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Design Rules of 35 kV-220 kV Urban Underground Substation

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Contents

Foreword

These rules are prepared in accordance with the *Notice on Issuing the Plan of Preparation and Amendment of Electric Power Industry Standards in 2002* issued by the former State Economic and Trade Commission (GJMDL〔2002〕No.973).

These rules are prepared to regulate the design of urban underground substations such that they are technically advanced, economically viable, convenient for operation and maintenance and can supply power in a safe and reliable manner.

These rules contain the principled provisions on the relevant issues regarding the design of 35 kV-220 kV substation and is developed based on GB 50059 *Design code for substation (35 kV-110 kV)*, SDJ 2 *Technical code for designing 220-500 kV substation* and with reference to the relevant national standards and electrical power industry standards.

These rules are prepared in the background that the design and construction of underground substations are not popular in China and through gathering experiences in respect of design, operation, and management from Beijing, Shanghai, Shandong and other regions.

These rules are proposed by China Electricity Council.

These rules are under jurisdiction of and interpreted by the Technical Committee on Electric Power Planning and Engineering of Standardization Administration of Power Industry.

These rules are mainly drafted by Beijing Electric Power Design Institute.

The organizations participating in drafting these rules include

Shanghai Electrical Power Design Institute Co., Ltd. and Shandong Electric Power Engineering Consulting Institute Co., Ltd.

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These rules are translated by SUNTHER Translation & Solutions under the authority of China Electric Power Planning & Engineering Association.

1 Scope

These rules specify the general technical requirements for design of urban underground substations with respect to selection of station site, layout of station area, electrical wiring, structure of buildings, environmental protection as well as the special technical requirements with respect to transportation of equipment, air ventilation, water proofing and fire prevention.

These rules apply to the design of 35 kV-220 kV urban underground substation.

2 Normative References

The following normative documents contain regulations which, through reference in this text, constitute regulations of this rule.

For dated references, subsequent amendments (excluding the contents of errata) to, or revision of, any of these publications do not apply. However, parties to agreements based on these rules are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

For undated references, the latest edition of the normative document referred to applies.

GB 3096 *Standard of Environmental Noise of Urban Area*

GB 8702 *Regulations for Electromagnetic Radiation Protection*

GB 8978 *Integrated Wastewater Discharge Standard*

GB 14285 *Technical Code for Relaying Protection and Security Automatic Equipment*

GB 50007 *Code for Design of Building Foundation*

GB 50011 *Code for Seismic Design of Buildings*

GB 50015 *Code for Design of Building Water Supply and Drainage*

GB 50019 *Code for Design of Heating Ventilation and Air Conditioning*

GB/T 50034 *Standard for Lighting Design of Buildings*

GB 50059 *Design Code for Substations (35 kV-110 kV)*

GB 50060 *Design Code for High Voltage Electrical Installation (3-110 kV)*

GB 50108 *Technical Code for Waterproofing of Underground*

Works

GB 50116 *Code for Design of Automatic Fire Alarm System*

GB 50217 *Code for Design of Cables Electric Work*

GB 50222 *Code for Fire Prevention in Design of Interior Decoration of Buildings*

GB 50227 *Code for Design of Installation of Shunt Capacitors*

GB 50229 *Code for Fire-protection Design Power Plant and Substation*

GB 50260 *Code for Design of Seismic of Electrical Installations*

GBJ 16 (2001 Edition) *Code of Design on Building Fire Protection and Prevention*

DL/T 620 *Overvoltage Protection and Insulation Coordination for AC Electrical Installations*

DL/T 621 *Grounding for AC Electrical Installations*

DL/T 5003 *Specifications for the Design of Dispatch Automation in Electric Power Systems*

DL/T 5044 *DC System Technical Code for Designing Fossil Fuel Power Plants and Substation*

DL/T 5056 *Technical Code of General Plan Design for Substation*

DL/T 5120 *DC System Design Code for Small Electric Power Project*

DL/T 5136 *Technical Code for Designing of Electrical Secondary Wiring in Fossil Fuel Power Plants and Substations*

DL/T 5137 *Technical Code for Designing Electrical Measuring and Energy Metering Device*

DL/T 5149 *Technical Code for Designing Computerized Monitoring and Control System of 220 kV-500 kV Substations*

DL/T 5155 *Technical Code for Designing AC Station Service*

of 220 kV-500 kV Substation

JGJ 120 *Technical Specification for Retaining and Protection of Building Foundation Excavations*

SDJ 2 *Technical Code for Designing 220-500 kV Substations*

SDJ 5 *Technical Code for Designing High Voltage Electrical Switchgear*

NYD〔1993〕No.228 *Code of Planning and Design of Urban Electric Network*

3 Terms and Definitions

The following terms and definitions apply to this rule.

