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THE SOLUTIONS FOR THE PROBLEM OF OUTPUT RELAYS IN MICROPROCESSOR–BASED RELAY PROTECTIVE DEVICES

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The parameters of the miniature electromechanical relays widely used as output elements of microprocessor-based protective devices are inappropriate for the actual operating conditions, i.e., the switching of an inductive load (trip coils of the circuit breakers or coils of the auxiliary relays) at 220VDC. In the article offers alternative solution for the problem.

Keywords: switching capacity, electrical endurance, electrical contacts, electromechanical relays, solid-state relays, microprocessor-based devices, relay protection.

The switching ability and electrical life of contacts in electromechanical relays at voltages above 30V largely depends on the kind of switching voltage and the kind of load. It is known that in DC switching at voltages above 30V the parameters are much more lower than those for AC switching, and for inductive loads these parameters are even lower, Fig. 1. And, because of contact bouncing during make process, the DC switching ability of contacts at make does not exceed the switching ability at a break [1].

In the previous research that we have conducted [2] it has been shown that the parameters of the miniature electromechanical relays used as output elements of microprocessor-based protective devices (MPD) are inappropriate for the actual operating conditions, i.e., the switching of an inductive load (trip coils of the circuit breakers or coils of the auxiliary relays) at 220VDC. The contact systems of these relays simply are not intended for switching loads such as this owing to the fact that the contacts rapidly wear out due to electric erosion, sharply reducing the functioning reliability of the MPD, Fig. 1.

The wide usage of such non-suitable electromechanical relays in practically all types of MPD, and also in the microprocessor-based devices providing communication between the protective relays and in other analogous devices which are available in the market has come about due to the aspiration of manufacturers to reduce the mass and the dimensions of these devices. In a large number of such output relays sometimes reaching up to several tens, the sizes of the MPD needs to be doubled – even three times if to use a big size outpur relays with the suitable parameters. It is clear that MPD manufacturers cannot adopt such a step as the MPD sizes are one of the important advertising criteria in the struggle for the potential buyer. But who pays for this? The MPD user pays. The question arises if it is possible to solve the problem? Yes, the author answers and offers alternatives for solving the problem.

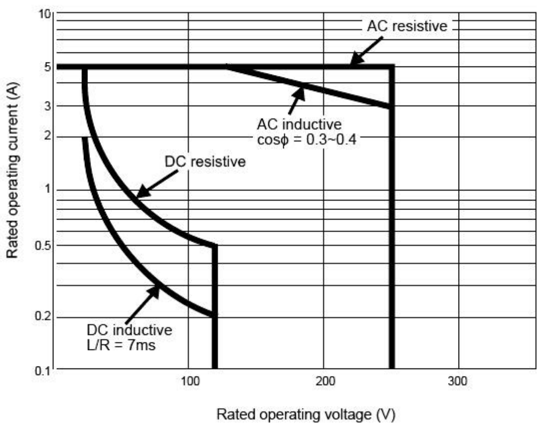

Fig.1. Typical switching ability for contacts of the miniature electromagnetic relays applied in MPD at various kinds of loads

The general solution offered by us consists of rejecting the installation of output electromechanical relays inside the MPD. Such relays should not be part MPD at all, and should be chosen and received by a user (or be delivered complete with the MPD) separately depending on the concrete conditions. These conditions can vary considerably placing different demands on the output relays, that is, which contacts are to be used in the circuits. For example, for switching low-voltage low-current signals (so-called "dry" circuits) in electronic circuits it is necessary to use a relay with bifurcated gold or gilt contacts, whereas for switching current of a few amperes at 220VAC silver based alloys contacts are necessary. For switching inductive loads at 220VDC, in general, it was observed that special relays are necessary; practical implementation for them can be effected in two principal ways:

1. Installing in the MPD a special solid-state element intended for switching coils of external electromechanical relays;
2. Making each output channel in the form of a voltage source for power, sufficient for operating an external electromagnetic relays or semiconductor relays.

We shall examine each of these ways in the course of this article.

