Functional grounding of digital protective relays: a vital necessity?

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This article discusses the necessity for functional grounding of digital protective relays (DPR). In the article it is shown that due to the large physical size of the electric power facility and galvanic coupling between remote DPR units, functional grounding does not do more than play a role of establishing an equipotential plane with zero potential which is required for reliable operation of electronic circuits. On the other hand, the design of modern DPR does not require functional grounding at all. In the article a new approach for DPR grounding is suggested.

Nowadays, all digital protective relays (DPR) are manufactured in metal casings, installed in metal cabinets and equipped with multipoint grounding with equipotential plane (Figs. 1 and 2). The main function of the DPR is to process information coming to its input terminals (represented by currents, voltages and logic signals), store (internal oscillography) and return the results of this process as signals on its output terminal.

Due to these functions DPR is part of the scope of IEC 60950-1 [1]. According to clause 2.6.2 of the standard: "functional earthing circuit shell be separated from parts at hazardous voltages".

Is the requirement of this definition met under real conditions of relay protection systems used at sub-stations and power plants? According to [2] in the situation, where a lot of electrical devices and separate units of relay protection of power facilities are located at a significant distance from each other and grounded at their location, there will inevitably be a difference of potential between the points of grounding, which can reach as high as 10 kV during a lightning strike. When two DPRs are located at a significant distance from each other and their communication ports are connected via an ethernet link (Fig. 3), this voltage will be applied to the least protected (from high voltage) components of the DPR. According to [3]: "the larger the physical size of the facility, the greater the potential for problem".

Due to the low protection of communication ports they are not tested (unlike other inputs and outputs of the DPR) by applying a high voltage pulse (standards IEC 60255-5, 60255-22-5) and where they are, they are tested by a reduced test voltage (standards IEC 60255-22-1, 60255-22-4). As evidenced by [2], the level of the pulse overvoltage emerging during a lightning strike and applied to the insulation of electronic circuits exceeds the established resistance levels of commercial electronic equipment by several times. This happens during the flow of lightning current through a grounding system as affected by ordinary lightning charges. However, lightning charges are not the only source of a powerful electromagnetic impact on the DPR.

Recently, the problem of protecting electric power systems from so-called intentional destructive electromagnetic impacts [4], the most powerful of which is the high altitude electromagnetic pulse of a nuclear explosion (HEMP), has become very relevant. The E1 component of HEMP creates an electric field pulse with a density of up to 50 kV/m [4] at the ground surface. The branched grounding system acts as a huge antenna for this pulse, absorbing energy from a large area and delivering it directly to sensitive electronic equipment, including DPR through grounding circuits.

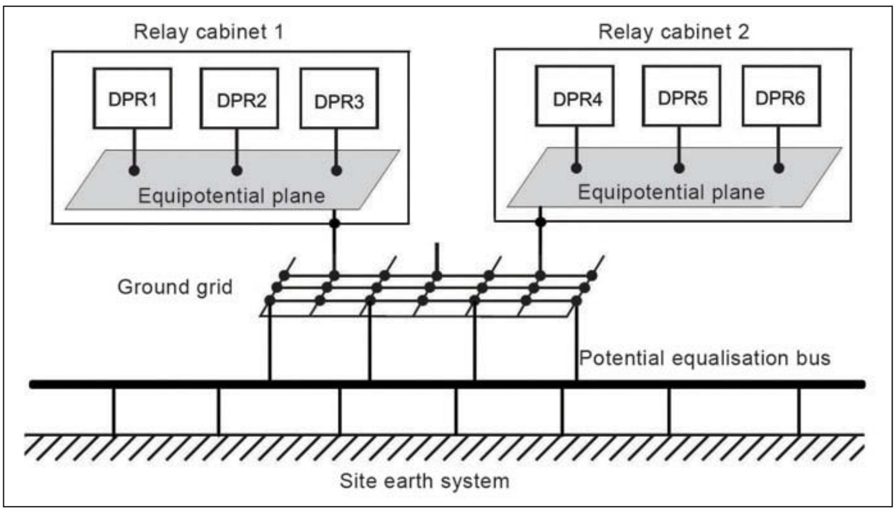

Fig. 1: Arrangement of multipoint grounding with equipotential plane.

