passive lossless technology will be more widely used in PWM power converters.

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