Today in the market of semiconductor devices there is a wide assortment of miniature high-voltage MOSFET and IGBT transistors for voltages 1000 – 1500V and currents 5 - 50A, and also matching drivers with optical decoupling for them. For instance it is possible to specify transistors of types: IXYS05N100, STFV4N150, STP4N150, STP5NB100, STP5NK100Z, etc., associated with the TO-220 case type, and also transistors STPW4N150, STW11NK100Z, APT15GN120BDQ1, APT35GN120B, IRG4PH20K, IXDH20N120, IXGH25N160, etc., associated with the TO-247 case type [3]. Installed on the MPD printed-circuit-board without a heat sink and supplied with the overvoltage protection element (varistors of sufficient power) these transistors are capable of making and breaking coils of the external auxiliary relays and small contactors directly with currents of up to 1A at the rated voltage of 220VDC. Recently, the well known firm of CP Clare has mastered mass production of high-voltage MOSFET-transistors in the case ISOPLUS264 type with built-in drivers having optical decoupling Fig. 2. This device can be controlled directly by current of 10 mA from the internal electronic circuits of the MPD and carry out switching the coils of external electromagnetic relays with currents of up to 1A at the rated voltage of 220VDC.

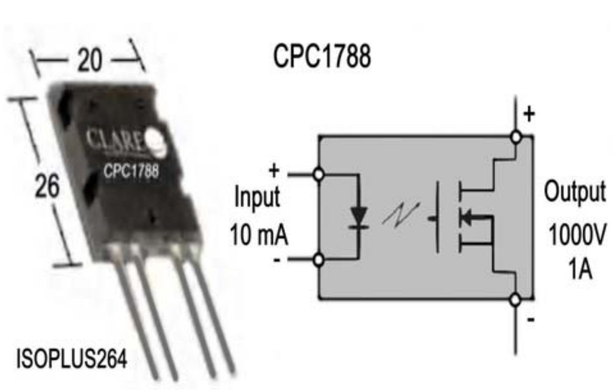

Fig. 2. High-voltage MOSFET transistor CPC1788 type in an ISOPLUS264 case with a built-in optical decoupling driver made by the CP Clare firm

In this way MPD developers have pretty much exhausted the first method, mentioned above, for solving the problem.

We now turn our attention to the second way for solving the problem, and we will see that there are many more possible alternatives.

First, there are some alternatives in using the CPC1788 type component presented above as a structural element of the external module, for example, for switching-on the trip coil of the circuit breaker, Fig. 3, or switching the auxiliary electromagnetic relay, Fig. 4. CPC1788 has considerable sensitivity that allows connecting directly in the circuit of the existing MPD stage without any changes of operating modes, instead of the coils of miniature electromechanical relays used today.

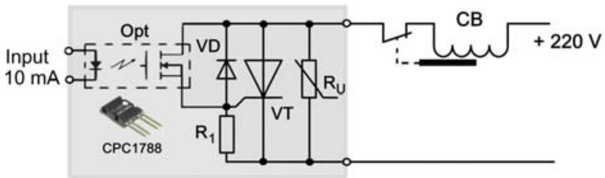

Fig. 3. The circuit diagram of the external module on the basis of the CPC1788 element, connected to the MPD output for switching the trip coil of the circuit breaker (CB) with a mains supply of 220VDC:
VT - thyristor; R_U - varistor

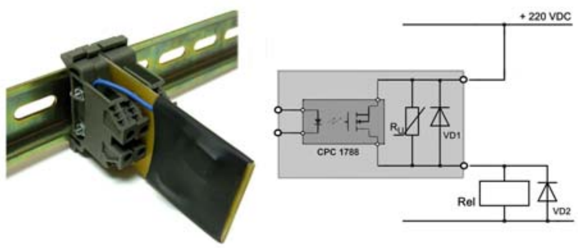

Fig. 4. The external view and circuit diagram of the external module of an elementary construction based on the CPC1788 element connected to the MPD output for switching auxiliary relays

In the market there are also other types of solid state relays suitable for use at 220VDC, for example, the SSC1000-25, with a maximum voltage of 1000V and a maximum current 25A, Fig. 5.

