Incident Summary #II-1140811-2021 (#20659) (FINAL)

SUPPORTING INFORMATION	Incident Date		February 1, 2021
	Location		Cowichan Bay, BC
	Regulated industry sector		Electrical - Low voltage electrical system (30V to 750V)
	Impact – Injury	Qty injuries	0
		Injury description	None
		Injury rating	None
	Impact – Damage	Damage description	Melting, smoke, and fire damage to the main distribution panel board and surge protective device (SPD) beyond repair. Minor smoke damage to the drywall above the panel. Electrical damage to the television, hot tub control panel, and various light bulbs beyond repair. The oven's 120 Volt control panel had to be replaced.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		An SPD was installed in the home's main electrical panel to prevent overvoltage damage to electrical devices that had been occurring. With the SPD installed, the overvoltage damages continued to occur periodically as there were fluctuations in the system voltages related to an underlying conductor termination issue known as an open neutral. The SPD was damaged by the overvoltage and eventually burst into flames with smoke billowing from the panel.
IINVESTIGATION CONCLUSIONS	Site, system and components		**Power system** • The home has a 120/240 Volt, 200 Amp rated service. The 240 Volt supply is fed from the secondary winding of the supply transformer at the center tap where the grounded neutral line connects (Image 3). The nominal voltage is 120 volt between the grounded neutral conductor and each 240 Volt conductor. • The service transfers from overhead to underground at the pole mounted meter base and main breaker combo unit on the property (Image 3). • Inside the combo unit are neutral conductor termination points and system bonding jumper (Image 4). This is the exclusive location for the home's electrical system where the neutral connects to the grounding system. • An aluminum armoured cable feeds underground from the service equipment on the pole to the home's push-on panel (meaning the breakers push on to the panel, rather than bolt on), that has the neutral conductor isolated from ground. **Open service neutral** • Solid neutral terminations from the service all the way to the connected electrical equipment is an important factor in maintaining proper system voltages. • If a three wire 120/240 Volt system's neutral conductor becomes loose or disconnected it can result in power quality issues. Depending on the difference in connected loads between the two 120 Volt lines, the respective voltages may vary between 0 to 240 Volts from the nominal 120 Volt (Image 5). • The results of the voltage variations may include flickering, dimming, and brightening of lighting as well as overvoltage damage to 120 Volt rated appliance components or devices.

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	Surge protective device • The main panel had an SPD (Image 1) designed to protect the electrical service and major household appliances, excluding electronic devices, from momentary surges by clamping excess voltage. • The SPD product standard is - Type 2 SPDs - CSA C22.2 No. 269.2-13, "Surge Protective Devices - Permanently connected", 1st Edition, dated June 2013. • UL1449 product standard item 3.47, which applies this SPD, defines a surge as a transient wave of current, potential, or power in an electric circuit. For the purposes of the standard, surges do not include temporary overvoltage's (TOV's) consisting of an increase in the power frequency voltage for several cycles. • The local power system utilizes typical 60 Hertz power (60 cycles per second) so a TOV would be a surge for 3/60ths of one second or more. • The SPD can withstand a line to neutral maximum continuous operating voltage (MCOV) of 175 Volt. • The SPD has an integral light emitting diode (LED) that indicates "OK" status if the LED is green or "Replace" status if the LED is off when the power is on. • For protection against surges, the SPD uses 3 radial metal oxide varistors (MOV's) per phase that are rated for 180 Volts maximum alternating current. • A varistor is a variable resistor whose resistance decreases when the voltage increases beyond the circuit ratings to absorb voltage surges. • The varistor acting as a resistive load, when the voltage is over the circuit ratings, can degrade from exposure to many voltage spikes that are not long enough or high enough current to trip the protective fuses. • Each MOV is protected by 1 thermal cut off and 1 current limiting fuse (Image 6). • The SPD's plastic case has sand insulating fill for the components (Image 7).
Failure scenario(s)	During the original electrical installation, two years before the incident, the neutral lug in the meter base was left untightened creating an open neutral condition. Eight months before the incident, the control panel for the oven and various light bulbs in the house stopped working from over voltage occurrences. An electrical contractor was called to site and found the voltage levels at a receptacle to be 204 Volts but returning to 120 Volt after they went outside briefly. At that time, the electrician attributed the over voltages to utility power surges and installed the SPD in the panel to protect against any further surges. One day before the incident, another over voltage occurrence again damaged some light bulbs, the television, and the oven panel, so the occupant called the electrician to arrange for them to re-examine. Prior to the electricians scheduled visit, when an occupant turned on a light in a bedroom, the light bulb stopped working. They went to the panel to check on the status of the SPD's green light and upon opening the panel door, the SPD sparked, exploded and then the top half of the panel burst into flames. The open neutral condition led to intermittently fluctuating voltages varying with the quantity of loads energized at any given time between each line conductor and the neutral. The SPD was exposed to voltages that reached beyond the nominal 120 Volts to at least 204 Volts. The voltages intermittently reaching over 180 Volts degraded the MOV's while they acted as a load. Overvoltages of short duration and/or levels of current not high enough to trip the thermal cut-off or current limiting fuses allowed the MOV's over time to degrade until catching on fire with the SPD melting and bursting into flames.

