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RELIABILITY OF LOGIC INPUTS IN MICROPROCESSOR BASED PROTECTIVE DEVICES

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Problems with the reliability of microprocessor-based protective devices (MPD) have arisen in connection with the worldwide moving away from electromechanical and static protective relays to MPDs. The common misconception that MPDs have reliability considerably exceeding that of electromechanical and static protective relays is, in actual fact, no more than a myth. This paper is continuation of author's papers on this theme and it is describes a problem with reliability of the MPD's logic inputs.

Key words: reliability, digital protective relays, logical inputs, ceramic capacitors, optocouplers.

Problems with the reliability of microprocessor-based protective devices (MPD) have arisen in connection with the worldwide moving away from electromechanical and static protective relays to MPDs. As shown in [1, 2], the common misconception that MPDs have reliability considerably exceeding that of electromechanical and static protective relays is, in actual fact, no more than a myth fostered through the years by the advertising publications of MPD manufacturers. It is abundantly clear that such complex multipurpose structures as MPDs cannot, even theoretically, be free of problems, cannot be absolutely reliable, and cannot be devoid of failure statistics during 15–20 years of maintenance.

Previously we have discussed the problems connected with insufficient reliability of the output miniature electromagnetic relays of MPD intended for the direct tripping of high-voltage circuit-breakers [3]. This paper addresses a problem with the reliability of logic inputs in the MPD using the RE*316 series (REL, RET, REC, etc.) as an example. The RE*316 series has been widely used over the past 10–15 years.

Digital (logic) inputs in the MPD of these types consist of a set of completely identical elements functionally representing the logical function "Prohibition", Fig. 1.

The direct input and prohibited input of the each of these elements are connected respectively to input circuit of the MPD and to the CPU through optocouplers: Opt1 and Opt2. The starting signal from optocoupler Opt2 logically repeats the presence or absence of an input voltage. The functioning of this circuit can be blocked (prohibited) through a CPU internal logic. Thus the blocking signal from the CPU through matching electronic circuits acts on the prohibiting input (an input of optocoupler Opt1).

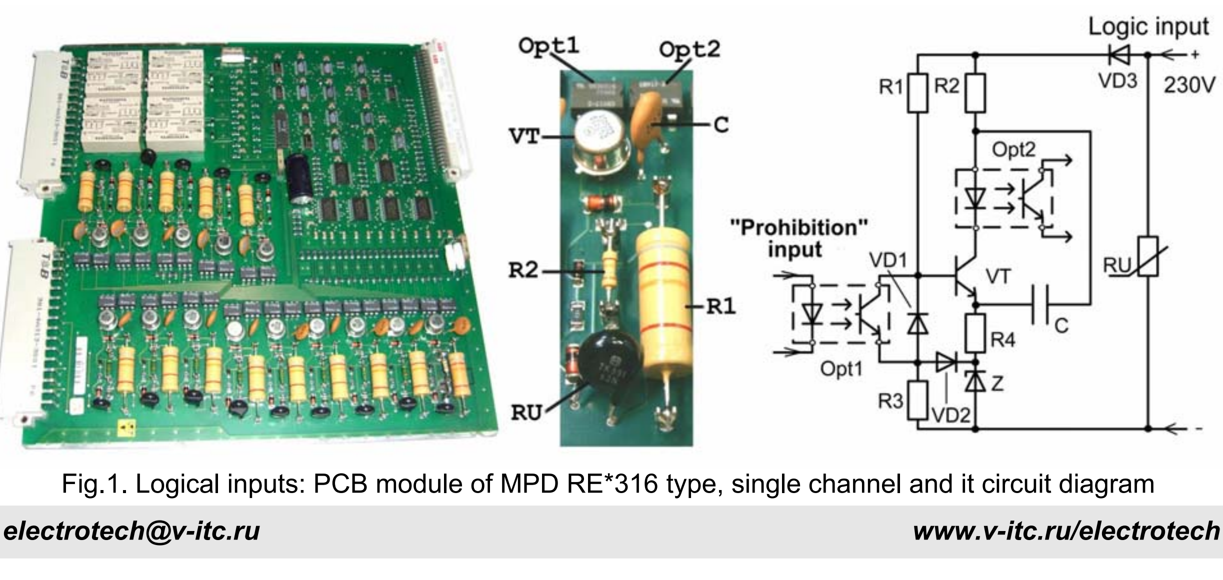

Fig.1. Logical inputs: PCB module of MPD RE*316 type, single channel and it circuit diagram

The problem of this type of logic cell consists in the high level of an input signal (220–250 V DC) which needs to be attenuated up to a level of 1.5–2 V at which point the Opt2 optocoupler operates. The total current consumed by the input circuit is split approximately fifty-fifty between resistors R1 and R2; therefore both of them, basically, should be equal. However there is no place on a printed-circuit-board (PCB) for two large resistors such as R1 and R2 (including the distance between them, necessary for cooling). Therefore to dissipate the superfluous power of this element the MPD designers have assigned to a transistor, VT, working not in a switching mode, as is usual in such circuit, but in amplification. It is natural that resistor for R2 is therefore selected as a low power and small size. In practice, such aspirations to a miniaturization lead to serious problems: resistor R2 often completely burns out, leading sometimes to burn-out of sections of the PCB and even those components in its vicinity.