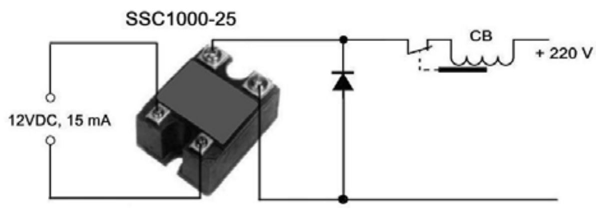

Fig. 5. The connection diagram of the powerful solid state relay SSC1000-25 type for switching the CB trip coil

There are, however, a couple of characteristics of this relay that must be taken into account. First, it has a minimum switching current (20 мА), and, secondly, a minimum control voltage (12 V). The first characteristic means that the device can only be used in applications for loads that are powerful enough, such as trip coils of the circuit breakers, powerful contactors, etc. The second characteristic engenders changes that must be made in the internal electronic circuit MPD, since ordinarily the coils of the built-in output relays operated by voltages of 5V. In order to use SSC1000-25 as an external output relay the development engineers of a new MPD have to provide an increase in the level of the operating voltage, up to 12V.

Less powerful solid state switching devices intended for a current no more than 1 - 1.5A can be used for controlling low-power auxiliary electromechanical relays widely used in relay protective systems, Fig. 6.

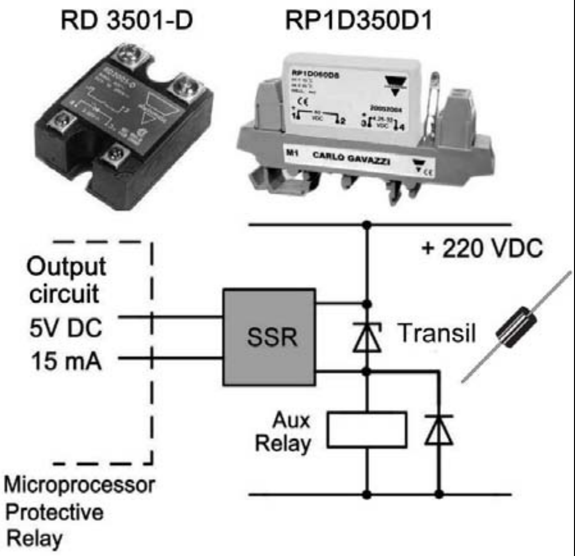

Fig. 6. External output elements of the MPD based on low-power solid state relays for switching coils of auxiliary electromechanical relays at 220VDC (Transil® - the semi-conductor element intended for overvoltage protection of solid state relay SSR)

These solid state relays have no lower limits of switching currents and can be operated by voltages of 5V, this frees the development engineers from necessity of changing internal output circuits of the MPD.

On the other hand, if a new MPD is developed to increase the power of a control signal up to values of 12V and 100mA, here is an opportunity of using external powerful enough electromagnetic relays without any auxiliary solid state elements.

It is necessary to note that many loads used on installations of electric power industry in a 220VDC network have inductive character. This imposes special requirements on auxiliary electromechanical relays the contacts of which should be capable to switching such loads. The analysis of specifications of the most widely used types of electromagnetic relays shows that the majority of them are not intended for switching inductive loads at 220VDC. For this purpose relays with special designs providing a double make of the load are used (Fig. 7) or those containing a permanent magnet (blow-out magnet) near the contacts intended for repulsing an electric arc from the contact gap, Fig 8.

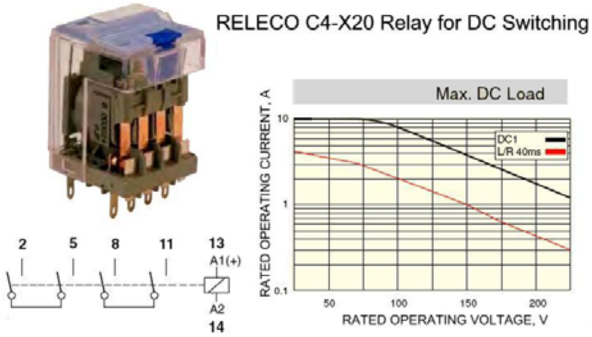

Fig. 7. The C4-X20 (RELECO) relay type (with the cover partially removed) with two double make contacts and its switching ability on a DC

