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Technical Code for Designing High Voltage Electrical Switchgear

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Contents

| | |
|---|-----|
| Foreword | III |
| 1 Scope | 1 |
| 2 Normative References | 2 |
| 3 Terms and Definitions | 3 |
| 4 General | 4 |
| 5 Basic Rules | 5 |
| 5.1 Air Insulated Switchgear | 5 |
| 5.2 Gas Insulated Switchgear | 7 |
| 6 Ambient Conditions | 9 |
| 7 Selection of Conductors and Electrical Equipment | 13 |
| 7.1 General Provisions | 13 |
| 7.2 Selection of Conductors | 15 |
| 7.3 Selection of Electrical Equipment | 16 |
| 8 Type and Layout of Switchgears | 18 |
| 8.1 Minimum Safety Clearance | 18 |
| 8.2 Type Selection | 25 |
| 8.3 Layout | 26 |
| 8.4 Passage and Fence | 28 |
| 8.5 Fire Protection and Oil Storage Facilities | 30 |
| 9 Requirements on Buildings and Structures for Switchgear | 34 |
| 9.1 Architectural Requirements of Indoor Switchgear | 34 |
| 9.2 Load Requirements for Outdoor Switchgear Structures | 35 |
| 9.3 Requirements on Civil Works for GIS Switchgear | 37 |
| Appendix A (Informative Appendix) Pollution Classification | |

| | | |
|-----------------------------------|---|----|
| | Plants and Substations/ Specific Creepage Distances under Various Pollution Levels | 38 |
| Appendix B (Informative Appendix) | Correction of value A in Case of Altitude above 1000m ... | 40 |
| Appendix C (Informative Appendix) | Fire Risk Classification and Minimum Fire Resistance Class of Buildings/Structures during Production | 41 |
| Appendix D (Informative Appendix) | Minimum Spacing between Buildings/Structures | 43 |
| Appendix E (Informative Appendix) | Minimum Safety Clearance of 750kV Outdoor Switchgear | 46 |

Foreword

This Standard is updated from SDJ 5—1985 *Technical Code for Designing High Voltage Electrical Switchgear* in response to the *Notice of the General Office of National Development and Reform Commission on Printing and Distributing 2006 Industry Standard Plan* (Fa Gai Ban Gong Ye [2006] No. 1093).

The SDJ 5—1985 *Technical Code for Designing High Voltage Electrical Switchgear*, which was issued by the former Ministry of Water Conservancy and Electric Power, has been playing an important guiding role in type selection and equipment layout of switchgears during design since its implementation, and offered a scientific reference for design, optimization, and innovation of switchgears in power plants and substations. However, with the development of electrical technology and electric power construction both at home and abroad, the application of new technology, new products and new equipment in the area of switchgears, and the continuous change of energy policy of China, the design criteria and some clauses of SDJ 5—1985 has become unable to satisfy the demand of technology development and power industry development.

This revision DL/T 5352—2006 is completed incorporating power construction and operation experience in recent two decades and taking into consideration the current national technical and economic policies. Compared with SDJ 5—1985, the applicable clauses are retained and the following additions are included in this revision:

- 1) Application scope;

- 2) Reference standards;
- 3) Ambient conditions;
- 4) Application scope and specifications of gas insulated switchgear (GIS);
- 5) Fire protection requirements of transformers and other oil-filled electrical equipment;
- 6) Requirements on buildings and structures for switchgear;
- 7) Requirements on lighting, ventilation, weather proofing, sand proofing and antipollution of indoor switchgears;
- 8) Protection requirements for relay kiosk in outdoor switchgear.

This Standard will supersede SDJ 5—1985 since its implementation. Appendices A, B, C, D and E in this Standard are regarded as informative appendices.

The Standard was proposed by China Electricity Council.

This Standard is under jurisdiction and explanation of China Electric Power Planning and Engineering Association Standardization Technical Committee.

This Standard is prepared by Northwest Electric Power Design Institute with the participation of Changjiang Institute of Survey, Planning, Design and Research.

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This Standard is initially issued on September 17, 1985 and this is the first revision thereof.

1 Scope

This Standard has specified the basic requirements for designing 3kV–500kV high voltage switchgears in newly-built power plants and substations.

This Standard is applicable to the design of newly added 3kV–500kV AC switchgears in power plants and substations. This Standard may be referred to during the design of switchgear(s) to be expanded or modified.

