CURRENT PROTECTION OF POWER ELECTRONIC CONVERTERS

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Abstract: The implementation of secure current protection is essential for the reliable operation of power electronic converters. The article discusses a circuit of such protection, galvanic separated from the power circuit of the converter, its action is described, the results of an experimental study are applied. A major advantage of the proposed solution is its flexibility and versatility: it can be placed in different place of the power circuit of the converter, adjusting the trigger threshold and the time of interruption of the control pulses to the transistors of the converter.

Key words: current; protection; power electronic converters.

1. INTRODUCTION

The basic principles for current protection of transistor inverters are discussed in [1]. [2] examines the possible emergency modes of the electric drives and offers solutions for protection. The real-time monitoring system [3] provides protection options as well. There are different approaches for implementation of current protection of transistor inverters. The main one is related to monitoring the transistor switching mode. For this purpose, an additional circuit at switching off is available in [4]. The coordinate transformation in the control system is used for the analysis of the mode, according to the currents as well [5]. An additional inductance with saturation, that influences the transistor switching process, is shown in [6]. [7] analyzes the gate voltage on switching on to detect current overload. Various current sensors are also used, as the solution proposed in [8] is of interest, which however is applicable to small current values. The issues of current overload protection for DC systems [9,10,11] are also of interest. A solution with connection of additional transistors to the input of the converter is proposed in [12]. [13] presents a solution with the so-called "microprocessor relay". Various current monitoring situations in photovoltaic systems and buck-boost converter are presented in [14]. The latest solution is for monitoring the saturation voltage of the transistor to detect current overloads, with built-in driver capabilities [15,16].

The purpose of this work is to present an opportunity for current protection by interruption the control pulses to the transistors of the converter, which to be used as the first level of protection - before the response of the one provided in the transistors drivers. Once the response of the first level, the microcontroller is given the opportunity, for a certain time, to analyze the possible causes and to decide whether to continue to deliver control pulses to the transistors of the converter.

Part II presents the electronic circuit and describes its operation, and in Part III the results of an experimental study and application are presented.

2. ELECTRONIC CIRCUIT AND DESCRIPTIONOF THE ACTION

The complete electronic circuit is shown in Fig.1.

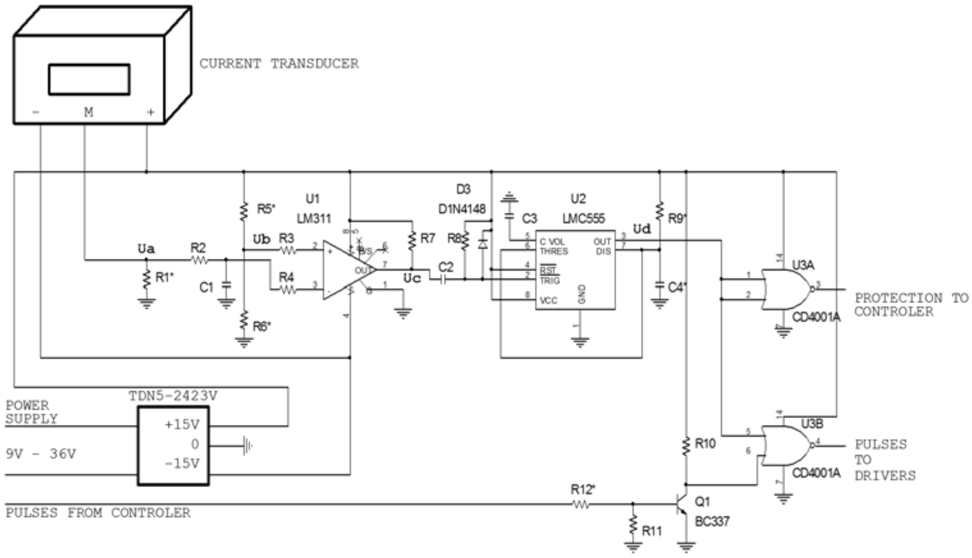


Fig. 1. Electronic circuit

The protection circuit is galvanic isolated from the Power Electronic Converter circuit, as the current monitoring is done by a current sensor "CURRENT TRANSDUCER". The conductor through which this current flows (hereinafter referred to as I primary) passes through the transducer hole. The protection circuit has a self-powered supply provided by the DC/ DC Converter TDN5-2423W, and is galvanic isolated from the rest of the power supply. The voltage value $\boldsymbol{U_a}$ on the resistor $R1^*$is proportional to the I primary current value. Through $R2, C1$is implemented a filter for removing potential interfering signals overlaid on the useful information signal.

