AN UNINTERRUPTIBLE POWER SYSTEM CONTAINING A BRIDGE INVERTER COMBINED WITH A BATTERY CHARGING UNIT

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Abstract

Uninterruptible power systems (UPSs) have been commonly used for powering computers and for continuous technological processes in various branches of industry and medicine [1]. The lives of people and the safety of large streams of information depend on the reliability of operation of UPSs. Regardless of the topology of implementation of UPSs, they contain batteries that should be recharged. In most cases, separate assembly units are used; they increase the cost of the devices and decrease their reliability. This paper describes a method for charging the battery without changing the circuit in cases where a bridge circuit is used in the inverter part.

1. Introduction

The developed device can be used in the field of powered electrical engineering, namely, single-phase bridge transistor inverters used in various uninterruptible power systems (UPSs). The technical problem that can be solved by means of this device is the simplification of the battery charging circuit owing to a variation in the control pulses as indicated in Fig. 1. The two included lower power switches, together with the secondary winding of the power transformer, accumulate the energy received from the network in the form of a magnetic field, which subsequently, during the locked state of these power switches, is released in the form of a current flowing alternately through their free-wheeling diodes. This current charges the battery during both half-periods of the mains voltage.

The use of microprocessors made it possible to develop a simple and still efficient control circuit for all four power switches.

The novelty is that the original circuit of the bridge inverter is not changed, and the technical result is achieved owing to the introduction of an additional algorithm of operation of the power switch control circuit, while the UPS containing a bridge inverter combined with a battery charging unit is connected to the industrial network. Figure 1 shows a well-known single-ended flyback step-up inverter.

It is evident from Fig. 1 that, with the closed switch *K*, energy accumulates in inductor *L*1 by loop current *I*1, which, after closing switch *K*, continues as loop current *I*2, which charges battery *Acc* via diode *VD*.

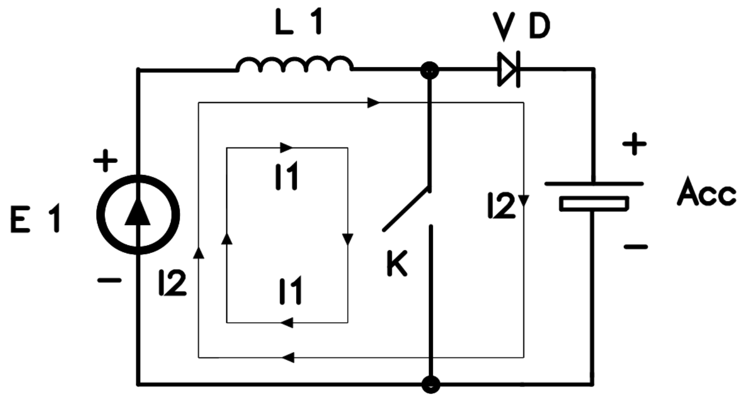

Fig. 1. Circuit and current flow in a single-ended flyback step-up inverter.

If we assume that, in Figs. 3 and 4, the two lower power switches of the bridge inverter *Q*3 and *Q*4 form switch *K* and the secondary winding *W*2 of the power transformer forms inductor *L*1 and if we replace current source *E*1 with the induced voltage in the secondary winding of the power transformer cut into mains, then, by changing the control signals as shown in Fig. 2, it is possible to form a circuit of a single-ended flyback step-up inverter from the bridge circuit of a two-stroke inverter. The control pulses applied to the input of the power switches are represented by the oscillograms shown in Fig. 2.

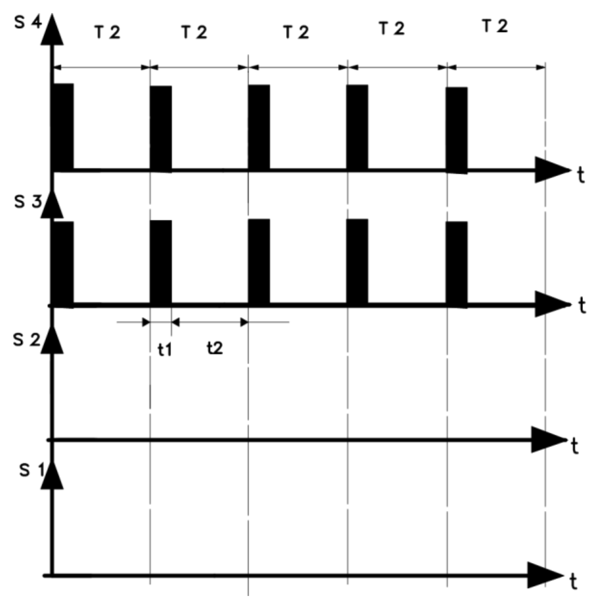

Fig. 2. Oscillograms of signals supplied to the input of the power switches.

