



PLATFORM SCREEN DOORS EARTHING AND BONDING STRATEGIES FOR DESIGN AND MAINTENANCE

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Abstract

The EN 17168 has finally provided a reference for the electrical design of Platform Screen Doors (or Platform Barrier Systems) for the interface with the station, the rolling stock and the platform, including interaction with passengers. Two main configurations are possible, with PSD potential bonded to the station earth or to the track (or floating, insulated from both), each with advantages and disadvantages that deserve attention for suitability for construction and maintenance, as well as for a system assurance perspective. The risk assessment and the technical judgment are carried out half formally half recurring to past experience, thus deviating often from a formal system-assurance-oriented approach in favor of clarity and completeness. Issues related to maintenance are discussed considering typical approaches, the most frequent repair and verification operations, and the normal aging of materials and systems. The outcome of the analysis is a preference for the earthed PSD that allows a better control of interfaces and a more durable design.

Keywords: earthing, electrical safety, platform screen doors, stray current, track

1 Introduction

Platform Screen Doors (PSDs) are becoming a relevant element of modern guideway transportation systems, with several examples in the world for railways, metros and tramways. Although the relevant cost, the advantages are in particular two: first, a dramatic improvement of safety, eliminating incidents of people falling on the track, intentionally or by mistake, and, second, the improvement of climate control and air quality, confining the platform area, drastically reducing the ingress of dust and humidity with a significant energy saving for heating and conditioning.

The PSD system, however, although comprised of a facade at the platform edge with sliding and tilting doors, controlled by a PSD electrical room, is a complex interface system for the following reasons. First of all, it must be mechanically robust to withstand the piston effect for stations in tunnels and the vertical weight of decorative facades. It is also exposed to the outdoor environment, so that it necessitates design margins with respect to the environmental agents (humidity, temperature, solar radiation, salt) for corrosion, electrical insulation (EI), etc. In particular, it may be seen as an iconic decorative element with which the passengers engage for a long time e.g. while waiting the next train, so that aesthetic impact, look, acoustic noise and electrical safety are key factors in order of technical relevance. PSDs have a complex interface with the civil structure (for mechanical robustness, index of protection and electrical insulation) together with lighting, announcements and passenger information services.

In this work we focus on those solutions that have an impact on electrical safety (including stray current and corrosion, electrical incidents, etc.) and that have been changing and im-

proving in the last years, following a more diffused awareness among manufacturers, the more detailed requirements of new transportation projects and the recent product standard EN 17168 [1]. For these points a qualitative comparison of the relative risk is also carried out.

2 Electrical safety and stray current protection

The EN 17168 [1] has synthesized and reported with normative dignity what was discussed in a few occasions [2] for the electrical safety (ES) and stray current protection (SCP) aspects. Its sec. 4.8.2 reports some important aspects and recalls that earthing & bonding (E&B) requirements must be harmonized also with lightning protection and electromagnetic compatibility (EMC). The Annex C in particular stigmatizes three “principles” (better called configurations, as in the following) that are graphically described in Fig. 1 and explained in the following.

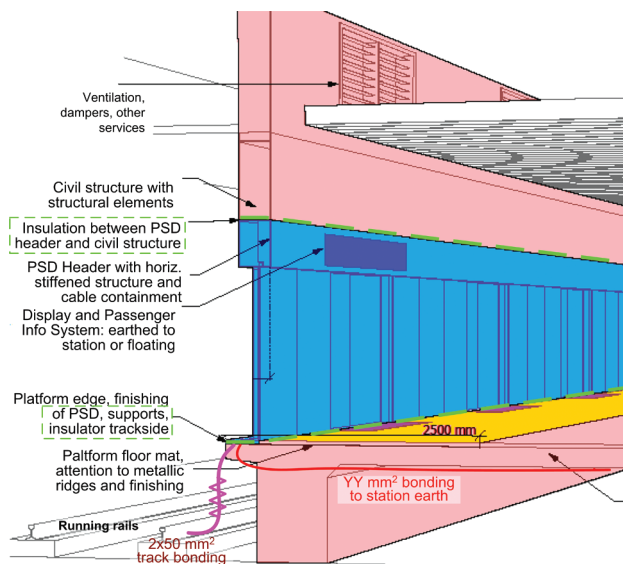


Figure 1 The three E&B configurations of PSD (EN 17168, Annex C): station structure (light red), PSD facade (light blue), Cfg. A (EPB) in red, Cfg. C (TPB) in magenta, Cfg. B without red and magenta elements

