# The Transrapid Guideway Switch – Test and Verifikation

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**Keywords**

Approval, Guideway, Switch, Transrapid, Verification

**Abstract**

Guideway switches are the moveable elements of every guided traffic system like railway and maglev. They allow the vehicles to change the track without stopping the run. The report describes the way from the first ideas to construct a modular guideway switch to the latest results of operation in Shanghai.

## 1 Summary

For maglev projects different types of guideway switches like 2- and 3-way-switches had to be developed and approved. The report describes the way from the first ideas to construct a modular switch to the latest results of the first operation in Shanghai (see Fig. 1) regarding the project specific requirements. The steps of the theoretical verification and the approval procedure, the planning and production phase and last but not least the description of the preparation of the commissioning, the commissioning itself and the tests for the practical verification in operation are the main topics of the presentation.

**Fig. 1 - Project Shanghai: Guideway Switch 8**

## 2 Design and Development Requirements

The development of guideway switches for the Transrapid Maglev System was based on the TVE experience and the high demands on economic efficiency and operational availability. Therefor new ideas and preliminary assumptions for future requirements resulted in the layout of a prototype 3-way-guideway switch for passing velocities witch about 100 km/h in bent off position and 500 km/h in straight position. The main topics of the development were

- modular construction of all switch components
- rugged design
- assumptions of a future operation for theoretical prognosis of the fatigue resistance
- specification of the interface to the operation control system (OCS)
- type approval of the Eisenbahn Bundesamt (German Federal Railway Authority, EBA) for the application in Germany

# 3 Prototype Switch for Low Turn-out Speed

## 3.1 General

The development of a switch for low turn-out speed 100 km/h (LFW) on the basis of the aforementioned requirements resulted in the Prototype Guideway Switch 4, which was built in 1998/1999 after the specification of the requirements, the dimensioning and theoretical verification. The application for type approval of the EBA was made in 1997.

