# Guideway Monitoring during Operational Use on the First Transrapid Line in Shanghai


Nieters, Willi

Industrieanlagen-Betriebsgesellschaft mbH,
Maglev Test Facility

Hermann Kemper Str. 23

D-49762 Lathen – Germany

Phone: +495933-6276 Fax: +495933-6220
e-mail: willi.nieters@tm.iabg.de



**Keywords**

Guideway monitoring; Maglev line shanghai, Transrapid Test Facility,



**Abstract**

The monitoring of the guideway with contact-free measurement gap sensors has been used for many years on the TVE in Germany.
This article describes the further development of the individual systems into an integrated measurement system, which monitors the position of the statorpacks and guidance rails, using the vehicle's own sensors, on the first public service route in Shanghai.


## 1 Introduction

The implemented high-speed electromagnetic levitation technology for Transrapid demands a magnetic set-up, which records the gap between magnets and response surfaces using contract-free gap sensors.

By using this measurement principle, the position of the response rails (statorpack and guidance rail) can be determined. Based on this procedure, various measurement systems have been developed and used on the Transrapid Test Facility for monitoring the geometry of the functional components of the guideway, as described in [1]. The measurement system enables the monitoring of the statorpack fastenings and guidance rails or module fastenings for the hybrid guideway to be carried out. Moreover, by evaluation of the guidance rail data, conclusions can be drawn regarding the functionality of the beam - bearings.

For use on the first Maglev public service route in Shanghai, the different, separate measurement systems were optimised, further developed and amalgamated into one usable complete system for daily operations.

## 2 Measurement Data Recording and Processing

### 2.1 Hardware

The hardware for recording and evaluating the measurement data has been completely integrated into the overall architecture of the vehicles. In Figure 1 is a block diagram of the measurement system:

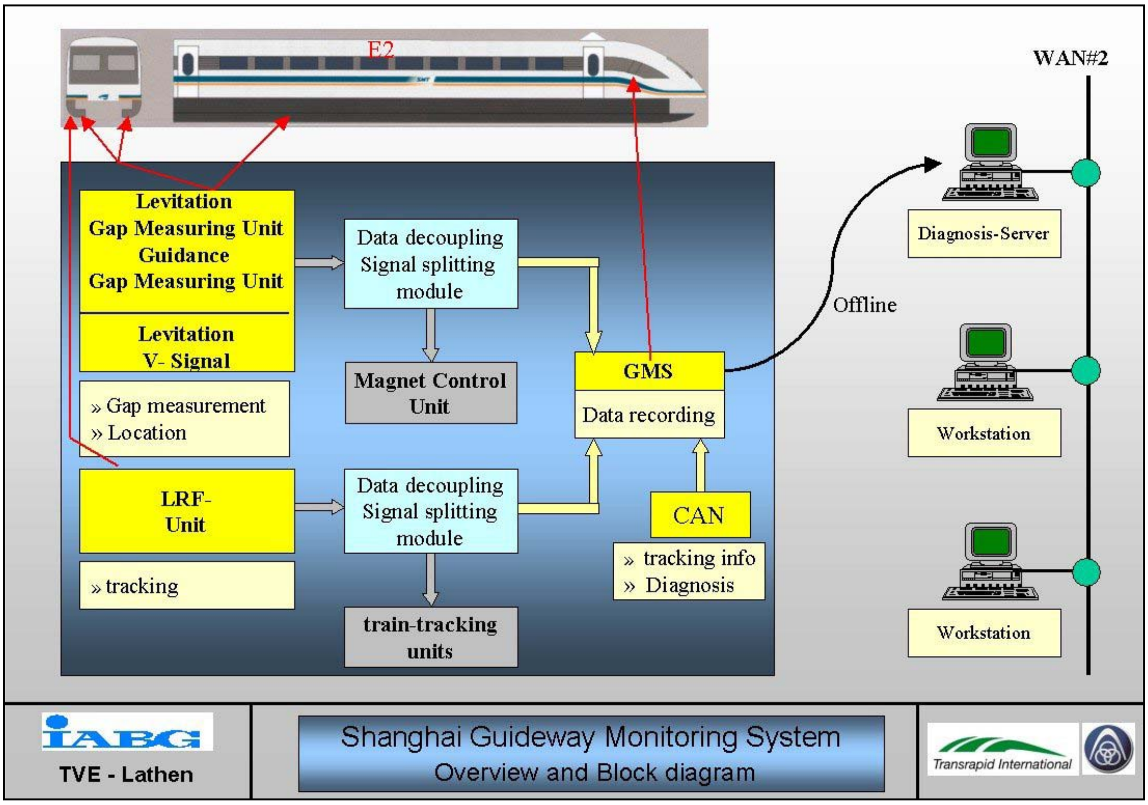


**Figure 1: Block Diagram**

All measuring data for the offset diagnosis are obtained from vehicle-own gap measurement units. For this, the gap signal and also the so-called "v-signal " from the levitation gap measurement units are decoupled at a measuring section in Section E2 reactionlessly from the signal path between gap measurement unit and magnet control unit and made available to the Guideway Monitoring System (GMS). Per vehicle side, one levitation gap measurement unit is decoupled, for the determination of the offsets at the guidance rails, 2 sensors per vehicle side (top and bottom) are used.

For determining the exact vehicle position, the signal of an Location Reference Flag (LRF) reader (vehicle location system) is similarly reactionlessly undertaken directly at the reader. Moreover, signals of the vehicle-own diagnosis system (CAN – Bus) are used for tracking. Failure states in the system are, in addition, reported via the diagnosis bus to the central vehicle diagnosis system.

Two vehicles are equipped with the GMS – measuring units, per vehicle, one statorpack measurement unit and one guidance rail measurement unit have been installed in a service cabinet (cf. Figure 2 and Figure 3).

Figure 2: Measurement Units in the Vehicle

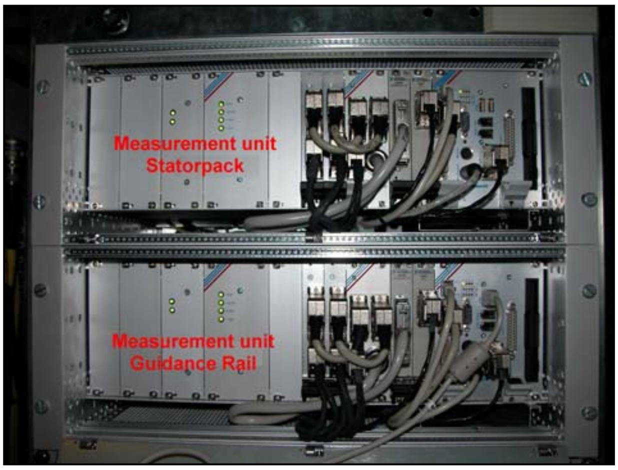


Figure 3: Measurement Units in the Vehicle

The measurement units are activated automatically, when the vehicle is switched on. The GMS – software starts automatically and begins the online – measurement and processing as soon as a speed of 20 km/h is exceeded. The result data are stored immediately on the hard disk and cyclically transferred by an operator to an external memory card. The latter is then read by the GMS – Server and the data are made available for further evaluation.

## 2.2 Software

The offset between 2 adjacent stator packs or 2 adjacent guidance rails is evaluated.
Decisive for the precise measurement is the exact determination of the position and thus the transition between 2 guideway components. For this the "v-signal" shown in the levitation gap measurement units is evaluated, which provides an image of the stator pack with the slot and tooth sequence. By counting the pulse edges and the comparison with the deposited guideway track information, the measured location can be determined very precisely (cf. Figure 4). Now respectively at the end of a component (stator pack or guidance rail) and at the beginning of the subsequent component a mean value is formed. The difference between these mean values gives the offset between the components.

