PULSE DENSITY MODULATION CIRCUIT

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Abstract. The research paper discusses principles of pulse density modulation control circuit and power switching design. Two different designs of control circuit are given. Power switching circuit test bench measurements are discussed.

Keywords: Pulse density modulation, power converter control circuit, asynchronous electric drive converter, sinusoidal shape current.

Introduction

Pulse density modulation (PDM) circuit is related to power converters and can be used in power electronics. PDM power converter development is a very topical issue. This principle is discussed before [2] where classification of PDM converters are based on the pulse width converter classifications, there are not given the principles of organization charts and PDM device is observed superficially, there is given only the pulse width modulation flowcharts, it is not shown how sinusoidal form current can be obtained [3].

The aim of the research is to create a simple asynchronous electric drive and power management system that enables high-quality producing of sinusoidal alternating current. The pulse density modulation system consists of a low-voltage control circuit and power switching circuit. The management circuit drives the high current contactless switching system which forms asynchronous electric drive power supply current of the capacitive energy accumulator. PDM management scheme in principle is based on a special function of the grid [1] with additional conditions.

Voltage pulse width chart. The system control circuit is enforceable as an analogue or digital electronics solution. The first version of the circuit is built on operational amplifier-based and inclusive capacitor, this principle converts small-scale input voltage into voltage pulse series, which drives the high current high-frequency power generator, the higher the input voltage value, the high-frequency power generator is turned on more often and vice versa, see the flowchart in Figure 1.

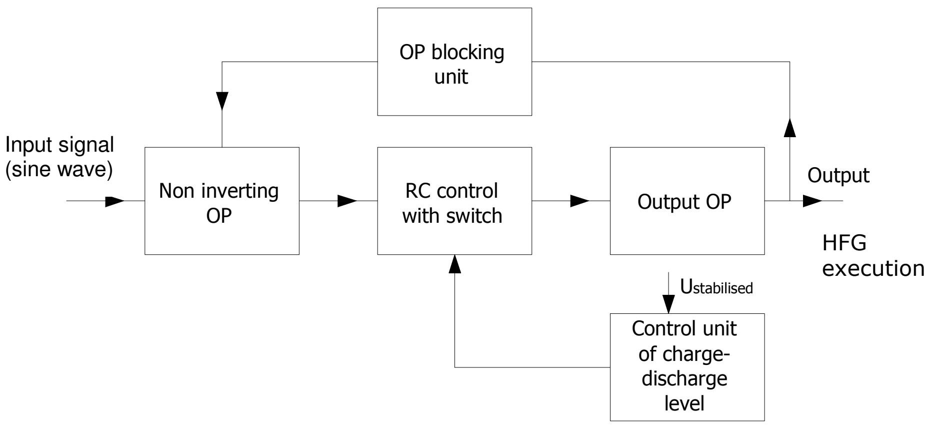

Fig. 1. **Pulse density modulation circuit analogue electronics version block diagram**

The second option power switches are operated using a computer system or pre-programmed memory unit, the pulse density modulation can be met with 5 μs (pulse or pause length) and higher resolution, as is permitted by the high current contactless switching system. Both methods enable to form asynchronous AC drive sinusoidal form. The pulse density modulation converter is specially designed for active-inductive nature of the load.

The pulse density modulation control circuit analogue operation is based on the input signal integration on capacity up to a certain level, the process can be changed by reducing the level then higher pill factors of pulses are achieved and vice versa. At the time when the capacity reaches the voltage level of the comparison it is being discharged through small resistance which determines the output pulse length at the circuit output. After the capacity is fully discharged it is being charged again. The grid function [1] which defines the formation of circuit output pulse shifts depending on the input signal instantaneous value, see Figure 2. The special grid function is described by the following equations determining it with discretization periods:

$$G(t)\{0;\sum_{k=o}^{k-1}(t_{i(k-1)}+t_{p(k-1)})<t<\sum_{k=o}^{k}(t_{ik}+t_{pk}), \tag{1}$$

$$G(t)\{A;\sum_{k=o}^{k}(t_{ik}+t_{pk})<t<\sum_{k=o}^{k+1}(t_{i(k+1)}+t_{p(k+1)}), \tag{2}$$

where $t_{ik} = t_{rfik} + \Delta t_k$;
$\Delta t_k = f[A(t)]$;
$A(t)$ – continuous function to discretize, which does not contain the function breaking point;
$G(t)$ – resulting discrete function;
k – number of the discretization step;
t_{ik} – k-th pulse length;
t_{pk} – k-th pulse break;
t_{rfik} – k-th pulse in the grid function pulse width;
Δt_k – k-th pulse width increase value, which functionally depends on the discretized function $A(t)$.

Forming discrete values law is nonlinear. The obtained discrete functions $G(t)$ characteristics include continuous discretized function change in each forming stage, achieving the pulse density change with a variable period.