**Fig. 2 - Prototyp Switch 4 in Kassel**

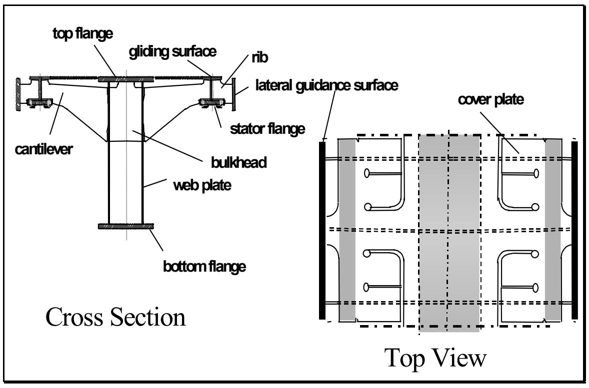



**Fig. 3 - Cross Section and Top View of the 3W-LFW**

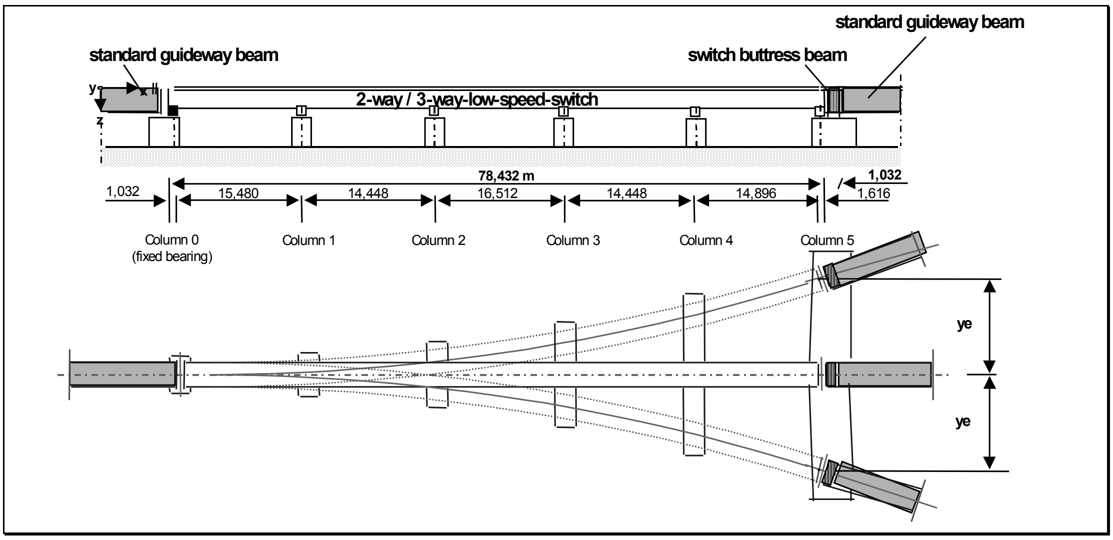



**Fig. 4 - Low Speed Switch (schematic presentation)**

In Fig. 2 the Prototyp Switch is shown during the mounting phase in a production hall at TKT-TR in Kassel. The possible positions of the switch are right bent off, straight and left bent off. This type is called a 3-way switch (3W-LFW). The 2-way switches have only 2 postions (straight - left or straight ricght or left - right).

### 3.2 Construction

The length of the 3W-LFW is about 78 m. The cross section and a section of the top flange of the bending beam is shown in Fig. 3. The minimum bending radius is about 658 m. This bending radius is possible because of the narrow bending beam. The bending beam is supported on 6 bearings (see Fig. 4).

### 3.3 Qualification

In 1999 the prequalification tests were executed. The loads as a result of the bending action were measured. The dynamical behaviour of the cantilever was examinated by an external incitation of the switch. On the other hand the function tests of the electrical and mechanical equipment were carried out successfully. The interface between switch control and operation control system was simulated.

### 3.4 Type Approval

All test and qualification results in combination with the theoretical investigations contributed to the assurance of the type approval with additional stipulations in 2000. This main stipulations consider the

- compliance with project specific conditions and requirements
- the verification of the loads as a result of the vehicle action and the project specific environmental conditions
- the verification of the geometry (long wave curvature)
- the verification of the safety of the switch control system interacting with the operation control system

The tests to fulfill these stipulations were carried out at the guideway switches in Shanghai for the issue of the operation licence.

## 4 Guideway Switches for the Shanghai Maglev Project

### 4.1 General

The alignment of the first commercial Transrapid Project in Shanghai required the application of 8 guideway switches for low turn-out speed. The position of the guideway switches is shown in following figure.

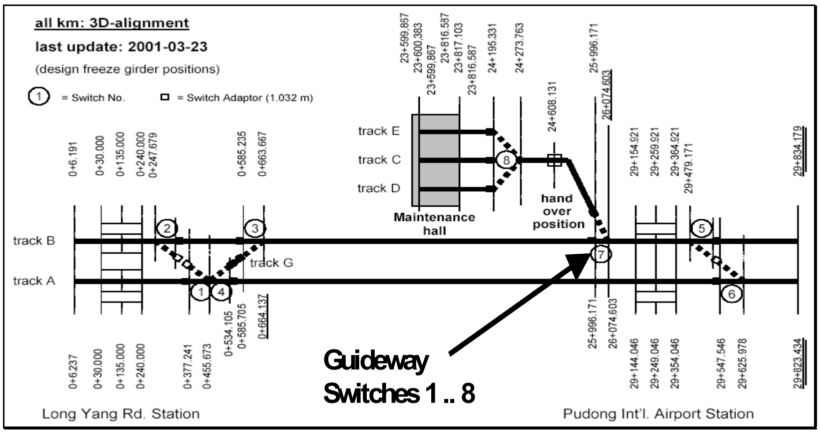



**Fig. 5 - Track Scheme of the Shanghai Maglev Guideway with the Position of the Guideway Switches**

The guideway switches no. 1..7 are 2-way-switches, the switch 8 at the maintanace center is a 3-way switch. The 2-switches and 3-way switch differ only in the supporting and the switch control.