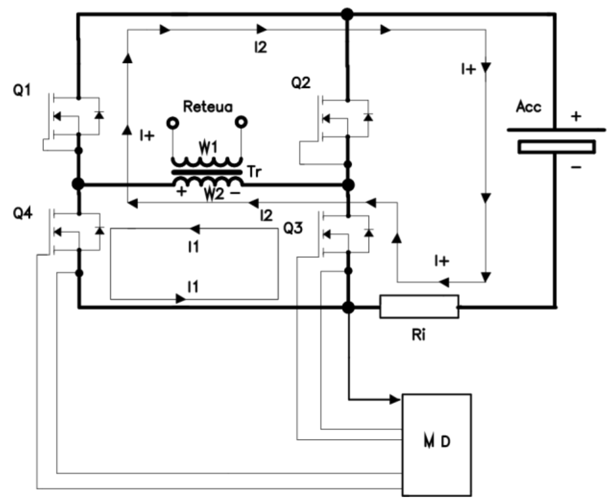

Fig. 3. Passage of the charging current during the positive half-wave of the mains voltage.

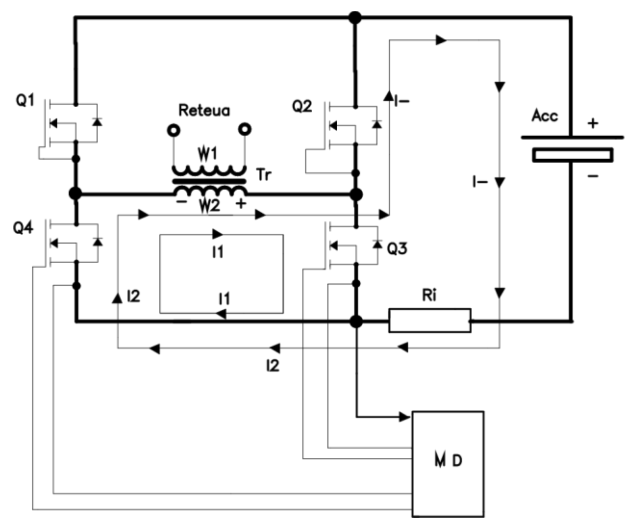

Fig. 4. Passage of the charging current during the negative half-wave of the mains voltage.

The passage of the charging currents during the positive and negative half-waves of the mains voltage is shown in Figs. 3 and 4, respectively. Currents *I*1 and *I*2 correspond to time periods *t*1 and *t*2 in Fig. 2.

An UPS containing a bridge inverter combined with a battery charging unit is shown in Fig. 5.

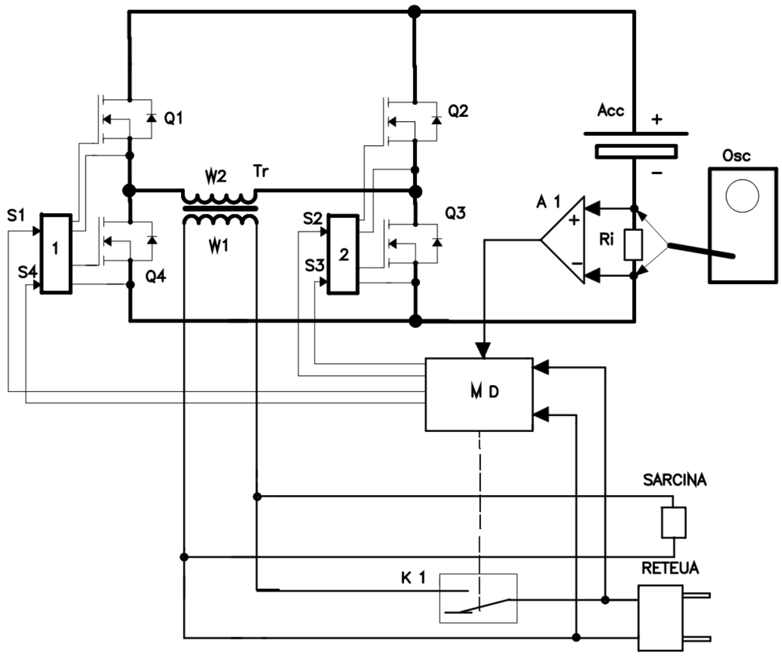

Fig. 5. UPS containing a bridge inverter combined with a battery charging unit.

Here, *1* and *2* are drivers; *Q*1, *Q*2, *Q*3, and *Q*4 are power switches; *Tr* is a power transformer; *W*1 is the primary winding of the power transformer; *W*2 is the secondary winding of the power transformer; *Acc* is a battery; *Ri* is a current sensor; *A*1 is a direct current amplifier; *Osc* is an oscillograph; *S*1, *S*2, *S*3, and *S*4 are signals at the input of the power switches; *MD* is a control unit; *K*1 is a relay; SARCINA is load; and RETEUA is network.

