International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 5, Issue 2, pp: (35-39), Month: April - June 2017, Available at: www.researchpublish.com

High-Voltage Link for Transmitting Discrete Commands in Relay Protection, Automation and Control Systems

Vladimir Gurevich

Ph.D., Central Electric Laboratory, Israel Electric Corp.

Abstract: **This article discusses the communication links used in power system relay protection to exchange discrete signals generated by the dry contacts. It explains why fiber-optic communication links, traditionally deemed as absolutely immune to external electromagnetic impacts, are not adequate for high-power electromagnetic impacts. In order to improve the reliability and immunity to high-power electromagnetic impacts, especially to HEMP, in this article, it is suggested to use reed switch based high-voltage insulating interfaces ("gerkotrons").**

Keywords: **High Altitude Electromagnetic Pulse (HEMP), Digital Protective Relays – DDR, Communication Link.**

1. INTRODUCTION

Relay protection and automation devices, providing protection, automation and control (PAC), exchange the high number of discrete commands (such as ON-OFF signals from the so called "dry contacts") transmitted between the separate PACs, as well as between such devices and actuators (such as disconnectors, circuit breakers, etc.) within the same substation or between the remote substations. Such commands are transmitted through the special communication channels.

Between the remote substations, the communication is made by the high-voltage overhead transmission lines (HVOTL), with two sets of high-voltage transceivers connected to each side of HVOTL through the special connecting devices (power-line carrier equipment). Often, the conductors designed for construction of new HVOTL contain inside optical fibers, covered with special steel shields, to be used for establishing communication channels between the remote substations. Encoded radio-relay links, and recently, Ethernet-based communications are also used for this purpose.

2. EXISTING COMMUNICATION LINKS

Generally, the communication between PACs and telecommunication equipment, as well as local communications between different devices of the same substation, is realized through the special communication links based on different operation principles, see Fig. 1.

For example, there are links designed to transform discrete input signals generated by dry contacts into coded optical signals to be transmitted through the optical fiber, and then decoded and restored, see Fig, 2, while other devices communicate over the local Ethernet network.

What is the advantage of a communication fiber-optic link over the common control multicore copper cable? First, it is the cost savings, as the fiber-optic cables are cheaper than the copper ones. Second, it is the improved immunity to the external electromagnetic noises compared to the ordinary control cables. The situation is seemingly clear and straightforward However; it is not all that simple.

Fig. 1. Communication links used for transmitting PACs discrete commands based on different operation principles.

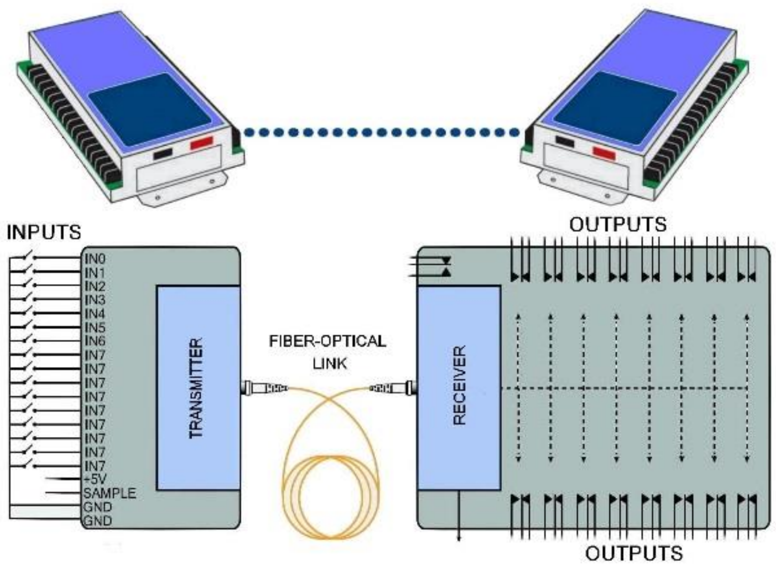

Fig. 2. Contact closure communication fiber-optic link diagram.

Certainly, the above advantages of the fiber-optic cables are obvious. However, the fiber-optic cable is only the one component of the comprehensive set of equipment ensuring fiber-optic communication. Two other components of the set (coding and decoding devices) are not that cheap and are immune to the external electromagnetic noises [1]. Moreover, their reliability is also questionable due to their complexity. The complexity of such microprocessor-based equipment is shown in Fig.1. As can be seen, at least three microprocessors are located on the circuit boards of the multiplexer FOCUS mentioned in [1]. On the other hand, the adequate copper control cable with a properly grounded shield [2] provides the same high noise immunity as the optic fiber. Today, there are multicore control cables consisting of twisted-pair wires each screened with the individual shield available on the market, see Fig. 3. Additionally, such cables are wrapped into the common foil screen covered with a copper braided screen with 85% coverage, and protected with an external plastic cover.

