

SJ's Class X2 EMU Refit Progress

On 16 December 2016 ABB Traction's Chief Operating Officer, Harald Hepp, gave an insight presentation at the SOB (Südostbahn) workshops in Switzerland showing the progress being made with the X2U modernisation project being realised for SJ. The first three refitted cars of the pilot train (a powered end car, an intermediate car and a driving trailer), had then been subjected to static testing for a couple of weeks.

Three years ago, on 16 January 2014, SJ awarded ABB a 147 million EUR **contract** for the technical upgrade of its fleet of 200 km/h Class X2 tilting EMUs. The class designation is that of the power cars, while the trains are more commonly known as Class X2000. The work involves the provision of new electrical equipment, traction converters, main transformers, a train control and monitoring system (TCMS), and in-cab fittings. The objective is to restore the trains' high reliability and performance by replacing obsolete systems. On 19 March 2015 Stadler announced that it had signed a co-operation sub-contract with ABB for vehicle integration and reassembly, this being the fruit of the companies having enjoyed satisfactory long term co-operation (see R 1/15, p. 33 and R 2/15, pp. 26 - 28).

Refitting 25-year-old technology involves the **understanding** of 1990s state-of-art technology and how it can be replaced with and integrated into the technological systems available in the second decade of the new millennium. Moreover, during the long service life of the X2 fleet SJ realised a number of renovation programmes mainly focused on interior refurbishment. Starting 2005 SJ also revised the exterior livery, repainting the trains from their original blue, grey and white livery to all-over grey.

The first two years of the project involved not only engineering work, but also the comparison of the cars with the original manufacturing documentation. Subsequently there was the prototype manufacturing of replacement parts, negotiations with the suppliers about their integration, and suchlike. It was also necessary to establish a level of common engineering understanding between SJ, ABB and Stadler. It was decided that the re-authorisation of the X2Us could take place without the modernised trains having to be submitted to a complete authorisation procedure.

Project Status And Progress

To counter the new competitors which have emerged on Swedish passenger services, SJ intends to substantially modernise its 36 Class X2 EMUs. Each X2 consists of one non-tilting powered end car, one non-powered driving trailer and five intermediate cars - two first class cars, two second class cars, and a bistro car, all with bodyshell tilting.

The **pilot** modernised train will be a full seven-car X2, which will be formed in Sweden. The first three vehicles - power car X2 2005, second class driving trailer UB2X 2509 and first class intermediate car UA2 2818 - were moved to Samstagern for upgrading, leaving Sweden on 10 December 2014 (see R 2/15, pp. 26 - 28), while the remain-



The first three cars of the refurbished pilot train at SOB's Samstagern works on 16 December 2016. On the left is second class driving trailer S-SJ 93 74 302 2509-7 UB2X, and on the right is power car S-SJ 93 74 302 2005-6 X2-1, together with first class intermediate car S-SJ 93 74 302 2818-2 UA2.

ing four cars were dealt with at the works in Tillberga, north of Västerås. The vehicles were initially used for engineering verification, in-situ design development and the development of workshop procedures and methods for the upgrade. The numbers of the four cars being modified at Tillberga are UA2 2820, UB2 2844, URB2 2614 and UB2 2851. „U“ stands for „Upgrade“, so the modified trains will subsequently be designated Class X2U.

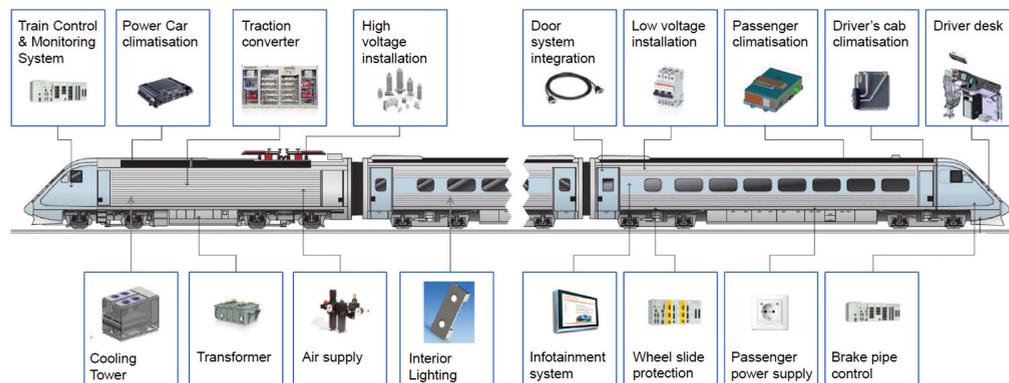
The X2s were built between 1989 and 1998 by Kalmar Verkstad and ASEA, which was one of ABB's predecessors, and entered service in 1990 on the Stockholm to Göteborg line, subse-

quently extending their activities to other routes. The reason for moving the power car to Switzerland was that at the **heart** of the refit are the traction converter and transformer. ABB has its traction converter competence centre at Turgi (near Zürich) and its transformer competence centre at Genève. Project management, design and engineering is being realised by ABB Switzerland's Turgi factory, and the key technical components are also to be produced in Switzerland. Dismantling and mounting of components on the batch-upgraded trains, and testing, are to be realised in Sweden.

