Protecting relay protection systems

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Relay protection is designed to protect electrical equipment during emergency situations, but it appears that relay protection itself needs to be protected. How and from what must we protect the relay protection?

One of the major problems is cyber-security of digital protective relay (DPR)-based relay protection in the light of the sharp increase in DPR-based relay protection susceptibility to "intended electromagnetic destructive impact" (IEDI). These problems together with a mass of smaller technical problems specific to DPR result in the deterioration of the reliability of DPR-based relay protection compared to electromechanical devices.

The arguments in favour of DPR usually include outstanding protection characteristics, informational capacity, convenience during setup and adjustment, and broad functionality. Of course, DPR has significant and unquestionable advantages both in terms of its features and functionality, but would these advantages mitigate the above mentioned problems and disadvantages of DPR? Do those wonderful features of DPR (unavailable to electromechanical devices) make them more resistant to IEDI? It appears that they don't and, moreover, these very features reduce the general reliability of relay protection [1].

Problem with the reliability of digital protective relays

It is shown in [2] that unlike other types of electronic equipment, the reliability of relay protection is far more important than the protection characteristics and functionality. Sometimes one hears that if one device fails another will definitely be triggered and thus the risk of reliability when converting from electromechanical devices to DPR is not very great. However, it seems that people do not understand that the malfunction of a protective relay is not only its non-actuation in the emergency mode, but also unnecessary tripping under normal conditions which can result in a situation which would be similar in terms to cascading failures or the collapse of the power system. In at least 25% of cases, the reason for large system collapses in the world were failures of the relay protection [3]. In over 50% of transition to emergency modes leading to large system collapses, guilt also falls on the protective relays [3]. Protection relays are responsible for practically all power system failures.

How to solve the problem

What we should do is to combine the best features of DPR with the best features of electromechanical devices. Is it possible to create a hybrid like this? The idea of a hybrid relay protection, which included the interference resistance of electromechanical relays and the wonderful features and broad functionality of DPR, was first discussed by the author 17 years ago [4], when the problems of DPR had just started to show up. In that article it was suggested that a reed relay be used as a starting unit (SU) to actuate the DPR. The author's experience in the area of development and implementation of reed switches and reed relays (including aerospace and military equipment) showed that it is possible to create a broad spectrum of devices using reed relays with strengthened insulation, which would possess wonderful characteristics [5] and could be successfully used as a SU for DPR. An instantaneous reed relay can be used as a SU of this kind [6]. This SU cannot be actuated by a cyber attack; it is far more resistant to IEDI compared to a DPR. If the sensitive inputs of DPR are shunted by normally-closed reed switches of a SU, high-voltage impulses can be prevented from entering the sensitive inputs of the DPR. The connection of normally open reed switches of such SUs in series with a DPR's output relay terminals (its trip output) will prevent unauthorised triggering of the protection relay by cyber interference from outside. Thus, if the SU is not actuated by current and/or voltage, the DPR will not be able to influence the operational mode of a power system even if it is actuated by a cyber attack or affected by IEDI.

Modern reed switches, pressurised with an inert gas or vacuumised, have excellent insulation, as well as good switching and timing characteristics; they do not require any maintenance, operate over a wide temperature range, are not affected by air humidity and represent a wonderful element base for many automation devices [5, 7]. For example, the Bestact R15U by Yaskawa Company, is a small gas-filled reed switch with a special doubled two-staged member (Fig. 1) is intended for switching currents up to 30 A at 240 V and can be successfully used for series connection with a trip contact of an internal DPR's output relay. Small high-voltage vacuum reed switches of different types, with normally closed contacts, Table 1, can be used in a SU to shunt a DPR's sensitive inputs.

Reed switches have a stable pick-up threshold which facilitates the

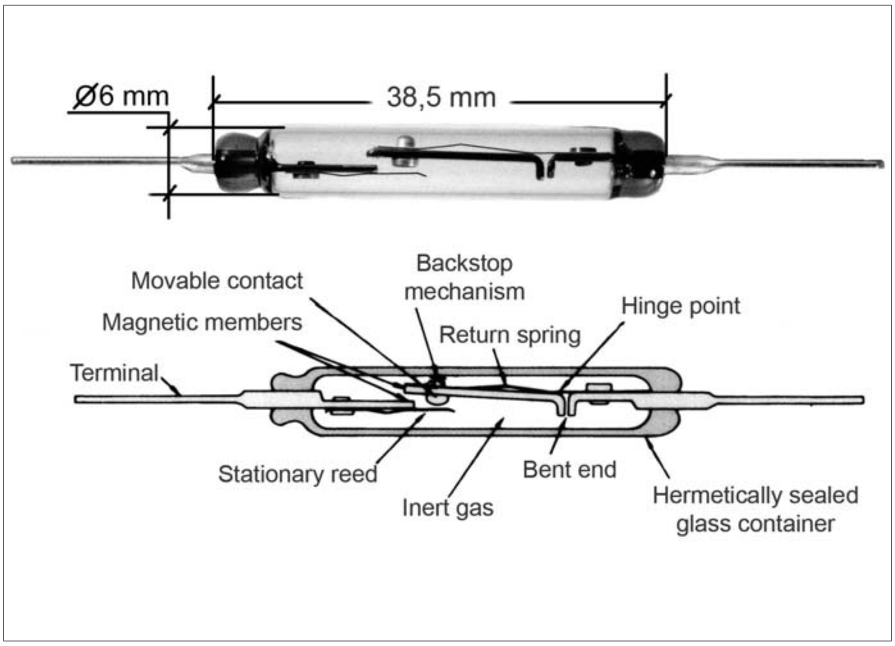

Fig. 1: A powerful gas-filled reed switch Bestact R15U by Yaskawa with a two-stage switching.

