Unit 1

Railway Power Supply Systems

Learning Objectives

After learning this unit, you'll be able to:

- master the main technical terms related to railway power supply systems
- master the composition and main functions of railway power distribution systems
- master the composition and main functions of electric traction power supply systems
- talk about railway power supply systems in English

Part One Lead-in

1. **Directions:** Have you ever seen railways like the ones shown in the pictures below? Read the descriptions to learn about their similarities and differences.

The picture on the left shows a train being pulled by a steam locomotive. Through coal combustion, water is converted into high temperature and high pressure steam to drive piston movement and therefore train traction is realized. Because of the inefficiency of coal-fired heat conversion, heavy pollution, small power and low running speed, this kind of train is no longer in use today and can only be seen in railway museums.

The picture on the left shows a train being pulled by a diesel locomotive. In this type of train, diesel is burned to produce the driving power. The diesel locomotives are better than steam locomotives in efficiency and performance, thus becoming the main means of railway motive power in the 20th century.

The picture on the left shows a high-speed Electric Multiple Unit (EMU). It uses electricity as motive power, which is known as electric traction, featuring large power, high speed, great energy efficiency, little pollution, less maintenance and high energy utilization rates. Most heavy-haul railways and high-speed railways use electric traction, which has become the main means of traction power in the 21st century. Railways that use electric traction are also called electrified railways.

2. **Directions:** When you take the train, have you ever noticed any railway facilities powered by electricity? Do you know where the electricity comes from? Have a look at the pictures to find out more about railway power supply.

The picture on the left shows the high-voltage switchgear room of a 10 kV railway substation and distribution station. It redistributes the electric power from two 10 kV incoming currents into multiple 10 kV currents. The electricity is then transmitted to the railway electrical equipment through power lines.

The picture on the left shows the railway overhead power lines. They transmit the electric power from the substation and distribution stations to the electrical equipment along the railway.

The picture on the left shows the connection between the railway power line and the transformer. The transformer converts high-voltage electricity into 0.4 kV power, which will supply the nearby 380 V and 220 V electrical facilities, to ensure the normal operation of the ticketing machines, ticket checking machines, lighting equipment, air conditioning, cargo handling equipment, as well as signal and communication equipment.

The picture on the left shows a railway traction substation. It converts two lines of three-phase 110 kV or 220 kV (330 kV occasionally) alternating current power (AC power) from the public grid into multiple single-phase 27.5 kV AC power supply lines, which will supply the electric locomotives or EMUs through the lines of the overhead contact system (OCS).

The picture on the left shows the OCS lines. Mounted above the tracks, they are a special kind of power line transmitting electric power to the electric locomotives or EMUs.

The picture on the left shows an electric locomotive. It is a type of fast-moving electrical equipment, which gains electric power from contact of the pantograph with the OCS, and then converts the electric power into traction power to pull the train.

Part Two Reading Materials

Material A

Railway Power Distribution System

A railway power supply system consists of two parts: a railway power distribution system and an electric traction power supply system. The electric power facilities and networks managed by the rail system itself and used for railway transport production and consumption are collectively called the railway power distribution system. Figure 1.1 shows a power distribution system for high-speed railways, mainly consisting of a railway substation and distribution station and railway power lines. Part Ⅰ of the figure represents the run-through power line of load level Ⅰ while Part Ⅱ represents the run-through power line of comprehensive loads.