The first problem of this arrangement centers on the transistor, VT. In operating in amplification mode and continually dissipating the superfluous power it heats up to temperatures 70–80 ºC. Unlike the usual resistor the resistance of which slightly increases with increase of temperature, resistance of the n-p-n transition of the transistor with the increase of temperature essentially decreases owing to the drift of the operating point (referred to as the “quiescent point”) on the characteristic and increases in the coefficient of amplification. This leads to an increase of the collector current, that is, the current through resistor R2. With the simultaneous heating of many resistors R1 and transistors VT combinations in a ten-fifteen input circuits, the temperature inside of the input section (in the case that the MPD is divided into sections by internal diaphragms) can essentially increase. This leads to a further drift of a quiescent point of the transistor, further increasing its collector current and the overheating of resistor R1. Thus diode VD, intended for stabilizing the quiescent point of the transistor, appears ineffective because its temperature and the temperature of the transistor discriminate on 50–60 grades. Thus, the aspiration of the manufacturer to reduce MPD sizes, using a transistor instead of a powerful resistor for superfluous power dissipation, has led to a decrease of MPD reliability. The problem of insufficient reliability of this circuit connected with aspirations for miniaturization is not restricted only to this problem.

The second problem is the miniature disk ceramic capacitor, C, with a capacitance of 2.2 nF. Ceramic capacitors are considered as one of the most resistant to the affects of electric operational loads and are stable over long duration.

However, in ceramic capacitors with badly isolated gaps between electrodes there is the possibility of a decrease in the insulation resistance and even an electric breakdown due to migration of metal ions of facings (especially silver) on the butt end of the capacitor, especially in conditions of a wet tropical climate. At an input voltage of the MPD below 100 V capacitors such as these give no indication of the defects and at "procall", a usual tester, show full serviceability. But already at voltages of 180–230 V an outflow current through the capacitor increases (Fig. 2) such that normal operation of the transistor and optocoupler become impossible. Moreover, there is a long range influence of an input voltage of 220–230 V because of the increased outflow current through this capacitor, the power dissipation on resistor R2 increases and it simply burns out, Fig. 2.

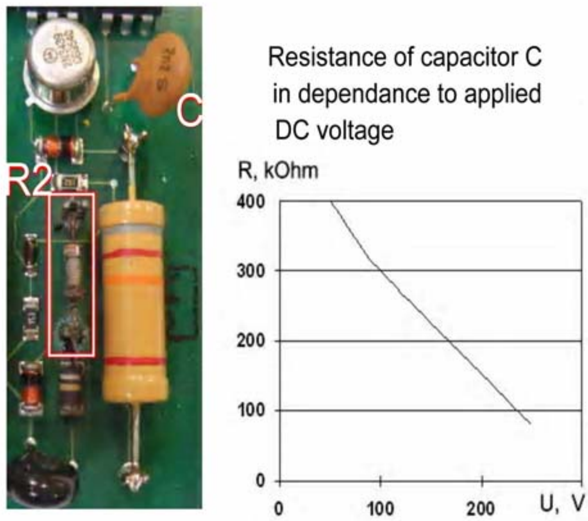

Fig. 2. Reason for R2 burning is increasing leakage current trough capacitor C

The third problem is the internal cutoff failures appearing in the course of time in the powerful R1 resistors, Fig. 1. This phenomenon presumably originates owing to a contact fault between metal cups at end faces of the resistor and a resistive layer on a surface of the ceramic cylinder because of its shelling in cheap resistors used in the MPD.

The fourth problem is mass failures of the Opt2 optocouplers. For example, once we had to replace 7 optocoupler units of type CNY17-2 on only single PCB of logic inputs unit of relay REC316!

Optocouplers of this type have following parameters:

– Average forward current (a current through light emitting element - I_F) - 60 мA;

– Max. forward current (I_F) - 100 мA;

– Rated collector current of the output transistor – 50 мA;

– The max. collector current - 150 мA;

It appears that these optocouplers operate in the MPD in a mode that is far from nominal; rather they operate with very small input (forward) and output (collector) currents, practically on the bottom boundary line of these currents.

