Novel Feeding System for Maglev aiming at Cost Reduction

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Topic number: **4.3** Power Supply for Propulsion

We suggest replacement of the existing triplex feeding system for superconducting maglev with a novel duplex system to reduce system costs. Two types of duplex feeding systems are under examination, each having a problem. This paper describes compositions and characteristics of each duplex feeding system.

Keywords: maglev, linear synchronous motor (LSM), feeding system for maglev

1. Introduction

Vehicle running tests have progressed smoothly on the Yamanashi Maglev Test Line since their start on April 1997. We need to perform long-term durability tests and develop ways to reduce costs in order to realize a commercial system. As for the power supply system, we have developed and examined various ways to reduce costs, such as a neutral point bias control of the inverter for driving a linear synchronous motor (LSM) [1]. Now, we are developing the novel duplex feeding system to replace the existing triplex feeding system to cut costs further.

We adopt LSM to drive trains, which consists of superconducting-magnet field coils loaded on the trains and propulsion coils arranged along the guideway as armature coils. The propulsion coils are divided into a number of groups of certain length (hereinafter referred to as sections) to improve the power factor and efficiency of LSM. Each section has a changeover switchgear. We properly select the sections supplied with driving power corresponding to the movement of trains. More importantly, the section changeover should be controlled smoothly in the feeding system.

As a feeding system for the Yamanashi Maglev Test Center, we adopt a staggered triplex feeding system which consists of three systems of an inverter, a feeder cable and sections. This system enables smooth changeover of sections, and also continuous operation of trains, even if one of the three systems breaks down. We need to develop a duplex feeding system in consideration of the stability of the exiting system, that is, the continuous operation of trains. According to this requirement, we investigate two duplex feeding systems.

In this paper, we describe the composition of the existing triplex feeding system first, and then compositions, changeover procedure of sections, characteristics and problems of two duplex feeding systems.

2. Existing triplex feeding system

Fig. 1 shows the composition of the staggered triplex feeding system for the Yamanashi Maglev Test Center. This has three individual systems, each consisting of an inverter and a feeder cable. Sections are alternately arranged along the

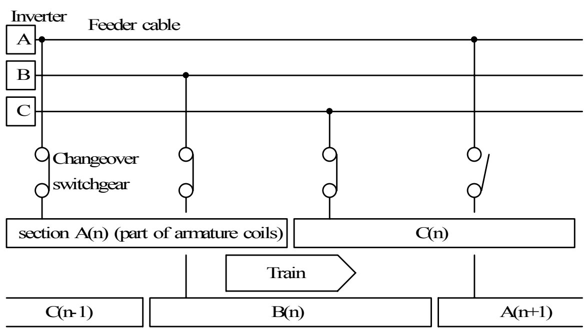

Fig. 1. Composition of the triplex feeding system

guideway and connected with each feeder cable through changeover switchgears. We hereafter refer to the sections connected with the system A as section A(n), A(n+1) and so on.

This system enables smooth changeover of sections by keeping the propulsion force of the train constant. For example, the inverter A stops its output when a train has left section A(n), and then the switchgear in A(n) is opened and the switchgear in A(n+1) is closed with no current. The train can get the necessary propulsion force from section B(n) and C(n) while the inverter A is at a stop. When the train approaches section A(n+1), the inverter A resumes its output.

3. Outline of the duplex feeding system

Although the existing feeding system is stable because of its redundancy, we may adopt a duplex feeding system so far as the redundancy of driving trains is concerned. We can reduce the costs by replacing the existing triplex system with a duplex system. However, this will lose the redundancy of changeover of sections, that is, changeover under constant propulsion force or in the no-current state. Taking these characteristics into consideration, we describe two types of duplex feeding systems. One is the “instant changeover” system, and the other is the “variable section length” system.

3.1 Instant changeover duplex system

3.1.1 System composition

Fig. 2 shows a composition of the instant-changeover duplex feeding system. As the sections belonging to each system are separated on each side of trains, we can operate trains continuously even if one system has broken down. However, we cannot help accepting continual fluctuation of propulsion force if we adopt this system. An example of the changeover of sections on the system A is as follows.

(1) The inverter A keeps on supplying power for section A(n) even if the front of a train enters section A(n+1). As the part of the train which enters A(n+1) gets propulsion force only from B(n), the total propulsion force of the train reduces.