This research is based on the theory of special grid functions with added a condition that $\Delta t_k = 0$, i.e. the discretization pulse width remains constant throughout the function $A(t)$ all the discretization time. This means that the discretized function properties are included in the pauses between t_{pk} discretization pulses.

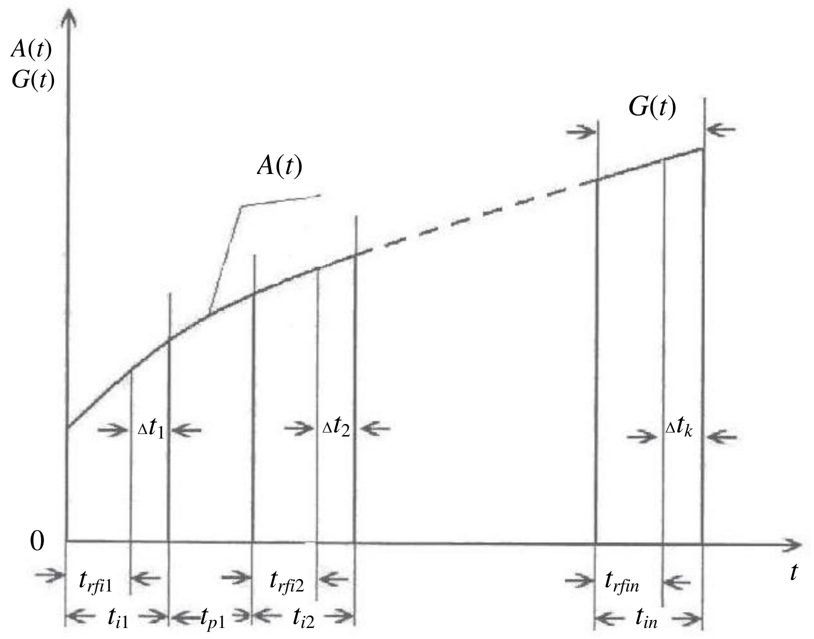

Fig. 2. **Characteristics of the special grid function**

Current pulse width modulation chart. For process modeling the test bench was created displayed in Figure 3. The test bench is designed to simulate the high current circuit with active inductive loads. Executing the circuit begins the process of inductance charging and discharging in stages with unipolar pulses.

For practical researches of the performance an analogue circuit is replaced by a programmable digital electronic block. This provides an opportunity to obtain unipolar output pulses with a resolution of 5 μs. In the result test bench consists of a programmable memory unit, active-inductive load and discharge diode with series resistance, see Figure 3.