The three configurations are not listed in a particular order. Beginning with the most widespread and until recently accepted without discussion, Cfg. C, we have the PSD electrically bonded to the track potential (TPB), providing protection for the scenario of passengers boarding and alighting in a few seconds the train and touching conductive parts both on-board rolling stock (at track potential through its wheels) and of PSD. However, this shifts the ES-relevant interface to the whole platform, where passengers may stay and interact with the PSD for a much longer time (minutes). The associated risk is thus almost two orders of magnitude higher. All (partially) conductive masses that can be touched together with the PSD (walls, floors and equipment) within 2.5 m (IEC 60364-4-41, Annex C [3]) are subjected to an EI requirement (shown in yellow in Fig. 1).

Cfg. A instead sees the PSD electrically bonded to station earth (EPB): this is a rather new solution that is slowly being proposed and applied. The platform area is freed of EI requirements except for the areas around the motorized screen doors (MSDs), shown in purple in Fig. 1, where ES issues concentrate with the difference of potential between rolling stock and PSD (the track voltage). It is immediate that the associated risk is proportionally reduced as the ratio of the areas. We may also recall that the track voltage is anyway made safe for the compulsory touch voltage limits of the EN 50122-2 [4], implemented with an OVPD (Over-Volt-

age Protecting Device). The earthing of the PSD structure has also the advantage of removing the stray current issues and consequences of accidental bridging of insulation, as the track is not part of the circuit any longer.

Cfg. B is simply a complete isolation of the PSD that is difficult to maintain and exposes to ES risks for which a complex selective bonding would be needed.

In the rest of this section, we review the main factors that will drive the formulation of requirements for the PSD design (that will be discussed in Section 3).

2.1 Touch voltage and electrical safety

Electrical safety is related to exposure to body current for human beings and livestock [5] with different reactions and risks for DC and AC phenomena, frequency and part of the body where the current flows. Body current is the consequence of a difference of potential between two parts of the body. Touch voltage is translated into body voltage and then body current under various assumptions related to wearing shoes or barefoot, the type of contact with floor and walls, the statistical significance to assign to the selected value of the body resistance and susceptibility to current intensity and frequency [5].

For railways the reference electrical safety standard is the EN 50122-1 [6], setting the limits of touch voltage amplitude vs. time $V_{lim}(t)$, with an OVPD for protection of the track as accessible conductive part, and as a consequence of the PSD in TPB configuration. It is immediate to observe that if there is an OVPD at each station the local track voltage $V_{tr}(t)$ is safe and the required EI resistance for the floors and walls is an additional mitigation. Of course the final objective is to increase the level of protection ensuring that not only unsafe but also painful or unpleasant scenarios are ruled out.