Stadler is the main subcontractor in the project, contributing its knowledge

of integration and engineering involving the TCMS, produced by the Swiss firm of Selectron. Stadler is also providing and installing the new low voltage wiring, of the type used on its FLIRT and KISS EMUs. Stadler's involvement in this modernisation project will generate between 50 and 60 new jobs in Sweden, and includes the partial dismantling of the X2000s as required, installation of new components including a new passenger information system, and testing, this to be realised in Sweden.

The **SOB**, which passes through Samstagern, is able to provide local support, knowledge and monitoring of ABB components used in the X2U project.



What is involved in the X2 upgrade. About 40 % of the value of the project is supplied by subcontractors for different systems, new or refurbished. The core unit is the new IGBT traction converter. This offers a wider range of opportunities for control systems and energy savings, and has fewer components than did the old GTO converter.

This is because it operates a fleet of FLIRT EMUs, with these ABB-produced components installed. Moreover, at Samstageren depot SOB provides for the X2U pilot works a workshop team of six, a warehouse, and office facilities.

ABB and SOB have in the past worked together on other technical projects, while Samstageren is only about 60 km from Turgi, and relatively close to both Genève and the Stadler works at Bussnang. This meant that costly and time-consuming journeys to and from Sweden could be avoided, while engineering, production and logistics could be carried out all in close proximity.

The integration of orders for **components** and the realisation of work was done by ABB and Stadler under what is known as a customised ERP (Enterprise Resource Planning) system. This also involved dismantling and re-assembly of the four pilot X2 intermediate cars at the works in Tillberga. ERP will also form the backbone for the batch refitting of the X2s, which will be realised in Sweden. It was decided that the compilation of a database using old and new components using ABB or Stadler software would be inefficient and too complicated.

The X2 Upgrade

Two contracts were awarded for upgrading SJ's fleet of 36 seven-car Class X2 EMUs, consisting of 228 intermediate and driving trailer cars and 42 power cars, including reserve vehicles (origi-



As part of the interior refurbishment new driving consoles are installed in the power car and driving trailer. The edge of the driving console is now curved, thus being more ergonomic (compare with the photo on the right, showing the original console). The new consoles are also prepared for the future installation of on-board ETCS displays. To comply with safety requirements the driver's seat is designed to be pushed back so that the occupant can leave it quickly in an emergency.

nally SJ had 43 X2 trains in service, with a variable number of between four and seven non-powered cars in the formations). Both contracts are to be realised in the **Tillberga** works, which is run by the State-owned rail real estate manager Jernhusen, responsible for stations and other buildings, using different parts of the works complex and involving two independent suppliers.

The first contract is that awarded to ABB on 16 January 2014, described subsequently as the „**X2 Technical**

Upgrade“. In April 2016 ABB reported that the project was at the final stages of the design phase. Previously it was published the contract was scheduled for completion in 2019. However ABB states that since this is a retrofit project, with new requirements and insights cropping up during its design phase, it is currently expected that completion will be in 2021.

The second contract, the „X2 Interior Upgrade“, now referred to as the „**X2 Komfort**“ project, involves interior



Photo: SJ
Per Teckman / Jernstallgi

refurbishment, to increase passenger accommodation comfort. SJ awarded this contract, worth over 1 billion SEK (around 109 million EUR), to Knorr-Bremse subsidiary Swedtrac on 4 April 2016. On 18 April 2016 PROSE's Swedish subsidiary, PROSE AB of Västerås, signed a co-operation agreement with Swedtrac, for which PROSE had acted as an advisor during the tendering procedures. PROSE is responsible for technical project management, electrical and mechanical engineering, autho-



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The X2s are to be equipped with BORDLINE CC1500 AC 25 - 15 kV X2U traction converters. These Compact Converters (CC) are housed in an IP54 cabinet, measuring 3,350 mm long by 780 mm wide by 1,870 mm high, and weighing 2,200 kg, designed for mounting within the machinery space. The „1500“ refers to the high power propulsion product line. They incorporate a 15/25 kV system switch, an input contactor and a pre-charger, two 4Q line converters, a DC link and resonant filter capacitor, one voltage limiter, one propulsion inverter, one auxiliary inverter (feeding all the auxiliary power consumers) and an AC 800PEC (Power Electronics Controller) control module.

risation, evaluation of RAM (Reliability, Availability and Maintainability), and will provide technical documentation services and acquisition of all equipment required for the refurbishment, embracing everything from carpets to luggage shelves, with the exception of seats, which SJ purchases independently.