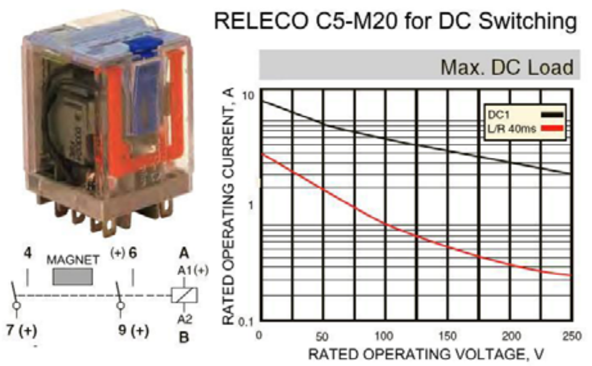

Fig. 8. The C5-M20 (RELECO) relay type with two make contacts and a blow-out magnet and the switching ability of its contacts for an inductive load

On the market there are also smaller sized multi-contact relays with blow-out magnets, even intended for mounting on the printed circuit board, Fig. 9.

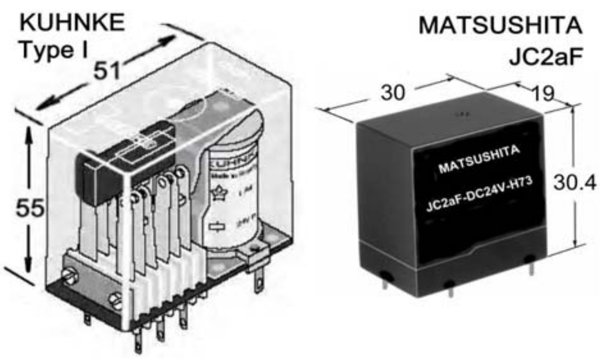

Fig. 9. Small-sized relays with blow-out magnets

Relays with triple make contacts are available as well, Fig. 10, enabling operating a sufficiently powerful inductive load at 220VDC, for example, trip coils of circuit breakers, especially the old types.

There are also good prospects is in the use of reed switch based relays, especially with the new small-sized, high power reed switches made by the Yaskawa company, under the BESTACT® trade mark, Fig. 11. Reed switches of this type have double make contacts (basic and arc-quenching), with sequence switching allowing making and breaking high inductive loads (L/R = 100 ms) with a current of 0.2A and a voltage of 220VDC. Control coils of relays based on this reed switch have the parameters analogous to parameters observed above for the electromechanical relays.

Fig. 10. The RMEA-FT-1 (RELEQUICK S. A.) relay type with one triple make contact, capable of switching currents up to 3A in an inductive load at 220VDC

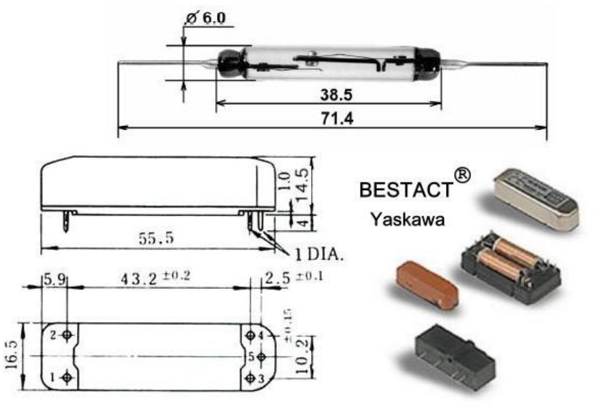

Fig. 11. Powerful R14U (R15U) reed switch type with double makes contact and the relays as its basis, manufactured by Yaskawa

When implementing modernization of MPDs intended for external relay connections based on changing their output channels in the form of 5V or 12V sources as detailed above, it is necessary to take into account necessity of protecting the MPD internal circuits against overloads and faults due to incorrect connections of these outputs. One way of constructing such outputs is presented in Fig. 12.

