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THE SIMULATION AND ANALYSIS FOR A NEW CONCEPT OF THE STATOR POWER SUPPLY MODE OF A MEDIUM SPEED MAGLEV SYSTEM

Aim: The Aim of this paper is to demonstrate the structure of the proposed new stator power supply mode.

Methods: analyze the results of some simulation work to see whether the new concept could meet the requirements of the medium speed maglev transportation system or not. The study is based on some simulation work which is done by the software tool developed in the research work in “The 11th Five-year plan” of China.

Results: The calculation results indicate that, from the point of view of top speed, that say 200 km/h, the structure of the new concept could meet the requirement of the medium speed system, but further studies are demanded for the engineering application.

Conclusion: The advantage of this structure is to reduce the demand for the capacity of the inverters and eliminate the requirements for the cable lines and the stator switches. However, the disadvantage is also explicit. The structure is more complex than its high speed peer, and thus need more complex control strategies. And the structure is more fixed and thus maybe need more invest at the beginning of an engineering project.

Keywords: medium speed transport, power supply mode, medium power converter, simulation, long stator synchronized linear motor

INTRODUCTION

Since 40s of last century, Maglev transportation technology has been studied and developed for over 70 years. The application speed mainly focuses on two areas: below 120 km/h or higher than 430 km/h. For the slow speed range, the short stator linear induction motor is applied, for example the HSST demonstration line in the Tsukuba World Exposition and the Changsha Maglev Express Line. As for the high speed range, the long stator linear synchronous motor is the better choice. Transrapid Maglev technology, which is used in Shanghai Maglev Project, and SCMaglev technology, which will be used in Chuo Shinkansen Project, are both this type of linear motor.

Recently, some Chinese government officials and experts are seeking for a transportation type around 200 km/h operation speed to solve the relatively short inter-city traffic problem, which demand more strong acceleration capability than

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traditional wheel rail technology to shorten the accelerating periods, and then make the whole travel time reasonable. The long stator synchronous motor therefore is taken into account. The new concept structure of the stator power supply mode, which is just designed for this medium speed system, proposed firstly by CRRC Zhuzhou Locomotive Co., Ltd. Then the research work is supported by Ministry of Science and Technology of China in “The 13th Five-year plan”.

This paper describes the details of this new structure. The main idea is to degrade the capacity requirement of the motor, and put more general industrial converters into consideration. The paper reveals the feasibility of this new concept from the point of view of speed requirements. Other details about the engineering adaption are still under further research.

In the following description, the new structure of the power supply mode is introduced firstly. Then the simulation results based on the same motor parameters as Shanghai Maglev Project are presented. After analyzing the advantages and disadvantages of the system, some conclusions are drew at the end of the paper.

THE NEW CONCEPT OF POWER SUPPLY STRUCTURE

The proposed structure is presented in Fig. 1. Basically, the linear motor, including the materials, size, the stators and the rotors on the train, is as same as the one applied in Shanghai Maglev Project. The main difference is the connection types.

Fig. 1a shows the supply mode when the system is configured 4-car trains. There are two long stator sections in (a). Each section locates on one side of the boundary line and is divided into two groups of subsections, which are named Stator Unit in the figures. The color blue stands for one group of stator units and red stands for another. One stator units is about two carriages long. The stator units in the same group are arranged at intervals and connected directly by stator cables. As a result, the total length of one stator units group is about half of one stator section.

The situation of 6-car trains is present in Fig. 1b. The difference between (a) and (b) is that each stator section is divided into three groups of stator units. As can be seen in (b), the color green on the track means the third group of stator units. The stator units from the three groups is arranged in sequence along the track, and therefore each group of stator units is about one third of the stator section length. According to the same principle in Fig. 1c, if the system demand for 8-car trains, the stator section will consist of four groups of stator units, each of which is about one forth long of the stator section. The fourth group is color orange in (c). The length of stator units in (b) and (c) is same as that in (a), which is about two carriages long of the train.