The project mainly involves **interior**, but also some exterior refurbishment of all the X2 EMUs. Interior refurbishment will result in around 15 % more seats than at present - from 332 (of them 29 in the bistro car) to 360, since one of the two first class cars in each train is to become second class, while the bistro car is to be reconfigured. The latter will offer a different range of services, while a separate pantry will be provided for catering in first class. The new seat units, produced by TAPS of Łódź, will be thinner than the existing ones, thus enabling them to be positioned closer together.

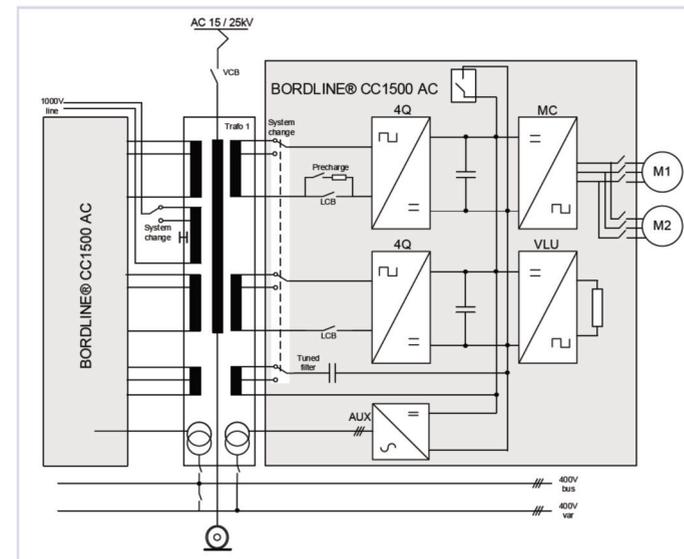
The original distance between seat backs is 1,000 mm in second class and 1,050 mm in first class. This is being modified constantly as the project progresses, although following refurbishment the distance between seat backs

will definitely be reduced as a result of the new configuration. However the objective remains that passenger comfort will not be compromised.

Following refurbishment the upgraded X2s will receive a new livery, though details of this have not yet been worked out. The air conditioning system is to be upgraded by Faiveley, which will also modernise the entrance doors. The interior doors will be modernised by Pintsch Bamag, while the interior illumination will be upgraded by the Swiss company RailTronic.

The old GTO thyristor-equipped traction **converters** are to be replaced with new 25/15 kV AC BORDLINE CC1500 converters. The incorporation of 25 kV AC will enable all the X2Us to operate in Denmark, something which so far has only been possible with the 12 Class X2000s whose power cars were rebuilt in 2000-01 for operation of both voltages, subsequently becoming Class X2K under SJ's internal designation system.

The BORDLINE CC1500 MS compact converter, a rugged unit incorporating modern IGBT technology, is based



on ABB's well-proven three-level topology, which has several advantages over conventional two-level solutions. It is better for the motor, better for the power system, and it saves energy.

The **three-level** converter optimises the sinusoidal current waveform compared with that of a two-level converter. Current and torque ripples are reduced by more than fourfold, this in turn drastically reducing losses, audible noise and mechanical stress on the traction motor. In addition, the voltage gradient stress on the motor's insulation materials is reduced twofold. These traction motor-friendly characteristics render the three-level inverter an ideal solution for retrofit projects where the existing traction motors can be disposed of and replaced.

Each of the new converters has a 1,500 V AC voltage input and a propulsion output from zero to 2,000 V AC, resulting in a possible power rating for the traction motors of 2,000 kW. However the original 815 kW asynchronous traction motors, and the present body-shell tilting system, will be retained, on account of the fact that their state was

assessed by SJ and ABB as satisfactory.

SJ decided to retain the existing traction motors, gearboxes and axles. The existing continuous power rating of 3,260 kW, and the maximum one of 4,000 kW are thus retained, as is the maximum service speed of 200 km/h (the maximum design speed is 210 km/h) and the acceleration rate of 0.4 m/s², which, by today's standards, is rather low. The tilting system will only be equipped with new control hardware, to be developed by Stadler and Selectron.

