Singaporean retractioning project pays dividends

Singapore's SMRT Trains is the first metro operator outside of Japan to adopt Toshiba's permanent magnet synchronous motor (PMSM) propulsion system for metro trains. Kevin Smith visited its Bishan depot to find out more about the retrofit project currently underway on C151 trains, and Railise the company now marketing the system outside of Japan.

SINGAPORE's inaugural North-South and East-West metro lines opened in stages between November 1987 and July 1990 and were initially served by a fleet of 66 six-car C151 trains supplied by Kawasaki Heavy Industries (KHI).

By 2010, 23 years since the opening of the network, Singapore's metro had grown rapidly to 170.7km of track and four lines. With further ambitious expansion on the agenda, a project was initiated to investigate the viability of refurbishing the first-generation trains, including replacing their propulsion system.

"The trains were approaching the end of their expected 30-year design life so we commenced a project to look at the carbody structure of the train and to determine whether it would last beyond this," says Mr Ng Peng Hoe, principal fellow at SMRT's rolling stock engineering centre. "The finite element analysis was conducted and found that the carbody structures were sound for another 30 years."

With consultant TUV recommending replacement of the bogie frame, attention then shifted to the traction system. The original dc motor system was now obsolete so it was concluded that an upgrade would be required, but according to Ng rather than following usual practice and upgrading to another system based on induction motors, which were first developed in the mid-1990s, a more forward-looking approach was taken.

"Induction motors have had a 20-year life history so we wanted to look at the latest technology and the next-generation of traction motors for our project," Ng says. "We found Toshiba's permanent magnet synchronous motor (PMSM) propulsion system, which promised advanced energy savings over our existing system. We subsequently went to Japan and visited the Marunouchi Line on Tokyo metro, one of the first adopters of PMSM. We visited the line and the depot, and found the system met our requirements. I was impressed with its performance and it was at this point that we initiated more detailed discussions."

Key features

The completely-enclosed motor, and its simple design, are key features of the PMSM motor. While similar in size to other traction motors, it is much lighter and has fewer moving parts than dc motors such as a commutator and ventilation fans which are absent due to the use of natural cooling. This simplicity also means that it is straightforward to maintain. The unit is sealed, meaning that dust cannot penetrate the motor or compromise the magnets, with a straightforward bearing replacement the only maintenance operation required after eight years in service.

Due to the use of permanent magnets rather than copper windings in the rotor, PMSM also promises significant energy savings compared with the dc system by reducing conductive losses in

Toshiba's PMSM motor for SMRT's C151 trains.

Installation of the PMSM system on a third C151 set is underway, and work on a fourth is expected to start in October.

the rotor. It also offers higher utilisation of regenerative braking, ideal for metro operations. Indeed, while the existing motor offers efficiency of 88-90%, PMSM promises 97% efficiency. In addition, simulations and tests on SMRT's test track at the Bishan depot demonstrated that this improved regenerative braking performance would enable the system to offer a 32.8% energy saving compared with the existing dc system.

With SMRT convinced by Toshiba's PMSM after comparing it with other traction systems available on the market, an on-board trial was initiated on two C151 trains under a contract agreed with Toshiba in July 2013. The trial would identify whether the system could meet three key performance indicators (KPIs): deliver energy savings of at least 30% compared with the current system; a noise reduction of at least 12dB; and the completion of a six-car train recovery during an emergency operations test.

"We conducted two trials, one to compare with our existing dc system, and another to compare the two trial trains," Ng says. "We were looking for consistencies between the two trains, and if we approved the system, we planned to install it on the remaining 64 trains in the C151 fleet."

The main equipment supplied for the C151 project consists of a traction inverter, a high-speed circuit breaker, a filter reactor, and the PMSM motor. The design of the PMSM system for the two trial C151 trains was subsequently approved in April 2014, with manufacturing and interfacing continuing until October 2014 when the system was shipped to Singapore and installed in December that year.

Testing then proceeded, beginning with type tests on SMRT's test track between February and April 2015, followed by compatibility tests with Siemens automatic train operation systems, before main line tests in June and July 2015 and the successful completion of a 12-car push out rescue test. From July 30 the two trains entered revenue service.

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Performance

By December 2015 Ng says that each of the three KPIs had been achieved, and with no in-service failures reported, SMRT was suitably convinced with the system's performance and instructed Toshiba to proceed with the contract for the remaining 64 C151 trains. "Since September 30 2015, the trains were operating on the North-South and East-West lines, and on-board energy measurement tests carried out on the main line on December 7-11 achieved an average energy saving of 38.6%," Ng says. "This was even better than the 32.81% achieved during tests."

The contract for the full-fleet rollout was subsequently awarded in January 2016, and with installation on the next set underway, Ng says this will be

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followed by another train in October at which point the rollout will become more regular. "Initially we will complete installation of one train per month for the first three trains, before increasing installations to two trains per month," Ng says. "The aim is to complete the project by December 2019 and we are on schedule."

Toshiba is working with Japan Transport Engineering Company (Jtrec) to integrate the PMSM system on the trains, continuing a partnership that began with the first installation of PMSM in 2014.

However, Singapore's second contract for PMSM for the mid-life refurbishment of the C651 Siemens trains, which was awarded in March 2015, is the responsibility of a new company: Railise.

Despite widespread adoption in Japan - three different versions of PMSM are now in service on 61 trains and one locomotive with four further projects for another 64 trains underway - SMRT is Toshiba's first international customer. According to Mr Mario Favaits, SRE's managing director, SRE felt that it could assist Toshiba with marketing the system outside of Japan to realise its obvious potential in overseas markets.

Railise was subsequently founded in September 2014 as a 50:50 joint venture between the two companies, which would hold the license to sell, deliver and integrate the PMSM solution in rolling stock refurbishment projects outside of Japan.

"The idea is that Railise will market PMSM to operators through the joint venture, which as a sister company of an operator, will be in a better position to sell the system than a usual vendor," Favaits says. "Instead of pushing the system to a car builder, which then has to meet the operator's requirements in a tender, which often does not focus on reliability or life cycle costs but the upfront cost of the system, we can go to the operator and sell the benefits of PMSM directly to them."

With interest in PMSM from New York City Transit (NYCT) and Melbourne Metro, already Railise appears to be opening doors for the system. And with SMRT set to benefit from significant savings in energy bills as PMSM is rolled out on the C151 and C651 trains, the company has a strong case to make to other operators considering a traction upgrade. **IRJ**