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Facts and evidence	**Manufacturer communications** • The SPD cannot withstand a continued overvoltage that exceeds the MCOV. • The SPD is not rated for TOV's [an increase in the power frequency voltage for several cycles or 3/60th's of one second]. • When a surge causes the voltage to exceed its normal value, the surge arrester holds or 'clamps' the voltage. At the same time, the surge arrester dissipates and diverts the transient current until the surge passes. • The SPD uses three types of protection including thermal cut off fuses, current limiting fuses, and silica sand packing around the components. • The SPD has thermal cut off fuses with a cut off temperature of 135 degrees Celsius (+/-3) to protect the MOV's within. • After applying 240v across the MOV, its MCOV is exceeded. Then, it starts conducting current. Temperatures start to increase in the MOV and the TCO - causing a disconnection. MOV – Metal Oxide Varistor, MCOV – Maximum Continuous Operating Voltage, TCO – Thermal cut off. • Test SPD's had 240 Volt at 10 Amps applied to their 120 Volt circuitry and in each of the 4 cases, the SPD disconnected itself from the circuit without damage. **Occupant statements** • The house was completed in the fall of 2019. • There was an incident in the summer of 2020 where a few of the breakers blew and the control panel for the oven and various light bulbs in the house stopped working. • After that, a surge protector was installed in the electrical panel. • On Jan 31, 2021 there was a power surge that affected some light bulbs, the television, and the oven panel. The surge protector seemed to have limited the damage and it was arranged to have the Electrician come on Feb 02, 2021 to investigate and repair the issue. • On the evening of Feb 01, 2021, after the bathroom light was turned on, that quickly caused the breaker to shut off. • They went to their child's room where the electrical panel is to see if the surge protector was still activated, they have a green light if they're still active, and to see which breaker switches were off and if anything else was going on. • As soon as they opened the panel and looked in, that's when it blew. They were standing in front of the panel, the surge protector sparked, exploded and then the top half of the electrical panel burst into flames. • Being 10:20 pm and completely dark, while they were attempting to find the phone to call the fire dept, the flames eventually died down. • They also shut the main breaker off and contacted the electrician to inform that the situation had escalated significantly. • After arriving first thing the next morning, the electrician discovered at the main power pole that major connections were loose and/or not connected securely. • Repairs include new drywall, new paint, a new breaker panel, a new surge protector, a new TV, hot tub repair work, a lot of light bulbs, and the control panel screen on the stove had to be replaced. **Electrical contractor statements** **Summer 2020 site visit** • Called out there one time for a problem with the lights and the clock on the stove knocked out. • It happened a couple of times that day, that's why the contractor was called out, it must have been a windy day.