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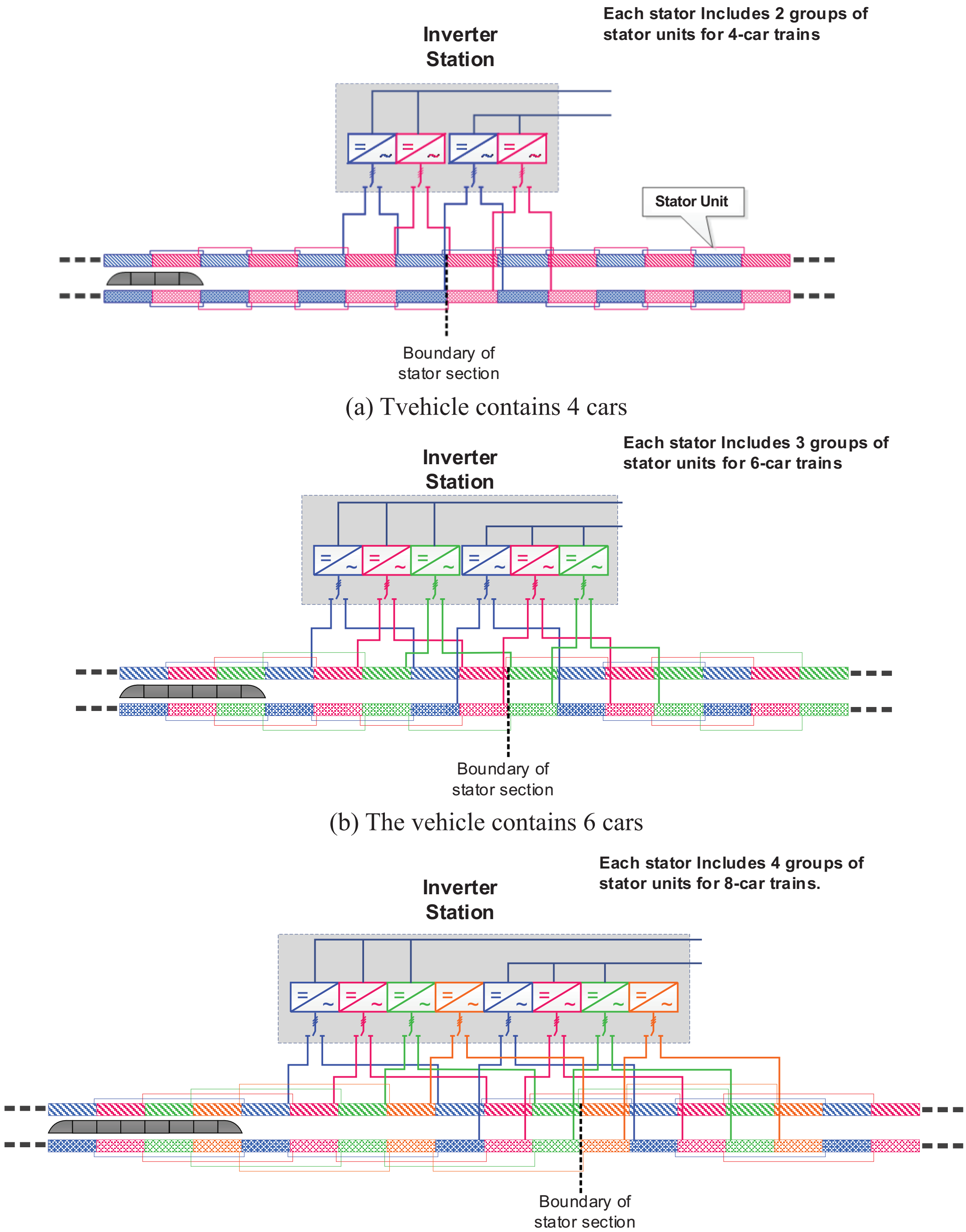