## 4.2 Realization in Shanghai; Production/Preintegration and Mounting

The steel structure and the electrical, mechannical and Transrapid specific equipment was produced and preintegrated in Germany at the works of Tyssenkrupp Stahlbau, Hannover.

**Fig. 6 - Preintegrated Girder Segment**

**Fig. 7 - Assembled Locking and Propulsion Unit**

## 4.3 Tests and Verifications for Operating Licence

### 4.3.1 General

After the mounting of the guideway switches in Shanghai the function, qualification and verification tests were executed during the commissioning (commissioning tests).

### 4.3.2 Safety of the Structural Construction

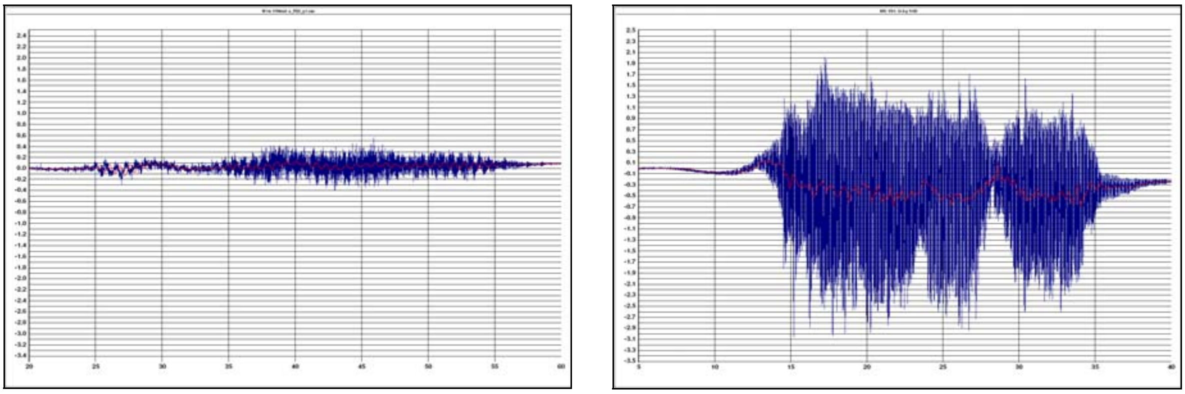
The verification of the safety of the structural construction contents the analysis and verification of the stability of the guideway switches on the basis of the rules and regulations taking into account all actions and the combinations of the actions.

In coordination with the safety expert from EBA the necessary measurements for the verification of the loads due to the vehicle and the environment temperature were specified. The first measurements were carried out in Nov. 2002 at guideway switch 7. The goal of this measurement was the issue of the preliminary licence for the commissioning operation. With the statement of the expert the required safety (stability) of the guideway switches could be approved.

### 4.3.3 Verification of Fatigue Strength

An extensive measurement program was specified to verify the fatigue strength of the guideway switches due to the dymanical loads. Additionally to the measurements at guideway switch no. 7 the loads due to the vibrations at guideway switch no. 8 were measured and analysed. The vibrations at guidway switch 8 result from the incitation of the natural frequency by the action of the levitation magnets at low vehicle velocity. The value of incitation depends on the vehicle velocity. At a vehicle speed greater than 80 km/h the effect of the incitation is not existing.

It was found, that the vibrations of the bending beam had to be reduced with respect to fatigue and noise. By installation of a tuned mass damper TMD the loads due to the oscillations could be reduced as expected. The effectivity of the TMD (see Fig. 8) is verified at all switches by the measurement of the accelerations at the bending beam.



