Performance Advantages and Disadvantages of Electromechanical and Solid-State Switches

Grant G Justice
Senior Research Metallurgist

Solid-state switches are entering high voltage and high current applications that were previously the exclusive domain of electromechanical switches. The additional design freedom offered by having two types of switches available with different performance characteristics is valuable to design engineers; this article will discuss some of the advantages and disadvantages of mechanical vs solid-state switches for applications at or above line voltages (>100 V).

Electromechanical switches are composed of an electromagnet that actuates a mechanical switch opening and closing electrical contacts. These switches contain moving mechanical parts that are subject to wear and contact tips that are subject to damage from the opening and closing arcs. Solid-state switches operate by changing a semiconductor between from an ‘off’ state (insulating) and an ‘on’ state (conducting) depending on the applied control voltage. This process is completely reversible and, under the right conditions, these switches can operate nearly forever.

Both electromechanical and solid-state switches have some operational consequences arising from their design. Electromechanical switches take time to open and close, frequently on the order of tens of milliseconds, and tend to work more easily with AC power, as it is easier to extinguish an AC arc compared to a DC arc[1]. Contrastingly, solid-state switches change state faster and work more easily with DC power due to inherent directionality of semiconductor junctions. When on, the solid-state switch will always have a voltage drop across the switch that is independent of the voltage applied and when off solid-state switches will leak a small amount of current, e.g. the circuit will never completely de-energize. Additionally, solid-state switches tend to have a lower breakdown voltage and higher internal resistance versus the contact resistance within electromechanical switch. The thermal rise associated with a solid-state switch is higher, necessitating a heatsink and results in faster derating with temperature when compared to an electromechanical switch. An example of the derating curve of a solid-state switch can be found in Figure 1. A general comparison between similar commercially available solid-state and electromechanical switches can be found below in Table 1. These switches were selected from in stock items sold by major online electronics retailers, at the time of publication the solid-state switch was more expensive vs the electromechanical switch.

Performance Advantages and Disadvantages of Electromechanical and Solid-State Switches

Continued from Page 1

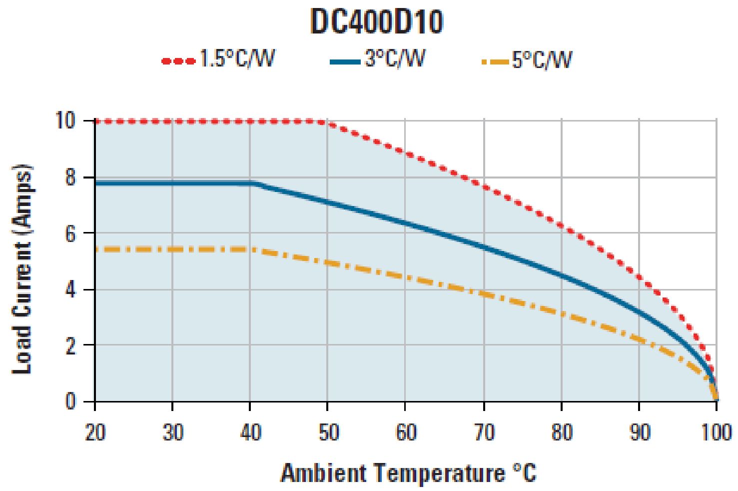

Figure 1: *Thermal derate curves for load capacity of the solid-state switch described in Table 1 at three heatsink sizes².*

Table 1: *Comparison of performance values for example solid-state and mechanical switches*

	Solid-state - Example² 10A 300V Switch	**Mechanical - Example³** 10A 250V Switch
Switch Size	2.25 x 1.75 x 0.89 inches	1.12 x 0.48 x 0.39 inches
Time to Open/Close	0.075 to 0.100 ms	5 to 10 ms
Leak Current	0.4 mA	0
Voltage Drop	1.55 V	0
Breakdown Voltage	3750 V	5000 V
Contact Resistance	0.155 Ω	0.100 Ω
Mechanical Life of Switch	N/A	10,000,000
Rated Electrical Switching Cycles	Infinite	50,000
Power Consumption of Control Signal - On	44 - 448 mW	240 mW
Max Temperature	100°C*	85°C*

**Does not account for thermal derating of switch, see Figure 1 for details for this solid-state switch.*

One of the largest differences between electromechanical and solid-state switches is the causes and consequences of switch failure. Electromechanical switches usually fail due to degradation of the contact points which results in an unacceptably high resistance up to the point of the circuit being permanently open. This is usually a gradual and predictable failure primarily driven by the number of switching cycles completed[1]. Solid-state switches on the other hand have no moving parts and have failure modes that are independent of switching cycles. Their main failure modes have to do with exceeding their rated voltage, current, or temperature resulting in a material breakdown causing the switch to fail closed and

Performance Advantages and Disadvantages of Electromechanical and Solid-State Switches

Continued from Page 2

energizing the circuit[4]. This tendency for solid-state switches to fail closed is often undesirable, as the unexpected energizing of a circuit can present safety and performance risks.

Electromechanical and solid-state switches have distinct performance differences making them suitable for different applications. An understanding of the fundamental differences of the two switches and engineering judgement is needed to understand what type or combination of switches is needed to provide a robust, safe and cost effective solution.

References:

1. Slade, Paul G., ed. Electrical contacts: principles and applications (2nd ed.). CRC press, 2017.

2. crydom, “Power Plus DC Series”.
   http://www.crydom.com/en/products/catalog/power-plus-dc-series-200-dc-panel-mount.pdf

3. OMRON, “G6RL PCB Power Relay”, https://omronfs.omron.com/en_US/ecb/products/pdf/en-g6rl.pdf

4. “Safety Precautions for Solid-State Relays” OMRON, 12 Dec 2021,
   www.ia.omron.com/product/cautions/18/safety_precautions.html