U.P.B. Sci. Bull., Series C, Vol. 68, No. 1, 2006

MONOPHASE CONVERTER OF DIRECT CURRENT – ALTERNATIVE CURRENT FOR THE MEASUREMENT OF THE DISPERSION RESISTENCE OF EARTH GROUNDS

D. BUMBAR, Brandusa PANTELIMON*

Convertorul cc-ca monofazat descris mai jos este parte integrantă într-un tester pentru măsurarea rezistenței de dispersie a prizelor de pământ.Prizele de pamant sunt componente importante ale instalatiilor electrice cu numeroase functii de protectie. Articolul prezinta alegerea si caracteristicile unui convertor cc-ca monofazat care sa corespunda metodei de masurare a unor rezistente, metoda ce impune utilizarea unui semnal care poate pune in evidenta un fenomen fizic cu intensitatea direct proportionala cu marimea de masurat.

The monophase direct current - alternative current converter, hereinafter described, is an integrant part of a tester for the measurement of the dispersion resistance of the earth ground. The earth ground are very important components of electrical equipments having many protection functions. This article presents the selection of a dc-ac convertor corresponding to a resistance measurement method, method which imposes the use of a suitable signal to emphasize a physical phenomenon of an intensity which is directly proportional to the quantity to be measured.

Introduction

The earth ground represent the technical means by which the earth ground can be used as an electric conductor for normal working or fault currents [2]. As the value to be measured, the electrical resistance respectively, is of a passive type, the measuring method needs the use of a signal to emphasize a physical phenomenon having the intensity directly proportional to the value that is to be measured. Additionally, the principle of this method forbids this signal to interfere with other devices connected to the earth ground and be influenced by perturbing factors which are usually met in an electric installation (e.g.: accidental earth ground).

Considering these, it is required that the measurement be done based on an alternative voltage which is applied between two electrodes: a testing electrode and the earth ground that is to be measured. The using of an alternative voltage has the following advantages:

* Eng., U.M. 0328 Bucharest, Romania, Prof., Dept. of Electrical Measurements, Electrical Apparatus and Static Converters, University POLITEHNICA of Bucharest, Romania

- frequencies which are different from those usually met in an electrical installation can be generated, the useful signal being thus separated from the parasite signals (the network frequency and its odd harmonics are avoided);
- a transformer able to insulate the device from the installation subject to the measurement can be used;
- the transformer in use may also play the role of a protection device for over-voltage and short circuit, when it is suitably wound.

As the device will be supplied with direct current and the generated voltage must have a very accurately controlled frequency, the generation of this voltage is done with a static converter of monophase inverter type, which is implemented with a “H” bridge of 4 transistors, having as charge a transformer for voltage increasing (as the highest voltage on the plate is of 12 V d.c.) [1].

1. Generating of PWM control signals

The generation of the control signals is done using the timer 3 (of 16 bits) of the ATmega128 microcontroller produced by Atmel Company [5]. This allows the generation of frequencies within the range 25 – 160 Hz with a resolution of 0.02 Hz starting from a watch signal of 1.38 MHz which is taken over from the microcontroller. The stability of the generated frequency is that of the quartz used for the oscillator of the microcontroller (maximum deviation of 70 p.p.m.).

The control signal for inverter could be generated in several ways, because this timer is a very versatile one and the checking possibilities in the software are various.

In order to have the possibility to check the dead times necessary to a qualitative order for the bridge transistors, it was chosen the generation of a single signal having a filling factor less than 50 % and double frequency as compared to that which is needed to the inverted outlet. This signal shall be applied, turn by turn, to each diagonal of the bridge. In order to allow the testing of some other driver types for inverter and even for ordering another external inverter with the aim of checking/studying it, the OC3A outlet of the timer was completed with the other two outlets, OC3B and OC3C, together with the outlets of the other timer of 16 bits, the timer 1. All these outlets from the timer were connected both to the outlet connector (J9) and a configuration modulus with jumpers (J8) in order to allow different selections of the control signal of the used inverter.

The timer 3 was set as follows:

- Working mode: Phase and Frequency Correct PWM;
- $f_{crystal}/8$ pre-scaler;
- generating interruption when the equality in the A comparator is achieved;

- non-inverting, active outlet from the A comparator.

When generating the interruption, if it was given the order to start up the inverter, the pins OC3B and OC3C would be passed, turn by turn, in the logic stage "1" by the treatment routine of the interruption generated by the timer 3 [6].

