Frank Schumann with his team troubleshooting the Electronics of a metro train

Underground Electronics

The Friedrichsfelde workshop is one of several belonging to the Berlin public transport authority, Berliner Verkehrsbetriebe, (BVG), where service and maintenance of metro trains is performed

At least every 480.000 km or every six years, every metro train is brought to the workshop for a complete service. In approximately 14 days, the carriage is almost entirely disassembled, defective parts replaced, necessary maintenance carried out and damage caused by vandalism restored.

BVG has three locations for such maintenance and repair work. One of these, the Friedrichsfelde metro train workshop, is located in the east of the city. This site started operations in December 1930 together with the E metro line, (The U5 today), and has two workshop halls of 120-meters, which is equal to the length of a complete train with six carriages. A total of 11 tracks are available, some with a pit and a lifting platform to enable work to be carried out under the carriage. In addition, a train wash is available to clean a complete train. The Friedrichsfelde workshop currently services 386 of the so called 'large profile' metro carriages of lines 5, 8 and 9, where the oldest series F trains originate from 1974.

In addition to the mechanical work, the electrical systems of the trains are also serviced and refurbished at Friedrichsfelde. The electronics are mainly housed below the carriage in roll cages in order to enable parts to be quickly replaced. Depending on the actual position of the carriage in the train, different functional units are situated, such as central control, PLC (Programmable Logic Control), traction control, Power converters, brake control, brake resistor and the passenger information system.

Inverter-controlled Three-phase motors

The power for the trains in Berlin is supplied by a so called "third rail" which provides 750 volts DC. Whereas in the past the train was driven by DC motors, since about 1980 it became progressively more economic to use three-phase asynchronous motors. The most advanced feature of the Series H trains originated between 1994 and 2002, with the use of two motors per wheel truck (bogie) and thus 24 motors per train, each providing about 90 kW. This is equivalent to a total rated output of 2,160 kW per train. Each drive unit (2 carriages) has a two-quadrant DC converter and inverter in which the DC voltage of 750 volts is converted into three-phase AC voltage of 560 Volts to drive the motors. The electric induction motors can be used during breaking as asynchronous generators to release the energy through the two-quadrant DC converter back into the grid.

Troubleshooting via laptop PC and Oscilloscope

Since many problems in the electronics of the metro trains only occur under certain operating conditions or sporadically, the control units each have their own event log. During normal operation each irregularity in the electrical system will be captured in the event log. Critical errors are immediately signaled to the train cabin, so that the train can be delivered to the workshop. With the help of a laptop PC the respective event log is downloaded. Using this information, the error can then be located more accurately using Test & Measurement equipment.

Currently there is a train in Hall 2 with a reported a fault in the area of the drive controller in one of the carriages. With the help of the logged error, shift supervisor Frank Schumann's team is able to quickly identify that the problem is in the inverter. The next step will be to use an Oscilloscope to check the signals coming from capsule thyristors in the inverter. Since a three-phase motor is used and a total of six thyristors need to be investigated, a Yokogawa DL850 ScopeCorder is used instead of a conventional oscilloscope. The DL850 can save up to 16 analog channels so that the signals from all six thyristors can be easily displayed simultaneously. Firstly the output signal of the ignition transformers is checked. If the proper voltage level is not reached, it does not trigger the thyristor. Such an error is immediately shown on the display of ScopeCorder. If the problem is not identified in this way, then additionally the digital output signals of the control device have to be monitored.

Berlin Metro in Figures

First journey:
15th February 1902

Number of metro lines:
9

Total network length:
146 km

Number of stations:
173

Number of metro carriages:
1243

Total kilometers per year:
about 20.6 million km

Passenger kilometers:
2335.8 million km

(All figures from 2010)

Markus Rohde replacing a capsule thyristor in the drive control

For this purpose, the ScopeCorder can be equipped with digital channels. "The DL850 ScopeCorder from Yokogawa is ideal for us because it offers both analog and digital Channels in sufficient numbers in one instrument. In addition, the device has a high withstand voltage up to 1,000 volts" says Frank Schumann.

The most common causes of failure in this area include defective thyristors, capacitors, ignition transformers and line interruptions. Often defective components can be replaced locally. If this is not possible, the repair is done in the electrical workshop.

Measurements during the train journey

To troubleshoot a vehicle when it is stationary, the ignition transformer can be used to fire the thyristor for fault finding. However errors sometimes only occur in normal service and thus are only traceable under normal driving conditions. In those situations the ScopeCorder goes along for a test ride. Since the three-phase motors have their own current sensors, measurements can be easily made on the motors during the journey. "With the DL850 ScopeCorder we record the signals during a test drive and then take the time to evaluate them afterwards. For sporadic errors we regularly make long-term measurements in the workshop in which the loads are simulated by resistors" Says Frank Schumann.

ScopeCorders from Yokogawa are also used in other Berlin U-Bahn workshops. For example, those for Berlin trams, as these vehicles have very similar electrics.

All electronics modules that cannot be repaired directly on the train are removed from the train and are further processed in the electrical workshop. Here, laptop PCs and oscilloscopes also dominate as the most important diagnostic tools. In the Friedrichsfelde maintenance workshop practically all types of Electronic module are repaired down to component level, only the motors themselves are sent for repair to the refurbish department in Grunewald. Due to the mixed generation structure of the carriage, which sometimes contains 30 year old engineering combined with modern electronics, a lot of experience is required for trouble-shooting and repair work. Increasingly challenging is the supply of spare parts. The engineering used in trains purchased about 10 years ago was developed in the mid-90s but should still be usable for another 20 years. Already, some parts are hard to get. The older trains from the 70s have therefore been re-equipped with modern electronics and PLCs.

In this respect the period carriages from 1908 to 1929 of the BVG, which are also located in the hall, do not suffer from this kind of problem. The carriages are looked after by the 'Arbeitsgemeinschaft Berlin U-Bahn e.V'.(the Berlin U-Bahn Association) and are still being used for events and special tours. For these it is sufficient to clean the contacts from time to time and lubricate the moving parts. In case parts need to be replaced, they can usually be easily manufactured in the well equipped workshop.

Capsule Thyristors

These thyristors are in a disc-shaped ceramic package and have large upper and lower contact surfaces. They are not soldered, but connection is made using pressure on the contact plates. They are available in powers of several Kilowatts to Gigawatts. The tests which are carried out in the development and manufacturing of these thyristors can be read in the last issue of our German Yokogawa Test & Measurement inhouse Magazine No. 21 in the report "Megawatt-semiconductor" (Megawatt-Halbleiter) about Infineon Technologies Bipolar GmbH & Co. KG.

Troubleshooting with a ScopeCorder and schematic drawings