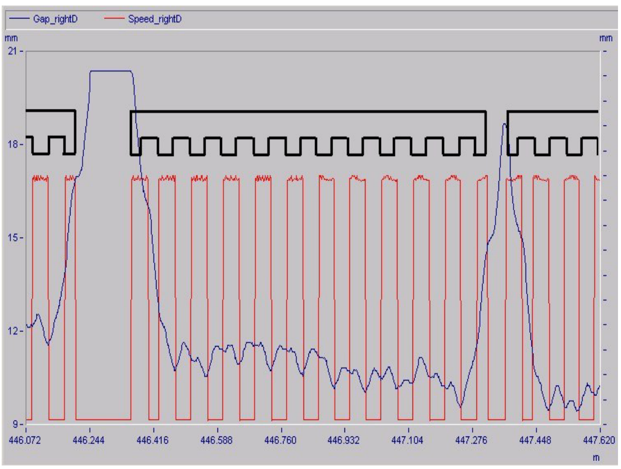


**Figure 4: Determination of the Exact Statorpack Transition**

With a constant sampling rate, far fewer measurement values are determined at high speed at the same location than at low speed. The transition between two components would be mapped differently dependent of the speed. As the measurement must be performed irrespective of the speed, the current speed is determined from the v-signal and information via the CAN – bus and the scanning rate is adapted correspondingly. Thereby per distance unit, irrespective of the speed, there is always the same number of scanning values present (Figure 5). A value is recorded about every 7 mm.

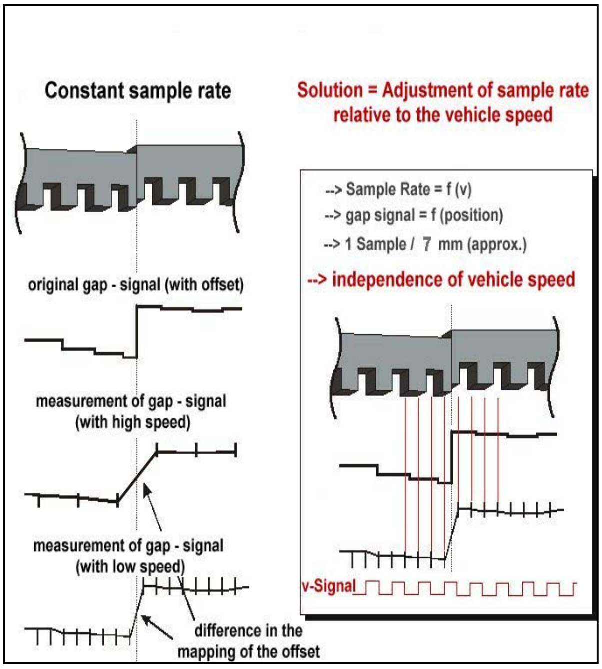


**Figure 5: Speed-Dependent Scanning**

From various measurements, an offset value was determined by averaging values for each statorpack – transition and each guidance rail – transition and stored in a reference dataset. Thereby the installation position at this location is defined. For each new run, the offset is formed online again between two components and compared with the stored reference value at this transition. If deviations above a certain limit occur between the installation position (reference value) and the current value, an entry is stored in an alarm file (Figure 6).

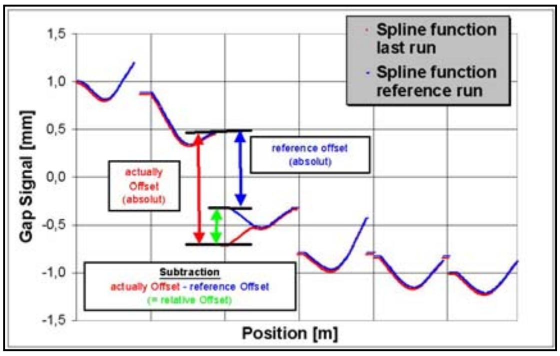


**Figure 6: Offset - Determination**

This entry consists, in addition to the location specification and the measurement value, also of a section of the gap signal, in order to facilitate the later evaluation. The comparison between reference value and currently determined offset required a high level of reproducibility in running performance. The reproducibility has been enhanced with increasing speed. Thereby a minimum speed of 20 km/h is required for the measurement, moreover, altered limit values apply in the low-speed range.

## 3 Data Evaluation

The results datasets of the offset measurement of the statorpack and the offset measurement of the guidance rail transferred to the diagnosis server are evaluated with a common program. The evaluation can be seen in Figure 7:

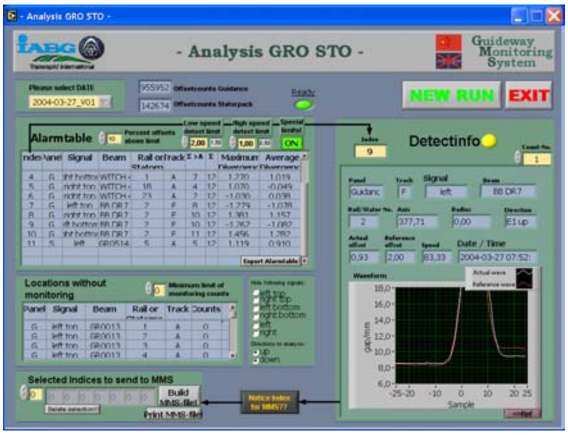

**Figure 7: Evaluation Program**

The evaluation module can be performed on the server or at the workstations linked to the server. The results can be transferred directly into the Maintenance Management System via a software – interface in order to generate error reports or work orders for the guideway maintenance.