The UPS containing a bridge inverter combined with a battery charging unit, which is shown in Fig. 5, operates as follows: if the mains voltage is below or above the set values, control unit *MD* analyzes it and preserves the position of relay *K*1 as indicated in the circuit; in addition, it generates control signals *S*1, *S*2, *S*3, and *S*4 at regular intervals of 10 ms; the signals activate power switches *Q*1, *Q*2, *Q*3, and *Q*4 and generate heteropolar current pulses on secondary winding *W*2 of power transformer *Tr*; the pulses are induced in primary winding *W*1 of power transformer *Tr* connected to load SARCINA. If the mains voltage lies within the specified limits, control unit *MD* analyzes it and switches the relay to the upper position according to the circuit and simultaneously changes control signals *S*1, *S*2, *S*3, and *S*4 as shown in Fig. 2; the mains voltage is simultaneously supplied to load SARCINA and primary winding *W*1 of power transformer *Tr*; as a result, a heteropolar current is induced on secondary winding *W*2 of power transformer *Tr* at regular intervals of 10 ms; every 50 μs, the current is closed for a short time by power switches *Q*4 and *Q*3, and the power transformer accumulates energy in the form of a magnetic field. After switching off power switches *Q*4 and *Q*3, this energy is released in the form of current pulses, which flow through the free-wheeling diodes of locked power switches *Q*1 or *Q*2 and charge the battery with a current whose strength depends on the duration of the opening pulses and is set by control unit *MD* according to the voltage across current sensor *Ri*.

2. Experimental

A 500-W prototype model of this UPS was assembled. An ATMEGA 8 microprocessor was used in control unit *MD*; a special program was developed for this microprocessor. Power transformer *Tr* was wound on an S-shaped transformer iron frame of the EI133 type; IRF2804 field-effect transistors were used as the power switches; IR2011 drivers and a GP12200 battery (CSB, China) were used. The maximum (ultimate) charging current was selected to be I_{max} = 3A; to increase the efficiency of the device, the ohmic resistance of the current sensor was low (Ri = 0.001 Ω); a low-noise direct current amplifier *A*1 (K_{am} = 1000) was introduced. At variations in the mains voltage from 180 to 250 V, the charging current oscillation was no more than $\Delta I = \pm 0.15$A.

The shape of the charging current observed on oscillograph *Osc* (see Fig. 5) connected in parallel to current sensor *Ri* is shown in Fig. 6.

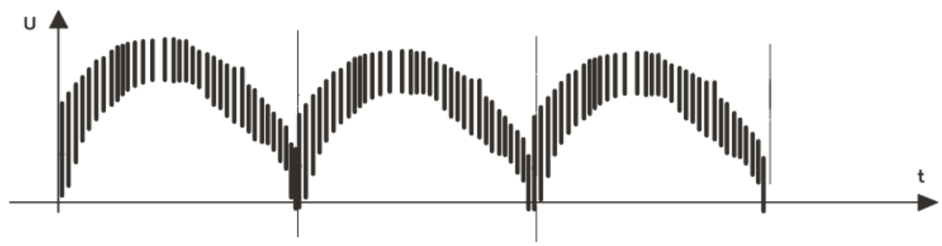

Fig. 6. Charging current oscillogram.

The physical form of the prototype model is shown in Fig. 7.

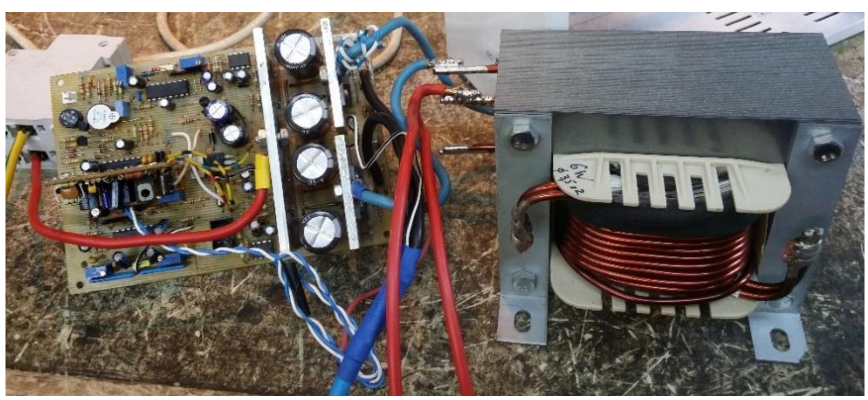

Fig. 7. Physical form of the prototype model of an UPS containing a bridge inverter combined with a battery charging unit.

According to the results of the work, an application for an invention was submitted [2].

3. Conclusions

This design has been tested in real time and proved to be very reliable. The long-term tests have shown that the simplicity of the design does not interfere with the reliable operation of the inverter circuit and charging the battery. The level of interference generated in the network during the battery charging is easily suppressed by a simple filter and does not exceed the maximum allowed.

The temperature of all the power elements and the power transformer during the tests was 10–15°C above the ambient temperature. This finding suggests that the system will reliably operate in the future.

References

[1] M.A. Shustov, Prakticheskaya skhemotekhnika. Preobrazovateli napryazheniya, Altex, Moscow, book 3, 2002.

http://publ.lib.ru/ARCHIVES/P/"Prakticheskaya_shemotehnika"/_"Prakticheskaya_shemotehnika".html

[2] Iu. Sainsus, A. Conev, Iu. Russev, and A. Sidorenko, MD Short-Term Patent no. 1822 (2016).