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	• The contractor went out, had the meter out and checked one of the receptacles just in the hallway, line to neutral was reading 204 volts and some of the lights were out. • Went outside, looked at the connection point for the triplex [overhead service line] to the pole. Seeing that it looked good, went back, and put their meter back in the plug 120 [Volt]. That's why the contractor thought it was a power surge. • The contractor asked the neighbor outside has anything weird happened with their power and they said no. • After it was reading 120 [Volt], the contractor pulled the panel cover off, pulled the inspection cover off, checked the lugs, measured everything again with their multimeter about five times before they said OK, everything is good. • Thought the power surged because there seems to be power surges down there quite a bit. • It's a rural area and there's lots of windstorms and lots of trees and it seems like they have lots of problems with surges. • The contractor called the utility and asked them has there been any surges in the area today, they said no. • There was 120/240 [Volt] at the panel. Nothing was visually obvious. The contractor went and looked and everything inside the house is working correctly minus the stove clock was punched out. Checked [metered] every single point of anything they could check, line to ground, etc. • At that point the contractor didn't even think to look at the pole, because everything is metering properly, everything is safe and good. The contractor said to the owner, look at getting your stove fixed. • A system bonding jumper was removed [not in place in the panel] because the first breaker is at the pole, so there was no bond strap in the main panel. [indicative of single point neutral bonding, as expected for this configuration] **Feb 02, 2021 site visit** • There was a problem again, come back, now the surge protectors melted inside the panel. You can smell electrical burning. Start investigation, there was crazy voltage happening inside the panel. • Go to the meter base/disconnect at the pole, pop the bottom of the bank meter panel off, immediately can see that the neutral Allen lug hadn't been tightened up inside the meter base. • What the contractor came up with was, as the wind blew or that pole moved, briefly the house was losing the neutral. • It [The Allen lug barrel] was completely backed off, it's a 250 [diameter] feeder into the lug that's meant for 250, there's no room there, and the Allen lug was sticking out the whole way. The contractor got it from all the way out to tight, minimum 2 1/2 revolutions at least. [meaning the lug barrel had to be rotated 900 degrees to tighten it] **TSBC finding - Panel and SPD** There was no visual evidence that the fire started at the knife blade interface between the Square D SPD and the Eaton panel, rather the origin of the damage shows in the center of the SPD.
Causes and contributing factors	The cause of the incident was a loose termination in the meter base unit that caused an open neutral condition in the home. The open neutral condition resulted in intermittent over voltages that caused the MOV's to ignite in flames that melted through the SPD enclosure. The SPD's integral thermal cut off and current limiting fuses not opening in time to prevent damage to the MOV's was a contributing factor. The open neutral also caused the damage to various 120 Volt rated equipment.

Image 1 – Main panel board with smoke billowing out, SPD, and example SPD on right.

