Power Converter Retrofit Solutions

Obsolescence of key components, such as IGBT modules, can cause serious problems for the train operator. AmePower and Amantys Power Electronics Ltd have collaborated on a project to cost effectively upgrade the traction converter to use more modern components and protect against future obsolescence.

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Introduction

Train operating companies require their assets to have a long lifetime of at least 20 years. During the 20 year life of an electronic component assembly the part may wear out, suffer supply chain problems or become obsolete. Usually at the time spare parts are required, they are no longer available or become prohibitively expensive to source.

Upgrading high power converters is usually considered to be something that only the original equipment manufacturer (OEM) can undertake. However, AmePower and Amantys Power Electronics Limited have collaborated on a project to upgrade the IGBT modules and the gate drives in a traction converter to provide a cost effective solution for the operating and maintenance department of the train operator.

Degradation in IGBT Modules

IGBT modules are commonly used in power converters for traction applications. As the IGBT modules reach the end of their life they can degrade due to effect such as:

- the bond wires lifting off the semiconductor die and breaking the connections inside the module
- the propagation of cracks under the ceramic substrate or under the semiconductor die causing the power semiconductor to overheat.

Bond wire lift off and solder cracking are caused by the repeated heating and cooling of the power semiconductor die as the train accelerates and decelerates in service. Solder cracking under the die and the ceramic substrates increases the thermal resistance of the IGBT module leading to the power semiconductor to over heat and ultimately fail. Figure (1) shows an example of a failed IGBT module. The failure in this case was catastrophic and as well as destroying the IGBT module, there can also be a high degree of collateral damage in the converter.

Figure [1] – Example of a failed IGBT

These failure mechanisms are caused by repeated stress on the IGBT module and since they are cumulative, are more common towards the end of life of the converter.

The challenge

After 15 to 20 years of service the challenge of sourcing replacement IGBT modules and gate drivers can become a major problem for the maintenance department and the train operating company, directly impacting the maintenance cost and the availability of trains for revenue generating service.

The traction converter is an area that traditionally is viewed as requiring a high degree of knowledge and skill to maintain and upgrade. However, as the project has shown this is not necessarily a barrier to upgrading the power converter.

The retrofit solution for the traction converter needs to work with the existing power stack configuration; for example, the heat sink, bus bars, capacitors and the central controller will all stay in place. The practical implications of this are:

- The stray inductance (Ls) in the converter will be fixed;

- A newer, faster switching IGBT module compared to the original, coupled with the fixed stray inductance (Ls), may generate a large voltage overshoot that can damage the IGBT module;
- The central controller may have a proprietary protocol to communicate with gate drives;
- The thermal management of the converter will be fixed so any retrofit solution will need to work within the existing thermal envelope of the converter, i.e. result in no greater loss;
- The mechanical arrangement of the gate drive within the converter is fixed.

The challenge therefore is to provide a solution that will work within these constraints and still provide a reliable and cost effective solution.

The solution

Amantys Power Electronics Limited has been working on intelligent gate drives that can be configured by the manufacturer or the end user. The configuration of the gate drive is typically used to enable optimization of the electrical characteristics of the gate drive and the IGBT module to achieve the lowest switching losses in the target power stack for the constraints of stray inductance and voltage overshoot allowable.

In the case of a retrofit application the configurability of the gate drive can now be used to configure the gate drive to switch a modern IGBT module with similar switching characteristics as the original IGBT module. Amantys has provided a software tool, shown in Figure (2), which makes the process of configuration easier.

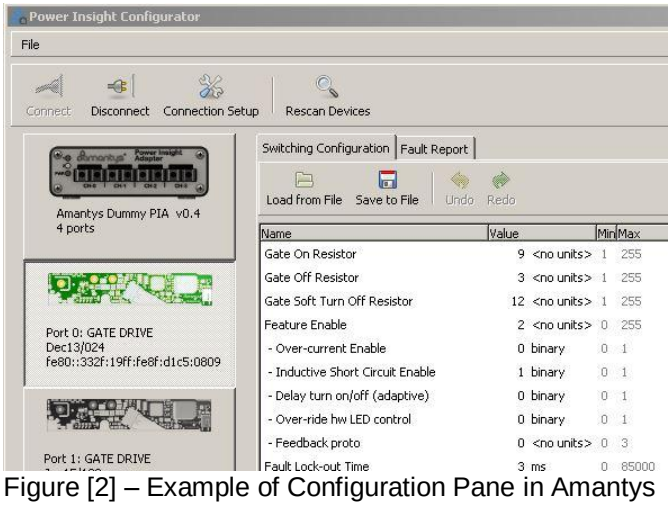

Figure [2] – Example of Configuration Pane in Amantys Power Insight Configurator

Control of the overshoot can be achieved by configuring the gate resistor on the gate drive to turn the IGBT module off with a similar dI_C/dt as the original. It may also be necessary to adjust the turn on resistor to limit the diode reverse recovery peak power so that the freewheel diode remains within its RBSOA curve.