On the configuration modulus there were not connections made because there is no external inverter used. To the outlets of the timer 3 the following connections were made:

OC1A ↔ Pulse
OC3B ↔ Negative Wave
OC3C ↔ Positive Wave

2. Conditioning of PWM signals

The rectangular signals coming from the microcontroller are conditioned with a logic gate [7] for avoiding the ordering of the simultaneous entering the conduction of both diagonals in case of a wrong order coming from the microcontroller (Fig. 1).

The conditioning block itself was implemented with the logic gates "AND" and "NO", existing in the integrated circuits of HCT type, which are marked in the diagram with the indicatives U17 and U18.

Two identical channels were implemented, each of them made up of two "AND" gates and a "NO" inverting gate.

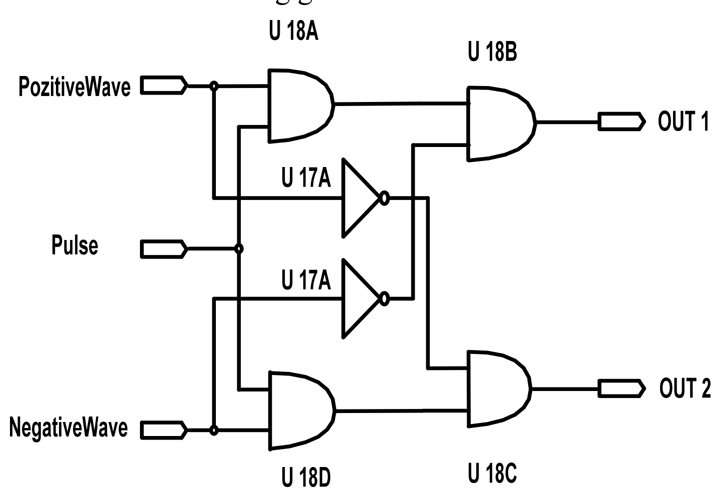

Fig. 1 Conditioning of PWM signals

The operation is according to the Table 1 of truth table, of below:

Table 1

The truth table for the conditioning block

Pulse	Negative Wave	Positive Wave	OUT 1	OUT 2
0	X	X	0	0
1	0	0	0	0
1	0	1	1	0
1	1	0	0	1
1	1	1	0	0

The inverting gates that remained unused were connected with their inlets to the digital mass for non-entering into oscillations.

3. Static converter – the power part

The static converter is of monophase inverter type, implemented with a complete "H" bridge that is made up of 4 MOFSET transistors (Q9, Q10, Q11 and Q12) as it is shown in Fig. 2. It was chosen the solution of implementation with identical MOFSET transistors with N channel, because this type of inverter ensures in a natural way the form symmetry of the generated wave eliminating the risk of injecting undesired components of the signal in the installation subject to the measurement. But this type of inverter needs drivers that are more complicated than in the case of a bridge with upper transistors and P type channel.

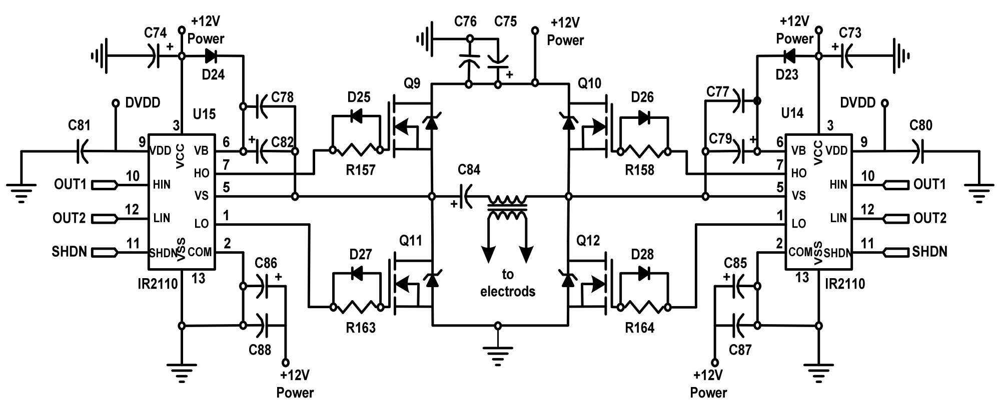

Fig. 2 Static converter – the power part

To ensure the firm control of the transistors making-up the inverter and to separate the control signal of TTL level from the voltage of 12 -direct current that is used to the power part supplying, by taking also into consideration the fact that the superior transistor in the bridge needs a control with floating potential, special drivers were used for this scope and namely those of IR2110 type (International Rectifier) [4] that are marked on the diagram with U14 and U15.