Girder deflection in y-direction with TMD — Girder deflection in y-direction without TMD

**Fig. 8 - Reduction of the Oscillation Range due to the Tuned Mass Damper**

The fatigue load of the guideway switch results from the bending operation load and the vehicle passing action. The following figure (Fig. 9) shows a typicle situation of guideway switch 6:

- The switch position at the begin of the measurement is straight.
- The vehicle passes the guideway switch in straight position (see (1)).
- After passing the guideway switch is put into bent off position (see (2)).
- At the end of the diagram the vehicle passe the switch again in bent off position (see (3)).

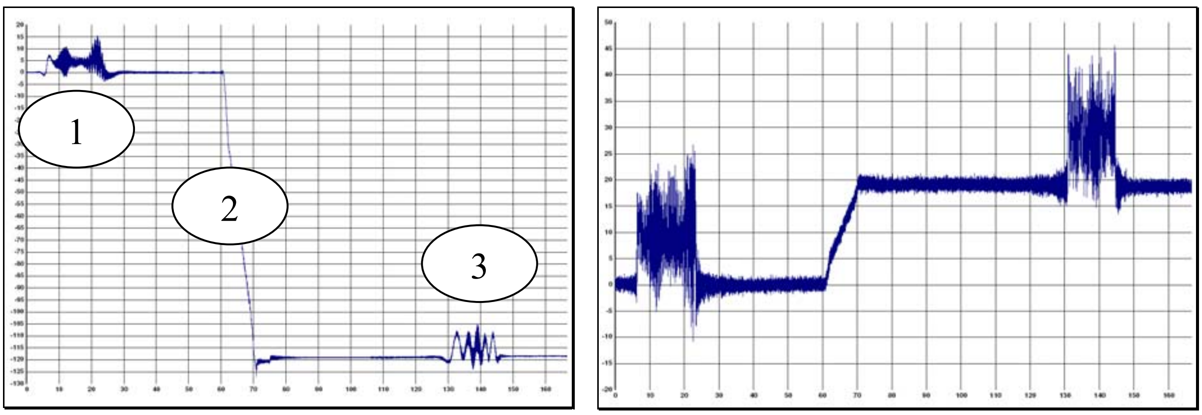



**Fig. 9 - Loads due to Bending Operation and Vehicle Passings (left: Bending Beam; right: Cantilever)**

The 2 diagrams of Fig. 9 show, that the influence of the vehicle action is not dominant for the bending beam. For the cantilever plate and it's connection to the bending beam, the stress range due to vehicle is nearly the same as the stress range due to bending operation. To verify the fatigue resistance of the structure the measurement results were analysed by calculating a stress range spectrum using the rainflow counting methode. This spectrum was the basis of the Palmgreen-Miner calculation of the possible load cycles. The results of these calculations show, that all switches fulfill the fatigue requirements.

#### 4.3.4 Verification of Serviceability

The serviceablility of the guideway switches is defined with the limitations of the geometrical deviations of the function surfaces. Complying with the stipulation of assurance for type approval by Eisenbahn-Bundesamt (EBA) the test should be executed for verification the guideway geometry for all guideway switches. The measurement should be carried out from the EBA-surveying expert.

The short wave position and the gaps were proofed in works in Hannover. Impermissible deviations could be corrected before application of the corrosion protection. The longwave position in z- and y-direction was surveyed after the complete mounting of the guideway switches in Shanghai. The results of the bent off and straight positions were analysed. After some corrections of the y-position the EBA expert approved the serviceability taking into account the specific requirements of the Transrapid system. Result: Lateral deviation: ≤ 4 mm, Vertical deviation: ≤ 2 mm.The following figures (Fig. 10 and Fig. 11) show examples of the surveying results.

