Keeping the Trains on Track

Innovators collaborate to upgrade existing locomotives to state of the art insulated gate bipolar transistor (IGBT) modules with Amantys power insight™ performance monitoring

By Amantys® and EMEF

The challenge facing many train operator and maintenance companies today is how to keep ageing electric locomotives available cost effectively for operations as they reach the end of their operational life. Economic circumstances dictate that budgets are not available for capital expenditure on new locomotives, and moreover, that locomotives must be maintained at lower operational cost.

The further challenge facing networks in Portugal with some locomotives in the fleet is that the 2300/2400 Series EMU from CP Lisbon operations have been in service for twenty years, and the traction converter itself is based on now dated Gate Turn Off Thyristors (GTOs); these in turn are heading for end of life in the supply chain, exacerbating the reliability, efficiency and operating costs of the trains.

In any normal situation, this would be an intractable set of circumstances, but in this case, EMEF (Empresa de Manutenção de Equipamento Ferroviário, S.A) in collaboration with Amantys Ltd may have a solution. EMEF have primary responsibility for Portuguese railway maintenance and have developed "Lusogate" – a modular solution to upgrade and renew the locomotive traction system, and monitoring train performance and maintenance needs in real-time.

In collaboration with Amantys their drive module now uses newer, energy efficient Dynex DMOS+ (d2) 4,500V IGBT Modules, with power switching controlled and monitored through Amantys Power InsightTM. The combination of these IGBT Modules and Amantys Power DrivesTM returns ageing locomotives to the forefront of power switching efficiency.

Figure 1: The Siemens 2400 Series EMU introduced in 1992 are targeted for power converter upgrade to extend track life and reliability

The train operator challenge

The pressure to reduce CO2 emissions, to lower maintenance costs, and to increase availability of locomotives in today's economic situation add up to big challenge for train operator and the maintenance companies.

The 2300/2400 series fleet uses power modules based on GTO based traction converters; the maintenance regime is increasing in complexity due to several factors such as the security of supply of replacement GTO power semiconductors, and the difficulty in sourcing replacement driver cards or repairing existing driver cards.

GTOs are problematical due to the higher harmonic generation and higher losses compared to IGBT modules which offer an immediate improvement in power efficiency in the traction converter. The GTO traction converter also uses a chemical cooling fluid which is difficult to handle in use and maintenance, and environmentally challenging when it comes to disposal.

EMEF solution

EMEF are an innovative railway maintenance company, transforming operational practice from schedule-based maintenance to Reliability Centred Maintenance (RCM); in simple terms - maintain the equipment when it shows the need. The company has developed Lusogate to upgrade the traction converter with IGBT Modules in an air cooled system, eliminating the need for chemical coolants, and providing an information gateway to the train management system.

The use of IGBT Modules opens up sourcing options with several manufacturers offering equivalent - and current - products; IGBT gate drivers from Amantys can be configured to drive different supplier's modules, so there's a much greater security and flexibility of supply.

EMEF has implemented a condition based maintenance (CBM) regime on the fleet of locomotives that has resulted in a significant improvement in the track availability of the locomotives whilst reducing the maintenance costs. With the integration of Amantys Power Insight into Lusogate, EMEF is extending the condition based maintenance regime into the traction converter.

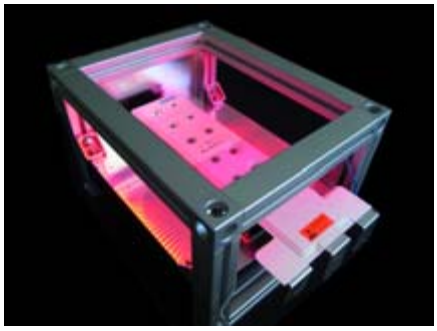

Figure 2: EMEF IGBT Replacement Module

The locomotive can now generate reports from the train management system that prioritise tasks for the maintenance crews and highlight train systems that are deteriorating. The system looks for deviations and trends from normal operation.

Amantys igbt driver solution

Amantys develops power switching technology primarily aimed at the IGBT market, and offers Amantys Power InsightTM - a unique condition monitoring functionality built into their IGBT gate drivers.

One of the key differentiators for Amantys was the use of more intelligence in the power switching process to improve optimisations and provide the ability to export condition monitoring data from the heart of the power switching process, a software and hardware sub-system known as Amantys Power Insight. Their range of IGBT gate drivers incorporates the ability to monitor six key parameters around the IGBT and export the information over the existing fibre optic links. Historically it has been very challenging to export meaningful readings across the high voltage isolation barrier, but the breakthrough at Amantys solves this problem. The use of Amantys Power Insight over the existing fibre optic links also minimises cost and complexity associated with the technology.