3.0.1

Underground substation

Underground substation includes fully underground substation and partially underground substation whose buildings may be built independently or in combination with other buildings (structures).

3.0.2

Fully underground substation

Main buildings of the substation are built underground and the main transformers and other main electrical equipment are installed in underground buildings. Above the ground level only a few buildings are arranged, such as the ventilation opening and equipment, personnel entrances/exits as well as the cooling equipment of large-sized main transformers and main control room possibly located above the ground level.

3.0.3

Partially underground substation

Underground buildings dominate this type of substations and the main transformers and other main electrical equipment are installed in underground buildings.

4 General

4.0.1 Underground substation is a special type of substation which is built in cases where a substation above the ground level cannot be built in a conventional way. The substation can be built independently or in combination with other buildings (structures).

4.0.2 The underground substation shall be designed on the basis of the grid planning for not less than 10 years, have its final size determined in accordance with the grid structure and nature of the substation, and have its civil works completed once for all.

4.0.3 The design of underground substation must be closely tied to the urban planning and overall planning of underground buildings, taking into account the overall situations comprehensively. The design scheme of fully underground substation or partially underground substation shall be determined comprehensively taking into account the factors including project scale, overall layout of the substation, ventilation of underground buildings, fire fighting, transportation of equipment, personnel entrances/exits as well as environmental protection.

4.0.4 The equipment for the underground substation shall be of approved product with excellent quality and reliable performance and shall be selected by adherence to the principle of ensuring that they are appropriately leading, safe and reliable, technically advanced and cost effective while placing emphasis on the miniaturization, oil-free, automation and less or free of maintenance of the equipment.

4.0.5 The design of underground substation must adhere to the principle of “reducing the land use to the minimum”, endeavoring to

reduce the work quantities of building blocks so as to save construction land and control project construction costs.

4.0.6 The underground substation must be soundly designed in respect of equipment transportation, water proofing and drainage of buildings, ventilation, and fire fighting.

4.0.7 The seismic design of underground substations shall comply with the provisions of GB 50011 and GB 50260.

4.0.8 In addition to this rule, the design for underground substations shall comply with the relevant national laws, regulations, standards, the standards of electric power industry, and the local standards.

5 Station Site Selection and Station Area Layout

5.1 Station Site Selection

5.1.1 In areas where the urban electrical loads are concentrated while the conditions for construction of above-ground substations are limited, the underground substation may be built independently utilizing the urban green space and the ground-level facilities, such as play grounds and parking lots. Alternatively, it may be built in combination with other industrial or civil buildings (structures).

5.1.2 The site of underground substation shall be selected by closely coordinating with urban planning authorities so that the ground-level roads, underground pipelines and cable raceways are planned in a unified way for ease of transportation and lifting of equipment and installation of incoming and outgoing cable lines.

5.1.3 The station site shall enjoy favorable hydrological and geological conditions for construction of underground buildings (e.g., it shall be clear of seismic fracture zone, subsidence area, and other unfavorable geologic structures). Additionally, the station site shall not be located at the places where cultural relics are spotted underground or above the ground level.

5.1.4 When selecting station site, the mutual influences between the substation and neighboring surroundings and adjacent facilities shall be considered.

5.1.5 In addition to the limiting conditions of equipment transportation roads outside the substation area, such as turning radius, transportation height, the bearing capacity of underground

facilities below the transportation roads of the neighboring areas shall be checked as well.

5.2 Station Area Layout

5.2.1 The layout of above-ground-level buildings (structures), roads and underground pipelines of underground substation shall be in harmony with the urban planning.

5.2.2 The general layout of an underground substation shall be as compact as possible on the premise that the technological requirements are met, comprehensively taking into account the various factors including equipment transportation, ventilation, fire fighting, installation and repair, operation and maintenance as well as personnel evacuation. When the substation is built in combination with other buildings (structures), the relevant conditions of these buildings (structures) shall be fully utilized such that they are designed from an overall view.

