SIMPLE SEMICONDUCTOR SWITCH IN ZERO OF AC VOLTAGE WITH MINIMUM ELECTROMAGNETIC INFLUENCE (EMC) ON POWER SUPPLY NETWORK

ПРОСТОЙ ПОЛУПРОВОДНИКОЫЙ ВЫКЛЮЧАТЕЛЬ В НАСТОЯИМ ИУЛЬ ЗНАКОПЕРЕМЕННОГО НАПРЯЖЕНИЯ С МИНИМАЛЬИЫМ ВЛИЯИЕМ НА ТЯЛОВУЮ СЕТЬ.

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Abstract
Article is describing simply semiconductor switch. It's advantages are switching in zero voltage and so called self supplying. It's aimed for resistive load or for resistive-inductive load with small inductive part. There is using cycle control of load but not for phase for wide range of performance. It can work in single phase and three phase system. Functionality is represented on real sample for performance 60 kW in saving connection.

Keywords: power switch, switch in zero voltage, electromagnetic compatibility (EMC)

Introduction

AC voltage converter are like as rectifiers power supplied from AC network and have very disadvantageous backward influence of power supply network.
Reactive component of power drain of converter. Phase control AC voltage converter is phase move first harmonic current of load, which is identical with current withdraw of load from supply network, in respect of supply voltage. The same effect is also in case resistive load. There is creating of control reactive component power drain of converter.
Influence of higher harmonics of the current load. Current drained from AC voltage converter from supply network, i.e. current of load i_z, has no harmonic waveform.
When steady-state harmonics are present, instantaneous voltage and current can be represented by Fourier series as follows:

$$u(t)=U_0+\sum_{n=1}^{\infty}\sqrt{2}.U_n\,sin(n\omega t+\varphi_{U,n}) \quad (1)$$

$$i(t)=I_0+\sum_{n=1}^{\infty}\sqrt{2}.I_n\,sin(n\omega t+\varphi_{I,n}) \quad (2)$$

U_n and I_n are rms values for n-th order of harmonic voltage and current, respectively.
For U–rms:

$$U=\sqrt{\frac{1}{T}\int_0^T\left[\sum_{n=1}^{q}\sqrt{2}.U_n\,sin(n\omega t+\varphi_{U,n})\right]^2 dt}=\sqrt{\sum_{n=1}^{\infty}U_n^2} \quad (3)$$

and analogical for I–rms:

$$I=\sqrt{\sum_{n=1}^{\infty}I_n^2} \quad (4)$$

The instantaneous power is defined as:

$$p(t)=u(t).i(t) \quad (5)$$

and the average value of the active power over one period T of p(t) is defined as:

$$P=\frac{1}{T}\int_0^T p(t)dt=\frac{1}{T}\int_0^T u(t).i(t)dt \quad (6)$$

$$P=P_0+\sum_{n=1}^{\infty}U_nI_n\,cos(\varphi_n) \quad (7)$$

$$\varphi_n=\varphi_{U,n}-\varphi_{I,n} \quad (8)$$

$$P_0=U_0+I_0 \quad (9)$$

This the dc term is usually ignored. The apparent power is given by:

$$S=UI=\sqrt{\sum_{n=0}^{\infty}U_n^2\sum_{n=0}^{\infty}I_n^2} \quad (10)$$

where Q is the reactive power defined as

$$Q=\sum_{n=1}^{\infty}U_nI_n\,sin(\varphi_n) \quad (11)$$

Because for non harmonic waveforms is:

$$S\ge\sqrt{P^2+Q^2} \quad (12)$$

then widely accepted definition of apparent power is

$$S=\sqrt{P^2+Q^2+D^2} \quad (13)$$

and D is defined as the distortion power which correspond to the products of voltages and currents of different frequency components in (1) and (2).

$$D=\sqrt{S^2-(P^2+Q^2)} \quad (14)$$

The concept of power factor originated from the need to quantify how efficiently a load utilizes the current that it draws from the ac power system. Regardless of sinusoidal or nonsinusoidal situation, the total power factor is defined as:

$$\lambda=\frac{P}{S}=\frac{P}{\sqrt{P^2+Q^2+D^2}}=\frac{\sum_{n=0}^{\infty}U_nI_n\,cos(\varphi_n)}{\sqrt{\sum_{n=0}^{\infty}U_n^2\sum_{n=0}^{\infty}I_n^2}} \quad (15)$$

where P is the average power contributed by the fundamental frequency component and other harmonic components, as shown in (7). In the next section, we also will show the relationship between the power factor and some harmonic distortion indices.