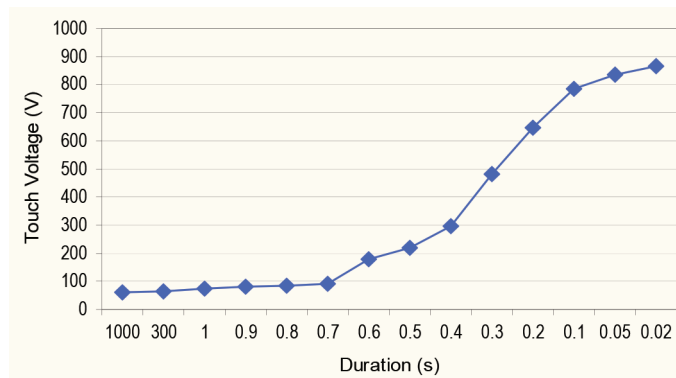


Figure 2 Touch voltage limit curve vs. time as per EN 50122-1

2.2 Stray current protection and insulation breach incidents

Stray current protection requirements are sometimes confused with those for ES. Stray current through the PSD is relevant only in the TPB configuration and two scenarios may be identified: a uniform leakage due to multiple conductive paths e.g. due to effects of humidity and condensation [2], and a hot spot, where EI is breached with a consequential large flow of current (that may be called stray current since the origin is the track, but is in reality a fault current).

The distributed stray current scenario may be addressed by considering the limits of the EN 50122-2 stipulating a 2.5 mA/m limit to protect the track and its fastening system [7, 8]. The PSD is made of similar, but thinner, material and it's a well visible part: a more conservative

limit may be selected reducing the allowed leakage by an order of magnitude (0.25 mA/m). Considering a PSD length $L = 100$ m and an average track voltage $V_{tr,av} = 20$ V (that is quite conservative estimate, suitable for modern metro system with very high exploitation), the required insulation level is

$$R_{PSD,lim} = \frac{V_{tr,av}}{I_{sc,lim} L} = \frac{20V}{0.25mA/m \times 100m} = 800\Omega \quad (1)$$

It is easy to see that this limit value is much less than those normally called in cause for ES, such as 50 k Ω and 500 k Ω .

This approach is not valid if we face a hot spot with large current flow due to an EI breach incident. Examples are loose panels, hardware falling in the air gaps, forgotten tools, etc. The consequence is significant arcing, metal melting, possibly fire in the presence of plastic materials reaching the ignition point.

This kind of incidents would not have any remarkable consequence if the PSD were at the station earth potential, so in EPB configuration. The best mitigation for the TPB configuration is bonding the PSD to the track through a resistor, that would limit the flowing current to safe values even under the worst-case track voltage (it must be remembered that this phenomenon is instantaneous, to be assessed with respect to maximum values, oppositely to distributed stray current and corrosion that are evaluated against average values). With $V_{tr,max} = 100$ V a resistive value of 100 Ω would let flow only 1 A, that is perfectly safe for arcing and fire; this holds true even for the maximum temporary voltages allowed by the OVPD settings. For increased margin the value may be brought to 200-300 Ω .

2.3 Traction short-circuit events

One point that is often neglected is the verification of PSD sizing and protection in case of a short circuit originating from the traction circuit, e.g. caused by a falling catenary, a derailed pantograph or sliding shoe, or an accidental contact of other nature. For both configurations (TPB and EPB) the bonding cable should be suitably sized (the 2x50 mm² required by the EN 17168 is already on the safe side). However, the PSD internal bonding conductors are never sized for even a fraction of that current, as common cross sections are 10 and 16 mm²; it is nevertheless true that the exposed conductive part trackside hit by the short circuit is bolted in several points to the rest of the structure and the conductive paths in parallel are many, although difficult to quantify.

3 Characteristics and requirements of the PSD subsystem

For what related to electrical safety at large (including stray current and corrosion, electrical incidents, etc.), the following relevant parts and subsystems may be identified: structure and anchoring to the civil structure, panels and covers, insulators as part of the fastening systems, cableways within the PSD structure and around in the platform, electrical distribution, earthing and bonding means, monitoring and diagnostic systems.

3.1 Structure and anchoring to the civil structure

The PSD structure is characterized by a non-negligible weight, especially if overhead aesthetic elements are considered (such as glass decoration). The structure must thus be able to discharge the vertical load, as well as to sustain the horizontal dynamic loading due to the piston effect, resulting in a significant flexure of the PSD system.