5.2.3 The fire fighting access and fire prevention space between the above-ground-level buildings (including those built in combination with other buildings) of underground substation and the adjacent buildings shall comply with the provisions of GBJ 16.

5.2.4 The setting of ground-level roads in the station area shall comply with the provisions of DL/T 5056.

5.2.5 The number of emergency exits of underground substation shall not be less than two, and, if conditions permit, the adjacent buildings may be utilized to dispose the emergency exits.

5.2.6 The main control room of the underground substation should be arranged above the ground level if the conditions permit. Where the conditions do not permit, it shall be arranged below the ground level and should be located proximate to the ground surface. For

large-scale underground substations with multiple stories, passenger elevators may be installed.

5.2.7 The air inlet and air outlet of underground substations shall be disposed separately. The air inlet should be disposed at the windward side of the summer prevailing wind direction.

5.2.8 For underground substations, lifting openings should be respectively provided for large-sized and small-sized equipment. The lifting opening for large-sized equipment is used for lifting large-sized equipment such as transformers. It may be integrated with the air inlet. The lifting opening for small-sized equipment is permanently provided and used for routine lifting of the repair and test equipment and small-sized equipment.

5.2.9 The lifting opening for large-sized equipment shall be located such that it suits the working conditions of large transportation and lifting vehicles used for the transportation of the substation equipment.

5.2.10 Oil-immersed power transformers arranged indoors in underground substation should be installed in a separate explosion-proof room.

5.3 Cable Raceways for Incoming and Outgoing Lines

5.3.1 The power cable raceways of underground substations shall be commensurate with the number of outgoing cables and have appropriate margin reserved. Where conditions permit, the power cables of the substations should be led into the substation through different cable raceways.

5.3.2 Where power cable mezzanines of underground substations are arranged at relatively deep locations, the cables may be led up through cable shaft and then connected with cable tunnels (ducts)

outside the substation.

5.4 Others

The greening within the underground substation area shall comply with the requirements of urban planning. The varieties of greening trees shall not affect the safe operation of underground substation.

6 Electrical Part

6.1 Main Electrical Wiring and Selection of Equipment

6.1.1 The main electrical wiring of an underground substation shall be determined comprehensively taking into account the role of the substation in the power grid, planned capacity, voltage level, total number of connecting components such as lines and transformers, nature of loads, and characteristics of various pieces of equipment and in such a manner that allows reliable power supply, flexible operation, convenient operation and repair, less investment costs, and ease of expansion.

The voltage level should be reduced and the wiring be simplified provided that the underground substation meets the grid planning and the reliability requirements.

6.1.2 The terminal substation where the number of circuits of high voltage side lines is no more than three and the number of main transformers is no more than there should employ line-transformer unit in bridge or enlarging bridge connection mode. The substations with system penetration power at high voltage side lines should employ external bridge connection, enlarging external bridge-circuit connection, single busbar, sectionalized single busbar or other connection modes. The line branch connection may be employed as well if the relay protection of the substation can meet the relevant requirements. The power source capacity and line circuit numbers shall be determined in accordance with the requirements of NYD〔1993〕No.228 *Code of Planning and Design of Urban Electric*

Network.

6.1.3 Where an underground substation is equipped with no less than two main transformers, the 6 kV-110 kV load side should employ sectionalized single busbar or other connections. The sectionalization mode should be such that, when one of the transformers is removed out of service, it facilitates the uniform distribution of loads of the remaining transformers. Where the substation is equipped with four main transformers, all of which being operated under loads, the 6 kV-110 kV load side may employ ringed sectionalized single busbar connection.

6.1.4 Where it is necessary to limit the short-circuit current of the 6 kV-10 kV line of the substation, the following measures may be taken:

1 Operating the transformers separately;

2 Application of high-impedance transformers; and

3 Connecting current-limiting reactors in series in transformer circuit.

6.1.5 Oil-free circuit breakers with favorable current interrupting performance shall be used in underground substations.

The 66 kV-220 kV switchgears used for underground substations should be of SF_6-gas insulated switchgear (GIS).

The 35 kV and below switchgears should employ switch cabinet (including cabinet type GIS).