Fig. 3. Multicore control cable IBI0508P series (Hosiwell) with 8 twisted-pair wires and a three-layer screen

As for the reliability, it hardly needs saying that copper cable is more reliable than the sophisticated microprocessor-based fiber-optic link. However, optic fiber also provides full galvanic isolation between connected circuits, while the common shielded cable is not capable of providing it, even when such shielding is very effective.

3. OFFERED COMMUNICATION LINK

Today, equipping PACs with highly efficient galvanic isolation becomes extremely important due to the necessity to ensure power system electronics immunity to High Altitude Electromagnetic Pulse (HEMP) [3, 4] generating electric field, with very high strength: up to 50 kV/m near the ground surface.

For this purpose, to ensure the reliable transmission of contact closure commands on the PACs, combined with high-level galvanic circuit isolation developed by author, the high-voltage isolation interfaces are built on reed switches (“gerkotrons”), see Fig. 4.

Initially, these devices were developed for military and electrophysical applications [5], according to military standard MIL-STD-202 for electrical and electronic components, and as such are highly reliable. There are many designs of such devices developed each with different properties, parameters and functions [6].

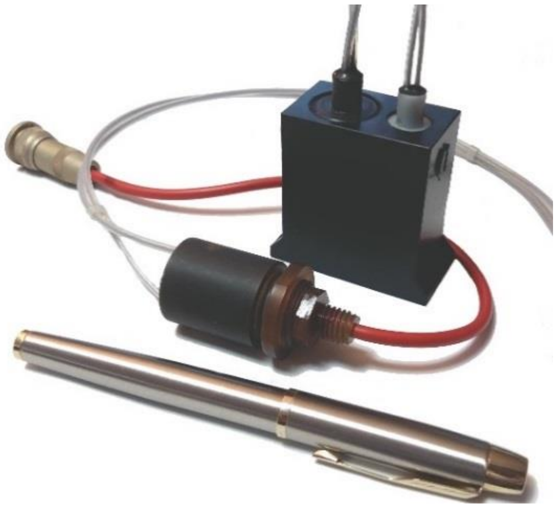

Fig. 4. High-voltage isolation interfaces built on reed switches (“gerkotrons”) designed to work under pulsed voltage up to 50 kV between input and output

However, the simplest gerkotrons are suitable for the purpose mentioned above, see Fig. 5. They should contain a reed switch separated with HV isolation from the control coil, or equipped with an auxiliary high-power switching element for direct control of the HV circuit breaker trip coil (transfer trip).

These devices are equipped with very robust elements. For example, the miniature reed switch type KSK-1A85 (MK23-85) has the best combination of switching parameters and sizes: switching current up to 1A, voltage up to 1000V (under switching power of 100W), withstanding voltage between contacts up to 1500V, operation time 1 ms, balloon diameter 2.7mm, balloon length 21mm. The Compact thyristor type GS60-16io1 is able to switch (short-time) up to 75A (pulse current up to 1500 A) and has the withstanding voltage of 1600V.

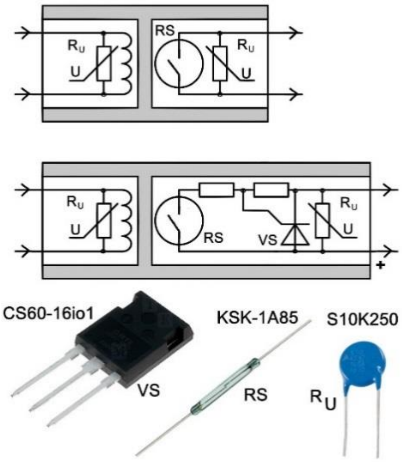

Fig. 5. Diagrams and elements of two simplest types of gerkotrons: top – gerkotrons used for transmission of contact closure commands between PACs, bottom – higher power gerkotrons used for direct control of the circuit breaker trip coil (transfer trip). RS – reed switch; VS – HV thyristor; R_U – zinc-oxide varistor.

The HV isolation body of the gerkotrons is made of a special plastic type Ultem-1000, combining the range of outstanding isolation, mechanical and climatic parameters, together with a high epoxy compound adhesion. In the devices, the control coil and switching elements are protected with varistors. The outputs are made of special flexible wire capable type 178-8195 (made by Reynolds Industries), to withstand the test voltage of 50kV: the outer isolation diameter is 2.54 mm only, and the conductor core section is 0.6mm^2. Additionally, the wire surface finishing ensures high epoxy compound adhesion.

The gerkotron operation time is 1 ms (it can take a little more time due to the control coil inductance) — it is too small to negatively affect the PACs operation, while it is too big to result in false operation under the high-power, but very short-time HEMP pulse. That is, except for HV galvanic circuit isolation, the gerkotron also acts as the impulse filter preventing the high-power disturbing signals of less than 1 ms from entering the inputs of electronic PACs.