(a) Tvehicle contains 4 cars

(b) The vehicle contains 6 cars

(c) The vehicle contains 8 cars

Fig. 1. The sturcture of the new concept power supply mode:
Same color means belonging to the same stator unit group which is excited by the inverter in the same color

Another important issue that needs to be addressed is about inverters, which are located by the track near the boundary of stator sections, and shared by two adjacent stator sections through the output switches. Compared with the arrangement in Shanghai Maglev Project, this kind of design saves the feeder line

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cables along the tracks, and thus avoids the voltage drops on the feeder cables. The trackside switch stations now should be called propulsion/inverter stations, for the stator switches are replaced by inverters now. In Fig. 1, Each group of stator units is corresponding to one inverter that is in the same color.

Fig. 2 gives an example of the whole structure of the new concept, which is a draft of the propulsion system for a medium speed test line. There are two inverter stations and a power station. The rectifiers in power station transform the 20 kV input AC voltage to 3000 V DC voltage, and then supply the DC power to trackside inverters.

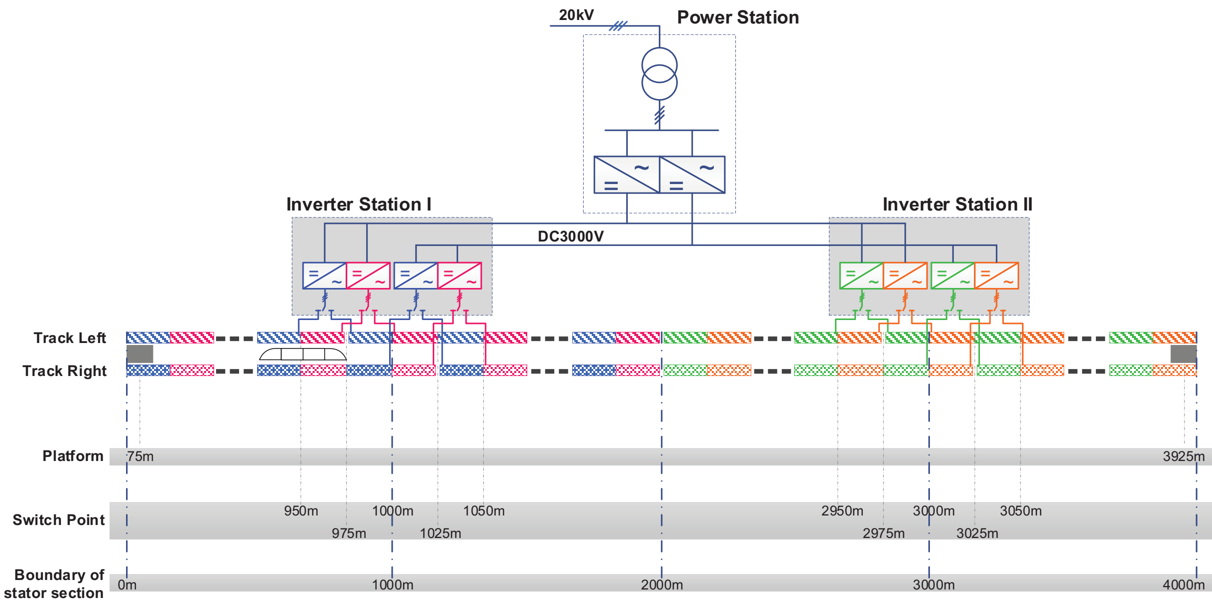

Fig. 2. A draft outline of the propulsion system for a medium speed test line

SIMULATION RESULTS

The track line in Fig. 2 is about 4 km long, which is constraint by the onsite geographical conditions and the project budget. To evaluate the acceleration capability of and the electrical characteristics of the new power supply mode, the length of the track is set to 5 km (for 1000 m stator section) or 8 km (for 2000 m stator section) to ensure that the propulsion system has enough distance to reach 200 km/h. In addition, the plane and vertical curves of the track are neglected too. The other simulation conditions are listed in Table 1.