A voltage comparator is implemented via the integrated circuit $U1$, as the triggering threshold U_b is set by means of the voltage divider consisting of the resistors $R5^*, R6^*$. The integral timer $U2$ is connected to a one-shot generator. It is started from the comparator U_c output signal by means of a differential circuit consisting of the elements $R8, C2$. The duration of the output pulse, indicated in Figure 1 as U_d signal, is set with the values of the elements $R9^*$and $C4^*$. The signal U_d is inverted by a logical element $U3A$ and the signal "PROTECTION TO CONTROLLER" is received, which is used to inform the controller that the protection is triggered. The pulses coming from the controller ("PULSES FROM CONTROLLER" signal) designed to switch on and off the transistors of the Power Electronic Converter, are inverted by the transistor $Q1$. After logical processing with the signal U_d the driver pulses - "PULSES TO DRIVERS" are obtained. The value of the resistor $R12^*$ is selected depending on the signal level "PULSES FROM CONTROLLER".

Fig. 2 presents time diagrams illustrating the operation. Voltage and signals indication correspond to those shown in Fig. 1. It is assumed that the Power Electronic Converter is working normally till $t1$. For some reason, at the moment $t1$, the primary current I primary through Current Transducer has risen above the permissible I reference value. Accordingly, the voltage value U_a is greater than the voltage value U_b. The value of the voltage U_c at the output of the comparator $U1$ is equal to 0 and this causes the start of the one-shot generator $U2$. This generator always produces U_d pulse at its output with set duration *t*-pulse. This pulse causes the interruption of the pulses to the drivers "PULSES TO DRIVERS" of the transistors from the converter, and transmission of a low-level signal to the controller – the moment $t1$. The interruption of the pulses to the drivers causes decrease of the I primary current, which at $t2$ falls below the permissible I reference value. Accordingly, the voltage value U_a becomes lower than the voltage value U_b.

The voltage value U_c at the output of the comparator $U1$ increases again. However, pulses to the drivers between the moments $t1$ and $t3$ are not transmitted, although there are pulses from the controller - "PULSES FROM CONTROLLER" at the input. For the case shown in Fig. 2, it is assumed that after receiving the "PROTECTION TO CONTROLLER" signal at the moment $t1$, the controller has analyzed the reason for the current increase and has decided to continue to transmit pulses. In this case, after $t3$ the pulse transmit to the drivers "PULSES TO DRIVERS" is restored. The Power Electronic Converter working mode is restored as well and the I primary current increases gradually. In case of, after receiving the signal "PROTECTION TO CONTROLLER" at $t1$, the controller stops pulse transmission, then after $t3$ there will be no pulses to the drivers "PULSES TO DRIVERS" and the Power Electronic Converter stops working. The duration $t1 \div t3$ of the time interval corresponding to the tpulse time, can be determined at the designing of the converter depending on various considerations - its operating frequency, the type of power circuit, its elements, etc. Depending on this, this duration may be equal to a half-period of the converter's operation, one period of its operation, but may be even bigger. This duration is set with the values of the elements $R9^*$ and $C4^*$ in Fig. 1.