Parameter Type, manufacturer	GC 1917 Comus	HSR-830R Hermetic Switch, Inc.	HSR-834 Hermetic Switch, Inc.	HSR-V933W Hermetic Switch, Inc
Max. switching power, W	60	25	100	100
Max. switching voltage, V	400	250	500	500
Max. switching current, A	1	1	3	3
Dielectric strength, V	1000	1000	1000	1500
Operate time, ms	4,0	3,6	2,0	4,2
Release time, ms	0,15	4,2	1,0	3,7
Balloon dimensions, mm	D=5,6 L=36	D=5,3 L=32	D=5,3 L=34	D=5,3 L=33

Table 1: Main parameters of some types of changover reed switches.

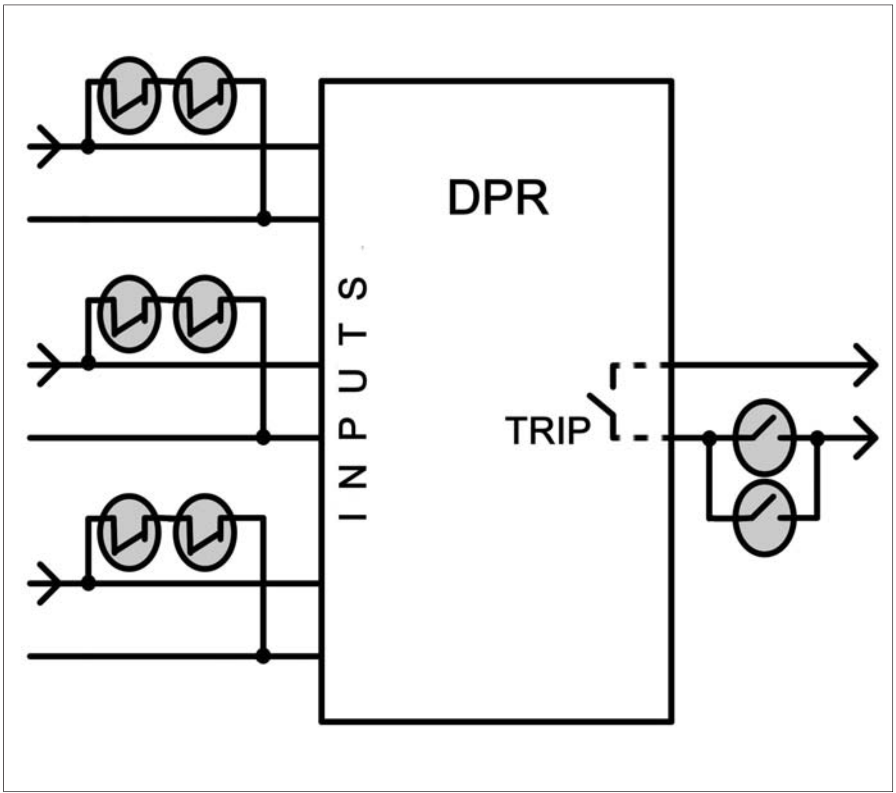

Fig. 2: Use of doubled reed switch pairs to increase reliability of electromechanical starting unit of DPR.

development of SUs based on an electromagnetic system without any moving parts. These can be rather simple threshold devices, which do not possess complex characteristics, since actuation of this type of device does not result in the actuation of a protection relay; it is just part of a relay protection system using all its functions and special features.

Obviously, according to the theory of reliability, connection of additional contacts (even those that are highly reliable) in series with the trip contacts of a DPR's output relay, or in parallel to its inputs, will result in a certain reduction of reliability of relay protection. How much? It is very difficult to answer this question today as there is inadequate information and a lack of experience of using such devices. However, should it be necessary, this reduction of reliability can be compensated by using two reed switches connected in series or parallel as an additional contacts, Fig. 2.

The probability of the unwanted operation of an electromechanical relay is much lower than the probability of non-operation, that is why they should be connected in parallel. This configuration will definitely increase the reliability of a trip output. For normally-closed contacts, which are used to shunt the inputs of a DPR, reliability can be increased by a series connection of these normally-closed contacts with each other, as can be seen in Fig. 2.

The proposed technical solutions are not directed at the protection of the DPR itself but towards the protection of an electrical power system against the unpredictable actions of DPRs arising from cyber-attack or IEDI influences. Two DPRs in parallel, protected by SUs as described, will protect especially crucial parts of a power system. The solutions proposed here represent just a general concept, which should be developed more thoroughly. However, they show the way for solving actual problems facing relay protection today. In our future works more concrete technical solutions and circuit diagrams for starting unit will be developed.

References

[1] V Gurevich: "Digital Protective Relays: Problems and Solutions", 2011.

[2] V Gurevich: "The Issues of Philosophy in Relay Protection". Energy Saving, Power Engineering, Energy Audit, 2013.

[3] NE Saratova: "The Analysis of Approaches to Research of Processes of System Collapses", System Researches in Power Engineering, 2007.

[4] V Gurevich: "About of a Some Ways for Solving Problem of Electromagnetic Compatibility of Protective Relaying", Industrial Power Engineering, 1996.

[5] V Gurevich: "Electronic Devices on Discrete Components for Industrial and Power Engineering", 2008.

[6] V Gurevich: "Hybrid Reed-Solid-State Devices are a New Generation of Protective Relays", 2007.

[7] V Gurevich: "Electric Relays: Principles and Applications", 2005.

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