Should an offset between 2 components change in size above a certain value, this is recorded in a list; moreover, a section of the gap signal is shown with this measurement.

For further appraisal, the possibility now exists of evaluating a history at this guideway location (Figure 8), i.e. all offsets determined at this location are presented over the time. In this way, long-term 'creeper' position changes can be assessed, as soon as they exceed the limit value. In addition, also very minor positional changes can be clearly evaluated.

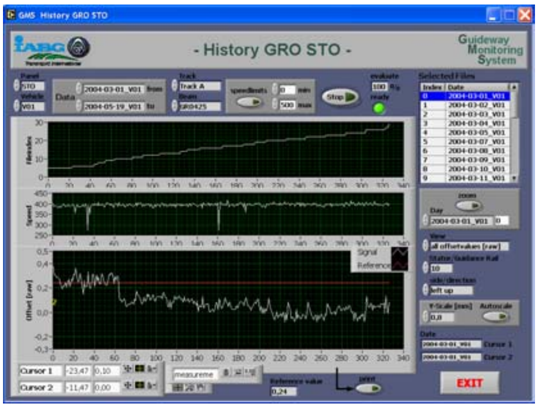

**Figure 8: History**

## 4 GMS Low Speed

As a result of the specified minimum speed, the whole guideway cannot be covered in Shanghai by GMS. For the guideway sectors in which the minimum speed of 20 km/h is not given (stations, maintenance area), separate software modules are available. Here the gap signal is recorded and compared visually with a reference dataset (Figure 9).

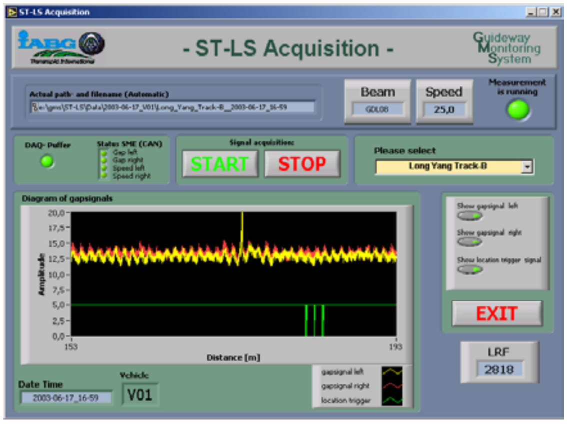


**Figure 9: GMS – Low Speed**

Exact driving profiles are specified from which then, for the measurement one can be selected. This measurement is performed manually at longer time intervals.

A very small guideway sector, which cannot be travelled over with Section E2 (installation place of GMS) of the maglev vehicle, must be monitored manually at longer time intervals.

# 5 GMS - Ratings

Measurements / Interfaces:

- Gap and v-Signal (levitation)
- Gap (guidance)
- LRF – Signal (tracking)
- CAN – Bus (diagnosis, tracking)
- Maintenance Management System (MMS)

Speed Ranges and Resolutions:

- online measurement and calculation from 20 km/h to 500 km/h
- 20 km/h to 70 km/h: Detection of offset changes ≥ 2mm
- 70 km/h to 500 km/h: Detection of offset changes ≥ 1mm
- Special Low Speed Measurements in ranges under 20 km/h

# 6 Future Prospects

With the help of GMS, further extensions to automatic guideway diagnosis are possible. This affects both the recording of further parameters and also intelligent pre-evaluation, which weights and assesses the determined offset changes before the operator evaluates the results. This is of course necessary particularly against the background of longer track distances.

## References

[1] Nieters W., Snieders G., Runde H.G.
Guideway Monitoring Systems for the High-Speed Maglev Train
Maglev 2000