Since every two stator sections corresponding to one trackside inverter, the length of the stator section is the crucial data for the cost of inverters. In consequence, the behavior of the propulsion capability with different lengths of the stator section is concerned. The different numbers of the carriages of the train are also taken into account in the calculation. All trains are full loaded. The simulation

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Table 1. Simulation Conditions

Items	Contents	
Track	Length: 5 km / 8 km without plane and vertical curves	
Vehicle	Number of cars	4-car, 6-car or 8 car 1.5 m/car
	Weight	Each empty car: 24.5 t end 24 middle; Each full car: 31.2 end 31.2 middle
Inverter	Current Limit	1200 A
	Voltage Limit	2200 V (Line Voltage)
Stator Section Length	1000 m / 2000 m	

results with 1000 m and 2000 m stator section are presented respectively in the following paragraph. All the simulation work is carried out by the software named MaglevPDS, which is a research achievement in the "The 11th Five-year plan".

1. 5 KM TRACK FOR 1000 M STATOR SECTION

The speed and acceleration profiles with are shown in Fig. 3. The acceleration capability data is listed in Table 2.

Fig. 4 is the power profiles for each numbers of carriages. The relative power data is listed in Table 3.

Table 2. List of Acceleration Capability Data (1000 m stator section, 5 km track)

Number of cars	Running Time (s)	Accl. Distance (km)	Accl. Time (s)	Max. Accl. (m/s^2)	Average Accl. (m/s^2)
4*	180	2.94	104	0.673	0.534
4**	198	3.01	105.2	0.673	0.528
6	180	2.79	101.4	0.632	0.548
8	181	2.78	101.6	0.591	0.545

* A 4-car train can not reach 200 km/h with 5 km track. The maximum speed is 198.6 km/h.

** If the track is extended to 6km, thetrain can reach 200 km/h.

Table 3. List of Power Data (1000m stator section, 5km track)

Number of cars	Max. Power for Each Inverter (MW)	Maximum Total Power (MW)
4	2.00	8.01
6	2.17	13.02
8	2.10	16.77

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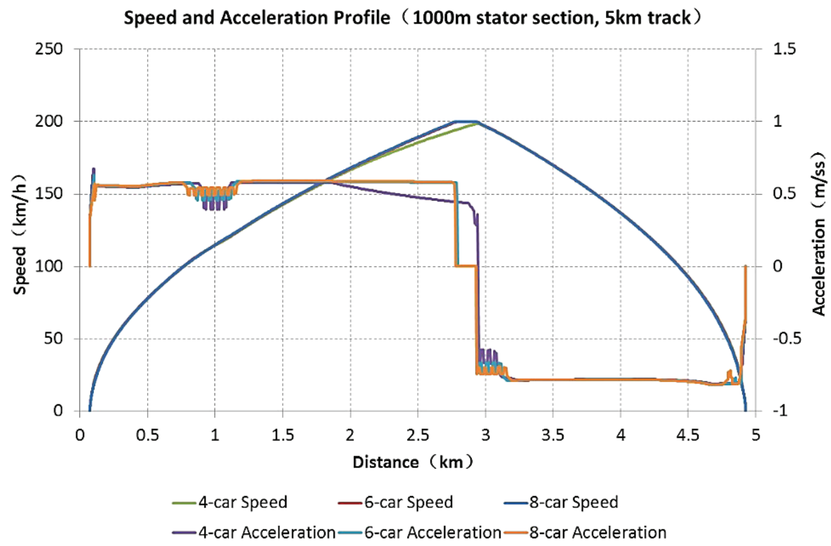

Fig. 3. Speed and acceleration profiles for 1000 m stator section with 5 km track