$$THD_U = \frac{\sqrt{\sum_{n=2}^{\infty} U_n^2}}{U_1} \qquad (16)$$

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1} \qquad (17)$$

which is defined as the ratio of the rms value of the harmonic components to the rms value of the fundamental component and usually expressed in percent. This index is used to measure the deviation of a periodic waveform containing harmonics from a perfect sinewave. For a perfect sinewave at fundamental frequency, the THD is zero. Similarly, the measures of individual harmonic distortion for voltage and current at n-th order are defined as U_n/U_1 and I_n/I_1, respectively.
The total demand distortion (TDD) is the total harmonic current distortion defined as

$$TDD = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I} \qquad (18)$$

From consideration result, that higher harmonic current of converter causing creation of deformation power, which is next to increasing itself whole reactive power drain of converter and get worse power factor.
Deformation of converter input voltage. By supplying of AC voltage converter from real power supply, i.e. supply of alternating voltage with non zero inside impedance, create drain of no harmonic current and nonharmonic drain of voltage. On input of converter then create alternating voltage, which includes higher harmonic network frequencies.
This effect, which is same as by rectifier, has but by alternating converters bigger sense because of these converters itself in many case connected to power network direct, without transformer. Therefore converter deforms voltage often in extensive section supply network, till to nearest to transformer, on impedance which mentioned no harmonic decrease of voltage emergent.
So that deformation of supply network non overlap bearing boundary, is feasible performance of converter connected directly to supply network limited, for example to 1 % of short-circuit power in point of connecting converter.
High frequency interference causing, such as rectifiers, temporary jump phenomenon of conductivity semiconductor parts, for example, by turn-on thyristors of AC voltage converter. Influence of high frequency noise is limited by suppression filters.
Essential cut-down all described influences of converter on supply network we can reach individual method of control, when control angle is not changed fluently in scope $0 \le \alpha \le \alpha_{max}$ but obtain only two outer limit values: zero, when is converter full open, and maximal, when is converter full closed. Converter works as cyclic switched switch of alternating current.

For load of resistive character has by that control output voltage course according fig. 1. Effective value voltage of the load $U_{z\,(RMS)}$:

In harmonic analysis there are several important indices used to describe the effects of harmonics on power system components and communication systems. This section describes the definitions of those harmonic indices in common use.
The most commonly used harmonic index is

$$U_{z(RMS)} = U\sqrt{\frac{t_z}{T}} \qquad (19)$$

where t_z is time of open converter and T is period of change control angle (length of cycle).

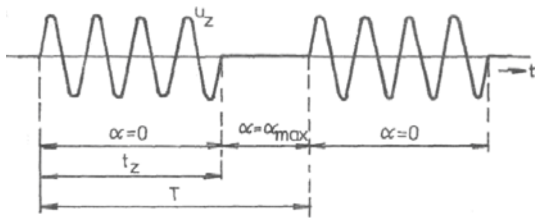

Fig. 1. Output voltage of converter by cyclic switching

From past consideration results, those in this case do not resort to increase of drain reactive energy nor to deformation of removal current and also AC supply voltage. The same is limited high frequency noise of high frequency of converter, because of don’t resort to step change voltage or current in circuit of converter.
Disadvantages this described method control is creation of sub harmonic vibration with frequency 1/T in supply system. Therefore is suitable only for load with long time constants, for example for supplying electro thermal systems, where heating or cooling time constant is incomparably bigger as period of change control angles, and oscillation of temperature will be negligible. Like that we cannot control of lighting appliances or motors.
Problems of the controlling the big resistance load performance was described in many literatures. For load with long time constant load is possible to use switch, which is described in this article. Article describing circuit, which has these properties:

- minimal backward effect (interference) on power supply network
- is modified for voltage 3x400V,
- switch in zero of voltage
- is "self supplying",

Advantage of zero switching of power supply voltage is not necessary more closely describing. There is elimination of problem higher harmonics of current and voltage, and arising back influence of system to power supply and too disturbance of electrical systems and control systems [2] [4]. Problems with electromagnetic compatibility initial in recent time increasingly receive importance with innovation of new standards from aspect of environmental influence electrical systems [6], [7], [9]. Next advantage of its properties is that don’t need extra power supply (transformer, regulator, stabilization). Power supply for control circuit is transferred from semiconductor switch in switch-off state.

Description of function.

Fact, that circuit is full functional for voltage 3x400 V too is accentuated because of using 230 V will this easy circuit even simplify. Scheme of power part of the connection, for resistive load so called saved connection is on fig. 2.

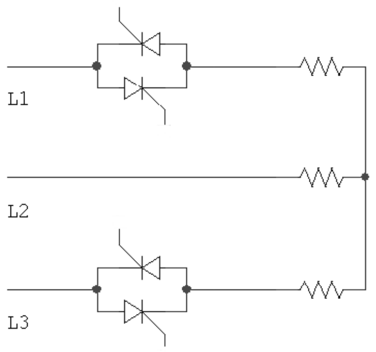

Fig. 2. “Low-cost” connection of the power converter for resistive load.

