Multiphase resonant inverter with sine wave output voltage

Irina Vavilova[1,*], and *Dmitriy* Ogorodnikov[1]

[1]National Research Tomsk Polytechnic University, 634050 Tomsk, Russia

Abstract. Methods to obtain the sinusoidal output voltage in DC-AC converters are considered. Large switching losses in power switches, high frequency interference, and the relatively high cost are the major disadvantages of DC-AC converters with pulse-width modulation. The circuit of a multiphase parallel resonant inverter with a pure sine wave output voltage is proposed. The operating principle of the two-phase inverter and the method of output voltage control are described. The results of resonant inverters OrCAD simulation are shown. The advantages of the proposed inverter circuit are shown in comparison with a single-phase circuit.

1 Introduction

The main part of the electronic equipment can be AC powered. But in cases where industrial network is not available, there is a necessity for devices that convert the primary power supply voltage to the AC network voltage. In most cases, as it is known, the primary sources do not satisfy the consumer's with frequency and magnitude of the output voltage or with the stability of its main parameters. Most often relatively low DC voltage of the primary source should be converted to a relatively high AC voltage. A power inverter, or an inverter, is an electronic device that changes the direct current to the alternating current. Since the inverter power switching devices (transistors, thyristors) generally operate in the switching mode, the natural form of the output voltage is a rectangular one. However, to achieve the flexibility of the inverter with respect to the AC loads, the inverter must generate the sine wave output voltage. Nowadays the idea of renewable energy is very popular, particularly solar and wind energy, so there is a constant need for devices which convert the unstabilized relative low DC voltage from wind turbines or solar panels to a relatively high sine wave voltage.

2 Materials and methods

The purpose of this study is to design a model of a multiphase circuit that controls the output sinusoidal voltage of the resonant inverter.

DC to AC conversion technologies received a significant development in recent years.

* Corresponding author: irenavavilova@gmail.com

Modern inverters provide a sinusoidal output voltage with low harmonic distortion, and low levels of electromagnetic interference [1]. Very often the inverter is used as one of elements in the power converter. The principal feature of such schemes is the increased operating frequency (up to several hundreds of kilohertz). For efficient operation of the converter at a high frequency more sophisticated and expensive electronic components are required.

The power converter must have a high efficiency, high reliability and have acceptable weight and size. It must also have a valid level of the higher harmonics (THD limits) in the output voltage and do not create unacceptable to the consumer level of output voltage ripples. Voltage inverters help information systems to eliminate or to reduce the dependence on operation of the AC main. For example, when electric power of the main goes off unexpectedly the backup battery paired with the inverter will ensure the operation of computers until the execution of the necessary tasks will be completed correctly.

Typically, the pulse width modulation (PWM) is used to control the inverter output voltage and the output frequency. The output voltage in such schemes has a pulse shape. However, a significant switching loss is the main disadvantage of the PWM inverters. One way to reduce the switching losses is to design the inverter circuit so that the switching is done at zero current or zero voltage (so-called "soft switching" technique). For example, sinusoidal nature of current in the resonant inverter provides a number of advantages: minimal switching losses of power switches, high reliability, low levels of radio-frequency interference (RFI), the possibility to use thyristors – devices for which only the turning on is controlled.

Resonant circuits are used in high-power thyristor motor drives and uninterruptible power supplies. However, they are rarely used in low-power converters.

In cases when the load varies over a wide range (including open circuit case), the preference is given to the parallel resonant inverter. Besides the advantages mentioned above, the work in the series resonant circuit at resonance mode also allows receiving an increased output in comparison with the input voltage without using a transformer.

Despite the advantages, only simple circuits of resonant inverters are discussed in the literature. These schemes are not widely used as the sine wave generators. In particular, this happened due to the rather strong dependence of the output voltage on the oscillating circuit quality factor.

2.1 Resonant inverters

The circuit of the parallel resonant inverter providing power consumption regulation and, as a consequence, the stabilization of the output voltage is shown in Figure 1 [2, 3].

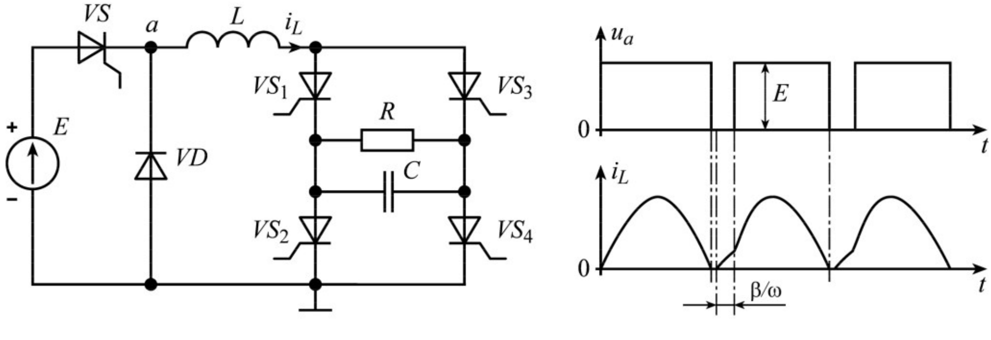

Fig. 1. The parallel resonant inverter with the input thyristor *VS* and its voltage and current-waveforms.

The pulsed input source energy consumption in the process of output voltage regulation requires the use of a smoothing filter. To reduce the weight and size parameters of this filter we need to reduce the form factor of the consumed current. The main idea is that in order to reduce the form factor of the current is expedient to consume the power from the input source through several parallel phases. These phases are included in the operation as needed (the switching time for the next phase depends on the load of the inverter). With this consumption method, the input current amplitude will be smaller and, hence, longer duration than in the single-channel circuit.