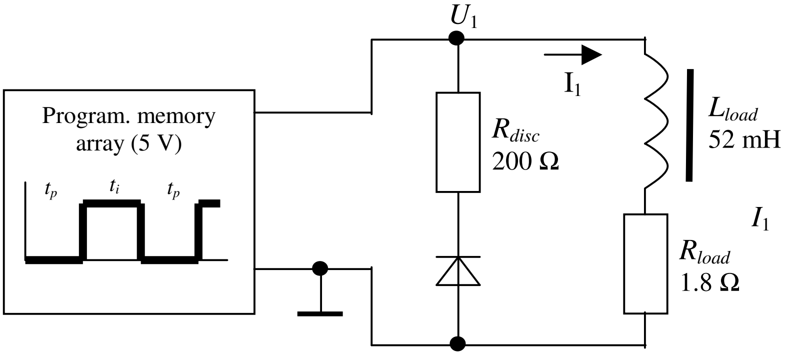

Fig. 3. **Test bench**

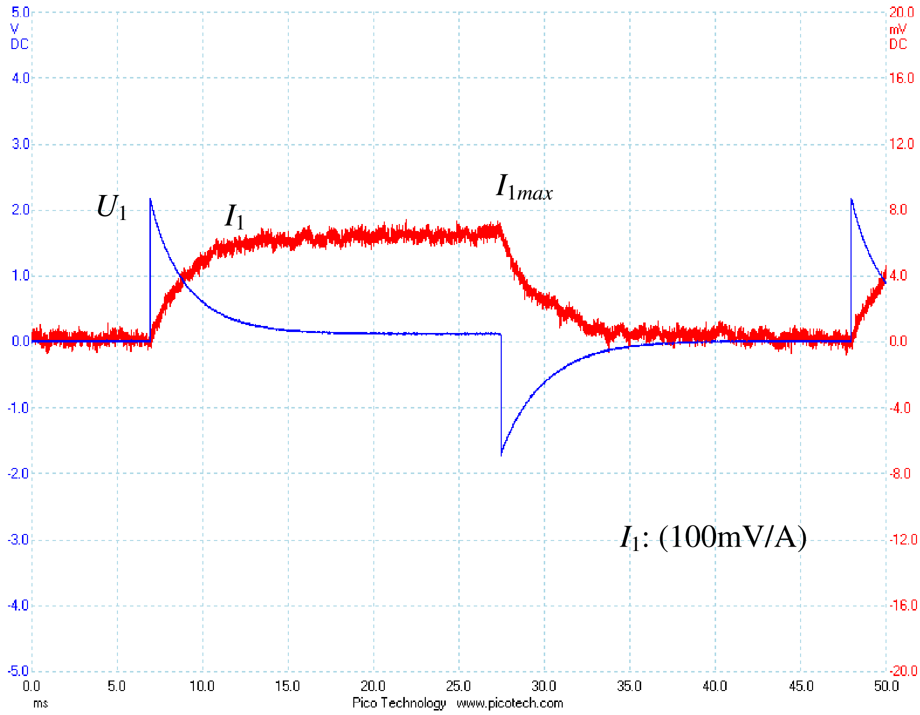

Fig. 4. **Voltage and current in-time at 20 ms impulse and 20 ms pause length**

Figure 4 shows the voltage and current form on the load, if the pulse lengths of 20 ms and 20 ms break. The measurement was carried out at low pulse frequency; therefore it shows the full inductance transition process. At the charging stage current is described by equation:

$$i_{ch} = \frac{U}{R_{common}}(1 - e^{\frac{-t}{\tau_{ch}}}), \tag{3}$$

discharge stage:

$$i_{disc} = \frac{U}{R_{disc}} e^{\frac{-t}{\tau_{disc}}} \tag{4}$$

where U – pulse amplitude;
$R_{common}= R_{load}+R_{disc}$;
$\tau_{ch}=L/R_{load}$ and $\tau_{disc}=L/R_{common}$ – time constants.

If the pulse and pause length is reduced to 0.25 ms, the voltage and current of the form are as it is seen in Figure 5.

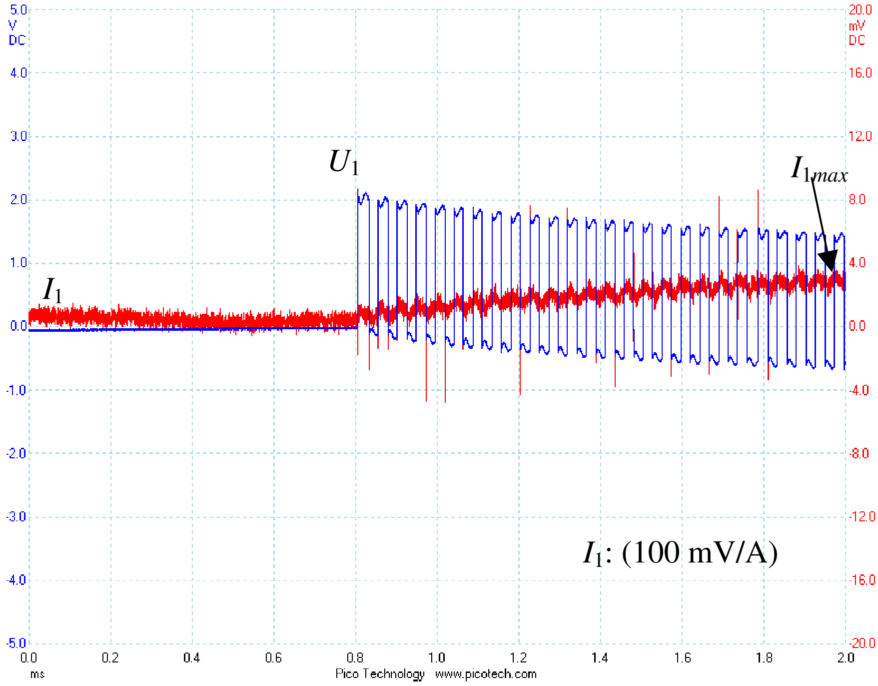

Fig. 5. **Voltage and current in-time at 0.25 ms impulse and 0.25 ms pause length**

The measurement shows, that the fill factor used is equal to 0.5 – pulse time is equal to the pause time. Once the load is connected to high-frequency unipolar pulsed power supply voltage, current in inductance increases and reaches a certain stabilised value, see Figure 5, I_{max}. The unipolar impulse power fill factor can be varied, i.e. when t_i/t_p is varied, the current gain speed and stabilized value I_{max} are varied too. As a result, there may be a DC converter created with sinusoidal output current. The sinusoidal shape current forming accuracy determines the last member of the sine projection in line. The errors do not exceed the value of the member, which is discarded.

$$\sin(x) = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} = \frac{x}{1!} - \frac{x^3}{3!} + \frac{x^5}{5!} \mp \dots \qquad (5)$$

Conclusions

The pulse density modulation principle DC power converter can be designed for the active inductive load with a sinusoidal output current shape using conditions discussed in this research. Changing the unipolar supply voltage pulse fill factor to obtain the required gain speed and stabilized current value which corresponds to a certain stage of the sinusoidal form can be obtained.

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