For offshore project, this Standard may be referred to and implemented in conjunction with the actual situation of the country where the project is located and the specific conditions of the project.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- GB/T 2900.1 *Electrotechnical Terminology Fundamental Terms* (IEC 60050, NEQ).
- GB/T 2900.15 *Electrotechnical Terminology Transformer, Instrument Transformer, Voltage Regulator and Reactor* [IEC 60050(421): 1990, IEC 60050 (321): 1986, NEQ].
- GB/T 2900.19 *Electrotechnical Terminology High Voltage Test Technique and Insulation Co-ordination* (IEC 60071–1: 1993, NEQ).
- GB/T 2900.20 *Electrotechnical Terminology High Voltage Switchgear* [IEC 60050(IEV): 1984, NEQ].
- GB 3096 *Standard of Environmental Noise of Urban Area.*
- GB 12348 *Standard of Noise at Boundary of Industrial Enterprises.*
- GB/T 16434 *Environmental Pollution Classification and External Insulation Selection for High Voltage Transmission Line, Power Plant and Substation.*
- GB 50260 *Code for Design of Seismic of Electrical Installations.*
- GB 50016 *Code for Design of Building Fire Protection*

3 Terms and Definitions

The terms and definitions established by GB/T 2900.1, GB/T 2900.15, GB/T 2900.19 and GB/T 2900.20 apply.

4 General

4.0.1 The design of high voltage (HV) switchgears shall conform to national laws, regulations, construction guidelines, technical and economical policies, and meet the requirements safety and reliability, easy operation and maintenance, cost-effectiveness and environmental protection.

4.0.2 In the design of HV switchgears, equipment shall be selected and layout scheme formulated reasonably in accordance with the properties of power loads, capacity, ambient conditions, and operation and maintenance requirements. Electrical equipment and materials with high efficiency and low energy consumption shall be adopted when technically and economically feasible.

4.0.3 The design of HV switchgears shall be based on the project characteristics, scale, and development plan, taking into consideration both long term and short term plan while highlighting the latter.

4.0.4 The design of HV switchgears must adhere to the principle of “minimization of land use”.

4.0.5 The design of HV switchgears shall not only comply with the provisions of this Standard, but also conform to the relevant current national standards and industry standards.

5 Basic Rules

5.1 Air Insulated Switchgear

5.1.1 The layout of switchgears and the selection of conductors, electrical equipment, and architecture shall meet the safety requirements for normal operation, installation and maintenance, short circuit and overvoltage conditions under the local circumstances, and satisfy the requirements of planning capacity.

5.1.2 The phase sequence for individual circuits of switchgears should be identical with each other. Generally, the phase sequences shall be A, B and C when facing the outgoing lines and viewing from left to right, from far to near, and from top to bottom. Indoor rigid conductors and outdoor busbar bridge bare conductors shall be labeled with phase color code which shall be yellow, green, and red for Phases A, B and C respectively. In case of extension project, the phase sequence shall be identical with the existing switchgears.

5.1.3 For busbar sequence inside switchgears, generally, the busbar at the transformer side is busbar I, and the busbar at the line side is busbar II. For switchgears with double-layer layout, the busbar on the lower layer is busbar I and that on the upper layer is busbar II.

5.1.4 The minimum safety clearance of outdoor switchgears of 110kV and above is basically determined without consideration of live-line maintenance. In cases where live-line maintenance is unavoidable, the minimum safety clearance shall be met.

5.1.5 For busbar arresters and voltage transformers of 110kV–220kV switchgears, common disconnectors shall be provided;

disconnectors shall not be provided for arrestors on 330kV and above incoming/outgoing lines and buses; disconnectors shall not be provided for voltage transformers for incoming/outgoing lines and should not be provided for busbar voltage transformers.

5.1.6 Circuit breakers or load switches should not be provided on shunt reactor circuits of 330kV and above lines, while shunt reactor circuits of 330kV and above buses shall be equipped with circuit breakers and disconnectors.

5.1.7 For switchgears of 66kV and above, the disconnectors on both sides of breakers shall be arranged close to the breaker side and the line disconnectors shall be arranged close to the line side; and the transformer side of the transformer incoming-line disconnector shall be provided with an earthing switch. For shunt reactors of 66kV and above, the high voltage side thereof shall be configured with earthing switches.

