Reliability rules challenge infrastructure designers

Roger Tall outlines how component manufacturers are responding to changes in the oil and gas and rail industries

In the oil and gas (O&G) and rail industries the need to ensure high reliability is an everyday design challenge, but now more is being demanded from these systems and from the designers who develop them.

For O&G these challenges include working at higher temperatures and pressures. For the rail industry, the need to integrate more electronic systems into rolling stock means that the power supply and system complexity are becoming increasingly important.

Oil and gas – drilling deeper

With the exception of Norway, there has been a decline in the number of exploratory wells drilled for new sources of oil and gas throughout Europe.

Having reached a peak in 2008 with around 65 new wells in the UK, this number declined to just over 30 in 2013, according to the International Association of Oil & Gas Producers.

While there are certainly significant geo-political factors influencing this trend, on a purely technological level, the fact is that new off-shore and on-shore deposits are now simply harder to reach.

In a conventional high temperature, high pressure (HT/HP) drilling environment, the typical operating conditions at the bottom of the well would be pressures of up 69 MegaPascal (MPa) and temperatures up to 177°C. In the new extreme high temperature, high pressure (xHTHP) conditions the pressure at the well-bottom can reach up to 138MPa and temperatures up to 204°C, according to Kemet.

Component manufacturers have responded to this by developing ceramic capacitors which combine higher temperature ratings with the ability to withstand extreme levels of shock and vibration.

The latest radial ceramic capacitors based on the C0G and X7R dielectrics, for example, are now manufactured

Higher temperature ratings for ceramic and MnO_2 capacitors

with a rated operating temperature of up to 260°C. Between them, these two dielectrics cover a capacitance range from 5.6pF up to 5.6µF. However, the relative stability of the different dielectrics means that a C0G capacitor may effectively provide the same volumetric capacitance as an equivalent X7R device at higher temperatures.

Previous tests on the comparative high-temperature performance of X7R and C0G ceramic capacitors have focused on operation over the standard military temperature range of -55°C to 125°C. When repeated at temperatures up to 250°C, these tests reveal a significant drop-off in capacitance for the X7R dielectric.

At 125°C, the capacitance falls by around 15%, while at 250°C the reduction in capacitance is over 50%. In comparison, the stability of a high-temperature C0G capacitor, measured as a temperature coefficient of capacitance (TCC), remains at 1% right up to 250°C (*Figure 1*).

The high level of stability over temperature also means that high-temperature C0G capacitors can help to provide the necessary stability for accurate control or measurement in down-hole and horizontally-drilled fracking applications.

While an X7R capacitor may be specified at a higher initial capacitance, this will be degraded at high temperature. A C0G capacitor with a lower initial capacitance could therefore deliver a comparable or higher capacitance per unit volume at temperatures over 125°C.

However, ceramic capacitors are not the only passives which are raising the threshold for high-temperature operation. The latest surface-mount manganese dioxide (MnO_2) tantalum capacitors are now also rated for operation at up to 175ºC, 200ºC or 230ºC.

Hybrid component manufacturers are also responding to the demands of down-hole applications with packaging technology that supports high temperature operation and high reliability, including compact multi-chip modules (MCMs) manufactured in high temperature co-fired ceramic (HTCC) which have been qualified for operation at over 200ºC.

In addition to robust passives, some bare semiconductor dies are rated for periods of up to five years at 230ºC, or extended periods at lower temperatures.

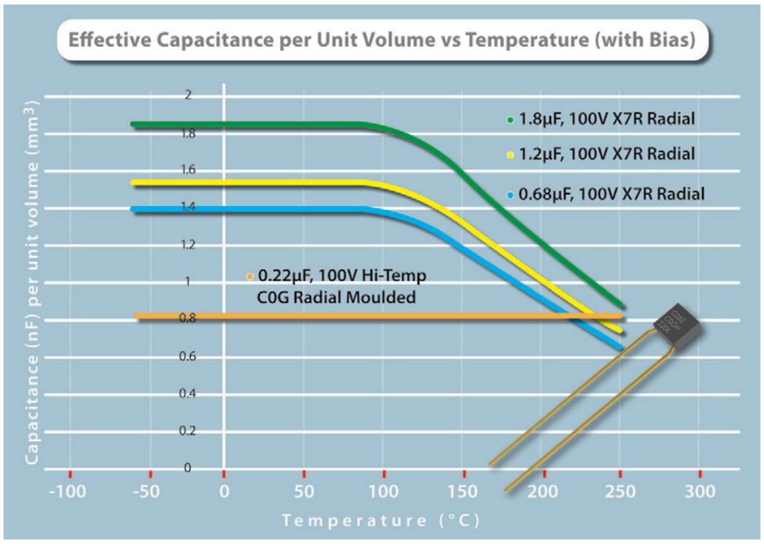

Figure 1: Capacitance per unit volume at maximum rated voltage

Rail – complex power and protection

Rail is facing different design challenges. As the number of the electronic systems increases, so the complexity of powering and protecting them is increased.

The flexibility to configure standard devices, or to use fully custom components, can help to address both of these issues. A custom resistor, for example, is being used as part of the voltage measurement system in a pantograph which draws power from the overhead lines.

The customised features of the resistor include tight control of the length and number of spiral turns and the use of opposing spirals on the resistor body. This enables the device to withstand surges of 125kV and to provide additional protection by suppressing magnetic interference from high line currents.

Customisation can also help to simplify the design of the power supplies for electronic systems in rolling stock. Most have an on-board power supply that is typically rated at 110V in the UK. This supply is then converted down to 12V or 24V, depending on the power required for each subsystem.

The ability to configure key parameters of a DC-DC converter, or to use a completely custom supply, can help to minimise the complexity of powering multiple electronic systems with different voltages. The integration of filtering circuits in some DC-DC converters adds the ability to save board-space by eliminating the need for external filtering components.

An alternative option for powering auxiliary systems on-board or at the trackside is to take power from the third rail. This requires a DC-DC converter which can operate over a very wide input voltage range of 400Vdc-1,100Vdc. This allows the power supplied by the third rail, at 600Vdc or 750Vdc, to be converted down to the 24V required by rolling stock or trackside systems.

Other components which enable cost-effective customisation despite the low production volumes which are typical in the rail market include inductors, transformers and circuit breakers.

Custom magnetic devices can help to achieve a reduction in system size for AC-DC and DC-DC applications, in addition to withstanding high levels of shock, vibration and temperature. The customised circuit breakers provide the flexibility to configure a range of parameters such as the number of circuits to be protected, the current ratings and load type, as well as the trip response time and optional auxiliary contacts or shunt trips.

These examples, and more, show how component manufacturers are responding to new demands within O&G and rail applications for products that operate at higher temperatures and provide easy customisation in addition to withstanding harsh operating environments.

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Customisation helps to reduce system complexity