Innovation of the Transrapid Propulsion System

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Markus Engel, Rolf Hellinger & Juergen Nothhaft
Siemens AG, Industry Sector, Mobility Division, Erlangen, Germany

ABSTRACT: The Transrapid system is currently optimized based on the operational experience gathered with the Shanghai Maglev Transrapid Project. The goal is to meet the requirements of future commercial lines. In the following, the current status of developments concerning the propulsion system is described.

1 INTRODUCTION

Since 2004 the first commercial operation of the Transrapid on the Shanghai track from Long Yang Road Station to Pudong Airport shows that the Transrapid System is highly available and very efficient in operation. In order to enhance the competitiveness for subsequent projects the Transrapid is optimized technically and economically within the scope of research and development projects. With regard to the complete system Siemens is carrying out these tasks together with its partners ThyssenKrupp, Transrapid International and the civil construction industry. The individual subsystems are also optimized. Four examples for innovations in the subsystem “propulsion” will be presented in the following as showcases.

2 ASSIGNABLE CONVERTER UNIT

2.1 Present solution

The present propulsion architecture [1] emanates from pure point-to-point connections: At the most a propulsion segment (ABE) borders to one further propulsion segment at each side. The propulsion blocks can be either allocated to two adjacent propulsion segments (propulsion block or substation of type I) or are attached to one propulsion segment (propulsion block or substation of type II). Regarding type I, a vehicle can only be driven in every second propulsion segment with the available resources. Regarding type II, this can occur in every propulsion segment so that a closer headway of trains is possible. In both cases the available resources are used to full capacity. This is shown as an example in the propulsion layout of the Transrapid on the Shanghai track from Long Yang Road Station to Pudong Airport (Figure 1): The propulsion blocks H (high power) in both substations are executed as type I. They can feed the allocated track of the main line as well as the turning segment. The propulsion block M (medium power) for the turning segment of vehicles behind Pudong Airport Station corresponds to type II as it is solely allocated to this propulsion segment.

The disadvantage of the present allocation is that a propulsion block cannot be reconfigured for the use in a third propulsion segment according to the architecture although the propulsion block may currently not be used for the vehicle operation in the two allocated segments. Particularly regarding routes with junctions and multi-tracked stations the case definitely arises that on the one hand available propulsion blocks are currently not required for the vehicle operation and on the other hand additional propulsion blocks have to be provided in order to ensure the vehicle operation in all spatially assigned propulsion segments.