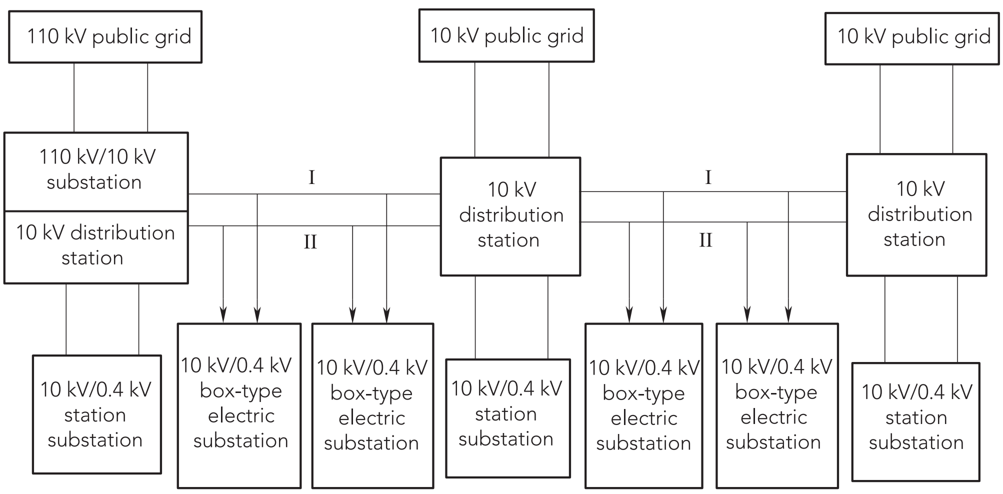

Figure 1.1 High-speed Railway Power Distribution System

Railway substations and distribution stations

Railway substations and distribution stations mainly include the following types: 110 kV/10 kV substations, 10 kV distribution stations, 10 kV/0.4 kV substations and 10 kV/0.4 kV box-type electric substations. 110 kV/10 kV substations and 10 kV distribution stations are normally used by railway hubs with heavy power-consuming loads or large stations.

Most railway substations and distribution stations employ maintenance-free or low-maintenance equipment to reduce maintenance loads. For remote monitoring, monitoring systems usually use integrated automation systems featuring high degree of automation, high-speed information processing and vast quantities of information.

Conventional railway power lines

Conventional railways are those with a speed of 160 km/h or below. They usually have two 10 kV or 35 kV power lines running along one side, called the run-through power line for automatic block system (ABS line) and the run-through power line respectively. The ABS line acts as the main power supply for signal equipment in automatic block sections and the standby power supply (SPS) for other loads of level Ⅰ along the railways. The run-through power line acts as the main power supply for power-consuming loads along the railways for running trains (except for automatic block signal equipment) and the SPS for automatic block signal equipment.

Figure 1.2 Conventional Railway Power Lines

The power lines of conventional railways, as shown in Figure 1.2, are usually overhead power lines. Some sections may adopt cable routes due to topographical restrictions.

High-speed railway power lines

High-speed railways are those with a speed of 200 km/h or above. Compared with conventional railways, high-speed railways have heavier CLASS 1 and CLASS 2 electrical loads for running trains in terms of communication and signals, heavier power-consuming loads at all stations and more distributed power-consuming load points within sections. Therefore, high-speed railways usually adopt run-through power lines of load level Ⅰ and run-through power lines of comprehensive loads to supply power. The former is the main power supply for communication, signals and the integrated dispatch system for train operation while the latter serves as SPS. Other power-consuming loads such as sections and stations along the railway receive power from the two kinds of lines respectively.

The two run-through power lines of high-speed railways normally use single-core cables which are laid along the cable trough on both sides of the railway in the form of waves, as shown in Figure 1.3. Compared with overhead power lines, the cable routes have better operating environment, lower maintenance requirements, and more reliable power supply. Some high-speed railways use both overhead power lines and cable routes for run-through power lines of comprehensive loads.

Figure 1.3　Cable Trough Laying of a High-speed Railway

Railway power-consuming loads

Railway power-consuming loads are divided into CLASS 1 electrical loads, CLASS 2 electrical loads and CLASS 3 electrical loads, as shown in Figure 1.4.