5.1.8 For outdoor switchgears, earthing switches or devices shall be installed on each busbar section to ensure safe maintenance of electrical equipment and buses; the number of earthing switches or devices to be installed shall be determined according to the electromagnetic induction voltage on buses, length of parallel buses and spacing therebetween.

5.1.9 The line side earthing switches of 330kV and above common-tower lines or parallel circuits shall be able to switch the electromagnetic induction current and the electrostatic induction current with its capacity determined based on specific project conditions.

5.1.10 The voltage transformer for switchgears of 110kV and above may be configured on busbar or circuit basis.

5.1.11 For 220kV and below indoor switchgears in low-level

arrangement, blocking devices shall be provided for the bay to avoid accidental entrance into the energized cubicle.

5.1.12 The layout of oil-filled electrical equipment shall allow for secure and convenient observation of oil level and oil temperature in energized conditions, and shall facilitate oil sampling.

5.1.13 The arrangement of switchgear shall minimize the length of roads, LV power/control cables within the site. In power plant, crossing of overhead line at different voltage class should be avoided.

5.2 Gas Insulated Switchgear

5.2.1 For gas insulated switchgears (GIS), the configuration of earthing switches shall meet the operation and maintenance requirements.

Earthing switches shall be configured for electrical equipment, busbar and outgoing lines connected to GIS switchgears and requiring separate maintenance. Generally, high-speed earthing switches capable of switching dynamic current shall be used for the line side earthing switches of outgoing circuits and earthing switch of busbar. Disconnectors is not required for busbar arresters and voltage transformers of 110kV–220kV GIS switchgears.

5.2.2 The GIS switchgear shall be equipped with arresters at its connections with overhead lines. Such arresters should be open type with the earthing terminal connected to the metal housing of GIS. Whether the GIS busbar shall be provided with lightning arresters depends on the calculation result of lightning intruded wave over-voltage.

5.2.3 The induced voltage on the GIS switchgears shall not jeopardize the security of people and equipment. The induced voltage on the housing or supports shall not be higher than 24V in normal

operating conditions, and shall not be higher than 100V in fault conditions.

5.2.4 An earthing busbar going through all the GIS bays or a ring earthing busbar shall be provided within GIS bays to connect the earthing wire of individual GIS bays with the earthing network.

5.2.5 Multipoint earthing mode should be adopted for GIS switchgears. In case of isolated-phase GIS, the housings for the three phases shall be shorted and earthing wire shall be led out from the shorting line, which shall be connected to the earthing busbar where it will further be led to the earthing network.

The cross section of the shorting line for the three phases shall allow for continuous maximum induced current, and shall be verified with short circuit current. In case of aluminum housings, aluminum bars shall be used for shorting; in case of steel housings, copper bars shall be used.

5.2.6 Each GIS bay shall comprise several compartments, the division of which shall satisfy the requirements for normal operation and maintenance of elements therein.

6 Ambient Conditions

6.0.1 For electrical equipment and insulators of outdoor switchgear, the external insulation class shall be determined based on the local pollution classification (see Appendix A).

The switchgears should be kept away from the water spray area of natural/mechanical draft cooling towers and the downwind side thereof in respect of the year-round prevailing wind. Generally, if the switchgear is at the upwind side of the natural draft cooling tower for the winter prevailing wind, the distance from the edge of switchgear structures to the external wall of the tower at the zero-meter level shall not be less than 25m; if the switchgear is at its downwind side, the said distance shall not be less than 40m.

In extremely cold regions, the distance between the edge of switchgear structures and the external wall of the mechanical draft cooling tower at the zero-meter level shall not be less than 60m, and shall not be less than 40m in other regions.

6.0.2 The ambient(air) temperature for selection of conductors and electrical equipment shall conform to the provisions stated in Table 6.0.2.