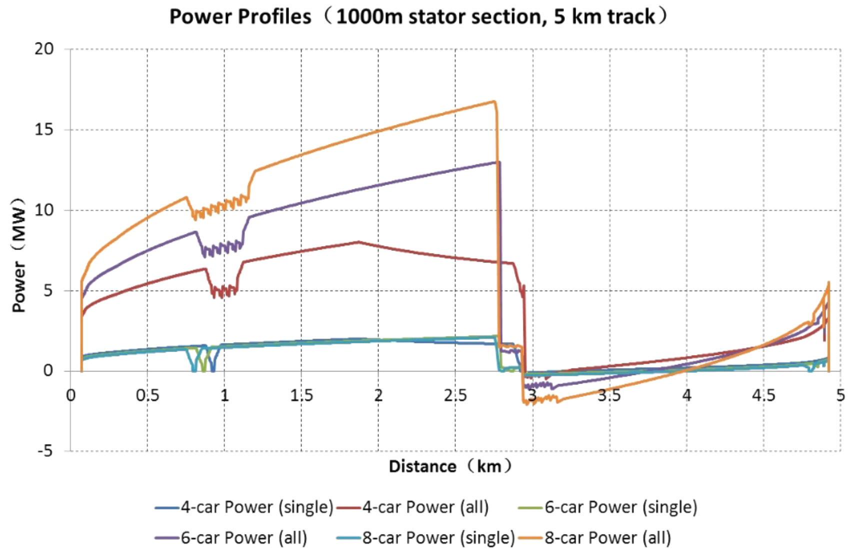

Fig. 4. Power profiles for 1000 m stator section with 5 km track

2. 8 KM TRACK FOR 2000 M STATOR SECTION

The speed and acceleration profiles with 2000 m stator section and 8 km track are shown in Fig. 5 and the acceleration capability data is listed in Table 4. Fig. 6 is the power profiles for each numbers of carriages. The relative power data is listed in Table 5.

ANALYSIS

The simulation results demonstrate that this new concept of power supply mode can meet the requirement of 200 km/h top speed, and can be one of the alternative designs for the medium speed system.

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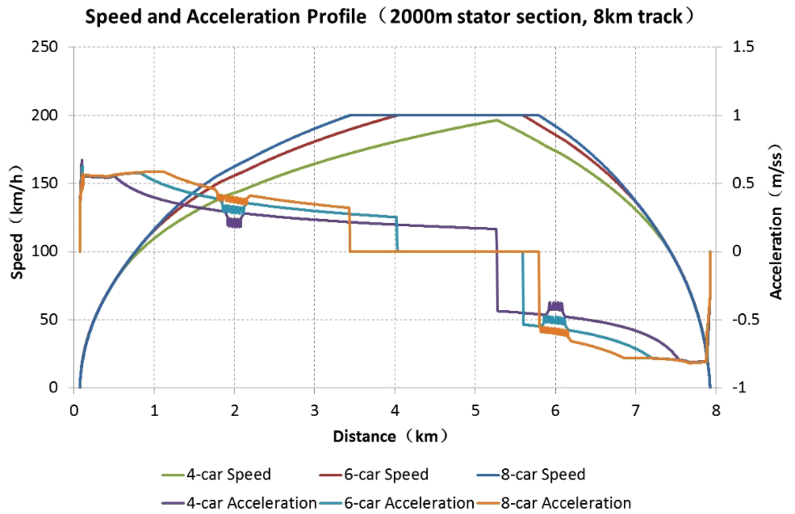

Fig. 5. Speed and acceleration profiles for 2000 m stator section with 8 km track

Table 4. List of Acceleration Capability Data (2000 m stator section, 8 km track)

Number of cars	Running Time (s)	Accl. Distance (km)	Accl. Time (s)	Max. Accl. (m/s2)	Average Accl. (m/s2)
4*	248	5.27	156.8	0.673	0.348
4**	266	5.60	162.7	0.673	0.341
6	239	4.03	127.3	0.632	0.436
8	237	3.44	114.8	0.589	0.484

* A 4-car train can not reach 200 km/h with 8 km track. The maximum speed is 196.5 km/h.
** If the track is extended to 9 km, thetrain can reach 200 km/h.