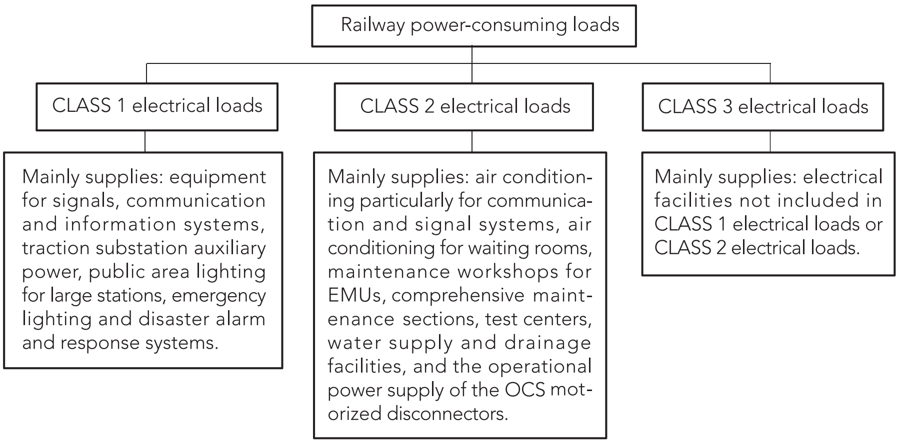

Figure 1.4　Classifications and Levels of Railway Electrical Loads

The railway power distribution system provides electricity for all the railway equipment, apart from those powered by traction power, to ensure their normal operations.

Exercise A

1. Directions: Answer the following questions based on the material.

(1) What are the main functions of the railway power distribution system?

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(2) Where are cable routes mainly used in railways?

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2. Directions: Fill in the blanks with the terms given below.

railway substation and distribution station	10 kV distribution station	0.4 kV
run-through power lines	10 kV	railway power lines

A railway power distribution system consists of a(n) (1) ________________ and (2) ____________________. A 110 kV substation converts 110 kV into (3) __________________ to supply a(n) (4) ____________ and (5) ____________, while a 10 kV substation converts 10 kV into (6) ______ to supply the electrical equipment.

Mini-project A

Objective

- Learn about railway power-consuming loads and the main functions of a railway power distribution system.

1. Directions: Work in groups. Each group is supposed to finish the following tasks.

(1) Based on your life experience and relevant materials, share your knowledge of railway electrical equipment and their main functions, and note down the key points.

(2) What are the differences between the requirements for CLASS 1 electrical loads and CLASS 2 electrical loads in a railway power distribution system?

(3) Discuss the relationship among power-consuming loads, power-supplying loads, and power-generating loads, based on Figure 1.5.

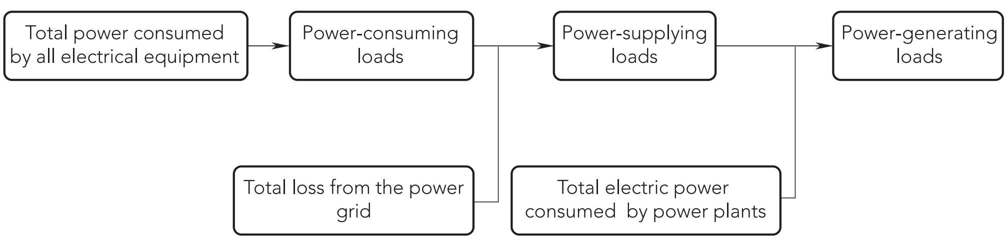

Figure 1.5 Relationship Among Three Types of Loads

2. Directions: Work in groups to discuss what you have learned.

Material B

Electric Traction Power Supply System

An electric traction power supply system is made up of traction substations, a traction network and other supporting power supply facilities. This system is an important facility of electrified railways and is of CLASS 1 electrical loads. It is used to supply traction power specially for electric locomotives or EMUs. Its composition is shown in Figure 1.6.

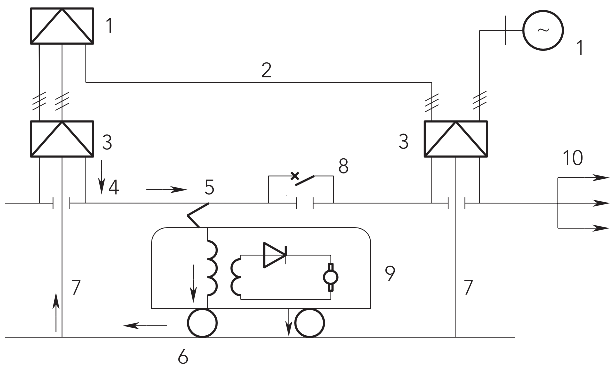

Figure 1.6 Electric Traction Power Supply System

Notes:

1. Area substation or power plant 2. High-voltage power transmission line 3. Traction substation 4. Feeder 5. OCS 6. Rail 7. Negative feeder 8. Track sectioning post (TSP) 9. Electric locomotive or EMU 10. Switching post (SP)

High-voltage power transmission line

Managed by the public grid companies, high-voltage power transmission lines provide power to the electric traction power supply system. Their boundary with the railway company is normally located at the substation side of the high-voltage transmission tower that is closer to the traction substation.