Amantys gate drives have the capability to configure separately the turn on, turn off and soft turn off gate resistors.

Amantys gate drives have been engineered so that the protocol on the fibre link can be configured to match the original protocol between the central controller and the original gate drive. This greatly simplifies the process on integrating the replacement gate drive into the converter. The process of evaluating and configuring the new gate driver can be completed in several days.

AmePower and Amantys Power Electronics Limited collaborated on the electrical and mechanical configuration of the gate drive to ensure that replacement IGBT modules would operate reliably in an existing converter. Figure (3) shows the Amantys gate drive mounted on an adapter board to make a drop in replacement for the existing gate drive.

Figure [3] – Amantys Gate Drive Adapted for legacy traction converter

Field Testing

The train operator retrofitted ten trains with replacement gate drives and IGBT modules. The trains were placed into revenue generating service for a 12 month field trial.

At the end of the field trial the gate drive and the IGBT module were inspected for any signs of degradation. No signs of degradation were detected.

For the duration of the field trial no faults were noted on the retrofitted traction converters. In some cases traction converters that had previously been a problem moved from multiple warnings per week before retrofitting to no warnings for the whole duration of the field trial.

The optimization of the gate drive also resulted in reduced losses compared with the original converter design. During operation the average temperature of the heat sink was reduced by 10°C. The reduction in the heat sink temperature allowed the converter to work with the existing cooling system and will have a direct impact on extending the lifetime of the converter.

Additional Benefits

The inclusion of more modern IGBT modules and gate drives in the traction converter also had additional benefits that were not foreseen at the start of the project. For example, Amantys introduced a new software tool called the Power Insight Configurator [See "User Configurable Gate Drives" Bodo's Power Systems May 2016] that makes the process of configuring the gate drive much easier. In future, the maintenance department would be able to configure the gate drives. This is an advantage if the IGBT module was made obsolete again and an alternative needed to be sourced for a second time.

A feature of Amantys gate drives is that all of the faults that the gate drive sees during its lifetime are recorded on the gate drive. The maintenance department requested the ability to view these faults at maintenance intervals so that the information could be used to track unusual operation, which may in some cases relate to the health of the converter. Figure (4) shows an example of the fault reports that can be read from the gate drive during a maintenance interval.

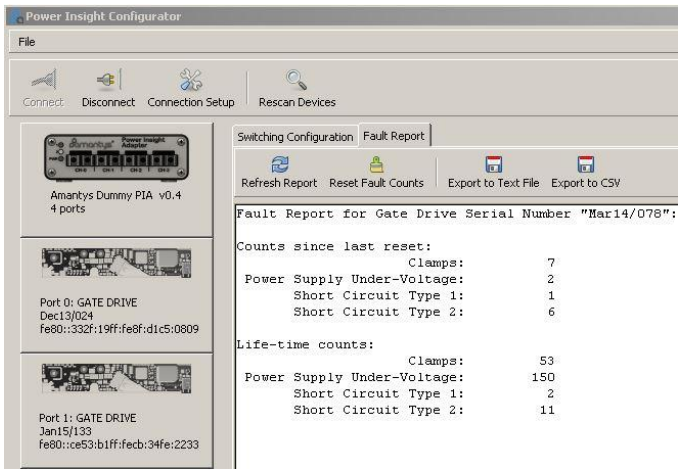

Figure [4] – Example of Fault Reporting in Amantys Power Insight Configurator

Conclusion

Traction converters can be retrofitted cost effectively, saving the train operator money when trying to source end of life or near obsolete components.

The inclusion of newer IGBT technology and optimization of the switching performance of the IGBT module has reduced the overall operating temperature of the power converter, saving power and extending the lifetime of the converter.

The security of supply is improved as newer IGBT modules can be sourced and incorporated into a legacy traction converter and the gate drive configuration process can be repeated if necessary.

Advantage can be taken of new IGBT technology and new features that are made available in gate drives. In the study cited, the inclusion of the fault counters into regular maintenance reports can improve the quality of information to the maintenance teams to identify converters that may have problems. The additional information can be included into a condition based maintenance programme to maximize the availability of the trains.

The additional benefits of the project were that the operating and maintenance company reported a reduction in the number of erroneous faults that required investigation. Previously these faults had required the train to be removed from service in order to investigate the faults, directly reducing the availability of the train for revenue generating service.

The use of new gate drive and IGBT technology offers the operating an maintenance company a real alternative to purchasing a new traction converter or train.