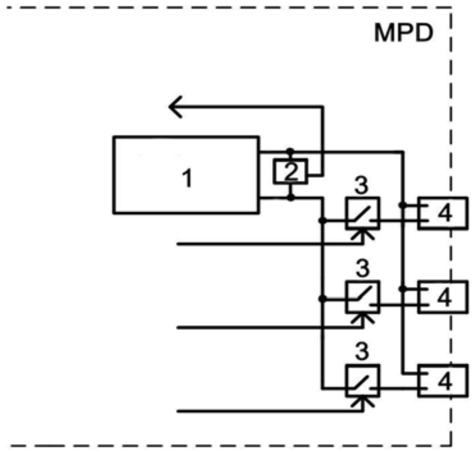

Fig. 12. Alternative construction of MPD outputs made in the form of sources of an operating voltage
1 - the separate power supply 5V or 12V with current limiting and protection against short circuits; 2 - the voltage transducer for monitoring the serviceability of the power supply; 3 - low-voltage optocouplers; 4 - output connectors for connecting of external relays

In our opinion, the ideal solution is using built-in powerful high-voltage optocouplers (like CPC1788) in the new MPD types, instead of the internal miniature electromechanical relays used today, for control of any type of external auxiliary relays chosen by a user. Another solution is delivery by the manufacturer of a separate module with the output relays of various types (upon request of a user) together with MPD provided with a special connector for coupling with the MPD. Destination and redestination (address modification) of these or other MPD outputs for using these or other kinds of output relays can be effected through software.

The designs observed above are intended for use in newly developed MPDs. The question arises what to do with the thousand devices already in use and those continuing to be released to the market? It is obvious that modification of such devices can be carried out only with external modules, without making any changes in the internal MPD circuits. One possibility of such modules is shown in Fig. 13. Any of the components discussed above can be used in it. As for control circuits of solid state modules at voltages as low as 12V-36V the resistor R (in the circuit diagram) is required for dissipation main part of the network voltage 220V and must be included.

The well known company Schweitzer Engineering Laboratories, Inc has developed and manufactures special active arc-quenching elements connected in parallel to these contacts, Fig. 14. These are specifically for switching the inductive load by output contacts of existing MPDs which are currently available on the market.

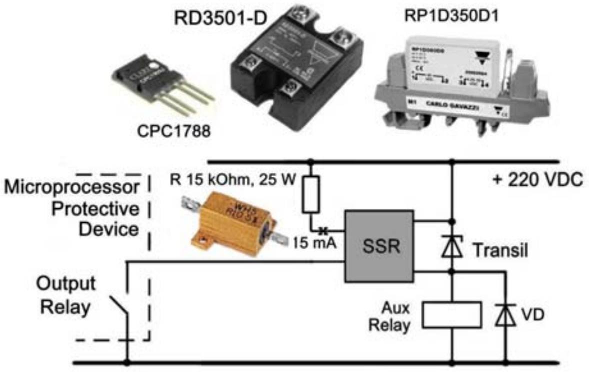

Fig. 13. Diagram of the connection of the external solid state module (SSR) to MPD output for switching an inductive load (a winding of the auxiliary relay) at 220VDC

Fig. 14. Active arc-quenching SEL-9501 and SEL-9502 element types (Schweitzer Engineering Laboratories, Inc)

In the case where as the load the coil of small low-power auxiliary relay is used, this can be simply replaced by a relay of the same type, but with coils with a voltage 12 – 48V connected in series with damping resistors of matching power. In addition, the coil of the relay should be shunted with a diode, connected in the opposite direction (as in Fig. 13).

Use of the coil of the auxiliary relay on smaller voltages (that is, consisting of a considerably smaller number of coils connected in series with the resistor leads essentially decreases the time constant of the coil $\tau = L/R$ and makes an easy switching process. As a matter of fact, the same principle is used also in some types of serial production relays, for example, in the small auxiliary relay of ST-REL7-HG220/4X21 type (with the contacts that are not intended for switching an inductive load at 220VDC), manufactured by Phoenix Contact. The relay contains the small printed-circuit-board with installed diodes, resistors, LED inside of its case, Fig. 15. The input circuit of the relay has a very high resistance and can be switched absolutely freely by contacts of output miniature relays of any type at a voltage 220VDC.

Fig. 15. ST-REL7-HG220/4X21 (Phoenix Contact) auxiliary relay type with the additional electronic components installed on the PCB inside of the relay case

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