Traction substation

The traction load is a CLASS 1 electrical load with an extremely high requirement for reliable power supply. Blackouts in the traction substation would lead directly to the stoppage of trains, and the shutdown of railway transport. This means the traction substation must be connected to a high-voltage power grid with a voltage of 110 kV or above, and with two independent power supply lines for mutual backups.

The traction substation converts the three-phase 110 kV or 220 kV power source provided by the public grid into multiple single-phase 27.5 kV power sources, which are then transmitted to the OCS through feeders.

Traction network

The traction network is a type of power supply network consisting of feeders, OCS and return circuits (composed of negative feeders, boosting wires, rails and the ground).

(1) Feeder

A feeder is the wire or cable connecting the traction substation with the OCS. It transmits single-phase 27.5 kV power from the secondary side of the traction transformer to the OCS. The feeders are usually made of steel-cored aluminum strands or single-core power cables.

(2) OCS

Mounted along the railway, the OCS refers to the special power line that transmits electricity to electric locomotives or EMUs through sliding contact with the pantograph. It is the main body of the traction network and normally uses single-phase 25 kV AC power, which has a rated voltage of 25 kV. Compared with the general power line, the OCS has a more complex structure, more difficult operating environment, higher maintenance loads and higher failure rates. The link between the pantograph and the OCS is simply called the "interaction behavior between pantograph and OCS", one of the three key technologies of electrified railways.

Figure 1.7 OCS and Electric Locomotives

(3) Return circuit

The traction current is transmitted to the pantograph through the OCS before reaching the traction transformers within the electric locomotive or EMU, and will be finally transmitted to the rail. Taking the direct feeding system with return conductor as an example, a boosting wire is set up every 3 km–4 km, which connects the negative feeder with the rail and the connection will bring the traction current back to the negative feeder via the rail. This allows the traction current to flow back to the traction substation via the negative feeder, the rail and the ground, as shown in Figure 1.8.

Track sectioning post (TSP)

The electric traction power supply system usually adopts single-end feeding, that is, setting up neutral sections on the OCS at the power supply end of two traction substations to ensure insulation, so that each section can only be powered by the traction substation from one side. For double-track single-end feeding, the TSP is set up at the end of sections (where neutral sections are set up), as shown in Figure 1.9.

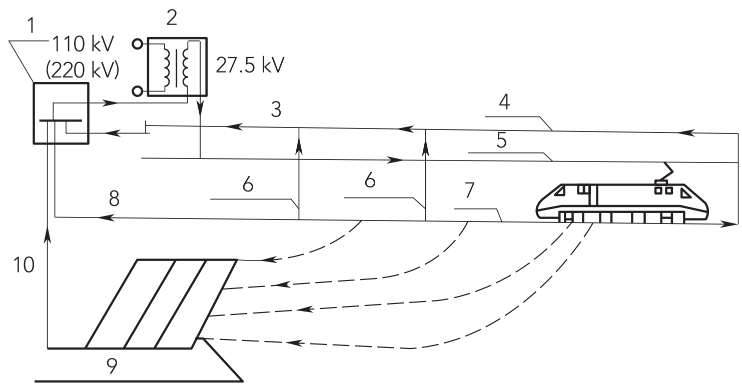

Figure 1.8 Return Current of an Electric Traction Power Supply System

Notes:

1. Return box
2. Traction transformer
3. Overhead return current
4. Negative feeder
5. Contact wire
6. Boosting wire
7. Rail
8. Rail return current
9. Traction substation earthing mesh
10. Earth return current