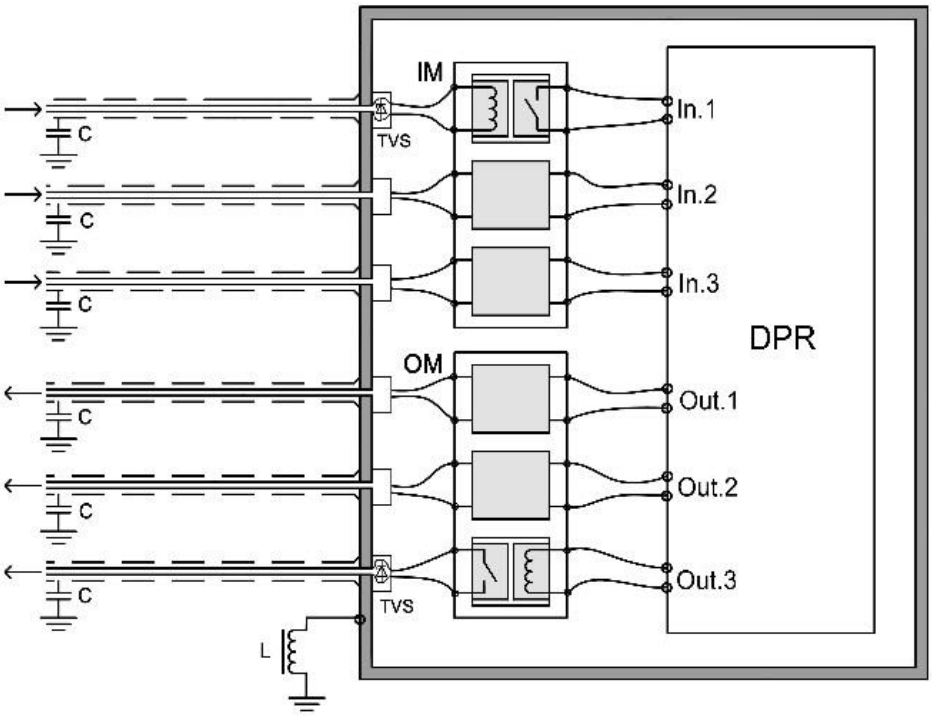

Fig. 6. Gerkotrons used to ensure HV isolation of DPR input and output circuits from external circuits during the contact closure commands transmission and receipt. IM – input module with the set of gerkotrons; OM – output module with the set of gerkotrons, TVS – additional protection elements (high-power bidirectional transient voltage suppressors) preventing the penetration of surge voltages into the relay protection cabinet.

See one of the application scenarios in Fig. 6 – the gerkotrons are used to ensure the HV isolation of input and output circuits of PACs (Digital Protection Relays - DPR, as an example) from external circuits during the contact closure commands transmission and receipt. In this case, the gerkotrons are used instead of fiber-optic communication links. They are installed together with a multicore copper control cable with a combined multilayer shield grounded on the one side with the capacitor, and on the other side, with the HF choke, according to the recommendations in [2]. All cabinet cable entries used to transmit discrete commands between PACs are additionally protected with high-power bidirectional transient voltage suppressors (TVS), see Fig. 7.

Fig. 7. High-power bidirectional transient voltage suppressors 58V, 15 kA (for input circuits protection – coils direction) and 430V 10 kA (for output circuits protection – reed switches or thyristors direction) manufactured by Bourns (left) and Littelfuse (right) companies.

In this situation, the transient voltage suppressor diodes (or TVS-diodes) are preferred over the traditional varistors, as TVS-diodes have significantly shorter response time and are able to adequately respond to E1 component of HEMP, having the very short pulse rise time of 2 ns. Previously, TVS-diodes had low power and were used for protection of electronic components located on the printed circuit boards. Today, two world leaders such as Bourns and Littelfuse, offer the high-power protection built on TVS-diodes, see Fig. 7.

4. CONCLUSION

The proposed technical solution allows to improve reliability and immunity of discrete contact closure command transmitting links used in PACs to high-power electromagnetic impacts, especially to HEMP.

REFERENCES

[1] Gurevich V. The Optoelectronic Transformers are the Panacea or Particular Solution for Particular Problem Only? – Electric Power News, 2010, No. 2 (by Russian).

[2] Gurevich V. Grounding of control cable shields: do we have a solution? – Energize, 2017, No. 4.

[3] Gurevich V. Cyber and Electromagnetic Threats in Modern Relay Protection. – Taylor & Francis Group, Boca Raton – London – New York, 2015.

[4] Gurevich V. Protection of Substation Critical Equipment against Intentional Electromagnetic Threats. – Wiley, 2017.

[5] Gurevich V. Protection Devices and Systems for High-Voltage Applications. –Marcel Dekker, New York – Basel, 2003.

[6] Gurevich V. Electronic Devices on Discrete Components for Industrial and Power Engineering. - Taylor & Francis Group, Boca Raton – London – New York.