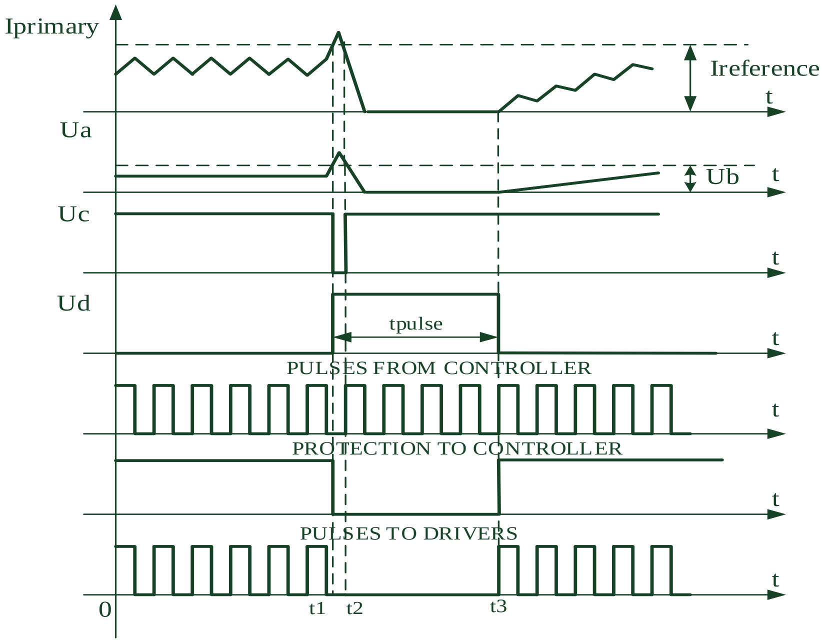


Fig. 2. Time diagrams, illustrating the operation

From the description of the protection circuit and the principle of its operation, a conclusion of its advantages compared to the known: universality and adaptability, can be made. They consist of the following: 1. Option for monitoring a selected current with galvanic isolation from the circuit of the Power Electronic Converter - by installing current sensor “CURRENT TRANSDUCER” at a suitable place depending on the operation of the converter. 2. Option for use at different powers - by selecting the type of the current sensor “CURRENT TRANSDUCER” and the value of the resistor $R1^*$. 3. Option for changing the current protection trigger threshold - by changing the value of the voltage U_b. In the diagram in Figure 1 this is done through the resistors $R5^*, R6^*$. It is also possible to set the voltage U_b from the controller via a Digital to Analog Converter, thereby achieving protection adaptability. 4. Option for changing the time tpulse, during which the pulses transmission to the drivers “PULSES TO DRIVERS“ is forbidden.

3. EXPERIMENTAL STUDY

The developed protection circuit has been successfully applied in the following cases: 1. The current sensor monitors the input current in the DC bus of a 1 phase and 3 phase transistor voltage source inverter. 2. The current sensor monitors the current through the transistor of step-down buck DC/ DC converter. Figure 3 shows the appearance of the protection with highlighting the more important elements.

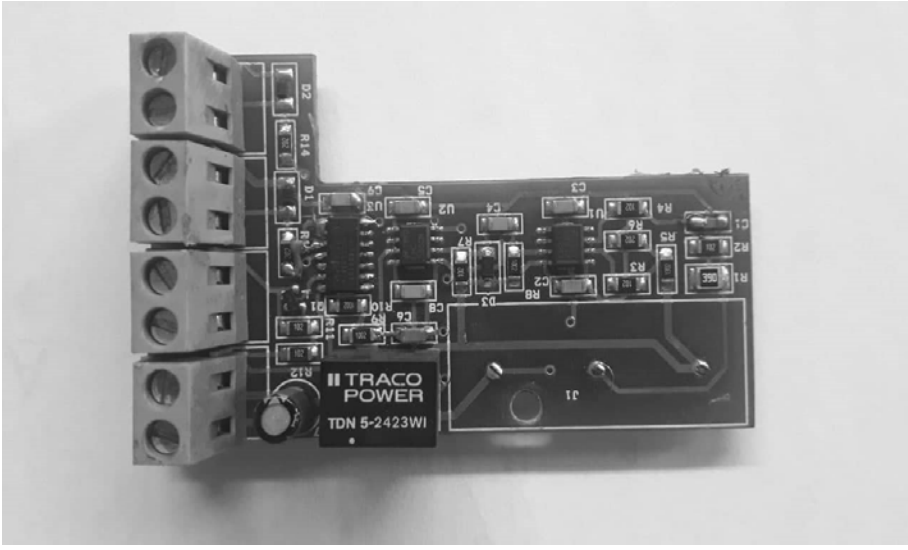
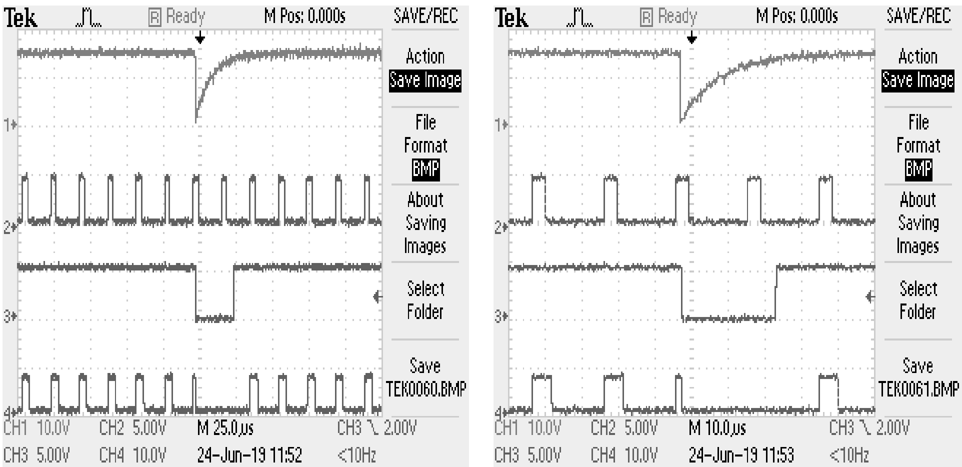