Table 6.0.2 Ambient (Air) Temperature for Selection of Conductors and Electrical Equipment °C

| Items | Installation Site | Ambient (Air) Temperature | |
|----------------|-------------------|---|------|
| | | Max. | Min. |
| Bare Conductor | Outdoors | Average max. temperature of the hottest month | |
| | Indoors | Temperature for ventilation design | |

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Table 6.0.2 (continued)

| Items | Installation Site | Ambient (Air) Temperature | |
|--|-------------------|---|-------------------------|
| | | Max. | Min. |
| Electrical Equipment | Outdoors | Annual max. temperature | Annual min. temperature |
| | Indoors | Max. exhaust air temperature for ventilation design | |
| <p>Note 1: The annual max./min. temperature means the average value(s) of the max./min. temperatures measured in multiple years.</p> <p>Note 2: The average max. temperature of the hottest month means the monthly average value of the daily max. temperatures of the hottest month, and is also the average value for multiple years.</p> <p>Note 3: In case of absence of data about indoor ventilation design temperature, the ambient temperature for selection of indoor bare conductor and other electrical equipment may be the average max. temperature of the hottest month plus 5°C.</p> | | | |

6.0.3 The ambient relative humidity for selection of the conductors and electrical equipment shall take the average relative humidity of the month with the highest humidity at the local area. In humid tropical regions, the humid tropics-type electrical equipment shall be adopted. In humid subtropical regions, electrical equipment for general purpose can be adopted, however, protective measures must be taken against moisture, condensation, water, rust, mould, insect pests and other hazards according to the local operational experience.

6.0.4 If the ambient temperature is lower than the minimum permissible temperature of electrical equipment, instruments and relays, heating devices shall be installed, or other thermal insulation measures shall be taken. In the areas subject to severe snow and ice, measures shall be taken to avoid accidents resulted from ice and snow. The icebreaking thickness of disconnectors shall not be less than the maximum ice thickness of the installation site.

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6.0.5 The maximum wind speed for selection of the conductors and electrical equipment of outdoor switchgears of 330kV and above may be the 10-minute average maximum wind speed at 10m above the ground with only one occurrence every 30 years. As for the conductors and electrical equipment of 500kV outdoor switchgears, the 10-minute average maximum wind speed at 10m above the ground with only one occurrence every 50 years may be used. In the regions with maximum design wind speed beyond 35m/s, countermeasures shall be included in the layout of outdoor switchgears.

6.0.6 The seismic design for switchgears shall conform to the provisions of GB 50260.

6.0.7 In regions with altitude exceeding 1000m, the electrical equipment and electric porcelain products applicable to high altitude shall be selected for switchgears, and their external insulation strength shall satisfy the insulation test voltage of high-voltage electrical equipment.

6.0.8 For designing switchgears, attention shall be paid to noise control, minimizing continuous noise level at some operating sites. In case of switchgears immediately adjacent to the residential area, the noise level outside the enclosing wall shall conform to the requirements of GB 3096, GB 12348 and other applicable requirements.

6.0.9 The strength of electrostatic induced field (the space field strength at 1.5m above the ground) outside the barrier for equipment of switchgears of 330kV and above should not exceed 10kV/m, but 15kV/m is allowed in a few locations.

The strength of electrostatic induced field (the space field strength at 1.5m above the ground) outside the enclosing wall (not in the direction of outgoing lines and adjacent to the residential area) of

the switchgear should not be higher than 5kV/m.

6.0.10 For switchgears of 330kV and above, attention shall be given to the control of radio interference. The selection of conductors and electrical equipment shall minimize the radio interference level of the entire switchgear. The radio interference level at 20m away from its enclosing wall (not in the outgoing line direction) should not exceed 50dB.

6.0.11 For electrical equipment and hardware of 110kV and above, visual corona shall not occur at the night of sunny day when operating under the voltage 1.1 times the maximum phase voltage. The corona critical voltage for 110kV and above conductors shall be higher than the maximum operating voltage at the installation location of conductors.

7 Selection of Conductors and Electrical Equipment

7.1 General Provisions

7.1.1 The maximum voltage of selected conductors and electrical equipment during design shall not be lower than the maximum operating voltage of the circuit, and the permanent permissible current shall not be less than the maximum possible continuous operating current of the circuit. The influence of sunshine on current capacity shall be considered for outdoor conductors.

7.1.2 The short circuit current used for verifying the rated peak withstand current and rated short-time withstand current of conductors and electrical equipment as well as the switched current of electrical equipment shall be calculated based on the designed and planned capacity of the project, taking into consideration the prospect plan of the electric power system.

The short circuit current shall be determined and calculated based on the normal wiring mode with maximum possible short circuit current, which may be generally verified with three-phase short circuit. If the single-phase or two-phase earthing short circuit current is greater than the three-phase short circuit current, the calculation shall be verified with the severe case, also taking into consideration the influence of DC component.