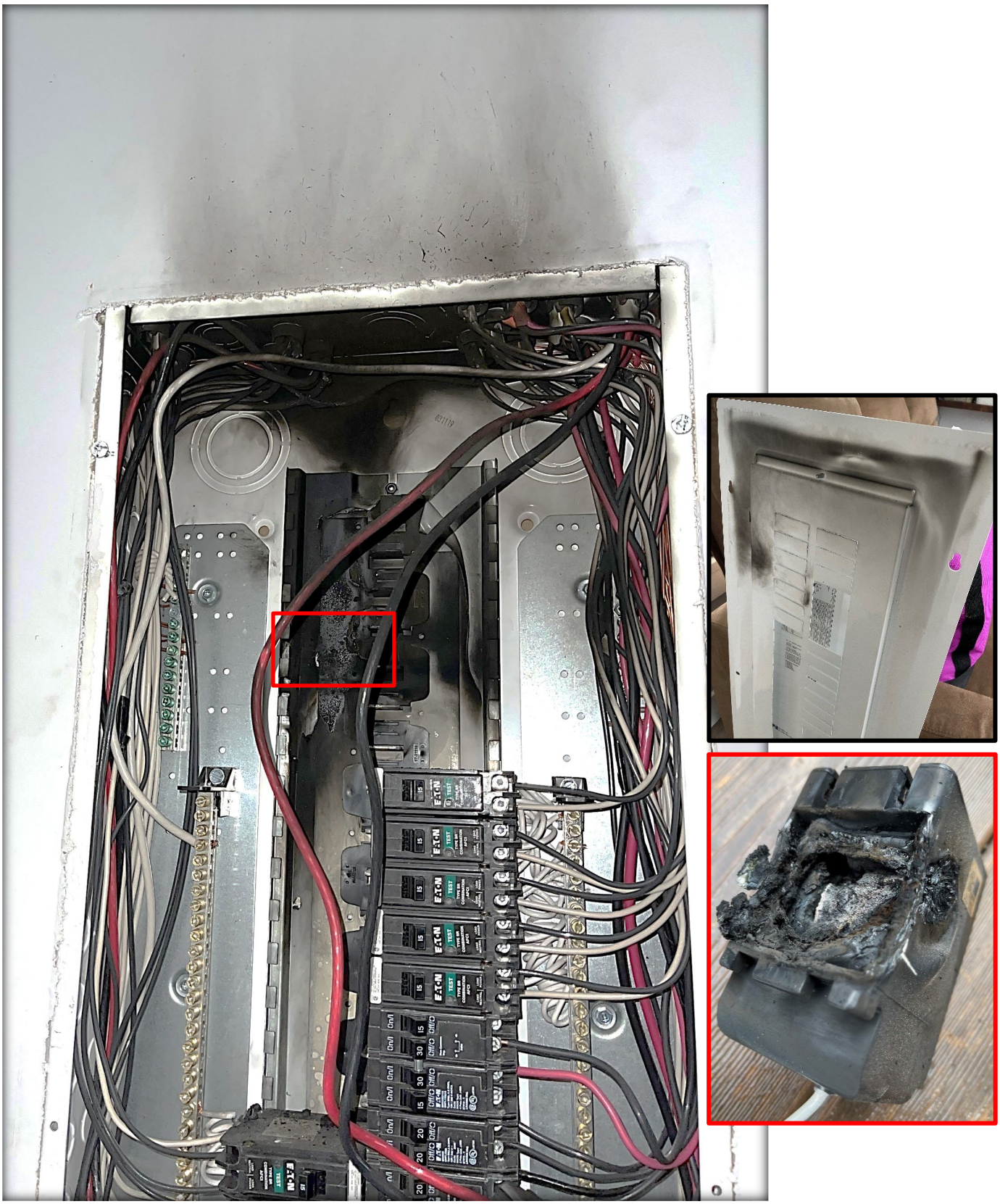

Image 2 – Burn and smoke damage to panel interior and wiring. Panel cover interior smoke damage (top right). SPD damage and panel interior damage behind SPD (red rectangles).

Image 3a,b,c – Supply transformer (blue rectangle), overhead supply line (blue arrows), and combination meter base with circuit breaker (orange rectangle).

Image 4 – Meter base combination unit example showing neutral termination location (red rectangle).