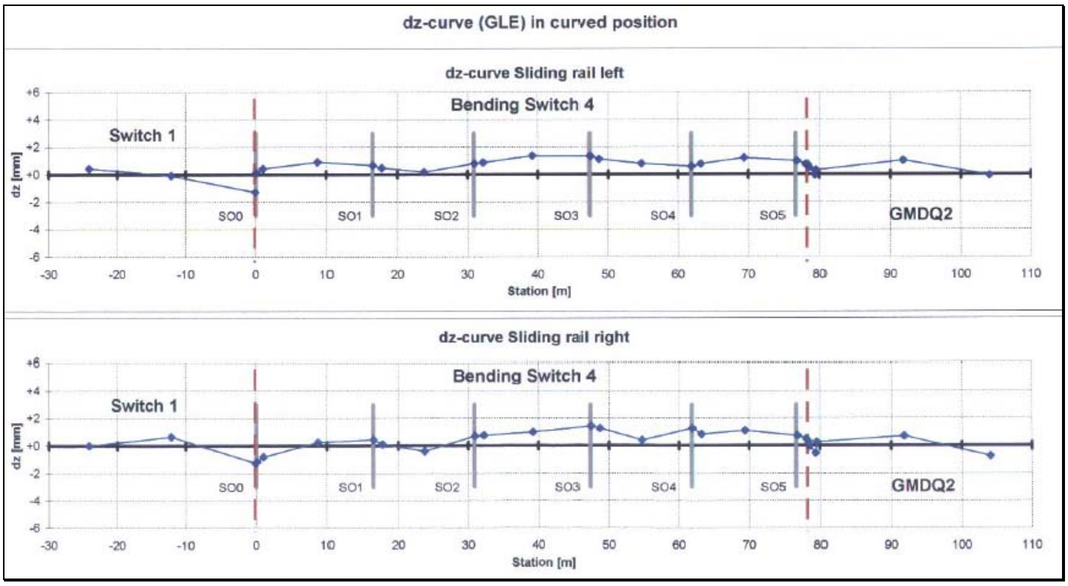



**Fig. 10 - Example of Long Wave Geometry of Switch 4 in z-Direction**

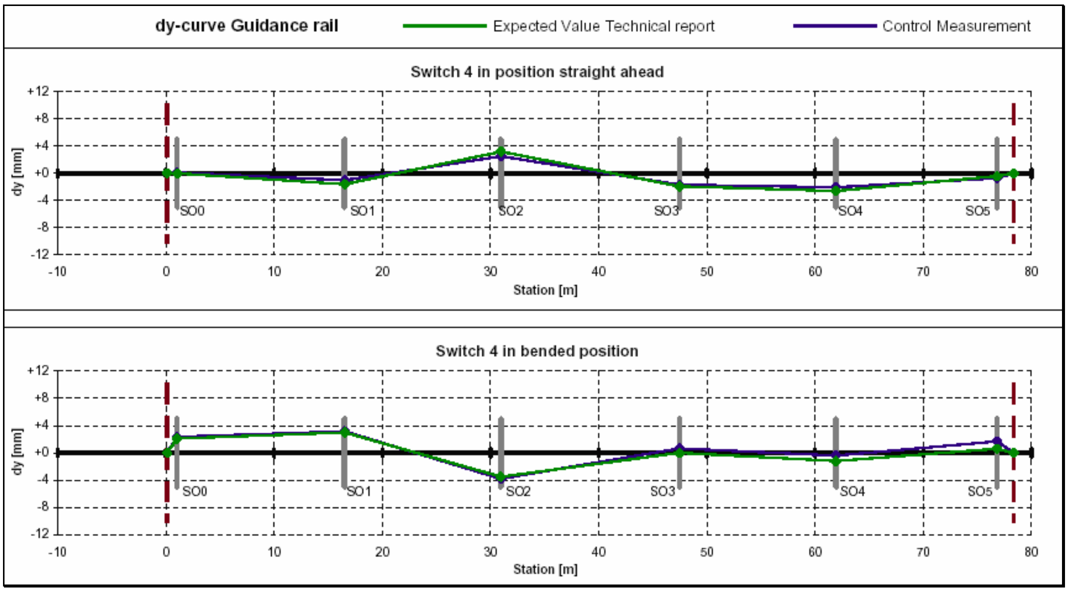



**Fig. 11 - Example of Long Wave Geometry of Switch 4 in y-Direction after the correcture of deviations**

The analysis of the EBA expert of the surveying of all 8 switches show that the residual deviations do comply with the requirements.