7.1.3 The calculation time for verifying the thermal effect of short circuit of bare conductors should be the operating time of the primary protection plus the break time of associate breaker. If there is a dead

band in the primary protection, an operating time and corresponding short circuit current that can eliminate the dead band shall be used for backup protection.

The calculation time for verifying the thermal effect of short circuit of electrical equipment should be the operating time of backup protection plus the break time of the associated breaker.

7.1.4 Thermal stability may not be verified for conductors and electrical equipment protected by fuses; dynamic stability of conductors and electrical equipment protected by fuses without current-limiting function shall be verified.

For voltage transformer circuits protected by fuses, dynamic and thermal stability may not be verified.

7.1.5 The normal maximum operating temperature of bare conductors shall not exceed 70°C generally. Taking into account the sunshine, the maximum operating temperature of aluminum conductor steel-reinforced (ACSR) and tubular conductor shall not be higher than 80°C .

The maximum operating temperature of special heat-resistant conductors can be selected based on the data offered by the manufacturer, but the influence of high temperature conductors on connecting equipment must be considered, and protective measures must be taken.

7.1.6 To verify the rated short time withstand current, the maximum permissible temperature can be 200°C for bare conductors made of duralumin and aluminum alloy, and 300°C for bare conductors made of hard copper. The conductor temperature before short circuit shall be the operating temperature under rated load.

7.1.7 If the cross section of bare conductors is selected based on the circuit normal operating current, the permanent permissible

ampacity of conductors shall be corrected according to the altitude and ambient temperature of the region where the conductor is located.

For multi-conductor line, the influence of adjacent effect and heat shielding on ampacity shall be considered.

7.1.8 Under normal operation or short circuit conditions, the maximum acting force of electrical equipment lead wire shall not be greater than the permissible load of electrical equipment terminals. The mechanical calculation of conductors, bushings, insulators, and hardware of outdoor switchgears shall be conducted based on local meteorological conditions and specific stressing conditions, and the safety coefficient shall not be less than that specified in Table 7.1.8.

Table 7.1.8 Safety Coefficient of Conductors and Insulators

| Items | Under Long-term Load | Under Short-term Load |
|--|----------------------|-----------------------|
| Bushings and Support Insulators | 2.5 | 1.67 |
| Suspension Insulators and Its hardware | 4 | 2.5 |
| Flexible Conductors | 4 | 2.5 |
| Rigid Conductors | 2.0 | 1.67 |
| <p>Note 1: The safety coefficient of suspension insulators corresponds to the 1-hour electromechanical test load but not the failure load. If the latter is referred to, the safety coefficient shall be 5.3 and 3.3 respectively.</p> <p>Note 2: The safety coefficient of rigid conductors corresponds to the destroy stress but not the stress of yield point, if the latter is referred to, the safety coefficient shall be changed into 1.6 and 1.4 respectively.</p> | | |

7.2 Selection of Conductors

7.2.1 Aluminum conductor steel reinforced should be used for 220kV and below flexible conductors; aluminum conductor steel reinforced or expanded hollow conductor should be used for 330kV flexible conductors; twin bundle conductor should be selected for

500kV flexible conductors.

7.2.2 Anti-corrosion aluminum stranded conductors or copper stranded conductors should be used for coastal area with high salinity of air or places with ambient gas obviously corrosive for aluminum.

7.2.3 Rigid conductors can be rectangular or double-groove conductor or tubular conductor. When the normal operating current in 20kV and below circuit is 4kA or below, rectangular conductors should be selected; in case of normal operating current between 4kA–8kA, double-groove conductors should be selected; in case of normal operating current above 8kA, tubular conductors should be selected.

For the rigid conductor of 66kV and below switchgears, both rectangular conductors and tubular conductors can be used.

For rigid conductors of switchgears of 110kV and above, tubular conductors should be adopted.

7.2.4 The effect of uneven settlement, temperature variation, vibration, and other factors shall be considered during the design of rigid conductors.

7.3 Selection of Electrical Equipment

7.3.1 For breakers of 35kV and below, the vacuum breaker or the SF₆ breaker are preferred, and for breakers of 66kV and above, the SF₆ breaker should be selected. In extremely cold regions, the SF₆ breaker shall be of tank type, and SF₆ gas liquefaction issues shall be considered.

7.3.2 The disconnectors shall be selected according to the requirements of both normal operating conditions and short circuit fault conditions.

7.3.3 When the single column vertical open disconnector is opened, the minimum electrical clearance between the movable contact and

the static contact shall not be less than the minimum safety clearance B_1 of the switchgear.