(2) The inverter A stops its output when the center of the train approaches section A(n+1), and then the switchgear of A(n) opens and the

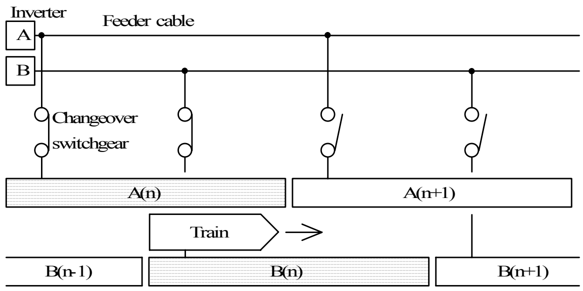

Fig. 2. Composition of the instant changeover duplex feeding system

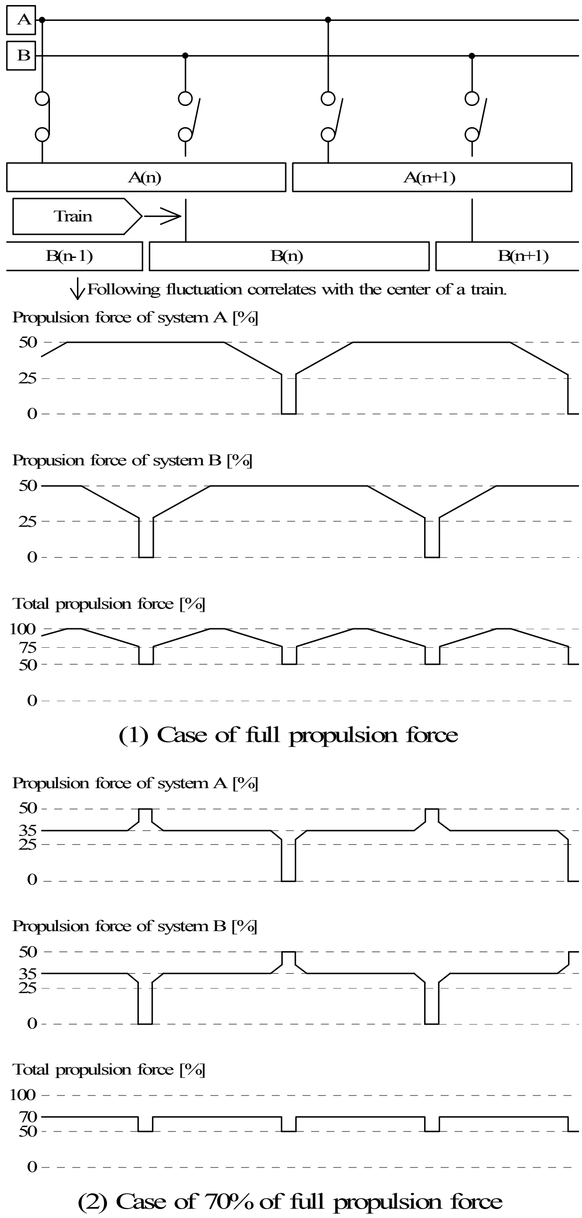

Fig. 3. Example of fluctuation of propulsion force

switchgear of A(n+1) closes with no current. The total propulsion force becomes a half of the necessary force while the inverter A is at a stop.

(3) The inverter A resumes its output after switchgears complete their operation. The total propulsion force reduces while a part of the train remains on section A(n).

Fig. 3 shows an example of the fluctuation of propulsion force when full propulsion force and 70% of full propulsion force are required. We show the full propulsion force of the existing triplex system as 100% in Fig. 3. In case of 70% propulsion force, we can reduce the fluctuation to a certain level by compensating for the shortage of propulsion force. This system has a problem that trains become less comfortable for passengers on board. Trains sway back and forth because of the fluctuation of propulsion force, and also right and left because of the imbalance of propulsion force on each side. If section borders on both sides match each other, the imbalance of propulsion force will disappear, but the fluctuation increases.

Fig. 4 shows a composition of instant changeover system where sections on each side of trains are connected in parallel. In this composition, each section is divided into some blocks with each block of system A and B arranged alternately along the guideway. Each block is shorter than a half of train length. This composition can remove imbalance of propulsion force without increasing fluctuation but needs extra cables to connect blocks.

3.1.2 Examination of ride comfort

Some compositions have already been investigated on the Transrapid system in Germany. However, we need to examine how comfortable (or uncomfortable) the trains become if we adopt these systems in the future. Therefore, we examined the ride comfort on the Yamanashi Maglev Test Line. We examined it equivalently as shown in Fig. 5 although the feeding system of the test line is a triplex one. For example, the inverter A stops its output before the center of the train reaches the border between sections A(n) and C(n). Then the inverter C resumes its output after the center of the train enters section C(n). The propulsion force reduces for the time (t-dead) from the stop point of inverter A until the resumption point of inverter C. We examined the ride comfort under various conditions of output current and t-dead.

