



Supports:
MFT-X1, MFT1800, MFT1700
(also: MIT400, MIT2500, IMT100 and MTR105)



Introduction

Surge Protection Devices (SPD) are used in electrical installations to provide an additional level of protection against temporary over-voltages (TOV), surges and impulses. The IET Wiring Regulations 18th Edition BS 7671:2018 (section 534.4.1, Fig. 534.2) specifies three types of SPD:

- **Type 1 installed at or near the origin of the electrical installation (e.g. main distribution board).**
- **Type 2 installed in the distribution circuits (e.g. sub-distribution board).**
- **Type 3 installed close to sensitive equipment.**

All three types (Type 1, 2, 3) comprise of some kind of non-linear active components whose resistance is very high at the nominal operating voltage (open circuit). However, in the event of an overvoltage the impedance becomes very low (clamping or short-circuiting), limiting the downstream energy.

BS 7671:18 (section 534.4.3, Fig. 534.3 and Fig. 534.4) also differentiates between two Connection Types internal to an SPD assembly. In Connection Type 1, all the non-linear components are connected from L1, L2, L3, and N to the common of the PE conductor (4+0). In Connection Type 2 they are connected from L1, L2, and L3 to the common N, and another component from N to PE (3+1).

Low-voltage surge protective devices IEC/BS EN 61643-11 requires the SPD body to be marked with the following information:

- **Manufacturer's name and model number**
- **Maximum continuous operating voltage U_c in V and type of current (for instance AC or ~)**
- **Test classification and discharge parameters, for:**
 - **Test Class I – name of class or [T1] and the impulse current I_{imp} in kA**
 - **Test Class II – name of class or [T2] and the nominal discharge current I_n in kA**
 - **Test Class III – name of class or [T3] and open-circuit voltage U_{oc} in kV**
- **Voltage protection level U_p in kV (peak voltage across SPD during the impulse test)**
- **Identification of terminals or leads**
- **Degree of Ingress Protection**
- **Rated load current I_L for SPDs with separate input/output terminals**

There can be also additional marking, such as the maximum discharge current I_{max} in kA (highest capability for a single surge) or the follow current interrupt rating I_{fi} in A (maximum short-circuit current interrupted without activation of a disconnect).

It should be noted that the SPD types, Connection Types or Test Classes do not define the type of components fitted within the device. Instead, the internal protection components are characterised by the amount of energy (impulse current and/or impulse voltage) to be dissipated, and the exact choice of implementation depends on the manufacturer of the SPD.

It should also be noted that the technical details provided on the SPD body or even in their data sheets are often insufficient to infer the type of components and their configuration. This application note gives some guidance on the interpretation of the test results which are likely to be obtained in the field when applying the insulation test as the means of SPD verification.

Types of non-linear components inside SPD Type 2

SPD Type 2 are typically installed at distribution boards and this application note focuses on such devices. Type 1 and Type 3 are likely to show similar behaviour but their construction is more varied between manufacturers.

Two main types of non-linear components are typically used inside an SPD, each activated by its own voltage threshold. A typical diagram of an SPD is shown in Fig. 1 (but other configurations are possible):

- **Between L-N (or L-L) there is a Metal Oxide Varistor (MOV), which behaves similarly to a Zener diode or Transient Voltage Suppression diode (TVS) so that overvoltage is limited to some level (e.g. 430 V, see Fig. 2).**
- **Between N-PE there is a Gas Discharge Tube (GDT) which behaves as a spark gap or thyristor and, once activated, it short-circuits to a much lower voltage (e.g. < 40 V, see Fig. 3), but opens automatically when the voltage decreases so that there is insufficient current to maintain the spark.**
- **SPDs can be equipped with an internal thermal Disconnecter which is typically linked to an “end of life” indicator. For example, this can be a joint which unsolders itself due to excessive heat dissipation. Such a traumatic event means “end of life” of an SPD.**