2.2 Multiphase circuit

The developed circuit to realize the proposed energy consumption principle is shown in Figure 2. In this example, the input circuit is divided into two phases (such circuits are called multiphase).

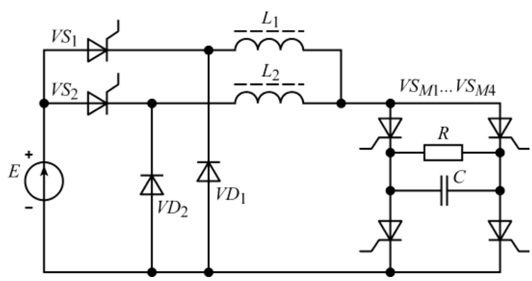

Fig. 2. The biphase circuit of a parallel resonant inverter.

In the first cycle of the inverter operation both input thyristors VS_1, VS_2 and a pair of thyristors in one of the diagonals of the H-bridge are switched on. The charge of the capacitor is influenced by the voltage source E. The difference between the input voltage and the voltage across the bridge diagonal is applied to the input inductors, and they are connected in parallel to each other. Hence it follows that to obtain the desired output frequency and Q-factor of this circuit the equivalent inductance of L_1 and L_2 inductors which are connected in parallel should be equal to the inductance L of the original single-phase circuit. Consequently, the inductance of each inductor should be two times higher than the inductance of a single-phase circuit. If L_1 and L_2 inductance are equal, the amplitude of the current in each phase will be equal to half of the current amplitude in the single-phase circuit, and the phase amplitudes are equal to each other.

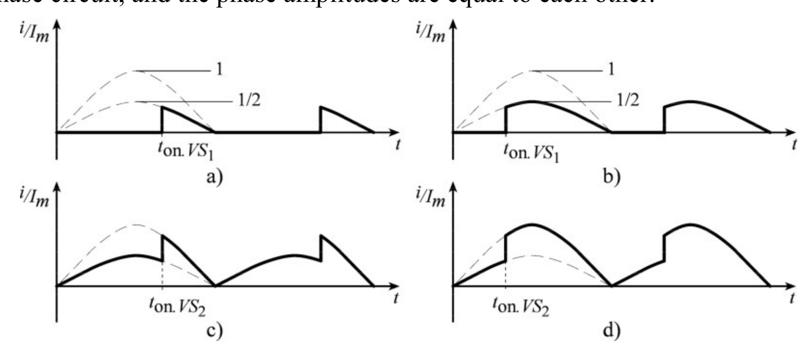

Fig. 3. The power supply current waveform with increase of the load of the biphase inverter circuit, where I_m is the amplitude of the power supply current at the maximum load.

The switch on time delay (firing angle) of the input thyristor with respect to the switch on time of H-bridge thyristors will be the smaller, the higher the inverter load is. At the light load mode the regulation (or stabilization) of the output voltage is provided only by one phase. But if the thyristor VS_1 already conducts during the whole period, and the power in the load is still not compensated, then the second phase (VS_2) starts to operate. Then thyristor VS_1 switches on simultaneously with the H-bridge thyristors (firing angle is zero), and the second phase thyristor VS_2 switches on with a delay. Thus, firing angles of the thyristors VS_1, VS_2 vary from 0 to π depending on the load, wherein the operation of the second phase thyristor takes place after the zero firing angle of the first phase input thyristor. The Figure 3 shows how the power supply current waveform changes with increasing the inverter load: from the light load (Figure 3, a) to the almost maximum load (Figure 3, d).

3 Results and Discussion

The study of a model of the biphase resonant inverter circuit using OrCAD, confirmed the correctness of our assumptions. PID controller is used to stabilize the output voltage. The output voltage and the power supply current waveforms are shown in Figure 4.

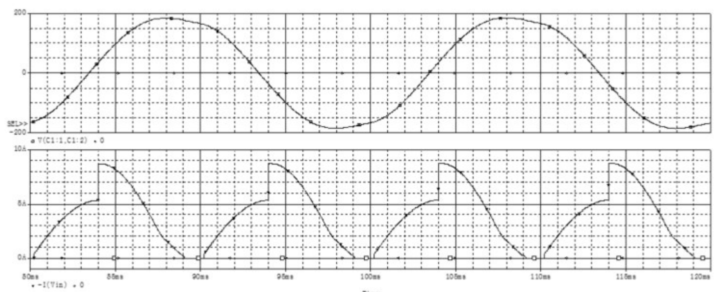

Fig. 4. The output voltage and the power supply current waveforms (steady-state operating mode, output voltage THD is about 5%).

The research shows that in a large range of firing angles (which corresponded to load change from about 3% to 80% of maximum) the advantage in RMS consumed current is not less than 20% compared with single phase resonant inverter. The maximum reduction of the form factor of the consumed current is about 67%. Transistors as fully controlled switches can be used instead of thyristors as input switches.

4 Conclusions

The biphase circuit provides not only decrease of the form factor, but also a decrease of the amplitudes of higher harmonics in the consumed current, which also would reduce the weight and size of the smoothing filter of the inverter.

References

1. V.M. Bushuev, V.A. Demyanskij, L.F. Zaharov i dr. *Elektropitanie ustrojstv i sistem telekommunikacij: Uchebnoe posobie dlya vuzov* (M.: Goryachaya liniya – Telekom, 2009) (in Russian)
2. D.N. Ogorodnikov, E.V. Yaroslavtsev, Instrum. Experim. Tech., **42(3)**, 383 (1999)
3. D.N. Ogorodnikov, *6th Annual International Siberian Workshop and Tutorials on Electron Devices and Materials (EDM)*, 1523212 (2005)