Fig. 6 shows an example of the examination results. The vertical axis shows the ride comfort of duplex system in dB. The ride comfort of triplex system is 0dB and the larger the value is, the less comfortable trains become. The horizontal axis shows the output current of inverters. We examined the ride comfort under the condition that the t-dead is 100ms and the train runs at constant velocity in this example. From Fig. 6 we can observe that the lager the output current becomes, the less comfortable trains become. On the basis of the results of various examinations, we may conclude that we can adopt this system only in limited areas where the required propulsion force is small, such as, the areas where trains run at constant velocity and also trains reduce velocity.

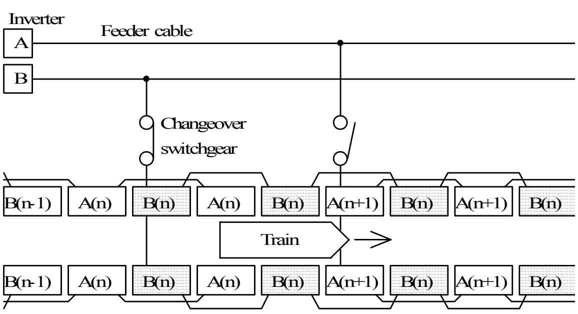

Fig. 4. Composition of the instant-changeover duplex feeding system (parallel type)

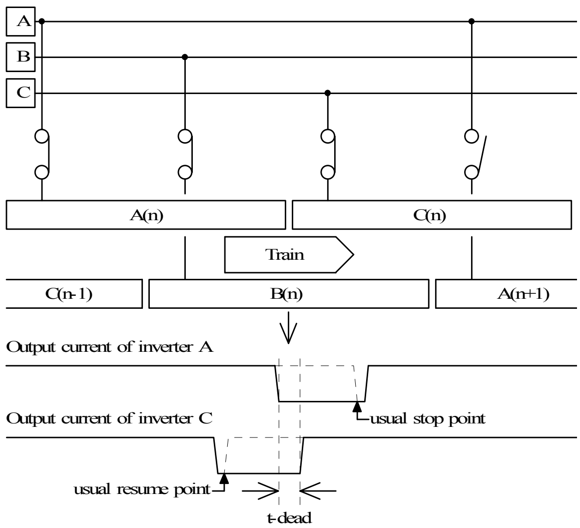

Fig. 5. Equivalent examination of ride comfort

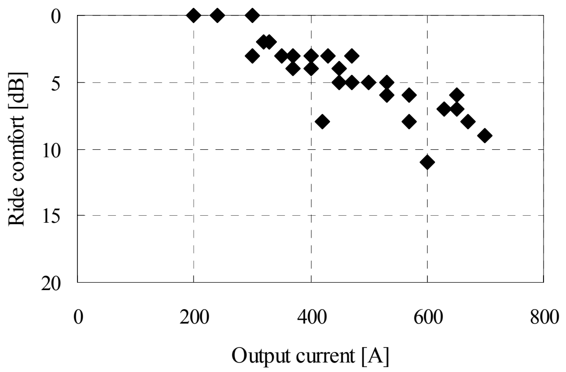

Fig. 6. Example of the examination results

3.2 Variable section length duplex system

Fig. 7 shows a composition of the variable section length duplex feeding system. This system also enables continuous operation of trains even if one system has broken down. Each section has three switchgears in this system. SW1 in Fig. 7 connects a section with a feeder cable; SW2 connects two adjoining sections and SW3 connects a section with its neutral point. An example of the changeover of sections on the system A is as follows.

(1) SW1A(n) and SW3A(n) are closed while a train exists on section A(n).

(2) SW2A(n) is closed when the train approaches section A(n+1), but most current flows to NP A(n) because the impedance of section A(n+1) is much higher than that of SW3A(n).

(3) SW3A(n) is opened when the train approaches section A(n+1) more. SW3A(n) has to cut off current at this moment. All current flows to section A(n) and A(n+1) through SW1A(n) and SW2A(n).

(4) SW1A(n+1) is closed when the train leaves section A(n). Most current flows to section A(n+1) through SW1A(n+1) because the impedance of section A(n) is much higher than that of the feeder cable. Then both SW1A(n) and SW2A(n) are opened.

