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The Comparison of the Several Front-end Converters Using in Photovoltaic Inverters

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Abstract: This paper introduces the fly-back circuit, active-clamp circuit, single-switch resonant circuit, single-switch resonant circuit with clamping, which are suitable for the pre-stage of low power photovoltaic inverter. simulated by Saber simulation software, their excitation methods, voltage across the switch and soft-switching conditions are compared, the general application are proposed.

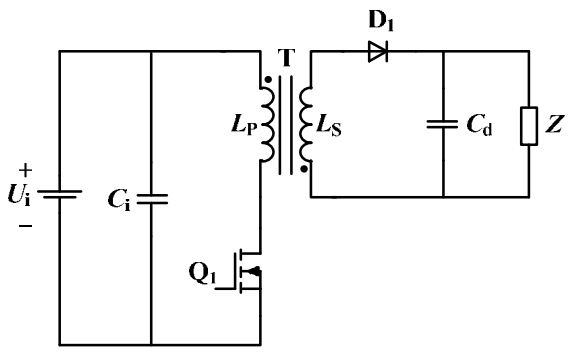
Keywords: photovoltaic; simulation; comparison

1. Introduction

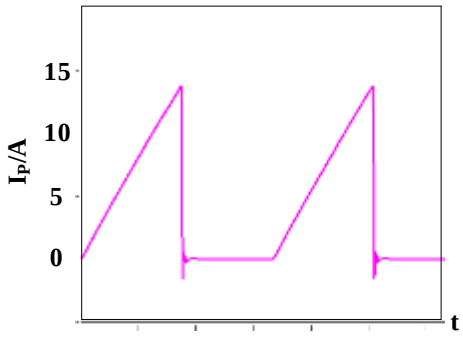
In recent years, low-power photovoltaic inverters for the family are developing rapidly, the common inverters uses two-stage structure, The first stage raises the output voltage of the solar panel(34.4 V_{dc}) to 400 V_{dc}. Topologies for the first stage include fly-back circuits, clamp circuits[1], single-switch resonant circuits[2], and single-switch resonant circuits with clamps[3]. Excitation operations, the voltage across the switches, and soft-switching conditions of these circuits are different. The four circuits are simulated by Saber, a detailed comparison of results are proposed.

2. Fly-back Circuit

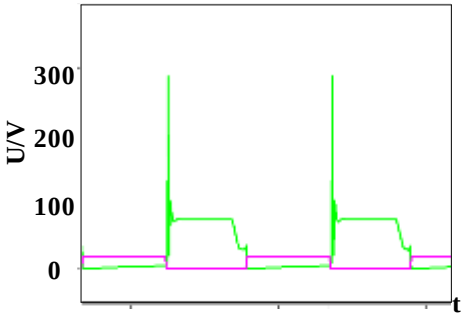
Figure 1(a) is the fly-back circuit, the circuit is simple in structure and easy to control, but its transformer is unidirectional excitation, as shown in Figure 1(b) below. Moreover, in practical applications, the transformer will inevitably produce leakage inductance, the energy of leakage inductance induces a voltage spike across the switch when the switch is off, as shown in Figure 1(c),The fly-back circuit cannot realize ZVS operation.



(a) fly-backcircuit



(b) excitation current



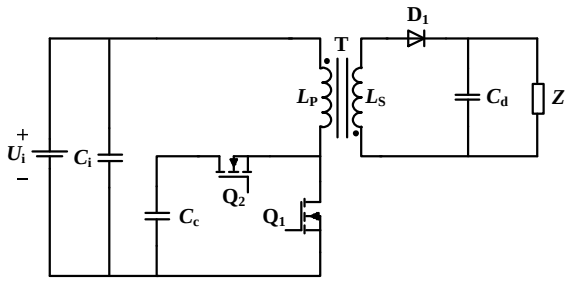
(c) waveforms of soft-switching

Figure 1. Analysis of fly-back circuit

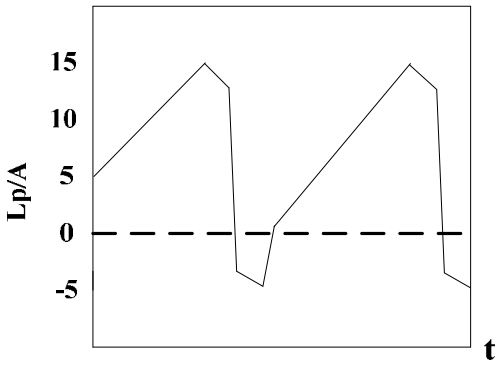
3. Active-clamp Circuit

The clamp circuit has one more branch than the fly-back circuit to regenerate the energy of the transformer leakage inductance and limit the voltage across the switch, as shown in Figure 2(c). In this operation, it can be seen that the main switch still cannot achieve ZVS operation, and the switch for clamping can realize ZVS turn-on. Although the excitation current has a negative value, but

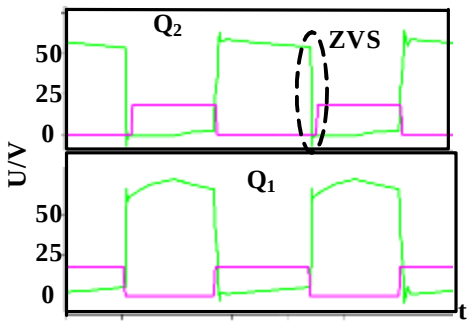
the period is very short, the transformer is still operated in single-winding excitation, as shown in Figure 2 (b).