Each new traction converter will control two traction motors in parallel in each bogie, as is the case in the existing configuration. The converters are liquid-cooled, this extending the service lifespan of all components and also enabling the converters to be of reduced size. The coolant used is ordinary tap water, mixed with glycol, and dissipates energy through an external heat exchanger situated in the centre of the power car. A 400 kVA auxiliary converter is provided, together with new battery chargers in all vehicles.

It is envisaged that the **reliability** and availability of the X2Us will be in-

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creased and the replacement of electrical equipment, combined with the provision of a new eco-driving support system, will result in a reduction of energy consumption of roughly between 5 and 10%. This will be achieved through lower losses in the traction motors, main transformers, filters and auxiliary systems, and by the more efficient use of recuperative electrodynamic brake.

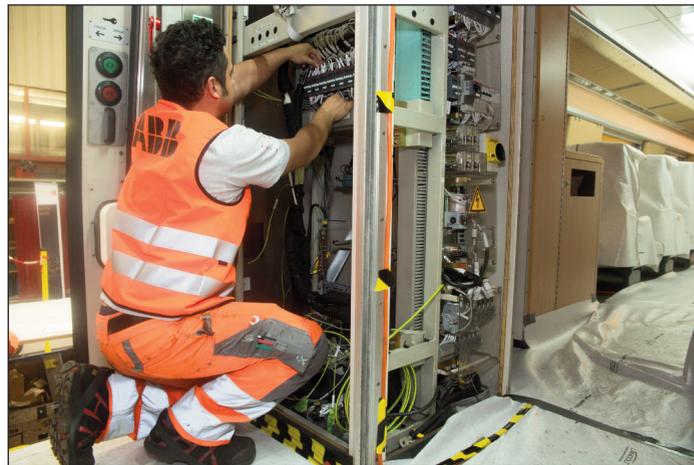
Future Prospects For The X2U EMUs

SJ carried out several satisfactory audits on the activities which have so far taken place at Samstagern works, and continues to make regular visits to monitor the activities which are evolving there. Good progress has been made during the engineering and installation phases with the three pilot X2U vehicles, on which static testing will continue during the first quarter of 2017. They were then returned to Sweden in February, to be coupled up with the four vehicles modified at Tillberga. The seven-car pilot upgraded X2 will then be subjected to static testing at Tillberga works, and will then proceed to dynamic testing. Partial

authorisation testing and design verification will follow.

At present it is reckoned that around 40 % of the full amount of **authorisation** testing will be necessary to get the X2U pilot train re-authorised. However, the results of the tests may imply the necessity of design changes. For instance, one modification required has been the addition of ballast to the power cars, to keep them within the required weight of 74 t (with an 18.5 t axle-load), to ensure that adhesion level remains unchanged. This was necessary because the new traction equipment weighs less than does the old. It is planned to have the dual-voltage capability and the new train control systems authorised for use in Sweden, Norway and Denmark.

Dynamic **testing** is envisaged for the pilot train on the Swedish network during 2017 and the first quarter of 2018. Initially, authorisation is to be obtained for nocturnal testing on stretches of line which are not used then by other trains. Then permission is to be granted for daytime testing on lines which are in regular use by other trains. All these tests will be realised without passengers on board. Full authorisation is ex-



Installation of new systems in an old design configuration, and refurbishing some of the original components, is time-consuming work.

pected to be granted during the first quarter of 2018. Afterwards, the train will be used for a four-month period of validation tests. Afterwards, if all is satisfactory, it will be possible to start batch upgrading of the X2 fleet, this scheduled to last until the end of 2020. The up-

grades will extend the working life of the X2Us until 2035.

**Peider Trippi
Jaromír Pernička**

**Photos, unless cited,
and diagrams: ABB**



Photo: Daniel Wipf



Photo: Daniel Wipf

During the evening of 31 January 2017 the three upgraded cars from a pilot X2000 left Switzerland en route for Sweden. These photos were taken at Pfäffikon SZ. While the two end cars could run on their own bogies, it was necessary to mount the intermediate car on RailAdventure's loco boggies for the run through Switzerland (see right-hand photo), on account of difficulties in obtaining permission for it to run on its own bogies, and to avoid the problems which occurred with this intermediate car during its movement to Switzerland (see R 2/15, pp. 26 - 27). For the run to the German border haulage was provided by a SBB's locomotive Re 4/4 II 11 256. At Basel the train was handed over to RailAdventure, which provided haulage using its 139 558 electric to Rostock.