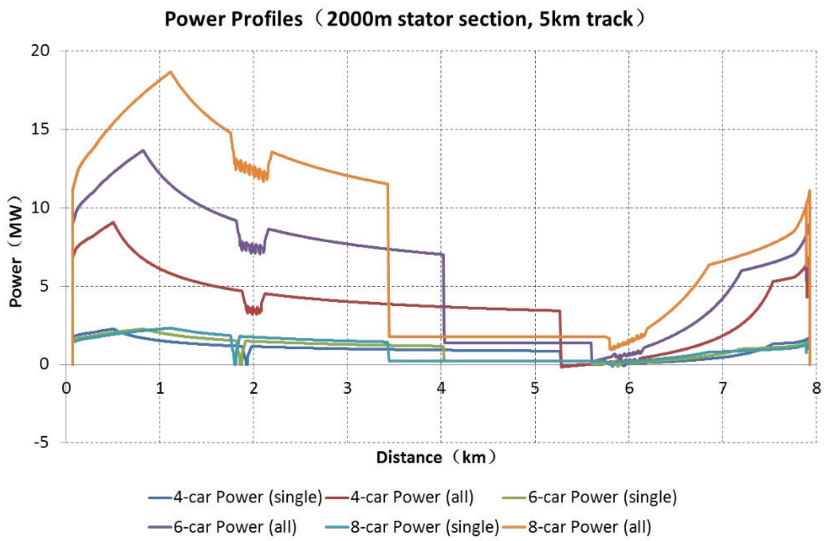

Fig. 6. Power profiles for 2000 m stator section with 8 km track

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Table 5. List of Power Data (2000 m stator section, 8 km track)

Number of cars	Max. Power for Each Inverter (MW)	Maximum Total Power (MW)
4	2.27	9.07
6	2.28	13.67
8	2.34	18.68

A special feature of the system is that the longer the train is, the more strong acceleration capability the system has. Since for the similar length of the stator section, longer train means shorter stator units group. For example, a 4-car train corresponding to 2 groups of stator units, which indicate one half of the stator section length for each group. While a 8-car train indicate one fourth for each group. This feature is more explicit in 2000 m stator section situation.

Another feature can be seen from the above results is that the output power of each single inverter is almost at the same level, no matter what the number of the carriages of a train is. That is because the inverters are located beside the track, the main part of the output voltage is the back EMF of the train. While each inverter only corresponds to two cars of the train, no matter how many the carriages the train has. Therefor the structure is easy to standardize and generalize.

From the data listed in Table 1, the capacity of inverters in this paper is around 4.5 MVA, which is less than 1/3 of the capacity of the high power converters used in Shanghai Maglev Project. That mainly benefits from the reduced top speed and the trackside inverter strategy. Since the voltage requirement is degraded, the output voltage of the inverter is sufficient for the system, and the output transformers are not necessary. The trackside stator switches are also removed which is another advantage of the trackside inverter.

This structure also has some obvious defect. The greatest one is the dependency between the stator connection type and the number of the carriages of a train. Due to the difficulty of change the connection type after the project put into operation, the inverters for the longest train must be allocated at the beginning of the formal operation. That indicates the project should invest more money for a long term planning at its initial term.

Additionally, because of the more complex structure, the stator section switch principle is more complex too, which indicate the control system need more resource to switch between stator sections.

Another disadvantages is about the 3000 V DC line. Since the DC cables are layout along the track, the voltage will drop on the cables. If the ripple of the DC voltage is too large, the output voltage of the inverter will be affected.

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CONCLUSION

This paper demonstrate a new concept power supply mode for the medium speed transportation system. Some simulation research results are presented and the advantages and disadvantages are analyzed. It is verified that the new concept structure is reasonable and feasible for a medium speed system, but further research is required before the concept put into reality.

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