Electromobility or the power of **transportation**

Mark Snook believes that the rail industry, far from being conservative, is embracing significant changes in power electronics technology

The power electronics industry, more than many, is considered a conservative one and none more so than in locomotive traction market. Of course the reasons for this cautious innovation cycle are clear – the consequences of adoption of new technologies before they are mature are severe. A locomotive that suffers a failure of any description has to be able to continue its journey despite that failure; systems must be able to "limp home" as a minimum – a broken down train on the line has intolerable consequences.

However, perhaps we can be too quick to judge – looking a little further, it's apparent that this industry has indeed progressed quite significantly within the last 10 -20 years. Historically, this progress in power electronics technology has been mainly driven by the introduction of successive generations of gate-controlled power switches beginning with bipolar junction transistors (BJTs), followed by MOSFETs and more recently, an industry dominated by insulated gate bipolar transistors (IGBTs). These switches have gradually taken over more and more of the applications and power ratings previously dominated by silicon controlled rectifiers (SCRs) and gate turnoff thyristors (GTOs).

When we look on a global scale, the architecture of the electric rail propulsion systems evolved quite differently in various parts of the world, and these variations are still apparent in today's transport systems. In particular, pre-2000, rail systems here in Europe as well as in Japan took the form of catenary supply systems, where we saw electric power supplied to the locomotive propulsion drives via overhead transmission lines. Today, AC adjustable-frequency rail propulsion equipment increasingly dominates new production for both light-rail (urban) and heavy-rail (intercity) traction systems around the world. Nevertheless, large population of locomotives still running on commutator machines prevail in many parts of the world today, and they are expected to remain in use for years to come.

In contrast to conventional transistors, IGBTs operate at very high currents in excess of 1000 Amps. The principle benefit we see with IGBTs compared to GTOs, is a higher switching frequency, with the consequent reduction in filter size, leading to smaller, lighter units with reduced noise.

These advances have made it possible to significantly improve the electrical performance of traction converters whilst simultaneously reducing their size and weight and cost. In 2012 these priorities are still at the forefront of the mind of suppliers into the transportation market.

Component sourcing

From the perspective of the current locomotive traction players, manufacturers can either design their own components, or source from the open market. Traditionally the gate drive unit (GDU), which drives each IGBT module, is considered fundamental to the reliability of the overall system. Manufacturers have crafted their gate drives and in many cases offer features not found in commercially available alternatives. However, there is a cost associated with the time and skill that goes into the custom crafting, and due to the relatively modest volumes, custom electronics can be prohibitively expensive.

With an emphasis on reliability, manufacturers are reluctant to change a working design, especially where there is a proven track record. Recent developments include adding additional monitoring capability to the GDU, and interest in 'Black Box' approaches to capture the switch activity in the lead up to a failure. This ability to monitor switch behaviour and device failure enables the gate drive manufacturer and IGBT module vendor to get feedback, essential to increasing reliability in the long term. And the inverse situation gives no visibility on the mode of failure with only three states available – on, off, or fault.

This, however, appears to be as far as the conversation about progress is willing to go, any further discussions are generally met with apprehension and reluctance to embrace ideas that the industry sees as radical and potentially unreliable.

The industry has already experienced difficulties and challenges associated with migrating from GTOs to IGBTs in traction/transportation convertors to achieve the higher switching frequencies and lower losses. Having to accommodate different failure rates with this product was not easy, but the industry adapted, and IGBT technology has been improved over time with good thermal cycling and better manufacturing processes. There is, unfortunately, a stand-off that seems to have been reached with resistance towards more sophisticated gate drive complexity to achieve the gains in size, weight and cost; the concept is treated with caution due to the perceived risk of reduced reliability.

Understanding the industry

The key to gaining entry in an established industry such as locomotive traction is to understand those challenges, acknowledge the limitations of your current technology, and work hard to create a roadmap to offers more value. Amantys began this process in 2011, with the launch of its first product, the Amantys Power Drive, a drop in replacement for similar gate drive products in the market, but with enhancements that deliver a number of benefits.

Capable of driving a range of IGBT modules without gate resistor changes, the newly launched Power Drive was able to reduce inventory for users who wanted flexibility in design and sourcing, and it helped to simplify the process for design engineers.

The GDU drives 3300V IGBT modules from the likes of Infineon, Mitsubishi, ABB and Hitachi. Supporting modules up to 1500A, the Power Drive is suitable for use in 2- and 3-level topologies and includes an integrated DC-DC converter. The 8W power block achieves excellent power density, even at the full industrial temperatures. The compact design sits within the power module dimensions to give a more robust design and a smaller footprint. The Power Drive is compatible with commercial alternatives that provide the same power and fibre-optic interface, and meets the rugged industrial and pollution standards demanded of the traction market.

The benefits of this type of gate drive for the locomotive traction market are clear. With a comprehensive testing programme, the low component count design ensures high reliability.

Most importantly, GDUs for this application need to meet traction and industrial safety standards and partial discharge expectations. The requirement for 3.3kV working voltage isolation is expected as standard, and the Power Drive is tested to 14kV. The industrial temperature range is -40°C to +85°C with products having to withstand 15 minutes at +85° for a baseline standard. However to ensure long lifetime, products are typically tested well beyond this temperature for periods of months rather than minutes.

The locomotive traction market will continue to ask more of our designs and demand further savings, but the monitoring and control aspects for locomotive traction will be critical. We, as a power electronics community, need to encourage engagement between component vendors and equipment manufacturers and support discussions surrounding future developments of power converters and what new technology can offer the industry. The industry must be willing to interact with those who plan to look outside the box, defining new building blocks and improved interfaces. It's now time for the next stage of development and to see what the power of transportation can achieve.

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