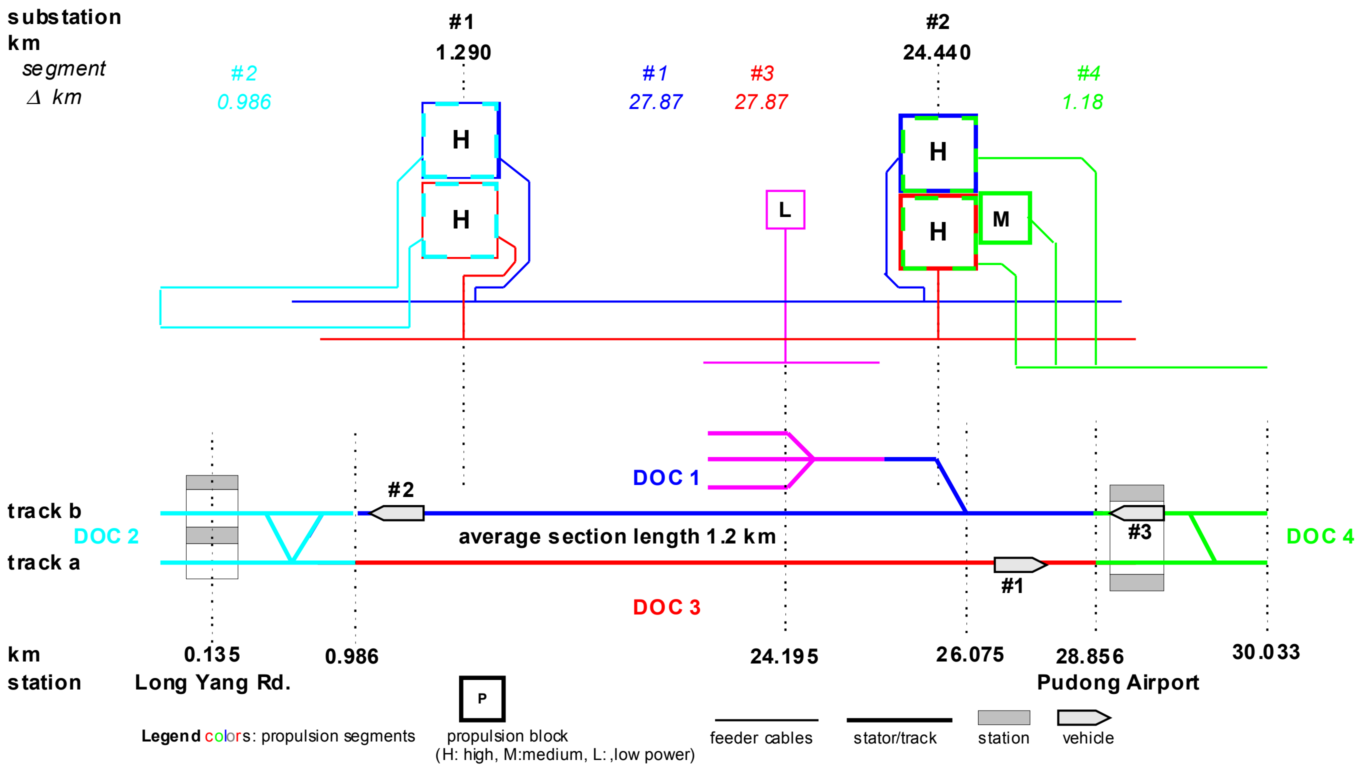

Figure 1: Propulsion layout of Transrapid Shanghai (Long Yang Road Station – Pudong Airport Line)

2.2 Innovation

In the future a propulsion block can be assigned to up to four propulsion segments. Thus the number of propulsion blocks and with it converter units required for the track layout will decrease depending on the project conditions. In this way the investment costs can be reduced. The converter units' output switchgear of a propulsion block has to be extended so far that contactors are available for four outgoing lines. Furthermore the possibility to allocate the propulsion block to up to four propulsion segments has to be considered in the resource control of the propulsion control system.

In the present architecture of the converter units there are circuit breakers in the outgoing lines for the safe propulsion shut-off (SIAB). On the one hand these SIAB circuit breakers can be omitted by the electronic safe propulsion shut-off through converter block [2]. On the other hand the converter units which can be assigned to several propulsion segments require that a converter unit can be put into operation again after a safe propulsion shut-off in the currently fed propulsion segment „#k". However this is only valid for safety reasons when the propulsion segment „#k" is separated safely from the converter unit. For this reason two contactors in series are provided in each outgoing line.

These selective SIAB functions require adjustments in the operation control system which controls and takes responsibility for the SIAB functions, too.

2.3 Status quo

On the Transrapid test track Emsland (TVE) the output switchgear of the converter unit #2 in the substation #3 has been reconstructed according to the described concept due to testing purposes. The final testing is planned at the beginning of 2009. This implies an according verification for the aspired type approval of the assignable converter unit.

The new concept of assignable converter units is already considered in the layout for the planned Transrapid track between Shanghai and Hangzhou.

3 COMPACT SWITCH STATION

3.1 Present solution

The switch stations which serve as supply for the individual stator segments of the long stator linear motor on the track are constructed as independent buildings and placed next to the guideway so far. The determining element for space in a switch station is the medium voltage switchgear. Typically it consists of six cabinets in the present design (double switch station). Two cabinets at a time are necessary for

- the link of the both feeder cable systems
- the feeding contactors of both allocated stator segments and
- the neutral point contactors of two further stator segments.