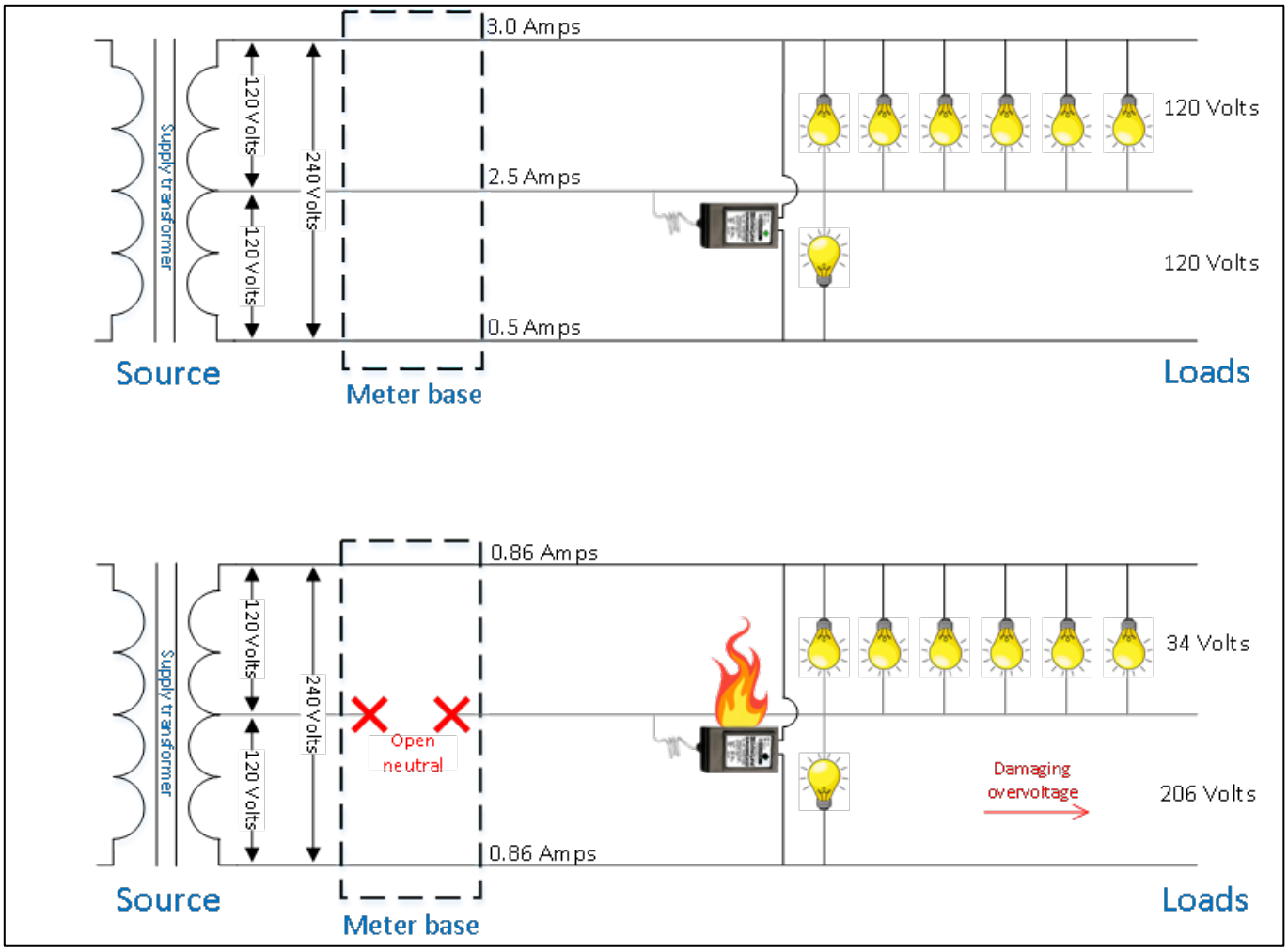

Image 5 – Comparison of the normal system circuitry to open neutral. Circuitry configuration, load types, load quantities, and current values used for example purposes and not based on site condition.