6.1.6 Where no reliable dust filter is available at air inlets of underground substations, the specific creepage distance of electric porcelain external insulation of the electrical equipment should be selected in a manner similar to that of the outdoor substations.

6.2 Main Transformer

6.2.1 The number and capacity of the main transformers shall be

determined comprehensively taking into account the power supply condition in the region, the nature of loads, the power consumption capacity, and the operating modes. The number of main transformers should not be less than two and should not be larger than four.

6.2.2 In case of substations equipped with two and above main transformers, when one main transformer is disconnected, the capacity of the remaining main transformers shall be able to meet the power consumption demands of all loads.

6.2.3 Underground substations should employ low-loss and low-noise power transformers. Oil-free equipment may be used where necessary depending upon the fire prevention requirement.

6.2.4 The cooling modes of power transformers installed below the ground level: The transformer with a single unit capacity of no more than 63 MVA should employ natural cooling or air cooling mode; The transformer with a single unit capacity above 63 MVA may employ water cooling mode; alternatively, the heat radiator of the transformer is placed at the ground level to be air cooled.

6.2.5 Water-cooled transformers of underground substations shall use double-layer copper tube cooling system.

6.2.6 When placing an order for main transformers of underground substations, the transportation dimensions of the transformers and transportation conditions of the city roads shall be checked.

6.3 Switchgears

The design of the switchgears of underground substations shall comply with the provisions of GB 50060 and SDJ 5.

6.4 Reactive Power Compensation Device

6.4.1 The reactive power compensation devices of underground

substations shall be arranged in a principle that allows local reactive power balance of the system and ease of voltage regulation.

6.4.2 The power compensation devices of underground substations should be of oil-free products.

6.4.3 The design of shunt capacitor installations shall comply with the provisions of GB 50227.

6.4.4 The series reactors used in shunt reactors and shunt capacitor banks should be of core-type equipment characterized by small volume and low magnetic leakage.

6.5 Station Service Power Supply and DC Equipment

6.5.1 The design of station service power supply of underground substations shall comply with the provisions of DL/T 5155.

6.5.2 In case of underground substations, two auxiliary transformers that have the same capacity and can back up each other and operate separately shall be connected respectively from the low voltage side of the main transformer. The two transformers shall each have a capacity sufficient to meet the demands for the calculated loads of the whole substation.

6.5.3 The auxiliary transformers of an underground substation shall be of oil-free equipment.

6.5.4 The station service power supply of an underground substation must be safe and reliable. For 220 kV underground substations and 110 kV major underground substations, another circuit of power supply shall be connected from outside the substation to serve the ventilation and fire fighting loads when the whole substation experiences blackouts.

6.5.5 The design of DC system of underground substations shall comply with the provisions and requirements of DL/T 5044 and DL/T

5120.

6.5.6 In underground substation, battery banks shall be provided to supply power to the loads including control, signaling, relay protection and automatic devices as well as AC uninterruptible power supply (UPS), circuit breaker operating mechanisms, and DC emergency lighting loads.

6.5.7 Two battery banks should be provided for 220 kV underground substations, one battery bank should be provided for 110 kV and below underground substations while two battery banks may be provided for major 110 kV underground substations. The battery should be of valve-regulated lead-acid type. The DC charging equipment should be of high-frequency switch charging type.

6.5.8 When selecting the capacity of battery banks, the station-wide AC emergency blackout time shall be determined to be one hour for manned substations and two hours for unmanned substations.

6.6 Main Control Room and Relay Room

In key substations the main control room and the relay room should be built separately, while in load substations the relay room should not be built independently. Where 220 kV, 110 kV/66 kV switchgears are of GIS equipment, the protection and control equipment may be arranged in the switchgear room.

6.7 Monitoring and Control and Secondary Wiring

6.7.1 The design of monitoring and control and secondary wiring of underground substations shall comply with the provisions of DL/T 5149 and DL/T 5136.

6.7.2 For underground substations, the circuit breakers, main transformer neutral point earthing disconnectors, main transformer

on-load tap changers shall be centrally monitored in the main control room; motor driven disconnectors should be centrally monitored in the main control room; earthing switches and busbar grounding devices should be operated locally.

6.7.3 The computer-based monitoring and control system of underground substations shall be of layered, distributed and open structure. For 220 kV key substations, double-network and double-computer redundant configuration should be employed for the network system; for other substations, single-network single-computer configuration should be employed.