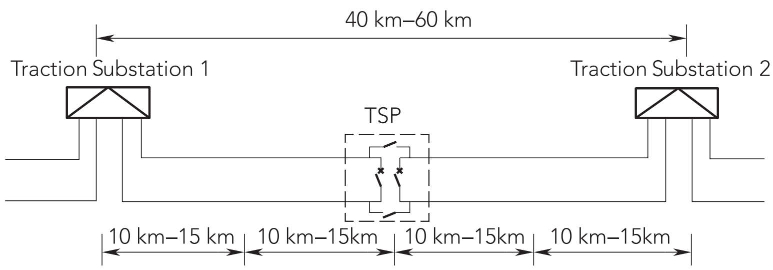

Figure 1.9 TSP of a Double-track Electrified Railway

High-voltage switchgears such as circuit breakers and disconnectors are set up within the TSP which has the following functions: firstly, providing parallel OCS power supply to increase voltage at the end of sections; secondly, when one traction substation has a power failure, temporary over-section feeding can be realized through the TSP, that is, another traction substation can temporarily supply power to the sections suffering the power failure to improve the reliability of the power supply.

Switching post (SP)

The SP does not change voltage and has similar functions to distribution stations, including increasing the number of feeders to meet the requirements of large stations and electric locomotive depots, and improving the flexibility of the OCS power supply. To ensure the reliability of power supply of the SP, two independent power lines should be used.

Electrified railways use electric traction and need dedicated electric traction power supply systems to supply power to electric locomotives or EMUs. Since traction loads feature mobile power supply and single-phase power supply, electric traction power supply systems have many unique properties.

Exercise B

1. Directions: Answer the following questions based on the material.

(1) What are the differences between the functions of the electric traction power supply system and the railway power distribution system?

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(2) In what ways does the traction current flow back to the traction substation?

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(3) What are the main functions of the TSP and the SP?

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2. Directions: Fill in the blanks with the terms given below.

220 kV	public grid	25 kV
27.5 kV	110 kV	40 km–60 km

The distance between two adjacent traction substations is usually (1) ________. Their power is supplied by the (2) ________ through (3) ________ or (4) ________ high-voltage power transmission lines. The output voltage of a traction substation is (5) ________ and the rated voltage of the OCS is (6) ________.

Mini-project B

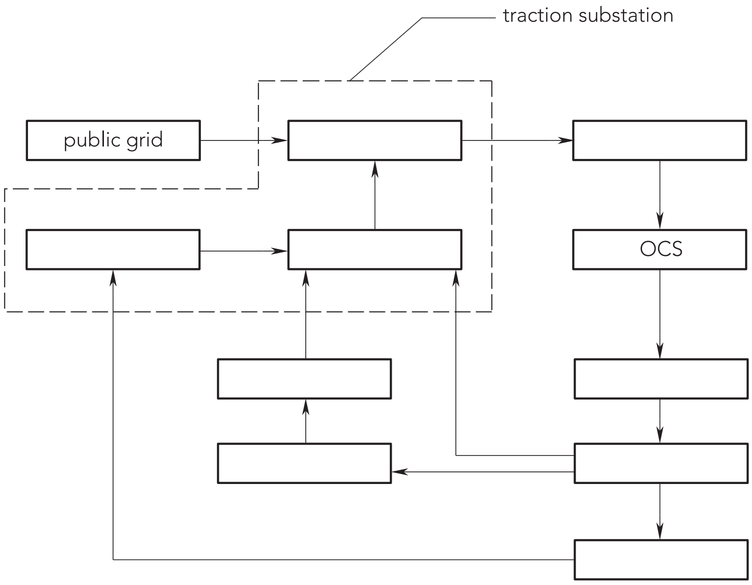
Objective

- Learn about the basic power supply process and functions of an electric traction power supply system.

1. Directions: Work in groups. Each group is supposed to finish the following tasks.

(1) Discuss the process through which the electric traction power supply system supplies power to electric locomotives, based on Figure 1.6 and Figure 1.8, and fill in the boxes with the terms given below.

negative feeder	traction transformer	rail
traction substation earthing mesh	traction substation return box	the ground
boosting wire	electric locomotive	feeder



(2) Discuss the consequences of the breakdown of negative feeders or boosting wires.