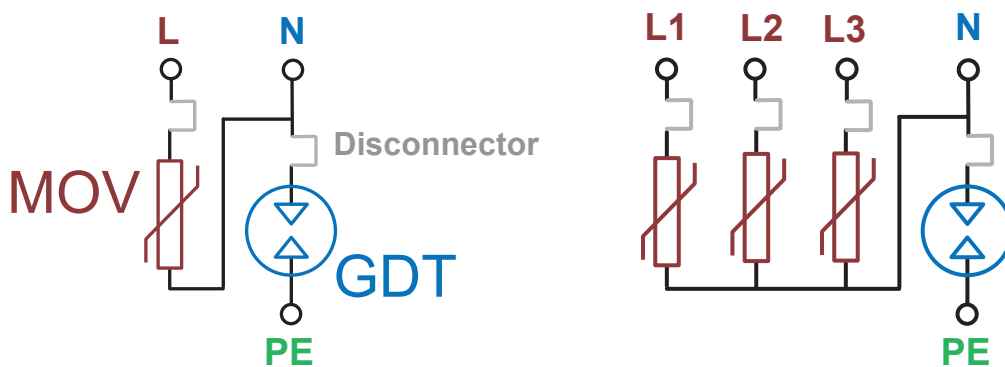


Fig 1: Circuit diagram of typical single-phase and three-phase SPDs

Types of non-linear components inside SPD Type 2

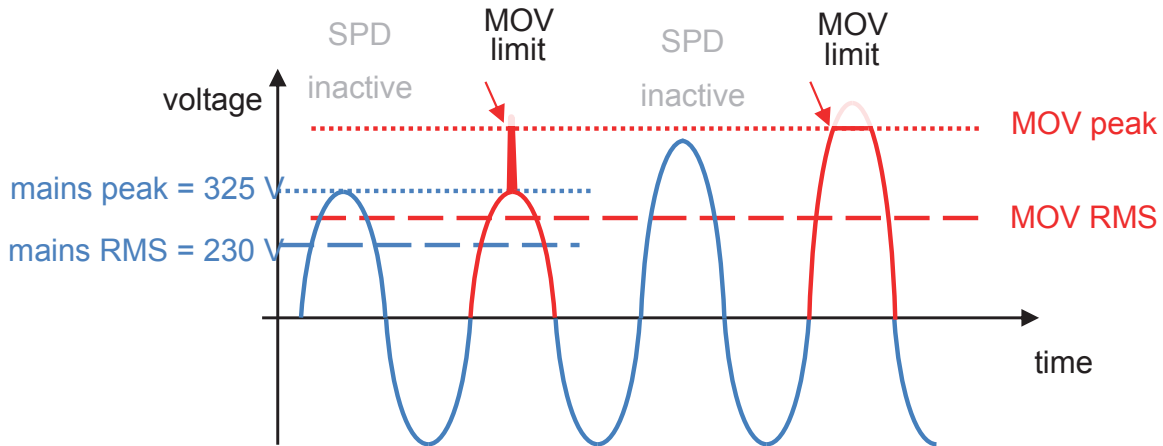


Fig 2: Typical voltage limiting by an MOV (e.g. between L-N)

The SPD maximum continuous operating voltage level U_c is normally specified in RMS values. For example, for the nominal mains voltage of 230 Vrms an SPD rated at $U_c = 275$ Vrms could be used (between L-N conductors). However, as shown in Fig. 2 and Fig. 3, SPDs are activated by the peak voltage, not RMS, so this RMS specification is somewhat imprecise with respect to the expected activation threshold. For example, a narrow impulse of overvoltage would not significantly change the RMS value, but if its peak exceeds the SPD threshold then it will be activated. An SPD will typically operate in any polarity of the applied voltage.

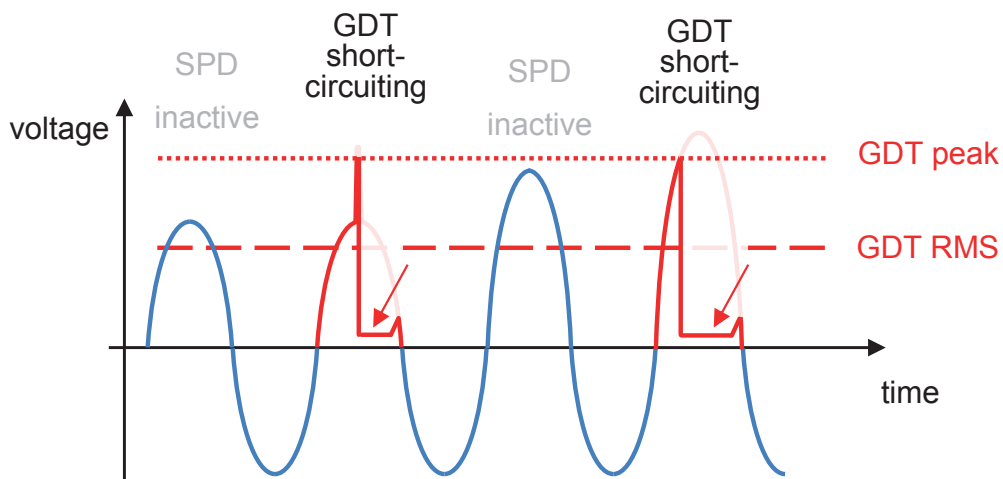


Fig 3: Typical voltage short-circuiting or "crowbarring" by GDT (e.g. between N-PE)