In order to allow the testing of some more types of drivers it was chosen the capsule of DIL type, sockets for CI being installed on the cabling.

The power part supplying is done by the means of some jumpers (PIN1, PIN2 and PIN3) from the voltage of +12V delivered by the supplying source of the device. It was provided a protection against the over-voltage and short circuit by a fusible cut-out, for the protection of the power components in case of defect, because the supplying source is protected inside but this protection is active to the high values of the voltage. There were provided filtering condensers of the supplying voltages of the inverter (C75, C76) because this is the block which produces the strongest perturbations.

As regards the components accompanying the drivers, these are the ones recommended by the producer. Thus, there were used condensers to decouple the supply (C88, C86, C81, C74, respectively C87, C85, C80 and C73). In order to use the superior transistor, which is at the floating potential, the drivers use a charge pump involving C82, C78 and the diode D24 and C77, C79 and the diode D23, respectively. The diodes are of Schotky type in order to have a reduced voltage falling and the condensers have the values existing in the application diagram recommended by the IR producer.

The two integrated circuits IR2110 of driver type for MOSFET transistors have an inhibition pin (SHDN → Shut Down). This pin allows the forced blocking of the MOSFET transistors in the bridge by bringing to the logic stage "1" the pin PA7 of the microcontroller. This signal of inhibition was programmed to be active during the reset stage of the microcontroller (when the pin is in the high impedance stage and the resistor integrated by the pull-up is activated). After reset, the pin becomes outlet with the logic stage "1" and shortly before the inverter start-up, this pin is brought in the logic stage "0", by removing the inhibition of the control signals for the power transistors. By this mechanism it is ensured a rigorous checking of the controls given towards the transistors bridge, thus avoiding the entering into parasite conduction.

The four transistors which form the bridge operate in switching condition being optimized for minimum losses in conduction and maximum switching speed.

The drivers outlets of transistors control the gride junctions – source achieved by the means of a contact made through tinning which is good during the service of separating the defect part in the scheme. Further more, the control signal is limited by a resistance (R157, 158, 163 and 164 having the value of 33 Ω), which together with the inner capacity of the controlled junction (of 1 nF order) create a timing circuit with time constancy of 33 ns, thus being avoided the intense requests of dI/dT type during the sudden entering into conduction of the transistor, without a significant influence on the switching time and hence the losses during the switching of the transistor. On the other side, the diode (D 25, 26, 27 and 28) which is in parallel installed to this resistor in the transistor grid has the task of enhancing the transistor outgoing from conduction, by bridging the resistor, because the MOSFET transistors outgoing from conduction is naturally slowly done.

Another task of the resistor serried with the controlled transistor grid is that of limiting the voltage coming out from the driver to a value which cannot destroy the outlet circuit of the driver. The used drivers allow some peak outlet currents up to 2 A (during periods of up to 10 μs) and by using the resistors having the value of 33 Ω, the maximum voltage was limited to 12V/33 Ω = 0.36 A (as the junction grid – source of MOSFET transistors acts like a condenser, initially the current has the value of a short circuit).

4. The inverter

The inverter itself is made-up of the 4 MOSFET power transistors, the transformer which is both the charge and an adaptor of the outlet power and the non-polarized condenser C83. This transformer has the additional task of limiting the short circuit current (when the electrodes put the secondary in short-circuit) as well as that of galvanic insulation between the power stage of the device and the grounding installation.

The chosen transistors are also oversized [8] (Vdss = 100V and Id = 16A), in order to be able to answer some more intense requests in case the outlet of the transformer is short-circuited as well as to increase the safe operation of the device. Additionally, this over-sizing has a neglecting cost. From the catalogue page of the transistor IRF530 [9] it could be noticed the resistance in reduced conduction ($R_{DS(on)}$ = 0.16 Ω), this leading to a more reduced losses in conduction and hence a reduction of radiator dimensions (this way being recovered the costs of transistors over-sizing).

The inverter projection was done starting from the transformer, which, at its turn has the characteristics asked by the nature of the charge [3]. The transformer charge is of resistive type with the resistance value ranging between 0.1Ω - 100Ω. The current going through the resistance must have the maximum value of 0.25 A.