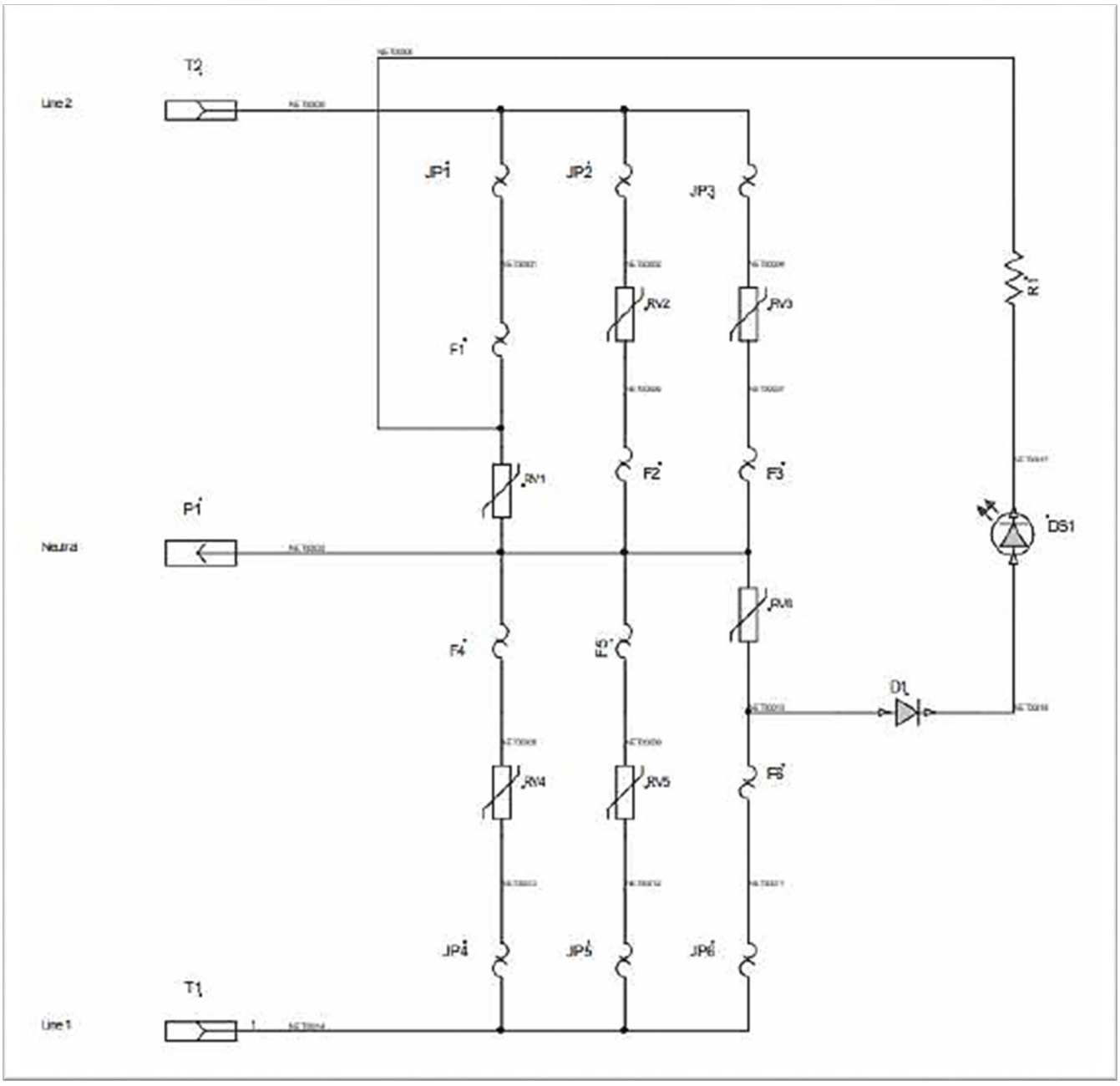

Image 6 – Schematic diagram showing the SPD device including the current limiting fuses (JP1-6), thermal cut-off fuses (F1-6), metal oxide varistors (RV1-6), and the indicating light circuit (D1, DS1, R1). The fuses in the SPD may not have tripped in this case due to lower levels of current, voltage, or temperature that were still able to degrade the MOV's until they failed.