Testing SPDs with an MFT

CAUTION : If the SPD is not fitted, or it is faulty or disconnected, then the full insulation test voltage will be present on the tested circuit. This high voltage could potentially damage equipment connected to the installation. It is recommended that voltage-sensitive equipment should be disconnected from the circuit before an SPD is tested, or the SPD can be removed from the circuit for testing.

CAUTION : Only use insulation testers that have built-in hardware current limits of less than 2 mA which will not damage the SPD, such as: Megger MFT1700, MFT1800, MFT-X, MIT400, MIT2500, IMT100, MTR105.

The ordinary **insulation resistance (IR)** test on an MFT (or other Megger test instruments as listed above) can be used to test SPDs. The IR test in the MFT is designed so that its output current is hardware-limited to less than 2 mA (in practice around 1.5 mA) and therefore such a test is completely harmless to an ordinary industrial SPD, with typical rating of kA. Even if the insulation test voltage is set to significantly exceed the voltage rating of the given SPD, during the test the MFT voltage will collapse automatically to the limited value of the SPD, as dictated by the resulting current.

Therefore, during an insulation resistance test, it is the indicated insulation test voltage that can be used to assess the condition of the SPD. The insulation resistance reading will also present supplementary information. No additional settings or accessories are required.

It should be noted that full functionality of an SPD cannot be tested, similarly as the full functionality of any fuse cannot be tested by an ohmmeter (only continuity and the resistance readings can be indicated, but not if the fuse will open with overcurrent). Therefore, similarly for the SPD, only the performance of the active components can be detected and measured, based on the low energy thresholds at which they are activated. However, in practical situations this typically provides adequate confirmation of performance and operation.

Testing L-N (MOV)

The electronic component manufacturers (not SPD manufacturers) often specify the limited voltage threshold as the voltage at which the DC current flowing through the MOV is 1 mA. Therefore, testing with a current of around 1.5 mA correctly identifies this threshold voltage.

The expected clamping voltage of an MOV in an SPD can be roughly estimated from two parameters: the continuous operating voltage U_c (for which the device must not activate), and the voltage protection level U_p (which is the highest expected peak voltage across the device at the maximum surge current during activation).

For the lower limit, for a typical SPD rated with $U_c = 275$ V rms the minimum activation voltage should be above $\sqrt{2} \times 275$ V rms = 389 V peak.

For the upper limit, a typical rating of $U_p = 1.2$ kV, $I_n = 20$ kA and $I_{max} = 40$ kA indicates that the MOV would exhibit up to 1.2 kV with a surge of 40 kA flowing through it. The MOV behaviour is such that the maximum voltage across the device is roughly two to four times the threshold voltage at 1 mA. Therefore, the maximum expected threshold voltage would be 1.2 kV / 2 = 600 V, which can be detected with a 1000 V insulation test.

Testing SPDs with an MFT

Therefore, the range of interest is $\sqrt{2} \times U_c < V_{DC \text{ test}} < U_p / 2$ or from 389 V to 600 V for the example values used above. Typically an activation closer to the bottom limit would be expected for an MOV. Example: For a single-phase SPD with an MOV component between L-N, a behaviour as shown in Fig. 4, is to be expected when tested at 500 V DC (IR test voltage set on MFT). In this case, the SPD was rated at $U_c = 275$ Vrms (so DC or peak range is expected between 389 V and 600 V). Indeed, the MOV was activated at 437 V (actual voltage displayed on MFT during the test), which is approximately 10% higher than the minimum expected value. The displayed test voltage was very stable. The insulation resistance reading was also very stable at 0.27 M Ω . This indicates typical correct behaviour of an MOV in a single-phase SPD.