6.8 Relay Protection, Dispatching Automation, and Electrical Measuring Instruments

6.8.1 The design of relay protection and automatic devices of underground substations shall comply with the provisions of GB 14285.

6.8.2 The design of dispatching automation of underground substations shall comply with the provisions of DL 5003.

6.8.3 The design of electrical measuring instruments of underground substations shall comply with the provisions of DL/T 5137.

6.9 Communication

6.9.1 The communication facilities of underground substations may be configured according to the communication requirements below:

1 Communication for system dispatching;

2 External administrative communication; and

3 Intra-station communication.

6.9.2 In underground substations, the channels used for telecontrol, relay protection and telephones shall be in the form of optical fiber,

leased postal telecommunications lines and dedicated communication cables. Two independent communication channels shall be made available between 66 kV-220 kV substations and the higher level dispatching center.

6.9.3 The communication equipment of underground substations shall be provided with reliable emergency standby power supply. Where dedicated battery banks act as the standby power supply, their capacity shall be calculated based on the service time of 2 h to 3 h.

6.10 Overvoltage Protection and Grounding

6.10.1 The design of overvoltage protection of underground substations shall comply with the provisions of DL/T 620.

6.10.2 The grounding of underground substations shall comply with the provisions of DL/T 621. Underground substations shall be provided with grounding nets which shall not only incorporate artificial grounding electrode but make full use of the steel bars of underground buildings.

6.10.3 In underground substations, the steel bars of individual storey of the buildings shall be welded into one net which is connected with the grounding busbar laid indoors.

6.10.4 In underground substation, the grounding busbar laid indoors shall be connected with the grounding net at a minimum of four points distributed in different directions.

6.10.5 The artificial grounding electrode of the grounding net of underground substations should be made of copper conductor. The indoor grounding busbar and the equipment grounding wires may be made of steel conductor.

6.10.6 In underground substations, the grounding net shall be connected with the grounding conductor of cable tunnel outside the

substation, with some connecting points that can be readily disconnected being made available.

6.11 Electric Lighting

6.11.1 The lighting of underground substations includes regular lighting, emergency lighting and repair lighting. The design of electric lighting for underground substations shall comply with the provisions in GB 50034.

6.11.2 The electric lighting shall be designed to work in the lighting mode characterized by reasonable lighting fittings, ready repair and cost effectiveness in accordance with the arrangement of various types of equipment.

6.11.3 Emergency lighting shall be provided in the main control room, relay room, main transformer room, switchgear room, auxiliary transformer room, fire fighting equipment room, main accesses and staircase room. For unmanned substation, the manual and automatic change-over switch of emergency lighting shall be disposed at the inside of the entrance or in the guard room and conspicuous symbols shall be provided.

6.11.4 The emergency lighting should be powered by the DC system in the substation and shall be controlled by areas. When the AC power supply fails, the emergency lighting of manned substation shall be switched in automatically and that of unmanned substation shall only be switched in manually when the staff is present at the site.

6.11.5 In underground substations, the average illuminance shall not be lower than the standard illuminance of the working surfaces as specified in Table 6.11.5.

Table 6.11.5 Standard illuminance of the working surfaces of underground substation

Workplace	Reference plane and its height	Standard illuminance (lx)		Unified glare rating *URG*	General color rendering index R_a
		Regular lighting	Emergency lighting		
Main control room	0.75 m horizontal plane	300	100	22	80
Relay room	0.75 m horizontal plane	200	20	22	60
Transformer room	Ground level	100	10	—	20
Switchgear room	0.75 m horizontal plane	200	20	22	60
Capacitor room	Ground level	100	10	—	60
Communication room	0.75 m horizontal plane	200	20	22	60
Duty room	0.75 m horizontal plane	100		22	80
Rest room	0.75 m horizontal plane	100		22	80
Toilet, bathroom	Ground level	75		—	60
Staircase room, access	Ground level	30	10	—	60

6.11.6 High-efficiency lighting equipment should be installed in main transformer room and switchgear room for repair purpose.

6.11.7 Illuminated evacuation indicating symbols shall be provided along the evacuation walkways and at evacuation doors.

6.12 Selection and Laying of Cable

6.12.1 The selection and laying of power cables and control cables