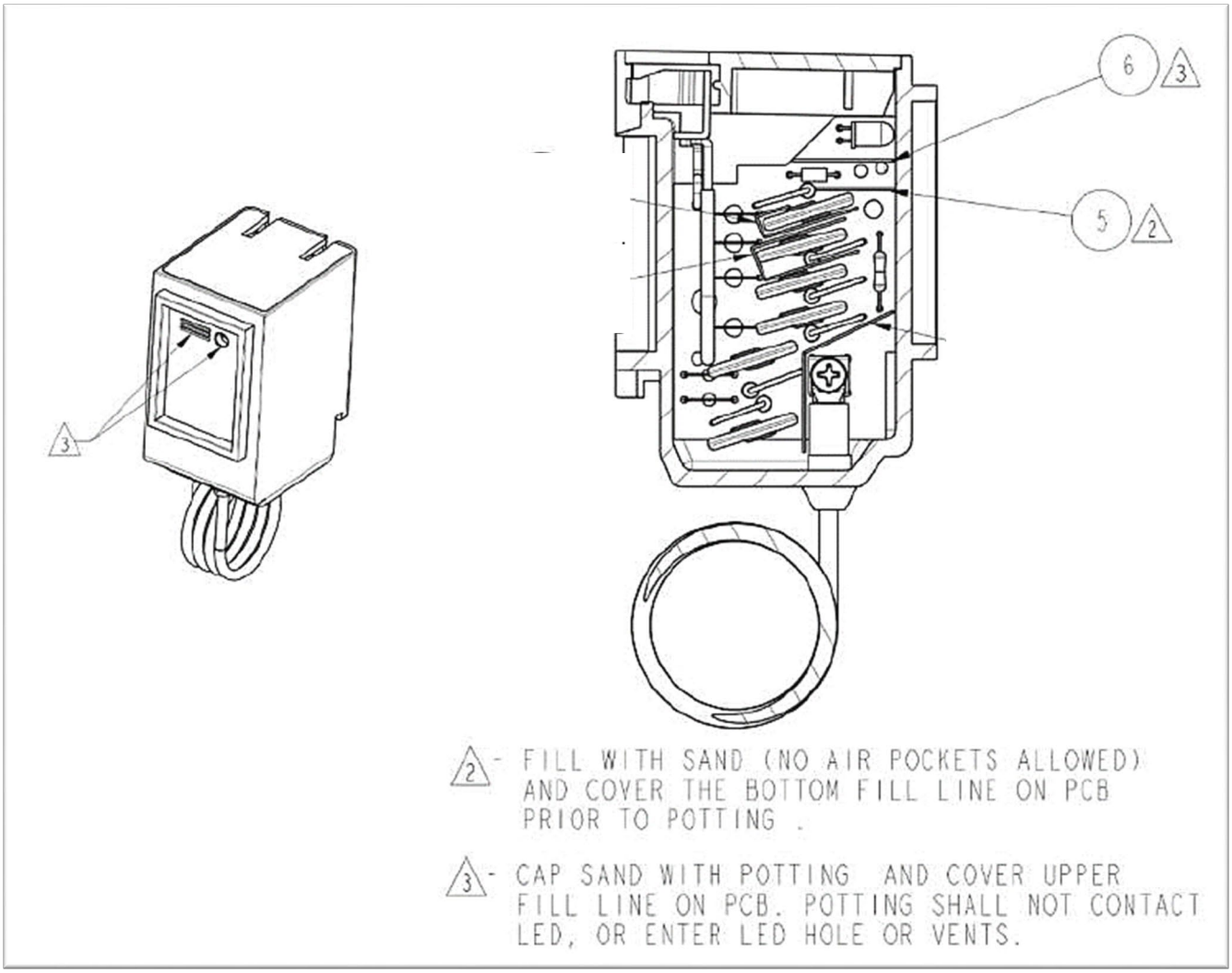

Image 7 – SPD detail drawing.