As the switch cabinets have been built with air-insulated technology so far this results in a respectively large and heavy building (length x width x height: approx. 6.6 m x 3.0 m x 3.5 m; mass: approximately 30 t). Figure 2 shows a switch station on the Transrapid track in Shanghai.

The switch stations are separately arranged due to size and weight. Normally they are not mounted directly at the place for feeding the stator segments. For this reason additional feeder cables are required. Moreover the buildings have to be considered for regional planning and planning approval processes.

Figure 2: Switch station and cable tray on the Shanghai track

3.2 Innovation

The aim is to minimize the switch station in a way that it is location-independent as far as possible and therefore can be installed directly at the point of feeding of the stator segments. Thus the previously required feeder cables do not have to be applied. Moreover the switch station has to be easily exchangeable in order to enable the shortest possible repair times in case of malfunction.

The switch stations are optimized in two stages:

1. The switch cabinets are mounted with gas-insulated technology. This technology permits pluggable cable connections and saves space. Thus the width of a switch cabinet is reduced from 1.1 m to 0.6 m. The housing for the switch cabinet can be configured smaller accordingly.
2. When doing without a separate accessible building for the switch stations, the switch cabinets and other required components (e.g. safety and control devices) can be placed in a housing of lightweight construction. However the housing has to be appropriate for an outdoor mounting. This type of construction called compact switch station can be mounted either on a foundation (clearly smaller dimensioned than before) alongside or underneath the guideway or directly at a guideway column (Figure 3). The expenses for the project planning process decline particularly in the latter case.

Switch station adapters are integrated in both types of construction which realize safety and control functions.

Figure 3: Compact switch station mounted at a guideway column

A test on the TVE is indispensable before the newly developed compact switch station comes into operation in commercial projects. The switch station adapter has to stand the test in combination with the propulsion control system on Sicomp basis innovated in the development program (WEP) of the German Federal Ministry of Transportation, Building and Urban Affairs (BMVBS) [2, 3]. In addition the functionality of the segment overlap shall be tested. On the TVE the both are only feasible with the converters in the feeder cable system 2. The following locations were selected against this background:

– Switch station 1 for the tests concerning the segment overlap
– Switch stations 4 and 6 for the tests together with the new control system and the new cable laying concept according to chapter 4

For the tests the new switch stations are embedded via existing switch stations in the propulsion system. Therefore they have to be installed as close as possible to the existing switch stations in order to keep the required electrical connections as short as possible.

In addition to the purely functional testing of the switch stations for propulsion purposes other aspects were also taken into consideration for the conception of the TVE tests:

– The three required compact switch stations have been purchased from two different suppliers in order to test different construction types.
– Both assembly types have been realized: the assembly on a foundation beside the guideway (switch stations 4 and 6) and the mounting of the switch station at a guideway column sectioning (switch station 1, Figure 3). Technical expertise shall be gained regarding both assembly types for mounting and commissioning. Instructions for maintenance and in particular for the component exchange shall be gathered.

3.3 Status quo

The assembly work for the three switch stations on the TVE is completed. The new switch stations are available for TVE operation along with the previous ones. The integration of the new switch stations into the propulsion control system including safety functions will be tested in the next weeks. Final driving tests in the complete Transrapid-system are scheduled for the end of 2008.

4 OPTIMIZED CABLE LAYING

4.1 Present solution

An elementary characteristic of the Transrapid with its long stator linear motor is the cable routing along the track from substation to substation in order to supply the individual stator segments of the track (schematic illustration in Figure 1). Power supply and communication cables parallel to the track have to be provided as well in order to supply the consumers alongside the track (switch stations, guideway switches, external onboard energy supply, radio transmission masts).