7.3.4 Remote/local motor driven operating mechanism shall be employed for disconnectors of 110kV and above arranged on the upper layer of switchgears in semi-high-level or high-level layout.

7.3.5 The current transformers (CT) of 3kV–35kV switchgears shall be equipped with cast-resin type insulation; 66kV and above switchgear CT can be independent CTs of oil immersed type, SF₆ gas insulation type or optical fiber-type depending on the installation/utilization conditions and manufacturing levels; if condition permits, for example, there are transformer bushings, breaker bushings or wall bushings in a circuit, bushing type current transformers should be adopted.

7.3.6 For 3kV–35kV switchgears, electromagnetic voltage transformers with cast-resin type insulation should be used; for switchgears of 66kV and above, electromagnetic voltage transformers or capacitor voltage transformers with oil-immersed insulation or SF₆ gas insulation should be used.

7.3.7 For 35kV and below circuits with vacuum breakers, metal oxide arresters or R-C surge suppressors should be adopted for overvoltage protection depending on the capacitive or inductive load to be operated.

7.3.8 Metal oxide arresters should be adopted for overvoltage protection of switchgears of 66kV and above.

7.3.9 The outdoor arc suppression coil should be of oil immersed type; and the indoor arc suppression coil should be of dry type.

7.3.10 If there is possibility of ice and snow accumulation on 3kV to 20kV outdoor post insulators and wall bushings, products for voltage one class higher should be used; and for 3kV to 6kV, products for voltage two classes higher should be used.

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8 Type and Layout of Switchgears

8.1 Minimum Safety Clearance

8.1.1 The minimum safety clearance of outdoor switchgears, which should be determined based on the protection level of metal oxide arresters, shall not be less than the value listed in Table 8.1.1, and shall be verified according to Fig.8.1.1-1, Fig.8.1.1-2 and Fig.8.1.1-3. If the distance from the lowest part of the electrical equipment external insulator to the ground is less than 2500mm, fixed barriers shall be provided.

8.1.2 If flexible conductors are used for outdoor switchgears, the minimum safety clearance between the live part and the earthed part and that between live parts of different phases under different conditions shall be verified according to Table 8.1.2, and the maximum value therein shall be used.

8.1.3 The safety clearance of indoor switchgears shall not be less than the value given in Table 8.1.3, and shall be verified according to Fig.8.1.3-1 and Fig.8.1.3-2.

If the distance from the lowest part of the electrical equipment external insulator to the ground is less than 2300mm, fixed barriers shall be mounted.

8.1.4 If the neighboring live parts of the switchgears are of different rated voltages, the minimum safety clearance shall be determined based on the higher rated voltage.

8.1.5 No overhead lighting, communication, or signal lines are allowed to cross above or below the live parts of outdoor switchgears; exposed lighting and power lines are also prohibited to cross above the live parts of indoor switchgears.

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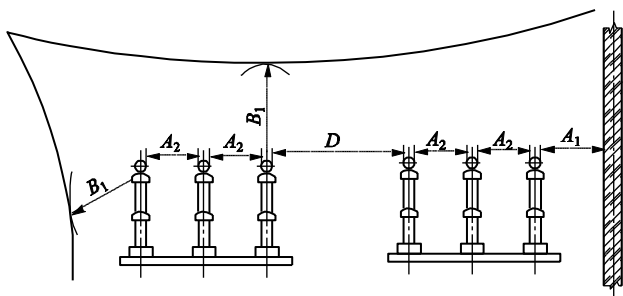