Whole converter can control phased or cycle. Typical waveform of phase control switch is on picture 3. A Fourier analysis is on picture 4. This switch is controlled in cycles. Typical waveform is on picture 5 and then is make again Fourier analyze for cycled controlled mode depicted on picture 6. Comparing of spectrum higher harmonically voltage by resistance load and current is obvious, that spectrum higher harmonic parts is worst in case phase control. In case cycled control is obvious, that backward influence on power supply is acceptably because is finding only by basic harmonic network.

Fig. 3 Load voltage for phase control converter

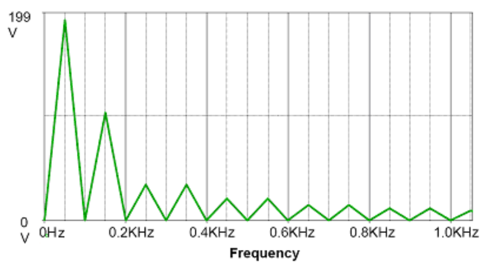

Fig. 4 Fourier analysis for load voltage in case phase control converter

Scheme of control circuit for one switch is on picture 7. Whole operation can be described in two states. First is state of turn off optoelectrical part (OC1) and second is by full to energize OC1. In first case is in operation circuit R1, R2, D7 a T1, which is full saturated and that in fact grounding gate VT3. Resistive divider is designed so that VT4 endure oscillation of line voltage to 440 V.

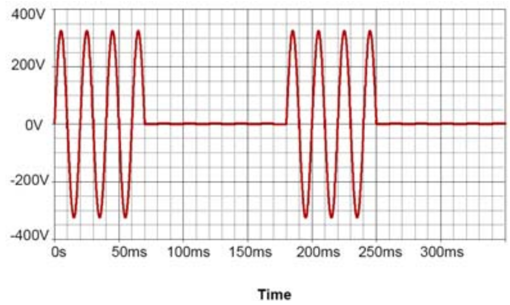

Fig. 5 Load voltage for cycle control converter

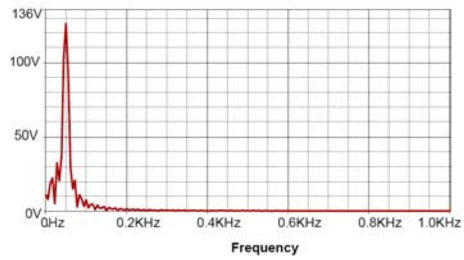

Fig. 6 Fourier analysis for load voltage in case cycle control converter

Second is state of conducting state OC1. Conducting state can arise in one from two time intervals of half sinus directional voltage from switch. First is time interval from zero voltage, when actual value directional voltage is equal of zener voltage. In that time interval is closed circuit R1, R2, OČ1, gate VT4, which incoming to his conducting state, next conducting state VT3 too and then in switch VT1 too or VT2 according that, which is from just in block state. As far as OC1 is not in conducting state to this time, the switch will be in conducting state in next half period. To operating mode will be initiate block circuit R1, R2, D7, T1.

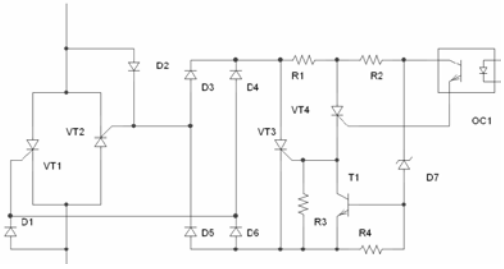

Fig. 7. Control circuit for one power switch

Conclusion

The circuit for his simplicity fined use by controlling of thermal resistive furnace with high performance [1], [3], [5], [8]. His main advantage is switching in zero voltage. Control circuit is universal for wide area of performance. This article is application character and it is possible to simplify according to application, for example according of performance or usability in single or three phase network. Detail information about design is material for next publication, or it is possible to provide on demand from authors. Experimental performances are from 15 kW to 60 kW. Realized example with withoutpotentional modules MTT 431-50–08 is on figure 8.

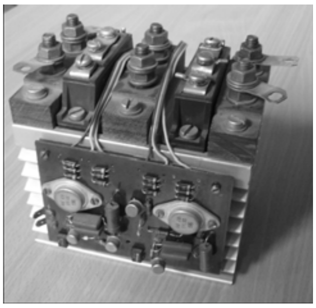

Fig. 8. Converter with MTT 43-50–08 modules

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