(a) active-clamp circuit



(b) excitation current

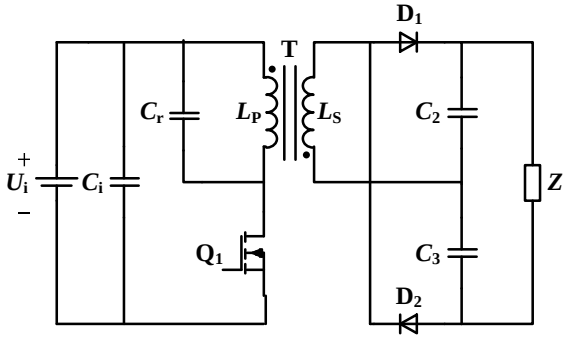


(c) waveforms of soft-switching

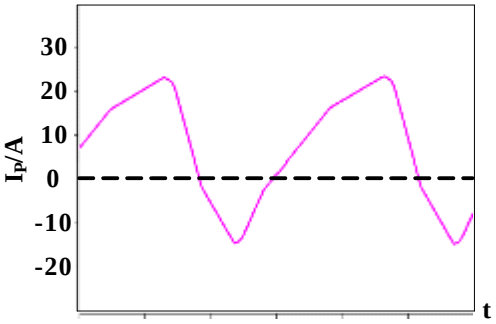
Figure 2. Analysis of active-clamp circuit

4. Single-switch Circuit

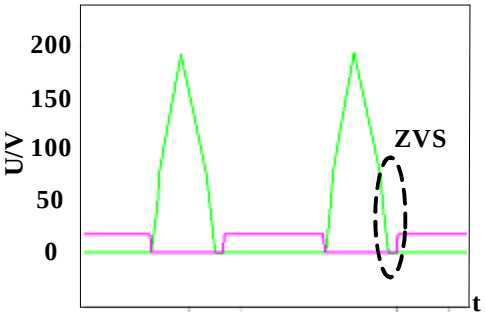
The single-switch circuit is shown in Figure 3 (a). This topology is using a resonant capacitor in the primary-side of the fly-back circuit, the resonant capacitor and inductor in primary-side provides the two-winding excitation, as shown in Figure 3 (b), in this operation, the resonant capacitor makes the voltage across the switch is much higher than the active-clamp circuit, as shown in Figure 3 (c), this problem can be partly solved by the ZVS operation.



(a) single-switch circuit



(b) excitation current

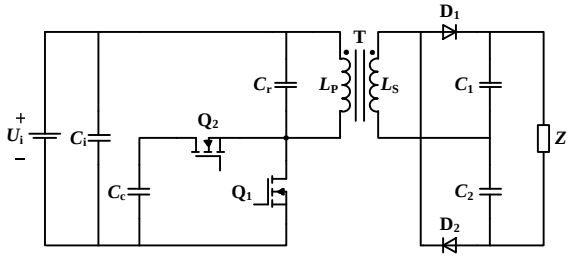


(c) waveforms of soft-switching

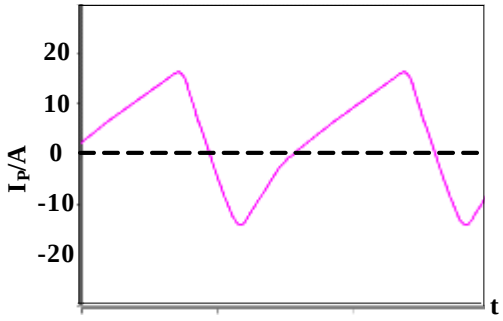
Figure 3. Analysis of single-switch circuit

5. Active-clamp Circuit with a Resonant Capacitor

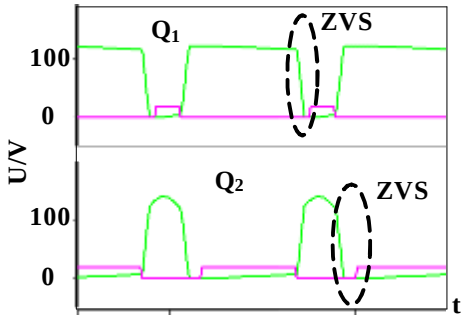
To solve the problem of the soft-switching and the excitation, add a resonant capacitor in the active-clamp circuit, the proposed circuit shows in Figure 4 (b), the circuit can realize two-winding excitation and limit the voltage across the switch Q1, the switches can both realize ZVS turn-on, the operation is shown in Figure 4 (c).



(a) active-clamp circuit with a resonant capacitor



(b) excitation current



(c) waveforms of soft-switching

Figure 4. Analysis of active-clamp circuit with a resonant capacitor

6. Conclusion

This paper contrasts the fly-back circuit, active-clamp circuit, single-switch circuit, and clamp circuit with a resonant capacitor, analyses the excitation characteristic, voltage on the switch, and the soft-switching of the circuits. The fly-back circuit contains one switch and a single-winding excitation transformer, the voltage across the switch is high, and the switch cannot realize ZVS operation, the circuit should using parallel topology to work in high power application; the single switch circuit contains one switch and a two-winding excitation transformer, the voltage across the switch is high, and the switch cannot realize ZVS operation, the circuit can use in high power application; the active-clamp circuit uses two switches and a single-winding excitation transformer, the clamp capacitor limits the voltage across the switch and regenerates energy stored in leakage inductance, the switch cannot realize ZVS operation. The circuit should using parallel topology to work in high power application; the active-clamp circuit with a resonant capacitor has a two-winding excitation transformer, the voltage on switch is limited, it can realize ZVS operation, and the circuit can work in high power application.

References

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