Fig.8.1.1-1 Values A_1 , A_2 , B_1 , D for verification, outdoor

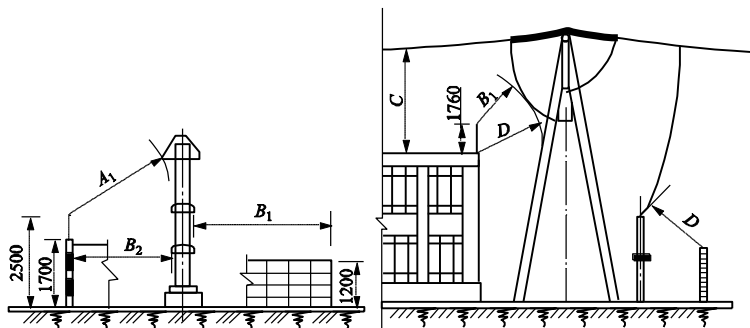


Fig.8.1.1-2 Values A_1 , B_1 , B_2 , C , D for verification, outdoor

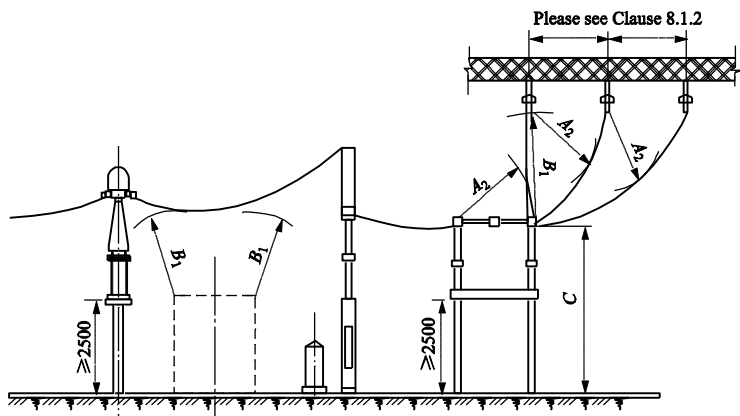


Fig.8.1.1-3 Values A , B , C for verification outdoor

Table 8.1.2 Calculated Wind Speed and Safety Clearance under Different Conditions

mm

| Conditions | Verification Conditions | Calculated Wind Speed m/s | Value A | System Nominal Voltage kV | | | | | | |
|-------------------------|--|---------------------------------|----------------|---------------------------|-----|------|------|------|------|------|
| | | | | 35 | 66 | 110J | 110 | 220J | 330J | 500J |
| Lightning Voltage | Lightning overvoltage and wind drift | 10 ¹⁾ | A ₁ | 400 | 650 | 900 | 1000 | 1800 | 2400 | 3200 |
| | | | A ₂ | 400 | 650 | 1000 | 1100 | 2000 | 2600 | 3600 |
| Switching Voltage | Switching overvoltage and wind drift | 50% of max. designed wind speed | A ₁ | — | — | — | — | 1800 | 2500 | 3500 |
| | | | A ₂ | — | — | — | — | 2000 | 2800 | 4300 |
| Power Frequency Voltage | 1. Max. operating voltage, short circuit and wind drift (wind speed 10m/s) 2. Max. operating voltage and wind drift (taking the max. design wind speed) | 10 or max. designed wind speed | A ₁ | 150 | 300 | 300 | 450 | 600 | 1100 | 1600 |
| | | | A ₂ | 150 | 300 | 500 | 500 | 900 | 1700 | 2400 |

1) In the regions with severe climatic conditions (e.g. the regions with the maximum design wind speed of 35m/s and above and that with high wind speed in case of thunderstorm), the wind speed 15m/s shall be used.