On the other hand, a question arises as to whether functional grounding of DPR is at all necessary? It is obvious that the existing grounding systems are not an equipotential plane with zero potential, which is required for reliable operation of electronic circuits; neither do they act as a return cable, which is necessary to return certain signals back to the DPR. Quite the opposite is true, during the most critical situations for which the system is actually intended, the grounding system becomes a source of high voltage pulses applied to sensitive electronic equipment.

In the early designs of DPR manufactured 20 and more years ago, the functional modules located on separate printed circuit boards had special cleared and silver-covered sections of wider conductor strips. When the printed circuit board was installed in a casing, these sections touched springs ensuring the contact between these conduction strips with the grounded casing of the DPR (Fig. 4).

Modern DPR designs rarely employ these techniques to ensure functional grounding. This is justified, since all the input and output circuits of the DPR (except communication ports) are well insulated from the ground and from other electric units: supply circuits by means of transformer of internal power source, analogue inputs by means of insulation of internal current and voltage transformers, logic inputs by means of optocouplers, the output circuit by means of output electromechanical relays.

Indeed, the functionality of internal electronic circuits of the DPR has nothing to do with the availability or lack of grounding. As for the efficiency of the protection of the DPR's sensitive electronic circuits from the impact of external electromagnetic fields by means of metal casing, which is intended to act as a Faraday cage, it should be noted that it is not dependent on the availability or lack of grounding. In other words, the grounding of the DPR's casing does not influence the efficiency of the casing's shielding effect.

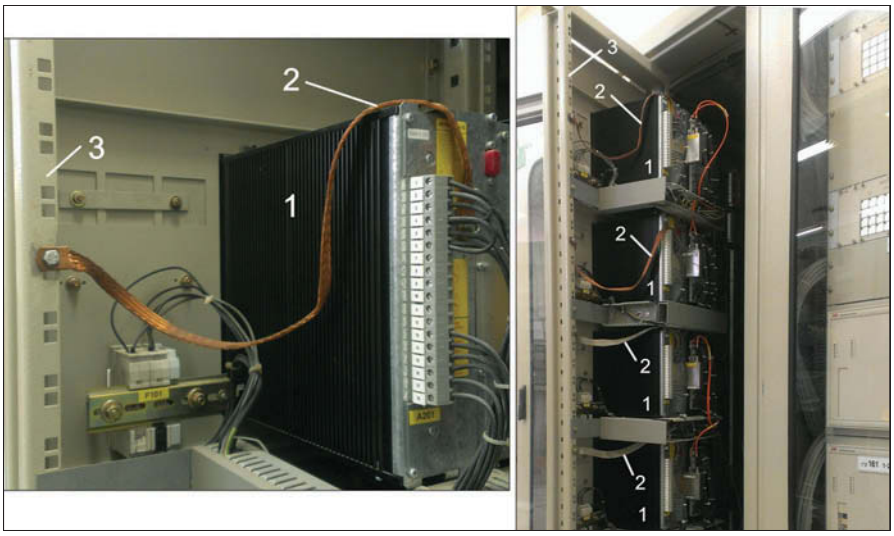

Fig. 2: Arrangement of DPR multipoint grounding with equipotential plane. 1: DPR in metal casings; 2: bounding strip; 3: metal cabinet's element that performs the role of the equipotential plane.

On the other hand, if the disturbance signals are coming to the electronic circuits of the DPR (located inside the casing) via cables, how can grounding of the casing prevent the impact of these disturbances (especially those of the differential type)? The answer is obvious: it cannot! Moreover, it should be pointed out that the grounding of the DPR casings will only worsen the situation and reduce disturbance resistance of the relay protection as real levels of overloading, which can be applied to different (even well insulated) internal circuits of spaced apart DPRs through grounding circuits, can significantly exceed allowable levels even when communication ports with their weak insulation are not accounted for.