2. Directions: Work in groups to discuss what you have learned.

Part Three Further Development

Material C

External Power Supply of Traction Substations

Railway companies usually do not have their own systems to generate power, so the railway power supply system receives the power from the public grids run by power companies. Railway power supply systems are users of public grids, their external power supply. The external power supply of traction substations described here refers to the electrical connections through which public grids supply power to railway traction substations. It mainly includes the following types.

1 Single-end feeding

Single-end feeding means that both power sources of a traction substation can only be supplied by the power source from one end of a public grid, as shown in Figure 1.10. The traction substations C_1, C_2 and C_3 in Figure 1.10 can only get power through the two power lines of the right-hand Power Plant A_1, where power is supplied from a single end. Power Plant A_1 is connected with power plants A_2 and A_3 through area substations B_1, B_2 and B_3, forming a reliable supply network, which ensures normal power supply even if one power line breaks down, and hence improves the reliability of power supply.

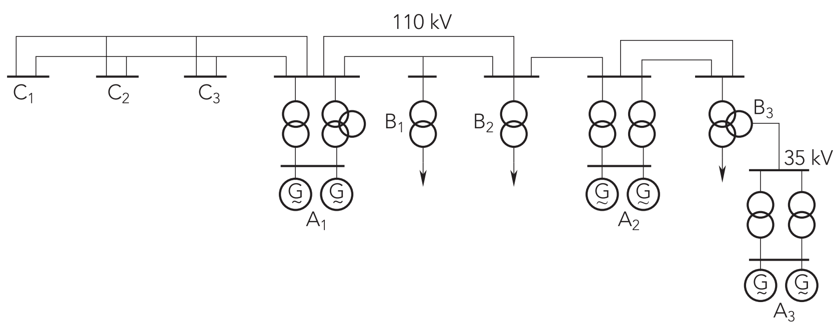


Figure 1.10　Single-end Feeding

2 Double-end feeding

Double-end feeding means that both power sources of a traction substation are supplied by the power sources from two ends of a public grid. As shown in Figure 1.11, the left-hand power source of Traction Substation C is supplied by Power Plant A_1 and Area Substation B, from two directions, while the right-hand power source of it is supplied only by Area Substation B. So the left-hand power source of Traction Substation C adopts double-end feeding, while the right-hand source adopts single-end feeding.

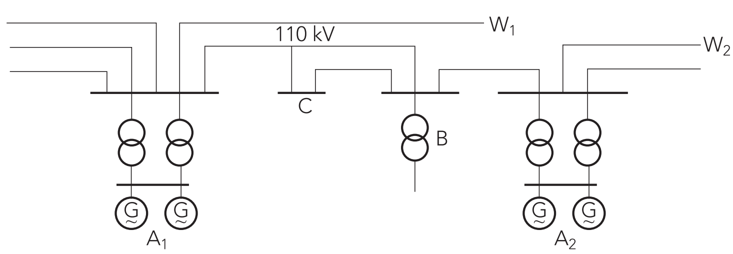


Figure 1.11　Double-end Feeding

3 Looped power supply

Looped power supply means a loop power network consisting of several power plants, area substations and traction substations connected by high-voltage power transmission lines, and the traction substations form a part of the loop-shaped public grid. As shown in Figure 1.12, if one power source of the traction substations (C_1, C_2, C_3 and C_4 in Figure 1.12) breaks down, the traction substations can still receive power from the other side of the loop so that it can supply power continuously.