As the inverters supply electric power for LSM continuously, propulsion force can be kept constant. This system, however, requires

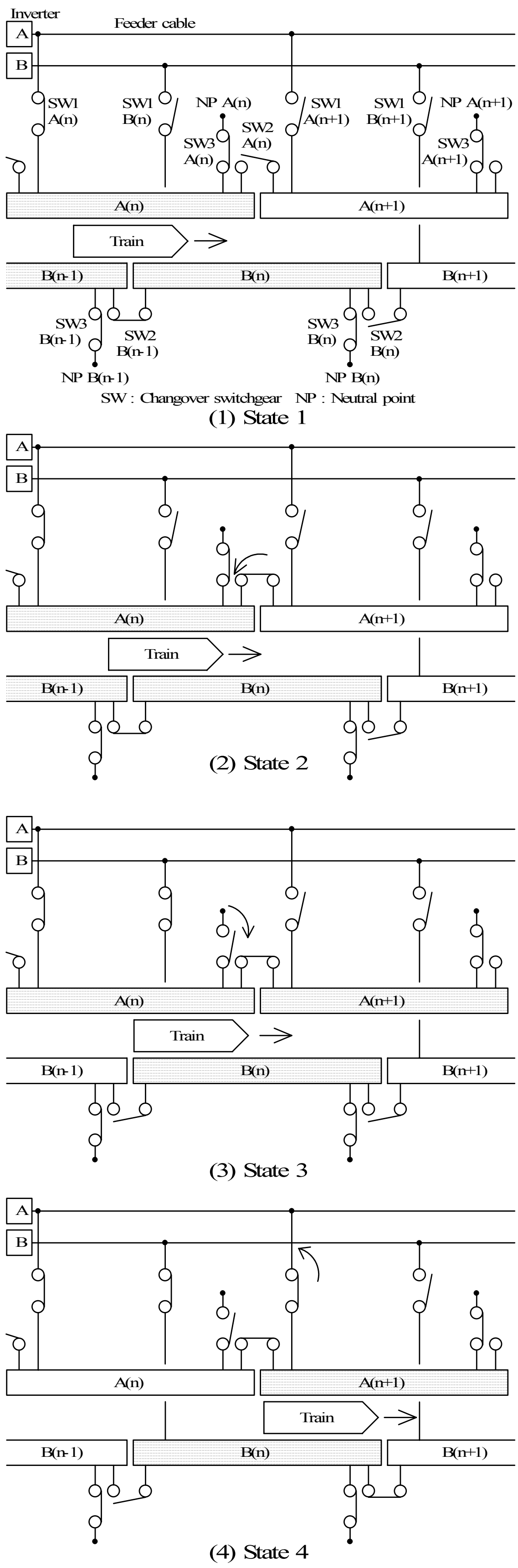

Fig. 7. Composition of the variable section length duplex feeding system

switchgears that can cut off current. As the output frequency of inverters is in proportion to the train velocity in particular, we need to develop switchgears that can cut off current in a low frequency range.

As this system requires three times as many switchgears as other systems do, the number of faults of switchgears will increase. On the other hand, the system can reduce the effects of the faults upon the train operation because this system is redundant. When a switchgear breaks down on the triplex system or the instant changeover system, for example, the system cannot supply the driving power to the section which is connected to the broken switchgear. Therefore, propulsion force reduces while a train exists on the section. Fig. 8 shows the case where SW1A(n) breaks down on the variable section length system. As the system can supply the driving power to section A(n) through section A(n-1) in this case, a train can get the required propulsion force even when it exists on section A(n). The system need to stop the inverter at the changeover from section A(n) to A(n+1). It should be added that the system can reduce effects of the faults of other switchgears, which is not explained here due to the limited space.

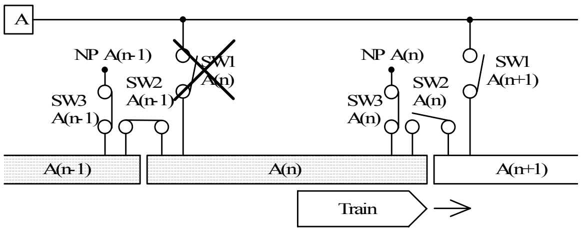

Fig. 8. Case that SW1A(n) breaks down

4. Conclusions

Each of the two duplex feeding systems investigated in this paper has a different problem. We have examined how we can accept fluctuation of propulsion force in order to keep trains comfortable for passengers on board for the instant changeover system, and concluded that we can adopt this system only in limited areas where the required propulsion force is small. On the other hand, we have to develop switchgears that can cut off current in a low frequency range for the variable section length system.

We will investigate the feasibility of the variable section length system and develop ways to overcome the problem in the future.

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References

[1] S. Kaga, I. Kawaguchi, A. Okui, J. Kitano: "Neutral point bias control method for large capacity inverter," quarterly report of RTRI, Vol. 41, No. 2, Jun. 2000