So far the cables are laid directly in earth or in an appropriate cable tray depending on the customer requirements and local conditions (Figure 2). Special constructions for the cable routing are required regarding the crossing of streets, waters etc. The resulting mounting effort is a significant share of the assembly work and therefore of the propulsion investment costs as well. The reduction of required space and cable laying expenses is aimed for an optimized cable laying beside the track. This implies a reduction of required cables (Figure 5). Moreover the feeder cable systems have to be arranged as independent as possible from local conditions of the project.

4.2 Innovation

Up to now feeder cable systems consist typically of two three-phase systems, connected in parallel, which are laid by bundle (triangular). This assembly leads to different currents (concerning magnitude and phasing) in the cable conductors and shielding due to the resulting deviations in the cable impedances. This effect of irregular distribution of current increases with higher operating frequencies of the synchronous long stator motor and has to be considered for the cable design.

Calculations for two cable systems consisting of single-wire cables in three-phase operation and connected in parallel have shown that all cable impedances will become equal (concerning magnitude and phasing) if the complete cable arrangement forms a circle and the phases connected in parallel are opposite. This knowledge has led to the development of an innovative cable clamp (see Figure 4, left part). The cable clamp cannot only hold the propulsion feeder cables but also the other necessary cables alongside a Transrapid guideway.

When applying the standardized power supply according to chapter 5, for a track equipped with the alternating-step method [1] only two cable clamps are required for both feeder cable systems and one cable clamp for the remaining low voltage and communication cables. This leads to a considerably reduced cross section area for the cable laying (see Figure 5 compared to Figure 2). Additionally the symmetric cable arrangement facilitates the ground leakage detection.

The cable clamp can be mounted in standardized cable trays, at walls or at a guideway beam.

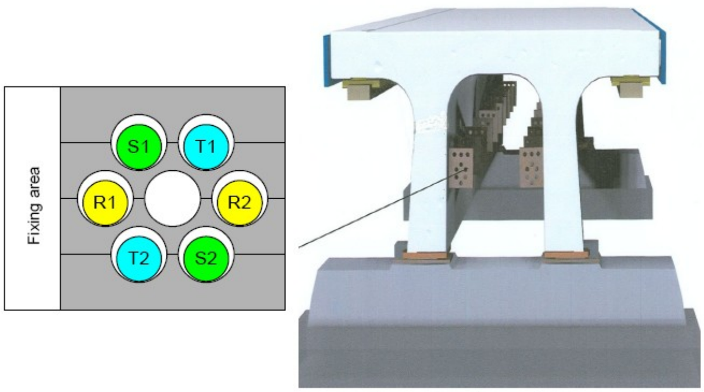

Figure 4: Bögl guideway beam with integrated cable clamp (schematic diagram with occupation of the feeder cables)

A solution for placing the cable clamp directly in the guideway beam was developed together with the construction company Max Bögl (Figure 4). Compared to the arrangement in cable trays, the cable arrangement directly in the guideway offers the advantage that no individual cable run alignment is required and therefore the planning process for the propulsion system is made considerably easier. Due to the cables lying in the guideway beam there are less cable cuttings. The environmental conditions are clearly defined so that the cable cross section (with regard to the requirements of the vehicle operation and track length) can be reduced.

4.3 Status quo

In the track section between switch stations 4 and 6 feeder cables have been mounted according to the optimized cable laying method. As expected the effort of laying and pulling the cable could be reduced thanks to cable clamps (Figure 5). Like the compact switch stations the cable clamps were also purchased from two different suppliers in order to test various designs of the cable clamp. The forecasted electrical features of the feeder cable arrangement shall be verified by the end of the year within the scope of the driving tests.

Figure 5: TVE track section for testing of the new cable clamps

5 STANDARDIZED AUXILIARY POWER SUPPLY FOR TRACKSIDE EQUIPMENT

5.1 Present solution

In order to feed the consumers along the track with auxiliary power supply, up to now a 20 kV cable is laid beside the track which supplies the transformer stations (arranged in regular distances). From these transformer stations the individual consumers are radially fed on the low voltage level (Figure 6).