### 4.3.5 Durability and Robustness

All mechanical and electrical components were choosen taking into account the durability and robustness. This means the use of qualified standard elements on the one hand, and the competent dimensioning on the other hand.

### 4.3.6 Safety of Guideway Switch Control

The safety of the guideway switch control was verified through simulation of the possible abnormal occurencies, which were specified in coordination with the customer and the EBA expert. The main topic of the verification were the safety of the guideway switch control-integration into the operation control system (OCS) and the redundant design of switch control elements to increase safety and avoid failures (e.g. position sensors).
The result of these function tests were, that not one of all simulated situations resulted in an uncertain condition.

### 4.3.7 Verification of Lightning Protection

An additional safety aspect is the lightning protection of the guideway switches. On the basis of the German regulations the lightning protection system was specified. After the check of the theoretical dimensioning by the EBA expert and after the mounting in Shanghai the correct function of the installation was tested. Additional to an extensive visual inspection of all lightning protection components the effectivity of the installation was checked through the measurement of the earthing resistance at all switches. After the elimination of some mounting failures the correctness of the lightning protection system could be verified through a duplicate measurement.

### 4.3.8 Verification of Environment Protection Requirements

To protect the environment from electromagnetic emission the dominant current conductions were covered. The effectivity of these coverings was checked at each guideway switch on the basis of a test specification and EN 50121-2:2000. The measurement of the electromagentic emission was carried out at normal operation and at special operation with maximum power load (see Fig. 12) at the defined measuring points. The test results (e.g. see Fig. 13) show compliance with the standard for electromagnetic emission.

Fig. 12 - Electromagnetic Emission Measurement

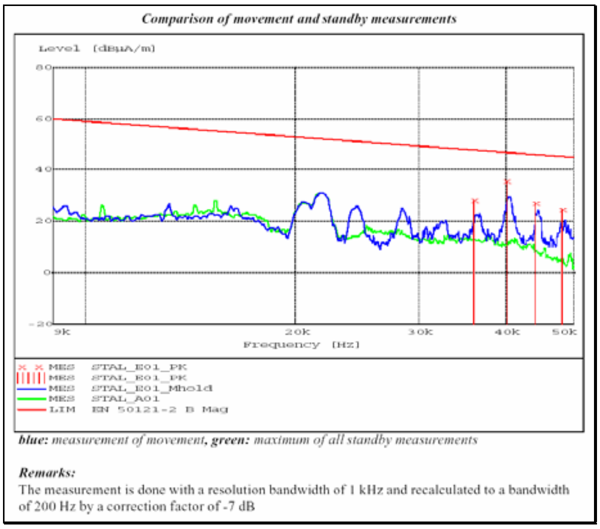



Fig. 13 - Example of EM-Measurement Result

### 4.4 Summary of Verification

After the analysis of the carried out commissioning tests and the positive check of the EBA experts the guideway switches in Shanghai can be used under to the required operation conditions.
The safety of all mechanical and electrical components is approved.

## 5 Operation Experience

Up to now the total number of switching cycles of the 8 guideway switches in Shanghai is about 60000 (see . Table 1).
The redundancy concept of the switch control system is successfully verified. In no case a bending operation was interrupted due to a technical failure.

Taking into account the total number of switching operations and the number of failures with impact on availability since Overall Acceptance Certificate the availability of the guideway switches in Shanghai is >> 99.9%.

| Switch No. | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| Total Number of Switching Operations | 2880 | 14640 | 2810 | 7414 | 2413 | 20453 | 3767 | 5956 |
| Total Number of all Switching Operations | **60333** | | | | | | | |

**Table 1 - Number of Switching Operations**