As the voltage in the secondary is set on arbitrary criteria, deviations of the real voltage at the transformer outlet compared to the calculated voltage will not influence the measurements accuracy because the device will simultaneously measure the voltage and current going through the resistance to be measured, the resistance being the same in case of the deviation of the estimated values calculated for the outlet voltage. It will also be chosen a much higher power of the transformer (practically a double one) because in the case of small transformers the output is low enough, the over-sizing doesn't ask for higher costs and in this way it could be avoided the necessity of making the connection in series with the primary of a more expensive condenser. The transformer will be wound with the primary near the secondary in order to have a strong falling down outlet characteristic [4]. The transforming ratio will be calculated taking into account the fact that the peak to peak voltage in the primary has a double value as compared to the supplying voltage of the inverter. The voltage falling in the transformer primary is diminished by the voltage fallings in the two transistors that are conducting at a given moment.

This calculation is an iterative one. It is estimated a current in the primary, neglecting the voltage fallings in transistors and bridge by calculating an initial transforming ratio:

$$I\ estimated_{primary} = \left(\frac{U_{secondary}}{\eta * U_{primary}} \right) * I_{secondary} \quad (1)$$

$$I\ estimated_{primary} = \left(\frac{25}{0{,}9 * 12} \right) * 0{,}25 = 0{,}58\ A \quad (2)$$

This current is used for the first calculations of the voltage fallings:

$$U\ peak_{primary} = U_{inverter} - U_{RP1} - 2 * U_{DS} \quad (3)$$

$$U\ peak_{primary} = 12 - 0{,}1\Omega * 0{,}5A - 2 * 0{,}16\Omega * 0{,}58A = 11{,}75\ V \quad (4)$$

The value of the output used for calculations is estimated and based on the catalogue data of some transformers having similar powers. It could be seen the much reduced importance of the voltage fallings in transistors and bridge. The voltage that will be applied to the primary is rectangular but the current which will be set will have a sinusoidal shape.

The transforming ratio will be then:

$$K = \left(\frac{I_{secondary}}{I_{primary}} \right) = \frac{0{,}25}{0{,}58} = 0{,}43 \quad (5)$$

The dissipated powers will be then:

$$P_{RP1} = I_{primary} * RP1 = 0{,}58 * 0{,}1\Omega = 0{,}058\ W \quad (6)$$

it was used a resistor of a nominal power of 1 W in order to resist in case of overcharge and defects.

$$P_{conductionMOSFET} = I_{primary} * R_{DS} = 0{,}58A * 0{,}16\Omega = 0{,}093\ W \quad (7)$$

$$P_{switching} = \left(U * \frac{I}{2}\right) * (1 - \Delta) = 12 * 0{,}58 * 0{,}04 = 0{,}28\,W \quad (8)$$

for transistors, to the dissipated power in conduction it was also added the power dissipated on switching. Taking into consideration a dead time of 4 %, it results a total power of 0.37W.

$$P_{totalMOSFET} = P_{conductionMOSFET} + P_{switching} \quad (9)$$

(as regards the calculations above shown, the dead time was not always taken into account a more unfavorable condition being thus considered and the deviation reduced).

Conclusions

The accurate selection and usage of the measurement methods and devices for dispersion resistance measurement imply the knowledge of the measurement conditions, choosing the optimum method, knowledge of earth ground forms and dimensions, as well as the possibilities offered by the device. The article presents the proper criteria for the selection of a monophase converter as a part of a tester device for measuring the dispersion resistance of an earth ground.

R E F E R E N C E S

1. *Fodor, D., Ionescu, F., Floricău, D.* Convertoare statice de putere speciale. Editura Printech, Bucureşti - 1997
2. *Cepişcă, C., Seriţan, G.C.* Măsurări electrice şi sisteme de măsură, Vol. 1. Editura Politehnica-Press, Bucureşti – 2004
3. *Cepişcă, C.* Mecatronica - Convertoare electromagnetice. Editura CONPHYS, Rm. Vâlcea - 2002
4. *Popescu, M.O., Manias, S.N.* Convertoare statice cu comutaţie de la reţea - alegere şi dimensionare. Editura ICPE - 1995
5.ATmega 128, ATmega 128 L, 8-bit AVR, Microcontroller with 128 K Bytes In-System Programmable Flash". Rev.2467K – AVR – 04/04
6. Algorithm Builder for AVR". ATMEL Applications Journal. www.atmel.com
7. Philips Semiconductors – 74HCT08 http://www.datasheetcatalog.comdatasheets_pdf/7/H/C/74HCT08.sthml
8. International Rectifier – IR 2110, PD-9.352 http://www.irf.com/product-info/datasheets/data/ir2110.pdf
9. International Rectifier – IRFD 024, PD-9.699B, http://www.irf.com/product-info/datasheets/data/irfd024.pdf
10. International rectifier – IRF 530, PD-9.3070 http://www.irf.com/product-info/datasheets/data/irf530.pdf