Table 1

Voltage drop (V) on output transistors (collector-emitter) of CNY17-2 optocouplers at collector current 0.5 mA and input (forward) currents 2 and 2.5 mA

I_F = 2.0 мA	I_F = 2.5 мA
Optocouplers, extracted from non working inputs of REC316	
1.471	0.992
1.027	0.344
0.574	0.188
1.452	0.967
1.315	0.769
0.734	0.201
0.634	0.178
New optocouplers same types, but other manufacturer	
0.134	0.120
0.143	0.127
0.132	0.119
0.144	0.127
0.139	0.123
0.139	0.124
0.134	0.120
0.143	0.125

Besides, as a result of research carried out by us, it has been found that optocouplers, de-soldered from not working inputs of the MPD, actually are not damaged. The difference between "working" and "not working" in MPD optocouplers has appeared only in their sensitivity to very small, lowest limit forward currents (I_F), Table 1.
Judging by the data in Table 1, the collector-emitter voltage drops of optocouplers from non-operating input circuits of the MPD considerably exceed typical values, Fig. 3 (0.18 V at forward current I_{IF} = 2 мA and collector current 0.5 mA), while the same values for new optocouplers of other manufacturers are below the typical.

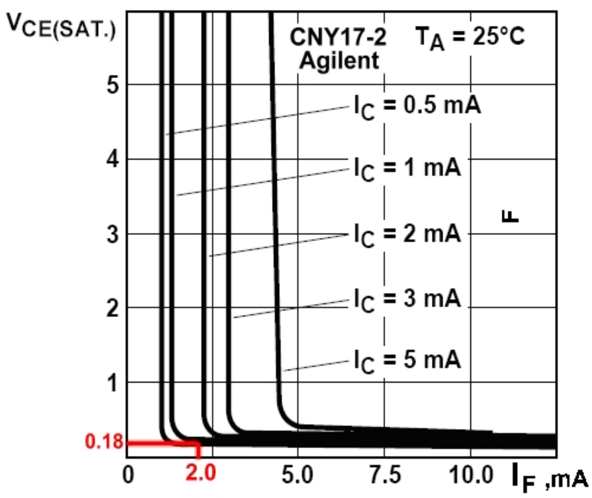

Fig. 3. Voltage drop on the output transistor $V_{CE(SAT)}$ in dependence from input current of the optocoupler (I_F) for different collector current values

Unfortunately, many optocoupler manufacturers (CNY17-2 type optocouplers are manufactured by the companies: Agilent, Toshiba, QT Optoelectronics, Fairchild, Vishay, Liteon, Everlight, Isocom, Opto Inc., etc.) simply do not present these major characteristics of photocouplers in their datasheets; therefore any claims regarding them are impossible to present. The claim can be made to designers of the electronic circuits (in our case to designers of RE*316 from company ABB) that the operation mode of the equipment (MPD) is on the boundary line of the characteristic of electronic components (optocouplers); therefore, the usual slightest technological dispersions in parameters of these electronic components lead to full loss of the working capability of such crucial equipment as MPD.

The fifth problem is the manufacturer selecting too wide a range of operating voltages (82–312 V) for logic inputs. This wide range of operating voltages is the source of two problems: low efficiency of overvoltage protection by means of the varistor and a problem of false operations.

The first problem is caused by that for maintaining the working capability at a voltage of 312 V (which, needless to say, is absolutely not realistic in the practical condition with DC network based on 220V batteries) the clamping voltage of the varistor RU (7K391 type in our case), Fig. 1, should be selected as not less than 650 V (because of the actual characteristics of varistors for a working voltage of 312 VDC). This means that all electronic circuit components will be exposed to the overvoltage reaching up to 650 V (for comparison: the maximum collector-emitter voltage allowed for transistor VT 2N3439 type does not exceed 350V).

The second of these two problems is caused by too low a value of the bottom boundary line of an operating voltage range: 82 V. When one of poles (positive or negative) in the DC power network, in which MPD is connected, is grounded to earth, there is a voltage pulse equivalent to half the value of the rated battery voltage (that is, nearby 110) caused by the discharge of the capacity of wires of a DC network that is produced. As shown in [4], at such conditions the spontaneous activation of logic inputs of MPD occurs if an operating threshold of logic inputs is below half of the mains voltage of a DC network (that is 110).

In just a fragment of the MPD circuit containing only ten electronic components, we have shown how many the problems connected with MPD reliability can originate in actual conditions of operation. It confirms the thesis put forward by us that modern MPDs are not the model of perfection and reliability at all as advertising catalogues try to present it. Further they represent a most complicated and not always reliable enough method to be employed. These problems should not be ignored as it is done today, rather they should be widely discussed.

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НАДЕЖНОСТЬ ЛОГИЧЕСКИХ ВХОДОВ МИКРОПРОЦЕССОРНЫХ УСТРОЙСТВ РЕЛЕЙНОЙ ЗАЩИТЫ

В.И. Гуревич

Проблемы надежности микропроцессорных устройств релейной защиты (МУРЗ) являются весьма актуальными в связи с повсеместным переходом от электромеханических и статических реле защиты к микропроцессорным. Широко распространенное мнение о якобы очень высокой надежности МУРЗ, на порядки превышающей надежность электромеханических и статических реле защиты, на поверку оказывается не более чем распространенным мифом. Данная статья является продолжением серии статей автора на эту тему и посвящена проблеме надежности входных логических входов МУРЗ.

Ключевые слова: надежность, микропроцессорные реле защиты, логические входы, керамические конденсаторы, оптроны.

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