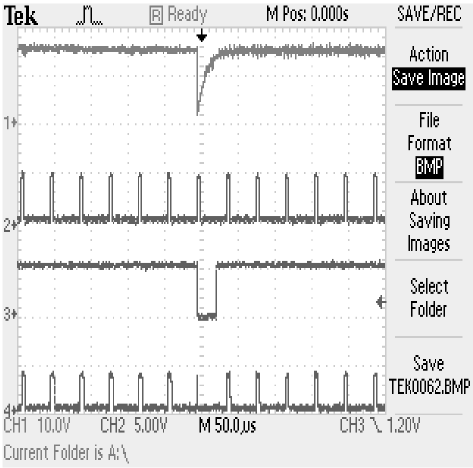
Fig. 3. Appearance of the developed and tested protection circuit.

Fig. 4 and Fig. 5 show oscillograms of experiments. The oscillograms of Figures (a) and Figures (b) are presented in various time base for clarity. In all cases, the interruption time tpulse is set to 25 µS.

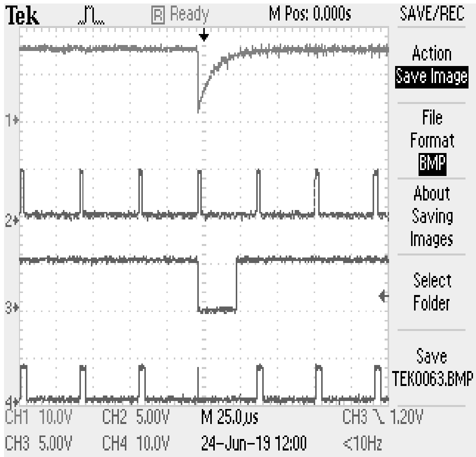


(a) *(b)*

Fig. 4. Oscillograms of experiment: (a) time base 25µS/div; (b) time base 10µS/div, CH1 – IC U2 – pin2; CH2 – pulses from controller; CH3 – protection to controller; CH4 – pulses to drivers.



(a)



(b)

Fig. 5. Oscillograms of experiment: (a) time base 50$\mu S/div$; (b) time base 25$\mu S/div$, CH1 – IC U2 – pin2; CH2 – pulses from controller; CH3 – protection to controller; CH4 – pulses to drivers.

The pulse frequency of the controller in Figure. 4 is 50 kHz. The figure shows that raising the power current above the set value causes the current impulse to the drivers to stop. In addition, the next impulse to them is interrupted.

The pulse frequency of the controller in Figure. 5 is 25 kHz. The figure shows that raising the power current above the set value causes the current impulse to the drivers to stop. The next impulse to them is resolved.

Additionally, the circuit in Figure 1 is implemented in the input circuit for driver control for IGBT [15,16]. In this way, two levels of protection with different current value and different priority were achieved: the first level is of the offered protection and the second level - of the protection built into the drivers.

4. CONCLUSION

Particular attention should be paid to the proposed in the present work concept for the realization of protection at two levels in the power electronic converters. For protection at lower current values, a circuit with options for interruption the control pulses and for analysis by the microcontroller is offered. The proposed solution is characterized by versatility and adaptability to various converter variants. For protection at the second level at higher current values, the built-in driver protection is used by monitoring the saturation voltage of the transistors.

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