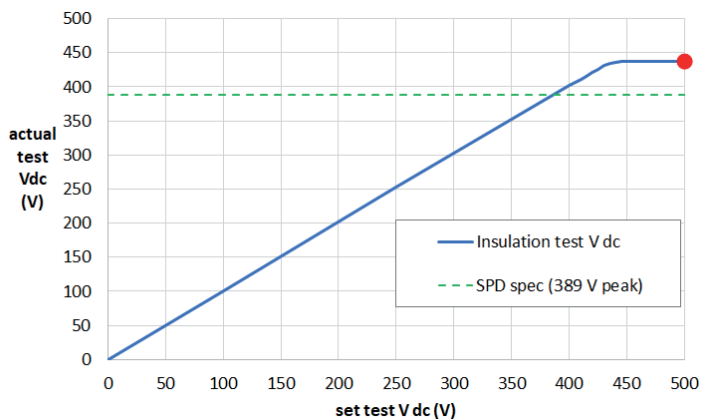


Fig 4: Applying the insulation test across L-N terminals of a typical SPD rated at $U_c = 275$ V rms. The marked point shows that the output voltage is limited to 437 V when the insulation test is set to 500 V.

However, for this particular SPD rated at $U_c = 275$ V rms, if the voltage were limited below 389 V DC, or not limited at all up to the 500 V peak, then this would mean that the SPD is either incorrectly installed (voltage rating is too low/limiting prematurely) or it is defective (no limiting at all). Either behaviour would require further investigation, such as testing at 1000 V in the event of no limiting. Additionally, MOVs can degrade when subjected to high-energy events. A correctly functioning MOV should have a negligibly low leakage current at the nominal voltage, so an IR test at a lower voltage (e.g. 250 V DC) should show very high resistance (typically >999 M Ω). Lower readings could indicate degradation or contamination on the surface.

However, if an SPD is tested at elevated temperatures (e.g. +60 °C) the resistance reading may be reduced, without indicating actual failure. An SPD should not be operated above its rated temperature as the leakage current could increase to unacceptably high values.

Also, significant differences between the readings of the three phases (L1-N, L2-N and L3-N) may indicate uneven degradation of the SPD protection in each phase.

Testing L-L (two MOVs in series)

It should be noted that when testing between L-L terminals there will be effectively two MOVs connected in series (refer to Fig. 1), and therefore the expected limited voltage would be twice that of the single-phase or L-N test.

Example: A three-phase SPD rated at $U_c = 275$ V rms tested between L-L terminals would not be activated because the expected limited voltage would be $2 \times \sqrt{2} \times 275$ Vrms = 778 V peak. A 500 V DC test would therefore be below the required threshold. The test voltage would remain stable at 500 V DC, and the measured value would likely be > 999 M Ω .

However, there is no need to test between the L-L terminals because testing L1-N, L2-N and L3-N will activate each MOV in a three-phase SPD, therefore verifying its correct operation. Alternatively, performing the L-L test at 1000 V is more likely to activate both MOV components in series. The behaviour would then be similar to that shown in Fig. 4, but with the limit at double the DC voltage.

Testing SPDs with an MFT

Testing N-PE terminals (GDT)

For a mains protection GDT with a high kA discharge current rating, a small test current of 1.5 mA will be harmless to the GDT itself. The range of activation can be estimated also as $\sqrt{2} \times U_c < V_{DC} \text{ test} < U_p / 2$. The bottom limit results from the conversion from RMS to peak. The upper limit is related to the test being carried out at low current applied, with a relatively slow rise time so the spark gap in the GDT is expected to ignite at a lower voltage than that expected when carrying out fast impulse tests.

Example: For the same SPD as in the example above, the rating was $U_c = 255 \text{ V rms}$ and $U_p = 1.5 \text{ kV}$ (there was a different rating for the N-PE terminals than for L-N), so the expected range was therefore from 361 V to 750 V. Applying 500 V did not trigger the GDT, even though the applied test voltage was significantly greater than the lower limit of the expected range. The MFT test voltage did not collapse and the insulation resistance reading was very high (>999 MΩ). This indicates the correct behavior for this type of GDT device.

The activation occurred above 586 V DC (around 60% higher than the lower limit of the expected range), which caused the MFT test voltage to intermittently collapse and recover when testing continuously over several seconds (Fig. 5).

The random firing of the GDT spark gap affects the test voltage and the insulation resistance readings in an erratic way as expected – this indicates the correct behaviour of the SPD.