According to [5], functional grounding cannot be treated separately from protective grounding, without infringement of operational safety standards. Let us ponder the veracity of this statement and consider these two types of grounding as separate and independent from each other. With this approach it will be possible to arrange DPR grounding using a new principle, which is based on the recommendation of IEC 60364-5-548 [6] regarding the improvement of disturbance resistance in information technology installations by separating these installations from disturbance sources. Since this example shows functional grounding as a "source of disturbance", I suggest that the DPR should be separated from it (Fig. 5).

According to this suggestion the steel container (item 3 in Fig. 5), with a minimum number of openings, is divided by internal partitioning into two zones: A: "dirty" and B: "clean". The DPR terminal in the plastic casing is located in the clean zone, which is free from electromagnetic radiance. Container 3 has a door (4), which provides access to the front panel of the DPR during maintenance. Container 3 is grounded, thereby meeting all of the traditional regulations and rules of grounding; and ensures the fulfillment of operational safety requirements.

Considering the rather large distance between the DPR and the internal walls of grounded metal container, for example, 5 to 7 cm, the parasitic capacitance of the

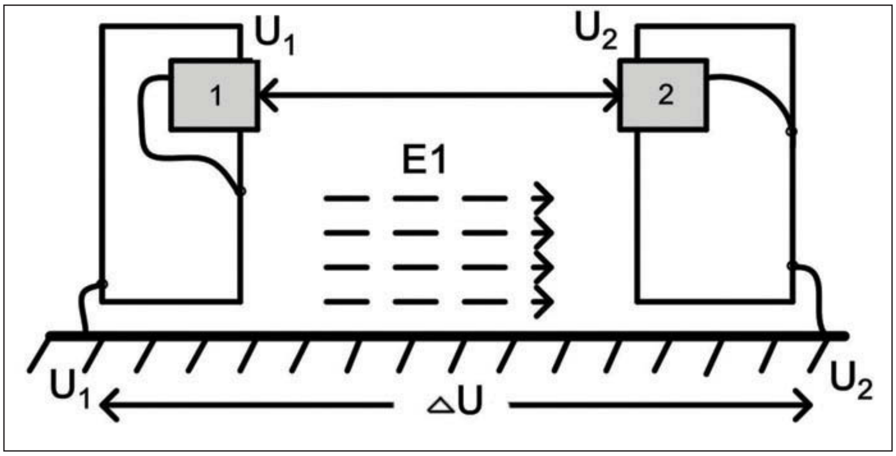

Fig. 3: Connection diagram of two DPRs (1 and 2) located at significant distances from each other with a non-insulated communication channel (twisted pair for ethernet network).

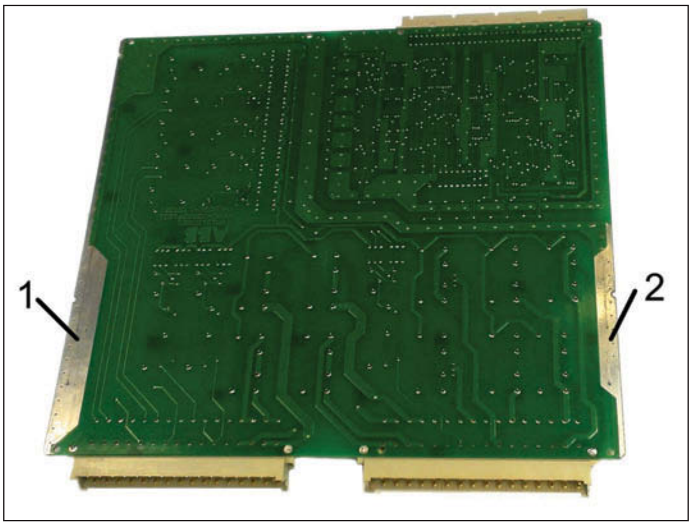

Fig. 4: The printed circuit board of DPR with cleared sections of printed wiring (points 1 and 2), which contact the grounded casing by means of a special spring.