Amantys worked with EMEF to export the condition monitoring data from the gate drives into the Lusogate interface and then into the train management system. In the 2300/2400 series EMU there are twenty four

IGBTs in the upgrade all of which can be monitored by the system.
The Amantys Power Drive with Power Insight can monitor the gate drive temperature, the collector to emitter voltage in both the on and the off state, the gate emitter voltage in both the on and the off state and the power supply voltage on the gate drive. In addition to this the Power Drive can log data about the driver for example, the number of switching cycles, the type and number of short circuit events and the number of clamp events. The data log information can also be exported to give an indication of the historical operating environment of the IGBT.

The target IGBT for the GTO to IGBT upgrade is a 4,500V IGBT from Dynex Semiconductor for which Amantys has developed an Amantys Power Drive with the Power Insight technology.

Figure 3: Power Insight-enabled Amantys Power Drive

System implementation
The system design for the GTO to IGBT upgrade involves replacing tem GTO modules with an IGBT phase leg that has an upper and a lower IGBT. The IGBTs are mounted on an air cooled heat sink. The bus bar arrangement has been redesigned to connect to the IGBTs but leave the connections to the rest of the train power system in the same place. The drive module upgrade is simplicity itself, replacing the existing block with the new design, slotting into the same physical space of the old one.
The existing traction converter control signals are interpreted by the Lusogate interface and re-timed to drive the IGBTs via the Amantys Power Drive. Each Lusogate interface receives data from the Power Drives and transmits the information over a local Ethernet network implemented over plastic optical fibre.
During the initial testing the Amantys and EMEF teams used the Amantys Power Insight Adapter to interface the Power Insight data to a personal computer. The Power Insight Adapter was very valuable in debugging and gaining confidence in the data prior to integration into the Lusogate system.

Figure 4: Configuration of replacement IGBT modules and how they are mounted in the locomotive

Initial trials with the system driving a traction motor have shown that the quality of the measurements is reliable in what could be a very electrically noisy environment. Initially the condition monitoring data will be interpreted offline from the train management system prior to full integration in operation.

System trials
The requirements for running an upgraded train on the existing network are very strict as the new technology cannot be allowed to introduce noise and perturbations onto the overhead power lines. The locomotive will undergo a series of static and dynamic testing to measure the harmonics and perturbations introduced onto the overhead lines, as well as electromagnetic emissions. Throughout the field trail the Amantys Power Drives will stream data from the traction converter to the train management system.
The condition monitoring data from the IGBT modules will be analysed to look for long term variations in the parameters that are being monitored, IGBT to IGBT variances and phase leg to phase leg variances. Figure (Y) shows a simple example of the temperature monitoring functionality in the condition monitoring system.
The replacement modules are now air cooled so there is expected to be a variation in the temperature of the modules as the train is in operation. The variation will be due to the climatic conditions and the operational load of the train during service. Large or sudden variations to the temperature could indicate early signs of failure in the IGBT or debris accumulating under the train. The condition based monitoring system can provide a warning to the train management system so that the maintenance crew can investigate.
Using the Amantys Power insight technology in combination with the Lusogate technology will enable the condition based methodology for maintenance to be applied to other parameters in the traction converter.

Delivering results
A successful collaboration between Amantys and EMEF has provided an innovative technology upgrade that delivers real benefits for the train operators. Using EMEF's Lusogate technology and Amantys Power Insight, the system is more efficient and environmentally friendly, whilst costing less to run with condition based maintenance.

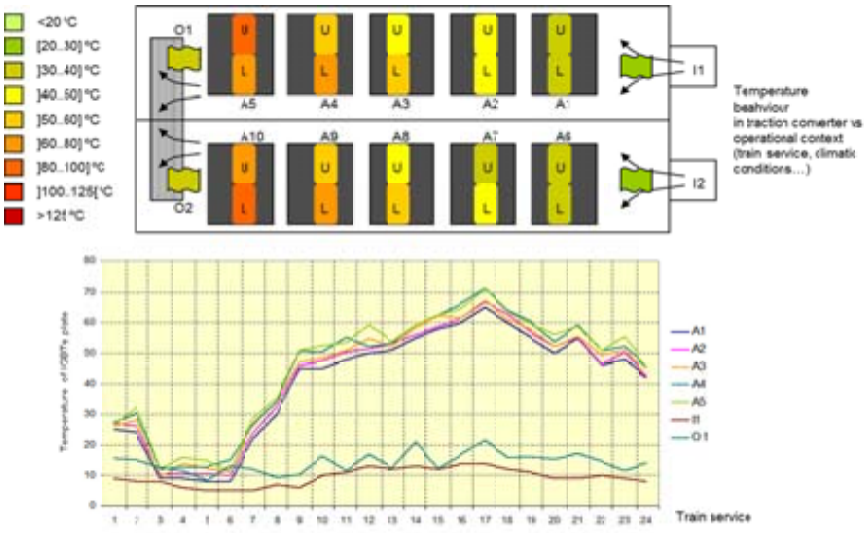

Figure 5: Temperature monitoring example in the IGBT modules

The train operator and the maintenance company gets the benefit of locomotives with improved availability and an extended lifetime thus deferring the point at which new capital expenditure is required.

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