When installing and commissioning the PSD system, fine adjustment must be carried out for each door section and a certain deal of vertical and horizontal trimming must be provided. There are construction arrangements centred around supporting columns, as well as those relying on horizontal stiffened supporting elements (integrated by vertical supporting elements). For each arrangement the fastening system has some peculiarity for the fine adjustment in site conditions, so under the weight of the installed structure, still ensuring a satisfactory electrical insulation between the PSD structure and the civil structure for track-potential-bonded (TPB) PSD configurations. Insulators are usually in disk form, made of nylon or, better, pseudo ceramic material (like resin, steatite, or similar), located at the bottom (when interfacing with supporting base), at the top (with horizontally bearing beam structures) or both, and represent the most relevant element for EI.

3.2 Fastening devices and insulators

Structural fixing (or fastening) devices are delicate elements to preserve the required EI level with respect to mechanical stress, vibrations, ageing and environmental conditions. The EI separating elements are often in disc form: the creepage distance is often quite limited for such elements, compared to the clearance through the material, whereas the pollution degree (PD) for the track environment is established by the EN 50124-1 and is PD4A, so one of the most demanding. The problem then to uniquely determine the minimum creepage distance is assigning a value to the “rated insulation voltage”, higher than the working voltage, but not defined for the track.

The suitability of insulators is a combination of assigned environmental conditions (the pollution degree) and expected amount of overvoltage (by which clearance is evaluated), as per EN 50124-1 [9]. However, there is no clear overvoltage class assigned to the running rails.

In conclusion, creepage distance and clearance can be more or less accurately determined using the EN 50124-1, but they will hardly be suitably sized for permanent conductive pollution trackside and foreign objects obstructing the clearance. For this reason mitigations are being considered like the interposition of insulating sheets with long creepage path (applicable during a major maintenance intervention) and increased clearance (applicable only during design).

3.3 Panels and covers

Panels and covers are relevant elements from two standpoints: they are accessible by passengers (and staff) for touch voltage scenarios and they can move and cause an isolation breach as they can extend to bridge established insulation clearance.

For touch voltage, being large flat surfaces, mitigations are either keeping them floating in terms of potential or electrically isolated, such as by means of surface treatment. The latter is the most convenient solution as with the recent adoption of anodized aluminium or by post-humous application of insulating films or varnish. The later fixes, as a matter of fact, issues of touch voltage by providing EI levels complying with the required 50 k Ω for floor and walls. The latter point is not negligible, as a moving mass like a metallic panel is first of all a hazard for passengers as a falling object, but also a significant insulation bridging element, where the applied strength due to the accelerated mass may damage a tiny insulating varnish layer, less likely a thick insulating film. Panels and covers in fact may accidentally touch other conductive parts at some tens of mm distance when a hinge or bolt breaks, whereas in normal conditions the existing air gap ensures the necessary EI. Hinges and bolt may break as the result of corrosion or simply for being undersized when selected and installed; another common reason is wrong fastening with inadequate screws after a maintenance operation (self threaded screws tend to get loose in oversized holes after some screw/unscrew operations,

also due to approximate positioning each time); threaded rivets and inserts with standardized thread are a much more effective solution.

Another situation where panels and covers represent a real threat to EI preservation is when tilting covers (the PSD overhead modules with up-and-over covers) do not have end stops, causing a likely over-extension and consequential contact with other conductive masses at station earth (e.g. overhead facade, lighting, etc.). Besides ensuring that the design includes end stops and that consequences of old pistons and mechanisms of tilting covers are taken into account, another suitable mitigation is the construction of reachable parts at station earth potential with non-conductive materials, or their protection with insulating film.

3.4 Cableways

Cableways are a significant source of insulation breach incidents when conductive. Metallic cable trays are usually specified for robustness and for EMC purposes. However, their presence crossing internally PSD modules impedes the electrical separation of modules for diagnostic purposes, as well as their origin from another part of the system brings inside the PSD the station earth potential, exposing to EI incidents in the TPB configuration. Successive patches in some projects have provided short sections of plastic containment to connect thus electrically independent sections of metallic containment. For separation of too close conductive containment elements at different potentials, if not provided by design, the only possibilities are the interposition of insulating layers having removed crossing fastening elements (however, weakening the structure and exposing more to vibrations) or the replacement of one of the two with non-conductive equivalent.