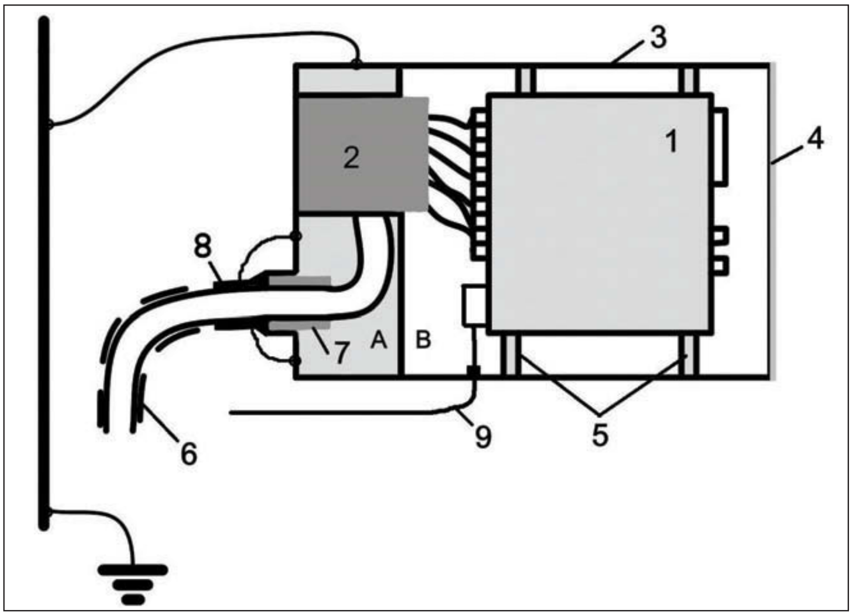

Fig. 5: Suggested principle of DPR arrangement, which ensures improved resistance to all type of electromagnetic impacts, including HEMP. A: "dirty" zone; B: "clean" zone; 1: DPR terminal in a thoroughly insulated plastic casing; 2: HEMP filter; 3: Steel casing; 4: Steel casing door; 5: Insulators; 6: Double-shielded control cable; 7: Wall tube; 8: Metal socket to couple cable braid with steel casing; 9: fiber-optic communication line (FOCL).

DPR electronic circuits to the ground will be very insignificant and its impact can be neglected. As for the DPR body, it should be thorouroughly insulated (made of plastic) employing any additional measures to prevent carry-over of a dangerous pair potential onto the surface of the body.

These measures can include: covering of the screen by a transparent plastic panel; locating the control buttons on the surface of the casing through the insulation inserts; using a LED to indicate the panel located on the casing's surface through a rigid transparent plastic rod; using an insulated optical port to connect an external computer to the DPR. Indeed, these are simple procedures which ensure safety. They are adopted in the absence of grounding in hand-held electric tools with a so-called double insulation and easily implemented in practice.

As for the removal of a potential electrostatic charge, which can accumulate on the insulated casing of a DPR, this can be solved by applying a thin layer of high-impedance semi-conducting cover on the inner surface of a plastic casing and connecting it to a grounded steel casing through a special high-voltage (50 – 100 kV) high-impedance (typically 20 to 50 MΩ) resistor. The static charge will leak to ground through this resistor. This technique is widely used in modern electronic equipment.

The suggested technical solution will ensure a high level of resistance against DPR disturbance, both under real conditions of use and under extreme situations such as HEMP impact, or that of other technical means of destructive remote electromagnetic impact [4]. Moreover, the cost of adoption of the suggested solution will not be unaffordable for the power industry, and might even be much lower than the cost associatewd with the reconstruction of an old grounding system at many electricity facilities, which do not provide for normal exploitation of the DPR.

References

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[2] MB Kuznetsov and MV Matveyev: "Protection from secondary effects of lightning and ensuring EMC of microprocessor-based equipment at oil-gas facilities", Energoexpert, 2007, No. 2, pp. 61 – 65.

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[6] IEC 60364-5-548 "1999: "Electrical installations of buildings - Part 5: Selections and erection of electrical equipment - Section 548: Farthing arrangements and equiponential bounding for information technology installations."

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