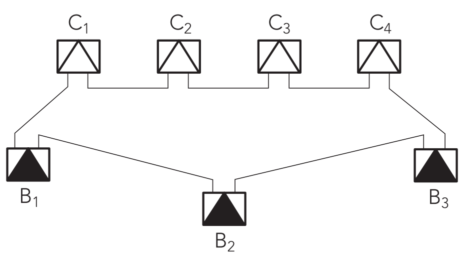


Figure 1.12 Looped Power Supply

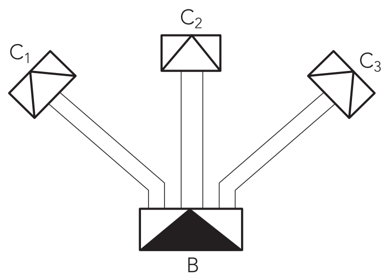


Figure 1.13 Distributed Feeding

4 Distributed feeding

When each traction substation is basically equidistant from the power source of a public grid, and single-end feeding would lead to higher costs, distributed power supply, as shown in Figure 1.13, may be a more economical choice. However, distributed power supply is less reliable, and requires an arched layout for the nearby traction substations C_1, C_2 and C_3 and power supply with two return circuits for Area Substation B.

By comparison, double-end feeding and looped power supply are more reliable and have better quality than single-end feeding and distributed feeding. The advantage of double-end feeding is that the power supply to railways is not interrupted when any power plant or area substation breaks down. The advantage of looped power supply is the frequency stability of the public grid with small voltage fluctuation. Therefore, it is advised for traction substations to adopt double-end feeding or looped power supply.

However, the actual condition of the grids along the railway must be considered when we select the method of external power supply. Sometimes several methods need to be used at the same time.

Exercise C

Directions: Which external power supply methods do Traction Substation A and Traction Substation B use in Figure 1.14?

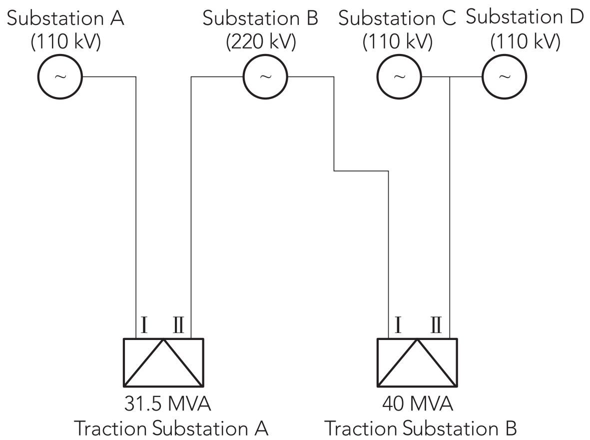


Figure 1.14 External Power Supply of Traction Substations

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Part Four Workshop

Objectives

- Learn about the equipment for the railway power supply system and its composition and functions.
- Learn about the main positions in the railway power supply system and their working procedures and basic professional requirements.

1. Tasks: Choose and finish one of the following two assignments.

☐ Assignment 1: Visit a railway substation and distribution station and observe the railway power lines.

Details:

(1) Observe the incoming power line, the high-voltage switchgear, the control room and the feeders of a railway substation and distribution station.

(2) Observe the railway power line.

(3) Visit a caretaker in a railway substation and distribution station and a worker taking care of the railway power line to learn about their working procedures, responsibilities and basic job requirements.

☐ Assignment 2: Visit a traction substation and observe the OCS of an electrified railway.

Details:

(1) Observe the high-voltage primary equipment, the control room and the feeders of a traction substation for an electrified railway.

(2) Observe the return current equipment of a traction substation for an electrified railway.

(3) Observe the OCS equipment of an electrified railway.

(4) Observe the daily work of a caretaker in a railway traction substation and an OCS worker to learn about their working procedures, responsibilities and basic job requirements.

2. Methods

(1) Method 1: Visit a railway company to observe the power supply equipment.

(2) Method 2: Watch videos or look at pictures of railway power supply.

3. Requirements

(1) Get well prepared for the assignment.

(2) Strictly comply with company rules when visiting, and do not touch the equipment without permission or act alone.

(3) Write an internship summary.

Self-assessment

Directions: Check the box (☺, 😐 and ☹) given for each learning objective and tick the one that best matches your performance.

Learning Objectives	My Performance		
	☺	😐	☹
Master the main technical terms related to railway power supply systems.			
Master the composition and main functions of railway power distribution systems.			
Master the composition and main functions of electric traction power supply systems.			
Talk about railway power supply systems in English.			