Galvanized iron flexible conduits are particularly troublesome as they work insulated for some years, as long as the outer plastic cover preserves in good conditions, and points where insulation deteriorates are possibly the least visible in contact with other metallic masses. To this aim sharp edges and rough surfaces must be particularly avoided or protected and this is never sufficiently enforced during design and installation.

It is clear that when replacing a metallic containment with a plastic one two characteristics are lost:

- detection of fault when hosted cables lose their electrical insulation because e.g. a damaged sheath (for which the use of screened cables obviates to the problem at a cost), and
- additional electromagnetic screening normally required by the EMC discipline (in which case harmonization with EMC requirements is to be sought, understanding if such additional screening is really necessary as the parallelism within a PSD is limited to about 80-100 m for cables that are not particularly noisy).

3.5 Electrical distribution

The upstream electrical distribution is based on an AC network of 400-415 V nominal. EI is required whenever the PSD structure is at a potential other than station earth, so in TPB configuration. Transformation to lower voltage levels to distribute in the PSD electrical room between cabinets and to the PSD structure at the platform is a matter of strategy: a traditional AC distribution with a bulkier isolation transformer (or more than one) or a more flexible DC distribution where isolation is provided with smaller high-frequency transformers within the AC/DC modules. A DC distribution is a natural choice for a PSD where the various loads are all by themselves working at DC: LED lights, panels, controls and the small power drives for the motorised screen doors, anyway requiring a dedicated inverter (or converter).

3.6 Monitoring and diagnostic systems

PSD current leakage may originate from its own power supply (so AC or DC depending on design choices) or from the track bonding connection for the TPB configuration. As leakage may occur at many points of the PSD structure, measuring must be carried out at the source: for the track a clamp-on probe on the bonding cables is the preferred solution, for the supply it may be a feature embedded in the AC/DC converters or it should be purposely deployed in the supply cabinet of the PSD electrical room. By experience it is important that the leakage detector has only the bandwidth that is necessary: for the track a pure DC or low-frequency detector is needed, as it may be easily disturbed by high-frequency noise, such as rolling stock emissions, as well as substation power conversion systems. A device like the Bender MRCDB300 has a low cut-off frequency at 60 Hz and variable thresholds between 30 mA and 300 mA [10], the Multi Measuring Instruments MDLA is even more selective operating only at DC with thresholds ranging between 10 and 200 mA [11].

Besides ensuring overall ES and integrity of the structure, a leakage detector with fast logging capability is also useful to detect momentarily EI losses. EI losses may occur during train passage (e.g. caused by vibrations or piston effect) and would never be spotted out if tests are carried out during engineering hours, so during the night with stopped traffic.

4 Conclusions

This work has reviewed the multi-faceted problem of ensuring the necessary electrical insulation level of Platform Screen Doors in face of the two most likely configurations, when the PSD is bonded to the track (TPB) or station earth (EPB) potentials. The review has covered electrical safety and stray current exigencies, including consequences for the most relevant parts, structural elements and auxiliary devices. This is the result of an on-going activity begun in July 2023 and the results and materials are much more than those presented in these pages. The results of this review are synthesized in the following Table 1.

Table 1 Summary of mitigations related to electrical safety and stray current

Electrical safety and stray current mitigations	Track Pot. Bonded (TPB)	Station Earth Bonded (EPB)
Increase gap clearance to avoid bridging	Advisable	Optional
Limitation of flowing current	Required	Not advisable
Electrical insulation of floor and walls	Required	Required, smaller area
Electrical insulation of PSD panels	Advisable	Optional
Electrical insulation of PSD door edge	Optional	Required
Non-conductive cable containment	Advisable	Optional
Leakage monitor	Required (traction & supply)	Advisable (supply only)

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