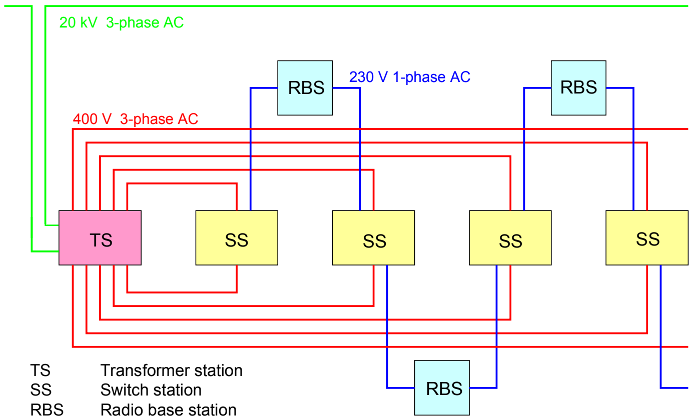

Figure 6: Radial supply of the consumers alongside the track

5.2 *Innovation*

The goal was to feed the switch stations through a low voltage cable alongside the track (linear structure with branches according to Figure 7) in order to avoid the efforts for a medium voltage supply. This was enabled by the low requirement of auxiliary power of the new compact switch stations. Because of the length of the low voltage feeder cable a line voltage drop of up to 50% has to be tolerated. Therefore the switch stations obtain a newly developed power supply unit which transforms the locally variable supply voltage to a constant voltage of 230 V AC. The unit is engineered so compact that it can be integrated in the housings of the medium voltage switch cabinets of the switch station. For this reason a so far necessary separate cabinet for auxiliary power distribution within the switch station can be omitted.

High-capacity consumers like guideway switch drives or external onboard energy supplies are mostly arranged nearby the substations and can be supplied directly from there. Therefore transformer stations and a continuous 20 kV cable alongside the track can be renounced. Redundant supply is performed so that no operational limitations occur if one line should be canceled.

The engineering of power supply alongside the track is made easier by the new concept. As a result there is a very steady number of power supply cables alongside the track (Figure 7).

5.3 *Status quo*

The development of the power supply unit is completed. Appropriate devices are installed in the compact switch stations 1, 4 and 6 on the TVE and will be tested together with them.

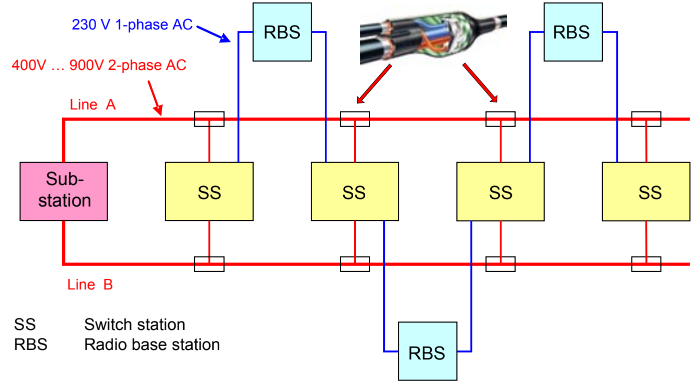

Figure 7: Linear supply of the consumers alongside the track

6 SUMMARY

The presented measures demonstrate an evolution in the propulsion system within the scope of its approved standardized structure [1]. The principal aim is to reduce the costs and therefore strengthen the competitiveness of the Transrapid. These targets can be reached by the presented methods. Furthermore planning works and processes required for a project can be facilitated.

The relevant work status was presented. According to the approved approach not only development and engineering work is necessary but also the testing of the innovations on the TVE is very important. After completion of this work the measures can be applied in the bid process for potential new tracks.

7 SOURCES

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