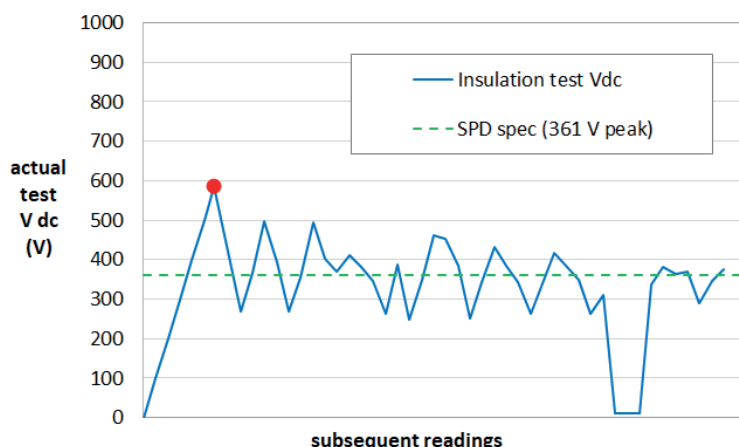


Fig 5: Erratic voltage readings caused by random firing of the spark gap. In this particular SPD the GDT was triggered above 586 V peak (marked point). Some readings are limited to < 10 V.

(Depending on the type of insulation tester, when the spark gap fires, the insulation test may continue, or it might automatically terminate and indicate a breakdown of insulation. This would also indicate a correct detection of a GDT component.)

Testing L-PE terminals (one MOV and one GDT in series)

Applying the insulation test at 500 V between the L-PE terminals will typically not trigger a mains-rated SPD because the MOV and GDT components are effectively in series (refer to Fig. 1), and therefore the combined peak voltages of both components are required for triggering.

For the examples discussed above, the combined real threshold would be $432 \text{ V} + 586 \text{ V} = 1018 \text{ V}$, which could be just beyond the capability of a 1000 V tester. If some activation took place then just the insulation resistance reading could be unstable, but the test voltage may or may not fluctuate. If the GDT is activated, it will short-circuit itself, but on top of the limited voltage of the MOV. Thus, the voltage would typically not collapse below the limited voltage of 432 V. In some cases this allows distinguishing between a GDT or a GDT=MOV in series connection.

However, there is no need for an additional test between the L-PE terminals as testing L-N, L1-N, L2-N, L3-N and N-PE will activate each MOV and/or GDT separately in a single-phase or three-phase SPD.

Summary

The presence and threshold voltages of typical single-phase and three-phase SPDs can be tested with the insulation test, as available on the Megger MFT1700/1800 series, the Megger MFT-X1 or the single function MIT400 or MIT2500 meters and the IMT100.

The Megger insulation testers have a built in current limit of >2 mA, harmless to typical industrial SPDs based on Metal Oxide Varistors MOV and Gas Discharge Tubes GDT. Testing SPDs across terminals that have Metal Oxide Varistors MOV (typically between L-N or L-L) will produce a stable, limited test voltage, typically between $\sqrt{2} \times U_c < V_{DC\ test} < U_p / 2$, and typically closer to the lower limit. A voltage limit or large leakage current below the lower voltage limit may indicate incorrectly rated SPD is fitted, the SPD is faulty, is suffering from degradation or contamination. No activation up to the higher limit may indicate an incorrectly rated SPD is fitted, an issue with the connection or a fault of the internal MOV component. An MOV should always limit the voltage below its U_p rating.

Testing SPDs across terminals that have Gas Discharge Tubes GDT (typically between N-PE) can produce erratic limited voltages and readings, indicating correct activation because of the random sparking in the GDT. This is typically within a range of $\sqrt{2} \times U_c < V_{DC\ test} < U_p / 2$ and typically closer to the middle of such range. Activation below the lower limit may indicate an incorrectly rated SPD is fitted, the SPD is faulty, is suffering from degradation or contamination. No activation up to the higher limit might indicate an incorrectly rated SPD is fitted, an issue with the connection or a fault within the GDT component. A GDT should activate below its U_p rating. Performing an insulation test on an SPD below its activation voltage of an MOV or GDT will typically produce an open circuit reading, without any voltage clamping and with >999 M Ω resistance reading. This indicates a correct behaviour of either SPD component.

Megger Limited
Archcliffe Road
Dover CT17 9EN
United Kingdom

www.megger.com

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