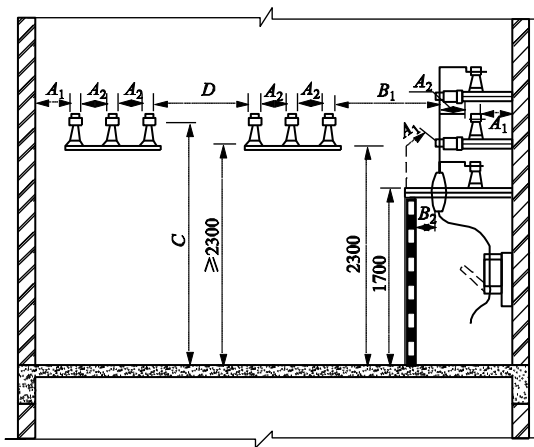


Fig.8.1.3-1 Values A₁, A₂, B₁, B₂, C, D for verification, indoor

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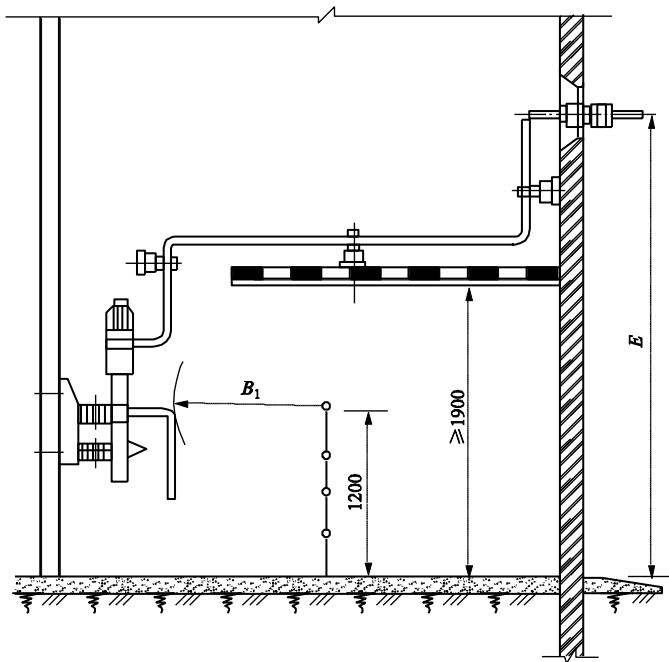


Fig.8.1.3-2 Values B_1 , E for verification, indoor

8.2 Type Selection

8.2.1 The type of switchgears shall be selected based on the equipment selection and wiring mode of incoming/outgoing line through technical and economical analysis, in combination with the actual situation of project as well as the overall layout of power plants, substations or associate hydro projects. The type with less land use shall be preferred if technically and economically feasible.

8.2.2 Generally, switchgears of 330kV and above shall be of outdoor medium-level type. 110kV and 220kV switchgears shall be of outdoor medium-level or semi-high-level type.

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8.2.3 Package high voltage cabinets should be used for 3kV–35kV switchgears.

8.2.4 For 110kV and 220kV switchgears installed in the areas with pollution class IV, downtown of metropolis and mountainous regions with numerous earthworks, indoor switchgears should be used, and gas-insulated switchgears (GIS) can be adopted if technically and economically feasible.

8.2.5 For switchgears of 330kV and above in the areas with pollution class IV and altitude above 2000m, GIS or HGIS switchgears can be adopted if technically and economically feasible.

8.2.6 For switchgears of 110kV and above in the regions with seismic intensity of degree 9 and above, GIS switchgears should be adopted.

8.3 Layout

8.3.1 The layout of switchgears shall be comprehensively considered in combination with the wiring mode, the equipment type and the overall layout of power plants and substations.

8.3.2 In case of voltage classes of 220kV–500kV, one and a half circuit breakers wiring mode and flexible buses or tubular buses with single-column, double-column, three-column or double-column extension disconnectors, the outdoor air-insulated switchgear (AIS) shall be arranged in medium-level layout. The breakers should be arranged in three-row layout, single-row layout or triangle layout.

8.3.3 In case of voltage classes of 220kV–500kV, double-bus wiring mode and flexible buses or tubular buses with single-column, double-column, three-column or double-column extension disconnectors, the outdoor AIS shall be arranged in medium-level layout. The breakers should be arranged in single-row layout or double-row layout.

8.3.4 In case of voltage classes of 35kV–110kV, double-bus wiring mode and flexible buses with single-column or double-column disconnectors for general purpose, the outdoor AIS should be arranged in medium-level layout. The breakers should be arranged in single-row layout or double-row layout.

As for voltage class of 110kV, double-bus wiring mode and tubular buses with double-column disconnectors, the outdoor AIS should be arranged in semi-high-level layout. The breakers should be arranged in single-row layout.

8.3.5 In case of voltage classes of 35kV–110kV, single busbar wiring mode and flexible buses with double-column disconnectors for general purpose, the outdoor AIS shall be arranged in medium-level layout. The breakers should be arranged in single-row or double-row layout.

8.3.6 In case of voltage classes of 110kV–220kV, double-bus wiring mode and tubular buses with double-column and three-column disconnectors, the outdoor AIS shall be arranged in double layers. The breakers should be arranged in double-row layout.

8.3.7 In case of voltage classes of 110kV–500kV, when the gas-insulated switchgear (GIS) is used, outdoor low-level layout shall be used and indoor layout may be acceptable in case of special environmental conditions.

8.3.8 When the tubular busbar is adopted for switchgears of 110kV and above, the tubular busbar should be single-tube structure which may be either supported or suspended. The suspended busbar should be used in the areas with seismic intensity of degree 8 and above.

The deflection of supported tubular busbar in iceless and windless condition should not be more than $(0.5\text{--}1.0) D$ (diameter of conductor), and the requirements for suspended busbar may be less

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